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In Search of the DomoNovus: Speculative Designs for the Computationally-Enhanced Domestic Environment

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IN SEARCH OF THE DOMONOVUS: SPECULATIVE DESIGNS FOR THE COMPUTATIONALLY–ENHANCED DOMESTIC ENVIRONMENT

by

STAVROS DIDAKIS

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in partial fulfilment for the degree of

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Many thanks to Professor Mike Phillips for the great support and motivation, and to Professor Roy Ascott for the confidence he has shown in me.

This work is dedicated to the memory of my mother.
Figure 1: The Search for DomoNovus
AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Sub-Committee.

Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment.

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ABSTRACT

The home is a physical place that provides isolation, comfort, access to essential needs on a daily basis, and it has a strong impact on a person’s life. Computational and media technologies (digital and electronic objects, devices, protocols, virtual spaces, telematics, interaction, social media, and cyberspace) become an important and vital part of the home ecology, although they have the ability to transform the domestic experience and the understanding of what a personal space is.

For this reason, this work investigates the domestication of computational media technology; how objects, systems, and devices become part of the personal and intimate space of the inhabitants. To better understand the taming process, the home is studied and analysed from a range of perspectives (philosophy, sociology, architecture, art, and technology), and a methodological process is proposed for critically exploring the topic with the development of artworks, designs, and computational systems.

The methodology of this research, which consists of five points (Context, Media Layers, Invisible Matter, Diffusion, and Symbiosis), suggests a procedure that is fundamental to the development and critical integration of the computationally-enhanced home. Accordingly, the home is observed as an ecological system that contains numerous properties (organic, inorganic, hybrid, virtual, augmented), and is viewed on a range of scales (micro, meso and macro). To identify the “choreographies” that are formed between these properties and scales, case studies have been developed to suggest, provoke, and speculate concepts, ideas, and alternative realities of the home. Part of
the speculation proposes the concept of *DomoNovus* (the “New Home”), where technological ubiquity supports the inhabitants’ awareness, perception, and imagination. *DomoNovus* intends to challenge our understanding of the domestic environment, and demonstrates a range of possibilities, threats, and limitations in relation to the future of home.

This thesis, thus, presents methods, experiments, and speculations that intend to inform and inspire, as well as define creative and imaginative dimensions of the computationally-enhanced home, suggesting directions for the further understanding of the domestic life.
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Chapter 1: Introduction

For our house is our corner of the world. As has often been said, it is our first universe, a real cosmos in every sense of the word. If we look at it intimately, the humblest dwelling has beauty. (Bachelard, 1994: 4)

The home is an essential part in everyone’s life, a fundamental criterion for well-being, and therefore an important object to be observed and understood. The domestic space acts as an interface that links the personal and intimate preferences of an inhabitant with the collective household, as well as with the outside world. As Gaston Bachelard describes (1994), the house is not only a real cosmos that consists of a wide array of properties and events often sensed, perceived, and identified, but is also often an entanglement of unseen interactions, emotions, frequencies, and particles, which define, to a certain extent, the ecological universe we exist in.

At the same time, home transcends into a computational dimension as an increasing amount of technologies infiltrate private life. Computer systems, mobile devices, cloud services, communication protocols, sensor interfaces, and portals to cyberspace are to be found almost everywhere. As a result of this convergence, domestic environments are changing. Rules, conditions, rituals, and functions all shift and transform according to the landscape that emerges from the computational and ubiquitous technological boom. Hybridization, virtuality, interactive facilitation, registration of events, and automatism become part of the domestic lexicon, gradually transforming inhabitants’ experience, perception, and awareness.

Ubiquitous technologies are becoming essential features of the household, directly influencing a person’s lifestyle and conscious
understanding, as the boundaries between physical, digital, augmented, and virtual habitats become blurred. The term “home” now relates to social media accounts, the World Wide Web, and accessible Wi-Fi hot spots; digital spaces that connect and link us to virtual worlds we feel calm and sheltered, secluded or connected. A contemporary house provides not only physical resources to assist and comfort its inhabitants, but also supports imaginative, poetic, and colourful properties accommodated by the media and technological infrastructure. These extensions become part of the domestic assemblage, slowly accumulating ideas, trends, and developments that reshape our notion of what home and domestic life is.

For this reason, one of the main purposes of this research is to investigate the transformational possibilities that ubiquitous technologies promote in the domestic environment, and to examine the house and its technological extensions as a system consisting of a spectrum of organic and inorganic properties (architectural structures, physical materials, biological bodies, digital information) on a range of scales, from micro to meso and macro. By examining the domestic space and its transformation assisted by the implemented technologies, this work intends to provide a critical and more holistic understanding related to intimate and personal environments.

To accomplish these resolutions, the thesis proposes a framework, which can be regarded as a methodological process for the study and exploration of the contemporary domestic ecology. The methodology consists of five parts: (1) context, (2) media layers, (3) invisible matter, (4) diffusion, and (5) symbiosis. These five methods aim to provide the necessary means for accomplishing the objectives of this research, and further assist in understanding the hybridization of the domestic space with the possibilities,
challenges, and risks that it offers. For this reason, every point is analysed theoretically as well as practically through the development of speculative artefacts, interactive artworks, installations, interface designs, software programming code, computational media applications, sensor electronics, communication systems, and design fiction.

The speculative and prototyping practices developed for this research intend to explore the emergent computationally-enhanced home, and to create and define links between real, virtual, digital, and immaterial dimensions of the domestic ecology. Furthermore, it will not only examine how computational and technological facilitation becomes tamed and domesticated, but it will also speculate on the alternative futures of the domestic environment and analyse the house on all possible scales (micro, meso, macro).

The following part of the chapter contains a contextual analysis that presents fundamental information for this research, the statement of the main problems of this work, the objectives and methodology involved, as well as the outline of the chapters of this thesis.

Contextual Information

Author’s Background
To better contextualize the research, I, the author, provide in this paragraph a short summary of my background to better inform the reader and contextualize the thesis within my professional life. My past studies related primarily to sound and music, such as composition and production of audio works, sound installations in public and private spaces, programming and
development of real-time media systems, computational media technologies, and interactive art. A large part of my Master’s thesis titled “A Framework for Interactive Sonic Design into Architectural Spaces” (Didakis, 2007), was to conceptualize, develop, and install a real-time generative system in the main hallway of the Royal Victoria Hospital in Belfast (a project funded by the Centre of Excellence in Teaching and Learning, CETL, Northern Ireland). The main aim of the installation was to enhance the functions of the space, and provide visitors with an alternative sound environment that was automatically composed based on sensed conditions (presence, motion, circulation, clusters of activity) provided by a computer vision system. Following my Masters, I continued my creative practice by developing interactive computational systems for public and private installations, artworks, and software applications for real-time media technologies, as well as participating in conferences and giving lecturers and workshops in multiple countries (for more information please review the Publications & Practice section at the end of this thesis).

Through my work I became more interested into the creative development of interactive and media works in relation to the architectural space, particularly the personal and intimate interior environment. Sources of inspiration for this work (and past projects I developed in the past) stem from the innovative and leading work of Hiroshi Ishii’s research from the MIT Tangible Media Group related to ambient intelligence, Roy Ascott’s concept of architecture and cyberception, Gregory Bateson’s studies on Cybernetics in relation to architecture, the interactive environments created by NOX Architects, and John Fraser’s work on evolutionary architecture that suggests design methods for spaces that are interactive, sustainable, and align with the
views of the user. The above works greatly inspired and motivated me to investigate the concept of interior space, and in particular the home, as a complex system of multiple dimensions and possibilities.

Research Background
Architecture originates from the compound Greek word αρχιτεκτονική, a combination of the words αρχι- “chief”/”master”, and τεκτονική “building”/”construction”. Traditionally speaking, architecture is the construction of physical materials into solid forms that remain static and stationary. However, the architectural practice is being reshaped by the emergence of computational media and technologies in sensor interfaces, communications, and engineering, which allow hard structures to facilitate new purposes that alter our perception on the spaces we occupy. Screens, electronic objects, mobile devices, and digital systems have been accepted by our contemporary lifestyles as elements that can morph the built environment into a multifunctional organism. Facades, interiors, and rooms can shift and transform with the use of creative and imaginative practices, facilitating needs and desires that “prolong our sense of freedom and possibility” (Rushkoff, 2002: 20). There are numerous case studies that demonstrate the need for architects, designers, and developers to challenge the preconceptions of the architectural practice and to assist in the realisation of concepts and ideas of buildings and spaces that transform, adapt, or disappear.

Le Corbusier wrote in 1929 that “with reinforced concrete you get rid of walls completely” (Corbusier, 1991: 38), and Frank Lloyd Wright in 1931 stated that “walls as walls fell away [with the dawn of the machine age]. The vanishing wall joined the disappearing cave” (Wright, 1955: 218). These
statements reinforce the understanding that current realities as we know them are subject to change if imaginable forms transcend into realisation through the streams of certain tools and media. Thus, architecture as a transitional medium assists and facilitates creative practices, hybrid designs, and explorative strategies, and co-evolves in accordance with technological progression.

In 1964, Archigram, one of the most well-known avant-garde architectural groups formed in the 1960s, presented the Plug-In City, a speculative framework for architectural infrastructures where modular residential units could be added to accommodate the basic needs and demands of its residents. As Peter Cook, the founder of Archigram, describes it:

The capsule dwelling was a set of components: whilst snugly and efficiently locked together they were capable of total inter-changeability. [...] There would be a continual exchange taking place, with constantly changing and evolving parts. Perhaps a dream-machine as well as a mere "house". (Cook, 1999: 44)

In Plug-In City the house is an add-on, a modular unit that, according to residents' needs, creates evolving ecologies that challenge and provoke architectural preconceptions. It proposes a fusion of machines, structures, and technologies that ultimately become a fluid event “realised by the active involvement of its inhabitants” (Sadler, 2005: 16). Similarly, Constant Nieuwenhuys' New Babylon (1956–74), which consists of a series of sketches, models, and designs, demonstrates linked, transformable and extendable structures where all elements (walls, floor, sound, colours, and so on) are “in a state of perpetual transformation” (Feireiss, 2007: 218). New Babylon suggests an architectural utopia where everything is interconnected and
always subject to change. Nothing is static, but rather it becomes an assemblage of its inhabitants' preferences.

![Figure 2: Archigram, Plug-In City (1964)](http://40.media.tumblr.com/d836ba287652cd20aad65c05de474/tumblr_n3668wZnSG1r6gio5o1_1280.jpg)

Nieuwenhuys envisioned architectural structures with the ability to accommodate occupants’ “need for playing, for adventure, for mobility, as well as all the conditions that facilitate the free creation of [their] own [lives]”; through the exploration and formation of the environment, inhabitants would be able to explore their own selves too, a process of a “generalized creativity that is manifested in all domains of activity” (Nieuwenhuys, 1974). *New Babylon* instigates the transformation of daily reality, as inhabitants could receive all necessary means for survival without struggle, and to experience new sensations, unconfined spaces, and mobile dwelling. Although Nieuwenhuys invested eighteen years in the project’s development, it failed to come to fruition, as it was over-ambitious, and the actual implementation was impossible mainly because it could not “critically engage the grip of existing cultural arrangements” (Roelofs, 2014: 199).

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1 Image from [http://40.media.tumblr.com/d836ba287652cd20aad65c05de474/tumblr_n3668wZnSG1r6gio5o1_1280.jpg](http://40.media.tumblr.com/d836ba287652cd20aad65c05de474/tumblr_n3668wZnSG1r6gio5o1_1280.jpg)
Fun Palace, a project devised by Cedric Price in 1961, demonstrates the dynamic possibilities of fluid and reconfigurable architectural space. Elements of the interior (such as walls, floors, and ceilings) can change and respond to occupants' desires. The most interesting aspect of Fun Palace is the ability to merge structure and technology, exemplifying notions of time-based and anticipatory architecture, as computers become active – even autonomous – control mechanisms of the physical construction.

For the technological needs of the project, Cedric Price invited Gordon Pask, a scientist and researcher, to further develop the computational abilities of Fun Palace using cybernetics – that is, the field of study of control and communication in goal-driven systems of animals and machines (Wiener, 1948). Pask wanted to use the structure itself as a dynamic tool based on an experimental approach on the social basis of cybernetics. This resulted in a “machine that would get bored and encourage the performer to try something new” (Pickering, 2010: 371), and one of its challenges was “to provide enough variety to keep a person interested and engaged without becoming so random

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2 Image from http://payload265.cargocollective.com/1/13/435963/7600729/cedric-pricebw_700.jpg
that its output appears nonsensical" (Usman, 2007: 57). Moreover, the system could construct evolving and variable interactions to ensure the outcomes resemble human communication – the residents, therefore, could more easily accept its performance. In one of his papers, Pask states:

The high point of functionalism is the concept of a house as a “machine for living in”. But the bias is towards a machine that acts as a tool serving the inhabitant. This notion will, I believe, be refined into the concept of an environment with which the inhabitant cooperates and in which he can externalize his mental processes. (Pask, 1969: 496)

In *Fun Palace*, the building becomes a multifunctional and flexible object that permits metamorphosis to accommodate people’s desires, and if requested, it even disappears completely. Exploring the ethereal, transformable, and evaporated architectural structure, Diller Scofidio and Renfro in Expo ’02 designed the *Blur Building*, an artificial cloud with a huge number of computer-controlled fog nozzles and an embedded viewing desk over Lake Neuchatel in Switzerland, resembling “a Buckminster Fuller geodesic dome shrouded in fog” (Dimendberg, 2013: 1). The *Blur Building* intends to make a statement concerning the transformation of the physical object into an ethereal substance that disappears with the help of the computational medium; “corporeal bearings are literally lost in cloud of information” (Hight, 2008: 40). As Diller and Scofidio explain:

Unlike entering a building, the experience of entering this habitable medium in which orientation is lost and time is suspended is like an immersion in “ether”. It is a perfect context for the experience of another all-pervading, yet infinitely elastic, massless medium – one for the transmission and propagation of information: the Internet. (Diller & Scofidio, cited in Dimendberg, 2003: 79)

Diller Scofidio and Renfro are therefore commenting on the architectural transformation into immaterial habitable spaces of digital
information, cyberspace, and computational media. In another paper, Diller writes that one of the aims of the project was “to synthesize architecture and technology in a way that each would exchange the characteristics of the other, that is to say, de-materialize architecture and to materialize technology” (Diller, 2000: 4). Peter Lunenfeld further explains that the “dematerialized imagescapes end up having a beneficent effect on the hardscapes of built spaces” (Lunenfeld, 2001: 11), an observation that leads creative practitioners to consider alternative realities for the transformation of the building (perhaps completely deconstructed and reimagined); a suggestion that also is considered in the following chapters of this research (in particular, Chapter 7).

Domotics & Ubicomp

The intrusion of the technological object within the domestic environment has often been perceived as an opportunity for enhanced experiences, carefree moments, and idealistic efficiencies. As early as the beginning of the twentieth century, architects and engineers were investigating the implementation of electrical machines to accomplish a range of automation practices to liberate the inhabitant from the labour of cleaning, cooking, and organising the household.

In 1919 the Home Economics movement manifesto initiated by Christine Frederick and Grete Lihotzky and inspired by Frederick Winslow Taylor, sought to approach the domestic space as a scientific laboratory, merging industrial efficiency into household activities, especially in the kitchen (Jorgensen, 2014: 165). One of the main aims of the movement was to reshape home economics through scientific rationality in the form of
laboursaving devices; “Lihotzky viewed cooking and cleaning up as necessary chores, ones that in her time were the burden of the housewife” (McLeod, 2010: 182). This practice reshaped the domestic household, the role of the participants, as well as the rhythms and routines, while breaking the traditional notion of domesticity.

From 1920 to 1960, electric appliances infiltrated the domestic territory, introducing new functions and systems that altered the perception of the home environment. These devices were domesticated rather easily, mainly because they had a clear purpose and function. In 1969, the American company Honeywell introduced to the market its Kitchen Computer, “a floor-standing, low-powered minicomputer based on the sixteen-bit Honeywell 316”, where it “lacked a screen or keyboard, presenting a user interface comprising only a few toggle switches and lights”, and “a front panel extended to form a chopping board” (Dourish & Bell, 2011: 161). The Kitchen Computer, and many other similar technological objects that were introduced with the advent of electronic and digital systems, failed to infiltrate the daily household routine or fulfil their futuristic promises due to the complexity of operation and maintenance, as well as the higher cost and spatial requirements that they required.

Many similar concepts have been developed over the last century, such as the “vast humanoid servants of the 1940s, the sinister semi-synthetic replicants of the 1980s, [or] the swarming medical nano-bots being proposed today” (Auger, 2007: 26), which demonstrate the ongoing drive to create technological “things” that automate and assist everyday tasks. The term “domotics” (“domestic” and “robotics”) refers to hardware or software units that monitor and automate the home environment with the purpose “to
enhance the quality of life and the needs of home occupants during their social, cultural, and economic activities or during their space time" (Andreoni & Pizzagalli, 2006: 1776).

In contrast, though, to the industrial robot, which is intended for the domestic environment, the technological object must adapt to a broad range of human needs; Jean Baudrillard comments about this domotic intrusion:

Consequently, the myth of the robot may be said to cover all paths taken by the unconscious in the realm of objects. The robot is a symbolic microcosm of both man and the world, which is to say that it simultaneously replaces both man and the world, synthesizing absolute functionality and absolute anthropomorphism. Its antecedents were

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electrical household appliances (cf. the “automatic maid”).
Fundamentally, therefore, the robot is simply the mythological end-
product of a naive phase of the imagination, a phase which implies the
projection of a continual and usable functionality. For the substitution in
question has to be visible: if it is to exert its fascination without creating
insecurity, the robot must unequivocally reveal its nature as a
mechanical prosthesis (its body is metallic, its gestures are discrete,
jerky and unhuman). A robot that mimicked man to the point where its
gestures had a truly human fluidity would create anxiety. (Baudrillard,
2005: 129)

For Baudrillard, the technological object (i.e. “the robot”) becomes a
symbolic representation of how the world should function according to
domestic needs, rather than challenge the household and its occupants,
which would result in its rejection. This explains why often the technological
facilitation is not successful, as it fails to locate its role within the household’s
playground, and to respond to the demands of the inhabitants.

Recent computational frameworks approach the domestic environment
with a more specific set of goals. Ubiquitous computing (ubicomp), Ambient
Intelligence (AmI), and the Internet of Things (IoT) are different practices that
intend to spatialise computational interfaces and applications into the
domestic sphere in order to resolve complicated daily tasks, build
computational responses that are context-aware and responsive to real-time
needs, and also to assist in monitoring and registering a range of information
and interactions. Ubicomp, AmI, and IoT need to be aware of the cultural
conditions that comprise the essential aspects of the domestic environment; a
world that consists of a complex network of material and immaterial entities.

The traditional architectural structure is slowly vanishing as new
systems and technologies become popular. Digital code allows the physical to
be transformed into a transparent, even non-existent “thing” – a simulation
that is more attractive, reconfigurable, cost-effective, and easily accessible. With the use of computational systems and media technologies, ubiquitous layers weave into the structural complexity of a space revealing “the emergence of post-digital architecture where ubicomp and ambient intelligence dominates over spatial arrangement and design methodology” (Didakis, 2012: 313), “just as system supersedes structure” (Ascott, 1969: 14). The static nature of architecture is overpowered, and at the same time elevated and crossbred.

**Statement of the Problem**

This research attempts to explore, analyse, and understand the extensions of the technological progress within the domestic space, and, in particular, to observe and critically evaluate the ubiquitous layers of computational media that transform the home and the experiences of inhabitants in real and digital dimensions. In doing so, it becomes necessary to define the domestication of technology, that is, how technological facilitation becomes an essential aspect of our experience, and how our perception is formed in realising what a personal space is.

Our constant interaction with cyberspace, social media, and mobile phone applications are just some examples of how the digital space we occupy daily can become an extension of our personal environment. Thus, our digital selves (and digital lives) need to be considered part of the domestic world, which now consists of amalgamated physical, virtual, and augmented substances. The relationship that emerges at present is blurred and unclear, as also is noted by the literature review; additional study is essential to
comprehend the fused personal space and how the digital self becomes part of the domestic sphere.

This research also attempts to view the home as a collection of things, not only architectural structures, interior objects, aesthetic design, and hardware devices, but also immaterial qualities that directly define or influence the domestic ecology. Thus, the house needs to be studied as a cybernetic system that registers and controls information and properties on multiple scales. The technological frameworks of digital media, sensor interfaces, telecommunication protocols, and web services can help monitor, study, and perceive the habitat from a more holistic perspective.

The miniaturization of computational and technological systems has resulted in devices small enough to easily permeate our environments. Many applications developed within the field of ubiquitous computing explore the concept of the smart home, focusing on labour-saving services and automation practices. The domestic environment, however, must be viewed and explored using speculative and experimental approaches that challenge the concept of the home and reveal alternative possible domestic futures – the practical implementation of which, may assist us to explore and understand the house with its intruding technologies.

Aims & Objectives

This research aims to provide a theoretical and practical analysis of the relationship between domestic environments and computational media technologies to achieve a deeper understanding of the possible futures of inhabitancy. One of the main goals of this work is to explore the augmentation
of digital technologies within the home environment, and to propose methodologies for understanding the domestication of ubiquity (with the opportunities and complications this may bring). The work will examine a vast amount of technological innovations and computational media, such as those used for sensing and contextualizing activity, accessing raw or processed information, and producing interactive interfaces and personalization applications; in doing so, this thesis will encourage and suggest methods to rethink dwelling alternatively.

In more detail, the objectives of this research are to:

- Explore the domestic environment from the perspectives of architecture, philosophy, sociology, art, and technology (computational media, sensor interfaces, ubiquitous computing, and the Internet of Things).
- Identify important aspects and trends that are essential for the domestication of ubiquity (digital systems, communication protocols, computational media, monitoring devices, cloud databases), and analyse the colonization of digital technology in the domestic household and the inhabitants’ lives.
- Use computational media as an architectural material to propose new functions and interactions in the domestic space (informational, aesthetic, and so on).
- Examine the domestic environment as an ecology on various scales (from micro to meso and macro), and propose prototyping tools to assist the practical exploration of the environment by monitoring, registering, analysing, and reusing information and events of the domestic space.
- Apply and evaluate a range of methods to capture information using sensor technologies in the household – information such as environmental data, or inhabitants’ intimate and affective properties that can help shape a personalized dwelling.

- Practically explore strategies for personalization using computational media, and view the domestic space as an augmented interactive interface that extends according to inhabitants’ lifestyles. Design and implement artefacts that reflect on customization and personalization, and through their uses, propose new possibilities for the domestic environment.

- Use practical experimentation and speculation to suggest alternative experiences, behaviours, and ideas that allow one to perceive the possibilities of domesticity through the lens of technological calibration.

- Through prototyping, develop mechanisms that speculate on future scenarios of the home.

**Research Question**

The main research question this thesis attempts to answer is how computational media technologies can become domesticated and part of the home environment? And how can further speculation on the future of the home be developed so that a wider understanding of the relationship between architecture, domestic space, and technology can be critically examined, analysed, and understood?
Methodology

This multidisciplinary practice-based research explores the relationship between computational media technologies and domestic space with the use of theoretical analysis and literature reviews, qualitative and quantitative methods, and case studies (interactive installations, computational media systems, digital prototypes, and speculative designs).

The methodological approach is inspired by Le Corbusier’s Five Points of Architecture (Corbusier, 1928), a manifesto that consists of proposed principles for the re-contextualization of the architectural practice. The features introduced by Le Corbusier include the pilotis, free design of a ground plan, horizontal window, roof garden, and façade; these according to Righini are “the result of the freedom gained by separating out the movement, structural, and enclosing functions of a building” (Righini, 2000: 115). When considered together, these features defined a new aesthetic of building design, and greatly influenced architectural and engineering practices, as the notion of architecture was reinvented; “orthodoxy should henceforth be anathema” (Unwin, 2015: 146).

Similarly, this research establishes five aspects for the development of computationally-enhanced homes – homes that embrace the domestication of ubiquity, as well as rethink the ecology on multiple spectra, scales, and realities. The following list explains these five points in more detail:

1) Context

Analyse the domestic environment from a range of perspectives and comprehend its essential aspects – functions, properties, and dimensions (individual, collective, commonplace, imaginative, poetic).
2) Media Layers

Explore the range of media layers a house consists of, such as physical, digital, and hybrid, propose computational and media technologies as materials of the domestic space, and investigate synthesis and orchestration techniques for the composition of engaging interiors.

3) Invisible Matter

Examine the house as an ecological system, analyse it on all possible scales (micro, meso, and macro), and consider the collected information as an essential aspect of the domestic consciousness.

4) Diffusion

Diffuse digital information within the physical and virtual surfaces of the house, merge media layers, cloud services, and invisible matter, and explore the networked manifestations of the domestic objects.

5) Symbiosis

Establish the house as a partner in symbiotic mutualism, where needs, opportunities, and desires of inhabitants and domestic space blend and co-evo

These five points are used as the main methods to explore the computationally-enhanced domestic space, in addition to the use of theoretical and practical work to develop speculations on the home’s alternative futures. Each of these points investigate a specific aspect of the relationship between ubiquitous technologies and the domestic environment – the following diagram visually explains the interconnections between them. Therefore, the five points demonstrate the steps for the theoretical and practical investigations that will be applied in this thesis.
According to this framework, proper contextualization must take place initially to recognize the importance of the domestic environment. This includes theoretical investigations that explain home from a range of perspectives, such as philosophical, sociological, technological, and artistic. For the contextualization process, primary qualitative and quantitative studies are carried out, to better define the basis of the research, and to assist in the collection of resources for accomplishing the stated objectives.

Various forms of media (light, colour, sounds, video projections) become standard materials for the transformation of interior spaces. By examining previous examples, from public to more intimate environments, it is possible to identify methods and practices that can be used to influence experience, awareness, perception, or memory. The way these media elements are layered, as well as their synthesis techniques constitute a
sophisticated art form. Practical investigations, such as the development of an interactive installation artwork further enlightens and reveals the importance of media layering composition as a necessary aspect in the configuration and parameterization of domestic habitats.

To properly understand the home environment, it is necessary to examine its various spectra, scales, and time frames. For this reason, the domestic space is investigated from its micro, meso, and macro perspectives, which indicate various elements to assist the comprehension of the household more accurately. A range of technological developments are devised and applied within the house to identify, record, and analyse a vast amount of information – information that indicates substances, elements, and interactions essential for our domestic awareness. Captured data from these processes are valued as parts of the house, a representation of the domestic world that indicates in great detail the simulated conditions that constitute this ecology.

The analysis and contextualization of the home environment – in combination with studies on media layering composition and practical developments on micro, meso, and macro sensing – establish the necessary foundation for diffusing information, data, media, events, and technologies within the domestic interior. Such diffusion intends to form the hybridization of the computationally-enhanced household that communicates through various physical and media elements information connected to personalized dataspaces, and same time link cloud services and sensor interfaces to user’s needs, actions, and requests. Case studies become an important part of the process, as they can demonstrate in practice how to establish methods of
binding the ubiquitous layers with surfaces, objects, and devices of the domestic interior.

An essential aspect in rethinking home and dwelling is to consider the possibilities offered by the symbiosis of the domestic space and the inhabitants. The implementation of a range of systems and technologies that respond to personalized preferences and settings through media and services transforms the static house into an organism that communicates and interacts. Part of the analysis is to identify aspects for the establishment of a symbiotic relationship between the environment and its occupants. The development of experimental works, such as interactive installations and computational media applications, exhibit directions on how the physical space and the inhabitants’ awareness is mutually reconfigured and re-contextualized.

By applying and analysing the practices mentioned above, numerous concepts and ideas emerge. A speculative design is presented at the end of this research, which describes abstractions sketched during the theoretical and practical investigations. Part of this speculative exploration is based on scientific and technological research, and part of it is purely fictional. Its main intention is to sketch ideas concerning the anticipated (or alternative) futures of domestic life, and the choice to be included here, as a methodology, is necessary and valuable.

This practice-based research consists of a number of artefacts – case studies, installations, speculative designs, and so on. In order to assist the reader, the following table displays in detail the developments that have been created to support the thesis.
<table>
<thead>
<tr>
<th>Name</th>
<th>Chapter #</th>
<th>Description</th>
<th>Keywords</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey</td>
<td>2</td>
<td>Primary research, online survey for quantitative data collection</td>
<td>Questionnaire, Data Analysis, Statistics</td>
<td>Identify trends and beliefs concerning home, technology, and media</td>
</tr>
<tr>
<td>Workshop</td>
<td>2</td>
<td>Primary, research, workshop for qualitative data collection</td>
<td>Video Recording, Discussions, Design Sketches, Questions &amp; Answers</td>
<td>Identify trends and beliefs concerning home, technology, and media</td>
</tr>
<tr>
<td>Plinthos Pavilion</td>
<td>3</td>
<td>Development of a performative and responsive architectural installation</td>
<td>LED, Lighting, Multi-Channel Sound, Sonification, Sensors, Programming</td>
<td>Art installation. Development, design, composition and interaction methods</td>
</tr>
<tr>
<td>DataGrid</td>
<td>4</td>
<td>Development of a monitoring device (prototype) that detects, stores, and distributes identified data in local and remote systems</td>
<td>Device, Environmental Monitoring, Sensos &amp; Electronics, Database, Communication, Cloud</td>
<td>Monitoring prototype. Ability to sense micro properties of the environment, log responses in database</td>
</tr>
<tr>
<td>Presence</td>
<td>4</td>
<td>Software application that identifies the occupants of the space</td>
<td>Software, Android, Python, Identification, Monitoring</td>
<td>Software prototype, and context-awareness, log responses in database</td>
</tr>
<tr>
<td>Spatial Proximity</td>
<td>4</td>
<td>A sensor device to identify user proximity</td>
<td>Sensor Device, Proximity, Communication, Database</td>
<td>Physical prototype, and context-awareness, log responses in database</td>
</tr>
<tr>
<td>Cyber-Sense</td>
<td>4</td>
<td>Software application developed to track users’ social media, and perform sentiment analysis</td>
<td>Social Media, Sentiment Analysis, Monitoring, Software Application</td>
<td>Software prototype. Sense users’ online activity, log responses in database</td>
</tr>
<tr>
<td>MoodLog</td>
<td>4</td>
<td>Software application to assist users log their current activities, mood, energy, and stress levels</td>
<td>Software Application, Mood &amp; Sentiment Logging, Visualization</td>
<td>Software application. Register users’ sensitive data, log responses in database</td>
</tr>
<tr>
<td>Bio-Data</td>
<td>4</td>
<td>Software prototype to extract users’ biometrics (Fitbit API), and log the information for further processing</td>
<td>Wearable, Biometrics, Context-Awareness, Monitoring, API</td>
<td>Software application. Register users’ biometric data, log responses in database</td>
</tr>
<tr>
<td>Macro Events</td>
<td>4</td>
<td>Software prototypes to scan environmental conditions of the external environment.</td>
<td>Software, Monitoring, Ecosystem, AQI Processing, API</td>
<td>Software application. Register environmental data, log responses in database</td>
</tr>
<tr>
<td>Project</td>
<td>Score</td>
<td>Description</td>
<td>Database</td>
<td>Application</td>
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</tr>
<tr>
<td>Heroku Cloud</td>
<td>4</td>
<td>Development of a web application, which logs sensor data, connects to a database, and visualizes the data.</td>
<td>Cloud, Database, Interface, Visualization</td>
<td>Use the cloud application to store and access information collected from the house</td>
</tr>
<tr>
<td>Node</td>
<td>5</td>
<td>Software application / middleware to allow integration between sensors, database and media.</td>
<td>Software Application, Android, Interface, Middleware, Database, Cloud</td>
<td>Use Node to connect logged data to distributed media in the environment</td>
</tr>
<tr>
<td>3D Simulation</td>
<td>5</td>
<td>Real-time 3D application to simulate an interactive light system that is controlled by data and information.</td>
<td>3D, Application, Realtime, Simulation, Light Design, Visualization</td>
<td>Explore the spatialization of digital information as lighting compositions</td>
</tr>
<tr>
<td>The Cloud</td>
<td>5</td>
<td>Lighting installation with embedded computational units that intends to visualize and communicate information.</td>
<td>Software &amp; Hardware Development, Installation, Cloud, Light, Architecture, LED, Performative, Database</td>
<td>Use of computational systems to set, control, and personalise the lighting compositions of the interior</td>
</tr>
<tr>
<td>DataBlobs</td>
<td>5</td>
<td>Interactive system for visualizing participants' current activities and mood.</td>
<td>Software Application, Interface, Interactive, Sentiment, Mood Visualization, Memory, Database</td>
<td>Use virtual space as an extension of the household's activities and memory</td>
</tr>
<tr>
<td>AFU</td>
<td>5</td>
<td>Interactive installation that responds to viewers' presence and motion, and engages playfully with the use of real-time media.</td>
<td>Software Application, Interactive, Computer Vision, Performance, Motion</td>
<td>Explore the dynamic shifts of the surface projections through actions and behaviours</td>
</tr>
<tr>
<td>Desktop Apparatus</td>
<td>5</td>
<td>DIY objects with microprocessors and communication abilities, to respond to personalized content of the user.</td>
<td>Hardware, Prototype, LED, Electronics, Identity, Database, Visualization</td>
<td>Investigate the diffusion of actions within objects and how information is distributed</td>
</tr>
<tr>
<td>Memorabilia</td>
<td>5</td>
<td>Digital photographic desktop frames that respond to users’ presence, and extract social media content.</td>
<td>Software Application, Visualization, Social Media, Composition, Memory, Sound</td>
<td>Blend and diffuse users’ cyber content into domestic objects as performative compositions</td>
</tr>
<tr>
<td>HexSpace</td>
<td>6</td>
<td>Interactive installation that includes a meta-wallpaper that allows users to extract parts of the domestic environment (physical and digital as well).</td>
<td>Interactive, Installation, Artwork, Sensors, Cloud, Database, Modular, Performative, Visualization, Ecosystem</td>
<td>Extend architecture into a reconfigurable interactive object that demonstrates awareness of its internal conditions.</td>
</tr>
<tr>
<td>DomoNovus</td>
<td>7</td>
<td>Speculative design (concept) that examines computational domestication and technological facilitation within home environments.</td>
<td>Architecture, Interface, Sensors, Cloud, Database, Modular, API, Ecosystem, Monitoring, Immersive</td>
<td>Manifesto, analysis, design sketches, and diagrams to explain the concept of DomoNovus – explain the possible future of domestic space.</td>
</tr>
</tbody>
</table>

Table 1 - List of practices

Outline

This section presents an overview that outlines the following chapters of this research:

“Chapter 2 – Domesticated Bodies” presents a contextualization framework that assists further developments of this research, and also analyses home from various perspectives in order to clarify complexities and encapsulated qualities of domestic spaces. Dwelling, an important characteristic of the domestic experience is examined to additionally support methods for the domestication of hybrid objects, frameworks, and computational technologies. Moreover, this chapter presents and discusses primary data collection methods that were used in order to understand in
more detail the public’s opinion on the home and technological tools and practices.

“Chapter 3 – Media Layers” investigates architectural interiors that accommodate a range of experiences through the use of media and technology. A short historical reference of interior design and art installation practices is provided in order to demonstrate applied methods for the transformation of interior spaces, allowing participants and inhabitants to alternatively experience meaning, information, and aesthetics. For the practical requirements of this chapter, an interactive installation was developed, which is further discussed and analysed. Plinthos Pavilion proposes an architectural structure that has a range of media layers, which extend the norm inanimate structure into an engaging, shiftable, fluid and immersive organism.

“Chapter 4 – The Invisible Home” explores the domestic space as an ecological system that consists not only of an architectural structure, interior objects, appliances, and biological bodies, but also of a range of particles, frequencies, substances, physical interactions, environmental conditions, and cyberspace events. An important consideration for this exploration is to view the domestic space on a range of scales, from micro, to meso, and macro. According to this need, a series of systems have been developed to accompany this research, demonstrating relevant methodologies for extending the sensorial dimensions of the habitat. These practices intend to capture the unseen spaces of the house and build a digital cartography of emerging immaterialities.
“Chapter 5 – Diffusion” explains theoretical and practical investigations related to spatialization of information into the computationally-enhanced home; challenges and opportunities of this process are also critically discussed. The chapter explains how the collected information of the household, such as media, visualizations, sounds, and so on, can be distributed into its physical (and virtual) space with the use of hybrid and augmented objects that facilitate linking, real-time processing, and interaction. Case studies are analysed and demonstrate how a range of inputs of information collected from various scales of the household can be diffused within the interior environment, extending personalization possibilities and challenging traditional roles of the house.

“Chapter 6 – Symbiosis” discusses concepts of interdependence between the computationally-enhanced home and the inhabitants, by extending J. C. R. Licklider’s visions of man-computer symbiosis (1960). Historical and contemporary studies on the subject are investigated, to explore the possibilities that emerge from this symbiotic relationship, such as speculative designs, interactive installations, experimental artworks, or science-fiction writings, which assist in contextualizing and further defining aspects of the symbiotic environment. Based on J. G. Ballard’s concept of a “psychotropic house” (Ballard, 1962) that is able to demonstrate metamorphosis, the idea of interior structural transformations is examined, closely followed by the presentation of HexSpace, an installation that was developed as part of this work to realize an augmented structure that physically shifts and transforms according to inhabitants’ actions – in real and virtual domains.
“Chapter 7 – DomoNovus” collects concepts, ideas, and practical investigations that were created and developed for this research in previous chapters, and presents a manifesto, which is used as a speculative design in a written form, sketches, and diagrams. Its role is to outline a hypothetical image of DomoNovus, a conceptual framework that provokes the reader to rethink home and the repercussions the computational abilities may have on domestic life. DomoNovus is analysed from a number of perspectives, leading to implementation suggestions and further research scenarios.

“Chapter 8 – Conclusion” discusses, disseminates, and summarizes the topics presented in this work, and reaches a final conclusion based on a conducted critical evaluation. By considering the accumulated concepts, ideas, reasoning, and practical developments, it determines to what extent the aims and objectives of this work were achieved. The implications devised in this study are presented, indicating the necessity of further research concerning the computationally-enhanced home, the domestication of ubiquity, and the recontextualization of inhabitancy.
Chapter 2: Domesticated Bodies

This chapter intends to provide a contextual analysis and to examine the concept of home from philosophical, poetic, architectural, sociological and artistic perspectives. It will also clarify home's complexities and its encapsulated qualities, which are essential aspects in the establishment of critical definitions, intended to assist further developments and research practices of this thesis. By understanding dwelling and domestic experience in more detail, and by examining the domestication of previous technological objects, it becomes easier to develop computational and media frameworks that speculate on possible futures of the domestic space. Additionally, this chapter presents a primary research that was conducted for this work to help understand in greater detail the public's opinion on the domestication of technological systems, and to observe their current lifestyles in relation to the home environment.

A Definition of Home

Domestic architecture is a form of architectural design that is linked to the creation of intimate and isolated spaces of everyday life; i.e. houses, homes, sheds. An important aspect in its development is to consider influencing factors such as aesthetics, practicality, daily interactions, safety, and security, to name a few. In its most simple description, home is a physical space that provides isolation, conformity, and access to essential needs on a daily basis – cooking, washing, and sleeping. It is also a place where we feel calm and free, having options to express unaccepted actions of public spaces, being able to get naked physically, psychologically and emotionally as well.
Home becomes the basis of a person’s world, an ontological cage, or according to Jacob von Uexküll’s term, an *Umwelt* (meaning “environment” in German), which is essentially to be “enclosed within phenomenological bubbles, worlds of perception and action” (Kirksey, 2015: 19). The concept of *Umwelt* influenced philosopher Maurice Merleau-Ponty, who was interested in the constitutions of meaning in human experience, and in particular the role of perception in understanding our surrounding world. Merleau-Ponty theorized about the “structural coupling” of the embodied human being with its environment, as they are always linked together inseparable from one another. In more detail, Mark Hansen expands further with the following:

The Umwelt [according to Merleau-Ponty] is not outside the body, and the body is not other than the Umwelt; rather, […] the two terms must be understood as divergences with respect to one another: the *Umwelt* […] is what makes the body self-dimensionalizing, a universal measurant, and the body is what makes the Umwelt transspatial, not an empirical “there,” but an absolute “here”. The coupling with an *Umwelt* is, then, precisely what clarifies the profound correlation of the body and the world, the belonging of one to the other that Merleau-Ponty calls the flesh. (Hansen, 2005: 252)

Merleau-Ponty, therefore, suggests that we understand the *Umwelt* (in this particular case, home) as a unified part of a person’s consciousness, perception, and experience. This also aligns with the views of the German philosopher Martin Heidegger, as he believed that “people make sense first through inhabitation of their surroundings, and their emotional responses to them” (Sharr, 2007: 2). Heidegger, who extensively studied phenomenology and existentialism, greatly influenced architectural practice, especially with his essay “Building, Dwelling, Thinking”, in which he unified the concepts of “building” with “dwelling”; Heidegger’s *Umwelt* “is meant to be the existentially rich understanding of where one dwells” (Davis, 2007: 125).
Thus, according to these insights, the personal and intimate environment of what constitutes a home is considered as a substantial part of a person’s world, merely for providing necessary tools for survival, but additionally because it acts like an artificial womb that supports, connects, and communicates on conscious and subconscious levels. Even in the studies of Sigmund Freud related to the symbolic representation one may find in dreams, Freud concluded that a “human person as a whole is in the form of a house” (Freud, 1920: 125). British anthropologist Mary Douglas defines home as a fundamental property in a person’s life that consists of a range of forms able to connect with the inhabitant through its "domestic things", its rhythms, or unidentified co-created entanglements. In one passage Douglas says:

Home is located in space, but it is not necessarily a fixed space. It does not need bricks and mortar; it can be a wagon, a caravan, a boat or a tent. It need not be a large space, but space there must be, for home starts by bringing some space under control. (Douglas, 1991: 289)

This mystical power of home to enchant and entwine inhabitants within its spatial coordinates becomes “one of the greatest powers of integration for the thoughts, memories, and dreams of mankind” according to Gaston Bachelard (Bachelard, 1994: 6). For Bachelard, home is a poetic object that allows one to maximize their personal experience, as the soul of a person meshes with domestic time and space, causing the integration of physical and metaphysical qualities of structure and living beings. Memories, actions, and experiences accumulate and blend with hard surfaces, witnessing transitions that spread like a virus from one room to another; as similarly Brand notes how a building’s “unchanging deep structure” never remains unchanged, as it builds and rebuilds according to the actions of the inhabitants (Brand, 1994: 2).
Steen Rasmussen argues that architecture has to provide the necessary confined space that establishes a functional framework for inhabitants to dwell, a space that has to be experienced and be closely observed; “you must dwell in the rooms, feel how they close about you, observe how you are naturally led from one to the other” (Rasmussen, 1959: 33). This exploration of the physical structure may indicate hidden layers of systems, meanings and memories, which according to Heidegger leads to dwelling; a fundamental quality of a home that provides strong emotional and psychological connections with its inhabitants, a connection that is not straightforwardly established:

These buildings house man. He inhabits them and yet does not dwell in them. In today’s housing shortage even this much is reassuring and to the good: residential buildings do indeed provide shelter; today’s houses may even be well planned, easy to keep, attractively cheap, open to air, light and sun, but do the houses in themselves hold any guarantee that dwelling occurs in them? (Heidegger, 1971: 145–46)

According to Heidegger, no matter how sophisticated or skilful the design of a house may be, it does not necessarily become a home – a dwelling is not automatically established. Terms like “well planned”, “easy to keep”, and “attractively cheap”, all miss the point of dwelling, or what home is. Heidegger believed that the systematized building industry becomes distant from the emotional and psychological needs of the inhabitants. The personal and intimate traces that appear in the poetic substances of the interior are the main ingredients for transforming the internal space (over a period of time) into a dwelling; the house needs to “be understood through tactile and imaginative experience; not as a detached object” (Sharr, 2007: 46).
Home is considered an object critical to the on-going human experience that constantly shifts according to the personalized attachment of its inhabitants. It is able to give significance to all items and objects related to its interior, as it “shelters and establishes a foundation of human meaning” (Gelven, 1989: 226). Similarly, according to Tim Ingold, dwelling is a “perspective that treats the immersion of the organism-person in an environment or lifeworld as an inescapable condition of existence” (Ingold, 2000: 153). Such an existence is defined by movement, a narrative of journeys in a world of motion, “continually coming into being through the combined action of human and non-human agencies” (ibid: 155).

An accumulation of domestic time and experience builds hidden layers of meaning, affection, and emotion between space and inhabitant. The architectural object according to Heidegger becomes an extension of a one’s personality and psyche, providing not only survival possibilities but also poetic and colourful properties, defining force fields in the perceptual universe: “cellar and attic can be detectors of imagined miseries, of those miseries which often, for all of life, leave their mark on the unconscious” (Bachelard, 2007: 74). Thus, based on this analysis, the quality of a domestic life is reliant upon the premise of establishing engaging and creative interiors that align with the desires of inhabitants.

Furthermore, a home is often characterized by the way it is being utilized, such as how, where, and when actions and behaviours take place, or even by environmental, social, or financial events triggered in local or distant territories across the world. Certain configurations take place and define the home itself with all that it may include. From the interpretation of Mary Douglas, over time each household establishes actions, rituals, and events
that become an organized system, an ecology of interconnected things: “the home makes its time rhythms in response to outside pressures; it is in real time”, as for example “the memory of severe winters is translated into a capacity for storage, storm windows, and extra blankets; holding the memory of summer droughts, the home responds by shade-giving roofs and water tanks” (Douglas, 1991: 294). Douglas argues that the household has a sense of coordination and synchrony, understanding needs, providing fair access to resources, and through mutual adjustments and constant negotiations, it becomes a complicated but remarkable object of observation.

**Dissected Spaces**

From the perspective of architects, home is a controversial subject, especially when innovation, provocation, and vanity are among the criteria for its development. Le Corbusier described the home as “a machine for living in” (Corbusier, 2008: 151), an attempt to express the need for functionality that collects practices from design, engineering, and technology, for the utmost convenience of the inhabitant. According to Corbusier, the house needs to be consistent on a number of points in order to produce beneficial and essential qualities and living requirements, such as an open plan space, free façades, access to services, or various aesthetic attributes (Corbusier, 1928).

On the other hand, Reyner Banham and François Dallegret with their proposal *A Home is not a House* (Banham & Dallegret, 1965) provoked the architectural world by claiming that home is only the infrastructure that supports fundamental needs of its inhabitants – such as watering supply, electrical devices, cables, and so on – without the need for walls and ceiling to
comprise the main structure. Their sketches “Anatomy of a Dwelling” display characteristically the most important elements that are needed in order to capture the essence of a home, the importance of a dwelling. It is absolutely critical for a domestic environment to provide layers that consist of modules, systems, and technologies, and it relates to the comprehension of our contemporary homes; to be unable to connect to the local Wi-Fi feels like a major part of our Umwelt is missing.

Figure 6: R. Banham & F. Dallegret, Anatomy of a Dwelling (1965)

From a different perspective, which largely contradicts Corbusier, Ben Nicholson’s Appliance House (Nicholson, 1990) attempts to challenge the

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preconceptions related to the industrialized and mass-produced "clean" and well designed home interior. Nicholson uses technology and kinetic appliances to construct a domestic environment based on the logic implemented on his modular device, the Kleptoman, which searches around the house to find forgotten objects and reposition them in areas of higher circulation. In doing so, the Kleptoman draws attention to unused and forgotten items in the house, retrieving and revealing forgotten memories and experiences of the past.

For most of us, the definition of an undesirable home would be one unable to meet our fundamental and essential needs. However, comfort according to Witold Rybczynski “has become a mass commodity”, as through “the mass production and industrialization” comfort has been universalized, becoming cheaper and more efficient (Rybczynski, 1986: 220). The standardization of values (aesthetic, functional, imaginative) is a phenomenon that constrains the expressivity and articulacy of occupants, resulting in uninspired ecologies for habitation. The following image demonstrates a public advertisement for a leading furniture company that has standardized design products around the world. In this advertisement, it is evident that the company wants to promote “personal environments” that are fixed and ready to be delivered as is; with a market-competitive cost, everyone can have a home – albeit the same home.
Le Corbusier’s work on domestic spaces emphasized the need for function both in the construction of space and its inhabitancy. There is, therefore, a matter to consider regarding the contrast between comfort, functionality, and aesthetics. They are all desirable when concerning the context or level of personalization for each lifestyle. The way a house assembles over time becomes a temporal composition; a metaphor used literally by Kurt Schwitters in his sculptural artwork *Merzbau*, a physical installation in his home in Hannover that provokes questions about intimacy and personalization. In this work, three-dimensional structures run free in the space and sometimes transcend it, “cutting through the ceiling and floor to original armature of the building” (Mansoor, 2002) with countless nooks and grottos filled with objects of daily use – combs, pencils, notes and even urine-filled cups. In this work it is evident how the physical space becomes a literal extension of the dweller, absorbing preferences, customs, and rituals. This coincides with Ingold’s view on dwelling, as he argues that it resembles the

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6 Kurt Schwitters was strongly influenced by Expressionism and later Dada artistic movements, and in 1923 he started building the *Merzbau*, a collage work with enigmatic structures that exist within an architectural space of eight rooms in his house in Hannover.
weaving a net; a continuous process that never ends but constantly interweaves “our lives with one another and with the manifold constituents of our environment” (Ingold, 2000: 348).

Figure 8: Kurt Schwitters, Merzbau (1923)

As also suggested by Bachelard, spatial and architectural design has to be understood in terms of emotional engagement with an interior space, and the expression of said engagement in such a way as to allow its inhabitants to meaningfully experience and perceive their environments. The standardization of interior properties and qualities prevents individuals from escaping norms and exploring the possibilities of affective, aesthetic, and emotional definitions of their domestic spaces. Birgit Cold states that,

7 Image from http://www.moma.org/explore/inside_out/2012/07/09/in-search-of-lost-art-kurt-schwitters-merzbau
[..] direct sensuous, aesthetically pleasurable or unpleasurable experiences and emotions related to the environment are rooted both in individual motivations and conditions and in the individual and collective subconscious field, while assessments, criticism and professional judgements or aesthetic quality are dominated by intellectual, rational and philosophical theories and ideas related to the conscious field. (Cold, 2001: 17)

Profit-driven professionalism and social norms could destroy personal taste and individual expression – something crucial to the domestic environment. However, this may not be straightforwardly apparent to the greater percentage of the population, as cultural constraints, social conventions, and a lack of individual self-awareness do not allow for this to emerge. For this reason, it is mainly various groups of professionals with specialized knowledge concerning the aesthetical definitions of interior spaces (artists, designers, architects), which decide what makes a good or a bad design/experience in a home environment.

A distinction as such makes it clear to understand that a functional and well-adjusted environment can never be standardized, but rather it has to enable inhabitants to sense, understand, and implement shiftable properties based on various internal and external conditions. For example, the cyclical patterns of the earth and the moon, circadian rhythms, individual or collective behaviours, light exposure, seasons, and so on, make it impossible to think in static terms, although, in practical terms, this method can be quite effective. As Kim Dovey says, “places which are frozen in a static state (conservation? museumization?), or are constantly maintained in a preferred image (sculpture? Bureaucratic management?), may die” (Dovey, 2001: 96). Therefore, it has to be acknowledged that the affective dimension of a domestic space is a canvas filled with memories, behaviours, fantasies, and
desires, and it oscillates and transforms, sometimes reaching an optimum condition, sometimes not, as this depends on the interactions and participations that form a collective result.

Affective qualities of an interior space can directly define inhabitants’ well-being, and they can be extrapolated from observation and analysis (although often impossible due to their metaphysical dimensions). Physiological reactions triggered by affective change can greatly impact a person’s mood, which indicates that health can be influenced too. The field of psycho-neuroimmunology suggests that a positive mood enhances the immune system to a great extent; pleasures and discomforts in daily life play a significant role in our overall well-being.

It is often noticeable that a particular space can dramatically affect mood, emotion, psychological, and behavioural responses. To define the problem using a methodological approach could lead to non-comprehensive results. However, Burridge and Ormandy suggest that we should be using the subjective judgements of participants, cultural definitions, and biophysiological responses between different people as research parameters, and that these should be carried out over a substantial period of time (Burridge & Ormandy, 1993). As it is very difficult to properly quantify aspects related to the affective layers of interior spaces, more often than usual measurable phenomena are used, such as temperature, sound, dampness, mould, size of rooms, price, location and appearance of the building, to name a few. As Roderick Lawrence also notes:

The qualitative definition of housing should be understood in terms of the contextual conditions in which that housing exists [and that] contextual conditions cannot be limited to a study of the site and the availability of construction materials because they define and are
defined by a range of architectural, economic, political, social and economic dimensions in a precise context at specific points in time. (Lawrence, 2001)

Therefore, it is necessary to contextualize and apply methods of measuring, calculating, analysing, and defining the layers of an interior space, assisting in identifying the mechanisms of a domestic space, and additionally to observe how technological services can further assist the facilitation or creation of alternative experiences – a main objective of this research.

**Domesticating Technologies**

In order to understand in what ways technological utilities, services, or frameworks can become part of the domestic environment, it is important to study the domestication process so that particular approaches can be identified. Thomas Berker et al. (2006) discuss the domestication process in more detail:

Domestication, in the traditional sense, refers to the taming of a wild animal. At a metaphorical level we can observe a domestication process when users, in a variety of environments, are confronted with new technologies. These “strange” and “wild” technologies have to be “house-trained”; they have to be integrated into the structures, daily routines and values of users and their environments. (2)

And also with the following addition:

In our understanding, domestication is, first of all, an analytical tool, which helps to illuminate the process where the user makes the technology “his/her own”; a process through which both the technology and its user are changed. This process takes place through various phases or dimensions and the artefact is fitted into the routines and the practices of the everyday life of its user. (126)
Therefore, according to Berker et al. (2006), when new technologies are introduced into the household, its members may possibly identify a particular function that accommodates a need. If the object fails to be included within the daily routine, its domestication will probably fail. The implementation of various systems and technologies within a home environment is always defined by the cultural and habitual needs of its occupants. If we assume that a technological innovation is to be properly domesticated, then it “has to find a place within the moral economy of the household, specifically regarding its incorporation into the routines of daily life” (Silverstone et al., 1994: 20).

The domestication of a particular technological system depends on whether the structural complexity of the household allows it to exist, from the way affected behavioural patterns within the environment shift to a desirable level, or if the possibilities offered by its functions extend to hybridizations of the domestic consciousness. Media displays, information and communication systems, or sensors and ubiquitous technologies may infiltrate the domestic structure and even though they can be visually or physically unnoticeable, they become objects (Csikszentmihalyi & Rochberg-Halton, 1981), extensions of the home and valued the same way as other non-technological physical things.

As Jean Baudrillard argues, the technological infrastructure – although unnoticeable in the daily life – is “profoundly real” as it enables the home to extend to additional dimensions. This statement implies that possibilities offered by machines, software, and systems must find a way to infiltrate the domestic space if they are to be accepted or needed by the rest of the habitat. Technology does not only access the physical environment but, more
importantly, accesses the psycho-affective states of the inhabitants, becoming itself indispensable and vital to domestic life:

In the strictest sense, what happens to the object in the technological sphere is essential, whereas what happens to it in the psychological or sociological sphere of needs and practices is in-essential. The discourse of psychology or sociology continually refers us to the object as apprehended at a more consistent level, a level unrelated to any individual or collective discourse, namely the supposed level of technological language. It is starting from this language, from this consistency of the technical model, that we can reach an understanding of what happens to objects by virtue of their being produced and consumed, possessed and personalized. (Baudrillard, 2005: 3)

Objects within the private and intimate space are bound with their owners in an affective relationship that defines a resonance and emotional presence (Baudrillard, 2005; Csikzentmihalyi & Rochberg-Halton, 1981), which can shape experiences and generate memory triggers that enable a particular understanding of the personalized environment. Merleau-Ponty placed a similar emphasis on the dependence of humans on things, saying that humans are situated in a world of things, become oriented among things and take stands in relation to them (Merleau-Ponty, 1963 [1942]).

Technological extensions of the house, such as scattered sensor interfaces and software applications in mobile and wearable devices, constitute a realm of a larger functional entity that transcends experience into an imaginary truth, an adapted relationship of technological ubiquity.

The collective household with its structural dynamics, functions, technologies, and aesthetic conditions has to be considered and understood as a whole:

[...] the appropriation and display of individual artefacts, technologies included, does not take place, nor can it be understood, in isolation. In this example, the television, the vase, the painting, the plastic rose all
signify together an expression of the systematic quality of a domestic aesthetic which in turn reveals, with varying degrees of coherence (and contradiction), the evaluative and cognitive universe of the household. (Silverstone & Hirsch, 1994: 15)

The domestication of various technological inventions such as electricity, the telephone, television, or the Internet has shifted and redefined the domestic space, and the way it is understood. This fact has allowed us to apprehend interactions with materials, to control aspects of the household, to extend spatial conditions, and to establish universal access and presence through digits and networks. The household does not only include a physical aspect, but transcends further dimensions of time, space, and social environment, giving access to portals of possibilities for functions, interactions, expressions, and aesthetics. As Zygmunt Bauman says, the house has become a “phantasmagoric” place that allows the “realms of the far” to become part of the “near” (Bauman, 2001).

For example, in the case of television the domestic environment shifted radically according to the ability of the medium to penetrate consciousness and awareness on a deep and intimate level. Starting with a strange bulky object that sat in an empty corner, the TV soon became the epicentre of the household. The interior decoration and furniture positioning was adjusted to accommodate the coronation of the new “king” of the house; “we design our spaces, habits, and even emotions around the TV” as Maud Lavin says (Lavin, 1990). Television was able to accommodate, assist, and contribute to the collection of personal and intimate memories, therefore, becoming fundamentally important to the members of a household. Thus, its domestication was inevitably successful as it was able to construct a lifestyle
of joyful memories from childhood to maturity resulting in an attachment that was accompanied with a home-like feeling of emotional warmth.

The technological object promises to resolve issues and difficulties its owner may have, or to assist and provide functions that range from essential and important to pointless and unnecessary. In any of these cases, however, some of them have been able to find their place into the house environment (e.g. vacuum cleaner, computer, purifier) although many of them have not been widely adopted due to cost and, in many cases, inefficiency (Webb, 2011: 22). The progressive modification of the domestic space into the technological realm demonstrates that “technologies are no longer merely supplementary to, but constitutive of, what the home itself now is” (Morley, 2006). Additionally, a technological object wishes to attach and relate to intimate and personalized aspects of the inhabitant, so that it might bring a sense of completeness, wellbeing, and psycho-mental stability, or even to become an extension of laziness, sloth, and lethargy, transforming humans into unconscious, incompetent and paralyzed beings. As John Thackara explains in the following text, it is necessary to listen to the needs of people, and use technologies in a way that it is meaningful, respectful, and inspiring:

We do amazing things with technology, and we’re filling the world with amazing systems and devices; but we find it hard to explain what this new stuff is for, or what value it adds to our lives. I don’t think we can evade these questions any longer... Do all these chips make for better products? Or a better life? Let me tell you a strange thing. Hardly anyone is asking that question. When it comes to innovation, we are looking down the wrong end of the telescope: away from people, toward technology. Industry suffers from a kind of global autism. Autism, as you may know, is a psychological disorder that is characterized by detachment from other human beings. (Thackara, 2001: 48)
Home & Technology: Primary Research Methods

For the requirements of this research, primary data collection methods were applied to understand in greater detail the public opinion on related matters, such as how the domestic space is utilized, the level of inhabitants' awareness concerning aesthetics, functionality, and quality, as well as their relationship with technological and computational tools and resources. The overall aim, therefore, is to locate trends, beliefs, and concepts necessary for establishing a foundation for this research. A survey was developed to collect quantitative responses, and a two-session workshop was conducted to extract qualitative information from the participants using observation and documentation of media content.

Survey

The survey that was conducted as part of this research makes an effort to contextualize in a systematic way respondents' opinions concerning their home environment and how media and other technologies fit into their everyday domestic routine. For the requirements of this survey, a questionnaire was designed consisting of four parts: Demographics, Interior Design/Decoration, Psychology/Mood/Well-being, and Technology. Appendix A includes a more detailed explanation about the survey and its results. The reader may access the accompanying USB flash drive (folder Chapter 2 – Survey) for the survey's form, participants' responses and their complete analysis.

The main goal of this survey was to collect the public's opinion in relation to these categories, and to further assist in understanding issues
concerning the domestic life of the respondents, as well as to acquire details about the domestic technological infiltration they experience daily. Moreover, it was necessary to understand how the design of the environment impacts mood and behaviour, and how media technologies of the domestic environment affect their experience. It was important to collect data for analysis to form a basis for understanding how participants perceive their home in combination with design and technology, so as to inform and support further practical experimentations for this research.

The analysis of the questionnaires reveals that participants consider the personal interior space as a critical aspect of their lives. A large majority agrees that a residence can directly affect emotional and psychological states and that a properly designed environment can enhance intellectual and/or physical performance. Participants believe the cleanliness of their interiors affect the domestic experience greatly, as it can have positive or negative effects on their health, and more than half of the respondents think technology could help them achieve a healthier lifestyle.

Furthermore, respondents prefer shiftable interiors to match their aesthetic preferences. Concerning technology, it is safe to say they feel comfortable with having a close relationship with computers and other electronic and digital technologies within their interior environments, although they are not comfortable enough yet to install sensors for tracking their every move and action in physical and virtual spaces. However, the responders agree that technological artefacts within the domestic space can help in providing less boring and more interesting moments – if technology does not fail to deliver what it has already promised.
Workshop

The previous survey offers an effective way to get an average estimation of the responses on specific questions, but it fails to provide qualitative data that may demonstrate further understanding concerning more comprehensive insights. For this reason, and the needs of this research, a workshop with 20 participants was organized to discuss in more detail their opinions related to the computational technologies that infiltrate domestic environments. The participants were either professionals or university students in the disciplines of architecture, interior design, digital media, and psychology. The workshop took place in MBS College (franchise of Nottingham Trent University, UK) in Heraklion, Greece (2011). Its overall duration was eight hours, split into two sessions over a week, consisting of a presentation, group discussions, and practical assignments (sketches and written responses to open questions). The overall aim of the workshop was to attain a deeper understanding of participants’ opinions concerning speculative artefacts of technologically enhanced domestic interiors, and to allow them to express their thoughts freely in a positive and constructive way. Appendix 2 includes the questions given to the participants and the answers they gave. The reader may access the accompanying USB flash drive (folder Chapter 2 – Workshop) for the artefacts that were developed, as well as the presentation material that was given in this workshop.
Most of the participants believe that the domestication of technologies will provide many benefits to the inhabitants, such as automate a range of mundane tasks, making life more efficient and enjoyable. Monitoring sensors and applications will be able to scan the occupants for a range of physiological responses, such as monitoring their health condition and taking further action if necessary (i.e. notifying the hospital or close relatives). However, the participants do not feel comfortable in wholly trusting the computational machines due to privacy and security issues, as the data of the house can be compromised, damaged, and misused by third parties without the authorization of the owners. Most of the participants accept the technological transformation of the domestic space, although they believe that the invasion may become obtrusive – therefore unwanted – when sensors, media, and other technological extensions monitor personal and intimate moments and spaces.

The Artificial Intelligent agents of the computationally-enhanced home are going to clash with personal preferences, as participants said, creating unbalances in the overall household. Moreover, the automated technological
home poses a threat to human creativity, according to the discussions that were made during the workshop. Although participants recognize that the possibilities offered by the technological frameworks, services, and devices are extensive, they firmly believe that inhabitants need to have absolute control of them at all times. In answer to this problem, their suggestion was to have a transparent way of viewing and understanding all processes of the household and to demonstrate in a clear way the benefits of various tasks, such as environmental monitoring of the space, or power savings based on specific automations.

Another issue raised during the group discussions was how the electronic and computational devices over-saturate the domestic environment with electromagnetic waves and transmission of frequencies, such as Wi-Fi, Bluetooth, or other wireless communication systems. Finally, the issue of perception towards technological facilitation was analysed, as participants think that their current memories and experiences directly influence their perception of the computationally-enhanced domestic environment. However, in the near future – as cultural trends shift – many of the services and applications will be universally accepted, completely blended in the household, and perceived by inhabitants as standard and ordinary.

**Chapter Summary**

This chapter attempts to contextualize the domestic space from a range of theoretical approaches across various disciplines to assist the analysis of a home, how dwelling is accumulated, and in what way affectivity builds essential attributes to the domestic experience. All of these aspects are
significant in considering the domestication of technological objects, devices, or systems as they intend to become part of the household and an extension of our intimate lives. Primary data collection methods were employed to assist this research, which contributed in accomplishing a detailed investigation concerning participants’ opinions on domestic space, media, and technology. From the dissemination of the results, it becomes clear that current trends and lifestyles demand a balanced relationship between technology and domestic space that respects inhabitants’ personal preferences without intruding either as a behavioural calibrator or as a monitoring agent that records private data with no easy and configurable access. In the following chapter, an analysis is presented concerning practices and methods of implementing media layers within an interior space, and how artistic techniques and processes assist in the development of interior spaces that alter and define experience, perception, and understanding.
Chapter 3: Media Layers

This chapter investigates methods and practices for the transformation of architectural interiors that accommodate a range of experiences through the addition of media and technology. This layered addition contains meaning, information, interactions or aesthetics that are able to accomplish a range of goals, such as to enable alternative spaces of exploration to be discovered, perceived, and integrated. Historical references are provided to convey the motives and objectives for using media layers to interior spaces (both public and domestic) that create transformations and alter occupants’ experiences and perceptions. Selected art installations are presented as well, which propose inspirational methods and techniques of using media and technological artefacts within interior environments to synthesize elaborate and extensive compositions. Although the installations are not linked to the domestic but rather to the public space, their analysis is useful as they offer a range of creative methods and practices to be extracted, acknowledged, and utilised. Finally, a case study that was developed by the author as part of this research is presented. *Plinthos Pavilion* is an interactive installation artwork that explores how the addition of media layers within an architectural space communicates affection and meaning, and alters visitors’ apprehension, understanding, and awareness.

**Early Manifestations**

The spatial arrangement and manipulation of interior elements and spaces is an intriguing and demanding process that requires time, money, and knowledge concerning the personal preferences of its inhabitants. But even
more than this, architects and designers are often obliged to develop hidden layers of meaning and functionality within a physical structure that simultaneously offers an aesthetically pleasing environment. Even from prehistoric times, we can identify cases where humans are involved with the aesthetic transformation of media spaces to reveal compositions that use veils of meaning, express information, and provoke particular and unique sets of experiences, as demonstrated in the following cases.

In the Lascaux Caves in France a visitor may find a Paleolithic “[…] 17,000 year-old frescoed theatre bestiarum: a main cavern and several steep galleries, all adorned with a splendid panorama of cavorting animals” (Wilken, 2005: 117). Ancient rock artists filled this complex of caves with immersive wall paintings using mineral pigments to depict figures important to the daily lives of that period (equines, cattle, bison, humans), but also abstract symbols and geometrical shapes. More than 2,000 paintings embellish the interior of the caves, shaping the physical properties and transforming the experience into an underground visual narration. However, this narration is only partially visual; it is fully realised by acknowledging the caves’ acoustics. As Steven Waller argues (Waller, 1993), this rock art is not randomly placed on different walls but rather according to a sophisticated selection method based on the aural nature of the space, as it can affect the way the paintings are perceived, giving them a specific orchestrated meaning. Different figures are presented in chambers that offer viewers an analogous impression, incorporating acoustics to bring visual images to life (Blesser & Salter, 2007), and carefully designing an interior environment that alters the spatial phenomenology into an immersive and captivating experience. As Joseph Nechvatal describes, the depicted wall paintings function “as a cognitive dissonance visualization field
and defocal virtualization area, which adjust the expanding and dilating eye/mind to the awareness of conflicting, non-rational omnijective realities […]” (Nechvatal, 2005: 185–86).

![Figure 10: Lascaux Caves](http://photography.nationalgeographic.com/photography/enlarge/lascaux-cave-walls-photography.html)

Similar examples appear from a multitude of early civilizations (Egyptians, Babylonians, Greeks, and Romans, to name a few) that were extremely aware of the importance of layering the interior space with forms of media (i.e. visual or acoustic) in order to exhibit particular functional characteristics and attach specific desirable attributes. During the Bronze Age, the Minoan Civilization in Crete reigned over the Mediterranean, having as its ceremonial and political centre the Palace of Knossos, one of the first palaces ever built in Europe. Within its structure, there is evidence to demonstrate that the architectural design was a convoluted matter, aiming to balance aesthetics, functionality, and well-being. Through openings and passages, sunlight can reach even the lowest parts of the palace; ventilation and water

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management solutions run throughout the structure. However, frescoes and paintings are present everywhere as the top layer of aesthetically pleasing interiors. Additionally, the design of specific rooms affects a higher state of consciousness, symbolizing the “soul’s liberation from the earthly body” (Castleden, 1990: 92), providing sanctuary and spiritual amplification.

Even during the Late Antiquity period, architects were able to design highly immersive and dominant churches on an excessive and colossal scale so that believers were easily attracted by the interior ambiance, crafted with such care as to reflect God’s greatness. The Renaissance churches and chapels of Sacri Monti in northern Italy provides another example of masterful craftsmanship of media layered strategies within interior spaces. One of Sacri Monti’s churches has “[…] an image wall [with] highly illusionistic, diorama type simulations of holy biblical places in which thousands of pilgrims a day could become immersed” (Grau, 2011). This is an evidence of the intention of

Figure 11: Queen’s Apartment, Palace of Knossos

9 Image from http://hgustafs.myweb.usf.edu/cre117.jpg
the Catholic Church to create interiors capable of causing a direct emotional impact on viewers. The imagery can provoke amazement and awe, and in combination with the reverberant sounds, it is able to shape particular impressions that can result in trickery and deception.

[...] Long reverberation was simply an unintentional consequence of the spatial grandeur of God’s earthly home. Nevertheless, for those who repeatedly attended services in these religious spaces, aural and visual symbolism became tightly linked. In this context, long reverberation indirectly acquired its meaning from the religion, with its liturgy, icons, and visual designs. And this link was further strengthened by religious music written for this highly reverberant space. (Blesser & Salter, 2007: 93)

It is also important to highlight the work of the German scholar and polymath Athanasius Kircher and his 1646 publication, *Ars Magna Lucis et Umbra* (The Great Art of Light and Shadow), a compilation of studies concerning light, mirrors, and astronomy. Most of the artefacts he developed were exhibited in his own museum, *Museo Kircherianum*, in Rome, where visitors could explore the “enhanced” environments that used light, shadows, and image projections.

With such technical artefacts and their specific arrangements, Kircher established a tradition of visual apparatus that, in the following centuries, was both highly effective and influential. Based on the concept of purifying the soul through catharsis, media machines were designed and built in such a way that their functioning mechanisms remained a mystery to the audience: the projected world must not be recognizable as an artificial construct. Above all else, the intention was that the effects should take the onlookers by surprise, captivate them, and prevent them from giving free rein to their imagination and reason (Zielinski, 2006: 137).
Kircher's main intention was to transform the interior space through the use of media (light, images, sound, acoustics) combined with technological artefacts in a subtle but nevertheless effective way, where the operative force or agent was not obvious to the eye. The interior became subject to a range of transformations, extending the visitors' awareness and perception. Moreover, Kircher proposed to install a listening system to remote locations that would become playful engagements between random displaced people. This proposes an environment that blurs the physical boundaries through the use of the technological object, offering the participant the opportunity to extend the notion of locality (Levin et al., 2002).

\(^{10}\) Image from http://smfaanimation.blogspot.hk/2010/02/ars-magna-lucis-et-umbrae.html
These examples demonstrate the human need over centuries, across geographical locations, cultural differences, and technological advancements, to develop interior spaces with a range of media, and to define new functions, processes, and experiences. To successfully accomplish this, specific methods have been used in order, for instance, to understand people’s preferences and particular requirements, to acknowledge the context of the site and the ecological conditions, to analyse related interactions that take place, or to incorporate technological means to communicate the necessary media content.

Many of art practices to have sprouted up in recent decades, such as Installation, New Media, and Interactive Art have followed similar methods and approaches to create works that transform a space, allowing media to infiltrate levels of the perceptual strata. For this reason, a selection of art installations are presented in the following part of this chapter to greater understand practices that relate to the layering of the environment using physical, digital, or hybrid components. This research does not intend to examine the architectural design and engineering necessities but rather investigate a speculative, creative, and artistic perspective that may allow us to understand the domestic space from an imaginative and resourceful perspective.

**Enchanted Interiors**

The fantasy of being trans-ported into another world, to be taken wholly into the imaginary real, is a primal desire. (Packer & Jordan, 2001: 22)
To properly contextualize the speculative interactions that may exist within a domestic space, various artworks are explored. As these works function in certain ways inside an interior space and try to define a close relationship between the architectural structure, the media environment, and the perceptual impact it causes to the observer, it becomes necessary to investigate their practices in more detail as it informs the methods developed for this research. These works may be very different conceptually, artistically, and technologically; however, they identify a particular aspect that is of importance: space becomes a function that is defined by the technological processes, influencing the inhabitants or participants’ perception, and creating a triangle (space, interface, inhabitant) of interconnected interactive relationships that constantly form each other in variable ways. As German art historian Oskar Batschmann argues, one characteristic element we find in art installations is the ability to form a space that can reform recursively according to the participants (De Oliveira & Oxley, 2003).

The exploration of architecture, media, and technology has been featured several times within the fields of Installation, New Media, and Interactive Art, exhibiting a range of combinations and practices. Through these experimentations we find approaches that use architectural space and media technology to create a feeling of emotional insecurity and alienation (Zbikowski, 2001), to build direct connections between the physical and the virtual realm (Shaw, 2003), to actively control narrative structures of the environment (Hershman, 1983), to enable multi-user interaction and arouse participant’s awareness (Sommerer & Mignonneau, 2008), to establish a case of responsiveness and fluidity (Spuybroek, 1997), to overlay physical and digital spaces that embrace the body with imperceptible interfaces
(Fleischmann & Strauss, 2008), to set a communication between the physical character of the space and people’s perception and experience providing a state of relaxation and contemplation (Eno, 1978), and to utilize the architectural space as a sonic instrument for relaxation that also links to presence, movement, and memory (van der Heide, 2004).

Installation Art entails “temporary, site-specific works designed to surround or interact with the spectator and/or extant architecture in a given exhibition space” (Gonzalez, 1998), and it has demonstrated a large set of methodologies for exploration and experimentation within architectural interiors for doing so. It is strongly connected with past art forms such as Constructivism, Minimalism, and Dada, and, with respect to this practice, it presents possible relationships between art, participant, and space, as they share and circulate energy and ideas.

Although the term ‘Installation Art’ was coined in the late 1980s (Walker, 1992), installation works existed before that time in various forms and expressions. In recent history, installation artworks were realized in spaces such as abandoned train stations, warehouses, and factories. In the late 1950s, artist Allan Kaprow started approaching galleries about creating events, performances, and “environments”, as he used to call his installations, to describe a new artistic expression with “room-sized multimedia works” (Reiss, 1999). In 1962, he exhibited Words in the Smolin Gallery in New York, where the visitors could write messages on the interior space, and transform the environment according to their personal ideas, aesthetics, and philosophies.
Words is an “environment”, the name given to an art that one enters, submits to, and is – in turn – influenced by. If it is different from most art in its impermanence and changeableness, it is like much contemporary work in being fashioned from the real and everyday world […] (Kaprow, 1962)

Kaprow also applied lights and sound to define a multimedia experience that “breaks down barriers between the spectator and the work of art” (Reiss, 1999). As the participants used the available tools (chalk, crayon, pencils, and rollers), they defined the characteristics of the space, adding their personal expressions to the existing layers of the interior, altering the environment into a continuously evolving immersion. Kaprow’s installations share similarities with Interactive Art, as they each require participation and engagement; however, they have particular differences, mainly concerning

\[11\] Image from http://dreher.netzliteratur.net/1_Kaprow_vs_Morris_B4.jpg
the systems and the technological elements (often computational) that are used in interactive works. As Roy Ascott describes:

This interactive art is characterized by a systems approach to creation, in which interactivity and connectivity are the essential features, such that the behaviour of the system (the artwork, network, product, or building) is responsive in important ways to the behaviour of its user (the viewer or consumer). More than simply responsive, it constitutes a structural coupling between everyone and everything within the Net. This kind of work is inherently cybernetic and typically constitutes an open-ended system whose transformative potential enables the user to be actively involved in the evolution of its content, form, or structure. (Ascott, 2003: 280)

The layered complexity of an interactive artwork is potentially great as it usually consists of digital, electronic, computational units, software, biological bodies, and physical materials. The following sketch attempts to visually analyse an interactive artwork that consists of three main layers. The first layer called “Making Art” refers to the tools and resources an artist uses to establish the main body of work. The second layer is responsible for the medium of presentation and the methods employed by the artist to exhibit his/her concepts and ideas. The first and second layers are connected via “Creative Process 1”, which demonstrates the level of creativity applied to blend tools and presentation media together. The third layer – the “Interface” – is positioned between the artwork and the user, and according to its sophistication, it can define “Creative Process 2”. This process involves the range of interactions that take place and shapes how this exploration can affect the appreciation or apprehension of the overall piece by the participant.
The analytical process of an interactive artwork assists in the understanding of the synthesis and composition techniques that can be applied in developing layered interior and domestic spaces with the use of media and computational resources. Using methods and techniques provided by creative practitioners, a whole new range of possibilities unfolds. By dissecting the complexity found in an interactive artwork and further acknowledging implementation strategies, the interior space can be transformed into a playground for the senses and the imagination.

An important characteristic of Interactive Art is the communication not only between the space-participant-artwork, but also between systems and processes, the fundamental components of this relationship. The technological elements strongly influence the aesthetics of an artwork, as in Robert Rauschnberg’s piece *Soundings*, which was exhibited in 1968 at the Museum of Modern Art (MoMA, New York). In this work, Rauschnberg used sound and noise emitted from the participants to electronically activate lights.

\[\text{Image from http://www.zics.eu/out/picture2.htm}\]
placed beneath the transparent inked Plexiglas, which covered a large 10x2.4m area. In this example, the participation is not enough as specific functions dictate how the lighting responds. Based on an analysis system, the sound of the environment is “divided into four frequency bands, so that a high-pitched voice or sound would trigger a different set of lights from a low-pitched voice or sound; that is, children would trigger different lights from adults standing beside them” (Kluver, 2000).

During the 1960s and 1970s, Myron Krueger, another pioneer of Interactive Art, explored the interactions that take place within responsive environments, as in his installation *Glowflow*, which consisted of a dark room with transparent tubes filled with phosphorescent particles attached to the four walls. The light emitted from the tubes was activated by floor pads, which allowed the visitors to interactively explore the performative space and understand the communication that was established with the media layers of the system. Kruger’s observations from this work are that “interactive art is potentially a richly composable medium quite distinct from the concerns of sculpture, graphic art, or music”, “in order to respond intelligently the computer should perceive as much as possible about the participant’s behaviour”, and that “the visual responses should not be judged as art nor the sounds as music [as the] only aesthetic concern is the quality of the interaction” (Krueger, 1977: 423).
In *Telematic Dreaming* (1992), Paul Sermon used an arrangement of two distant bedrooms that were connected via a network system to transfer real-time videos captured by cameras installed in one location, and then projected into the other. The bed became a transcended medium and a performative space that allowed the participants to communicate through gestural and body language with the projected images of the remote space. The psychological complexity of a familiar object like the bed “dissolves geographical distance” (Wilson, 2002: 519), causes an “out-of-body telepresence experience” (Lovejoy, 2004: 237), and provokes “physical improvisations with [...] unknown bodies” (Kozel, 1994: 12) to be utilized in a virtual space created by the new functions media technology has introduced.

The use of computational media and systems as embedded units in the surfaces of the house opens great possibilities in terms of providing physical and virtual interfaces. Such interfaces hold the potential to change the

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13 Image from http://artelectronicmedia.com/artwork/glowflow
understanding of the layering abilities of an interior space. Depending on the resolution and quality of a media system, it may be possible to blur the boundaries of what constitutes reality: “reality is 80 million polygons per second” (Smith, 2000: 3). Similarly, Ray Bradbury, in his short science-fiction novel *The Veldt*, presents a domestic interior that is able to come to life due to the crystal technology embedded in its structure. This new system constructs a virtuality that is dangerously real:

The nursery was silent. It was empty as a jungle glade at hot high noon. The walls were blank and two dimensional. Now, as George and Lydia Hadley stood in the centre of the room, the walls began to purr and recede into crystalline distance, it seemed, and presently an African veldt appeared, in three dimensions, on all sides, in colour reproduced to the final pebble and bit of straw. The ceiling above them became a deep sky with a hot yellow sun. (Bradbury, 2012: 10)

Bradbury continues by describing that additional layers of odour and sound are able to provide a holistic immersion that amplifies the sensorial engagement, effectively enchanting and captivating the occupants of the space:

Now the hidden odorophonics were beginning to blow a wind at the two people in the middle of the baked veldtland. The hot straw smell of lion grass, the cool green smell of the hidden water hole, the great rusty smell of animals, the smell of dust like a red paprika in the hot air. And now the sounds: the thump of distance antelope feet on grassy sod, the papery rustling of vultures. (Bradbury, 2012: 10)

Up to this point, it is evident how the use of media and technology becomes a powerful agent in an installation space, allowing it to transform according to the participants’ aesthetic views, and vice versa, or to define and project information that is necessary for the viewers. Media and technology permit instantaneous changeableness according to sensed conditions such as participants’ behaviours, becoming active components in open-ended
metamorphoses. Moreover, they provide the necessary tools and methods for
the alteration of content and structure that effectively influence the
atmosphere and the aesthetics of the interior environment.

These possibilities may also be applied to domestic spaces to offer a
broad range of interactions and a vast amount of transformations using
technological tools and embedded media layers. To further explore these
methodologies, a case study was developed by the author, presented in the
following part of this chapter, which offers more information on the
implementation of these methods and practices into an interactive
architectural artwork.

**Plinthos Pavilion**

*Plinthos Pavilion* is a collaborative project between the author and the
architectural office mabarchitects (www.mabarchitects.com), and was
commissioned by the Interior Design Show ’09 committee (Metamorphosis,
Athens). The conceptualization of the project, developed by the author and
mabarchitects, defined its physical manifestation as well as its functions and
aesthetics; mabarchitects developed the physical construction of the
architectural space, and the author was responsible for the development of
the lighting and audio installation, implementation of the sensor interfaces,
synthesis of the sonic material, as well as programming of the real-time
interactive system. Appendix 3 includes a list of online and print related to the
Plinthos Pavilion. The reader may access the accompanying USB flash drive
(folder Chapter 3 – Plinthos Pavilion) for a time-lapse video of the setup, a
demonstration of the work during its performance, and a set of high-resolution
images that display the system’s diagrams, user interfaces, as well as the final installation space.

Plinthos consists of an architectural structure with an embedded sensorial skin, which transforms the space into an interactive installation of inner discovery and a subliminal exploration of the self. Its structure invites visitors to navigate within thousands of perforations and multiple media layers that blend harmoniously to create a performative and responsive architectural installation, triggering intimacy through masterfully articulated poetic expressions. Each layer is responsible for a particular outcome; however,
elements inter-communicate with each other when necessary to exhibit an orchestrated intelligence as one of the structure's fundamental extensions.

A prior challenge for the construction of *Plinthos Pavilion* was to use recyclable materials found in abundance and supplied by local manufacturers. Plinthos (also known as clay brick) is a standard construction element that provides strength, durability, resistance, absorption, and isolation. In this installation, plinthos was stacked in an unusual way in order to create transparency, and combined with interactive and media mechanisms, which act not as an add-on but rather an integral part of the structure itself, to enhance visitor experience.

More than 20,000 hollow bricks were used to complete the floor plate and walls; but each plinthos reaches a paradox – an identity crisis – as transformation is achieved via misuse, stacking the bricks on end so that vertical voids are oriented horizontally. Inevitably, the porous sides are revealed, thus creating surfaces; openness is accumulated and transparency is employed, allowing the flow of air, light, and sound through them. At certain oblique angles, the structure becomes a conventional wall; however, direct view shows a high degree of porosity.
The main construction is built within a “black box” with a single entry point that leads to a space between outer and inner skin, which acts as a service area. The pavilion does not include an external façade, but instead offers a theatrical entrance, which reveals only a glimpse of the interior. The entry sequence is carefully choreographed as the visitor moves from the brightly lit exterior of the exhibition hall to a dimmed monochromatic all-brick interior. Based on visitor proximity to the curved wall, ventilation devices are triggered, blowing fresh air through the porous skin of the structure, allowing transparency to fully emerge. Space breathes through its permeable walls that sync with the synthesized soundscape and the expanding lighting system, transforming the structure into a living organism in which the visitor is completely immersed.
Behind the walls of the vertically rotated stacks of bricks, a big roll of reflective white paper wraps the environment as a protective membrane with its main intention not to provide safety but to reflect light emitted from a series of interconnected LED bars positioned on the bottom of the exterior wall. The light fixtures are tilted towards the white paper, to reflect a uniform lighting coating that can be viewed from the interior through the transparency that is created by the bricks’ open cells.

*Plinthos Pavilion* does not remain in stasis, but rather reacts to conditions such as patterns of human behaviour that shift and affect its compositional properties. Sound, light, and air become expressional elements of the environment, synthesizing a harmonious sensation and inviting exploration through tactile, auditory and ocular channels. A computer vision algorithm scans and analyses visitors’ interactions such as motion, presence, position, circulation, energy, or formation clusters, providing multi-dimensional information about spatial occurrences that help the system identify patterns and control media layers accordingly. This process creates a dynamic organism that completely immerses visitors in never-ending patterns of lighting compositions that oscillate in response to visitors’ actions. The accompanying sonic layer enhances this feeling of immersion, extending the perceptual levels using aural excitation mechanisms.
An extensive database of pre-recorded and synthesized sounds is fed into the main processing system that composes in real-time the soundtrack of the space. The final result is projected through a multi-channel speaker configuration that surrounds the environment, although audio equipment remains augmented beneath the hard surface. The sonified environment activates perceptual images of harmony and exhilaration, communicating aural awareness, closeness, and affection. Aside for the short-term memory of the spatial activity, Plinthos has long-term (and more specifically episodic) memories stored in its prefrontal cortex, mostly referring to recollections of its genesis. These memories remain hidden unless visitors activate them using the stem lights that appear in the middle of the structure, closely resembling
hair cells found in the human ear, acting as sensory receptors of tactile input, having direct access to digital memory space.

![Image of a person sitting in a room with lights and a brick wall]

Figure 19: Stavros Didakis & mabarchitects, *Plinthos Pavilion* (2010)

Specialized flex sensors are embedded within the lighting objects to allow the system to track changes using haptics and object movements. The amount of motion defines the aggressiveness of the sound pressure and the processed texture applied. The number of triggered light movements defines the selection of specific database categories that represent an equivalent level of complexity from the recorded material that was created during the construction of *Plinthos*—such as brick hits, smashes, scrapes, and breaks. These sonic triggers allow visitors to listen and experience these events as past snapshots of the structure’s embryotic state, and to provide a space for exploration that reacts to the way visitors engage, behave, and act.
Media prosthetics are fundamental components of this cyborgian object, providing authority of ether and time and transforming its porous structure into a mystical – almost sacred and ritualistic – organism that breathes, reacts, and communicates. The goal, therefore, of this work is to extend “the possibilities of an architecture” to the post-digital culture (Goulthorpe, 2008), and to speculate on the hybridization of architectural interiors with embedded media layers that contrast the old hard surface with ethereal and responsive qualities of new media and computational technologies. The arrangement and composition of the layered complexity is able to provoke and alter mental states, feelings, and senses.

At the beginning of the chapter, the Lascaux Caves were mentioned, as one of the first spaces where media elements were used to provoke the senses and consciousness. Thousands of years later, the same strong need is also present, as current technology offers tools to articulate masterful designs that intrigue, mesmerize, and enchant.
Chapter Summary

This chapter presents methods and practices in implementing media elements in interior spaces, extending the understanding of previous paradigms, and allowing novel creations to be provided for exploration by visitors and inhabitants. As demonstrated, the layering of media elements within an interior space is both a craft and art that can define the way spaces are used, experienced, and perceived. By applying a range of creative methods and practices, it is possible to influence and define a new range of layered combinations and compositional techniques that are able to exhibit creative manifestations. As in the case of *Plinthos Pavilion*, the architectural structure becomes the basis of the addition of ethereal media elements – light, sound, air – that are perplexed and interwoven according to the interactions of the interior. Static composition is for long gone, as the new playground consists of immaterial elements that are generated and composed according to real-time conditions and events. Based on this reason, the next chapter discusses in greater detail the immateriality of the domestic interior, and demonstrates tools and practices that can be applied to further consider and understand methods for bringing computational media and sensor technologies into the ecology of the household.
Chapter 4: The Invisible Home

The previous chapter analyses practices related to the use of various forms of media and technologies as creative compositional materials to the configuration of interior spaces. This chapter investigates the domestic space as an ecosystem on a number of possible scales, (micro, meso, and macro), not only acknowledging elements our physical senses can scan and perceive, but extending our understanding to invisible and imperceptible spectra where millions of particles, frequencies, substances, and events exist and interact. These unseen and uncaptured properties of the domestic environment have a substantial impact on organic and inorganic entities (architectural structures, physical materials, biological bodies, digital information). For this reason, a range of technological systems have been developed and are presented in this chapter to assist in the identification and analysis of untraceable events in order to have a greater understanding of the home, and demonstrate emerging and speculative possibilities that allow immateriality to emerge in physical and virtual domestic domains.

Observing Ecological Systems

To better understand home, it is important to investigate, explore, and analyse it as an ecological system that consists of a number of properties and a range of spectra. Ecology is a synthetic Greek word ("οικολογία") that derives from "οίκος" + "λόγος", which literally translates as the study of home. In 1973, Crawford S. Holling (Holling, 1973) published his research on the resilience and stability of ecological systems, and presented his findings on the behaviour of ecologies when critical events that affect their performance are
triggered. Holling was interested in observing the system from when it is in a state of dynamic equilibrium until the moment it "breaks", that is, when radical changes are triggered and detected. The research demonstrates that even when the ecology reaches and over-exceeds a critical limit, adaptive shifts emerge; a natural way for the system to survive and evolve, which often demonstrates a creative aspect as unanticipated phenomena begin to appear. In an analogous way, a home's ecosystem faces a critical limit. Within the current domestic space adaptive shifts take place as radical changes in the routines, rhythms, and properties appear due to the technological developments that infiltrate and redefine the home's natural order.

\begin{figure}[h]
\centering
\begin{tabular}{ccc}
\includegraphics[width=0.3\textwidth]{a.png} & \includegraphics[width=0.3\textwidth]{b.png} & \includegraphics[width=0.3\textwidth]{c.png} \\
\includegraphics[width=0.3\textwidth]{d.png} & \includegraphics[width=0.3\textwidth]{e.png} & \includegraphics[width=0.3\textwidth]{f.png}
\end{tabular}
\caption{Examples of possible behaviors of systems in a phase plane: (a) unstable equilibrium, (b) neutrally stable cycles, (c) stable equilibrium, (d) domain of attraction, (e) stable limit cycle, (f) stable node.}
\end{figure}

\textbf{Figure 22:} Crawford S. Holling, \textit{Ecological Behaviours} (Holling, 1973)

Thus, it is vital to investigate how the diversity of conditions in the domestic environment can achieve a dynamic equilibrium between inorganic, biological, and digital entities, or when and how the system over-exceeds its limits, resulting in new emergencies. Current technological trends ensure that the ability to monitor, log, analyse, and define numerous properties transform
the habitat into a cybernetic system. The networked manifestations of
domestic properties, behaviours, and sensed interactions become a multi-
dimensional digital cartography that accumulates and builds on a daily basis.
In contrast to Schwitters’ *Merzbau*, the surreal assemblage of the
computationally enhanced household offers the possibility to intervene
simultaneously in its physical, augmented, and virtual spaces.

The augmentation of tools and resources within the domestic space
aims to deliver an increased awareness of the household, whilst being
respectful of its dynamics and serving as a transparent silent layer in the
background. A vast array of computational systems (such as the frameworks
suggested by ubiquitous computing and the Internet of Things, which are
explained in more detail in following chapters) are able to sense, identify, and
collect information from the invisible space as well as the patterns created
from the unseen choreography of the household; they provide rich information
from the accumulation of the assembled events to construct knowledge and
understanding.

To rethink the domestic environment is not only a matter of adding
gadgets and technologies that are more efficient, sustainable, or trendier, but
rather it demands a larger inquiry that considers the practices of
computational technologies that monitor the home’s ecosystem in detail. It is
important to be aware of the unseen cosmoses of our domestic environments
as they have a substantial impact on physical and biological conditions that
alter and define material and immaterial structures. It is necessary to examine
the behaviour and performance of the home as a collective entity that includes
elements captured from the micro, meso, and macro scales. The ability to
perceive the unseen environment and the hidden relationship between objects,
spaces, digits, and bodies reveals an underlying multitude of processes and a swarm of functions that contextualize the experience of our domestic habitats.

**Seeing the Immaterial**

Information: Can mean anything from numbers to images, from white noise to noise to sound. A weather report, a portrait, a shadow in surveillance footage, a salary statement, birth and death statistics, a headcount in a gathering of friends, private e-mail, ultra high frequency signals, sale and purchase transactions and the patterns made by pedestrians as they walk in a city – all of this can be and is data. Data, like coal, uranium and other minerals vital to the running of the world economy is mined, processed, refined and sold at a high price. (Raqs Media Collective, 2003: 358)

Interior spaces contain an abundance of unseen properties that human senses are unable to trace or perceive; consequently, awareness of these properties is difficult to be achieved. However, these properties should not be considered unimportant and their value should not be dismissed, as they are part of the ecology of the house, and for this reason they need to be investigated in further detail. Consequently, unseen matter is explored through the micro, meso, and macro scales – molecules, particles, frequencies, domestic interactions, events of the household, weather conditions, and planetary events are all properties that affect to a lesser or greater degree the domestic ecology. These properties are fundamentally important as they play a major role in the way inhabitants feel, respond, behave, and interact. In order to examine the household on all possible scales, a large quantity of information has to be extracted, measured, analysed, and acknowledged. With the use of technology, a spectrum of this untraced matter can be captured and further used in practical, aesthetic, or experimental applications. By suggesting new ways of representing, accessing, and using
this information, additional aspects of our homes can be realised; our personal environments can achieve an alternative present and future.

Anthony Dunne in 1999 coined the term “Hertzian Space”, referring to the invisible properties that surround us, and how technology assists in altering the way we perceive and experience objects and environments. The experimentations that Dunne suggests help us reflect on the poetic exploration of the immaterial space through the speculative design of electronic or hybrid devices. Dunne notes the profound influence the dematerialized “skin” of electronic objects causes to their users, and discusses his considerations related to these interactions:

We are expecting a new kind of connection to our artificial environment. The electronic object is spread over many frequencies of the electromagnetic spectrum, partly visible, partly not. Sense organs function as transducers, converting environmental energy into neural signals. Our sense organs cannot transduce radio waves or other wavelengths outside the narrow bandwidth of visible light (and infra-red energy through the skin as warmth). Electronic objects are disembodied machines with extended invisible skins everywhere. They couple and decouple with our bodies without us knowing. Working on microscopic scales, often pathogenic, many electromagnetic fields interfere with the cellular structure of the body. Paranoia accompanies dealings with such hertzian machines. How do they touch us? Do they merely reflect off our skin, or the surface of our internal organs? In other words, do they merely ‘see’ us, or can they ‘read’ us too, extracting personal information about our identity, status, and health? (Dunne, 2005: 85)

Following Dunne’s inquiries, the project Bubbles of Radio by Ingeborg Marie Dehs Thomas (Thomas, 2008) attempted to visualize the invisible electromagnetic space of radio frequency protocols such as GMS, RFID, Wi-Fi, and Bluetooth. Critical and visual design was used in the development of a series of sketches, inspired by biology and natural history that demonstrate radio frequencies as organic structures in abstract form. The project does not
intend to provide scientific accuracy of the actual phenomena, but rather to start a conversation about the awareness concerning spectra that interact with us on a daily basis. Although most of the time we cannot consciously perceive them, we should nevertheless be aware and cautious of them, as their presence has a crucial impact on our lives in terms of our health, mood, and well-being.

Christopher Warnow and the design studio Onformative took this approach further with their 2011 collaboration *Immaterials*, a series of procedural light paintings within an enclosed space. With this technique, the creators utilise the ethereal aesthetics of light to demonstrate the physical manifestations of unseen spectra that co-exist and inhabit the domestic space, that is, frequencies that distribute their energy without the inhabitants being consciously aware of them. Similarly, the group Semiconductor, which consists of the UK artist duo Ruth Jarman and Joe Gerhardt, created the “Magnetic Movie” (2007), a fictional visualization of invisible magnetic fields that contain the tremendous power to shift the material structure of a space (Jarman & Gerhardt, 2007).

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Although the previous projects demonstrate visualizations of a range of properties that cannot be perceived by the human senses, they are mainly static and representational. In the project *Architecture of Radio*, Richard Vijgen developed an iPad application that accesses and displays the *infosphere* of an environment in real time. The *infosphere* is defined as a space that consists of “informational entities”, and in contrast with cyberspace, “infospheres are not limited to purely online environments” (Vijgen, 2016). The application allows users to view the augmented space in real-time, and in particular the invisible radio signals broadcasted from routers, cell towers, or overhead satellites.

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15 Image from http://christopherwarnow.com/portfolio/?p=244
The aforementioned projects and practices clearly exhibit the need to investigate the unseen properties of an interior space, and to view, understand, and control an environment with all its complexity, from larger to smaller scales. Convoluted properties, frequencies, and substances are fundamental aspects of the household as they greatly affect the overall performance of the environment, such as the occupants’ behaviour or well-being. For this reason, the next part of this chapter presents theoretical and practical investigations that were conducted as part of this research in relation to the monitoring and analysis of the micro, meso, and macro level of the domestic space using computational and technological tools.

**Breathing Spaces**

This part of the chapter investigates the microscopic scale of the domestic environment, which refers to properties small enough that cannot be perceived by the human senses. Matter such as cells, bacteria, molecules, and atoms require specialized equipment to be viewed and understood. The detail of the analysis is defined by the resolution of the monitoring mechanisms that also expresses the level of awareness in a particular study. In this part of the research a number of micro substances are studied and explored such as those that are contained within the air; an inseparable aspect of any interior space.

Air is one of the most fundamental properties of this planet and a primary condition for life to exist, and although its presence is imperative, it can be harmful as well. The air in the troposphere consists of numerous chemicals, such as nitrogen, oxygen, argon, neon, methane, carbon dioxide,
helium, krypton, hydrogen, xenon, ozone, nitrogen dioxide, iodine, carbon monoxide, and ammonia (Lide, 2003), it very often contains chemicals, particulate or biological molecules that are harmful and lethal to living organisms. These dangerous chemicals include sulfur oxides, nitrogen oxides, carbon monoxide, particulates, lead, mercury, ammonia, radioactive pollutants, a large number of hazardous air pollutants, and persistent organic pollutants, among others (Dewey, 2000). Further than this, within a home environment it is possible to find even more harmful substances such as benzene, formaldehyde, naphthalene, polycyclic aromatic hydrocarbons, radon, tetra- and tri-chloroethylene (World Health Organization, 2010), as well as dampness, mould, bacteria, fungi, and an extensive range of carcinoid elements.

Figure 25: Observing the house on a micro-scale

Thus, it is vital to be aware of these micro-substances especially when it comes to our personal spaces, where we are more relaxed, and, therefore, more vulnerable. According to the World Health Organization (WHO, 2014),
Air pollution is one of the greatest dangers in a human's life, as approximately 4.3 million people die prematurely every year due to indoor/household air pollution. In more detail, WHO describes:

Healthy indoor air is recognized as a basic right. People spend a large part of their time each day indoors: in homes, offices, schools, health care facilities, or other private or public buildings. The quality of the air they breathe in those buildings is an important determinant of their health and well-being. The inadequate control of indoor air quality therefore creates a considerable health burden. Indoor air pollution – such as from dampness and mould, chemicals and other biological agents – is a major cause of morbidity and mortality worldwide [...]. (World Health Organization, 2009: 11-12)

These chemical and harmful substances are able to penetrate live tissue and be absorbed by human organs, affecting the body in multiple ways – transforming and shifting on a cellular level its development, growth, and evolution. They can cause a range of symptoms and illnesses such as asthma, respiratory dysfunctions, nausea, suffocation, infections, damage to lung tissue, cardiovascular disease, chronic lung disease, anemia, kidney disease, reproductive disorders, neurological impairments, seizures, osteoporosis, cancer, premature death, and many more (EPA, 2007). Although these problems are extremely important (and in many cases, severe), public awareness is minimal. This is mainly due to inadequate education, inability of government bodies and architectural agencies to inform and apply solutions, insufficient financial coverage to properly monitor and control the quality of a house, and, in many cases, casualness and negligence by inhabitants, as they believe there is no immediate danger or life-threatening situation. As Christopher Day characteristically says:

The trouble is we become dulled to these things. We don’t notice the noise, the bad air, the harsh conflict of hard-edged shapes and forms. We become immune to the negative forces in our environment – and
that is when they do us most harm. Our sensitivities and our senses become dulled and our language and unconscious approach to daily life begin to reflect our surroundings. (Day, 2004: 17).

Based on this particular need, many research groups and companies focus on the development of solutions that monitor the environment to scan harmful and unwanted substances, offering the average user applications that can be easily purchased, installed, and accessed, as for example Air Mentor (https://www.air-mentor.com), Foobot (http://foobot.io), uHoo (http://uhooair.com), LaserEgg (http://laseregg.origins-china.com), Koto, (http://koto.io), and NetAtmo (https://www.netatmo.com). One of the main tasks of these devices is to measure indoor pollutants using sensor technologies and to collect information about gas properties and other particles such as carbon monoxide, carbon dioxide, nitrogen dioxide, or particulate matter. Furthermore, the systems store recorded data in online and offline databases so that users using mobile phone applications can easily retrieve necessary information and receive updates and advice about precautionary measures that need to be taken.

Although these systems offer convenient and effective ways to further understand the micro level of domestic environments, they do not have extensive sensorial mechanisms that can identify larger amounts of harmful substances. Their interfaces do not offer easy accessibility to hardware interventions that would allow extendibility and more accurate personalization to the demands of the user or the household. The same applies to their software services, as they do not provide a wide range of communication protocols to connect easily with a range of systems and devices, or compatibility with various databases to allow effortless storage and data
integration. Industrial standardized design makes it impossible to personalize according to individual needs or to provide open systems within the local network that shares their captured instances for computational prototyping and other creative practices.

Figure 26: Commercial air quality monitors

For this reason, and the requirements of this research, a monitoring device was developed to capture the substantial amount of micro-properties that exist in an environment, and at the same time to become an extendable object that links and communicates with diverse technological frameworks and systems. Part of this development is to demonstrate speculative possibilities that emerge in the domestic space, always with respect towards the inhabitants and their personalized habitats.
**DataGrid**

*DataGrid* is a monitoring device that was created for the needs of this research to establish a technological framework able to extend the sensorial dimensions of the domestic space. The development of *DataGrid* is one of the methods used to investigate practices related to the ways electronic and sensor technologies assist in monitoring and tracking a range of unseen properties and propose creative possibilities for the domestic space. Moreover, *DataGrid* promotes accessibility and parameterization according to the needs of the user, and it provides a range of communication protocols that offer wide connectivity with other technological and digital media systems. The reader may access the accompanying USB flash drive (folder Chapter 4 – *DataGrid*) that includes the documentation of the device, such as photos, 3D files of its design, and the full code of the micro-controller.

The main challenge for this development was to establish a system that measures and records a large amount of invisible matter (chemicals, particles, frequencies), in contrast to other commercial solutions with limited scope, and to develop an open-source framework based on accessible and affordable sensors and electronics. Furthermore, it was important to be able to easily distribute the gathered information using digital telecommunication networks to local or remote devices, promoting further possibilities for computationally-fused interiors. *DataGrid* facilitates these requirements and becomes a modular solution that permits easy configuration and setup based on the users' preferences or according to the requirements of each domestic space.
The hardware system was built using an Arduino Mega (Arduino, 2015), a commercially available micro-controller system with a large amount of digital and analogue inputs and outputs (54 inputs/output, 16 analogue inputs, 4 serial ports). Sensor devices are connected to the micro-controller, and based on their functionalities they operate in sensing particular aspects of the environment. Their readings are digitized, stored in an offline and online database, and shared in the local or remote network using the Ethernet or Wi-Fi modules that are part of the system. The sensors are able to scan the following properties: temperature, humidity, light intensity, sound intensity, liquefied petroleum gas (LPG), butane, propane, methane, hydrogen, nitrogen, smoke, ozone, carbon monoxide, carbon dioxide, particulate matter, and radiation. Moreover, the device includes a Light Emitting Diode (LED) screen that displays the sensor readings, and a piezoelectric speaker, which alerts users if a particular value exceeds the predefined limits so that caution can be taken.

For the selected microcontroller and sensor devices, inexpensive components were used so that they can easily be replaced and upgraded.
This was done to allow feasible extensibility and to motivate the community of users to design systems based on their own needs. According to this, the complete framework is open and free (schematics, configuration, connectivity sketches, coding, and even the 3D files that are required to print the skeleton and shell of the device), which offers users the opportunity to personalize the design and functionality of the system. This approach not only aligns with the personalization of the devices (as is similarly the case with the domestic space in general), but also with the demands of many users to have full control of their technologies. Many commercial devices share personal information of users with third-party companies such as Samsung, Google, Apple, Amazon, or even with government and international agencies, as has already been reported by many sources (Sanger, 2016; Timm, 2016; Olsen et al., 2016). *DataGrid* makes sure that the content remains in the hands of the user to be utilised in any way desired.

![3D design of DataGrid (shell and skeleton)](image)

Figure 28: 3D design of DataGrid (shell and skeleton)

To code *DataGrid*, Arduino IDE (Integrated Development Environment) was used, an open source and widely accepted multiplatform framework for building physical computing applications. The system's sensors are calibrated using computational calculations for domestic use, and they are configured to
provide the readings in clear and legible units (i.e. light is expressed in values of lux, sound in decibels, and so on). The digitization of the tracked information is stored and distributed in the local network in real-time using OSC (Open Sound Control), MQTT (Message Queue Telemetry Transport), and HTTP (HyperText Transfer Protocol) to allow compatibility in the current Internet of Things era, enabling DataGrid to communicate with domestic systems, appliances, and devices for the purpose of accomplishing specific computational and automation tasks. Moreover, the values captured by the sensor interfaces are uploaded and distributed in a remote cloud database, so that any Internet-enabled device can locally or remotely access and use the information.

**Figure 29: DataGrid schematics**

Overall, DataGrid becomes a non-obtrusive system acting as a layered sensorial skin that has the ability to represent in greater detail many substances of the interior space (such as air molecules or environmental properties), and to permit access of recorded information to auxiliary computational units for further analysis and processing. Certainly, DataGrid does not intend to become a universal monitoring solution but rather to assist as a methodological asset in the practices of this research, and to be used
further in artefacts and case studies that are presented in Chapters 4, 5, and 6.

Capturing Meso Interactions

In addition to the DataGrid prototype, other technologies have been created for the needs of this research in order to track and monitor events and interactions that take place within the meso scale of the space, including users’ physical and virtual preferences, activities, presence, as well as biological and emotional responses using wearable and mobile computing devices.

![Figure 30: Logging data in the meso-scale](image)

By scanning stored digital preferences, social media interactions, mood, activity, energy, and biological information, a large quantity of information is collected and used to comprehend in more detail the nature of a specific habitat, which is an important factor in understanding the domestic ecology in greater depth. In this part of the chapter, a description of these technologies is
presented, as well as how the developments assist other aspects of the sensorial dimensions of the domestic environment.

**Presence**

One of the basic requirements of the computational home is to know who enters the domestic space (and when), so that it is aware of the occupants’ presence. Several methods and technologies are able to assist in acquiring this information, as for example proximity detection using Wireless Local Area Network (WLAN) or Global System for Mobile Networks (GSM), Global Positioning System (GPS), infrared, ultrasound, computer vision, smart locks, or more advanced positioning solutions as the Ekahau WLAN and RSS fingerprint service (Ekahau, 2015), the Elpas EIRIS (Visonic, 2015), or UbiSense that uses a tracking system based on Ultra Wide Band radio technology (UbiSense, 2015).

These solutions can be, to varying degrees, ineffective, expensive, or time-consuming to develop and install. For example, computer vision has been used in numerous applications to detect motion, activity, presence, and spatial or facial recognition (Moeslund & Granum, 2001), and although it is straightforward to set up, it is not so easy to have a reliable system that can identify users under a range of lighting conditions. Concerning smart locks, there are many commercial solutions available, such as the Kwikset (http://www.kwikset.com), August (http://august.com), and Bolt (https://lockitron.com) that can detect users’ presence mainly using Bluetooth (or in some cases infrared and fingerprint sensors), and can control door access or trigger automation tasks. Although smart locks can be efficient and
reasonably safe, they are expensive, need specific hardware installation, may cause access problems, and require a power supply at all times.

Based on the above methods, several practices were developed by the author to investigate methods in sensing inhabitants’ presence and identification. Initially, a native Android application was programmed to run as a background service on a mobile phone that accesses its GPS sensor and sends a positive verification code if the device is within the geographical coordinates of the house. Through a Transmission Control Protocol (TCP) connection the data are sent to an assigned Internet Protocol (IP) address and port, which is scanned continuously by a local script installed on a Raspberry Pi microcomputer (https://www.raspberrypi.org).

This solution, however, was not satisfactory, as the GPS at times did not indicate the correct data – it also consumed a lot of energy. So, as an alternative, the Wi-Fi state was used to report whether the device was connected to the home’s router, and therefore report if a specific user is in the house. After a series of tests, this solution was also proven unsatisfactory, as the application had to run on the device continuously, therefore consuming a lot of energy too. To solve this problem, the identification system was transferred to the Raspberry Pi microcomputer that is installed at home, and it is responsible for continuously scanning the router for the identification of the devices of the inhabitants. If a MAC address of an occupant’s phone appears in the router scanning for example, the activity is stored in the database and is allowed to be viewed by any other systems or processes (i.e. contextual awareness). The reader may access the accompanying USB flash drive (folder Chapter 4 – Presence) that includes the full code of the Android application, and the Python script that was used for this system.
Spatial Proximities

As the MAC sniffing solution is able to track only when users are connected to the local network, it cannot identify their specific location within the home. For this reason, a device was developed by the author to log proximity interactions in specific areas using an infrared sensor that reports to the main system if and when a contact is made. By distributing several devices across different rooms and locations, it is possible to receive a large amount of information that reveals how the environment is being used, as well as to expose behaviour and activity traits. The design of the device can be personalized using LED lighting colours and a visualization screen that
displays content according to individual preferences. Although the device is fully built, its shell that is demonstrated in the following picture refers to a concept that is yet to be implemented in reality. The programming code of the device can be found on the accompanying USB flash drive in the folder Chapter 4 – Spatial Proximities.

![Image of scanning devices](image.png)

*Figure 32: Stavros Didakis – Scanning devices (2013). Concept designs (top), hardware development (bottom)*

**Cyber-Sense**

Navigation within the physical space is one set of interactions that can be extracted from the meso scale; however, another important parameter is to sense actions related to the virtual navigation of the inhabitants. As William Mitchell argues, “networked intelligence is being embedded everywhere, in every kind of physical system—both natural and artificial”, and “routinely, events in cyberspace are being reflected in physical space, and vice versa” (Mitchell, 2003: 3). The electronic footprints left by users in the vast Internet
spaces reveal information that can be used to identify aesthetic and ideological preferences, habits and attitudes or even mood and psychological states. These are important parameters that can be effectively utilized to shift properties of a household, to accurately adjust domestic preferences, and to respond and interact in real-time.

According to this need, an application was programmed in Processing (https://processing.org) and node.js (https://nodejs.org) to monitor and track specific attributes of users from the social media platforms Facebook, Instagram, and Twitter. The designed application monitors the online activity of a user (if access has been granted), and selectively obtains information about the user’s profile, things of interest, amount of online activity, and media content such as images and videos.

Textual responses of the users are further processed using sentiment analysis, a computational technique that estimates sentiment and emotion using natural language processing algorithms (Nasukawa & Yi, 2003). The responses provided by sentiment analysis indicate if the algorithm has identified a positive or negative post from the user, and, if the result is within a significant percentage of confidence, it is stored in the database for immediate or future use. The sentiment analysis algorithm is implemented into NodeRed, a rapid prototyping platform developed by IBM that offers a visual programming interface to blend Internet of Things applications together with a range of cloud and API services. The folder Chapter 4 – Sentiment Analysis of the accompanying USB flash drive includes the source code of the Processing application, as well as the code for NodeRed.
Although sentiment analysis can provide an indication of the emotional state of users, its percentage of successful tracking is low. For this reason, MoodLog was developed by the author, a desktop and Android application that assists in logging voluntarily responses concerning mood and current activities (the accompanying USB flash drive includes the full code of the application in folder Chapter 4 – MoodLog).

The interface design of the application was inspired by James Russell’s model of affect, a widely accepted method of classifying emotions in a dimensional fashion (Russell, 1980). The five categories available can be used to describe a person’s current activity, mood, mood intensity, stress, and energy levels. Each device corresponds to a particular user and, at random instances during the day, logs their present states (only if the person is in the home environment). The accumulation of responses provides a helpful approach in exploring habits, preferences, and behaviours related to the environment that can evoke critical and insightful reflections.
With the advent of wearable technology, electronic devices can easily be used as practical and functional systems attached to the wearer’s body, able to track activities and biological information even in real-time. Physiological sensors, transmission modules, and processing abilities of wearable devices monitor biometric data that indicate physical activity, physiological responses, mood fluctuation, and emotional health (Korhonen et al., 2003; Pantelopoulos & Bourbakis, 2010; Uğur, 2010). As wearable-computing applications can assist in providing a large range of this information, an application was developed for this research to extract data and monitor in real-time responses of the inhabitants’ biological information.
For this reason, the wearable device FitBit ChargeHR was used (FitBit, 2016), as it provides continuous heart rate monitoring, activity recognition, statistics, wireless synching, and long battery life. Through the FitBit Application Program Interface (API), data are extracted concerning users' recent activities, body measurements, sleep entries, and overall statistics on various timeframes. Node.js and Processing access the stored data of the FitBit API, and they can either read values in real-time, share readings to local or remote databases, or process an array of data using analytics to indicate trends and performances. The data provided using this approach become extremely beneficial in further understanding the rhythms of a particular household by having access to the inhabitants' biometric information. The accompanying USB flash drive includes a demo code of the application that was used to extract the FitBit data in the folder Chapter 4 – BioData).
Macro Events

Every ecosystem is constantly affected by planetary, climate, geomorphological, and weather conditions. It is impossible to study an environment without considering these implications, among others, that deeply influence and often define important events and activities. For example, momentary affective states (e.g. those produced by the weather) influence judgments about happiness and satisfaction (Schwarz & Clore, 1983; Barnston, 1975; Catalano & Dooley, 1977); the moon’s gravity causes tides that affect human behaviour (Govorushko, 2012); and Ultraviolet Index (UV) produces or initiates carcinogenesis in the human skin (Wilkening, 2006).

Concerning the importance of macro events, the Millennium Ecosystem Assessment Board notes:

There are natural and human-induced physical, chemical, and biological drivers of change. Natural drivers include solar radiation, climate variability and extreme weather events (such as droughts, floods, hurricanes, and cyclones), fires, volcanic eruptions, earthquakes, pest and disease out-breaks, and natural biological evolution. The primary human-induced drivers include land use changes, climate change, air and water pollution, acid deposition, soil erosion, soil salinization and fertility changes, irrigation, fertilizer use, harvesting, the use of persistent organic chemicals, and the introduction of non-native species. (Millennium Ecosystem Assessment Board, 2003)

As environmental properties are extremely important for inhabitants, a set of parameters can be monitored by various computational processes to assist the household by notifying it about conditions that exist on the macro scale. Accordingly, real-time information systems have been used, such as the Really Simple Syndication (RSS) feeds and APIs to provide information on weather conditions, measure the Air Quality Index (AQI), provide earthquake information, access data on solar radiation, and measure Ultraviolet Index
The data are collected frequently and stored on the database and can be easily retrieved by the users. The folder Chapter 4 – MacroEvents that can be found in the accompanying USB flash drive, the reader may find a demo application in Processing that was used in this part of the research for accessing and logging macro events.

Furthermore, social (Rae, 2005), hegemonic (Lefebvre, 1991), and cultural (Taylor & Thorpe, 2004) factors also play an on-going role in how an individual responds to their environment. For this, Twitter is used to indicate specific events via tweets, regarded as temporally authentic microscopic instantiations of public mood states (O’Connor et al., 2010). The monitoring of social trends based on geographical areas that relate to the household can reveal aspects that greatly influence the habitat (Schöning & Bonhage, 2015). Moreover, social, political, economic events, fluctuations in the stock market, crude oil price indices and major events in media and popular culture reflect significant, immediate, and highly specific effects on various dimensions of people’s mood (Bollen et al., 2010).
**Binding Data**

The previous cases present a range of systems and technologies that have been developed and applied for the needs of this research in order to sense the domestic environment on a micro, meso, and macro scales. Each different development allows us to better understand the home as an ecosystem, and to establish a significant level of awareness from the collected information of the analysed parameters. Systems and technologies have been applied to the domestic environment to detect chemical substances, frequencies, vibrations, inhabitants’ presence, habits, and activities in physical and virtual domains, as well as to monitor sentiment, affectivity, and biological responses, and to scan planetary, universal, or geographical information.

The received information from the sensor sources often reveal the context of an event or an interaction, which is something important for the household to know (inhabitants, system, A.I.), in order to execute a particular set of functions (automations). According to Melanie Hartmann and Gerhard Austaller, context information is divided into two parts:

Sensed context is information that can be derived by querying physical sensors or applications (virtual sensors). This data is often highly dynamic or at least frequently updated in response to periodic sensor output. Much inaccuracy can arise due to sensing errors or because the context information is completely unknown or stale. Sensors can also fail or networks can become disconnected, leading to a delay in the distribution process of the sensor data.

Inferred or derived context is information that is gathered by combining context data. For example, the activity of a person could be inferred by her motions, her location and the people nearby. The persistence and the quality of this data depend on the sensors used as input and on the derivation mechanism. (Hartmann & Austaller, 2008: 242)

Although both sensed context and inferred or derived context are essential in understanding the environment in finer detail, the acquiring
strategy in these particular cases is based on sensed context, as most of the interactions and sensor systems log data into the database without any derived processing. The extracted data demonstrate how the home ecology is shaped over time by internal or external conditions. According to this need, information has to be stored in a database that may exist locally or on the cloud, and to allow categorization, comparison, or analysis of logs on all possible timeframes.

![Data collection system](image)

*Figure 37: Data collection system (from top left to bottom right) – (1) Android applications for data logging, (2) Sniffing sentiment data from social media, (3) DataGrid monitoring device, (4) biometrics using FitBit, and (5) accessing remote APIs for environmental and planetary data. All logs from the above systems are recorded on the local system using a Raspberry Pi, and following that uploaded to the online MongoDB database.*

To practically demonstrate this process, a database has been developed in MongoDB for the demands of this research. MongoDB is a cross-platform open-source software with table-based relational structures in dynamic JavaScript Object Notation (JSON) format that makes it easy to integrate values from various sources. In order to easily access the database and organize, contrast, and visualize the values, a web application was developed in Heroku, a Platform as a Service (PaaS) that allows rapid
development and effective execution of applications on the cloud, supporting a range of programming languages and tools that build, run, and deploy easily scalable web applications.

As Heroku focuses on “building apps by removing the need for servers, system administration, and stack maintenance”, and because it can provide a “self-healing architecture, ensuring that [apps] do not require system administrators to manage the underlying platform in order to keep them secure and reliable” (Kemp & Gyger, 2013: 3), it was, therefore, a perfect fit for the development of this work. The web address of the application can be accessed from: http://hexspace.herokuapp.com/device.

The programming language of the cloud application Node.js was used, a software tool for creating fast, safe, and convenient web applications. Node.js is based on an asynchronous, event-driven design with modular functions “allowing complex programs to be assembled out of smaller and
simpler components” (Pasquali, 2013). It was chosen to handle the communication between Heroku and the sensor interfaces, and to assemble the interface functions in combination with the visualization of the stored data. To provide an efficient tracking of information updates and sensor readings, Meteor.js was implemented to allow real-time visualizations of the values in desktop and mobile web browsers. The reader may find in the accompanying USB flash drive (folder Chapter 4 – Heroku) the full code of the server application that was developed with node.js, Meteor.js, and MongoDB.

![Cloud services](image)

Figure 39: Cloud services

The online application can support a large set of extensions that might be needed for future upgrades (i.e. API, modules, scripts). Moreover, if additional sensors or devices are added to the sensing capabilities of the house, the application can accommodate them easily by adding and linking each reading to the database and the visualization functions. The following images demonstrate the interface of the web application, which show that it is possible to add, remove, and parameterize every separate sensor and system device, and in addition to visualize and access the database logs.
Overall, the cloud applications that are associated with the logging of the domestic properties assist in having a more accurate analysis of the cybernetic home. The cloud is now part of the domestic space, an extension of the habitat, and a remote memory place that is an integral part of the household. Its domestication is correlated with the way inhabitants access, process, and manipulate existing algorithms stored in server locations directly linked to their individual I.P. addresses.
Evaluation

The micro, meso, and macro sensing technologies that are presented in this chapter have been tested in four different households, each for a period of one week. The systems were configured and parameterized to log information from every place separately, and to allow inhabitants to access and use devices and applications (part of the results are shown below in the following figure). The main intention of this evaluation that consists of casual unstructured interviews was to investigate participants’ responses concerning the systems’ usability, functionality, and user experience. Initially, the participants felt intimidated in the beginning by the monitoring applications, as they were not exactly sure how much intrusive they were. Another main concern was that they did not feel very confident in operating some of their parameters (as for example the MoodLog interface). However, after the first couple of days, participants became more confident in the operation of the devices, and to be more tolerant and open in their interactions with them.

Although the sensors were continuously monitoring and recording values of the domestic space, the interviewed subjects admitted that their presence was unnoticeable, and that the indicators provided by the visual interface of the database were helpful and informative. Most of them agree that proper facilitation of these applications and devices needs to be further studied and researched, as through experimentations, ideal parameterised and personalised settings are more likely to occur.
Chapter Summary

This chapter presents theoretical and practical investigations that relate to the exploration of the domestic environment in a range of scales (micro, meso, macro). The work of this chapter intends to provide a set of resources to comprehend the house as an ecological system that includes a wide spectrum of material and immaterial elements. These elements greatly affect the domestic space by directly or indirectly controlling physical matter, influencing mood, behaviour and performance, causing manifestations of events, or defining inhabitants’ reactions. To identify this spectrum, a series of systems have been developed by the author to capture properties normally unnoticeable by the human senses, such as molecular and chemical properties, frequencies, air quality, external and internal environmental conditions, domestic interactions (inhabitants’ identification, presence, or activities), individual and collective sentiment and mood, cyberspace trends, or planetary information. These recorded instances, stored in a custom-built cloud application, provide substantial information for the analysis and control of the household. The cloud here becomes an integral part of the habitat, a necessary extension that enhances inhabitants’ awareness and facilitates additional functions for the domestic space (such as memory, senses, and
intelligence). The next chapter demonstrates how this information can be
diffused into the domestic environment with the use of computational media
technologies. Through the exploration of interfacing methods, the domestic
space is examined as a physical extension of the cloud; a window into the
ecology's cybernetic processes.
Chapter 5: Diffusion

This chapter analyses the diffusion of computational technologies into the domestic environment, which allows us to conceive of the house as a canvas full of emerging possibilities, and speculate on a range of issues, such as the personalization in physical, virtual, and augmented realities. To accommodate these objectives, it is necessary to critically discuss the domestication of ubiquitous computing from technological, philosophical, and social perspectives, demonstrating failings and successes, in combination with practices and techniques that establish the needed tools to be applied in additional exploration and development.

Case studies that are presented in this chapter analyse a range of methods for the diffusion of computational media technologies into the domestic environment, and further investigate the domestication of ubiquitous technologies through speculation and creative development. A substantial series of practical work has been created to support the needs of this research, which briefly contains: cloud services that demonstrate their importance within the current household; a middleware application that distributes information to media elements of the space; a lighting installation that becomes an agent of personalized actions; augmented surfaces that project visualizations of the household’s data or interactive visuals that respond to viewers’ behaviours; hybrid objects distributed across the domestic environment that intend to become an extension of the cloud properties; and photo frames that accommodate inhabitants’ memories and social media content.
In the previous chapters, context, media layers, and invisible matter were analysed as necessary methods for the exploration and analysis of the domestic space. For diffusion to emerge, these methods are used as necessary prerequisites, as the information and content collected from a range of sources in physical or cyber spaces can now be distributed spatially inside the domestic environment using surfaces, media properties, or even physical objects. Diffusion intends to bring these methods together, and through the developments presented here, which are to be viewed from their speculative context, to consider possible futures for the domestic life.

The Domestication of Ubiquity

Domestication, in the traditional sense, refers to the taming of a wild animal. At a metaphorical level we can observe a domestication process when users, in a variety of environments, are confronted with new technologies. These 'strange' and 'wild' technologies have to be 'house-trained'; they have to be integrated into the structures, daily routines and values of users and their environments. (Berker et al., 2006: 2)

The infiltration of technological objects into the domestic environment (one of the main subjects of study of this research), dates as far back as the nineteenth century in the speculative fiction stories of Edward Bellamy (Bellamy, 1960 [1888]), and ever since the 1930s there are examples that embrace the conceptualization of houses that incorporate intelligent and complicated mechanisms for providing more sophisticated and extended functions, as seen in Buckminster Fuller's Dymaxion House (Baldwin, 2016). Radical technological inventions, such as the telephone, radio, and television, completely altered the domestic interior, extending its noetic ambiance to broader timeframes and spaces. Nevertheless, the experiences offered were
limited, as the telephone could only transport a person to one particular place at a time, and the radio and television had a specific range of channel selections that were impossible to extend.

Starting in the early 1980s, the personal computer caused radical changes in the domestic interior (Turkle, 1984), which expanded and transformed the boundaries of the house. The computer managed “to shift or undermine what is taken for granted in the routines of domestic life” (Silverstone et al., 1994: 20), such as: to facilitate multiple functions; to incorporate media services that, prior to that, were provided by separate devices; to propose interactions with real-time feedback; to enable access to cyberspace; or to redesign all of the above with the help of the programmer/user. However, even more than that, the computer allowed the digitization of a range of analogue processes, and the possibility to access, diffuse, alter, and mix dissimilar properties together, inviting the user to explore cyberspaces of almost infinite possibilities. At present, the user does not only access a single computer but rather its diffused properties that are part of the house. On this topic, Mark Weiser says:

The arcane aura that surrounds personal computers is not just a ‘user interface’ problem. My colleagues and I at PARC think that the idea of a ‘personal’ computer itself is misplaced, and that the vision of laptop machines, dynabooks and ‘knowledge navigators’ is only a transitional step toward achieving the real potential of information technology. Such machines cannot truly make computing an integral, invisible part of the way people live their lives. Therefore we are trying to conceive a new way of thinking about computers in the world, one that takes into account the natural human environment and allows the computers themselves to vanish into the background. (Weiser, 1991: 94)

Weiser and his research group at Xerox Palo Alto Research Centre (PARC) predicted that computing would become ubiquitous, disappearing into
the background of our environment as also prophesized by Cedric Price, Archigram, Christopher Alexander, Ray Kurzweil, and Nicholas Negroponte, predicting the inevitability of the domestication of ubiquity. Nowadays, modern domestic architecture considers yet more layers for the construction of a house – seismic protection materials, sound and heat absorption and insulation, electricity, telecommunications, and information technology (Phillips & Didakis, 2013). Computing devices and sensor technologies are seeping into the fabric to become a layer in the architectural design process, offering cyberdomesticity – a domestic reality that consists of complex sensor networks and systems, inter-connected software, middleware, and hardware devices, as well as context-aware processing and modular computational intelligence units. If current lifestyles demand accurate personalization, instant adaptability, flexibility, and significant results, inevitably “we must consider technological prosthetics” (Spiller, 1998: 32).

Over the last 30 years, a range of experiments have attempted to explore the domestic environment as a playground for computational applications, and have sought to understand the problems and limitations concerning the implementation of practical solutions. Since 1995, the Georgia Institute of Technology has conducted a large body of work on the project Aware Home, which contains computational and technological frameworks that are meant to perceive and assist occupants in numerous scenarios, using extended ubiquitous sensing mechanisms, such as object recognition, multi-person tracking, and context-based activity (Kidd et al., 1999; Kietz et al., 2008). One of the challenges of the Aware Home is to provide a qualitative understanding of the everyday domestic life and to study how computational
processes suggest solutions for entertainment, health, sustainability, and well-being.

In 1999, the companies Electrolux and Ericsson developed *e2 Home*, which investigates the development and marketing of domestic networked products and services: “we want to make people’s life more convenient and enjoyable by combining household appliances and the resources of the Internet”, said the CEO and president of Electrolux Michael Treschow (Electrolux, 1999). Although this project looked promising, the responses from the consumers were mixed, and the company did not developed a more concrete framework.

Since 1998 a research group in the Department of Architecture at the Massachusetts Institute of Technology, develops *House_n*, a project that “explore[s] how new technologies, materials, and strategies for design can make possible dynamic, evolving places that respond to the complexities of life” (Massachusetts Institute of Technology, 2005). With the implementation of many technologies in the living environment, the domestic space becomes an observational research facility that attempts to identify users’ responses, trends, and actions. Kent Larsen argues that *House_n* does not have a single form driven by one ideology, but rather that it is infinitely adaptable to meet people’s needs (Larsen, 2000). However, it is noted that “variability is realized in market-driven terms”, as similarly to “Amazon.com or TiVo, *House_n* will let its inhabitants know what products they will like and it will even purchase them for them” (Spigel, 2005: 410).

These are significant projects that have tried to explore the domestic space for commercial or scientific research, and they have managed to trigger
the emergence of practices that investigate the uses of computational and information technologies within the domestic space. The practices explore homes from varying perspectives, and therefore attempt to semantically define it using different descriptions, such as: smart homes (Harper, 2003; Chetty et al., 2007); home automation and devices (Hamill, 2006); the networked home (Venkatesh et al., 2003; Little et al., 2009); the connected home (Harper, 2011); digital living (Anderson & Tracey 2001; Bly et al., 2006); and the home of the future (Venkatesh et al., 2003). The developments produced from these practices intend to explore the computationally-enhanced domestic space as a medium for providing a range of services to the inhabitants, such as automating specific events, or allowing access to cyber and virtual activities that enhance particular aspects of domestic life. These forms explore how applications and functions can be automated to variable degrees (Aldrich, 2003), build intelligence on preferences, and provide assistance to inhabitants.

Considerations

As was demonstrated in the literature review, many methods have been applied in order to embed computational systems within the structural complexity of the household, and, in general, to domesticate ubiquitous technologies; however, they have failed to encapsulate the essence of domestication and to support the diverse lifestyle of inhabitants. An important issue is that computational intelligence is not yet sophisticated enough to solve difficult problems encountered in a daily setting, as human subjects become extremely unpredictable (Greenfield, 2006) and it is impossible to
pre-define parameters, although a need for accumulative personalization is also essential.

One of the biggest problems for the domestication of technology is that inhabitants have difficulties in managing the structural and operational complexity of computational systems (Eckl & MacWilliams, 2009), as ubiquitous systems present an abundance of automated functions that often become useless and impractical. Even in the case of having a simple rule-based system (such as programming a thermostat), occupants feel overwhelmed, noting that the automation is problematic and error-prone, and, although many participants understand sufficiently the technology, they still find the control systems cumbersome (Bernheim-Brush et al., 2011). These types of controls are difficult to manage because they force the static definition of a complex a priori configuration that lacks a dynamic and holistic view of the home (Bernheim-Brush et al., 2011; Bartram & Woodbury, 2011; Eckl & MacWilliams, 2009). As in the movie Playtime (Tati, 1967) architecture is introduced as highly sophisticated and modern that nevertheless misses all the importance of caring, supporting, and inspiring. Rather, it becomes a cold and clean amalgam of specific functions that dominate on personalization – becoming unsuitable for habitation.

Another important issue is that ubiquitous technologies disturb the feeling of privacy, as if the security of the house’s data is breached, trust, reliance, and discretion is in jeopardy (Noy et al., 2006). It is necessary to consider that the security of personal data can become “vulnerable to intrusion and damage caused by outsiders”, as the registered and recorded information of the house may be “floating around without appropriate protection” (Aarts et al., 2002: 249). For this reason, the intrusion of
computational systems into the private lives of inhabitants causes them to feel uneasy and uncomfortable (Makonin et al., 2013).

An additional consideration is people’s fear that systems and objects are going to gain power and authority over the household, controlling a number of important decisions, or even worse, losing absolute control, enabling chaos, paranoia, and distress. A large amount of people exhibit technophobia (a fear of technology), which according to Sami and Pangannaiah may take three manifestations: “anxious technophobe”, which refers to a person who demonstrates negative physiological reactions (headaches, increased heart rate, etc); “cognitive technophobe”, which relates to users that accept technological facilitation, but whose psychological states are negatively affected by it; and finally, there is the “uncomfortable user”, who does not experience physiological or psychological issues, nevertheless, he/she feels anxious and uncomfortable with the technological object (Sami & Pangannaiah, 2006).

There is an inexhaustible discussion concerning the considerations and problems related to the domestication of computational and technological facilitation from a range of different fields – anthropology, sociology, psychology, and more, however, it is helpful to establish specific points that can be examined from the perspectives of this research. Therefore, it is important to minimize the operational involvement with the house to an adequate degree, allowing the technological background to help inhabitants to a certain extent (Intille, 2006; Tapia et al., 2004). Interface complexity should be avoided, but adaptive behaviour practices, context-aware systems (Tapia et al., 2004), and distributed smart sensor or agent networks (Makonin & Popowich, 2011; Makonin & Popowich, 2012) hold substantial promises for
technological services that can be tamed and allowed within the daily household.

Yvonne Rogers proposes that computational systems should be created as ensembles or ecologies of resources that serve specific purposes and are situated in particular places (Rogers, 2006: 406). Although this is a reasonable strategy, ubiquitous technologies within the home environment should encourage inhabitants to express and develop their potential and solutions, enabling them to be constructive, creative, and in control of the interactions that take place, rather than provide them with a set of predefined solutions. The main intentions of ubiquitous computing are to automate a range of functions to variable degrees (Aldrich, 2003), build intelligence on preferences, and provide assistance to inhabitants that will bring an increased ability for informed actions and necessary engagement and sensitivity.

The practical developments that are presented in the following part of this chapter do not claim that they are able to resolve these considerations, but rather intend to demonstrate how speculative artefacts utilize the concept of diffusion as a method for inspiring solutions to these problems. Keeping in mind the previous practices and issues generated from the domestication of ubiquitous computing and other technological frameworks, the creative developments discussed here intend to further explore practical possibilities that demonstrate how diffusion assists in binding together physical, virtual, and augmented realities, as well as context, media layers, and invisible matter, which are the main methods presented in the previous chapters.
Spatial Diffusion

Computational technology can be easily embedded into structures, systems, and environments. Its appearance in the domestic interior is, therefore, inevitable, and as in the case of ambient intelligence, intends to support people in their daily lives (Augusto, 2007) in a “seamless, unobtrusive, and invisible way” (IST Advisory Group, 2001: 8). The computational diffusion within the domestic interior proposes a new appreciation of the hybridized space, one that demonstrates functions and processes to extend inhabitants’ communication, perception, and creative potential, allowing itself to be effortlessly accepted by the members of the environment (Rogers, 1983: 11). No particular rules or guidance should be provided, as the “enhanced household” needs to define its own spatial interactions. Everett Rogers argues that:

Diffusion is a special type of communication, in which the messages are concerned with a new idea. It is this newness of the idea in the message content of communication that gives diffusion its special character. The newness means that some degree of uncertainty is involved. (Rogers, 1983: 6)

This uncertainty should not intimidate the development of a specific approach, but rather inspire its exploration without imposing limitations of explicit indications. Spatial diffusion can take flexible forms and infiltrate various layers of the domestic space, from the infrastructure, physical surfaces, scattered objects, furniture, virtual and augmented windows, to biological bodies, and noetic beings. As Nicholas Negroponte argues, humans exist simultaneously in a physical and virtual space as spatialized entities (Negroponte, 1995), emphasizing the blurring of the realities encapsulated in their Umwelts. Domestic properties of all sorts obtain identities and attributes
capable of providing interfaces integrated into an information network (Isikdag, 2015: 43), which transforms the household into a dynamic self-organizing body that merges with inhabitants, technologies, and inanimate things.

Surfaces of the house can be transformed into augmented and virtual windows with the use of media technologies, such as light or visuals, as is demonstrated in the following case studies of this chapter. The diffusion of information, media content, or personalized information into the domestic space can also be accommodated with the use of ambient displays; Wisneski et al. explain in further detail:

Ambient Displays takes a broader view of display than the conventional GUI, making use of the entire physical environment as an interface to digital information. Instead of various information sources competing against each other for a relatively small amount of real estate on the screen, information is moved off the screen into the physical environment, manifesting itself as subtle changes in form, movement, sound, colour, smell, temperature, or light. Ambient displays are well suited as a means to keep users aware of people or general states of large systems, like network traffic and weather. (Wisneski et al., 1998: 23)

Ambient displays, therefore, provide a flexible method of distributing information and altering the aesthetic environment without disrupting foreground tasks, residing on the periphery of consciousness, and allowing occupants to further understand their surrounding space. The flexibility offered by computational media applications helps users to parameterize the environment and arrange for resources to be displayed on a particular surface. It also hosts context-awareness processes that take care of the distribution and selection of the media content, as for example, identifying the presence of users and selecting material according to their stored preferences. This
approach, therefore, strongly depends on the collected information and the media used to distribute content into the interior space.

In the previous chapter, a range of systems is presented that was developed for the purposes of this research to demonstrate methods of capturing a large amount of the home’s invisible matter. The information and media content collected from micro, meso, and macro scales, becomes an important part in enhancing awareness and engagement with the domestic space. By combining the sensorial abilities of the household with the possibilities that emerge through its media layers (presented in Chapter 3), an assortment of conceivable explorations emerge. These explorations need to be studied through the development of case studies, artefacts, and systems related to spatialization and diffusion – these refer to the distribution of digital information (raw data, processed information, media content) using computational means into the domestic interior with the use of media and other physical computing practices.

More analytically, cloud services are presented, as they become a fundamental aspect in the diffusion process of a range of properties in the domestic space, as well as a middleware application that was developed to link cloud and sensor interfaces with the media layers of the interior environment. Moreover, applications and installations that were created for this research are analysed and discussed; these include diffusion practices through light, surfaces, and objects. It is necessary to comment that diffusion may be accomplished through other forms too, such as sound, cyberspace, or even biological organisms. However, time restrictions did not allow for this to occur during this work, but these practices may be further investigated in the future.
Cloud Computing

Cloud computing refers to: “software provided by a central Internet site that could be accessed by the user through any form of computer and connection [and] the user need not be concerned with where data is stored or the need to make backups, which are handled seamlessly” (Henderson, 2009: 29).

Computing utilities offered by cloud services are hidden in the network, which provides access to a pool of configurable resources, such as servers, databases, analysis software, and so on, with minimal management effort or service provider interaction.

In this particular case, a cloud computing application (that is partly presented in Chapter 4) has been configured to “manage scalable and customizable virtual hardware and software resources” (Isikdag, 2015: 19), and a Platform as a Service (PaaS) has been applied – although Software as a Service (SaaS) and Infrastructure as a Service (IaaS) are also available as the other two main segments of the cloud. The online database collects all the information from physical and virtual sensors installed in the domestic environment, allowing it to be shared across many different devices, ensuring an efficient method of distributing data for further needs.

In this instance, the cloud is not only a service that is used for the system to operate, but it becomes a necessary medium for the manipulation of captured instances, allowing a range of processing possibilities to emerge through modular applications, and offering a creative palette for the design of computationally-enhanced environments. The cloud is especially important in applications and case studies that are presented in this chapter, as diffusion becomes easily attainable through the invisibility of the remote servers.
Middleware

“The variety and heterogeneity of services [adds] more complexity to the design of applications [that] access an increased range of services” (Poslad, 2009: 85). For mainly this reason, middleware is used to simplify access to heterogeneous and distributed resources of multiple networked computing systems (Bernstein, 1996). Middleware is a software development that links dissimilar devices, platforms, and applications together, and it can connect a range of distributed sensors and actuators, as well as context-awareness processes (Yau et al., 2002; Roalter et al., 2010). According to Tatsuo Nakajima et al., middleware offers “non-functional properties such as context-awareness, timeliness, reliability, and security” while considering “psychological, social, and anthropological” aspects (Nakajima et al., 2004: 62). In this particular context, middleware does not offer a universal solution, but demonstrates how it can be used in a creative context and open up space for experimentation through the extraction and diffusion of data within the physical interior space.

Consequently, Node was developed for this work, a middleware application that allows seamless integration of information distribution between sensor interfaces and various elements of the interior space (lights, visuals, sound devices, physical objects). The reader may access the accompanying USB flash drive (folder Chapter 5 – Node) that includes the full code of the Node application, as well as screenshots and a video example that demonstrates the use of the software in action.

The application is compatible with a variety of operating systems (MacOS, Windows, Android), and it provides a visualization of the stored datasets that exist in the cloud database, as well as all the possible elements
that can be controlled in the domestic space, i.e. information collected from sources that are presented in Chapter 4. This intuitive process allows users to explore the digitally-enhanced habitat, and the interconnecting possibilities that emerge. If a new system or device is present in the environment, the interface of the application can instantly visualize it together with the current setup, allowing multiple users to simultaneously edit and view the changes that are made.

![Node interface](image)

**Figure 42: Stavros Didakis – Node interface (2013)**

By incorporating a large spectrum of information (from molecular particles to cosmological occurrences, as discussed in the previous chapter), users are free to explore how data readings affect elements of the interior space, using simple drag and drop connections on the application’s interface. Behind the main screen, numerous functions take place to interpolate and merge values from input and output systems. For example, a lighting system can be controlled by a sensor that has not previously been connected with directly, but instead linked in real-time by the user interactions, demonstrating
an instant way to spatialize data into the interior space, such as activating ambient displays that emit streams of information.

With the simple interactions and visualizations provided by *Node*, the user can rapidly set the environment to radiate specific information extracted from the cloud’s database. The functions offered by *Node* enable the diffusion and spatialization of information to control media elements such as lights, sound systems, kinetics, image projections, and so on, and to assist the configuration of real-time performative interiors.

![Figure 43: Node application in use](image)

**Visualizing Diffusions**

Due to the possibilities offered by the *Node* application and the sensor interfaces, a visualization application was developed to demonstrate how the information collected from input sources could be diffused into the domestic interior as a property of the lighting devices. A real-time application was developed in Unity that displays a three-dimensional model of a house and a series of lights distributed in its rooms. Each lighting fixture becomes a separate output property of the system, and therefore can be controlled from
a specific data source. With the use of Node, each sensor value that is extracted from the house (micro, meso, macro) can regulate the light intensity and colour of every possible lighting device of the simulated space in real-time, which, when combined, it results in unexpected compositional designs that shift and pulsate according to the conditions tracked by the sensorial systems.

The main intention of this development is to speculate on the possibilities related to the diffusion of the information into the domestic interior, and visualize how the interior conditions of the house change based on its sensing capabilities. Any sensor input (air quality, temperature, number of people present, heart rate of users, or sentiment analysis) can control the media extensions of the household (although in this case only lighting is used). With this 3D simulation the user can navigate and explore how each middleware selection affects the interior space, and also realise that the emitted light shifts are able to communicate a large amount of information.

This approach, therefore, intends to study methods that spatialize digital information within interior space, with the main intention to understand the possibilities offered by technological and media extensions. One issue that has been considered is that there is no particular technique or composition strategy for the distribution of the information into the light units. Instead, users can explore the house as a blank canvas that offers a playground of datasets and media resources. The reader may access the accompanying USB flash drive (folder Chapter 5 – Unity Visualization) that includes the Unity project file, as well as a video render that demonstrates how Node’s preferences control the 3D virtual space.
Figure 44: Real-time 3D visualizations in Unity. Link data to light intensity (top), set colour themes using keywords (middle), set of six different results (bottom)
Through Light

To further comprehend the process of spatializing and diffusing information within an interior space that consists of a network of objects, media, and processes, a range of practical experimentations have been implemented and tested in various scenarios. As an extension of this requirement, available media components of an interior space have been selected in order to demonstrate the possible outcomes that result from the previous studies, allowing inhabitants and users to understand the domestic environment through sets of alternative lenses. Accordingly, light, visualizations, and physical objects have been created to explore computational media as domestic properties that allow the diffusion and spatialization of digital information.

In this case, lighting is used as a communication medium as it strongly defines how the environment can be utilized, and if it is functional for specific activities, such as reading, working, or relaxing. It also has the power to change the usual “hardness” of architecture with properties that soften the space accordingly, as supported by Sommer (Sommer, 1974). The profound effects of lighting within architectural spaces are non-arguable, as everyone can instantly sense the mood being conveyed; “you only have to enter a Baroque church with its bright and inspiring atmosphere to see and feel what effects light can have in architecture, or, to the other extreme, look at Piranesi’s paintings of dungeons with their dark labyrinths, where the shadows conceal a never-ending source of horror” (Ganslandt & Hofmann, 1992: 119).

As light plays a significant role in the psychological state of inhabitants – such as provoking mood and cognition levels (Knez, 1995), (Baron et al.,
1992), influencing performance through the intervening variable of positive affect (Baron et al., 1992), triggering serotonin levels in the body, changing a person's mood and social behaviour (aan het Rot et al., 2008), and assisting interpersonal communication, stimulating more general communication, or encouraging intimacy (Gifford, 1988: 177) – it is a considerable factor in the development of an interior, as it is directly affects the emotional states of the inhabitants. Although some insist that, in particular studies, there was no evidence that subjects experienced differential affective reactions to various lighting conditions (Baron et al., 1992), nonetheless, it is perfectly logical to conclude an increase in positive energy on a bright and sunny day; "by providing brightness contrast, an environment may be created that has the attributes of a sunny day. In truth, the significant difference between a “dull, dreary day” and a “bright, cheerful” one is the quality of light" (Gordon, 2010: 11).

An Interactive Chandelier

To extend the possibilities of interior lighting into a case study, an installation was created by the author for the needs of this research, in which computational media, sensor technologies, and lighting design are applied to measure, analyse, and regulate aspects of the interior space. With the use of digital interfaces and a custom lighting solution, a large number of possibilities are presented for creating unexpected, flexible, and sensitive spaces that enhance awareness, providing added layers of information, affectivity, and aesthetics. The fundamental idea in this case was to construct a space that investigates the domestication of computational media with a prior interest in exploring interactions and dataset spatialization through the manifestation of
lighting compositions. With the developed system, it is possible to use interior lighting as a multi-layered canvas that can not only express an understanding of the inhabitants' needs, but it becomes a performative agent that oscillates and adjusts in response to real-time conditions.

The *Cloud* is a collaborative project of the author and the architectural office mabarchitects (http://www.mabarchitects.com), which consists of a minimalist chandelier with interactive functions and embedded technology able to communicate with a variety of platforms, illuminating the interior of its permanent location – an office/home space in Athens, Greece. The *Cloud* comprises a dozen circular panels with different sizes, levels, and positions, placed in a cloud formation on the ceiling of the main room, also making a metaphorical reference to the online cloud computing services used by the chandelier to express its lighting functions. A series of LED strips have been embedded inside the panels, which are controlled remotely using different data and protocols, allowing for an exploration of styles, patterns, and visualizations. The main aim of the installation is to speculate on possible design alternatives where technology, aesthetics, and architecture present responsive and affective spaces. The concept of the installation was developed collaboratively between the architectural office and the author: mabarchitects were responsible for the design and implementation of the circular panels, and the author for the development of the lighting installation, the communication system, and the programming of micro-controllers and interactive applications. In the accompanying USB flash drive (folder Chapter 5 – The Cloud) the reader may find a time-lapse video of the panels’ installation, photo documentation of the project, and the source code that was developed in Arduino, Max, and Processing.
Despite the fact that the *Cloud* can be used like any other contemporary “smart” lighting device, its extendable and open architecture becomes a significant tool for customized interiors. As the *Cloud* consists of separate panels with various dimensions positioned at different heights, each can radiate specific information, extracted either from the online database or “sniffed” in real-time directly from sensor data that are streamed on the local network. This fusion of digital information in the chandelier can assist the emergence of immersive and mesmerizing lighting patterns, as changes in intensity and colour can easily be achieved. The lighting system is fully controlled by the user through the use of a physical panel; it is also configured and parameterized by a middleware interface, accessible from a computer or mobile device. One of the advantages of this development is that many lighting units can also be installed into the space, either in the same area or at separate locations around the house, offering seamless extensibility with minimum software or hardware design. The overall lighting of the house can be split into different zones if needed, and it can be controlled simultaneously from individual channels. By using the same user interface, the lighting zones can be activated easily (simple drag and drop functions), creating a unique interactive palette of spatio-temporal design.
To set up the requirements needed for the lighting design of this particular interior, a number of issues first needed to be acknowledged, such as aesthetics, practicality, cost, sophistication of the design detail, and the overall effect that has to be achieved, as they are relevant and significant to the overall development and final result. The main lighting ambiance of the environment can be easily and instantly controlled to provide the desired setting and enhance or affect inhabitants’ consciousness and perception: “the ratio of ambient light to focal glow establishes the degree of brightness contrast in a space; sparkle adds the highlights that contribute to feelings of well-being” (Gordon, 2010: 14). This ability to control the space using light, colour, and rhythm, opens up new possibilities for the design of interior environments, such as enhanced variation and reduced monotony, which leads to boredom and depression through overfamiliarity. As Gordon says, “variation increases stimulation and impressions of pleasantness” (Gordon, 2010: 23).
A dynamic lighting system such as the *Cloud* might “at one extreme [...] mimic the warmth and intimacy of candlelight and on the other provide the lighting levels and even distribution of a sports hall, with every conceivable variant in between” (Coles & House, 2007: 124). The system adjusts to pre-set ranges that, according to stored settings, offer an optimum and accurate performance to accompany a relevant task. If the occupant selects a value for dining, the brightness level of the light is set to 300 lux, and if alternatively a brighter environment is needed, the light adjusts accordingly to meet the appropriate settings.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Illumination (lux, lumens/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public areas with dark surroundings</td>
<td>20 - 50</td>
</tr>
<tr>
<td>Simple orientation for short visits</td>
<td>50 - 100</td>
</tr>
<tr>
<td>Working areas where visual tasks are only occasionally performed</td>
<td>100 - 150</td>
</tr>
<tr>
<td>Warehouses, Homes, Theaters, Archives</td>
<td>150</td>
</tr>
<tr>
<td>Easy Office Work, Classes</td>
<td>250</td>
</tr>
<tr>
<td>Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories</td>
<td>600</td>
</tr>
<tr>
<td>Supermarkets, Mechanical Workshops, Office Landscapes</td>
<td>750</td>
</tr>
<tr>
<td>Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres</td>
<td>1,000</td>
</tr>
<tr>
<td>Detailed Drawing Work, Very Detailed Mechanical Works</td>
<td>1500 - 2000</td>
</tr>
<tr>
<td>Performance of visual tasks of low contrast and very small size for prolonged periods of time</td>
<td>2000 - 5000</td>
</tr>
<tr>
<td>Performance of very prolonged and exacting visual tasks</td>
<td>5000 - 10000</td>
</tr>
<tr>
<td>Performance of very special visual tasks of extremely low contrast and small size</td>
<td>10000 - 20000</td>
</tr>
</tbody>
</table>

*Figure 47: Common lux values*

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17 Image from http://i.stack.imgur.com/ZipZF.jpg
According to Boyce, this lighting optimization is likely to enhance a person’s performance on each task, a prerequisite for developing an ambiance that extends preferences and sustains well-being (Boyce, 2003).

As mentioned earlier, part of this lighting installation was to augment the lighting system with spatialization functions, which allows inhabitants to easily access separate lighted objects and link a particular type of digital information that is extracted from the online cloud services. By using a custom middleware, specific data readings can connect to any lighting area allowing the user to configure how information is going to be visualized, as well as how the interconnection between each lighting display is going to affect the total result. Thus, any micro, meso, or macro properties that can be sensed by the monitoring systems of the domestic interior can be used to alter parts of the composition. For example, the average mood of the household that is collected from the sensing devices (presented and analysed in the previous chapter) can be configured to display a particular lighting combination to assist the inhabitants in shaping their personalized interior space.

Furthermore, the system allows users to select automatic colour shifts with controllable speed to match their preferences. Additionally, a prototype application was programmed to scan Twitter for social sentiment, public events, or specific keywords that are set by the user, and to display results as ambient light that is distributed on different layers of the chandelier. The user can also define a geographical area for the Twitter’s search results, and also apply, if needed, a timeframe index: for example, define the period of the search results, such as for the current day, last three months, last year, and so on.
Finally, the system includes a function that assists users in composing aesthetically pleasant colour designs, using online APIs (Application Program Interfaces) that offer colour composition tools, such as Adobe Color (https://color.adobe.com), VHue (http://vhue.co), and ColourLovers (http://www.colourlovers.com).

![Colour palettes with keywords: summer, winter, love, envy, happy, sad.](image)

By operating these services, the user easily retrieves colour palettes that have been contributed by online creative communities, so that numerous colour combinations can instantly be accessed. The extracted colour palettes assist the composition of the chandelier’s panels, offering colours that complement and enhance one another, rather than cause a noisy mixture and a feeling of discomfort.
The ability to convey a certain mood or to express personalized actions is a highly vital condition in the development of domestic interiors. It is important to consider the demand “for objects with potent sensory and emotional resonance” as well as a desire for systems that embody “traits of consciousness, eccentricity and an increased responsiveness to emotional input” (Chapman, 2005: 19). In a similar sense, this installation allows users to spatialize and create aesthetic environments using colour palettes they mostly feel connected with, and to experience endless lighting shifts submerged into ambient landscapes. As a result, an unconventional chandelier becomes an extension of the data cloud, allowing inhabitants to express their aesthetic preferences with a canvas that is able to oscillate from simple and dull lighting to psychedelic nebula formations.

Figure 49: Stavros Didakis & mab architects – The Cloud, an interactive chandelier (2013-2016)

Diffusing light in space and creating areas of spatialized configurations can have a profound effect on inhabitants that are immersed in this collected datapool. As in the artworks of James Turrell, light can become something more than a source of illumination. It can become a surface with volume, information, and meaning, as well as something that it is vital to the perception or psychological and biological needs. The combination of space and time in relation to the light patterns can create mesmerizing and profound
experiential effects, defining architecture that is able to “integrate itself with human and cultural memory” and become “reflective and performative – in real time or retrospectively” (Spiller, 2009: 99). In this example lighting design is used as an expression of skin that empowers architectural movement, becoming able to use light and colour to create supportive and affective interior spaces.

The Cloud is a responsive lighting system that uses computational processes to identify properties of the environment as well as customized preferences. It can adjust itself automatically to specific conditions, providing aesthetically pleasing interiors that accompany certain needs, moods, and functions. However, this level of intelligence can be extended further with the use of more sophisticated sensorial systems that help in recognizing additional conditions and user preferences. Consequently, in future updates the system needs to provide context-awareness and identify particular tasks the inhabitants do so that it can easily adapt to these actions, as the identified tasks are going to enhance the system’s intelligence and allow it to reach a desired level of autonomy.

**Evaluation**

The evaluation of the Cloud consists of unstructured interviews that were conducted with the occupants of the space after the period of one year. On the positive side, occupants think that the space is completely transformed concerning its aesthetic and functional possibilities, as many times the lighting atmosphere of the space is inspiring and engaging, and they are often able to understand the information that is conveyed through the lighting patterns and
compositions. The diffused quality of the information becomes part of the interior space, and at times residents admit they feel uneasy if the Cloud is switched off.

As has already been discussed in this research, a fundamental consideration concerning the computational media technologies of the domestic space is to be open-source and reconfigurable so that inhabitants can parameterize and personalize properties according to their needs. Similarly, the open-source software and hardware design of the Cloud has allowed participants to personalize its functions, as they were able to program a Linux script that scans properties of the local network and links to the lighting panels information related to download and upload Internet speeds, bandwidth allocation, as well as inform them when the Internet connection has shut down.

![Figure 50: The Cloud (installation space)](image)

On the downside, occupants stated that the Cloud was not easy to familiarize with at the beginning, that it seemed odd and peculiar, and that
they needed time to properly adjust to it. Moreover, participants believe that if the *Cloud* becomes context-aware it will more easily adapt to their routines, and consequently sense their needs and adjust its rhythm, composition, and pulsation automatically. Finally, the maintenance of the system was a bit problematic at first, as occupants had to be technically aware about the system's details, and although it is recommended they should be informed about its functionality, they still consider this a disadvantage.

**Through Surfaces**

Occupants are responsible for the decoration of their homes based on their aesthetic and functional preferences. It is a common practice to use a table cover to add colour and patterns to the interior composition, or place a framed painting on a big empty wall. Usually, these items are replaceable, and new additions can completely alter the atmosphere of the space. The surface, “a partition that can be shared”, can be viewed as “a primary form of habitation for the material world”, and “understood as the material configuration of the relation between subjects and with objects, [and] a site of mediation and projection” (Bruno, 2014: 3).

The flexibility offered by new media technologies assist in the creation of shiftable and expressive interior surfaces as the applied content may be selected, altered, or changed by the occupants even in real-time. Media material can be displayed on interior surfaces either through the addition of LCD, LED, or projections, which open up a range of possibilities with virtual and augmented computational technologies. This aligns with Luigi Puglisi's view on multimediality: “multimediality represents the choice to transform the
building into an organism capable of conveying messages using various media, integrating then into the building fabric”, a process that transforms the house into “a screen that irradiates lights, colours, and sounds, and at the same time communicates information” (Puglisi, 1999: 10).

As in the RemoteHome by Smart Studio (2003), the wall surfaces of the house transform into a communicative agent that streams information from one setting to another “through kinetic, tangible features, and light installations” (Bullivant, 2005b: 75). A similar project is the Swisshouse, a prototype of physical and virtual technologies that become a habitable interface, where “traditional architectural elements, such as walls, ceilings and furniture are turned into communication media” (Huang & Waldvogel, 2008: 382). In addition to the examples above, two systems and installations, developed for the needs of this research, are presented in the following section. They demonstrate how surfaces within a domestic space can be used in combination with computational media, sensor interfaces, and interactive techniques. The main intention of these works is to explore the possibilities that emerge within the interior space through the added layers of media technologies that assist in understanding the diffusion of sensed manifestations.

DataBlobs

DataBlobs is an interactive application developed for this work to visualize in real-time current activities and moods of the household, and to demonstrate how a virtual space fuses with the domestic surfaces to accommodate important indications regarding the well-being of the household’s members.
The application receives users’ selections related to their current activities and emotional levels, and visualizes each entry into a collective visual space. To extract the necessary information from the participants, the *MoodLog* application is used (presented in Chapter 4), which is a desktop and Android application that assists users in logging responses concerning their activities, mood, mood intensity, and energy and stress levels. The reader may access the accompanying USB flash drive (folder Chapter 5 – DataBlobs) that contains the full code of the interactive Processing application.

**Figure 51: DataBlob schematic & interface selections**
A datablob is a circular custom-made shape that visualizes users’ selections by shifting its colour, form, and animation speed to accommodate every possible combination (five categories with ten possible selections each). Every entry set by the participants generates a new datablob that appears within the virtual collected pool. All datablobs have a specified temporality set by the user, and they can live a few days, weeks, or months. As datablobs get older, they move away from the user, towards the Z-axis, getting smaller and smaller, and they disappear when the reach the pre-defined age limit.

Within the virtual space, the viewer finds an important part of the home’s memory, things that have significant value, such as mood and activities that have taken place during a given timeframe. By viewing the logged responses as meta-data, a metaphorical box opens to reveal hidden affective aspects of the household, as seen in the project Memory Box by David Frohlich and Rachel Murphy (Frohlich & Murphy, 2000) – the project involves a container of numerous physical objects, such as a necklace, a printed photograph, and a pebble, and when these items are picked up by the participants, uncovered stories associated with them are shared via audio speakers.

Similarly, this project intends to create a collective visual dataspace of affective responses that can be shared with the inhabitants via the screen, which is projected on the interior’s surface. Peripheral sensing becomes sensitive and aware of the functional and affective properties of the domestic environment, extending the way the habitat is perceived.
AFU Installation

A case study was developed as part of this research to experiment further with the extension of the interior surfaces that are combined with computational media technologies. The main intention of the AFU installation is to explore the interior surface as a medium that is able to playfully engage occupants and participants, demonstrating real-time reactions of media
content based on sensed information captured by the computer vision analysis algorithm. The system was installed in the personal studio of Omniview, an architectural company based in Athens, Greece (http://www.omniview.com), and although it is not a domestic space, it is nevertheless an intimate environment where occupants spend most of their time, thus, they consider this a personal space and an extension of their lives.

The main purpose of the system is to investigate the potential of interactively shaping the media content that is displayed on a room’s surface based on algorithmic programming and image processing. Occupants define the content that is used and projected by the system by adding their preferred images to a shared dataspace. This curated digital environment becomes personalized by the selections of the users, and extends the notion of the domestic boundaries to the virtual cyberspace. After a predefined amount of time, an image is randomly selected from the collection and is projected on a surface of the interior. The accompanying USB flash drive (folder Chapter 5 – AFU) contains the Processing sketches that were used to develop this installation.
When the room is unoccupied, images are frozen, but when the system identifies occupants' presence or motion, the displayed image decomposes and transforms into an emergent kinetic structure – its organic behaviour depends on the viewer's actions. A computer vision analysis system is used to detect the participants' presence and motion, and according to the tracked information the projected images transform. The installation explores methods
of using the inanimate surfaces of the house as a canvas that is able to reveal artistic and ingenious transformations with the use of computational media technologies. The ability of the system to respond to inhabitants' actions and behaviours, and to express dynamic shifts through surface projections, becomes an important aspect in the understanding of the computationally-enhanced domestic space.

Through Objects

Human beings and objects are indeed bound together in a collusion in which the objects take on a certain density, an emotional value – what might be called a ‘presence’. What gives the houses of our childhood such depth and resonance in memory is clearly this complex structure of interiority, and the objects within it serve for us as boundary markers of the symbolic configuration known as home. (Baudrillard, 2005: 14)

In this excerpt, Jean Baudrillard discusses the importance of objects that we encounter on a daily basis, things that are inseparable from our home and fundamental to the domestic life. Their presence sets and indicates the household, lifestyle, and preferences of the inhabitants, and the combination of assorted things that exist within a house can explain the physical, economic, social, or psychological needs of their users, playing a central role throughout a person’s lifetime (Csikszentmihalyi & Rochberg-Halton, 1981). A value added to an object may be due to the practical abilities it can offer, or the dependency it creates by interacting with a person in a way that can often be casual, addictive, or even obsessive; in many cases it defines a human’s development and the sense of self (Bermudez et al., 1995; Cole, 1998; Minsky, 1994).
Reciprocity is established when the owners become possessed by the objects by “paying attention to, becoming associated with, becoming linked regarding history and memory, finding, keeping, using over time, applying force and the law to control access to things” (Hodder, 2012: 24). This aligns with Maurice Merleau-Ponty’s view on the dependence on things (Merleau-Ponty, 1963 [1942]). Merleau-Ponty explained that humans find their place in the world by the presence of items that help them to orient themselves, since by interacting, using, or breaking an object it becomes easier to understand the environment as well as their own identity – how interpersonal relationships are built, and how a person discovers the world.

Therefore, the relationship between humans and objects is essential to the study of domestic spaces, as is discussed in Chapter 2. Semantics, communication, and interactions build significant meaning through and with objects (Norman, 2004), and for this main reason ubiquitous computing and the Internet of Things are interested in their contextualization, analysis, and exploration. Technological enhancement of items that are found in the domestic environment allows an extended set of possibilities to emerge, a “transformation” that “is profoundly real: it is what governs all radical transformations of our environment” (Baudrillard, 2005: 3). For these reasons, the following projects explore the role of the technological object in the home, and how it is able to diffuse information and blend physical and virtual personalized spaces.
Desktop Apparatus

Advancements in rapid prototyping, open-source hardware, and software development have given power to a large community of users to explore and define their own systems of objects, strongly influencing contemporary consumerism (Catarina, 2011; Shewbridge et al., 2014; Mellis & Buechley, 2012). The main methods utilized by the community, based on constructivism, promote users to develop their own artefacts and achieve deeper learning about the functions the objects may offer. Users are not simply receivers of the technological things but they are heavily involved in the process of development that allows them to have clear insights and understanding about form, resources, texture, functions, connectivity, compatibility, and so on.

The following practice was developed with an aim to explore how the open-source hardware and software community affects the way objects of the household are conceived, built, and diffused. Accordingly, a set of objects was created using a mix of widely available 3D printing and rapid prototyping techniques, combined with microprocessors and electronics that enable the control and communication of the device with other objects and systems. Apparently, the extensibility of this set can be easily managed. If more devices are needed, they can be created within the home, without the need to purchase them from a store or wait for a technician for their installation; consumerism becomes obsolete, as the household accommodates the means to conceptualize, develop, and parameterize its own needs. The reader may access the accompanying USB flash drive (folder Chapter 5 – Desktop Apparatus) to find the 3D-printable file, as well as a code example that was used for this practice.
The cloud shape that was selected in this particular case makes a reference to the cloud computing services that communicate with the object. With the use of an interface that was developed for this work, the user can parameterize and select specific information to be visualized through the device. When the object is powered on, it extracts information from the cloud according to the user’s selections, and visualizes the current status of the tracked information, or provides notifications for certain events. The object uses changes in light to communicate with the owner, and depending on its lighting combinations, different results are expressed. Objects scattered around the house can indicate different sets of information that are shared among the household members, where each one of them can configure a specific device to a desired setting.

This project demonstrates how the technological infrastructure assists the household in extending functions and purposes that promote personalized interiors instead of adopting standardized and mass-produced “things” (a problem discussed in Chapter 2). Each household can apply diverse practices with particular semantic meaning to provide dynamic domestic experiences. The hybridized objects that are created according to the needs of the
inhabitants become an integral part of the domestic apparatus, demonstrating methods of diffusing the technological penetration within the ecological sphere of the house.

**Memorabilia**

Objects, as already suggested by Baudrillard, Heidegger, and Merleau-Ponty, evoke strong resonances to the emotional states of inhabitants. Through use and interaction, memories are built and recalled, which often define how inhabitants value their objects; “special objects turned out to be those with special memories or associations, those that helped evoke a special feeling in their owners” (Norman, 2004: 48). The memory space that is incubated within an object affects not only a particular owner, but also the quality of the dwelling experience in overall. The addition of computational memory within physical objects promises “the Era of Forgetting”, as “while we outsource memory to smart devices, we may free up our brains for other information, such as complex social linkages” (Guo et al., 2011: 297).

Memorabilia refers to a collection of items that relate to a particular person, group of people, event, or period, and are usually kept because they are worth remembering. Photographs are essential items as they can capture particularly significant moments, and their display within the domestic environment is often necessary; even from the early days of photography, pictures were used exclusively in the home (Holland, 2004). Photographs are often carefully framed by their owner and displayed in various areas of the house to embellish and to offer reminders of moments and experiences, to
preserve the “memory of personal ties” (Csikszentmihalyi & Rochberg-Halton, 1981), and to support individual identity and social sense.

For this reason, *Memorabilia*, a project developed for this research, uses a collection of digital photographs in combination with hardware and software developments to explore how memories of inhabitants accumulate, blend, and diffuse. This project attempts to explore the practice of memory-keeping through the development of computational processes that dynamically select and display on picture frames photographic images extracted from the occupants’ social media. Conventional desktop picture frames have been altered to accommodate an LCD screen and a microcontroller that communicates in real-time with other systems of the household (such as sensing devices, or middleware interfaces). *Memorabilia* is programmed to obtain photographic material from their social media accounts using a system (presented in Chapter 4), which identifies an inhabitants presence in the domestic space through their connected mobile devices. The extracted content is displayed on the picture frames as an automatically generated collage, which also provides the users with image-processing algorithms (such as filtering, noise, or glitching effects) to refine the final appearance and match a particular aesthetic style. The accompanying USB flash drive includes a demo of the Processing application (folder Chapter 5 – Memorabilia).

The dynamic collage that is displayed on the desktop photo frames assembles the content in real-time, constantly shifting based on the conditions that exist in the environment. Meta-data mined from the online accounts, such as geo-location, post date, comments, or keywords, are also used to build context processes and automations. The multi-screen visual composition is
accompanied by a generative soundscape that is produced to match and enhance the narrative aspects of the audio-visual synthesis. An extensive database of pre-recorded sound material is stored within the system, and based on specific conditions and extracted content, the variance of the soundscape is regulated accordingly.

![Figure 55: Stavros Didakis – Memorabilia (2014). Real-time photographic collage](image)

*Memorabilia* intends to explore in further detail how the collective space shares and distributes resources, as “the domestic environment is a negotiated space” (Sellen, 2011: 215), which includes a social construction to the fabrication of the ecology of the home (Hendon, 2000). Thus, it is necessary to acknowledge how the resources of the house (in this case the photo frames) are shared between the household members. According to this, the system tracks the presence of users within the home network, and based on their proximity towards the display area, selects – or not – their photographic material.
Following these technological implementations, we witness the house becoming a dynamic social system that it is shaped by physical, digital, and hybrid elements, and that includes a collective and individual memory space. By using computational media technologies, the environment becomes a sophisticated exhibition venue curated by its occupants, offering tools to visualize connections and meaning between things, surfaces, or ambient displays. As Abigail Sellen explains:

Having some sense of integration, connection, and collection between heterogeneous elements of the home, such as disparate display devices or disparate distillations, collections and gatherings of artefacts and the content itself would allow greater flexibility in how artefacts can be meaningfully handled. An integrated approach is thus like thinking about the connective (technological) tissue between objects and one layer of the socio-material fabric of the home. (Sellen, 2011: 203)

Memorabilia intends to investigate how the virtual preferences of inhabitants merge with objects of the domestic space, how static infrastructure can be animated with the use of computational media technologies, and the possible methods of diffusing media content and digital information within the home environment.

Chapter Summary

This chapter investigates the diffusion and spatialization of ubiquitous technologies within the domestic environment as a complex network of physical, virtual, and hybrid things. The main objective of this chapter is to explore the methods of diffusing digital content within the interior space, including its physical objects, media resources, and architectural surfaces. For this reason a short review is made to analyse the possibilities and limitations of current technological solutions of ubiquitous computing. For the practical
needs of this research, the diffusion of computational media technologies are explored through developments that intend to speculate rather than propose specific solutions to functional problems, and demonstrate case studies, artefacts, virtual interfaces, 3D visualizations, physical computing applications, and interactive installations.

Specific services of cloud computing are presented that have been applied in this work to demonstrate the importance of the cloud within the diffused and distributed environment. A middleware interface illustrates how digital information can be extracted from the cloud or sensor systems to control media elements of the house. Furthermore, a 3D simulation was created to demonstrate that cloud, middleware, and media resources could be combined to compose mesmerizing, reflexive and performative spaces. Surfaces that project data visualization of affective responses of inhabitants assist in demonstrating awareness and the way the habitat is perceived, as well as to playfully engage occupants and participants by exhibiting real-time responses through projected media content. The importance of objects within the household is finally studied through computationally-enhanced prototypes that explore personalization, diffusion, and memory.

Thus, it is evident in this chapter how sensor data and digital information become dynamic interior elements that blend with the environment and the occupants’ actions and behaviours. Through the use of ambient displays multiple sets of information can be revealed to the inhabitants that allows them to define the projected content, enhancing communication, aesthetics, and real-time design. From the development of apparatuses, the intersections of physical and digital domains are explored as a way of enabling objects to become part of the real and virtual domestic life,
including access to sensors, databases, and social media. Extending the practices of the networked manifestations of things, the domestic space becomes a playground of exploration and understanding, directly related to dwelling, memory, experience, and consciousness.

The next chapter discusses symbiosis, an important aspect in the identity of the house, and the domestication process of computational media technologies. Case studies are presented that demonstrate how a symbiotic relationship between inhabitants and the domestic space may be accomplished through the development of speculative experimentations. Finally, HexSpace is presented, an interactive installation developed for this work that exhibits how physical space and inhabitants’ awareness can be reconfigured and re-contextualized in a mutual way through structural transformations.
Chapter 6: Symbiosis

As has been discussed in the previous chapters, to further study and understand the domestication of ubiquity and the possibilities of computational media technologies in the home, it is necessary to contextualize, to dissect the layers of the space, and to propose media elements to accompany its overall composition. It is necessary to view the house on all possible scales, explore the networked manifestations of objects, services and properties, as well as experiment on how information and media content can be diffused within the home space. The next immediate step in this methodological process is to investigate how the domestic space and the inhabitants can develop a relationship that allows them to mutually co-evolve.

Based on earlier studies of J. C. R. Licklider, this chapter translocates the context of symbiosis between man and the machine into the built environment, and more specifically into contemporary methods for the design of affective and responsive domestic spaces. Different types of symbiosis are analysed to further contextualize and realize characteristic traits that are necessary for the development of computationally-enhanced homes. The chapter also discusses the implementation of media and sensor technologies within the architectural DNA to initiate the emergence of psychotropic spaces of Ballardian Architecture; structures that are capable of becoming extensions of the inhabitant’s mood, emotion, and consciousness (as they appear in the sci-fi novels of J.G. Ballard).

Furthermore, this chapter presents HexSpace, a speculative installation that was developed for this research to explore the physical and virtual structural transformation and personalization of the domestic interior.
according to inhabitants’ preferences and interactions. The main intention of this chapter is to speculate on the possibilities of the computationally-enhanced home that accommodates symbiotic conditions and personalization, and to set the ground for the manifestation of DomoNovus, a design fiction that is presented and analysed in the next chapter.

Requirements for Co-Existence

It is interesting to contemplate an entangled bank clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about. (Darwin, 2009 [1859]: 74)

Symbiosis derives from the Greek word sumbiōsis (συν “together” and βίωσις “living”), which means “living together”, and is used to describe the close physical association between two or more different organisms that co-exist in a certain environment temporarily or for a longer period of time. In this particular case, the organisms studied are the inhabitants and their domestic interiors; the house is not just a static container that simply provides safety and isolation, but rather is an active participant in a cooperative relationship; closed spaces with no fresh air will lead to mould on the walls, as well as affect the health of the person too (causing depression, fatigue, or even respiratory dysfunction). With the use of computational technologies, the objects, devices, and surfaces of the interior space are all considered to be a collective ubiquitous organism that perceives and reacts like a biological being, able to build sense and understanding of the ecological interactions. As Roy Ascott says in the following excerpt:

With feeling and sensing, artificial, intelligent sensors of considerable subtlety are becoming integral to human interaction with the environment and to the monitoring of both internal and external
ecologies. Human perception, understood as the product of active negotiation rather than passive reception, thus requires, within this evolving symbiosis of human/machine, telematic links of considerable complexity between the very diverse nodes of the worldwide artificial reticular sensorium. (Ascott, 1990: 238)

While technology advances, the resemblance between machine and human intelligence will become indistinguishable, as demonstrated in Alan Turing's *Imitation Game* (Turing, 1950). The increased functions of the technological object cause the human noesis to transform and adjust to the possibilities computational systems produce. Gordon Pask (Pask, 1972) explains that the machine becomes an evolving organism that is capable of performing numerous tasks, causing human perception to shift:

> It seems to me that the notion of machine that was current in the course of the Industrial Revolution – and which we might have inherited – is a notion, essentially, of a machine without goal, it had no goal 'of', it had a goal 'for'. And this gradually developed into the notion of machines with goals 'of', like thermostats, which I might begin to object to because they might compete with me. Now we’ve got the notion of a machine with an underspecified goal, the system that evolves. This is a new notion, nothing like the notion of machines that was current in the Industrial Revolution, absolutely nothing like it. It is, if you like, a much more biological notion, maybe I'm wrong to call such a thing a machine; I gave that label to it because I like to realize things as artefacts, but you might not call the system a machine, you might call it something else. (Pask, 1972: 54)

In 1960, Joseph C. R. Licklider (Licklider, 1960) identified two key points for achieving man-computer symbiosis: these are (1) “to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems”, and (2) “to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs” (Licklider, 1960: 4). To accomplish Licklider’s vision, it is necessary to further understand how a person responds to a particular situation, and how computational systems can assist people in achieving a
goal through formulative thinking. Similarly, in a domestic setting, it is important to understand the context and how the technological resources that are used by a system can assist in producing a desirable outcome.

Therefore, the relationship between man and machine can be a symbiosis of abstract (human) and calculative (machine) thinking. Although the technological object is not a "wet" living biological organism but rather a "dry" medium that consists of a silicon body, current practices of bio- and nano-engineering explore the possibilities of blending natural and artificial resources, creating cyborgian and moistmedia practices (Ascott, 2003: 363). One example is presented by the Bioelectronic Systems Lab at Columbia University, where the team has utilized the molecular machinery of living systems to power an integrated circuit, allowing the microchip to receive energy from the biological functions that are inseparable from the electronic system (Roseman et al., 2015). Likewise, in this context, the technological object becomes an actual living organism, part of the domestic environment, in a ubiquitous and transparent form that assists and resolves necessities while achieving the role of a symbiont partner.

Discussions related to symbiosis started in 1879 with Heinrich de Bary's work on biological organisms (de Bary, 1879), and ever since, studies have been made to analyse and categorize symbiotic relationships according to the interactions that take place within an ecology. It is characteristic that in many of these relationships not all organisms benefit equally, but to a varying degree. There are mainly three different types of symbiosis, as defined by Surindar Paracer and Vernon Ahmadjian (Paracer & Ahmadjian, 2000):
• Commensalism – In commensalism, one organism benefits from another, as in the case where one animal shares food caught by another animal; the benefit to one of the symbionts may be nutritional or protective. One example is the relationship between clown fish and sea anemone. In this relationship, the clown fish receives protection without affecting the anemone, which remains unharmed.

• Parasitism – Parasitism is a type of symbiosis in which one of the symbionts benefits at the expense of the other. Parasitic symbioses affect the host in different ways, as in the case of fleas and ticks that land on animals’ skin, harming them by sucking their blood, causing them to itch, and transmitting diseases to them.

• Mutualism – In mutual symbiosis, both partners benefit from the relationship. However, the extent to which each symbiont benefits may vary and is generally difficult to determine. For example, bacteria that live inside a human are able to survive while eating parts of the food that reside in the intestines, which also helps humans to better digest the consumed food.

A symbiosis between the inhabitants and their domestic environments relate to these three types in varying degrees. Most of the time it is Commensalism that takes place, as the environment provides all necessary elements for the benefit of the inhabitant such as security, warmth, and other essential properties. In this case, the house does not receive anything in return; it simply stands still and is always present to aid and support humans. In the case of Parasitism, the house is deeply hurt and negatively affected by the presence of people, which occurs when certain actions (or lack of actions)
and behaviours take place, such as leaving the interior unattended, dirty, and in poor condition. For example, a water leak may introduce mould and fungus, and, if left unattended, could damage the architectural structure beyond repair. If the house is not being taken care of properly, its quality will degrade, thus, it will become uninhabitable and deserted.

Mutualism is present when the inhabitant takes care of the domestic space to a satisfactory degree – a balanced nurturing agreement between the two parties. To respect the establishment is as important for the well-being as it is for the other members of the household. The ability to support and respect the ecological system is crucial. As Douglas Boucher et al. (Boucher et al., 1982) suggest, “a driving force behind the evolution of symbiotic mutualisms [is that] as more needs of the association are met by the combined abilities of the mutualists, the intensity of competition on those partners from ecologically similar species will diminish”, and that this “proceeds by selection of one symbiont to increase its fitness through changes that increase the fitness of the other symbiont.” (Boucher et al., 1982: 322). Therefore, mutualism promotes the term of collectiveness, exploring the environment as one organism with different parts that, nevertheless, are able to sustain the system in a balance.

The regulation mechanism in this case, can be defined as homeostasis, a term that refers to properties of a system that readjust and self-manage to maintain their stability. Homeostasis was originally coined by Norbert Wiener in the 1920s to describe “the body’s organic mechanism for maintaining healthy, stable states of internal equilibrium through a balance of self-regulating actions and reactions: sweating to cool the body when it becomes overheated, releasing hormones to excite or inhibit the action of the body’s
organs and nerve cells” (Conway & Siegelman, 2005: 16). Wiener also coined the term “cybernetics” (Wiener, 1948), which refers to the study and implementation of computational regulatory systems that include constraints and possibilities. Interaction loops allow the system to study “actions that lead to impacts on the environment that lead to sensing and further modification of actions” (Haque, 2007: 54). The cybernetic functions can be programmed to regulate the flow of information using feedback loops that “predict, control, and automate the behaviour of mechanical and biological systems” (Shanken, 2003: 18).

If the domestic habitat is examined as an ecological system, cybernetic practices can be applied to manage functions and processes with computational and interactive technologies. Homeostasis, for example, can be used to maintain a stable temperature independent of outside weather conditions, and logic units and cybernetic loop mechanisms can be used to readjust values to acceptable levels. Thus, the technological implementation of concepts and techniques within the home environment provides opportunities that are needed to achieve a symbiotic mutualism within the domestic space.

Speculative Organisms

To contribute to the production of a habitable world, design needs to be transformed, expanding its scope to include speculation on how best to provide the conditions for inhabitation. It must not just visualize a “better world” but arouse in the public the desire for one. Design approaches are needed that focus on the interaction between the portrayed reality of alternative scenarios, which so often appear didactic or utopian, and the everyday reality in which they are encountered. (Dunne, 2005: 83)
Anthony Dunne suggests viewing the “habitable world” as a space full of creative possibilities that not only provides new ideas and practical functions, but rather speculates on the impossible, misused, and redundant. It is necessary to investigate how a dynamic equilibrium between inorganic, biological, and digital entities can be achieved within the technologically enhanced space, and, more importantly, to stretch and exceed critical limits through speculative developments that reveal new dimensions to the exploration of domestic experiences. The aim of speculation, therefore, is “not to propose implementable product solutions, nor to offer answers to the questions they pose; they are intended to act as a mirror reflecting the role a specific technology plays or may play in each of our lives, instigating contemplation and discussion” (Auger, 2012: 29). Through experimentation and critical analysis, the observable experience transforms the conscious understanding into an imaginative and creative emergency.

Computational systems that regulate and readjust properties to achieve equilibrium and homeostasis are used to establish domestic mutualism, realising in a sense the dream of automatism. But more than this, each automated reaction assists or triggers other functions of the space, creating never-ending loops between diverse domains. One example is Philips’ *Microbial Home* (Philips Design, 2011), a design proposal for embedding sustainable functions into domestic activities in such a way so that resources can be recycled, reused, or reinvented. The home transforms into a biological machine that uses methane and composted material to feed bioluminescent bacteria that act as an energy source: plastic waste is decomposed to produce edible mushrooms, water is conserved from excess usage, and a domestic beehive is present to provide fresh honey for the residents.
Although this proposal is conceptually attractive and stimulating, and while it demonstrates a well-designed sustainable system that promotes mutualism, it cannot produce a sufficient amount of energy to be realistically applied. Moreover, additional work is needed to avoid health hazards that are generated from the biological and chemical processes.

**Figure 56: Philips, Microbial House (2011)**

*HORTUS.PARIS* is an interactive environment developed by London-based ecoLogicStudio, which focuses on architectural and urban design practices. The main intention of this project is to explore the ways biological organisms blend with digital technologies and visitors' interactions to become a dynamic self-regulated ecosystem. The columns of the structure consist of photobioreactors of microalgae that respond to various conditions in the environment, demonstrating how the living biological substances of the structure register fluidity, motion, growth, and transformation. This bio-

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architectural hybrid is fitted with ambient light, sensing technologies, and a virtual interface that are able to sense “flows of energy (artificial light radiation), matter (biomass, carbon dioxide) and information (tweets)” and “trigger inducing multiple mechanisms of self-regulation and evolution of novel forms of self-organisation” (ecoLogicStudio, 2013).

![Figure 57: ecoLogicStudio, HORTUS.PARIS (2013)](image from http://www.ecologicstudio.com/v2/project.php?idcat=7&idsubcat=59&idproj=127)

Scientific investigation has opened up a range of possibilities for the design and construction of spaces that absorb, monitor, and sense a range of visible or invisible properties, different spectra of light and energy, or interactions and behaviours caused by organisms, systems, and processes. The project Open-Columns (Khan, 2010) explores the possibilities of responsive architecture by using a series of composite urethane elastomers, actuators, and carbon dioxide (CO2) sensors that monitor air molecules in order to readjust and reconfigure the structure in real time. Programmatic and computational units calculate the responses, producing autonomous actions.
that cause the organic shape to readapt accordingly. Similarly, Phillip Bessley’s *Hylzoic Soil* proposes an environment that acts as a giant lung and digestive system, able to breathe in and out around its occupants. The installation becomes organic and almost life-like, “a visceral experience exploring the nuanced relationship between the biological and the artificial” (Beesley, 2006).

*Ada* is a project that investigates the implications of neuroinformatics in relation to social behaviour, architecture, and immersive multimedia environments. *Ada* (Delbruck et al., 2003; Eng et al., 2002) is an “intelligent” interactive installation that was designed mainly for public entertainment. Multimodal sensors receive visual, audio, and tactile information from the participants, and with the use of brain-like computational processing the system evaluates the results and demonstrates emotional states (Eng et al., 2002) through the use of visuals, lights, and a real-time musical system that synthesizes 12-voice soundscapes. The interactive space has a “high level of behavioural integration and time varying and adaptive functionality” (Bullivant, 2005a: 86), which transforms the room into a life-like being that responds to the way participants act and behave in real-time.

In James Auger’s project *Happylife* (Auger, 2010) the domestic environment becomes an emotional agent through the use of technology, as the system is able to scan the participants’ body thermal flow, and react through its interface in unpredictable ways. The accumulation of information and the probing analysis creates a sense of insecurity, as the “house” observes and readjusts through the information extracted from the biological fluctuations. The purpose of this work is to demonstrate possible alternatives in the responses of the domestic cognitive functions, which are expressed
through radial dials on an illuminated surface. Each dial has two pointers, “one showing the current state taken from the most recent thermal image capture and one showing the predicted state where the system would expect the dial to be based on the processing of accumulated statistical data” (Auger, 2012: 91). The device is not calibrated on specific settings, but rather shifts according to the participants’ interactions and responses. This practice allows viewers to produce a personal understanding of the device’s output, which results in conversational patterns, as also suggested by Gordon Pask.

Depending on human interaction that sets the input and output criteria, engaging conversations are triggered with the environment; the meaning is not explicitly or implicitly built into it (Cariani, 1997).

Figure 58: James Auger, HappyLife (2010) – Permission to reproduce this image has been granted by James Auger

These speculative artefacts demonstrate the importance of developing works that aim to inspire rather than propose a solution to a particular problem. It is necessary to speculate on practices that explore a set of resources capable of challenging experience, memory, and perception, and through this

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process, the domestic consciousness can be further understood. It also suggests ways that the technological object can create practices with the potential to become part of the daily household, and extend the symbiotic relationship of the man-computer-environment ecology.

**Blending Humans and Rooms**

In his very popular article “Man-Computer Symbiosis” published in 1960, J. C. R. Licklider (Licklider, 1960) anticipates that humans and computers will soon be coupled closely together, resulting in a partnership that will allow us to “think as no human brain has ever thought, and process data in a way not approached by the information-handling machines we know today” (Licklider, 1960: 4). Licklider proposed a relationship that makes use of the calculative power of the machine, and the parallel channels and cognitive processing of the human brain.

In the anticipated symbiotic partnership, men will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific thinking. Preliminary analyses indicate that the symbiotic partnership will perform intellectual operations much more effectively than man alone can perform them. (Licklider, 1960: 4)

Similarly, Donald Norman (Norman, 1999) argues that it is necessary to account for both mental and computational processing when it comes to the evaluation of activities and circumstances: “for people, decisions are flexible because they follow qualitative as well as quantitative assessment, modified by special circumstances and context, [and] for the machine, decisions are consistent, based upon quantitative evaluation of numerically specified context-free variables” (Norman, 1999: 160). Norman stresses the importance
of merging the differences of humans and computers so that they complement one another, but “only if the machine adapts itself to human requirements” (Norman, 1998: 161), since otherwise, the relationship becomes distorted and complicated.

Therefore, the embedded computational intelligence within the fabric of the household transforms the domestic interior into a ubiquitous system that further establishes the symbiotic man-machine relationship. This new spatialized form augments the computational processing and multimodal interaction that attempts to exhibit sensuous conditions and sympathetic properties. By accomplishing accurate personalization and context-aware processes, the environment demonstrates affectivity and emotional engagement that has the power to become psychotropic.

The term psychotropic comes from the compound Greek word “ψυχοτροπή” ("ψυχή", which translates to soul, and “τροπή”, which means turn) and implies the ability to change or affect mind and consciousness. In the short science fiction story The Thousand Dreams of Stellavista, J. G. Ballard (Ballard, 1962) introduces the concept of the Psychotropic House, which is an architectural space able to scan, record, and analyse mental and emotional profiles of the inhabitants, and react, communicate, adapt, and express itself through kinesis and metamorphosis.

It's always interesting to watch a psychotropic house try to adjust itself to strangers, particularly those at all guarded or suspicious. The responses vary, a blend of past reactions to negative emotions, the hostility of the previous tenants, a traumatic encounter with a bailiff or burglar (though both these usually stay well away from PT houses; the dangers of an inverting balcony or the sudden deflatus of a corridor are too great). (Ballard, 1962: 306)

I felt the room shift around me. The ceiling was dilating and contracting in steady pulses, an absurdly exaggerated response to our own
respiratory rhythms, but the motions were overlayed by sharp
transverse spasms, feed-back from some cardiac ailment. (ibid: 307)

A psychotropic house in Ballard’s story is like an animal with extra-
sensing mechanisms; it responds unpredictably and is capable of building
affective and emotional layers based on the inhabitants’ interactions and
behaviours. The house assimilates a character and personality that adapts
and responds to the properties of the domestic ecology.

But although the echoes of previous tenants can be intrusive, this
naturally has its advantages. Many medium-priced PT homes resonate
with the bygone laughter of happy families, the relaxed harmony of a
successful marriage. (ibid: 308)

With the use of the sensed information, the domestic space adjusts to
the conditions and its occupants, expressing itself accordingly. An ecology of
interconnected sensors is embedded in the physical structure of the building,
providing the ability to identify the external and internal processes of
inhabitants, such as movement, gestures, facial expressions, as well as mood,
behaviour, memory and emotional states.

In the cloakroom I tried to check my anger; the senso-cells had picked
up the cue and began to suck the irritation out of me, pouring it back
into the air until the walls of the cloakroom darkened and seethed. (ibid:
315)

The first PT houses had so many senso-cells distributed over them,
echoing every shift of mood and position of the occupants, that living in
one was like inhabiting someone else’s brain. (ibid: 308)

This fictional scenario proposes a superior architectural machine that
reaches a higher level of adaptability, able to absorb in its infrastructure
cognitive aspects of human beings. According to the level of mental infiltration,
the house reflects this information through morphopoiesis, accessing affective
properties that trigger instability and unpredictability; the outcome becomes far more exciting (and in some cases dangerous) than any pre-programmed logic the designer could define, as the house has human-like idiosyncrasies. Similarly, in Constant Nieuwenhuys’ *New Babylon*, which was presented in Chapter 1, the architectural structure becomes an amalgam of design, desire, and psychology that creates a psychic dimension inseparable from the space of action:

Every transformation of the space, no matter how minor, is understood as a direct intervention in social life that sets off a ‘chain reaction’ of responses. New forms of behaviour evolve, only to be challenged by the next spatial move, and so on. New Babylon is a vast playground in which the fantasy of self-critical avant-garde experimental art has been generalized into a collective lifestyle. Art as a discrete practice critiquing the dominant order becomes redundant. Daily life has become an all-embracing artwork using every available medium simultaneously, a ‘unitary’ urbanism. (Wigley, 1998: 14)

The implication of having a space that can emanate (almost telepathically) the desires of its occupants is mirrored in Andrei Tarkovsky’s science fiction film *Stalker* (*Stalker*, 1979). In this film, an area polluted with large amounts of radiation has resulted in the creation of a “magical” room that can grant the wishes of its visitors. The invisible matter that was fused in this Chernobyl area can penetrate and define alternative realities using the space as a living agent to express and communicate behaviours, reactions, or feelings; the Stalker in the film says:

The Zone is a very complicated system of traps, and they are all deadly. I don't know what's going on here in the absence of people, but the moment someone shows up, everything comes into motion. (*Stalker*, 1979)

In Tarkovsky’s film, the space – with everything that it consists of (landscape, objects, rooms, buildings) – creates numerous scenarios
according to the way people behave, interact, and live. The radioactive elements penetrate real matter and develop an environment that senses subtle differences in psycho-physiological or mental states defining the spatio-temporal characteristics in a manner that reflects bizarre attitudes and motivations. Therefore, a “room” can become something more than a representation of a cave, such as an engine, a process, or an organism.

The transformation of architecture according to information captured from the surroundings is also successfully portrayed in the popular film *The Matrix Reloaded* (2003). In a particular scene, the Architect (the person/algorithm responsible for the engines of this virtual world) is sitting in a room filled with monitors that collect and project any event that has taken place in digital time as well as every bit of historical information that has ever existed in the simulation. This room acts as a mediator of information, aesthetics, and even digital metaphysics – it seems that the Architect’s brain is directly linked to the room’s monitors, allowing for immediate responses that change and shift meaning and awareness.

These examples demonstrate speculations concerning the possibilities of various systems and technologies (senso-cells, radiation, metaphysics) to transform the environment into a “living” entity that senses and reacts to inhabitants’ physiological or psychological responses. Science and speculative fiction become necessary in this stage of this research, as when moving towards more challenging concepts and tasks – such as mutual symbiosis – the boundaries between alternative realities and future possibilities begin to blur. It is necessary to contemplate and reflect on ambitious probabilities, so that forthcoming of the domestic life can be
encountered and critically analysed – a process that is explored in more detail in the next chapter.

**Achieving Intimacy**

Imagine a world in which humans and objects coexist, living out epic tales of adoration, love and, above all, empathy – a sensual realm wherein the walls erected to separate flesh from polymer crumble giving way to a lawless and unsupervised consumer future. The born and the made – people and things – develop an oneness that finally enables them to coexist over vast periods of time in complete symbiosis. Imagine a world in which products are designed to support the investment of emotion – cherishable products, appliances and tools that not only sustain but also amplify sensations of attachment – a world where technological modernity is not the sole value indicator [...]. (Chapman, 2005: 163)

Jonathan Chapman discusses how objects, products, and services can offer emotional experiences in order to sustain a healthy relationship with their user. He proposes that objects need to accommodate meaningful experiences so that users can appreciate and amplify their sensation of attachment. This is an important view if it is considered within the context of the domestic space, as the home has to establish conditions for affective relationships to seed, grow, and evolve. If basic needs are covered, the symbiotic environment tends to move forward and pursue other goals, as has been explained by Abraham Maslow’s hierarchy of needs (Marlow, 1954). When human’s necessities are met at a basic level (food, oxygen, shelter, security), the individual tends to pursue higher-level needs, such as love, belonging, and esteem.

The purpose of enabling the technological extensions to become empathetic, affective and humane is to allow a more effective communication with inhabitants. As Byron Reeves and Clifford Nass argue, this interaction between humans and machines should be based on the very same concepts as the interaction between humans. For instance, it should be intuitive,
multimodal, and based on emotion (Reeves & Nass, 1996). Similarly, Donald
Norman suggests that affect and emotion should be incorporated into a
machine for it to be able to meaningfully interact with humans. Its actions
need to appear in such a way so that they reflect understanding of the current
processes, or if it is confused or unsure about a particular task (Norman,
2004).

Human emotion is difficult to evaluate as often it is a mixture of multiple
psychological states, which makes it harder to recognize and understand. For
a machine to be able to sense affective properties is even more difficult, as a
large amount of computational processes have to take place that often result
in an estimation rather than actual comprehension: “even if systems can
somehow disambiguate a mixture of basic emotions based on some
combination of facial recognition and physiological monitoring, this is only a
small part of comprehending the meaning of an emotional experience” (Gaver,
2009: 3597). Thus, even if mechanisms are applied to accomplish this, such
as sensors for detecting galvanized skin response, heart rate, eye dilation,
facial expressions, voice, and so on, it is difficult to capture emotions with a
high degree of confidence. Studies have shown that physiological responses
may not apply equally to everybody, particularly in different situations and
contexts (Leidelmeijer, 1991).

Rosalind Picard from the MIT Media Laboratory coined the term
Affective Computing (Picard, 2000) to refer to computing that relates to, arises
from, or influences emotion. The main objective is to facilitate machine
intelligence that perceives and registers affective information that is extracted
from human interactions. One of the main concerns of affective computing is
that the facilitation of emotional states could create further confusion to both
humans and machines. In order for the machine to be confident enough that it has extracted the right emotional state, it needs to know the context of the situation, as well as have enough information concerning the individual. If these requirements are not met then the application is going to be prone to errors, and the processing power that is needed for such a task would be overwhelming.

In a scenario where a machine is able to exhibit an emotional sense, ethical considerations emerge that may affect the human-machine symbiosis. To influence a person using a computational system may be considered a form of misconduct, even in cases where it can positively affect psychological and emotional health, or treat victims that have experienced a great amount of stress (rape victims, hostages, or abused individuals). This is a philosophical debate beyond the scope of this research, although it needs to be acknowledged that this level of intelligence needs to be treated respectfully. Within the domestic domain, computational systems should use affection and emotion as parameters for contextualization that allows the machine to sympathetically listen and assist, if necessary.

**Structural Transformations**

One of the main goals of this study was to develop an installation that demonstrates how the domestic space can be transformed using physical and virtual interactions, merged with the personalized preferences of inhabitants, so that a symbiotic relationship can be explored. Domestic interiors offer a range of patterns, symbols, and information displayed through the use of colours, aesthetics, the selection of wallpapers, and so on. These properties
can be reformed using computational technologies to propose extended meaning and purposes. In the previous chapter, for example, light was used as an ambient display to not only provide a particular set of helpful functions, but to also communicate to the user information extracted from the sensor interfaces.

In this case, patterns that are created from tiles, wallpapers, or textured walls are investigated to shed further light on the transformational possibilities of an interior space. Keith Critchlow and Seyyed Hossein Nasr in the book “Islamic Patterns: An Analytical and Cosmological Approach” discuss the importance of patterns that embellish Islamic interiors:

Ultimate Reality is at once Absolutely and Infinite, the source of all being, of all consciousness and of all life. Itself beyond form, it speaks to mankind through revealed forms, which, while externally bound and limited, open up inwardly towards the Boundless. Through revelations of this Word or Logos come into being the sacred traditions which although outwardly different are inwardly united into a Centre which transcends all forms. They are, however, the bridge to the Absolute, from the finite to the Infinite, from multiplicity to Unity. (Nasr, 1983: 6)

Hossein Nasr (Nasr, 1983) explains the importance of geometric Islamic patterns and argues that their design is based on complex mathematical calculations that emerge from a spiritual and immaterial substance – i.e. Truth, One, God, or Divine Unity. He explains that the spiritual world is reflected in the sensible world through the geometry and rhythm that is created in arabesques and calligraphy, and that these reflections are celestial archetypes that are found within “the cosmos and the minds and souls of men” (ibid: 6). Through the sophisticated design of the interior surface, viewers are subjected to a reality that provokes the senses and consciousness, and opens up possibilities for exploring the self and the
cosmos. The wall becomes a window to mystical matter that manifests from the geometrical patterns, and although the design blends ubiquitously with the information, careful observation extends and provokes awareness and mindfulness.

Similarly, the implementation of technological interfaces and computational media within the surfaces of the domestic interior has alike intentions and associations. Present knowledge and understanding of the environment can be extended, as well as the ability to view unseen matter on multiple scales, visualize interactions, access cosmological events, or become part of humanity’s hypercortex – a shared mind that spawns new realities and definitions of life and human identity; “a global network of collective cognition” (Ascott, 2003: 378). The implementation of these functions in the domestic space has to be sympathetic and respectful towards the household’s atmosphere; they must not obstruct nor confuse by injecting unwanted noise, and they must be easily operational and accessible. According to this, the following installation, which was developed as part of this research, speculates on possible domestic futures while greatly considering the aforementioned requirements. The hexagonal shape that was selected for this work was not done so randomly, but rather was carefully chosen based on inspirations from nature, religions, philosophical currents, and contemporary design practices.

**HexSpace**

Hexagon is a shape easily found in nature and it is well-known for its efficiency and inherent symmetry. The honeycombs of bees and snowflakes
often have a hexagonal shape in order to occupy optimum coverage area; “the planar hexagonal honeycomb provides the least-perimeter way to enclose and separate infinitely many regions of unit area” (Morgan, 1999: 1753). Moreover, hexagon is one of the subunits that structure the nucleotides that make up the chains of the DNA double helix macromolecule, and it can also be found in microscopic to macrocosmic structures (gigantic rock formations such as those of the famed Giant's Causeway of Ireland). The hexagon holds a key position in sacred geometry, among mandalas in Hindu, and with respect to Buddhist spiritual symbols that represent the symmetry in the universe, as well as mystical philosophies, such as the Nordic Runes, which believed that the hexagon held the potential of all life.

Moreover, the hexagon is often used as a decorative element in architectural and interior design, as for example in Japanese textile art, and it has been an important part of architectural design mainly due to the reason that hexagon networks are useful for joining spatial units, like Frank Lloyd Wright's Honeycomb House: “whether the hexagon is used structurally or decoratively, as a unit or in repetition, it is characterized by a feeling of stability and order” (Proctor, 1990: 70). But more importantly, the hexagon is to be viewed in its collectiveness, which provides “a composition of complex relationships, […] strengthened in multiples into an infinite network of connections” (Burkhauser, 2011: 9). Therefore, hexagonal patterns are to be understood as a metaphor for the interconnectedness between humans, technology, virtual spaces, and physical and metaphysical dimensions.
Description

*HexSpace* is a project that was developed by the author for this research to speculate on the possibilities of the interior space augmented with a technological framework. *HexSpace* is a *meta-wallpaper*, a physical layer placed on a wall, to extend the possibilities of the visual and functional apparatus of a conventional domestic area. Victoria & Albert Museum define wallpaper as:

> [...] the decorative art of the house, and it has an ephemeral nature due to the reason that it is often being replaced or readjusted to particular needs. Moreover, wallpaper is considered as the background of the house, although its role in the overall decorative scheme is a vital one, and its choice “affects the mood and style of a room, [...] influence the choice of other furnishings, [may] be indicative of the function of a room, and [...] reflect the age, status or gender of its inhabitants or habitual occupants”. (V&A, 2016)

In this particular case, the static nature of the wallpaper is enhanced with the use of microelectronics, data visualizations, and physical interactions. The purpose of this work is to develop a functional scenario concerning a computationally-enhanced domestic environment that reflects on its interior conditions, reacts to sensed interactions, allows users to make configurations based on individual needs, and enhances awareness of domestic consciousness. The physically transformational capabilities *HexSpace* offers are meant to engage the inhabitants in altering the structure themselves, as the architectural material becomes easy to extract, manipulate, and reposition. But most importantly, *HexSpace* demonstrates a scenario of symbiosis, as the domestic space exhibits consciousness and awareness concerning its internal conditions as well as the symbionts’ actions, which trigger responses that are suitable for each task.
In its normal arrangement, the wallpaper displays a static physical hexagonal texture. Fit within the structure, there are tangible objects that the participant can take out of the structure and that trigger responses from the sensor system that is embedded beneath the surface. If the object, when extracted from the surface, is rotated 180° with respect to the X- or Y-axis (so that its reverse side, which originally faced the surface, now faces the front) and repositioned back again inside the surface’s opening, it activates from the system a display screen that emerges on the front side of the hexagon. The placement of the object on the front or its back serves an important function: on its front, the object blends with the wallpaper, displaying a static image, but if the viewer wants to shift its inanimate function, the rotation of the object produces ambient visualizations displayed on the hexagon’s face. Therefore, with every interaction, the function of the object is reshaped.
When the ambient display has been activated for a particular hexagon, the system visualizes the data received from the sensors that have been incorporated into the domestic interior (in this case, from DataGrid, mobile devices that are used to log the inhabitants’ sentiments, i.e. MoodLog, and datasets stored on the cloud). Each sensor has its own visualization, although the parameters can be personalized according to the users’ preferences – the options are accessed from virtual interfaces enabled from a desktop application screen. The visualizations respond in real-time according to the values received: lower values result in a slower and less complicated visual structure, but as the data values get higher, the visuals readjust automatically.

Each hexagonal object offers six different visualizations. To select a new visualization, the user has to rotate the object by 60°. By shifting the objects into various formations, the collective visual responses are composed accordingly. An identification sensor (RFID) placed beneath the structure logs the object’s current rotation. Each position and rotation generates requests for
specific information from the real-time data streams or the database logs. The communication is accomplished using OSC, MQTT, and HTML.

![Diagram of HexSpace system](image)

**Figure 61: HexSpace, System Diagram**

In *HexSpace*, tangible interaction becomes a poetic interpretation of reconfigurable architecture, since by removing the physical parts of the construction and repositioning them in alternative ways, new functions emerge – shifted structures of interactive emergences. The installation does not intend to confuse or further inject informational “noise” into the aesthetic interior, as the wallpaper’s texture can always remain static, causing no discomfort, blending naturally into the “frozen” surrounding. But, on the other hand, if inhabitants demand to be informed about some aspect of their home’s collected datapool, or if they prefer reactive media embellishments within the domestic everyday routine, they can activate the wall-fitted objects with minimal action, initiating a real-time response from the system to gather the necessary information that controls the engaging animations that are projected to the hexagonal ambient displays.
System Evaluation
The system at present is installed in Roy Ascott’s studio in Shanghai (China), and the current occupants of the space operate it on a daily basis. Over the period of one month, and after extensive unstructured interviews, information was collected concerning the implications of the installation. The participants believe that HexSpace offers an interesting experience and provides helpful insights concerning the quality and nature of the interactions of the interior space. They also believe that it opens up an interesting discussion regarding the awareness concerning the immaterial dimensions of the interior space.
The system is intuitive and easy to understand, and the interaction is straightforward and effective. One of the issues raised is that, over time, users lose interest in the emitted patterns, which are lost in the periphery of perception. Overfamiliarity causes visualizations to become obsolete, therefore participants feel less motivated to explore the system and the information it can provide.

Further upgrades of HexSpace are going to include an extensive collection of information that can be accessed from the wallpaper’s physical structure, and this will include the actions and behaviours of the occupants (navigation, circulation, clustering), personalization options for data visualization, access to virtual and social media content, as well as the ability to sonify the visual flow. This intelligence should be able to provide a higher state of domestic consciousness, and a hub for techno-aware symbiosis, which will allow users to build a stronger understanding of the household dynamics. It should also be able to extract meaning and accumulate further insights related to the home’s members and the range of possibilities that lay within the routines of navigating the personal, physical, and virtual Umwelts.

Chapter Summary
This chapter discusses the relationship between inhabitants and the computationally-enhanced home, and analyses practices and developments that assist in defining specific characteristics for achieving symbiosis. To accomplish this goal, it is necessary to further explore man-machine-environment symbiosis and to establish conditions for distributing tasks to particular processing units of the house in order to accomplish effective
results. Thus, dry processing units (silicon-based technologies) process a large quantity of information, leaving the abstract thinking to moist units (biological/humans).

Mutual symbiosis is a challenging task, as symbionts need to assist each other for co-evolution and development; a critical condition that is able to recontextualize the way domestic environments are established, perceived, and used. In order to accomplish this goal, it is necessary to understand in great detail the symbionts’ needs, and identify, locate, and determine tools, resources, and methods for achieving symbiosis, such as ecological analysis, homeostatic practices, sustainability of resources, and affective, emotional, or even psychotropic properties.

The structural transformation of the interior space is also discussed in this chapter, and how the physical layers of the environment become an interface of information. This is an important condition in the symbiotic relationship, as it can facilitate communication between the space and the inhabitants. Moreover, this demonstrates how the skin of the house transforms according to certain conditions, expressing itself through the uses of various media, whilst extracting meaning and information from its dwellers, either through non-obtrusive techniques or permitting physical actions to communicate certain expressions and connotations. For this reason, HexSpace is presented, an interactive installation that allows participants to shift the physical and virtual properties of the domestic space by extracting and repositioning parts of the interior structure. HexSpace is a poetic interpretation of reconfigurable architecture that demonstrates how the augmented spaces we occupy shift properties according to inhabitants’ physical actions.
The following chapter presents a dissemination of the practices demonstrated in this research, and examines whether the objectives stated in Chapter 1 have been accomplished. Moreover, DomoNovus is presented, a design fiction that consists of a manifesto and various speculations concerning the possible futures of domestic life. DomoNovus consists of a range of concepts that have emerged from the practical developments of this research, and the speculative contribution that it provides becomes an important ingredient for this thesis and its objectives.
Chapter 7: DomoNovus

“There is no place like 109.107.36.145” (Didakis, 2016: 188)

In the previous chapters, the role of the computationally-enhanced home was discussed and analysed from philosophical, anthropological, sociological, technological, and artistic perspectives. The study of this enhancement is important as it transforms and alters the ecological universe of the house, which now consists of new functions, customs, and protocols that impact the overall domestic habitat. Multimodal interactions, cloud services, and embedded devices that are all connected to local or remote servers and online resources are extending what it is considered to be an intimate and personal space, and they are blurring the boundaries between time, reality, virtuality, cyberspace, and interface.

Following the concepts and methods that were studied in the previous practical works of this research, a design fiction is presented here, which speculates on the possible futures of the domestic environment, anticipating the repercussions of technological and scientific practices. The theoretical and practical explorations that are used in coherence with the five points of the computationally-enhanced home (Context, Media Layers, Invisible Matter, Diffusion, Symbiosis [as presented in Chapter 1]) assist the emergence of DomoNovus (Latin for “new house”), a concept that it is presented in this chapter and foresees and anticipates speculative possibilities for the technological home. DomoNovus explores the domestic environment as a medium in transcendence that extends opportunities and functionalities through technological and computational tools. The investigation of
DomNovus consists of a manifesto, a written analysis, conceptual sketches, and a system diagram.

**Mapping the Practice**

The projects that are presented in the last five chapters (Chapters 2 to 6), which include interactive installations, software and hardware developments, programming code, artefacts, and case studies, have introduced a range of concepts, keywords, and practices to the understanding of a new domestic reality. To assist the critical reflection and analysis of these works and to further link them with the current chapter, an interactive software application was developed (that can be found in the accompanying USB flash drive in the folder Chapter 7 –Map of Practice) to visually describe how the main keywords of each practice relate to each other (the following image displays a screenshot captured from the real-time visualization rendering).

The map displays the main practical elements of this thesis, which are identified by an individual colour; the name labels on the bottom of the visualization assist in recognizing each one of them on the network of the linked words. Based on the total number of keywords found, the text size varies accordingly, thus, Software, Database, Cloud, IoT, Modular, and Sensors appear larger than Wearable, Sound, Artificial Intelligence, and Immersive, which are used in fewer projects. The user can interactively explore the map, and see in detail the keywords attached to each project, and how they are interconnected with the rest of them. This becomes a helpful tool in assisting the reader/user better understand this work.
Figure 63: Keyword analysis of practical work

A primary objective of this visual analysis is to acknowledge the terms and glossary of the computationally-enhanced home, as defined in this research, and consider the possibilities that emerge through its exploration.

Following this, the concept of *DomNovus* is introduced and analysed in this chapter, which is a design fiction that consists of a manifesto, an analytical description, sketches, and a system diagram. Although *DomNovus* is purely fictional, nevertheless, and according to the visual map, it directly links and blends with the practices and concepts developed in this work. The speculative nature of this chapter intends to inspire and trigger the imagination of the reader in order to envisage a possible future for the domestic space. This aligns with an illustration and description by James Auger that explains how technological development and speculation affects forthcoming events and emergencies within the domestic environment.
At the origin is the here and now: everyday life and real products available on the high street. The lineage of these products can be traced back to where the technology became available to iterate them beyond their current form. The technology element on the left-hand side represents research and development work - the higher the line the more emergent the technology and the longer and less predictable its route to everyday life (domestication). As we move to the right of the diagram and into the future we see that speculative designs exist as projections of the lineage. They are developed using a technique that focuses on contemporary public understanding and desires and extrapolate these through the imagined application of an emerging technology. Alternative presents step out of the lineage at some relevant time in the past to re-imagine our technological present. These designs can challenge and question existing cultural, political and manufacturing systems. (Auger, 2012: 135)

![Diagram showing the relationship between here, now, speculative futures, and alternative presents.](image)

**Figure 64: James Auger, Alternative Presents and Speculative Futures (Auger, 2012) – Permission to reproduce this image has been granted by James Auger**

**The New Home**

While analysing the speculative futures of the domestic environment, it is important to consider the speculative futures of the human being (body, mind, intellect, and so on). In this context transhumanism and posthumanism are descriptions that attempt to analyse the future forms and functions of humans.
According to James Hughes (Hughes, 2004), “transhumanism is the idea that humans can use reason to transcend the limitations of the human condition” (ibid: 156). Max More in his essay “Transhumanism: Toward a Futurist Philosophy” (More, 1990) explains:

Transhumanism is a class of philosophies that seek to guide us towards a posthuman condition. Transhumanism shares many elements of humanism, including a respect for reason and science, a commitment to progress, and a valuing of human (or transhuman) existence in this life rather than in some supernatural “afterlife.” Transhumanism differs from humanism in recognizing and anticipating the radical alterations in the nature and possibilities of our lives resulting from various sciences and technologies such as neuroscience and neuropharmacology, life extension, nanotechnology, artificial ultra intelligence, and space habitation, combined with a rational philosophy and value system. (ibid: 6)

_Homo Novus_ (Latin for “new man”) refers to a trans-human fictional concept of a genetically engineered human species that evolves from Homo Sapiens (FutureWikia, 2016). In this speculative scenario, every _Homo Novus_ is enhanced with cybernetic and bio-synthetic devices that allow them to have an unprecedented area of brain activity, eidetic memory, hyper-awareness, virtual telepathy through synaptic transceivers, and increased biological endurance that includes cell regeneration and instant healing (ibid). _Homo Novi_ are the apotheosis of human evolution, as they have an optimized physical structure and extreme endurance to external conditions. Microcomputer implants into the cerebrum allows _Novi_ to access epitomized moistmedia functions with the use of artificial intelligence and memory interfaces that translate into exceptional multi-tasking abilities, as well as direct uploading and downloading of information from digital devices. Communication implants allow them to access any available network, satellite, or computer device instantaneously. The implants also facilitate virtual
telepathy and sharing of thought with other *Homo Novi*, resulting in a communal consciousness. Although the aforementioned description concerning the *Homo Novus* is fictional, it foresees a future that should be considered and critically analysed through science, art, and philosophy.

The Bio-Art practices of Eduardo Kac, Stelarc, Natasha Vita-Moore, and Aimee Mullins, among others, reimagine the biological normality by developing experimental provocations to envision alternative routes in the evolution of living beings. The enhancement of human properties such as the physical, intellectual, or emotional, can be achieved with “psychopharmaceutical drugs, somatic and germline genetic engineering, human cloning, molecular nanotechnology, artificial intelligence, and cryogenic science” (Walters, 2013: 1). These practices allow us to break the natural order of things and extend our understanding of the physical and biological conditions, as well as to search for new ways to comprehend what constitutes being human.

One vision of the future is that technological evolution merges with human biological natural processes, producing transhuman and posthuman conditions. According to Katherine Hayles, being posthuman means to “privilege informational pattern over material instantiation”, to consider consciousness as an epiphenomenon, to view the body as an original prosthesis that can be altered or replaced, and to “configure human being so that it can be seamlessly articulated with intelligent machines” (Hayles, 1999: 3). From an evolutionary perspective, this transition should be considered normal as the addition of technological artefacts will (theoretically) help extend possibilities, and provide better survival chances. However, there are many ethical and philosophical issues to be considered, as for example politics,
gender issues, evolutionary provocations, environmental repercussions, safety and security, as well as questions regarding the humanity's place in the ecological order.

When considering the domestic environment from this perspective, it is necessary to anticipate the radical changes to emerge in the substrate of human civilization, which will consequently cause shifts in its domestic ecologies too. It is necessary to consider the future of the home as an inseparable part of the human Umwelt, which greatly impacts physiological, biological, psychological, emotional, and intellectual characteristics, as it has also been analytically described in the previous chapters of this study.

DomoNovus is inspired by the trans-humanist concept of Homo Novus, and it speculates and examines how the domestication of ubiquitous technologies, computational media, and scientific innovation may affect the domestic environment in the near future. Through an open and imaginative exploration, trends and ideas aim to “break” the preconceptions of the domestic ecology, inviting us to consider promises that emerge, provoke and to consider further experimentation and research practices. To conceptually explore and define DomoNovus in more detail, a manifesto was written and is presented in the following page. Its purpose is to intrigue imaginative and creative thought, and to cultivate suggestions that may lead to an alternative understanding of the technoetic domestic space.
The beginning of our navigational points;
Where subconscious states rise and fall;
A place of trust and tranquillity, allowing access to
consciousness, planetary journeys, virtual spaces, cloud databases;
Casual instances of unnoticeable poetries;
   data mining of domestic truths;
Accumulated cells, things, moments, links;
A gate to distributed authorship,
an assemblage of stories, a blend of narratives, data, and memories;
Conversational processes of mutually calibrated hybrid "things';
No more an environment to wire our technologies,
no more a shelter for our ubicomp things,
but rather a home embodied, traversing in time and space;
Physical structures that emerge, transform, and recycle;
Rooms are nearly alive, fully responsive, co-operative;
Modular units, universal awareness, homogeneity of everything;
The domestication of ubiquity?
   No, the ubiquity IS the domestic;
Sustainability is present;
   all spectra are sensed, harvested, reused;
Pore of the skin; a house of the metropolis;
The biological body is monitored and reconstructed;
   the house is a nurse, a doctor, a therapist;
Sensorial engagement is constantly present;
   granted access to psychotropy;
Senses are fed, perceptions and experiences are transformed upon request;
Emotional tension spreads on the wall, like ripples in a lake;
Dwelling is captured in time and space, revisited, and remotely shared;
Spatial reflections of digital souls;
Can consciousness be habituated?
   If yes, then this is it.
Analysis

*DomoNovus* proposes a future for the domestic life that it strongly depends upon digital technologies, computational media, network protocols, and cloud services. As the universe of domestic properties slowly sinks into a digitized utopia, it is necessary to establish new frameworks that assist the cartography of this hybrid territory. The majority of electrical and electronic objects become “colonialized by computer code” (Dodge & Kitchin, 2008: 13). Similarly, mechanical household tools were “infected” with the integration of electrical control in the first half of the twentieth century (Cowan, 1983). The “New House”, therefore, becomes a self-sustainable environment that creates its own resources such as power, chemicals, and nutrients, and also allows inhabitants to reinvent and redesign the domestic interior (objects, embellishments, surfaces), as well as the computational functionality that is needed for the house to think and operate.

A house in the Age of *DomoNovus* does not resemble architecture anymore, but rather a human brain. Reasoning, cognition, planning, creative, and emotional functions are similar to those found in a frontal lobe. According to its modular configuration, *DomoNovus* can provide a performance that feels appropriate in a particular household using computational services for classification, analysis, and filtering of data and metadata that are received from the inhabitants and the environment. Personalized Artificial Intelligent agents process collected information clusters to identify trends, predict future events, or exercise psychological traits that can be further applied in domestic applications.
The eidetic memory of DomoNovus consists of a centralized storage space (local and remote server) that includes all data of individuals and the collective household. Decentralized hybrid and digital objects are also able to store information related to user interactions, accumulate identification and profiling instances, as well as record contextual information that is retrieved during certain events, developing “material instantiations of an immaterial system” (Sterling, 2005: 11). During particular moments when a domestic object senses a noteworthy interaction, such as the rise of an emotional state of an inhabitant, information is collected and shared, providing effortless captures of entire lives (Bell & Gemmell, 2009; Kientz & Abowd, 2009). If the spatial characteristics of such an object permit the implementation of the necessary hardware (e.g. infrared sensors, 3D camera, microphone), memory collection may also consist of 3D video and sound. Navigating the memory database of the household using a personalized interface and holographic virtual or augmented devices, the exploration of past moments of the
household manifests as a projected simulation in three dimensions with their associated ambiances\textsuperscript{21}.

Multisensory interfaces spatialized into the home’s interior collect a range of information that is transmitted to the cerebral cortex of \textit{DomoNovus}, which is responsible for complex processing, context-awareness, and problem-solving abilities. Similarly to the functions of the cerebellum, the house is able to accommodate physical reactions and motor automations, which are controlled by the main processing units to assist functional, mundane, or other necessary tasks. With the use of a range of media, the house communicates a variety of informational, assistive, or affective content with the inhabitants. Based on profiling and contextualization techniques, media technologies such as light displays, ambisonics, or ferrofluid tapestries\textsuperscript{22} are used to transmit the encoded information.

The nervous system of the house becomes the wireless networks and the communication protocols locally and remotely, as well as the Application Program Interface that is implemented to connect available resources and get, set, modify, or delete recorded values. \textit{DomoNovus} uses all accessible frequency bands and communication protocols to allow plug-and-play configurations, especially with newly added devices, assimilating a fluid and organic response to various changes in its techno-ecology.

\textsuperscript{21}The combination of multiple recorded instances assist in viewing multiple interpretations of the same event (or from different angles), as well as offering the ability to recreate the original acoustic environment using time intervals (pings) between objects that calculate sound propagation to accurately simulate reverberation – an ultimate acoustic recreation of past events.

\textsuperscript{22}The magnetic properties of ferrofluid are often used as information processing units, executing logical operations if needed, as they are immune to electromagnetic interferences (Katsikis et al., 2015).
Open-source culture greatly affects *DomoNovus*. The ability to download and edit virtual objects and physically recreate them using 3D-printers, plotters and laser-cutters unleashes a wave of possibilities for the design and configuration of the domestic space. Using any compatible material (such as plastic, wood, metal, cement, or glass), the form of the house changes in real-time based on the sensor and logic system, responding to the identified needs of the inhabitants; an extra chair is added or recycled, a wall is extended, an algorithmic sculpture emerges in the living room. The construction builder is the domestic 3D-Printer, the furniture store becomes the filament type selection, home accessories are shared torrent files, and all changes of the house are digitally saved as a 3D-model that shifts over time to demonstrate how implemented changes have transformed the interior. These practices elevate the concept of symbiosis, as the home can repair, upgrade, and evolve, while simultaneously documenting and registering the growth for historical and future reference and use.

A food printer becomes a necessary addition to the kitchen environment, which is responsible for preparing meals according to the users’ preferences. Recipes can be downloaded or shared with the community, providing a new palette to the eating experience – although it is impossible to ever completely replace the cooking. However, the food printer can provide a personalized meal for each inhabitant according to bio-sensing and context-aware applications that monitor performance and biological needs to calculate and design a meal with maximum nutrients supply. Most importantly, the collected intelligence of *DomoNovus* can be applied in the design of supplements that assist the biological functions of inhabitants to sustain optimum physical conditions.
A vast range of stimulants is provided by the house – chemical, edible, media – to regulate biological functions such as metabolism, or calibrate abnormalities (depression, jet lag, nausea, etc.). By using sensing instruments such as GSR (Galvanized Skin Response) sensors, biometric devices, or thermography, the house becomes a nurse, doctor, and therapist. Instant connection to relevant databases can fetch optimized treatments through available resources. Even the process of taking a bath becomes a session of healing; analysis is executed on a molecular level, cell reconstruction is performed (bio-stimulation, tissue regeneration), vitamins and proteins are supplied. Comfort and relaxation aids can be triggered via compositions of synaesthetic media using light, scents, sounds, and visuals to evoke sensorial stimuli that become a dwelling necessity.

The tracking of physiological, behavioural, and biological properties is an essential characteristic of DomoNovus, not only for calculating practical and detrimental issues, but also for exploring creative and imaginative processes, which become part of the house’s communicative and playful extensions. Interactive spaces are initiated when participants enter the house – physical and biological characteristics are monitored, spatialized, and expressed back through the use of media. The interaction with others becomes a natural interplay, a casual exchange of information in physical and virtual planes. The interaction becomes “banal”; “banal and remarkable” (Rokeby, 1996).

Initially, houses assisted humans in surviving natural phenomena, but now the main objectives have been extended to sterilize the environmentally polluted domestic landscape, as well as to filter oversaturated information emitted from physical, virtual, and cyber sources. The house becomes the
ultimate entertainment system – it intends to fulfil all needs and desires of its occupants, such as providing full immersion in virtual and augmented worlds, extract dwelling data from the community and spatialize alternative settings, offer options to extend individuality to multiplicity, or even exhibit domestic embodiment of a universal singularity.

Artificial agents are responsible for crawling over local or remote multimedia assets to collect snapshots for real-time compositional collages that suit the affective ambiances of the environment. For example, visual content is selected from personal, collective, or online archives according to the requirements established by the cognitive engine, which is subject to change at any moment. Files are mixed and edited based on their metadata evaluation and fused into the interior surfaces or headset devices. Rather than selecting and viewing a film, as was normally the case, inhabitants now watch how the house views them instead (based on its algorithms).

Meanwhile, ambient displays embedded in various locations around the house are either used to amplify the immersion, or to present supplementary media content that is listed as a secondary option. According to tracked interactions, the content shifts, almost telepathically, to show visual material that is extracted from various locations: online, the home’s databases, live feed captures from microscopic to macroscopic sources (i.e. videos of the domestic autonomous sample analyser, to streaming multi-satellite imagery), or any content that is manually defined by the user.

One might imagine that the power requirements of DomoNovus would be quite high. On the contrary, renewable energies and recycling facilities are fundamental parts of its structure, allowing it to be fully sustainable, cover its necessary needs, and even to distribute extra resources to the city’s power.
grid. Transparent solar panels integrated into the exterior surfaces of the house capture, store, and allocate energy interchangeably to increase the efficiency of electrical usage. Windows are built with solar panels that allow natural light to pass through, while converting infrared and ultraviolet light into electricity. Many low-powered electronic and digital devices of the interior harvest electromagnetic and radio frequencies as well as ambient light that continuously recharge small, low-cost capacitors, providing infinite life for the devices and thus maintaining its sustainable and efficient system.

Recycling equipment is available for objects and materials of the domestic space, and the process becomes necessary in minimizing resources, achieving sustainability and low costs for the ecosystem. Using combustion, bathroom and kitchen wastage is converted into methane gas, mainly for heating the interior space. Finally, microbial fuel cell technology is employed in order to extract electrical energy from organic matter, such as insects, fruit, or animals (Bristol Robotics Laboratory, 2014). In some controversial cases, though, the microbial fuel cell has been used to decompose the body of dead persons (Auger, 2012), and although macabre, its application initiates a critical discussion concerning the limits and possibilities of symbiotic mutualism.

DomoNovus proposes a domestic environment that is sympathetic, affectionate, and respectful towards its inhabitants and the personal and intimate spaces contained within the house. The mutual symbiotic relationship is an important objective and is not limited to the interior, but extends to the outside, affecting the neighbourhood, the city, and even the planet. Home, as a cell of a greater organism, interacts and communicates with local or remote systems, houses, and markets, forming an Internet of Homes that aims to
assist society and planetary consciousness through the use and sharing of physical, electrical, and digital resources. Each house is an instrument in the collection of energy, a pore of oxygen through the use of algae canopies, an agent that assists in minimizing the destruction of natural resources and reversing the catastrophes caused by the industrial age. Moreover, the data collected from each house can be shared in order to provide invaluable resources to scientific evolution – e.g. environmental studies that can monitor sustainability of the wider ecosystem and propose regulatory measures even in real-time.

Considerations

One of the main considerations that come to mind is whether a person will be able to physically and psychologically co-exist with DomoNovus. Will inhabitants be able to habituate in an environment that is constantly in transit between local, remote, and virtual worlds? The fluidity that DomoNovus suggests can be intimidating and problematic for inhabitants that have been accustomed to a computationally-free domestic spaces (an issue discussed in the workshop that is presented in Chapter 2). The social acceptance of the monitoring systems combined with Artificial Intelligent agents present a challenge to the domestic habitat. However, as has been discussed in the project HexSpace in Chapter 6, the functionality of a ubiquitous system should be defined by the behaviours and actions of the inhabitants at all times; a conversational process that fine-tunes expected circumstances and results, and co-expressed and co-calibrated performances based on symbiotic rules that are defined by the ecosystem. Furthermore, it is important to note that in the Age of DomoNovus, inhabitants will be closely accustomed to responsive
environments that are considered the norm. Therefore, the infiltration into their domestic habitats will be fluid, instantaneous, and unnoticeable.

Another consideration relates to the challenges that confront architectural and interior design; will those practices become obsolete? If people have instant access to a complete set of information collected from inside or outside the house on multiple scale, and available tools to build, reshape and recolour their houses, would it not be more intimate and direct for inhabitants to create their own environments? Besides, architects often design on paper or a computer screen, which does not allow them to “feel” the real space and shape it when and where it becomes appropriate and necessary. On the other hand, if inhabitants can use 3D or 4D printing, kinetic structures, nanotechnology, microelectronics, and computational media to change their domestic interiors according to their needs and tastes, the result would probably be more interesting and personalized – as demonstrated by Kurt Schwitters’ *Merzbau*. The process of accessorizing the house extends to the DIY development of computational and information communication systems that reshape inhabitants’ actions and consciousness, while allowing the domestication of technology to be accepted and firmly established.

Similarly, the computer desktop offers an adaptive environment that includes applications based on users’ needs; files organized according to their methods or a selection of wallpapers that better express their personality. The personal computer does not need a specialized operator, but instead offers a convenient and easy interface that even the most novice users can control. If Mark Weiser’s vision is realised (Weiser, 1991), the ubiquitous computer will diffuse into the domestic background and offer a similar ease of use and fluidity. However, the challenge here is that shared domestic resources have
to be understood both individually as well as collectively from the computational processing systems. In Chapter 5, the project *Memorabilia* proposed a method for mapping a range of occupants within one system, using an algorithm that equally distributes a shared virtual space. However, as different applications have diverse demands, it is appropriate to conduct further research to establish a range of methods that allow inhabitants to use the collective resources as efficiently as possible.

Another challenge is the maintenance, operation, and upgrading of all digital systems that exist within the house. Programming, coding, and prototyping become an essential aspect of the household, defining a new domestic lexicon; “update the database”, “check the query”, “refresh the Access Tokens,” are all daily tasks such as making the bed or doing the dishes. As technological infiltration becomes standard, inhabitants will be able to easily perform debugging practices for the needs of the household; “digital housekeeping” will be essential to keep software-driven appliances stable and secure (Crabtree et al., 2007).

**Safety and Ethics**

Walls, doors, and locks do not necessarily guarantee home privacy and security, as the most valuable assets of the household pass through the home’s router to the World Wide Web. Personal and corporate data, authorization codes, or credit card numbers can all be easily retrieved by anyone with an Internet connection if the network’s equipment is exploited to cross-site request forgery or cross-site scripting vulnerabilities (Goodin, 2016). The importance of the issue is amplified considering the fact that international
agencies, government bureau, and multi-national corporations try as hard as they can to become part of the ubiquitous computing layer that surrounds personal domestic spaces. Smart devices such as televisions and thermostats are listening and analysing customers’ discussions, which are then being shared to third-party services (DeMaria, 2015). This tactic is supported by intelligence agencies who use the Internet of Things to identify, monitor, extract location, or gain access to users’ credentials (Timm, 2016).

The effortless exploitation of digital telecommunication systems can also result in personal data hacking, which is when a user’s information is accessed and shared illegally and without consent by overriding a computer’s security defences. This is often caused by one’s inability to recognize an unsecure network and realize the dangers involved in joining said network. Therefore, this threat needs to become a vital part of the inhabitants’ techno-initiation so that they are fully aware of the importance of full-proof firewalls and secure privacy access settings. In doing so, the dwelling is made more secure, allowing the inhabitants to feel safer in their home. Moreover, the ability to control the visibility scope of the home’s digital resources (e.g. databases, reasoning, overall mood) to outsiders, can be perceived as an action of social conduct – similarly as when visitors are invited home to chat, socialize, or celebrate. Opening access to specific trusted agencies, foundations, or organizations, such as research groups of sociology, psychology, city planning, and health care, can greatly improve and advance scientific enquiry, not to mention creative uses of artistic and technological practices.

One other issue of concern is inhabitants’ difficulty to comprehend the continuous registration of personal and behavioural traits (as discussed in
Chapter 5), a process that is perceived as extremely pervasive and often infuriating and distracting. It is problematic for human users to permit a computational unit to monitor, analyse, and conclude their thoughts and actions on various daily settings and circumstances. However, with the right amount of registration transparency and detailed feedback that floats on the periphery of perception, users may not find this annoying but allow it to blend with their dwelling experience.

The sampling of actions and interactions assist the computational intelligence system to personalize and better understand the inhabitants, and to provide solutions for their daily needs. As discussed in Chapter 5 and 6, ubiquitous technologies can assist users in optimizing particular tasks, and even in some cases, block certain actions or behaviours if unacceptable attitudes are recognized; “the explicit knowledge about a so-called digital soul of human beings requires the development of different standards for social behaviour, and it might even be desired to protect people against their own attitude” (Aarts et al., 2002: 249). But this, however, often contradicts a human’s rules of engagement, leading to alienation or a blurring of reality (Rheingold, 1993), creating frictions in the symbiotic relationship between them and their domestic spaces.

**Automatism**

Jean Baudrillard (Baudrillard, 2005) argues that the perfection a machine intends to accomplish is proportional to its degree of automatism; the functions that need to be executed have to be fully automated so that the true potential of the machine is revealed and its function fulfilled. However, this
hermetically seals the object to a specified range of computational instances, rather than allow it to freely navigate, extend, or distort its functionalities if desired. It, therefore, remains specific to a range of spectra that assist the motionless users; “automatism amounts to a closing-off, to a sort of functional self-sufficiency which exiles man to the irresponsibility of a mere spectator” (ibid: 118).

It is evident that domotic appliances, as already have been discussed in Chapter 1, are required to undertake mundane tasks that often demand time and energy, but the extended automatism and oversimplification of functions and processes could result in problematic issues that need to be considered in further detail. It is, therefore, necessary to balance and equate the events and activities of the environment and its occupants, or the oversimplified household will become narcotized and numb. In Ray Bradbury’s novel The Veldt (Bradbury, 2012), there is this following dialogue between the father George and his son Peter:

"- Matter of fact, we’re thinking of turning the whole house off for about a month. Live sort of a carefree one-for-all-existence.

- That sounds dreadful! Would I have to tie my own shoes instead or letting the shoe tier do it? And brush my own teeth and comb my hair and give myself a bath?

- It would be fun for a change, don’t you think?

- No, it would be horrid. I didn’t like it when you took out the picture painter last month.

- That’s because I wanted you to learn to paint all by yourself, son.

- I don’t want to do anything but look and listen and smell; what else is there to do?” (ibid: 20)

Peter has been extremely fond of (and accustomed to) the benefits of an almost metaphysical techno-environment, whereby thinking alone conjures
objects, animals, and landscapes; a dreamy playground of automatism.

Unfortunately, this environment poses great dangers too, as it may execute functions against the benefit of its owners, or set conditions that are not considered conscious or ethical. In Bradbury’s novel, George, the father, wants to turn off the environment provided by the machine in order to balance and equate the domestic space between manual and automatic control – to restore vanity, arrogance, and narcissism. In an environment of automatism, the right balance of control according to different events should be of uttermost importance, and always in combination with playful engagements that respect domestic rituals and the fluidity of interactions and processes.

The considerations that are mentioned in this part of the chapter align with the responses of the public, which were collected during the workshop that is presented in Chapter 2, as well as the issues that have been raised by scholars and technologists in ubiquitous computing research (discussed in Chapters 5 and 6). For this reason, these reflections have to be understood as serious threats and dangers to our private and intimate homes.

**DomNovus Application Program Interface**

In 1914, Le Corbusier conceived *Maison “Dom-Ino”*, a standardized open system for the development of prefabricated houses that consisted of only a structural core “permitting a great flexibility to suit demands on the basis of aesthetics, climate, composition or view”(Sennott, 2004: 366). *Dom-Ino* allows each individual owner to supply the missing parts of the bare skeleton as “prefabricated window and wall sections would be made available in order to permit completion of every unit according to the needs of each dweller” (Von
Moos, 2009: 38). But most importantly, there is no need for an architect, as residents themselves define the design process; the house becomes a self-empowering system, and following Corbusier’s Five Points of Architecture (supports, roof gardens, free designing of ground-plan, horizontal windows, free design of façade), it accommodates all important features a domestic space needs.

One hundred years later, DomoNovus proposes something similar: the fundamental aspect for the development of a house consists of a main structural core, an Application Programming Interface (API), which allows the implementation of content, functions, processes, and media, to be defined and adjusted by the dwellers. The API allows inhabitants to set the role of the house and personalize it with the use of modules, systems, and media of their preference. Following the five points of the computationally-enhanced home that are introduced in Chapter 1 – Context, Media Layers, Invisible Matter, Diffusion, and Symbiosis – the design processes of the house and its systems

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23 Image from https://static.dezeen.com/uploads/2014/03/Le-Corbusier-Do-mino-diagram_dezeen_2.jpg
are parameterised according to the multiple dimensions the house is able to access, modify, and extend.

Normally, an API refers to computer code used to develop an abstraction framework for specifying "how clients should interact with software components that implement a solution to that problem", meaning that in essence, the API "[defines] reusable building blocks that allow modular pieces of functionality to be incorporated into end-user applications" (Reddy, 2011: 1). APIs are universally accepted in a variety of systems and applications, and can be found in desktop and mobile applications, Internet of Things platforms, web services, social media, and so on. Due to the multiverse nature of an API and the diversity of its applications, as well as its ability to merge and combine multiple units in a straightforward and convenient way, it is, therefore, an ideal resource to explore the modular and transparent ability that domesticated ubiquity demands; the API supports the building blocks of dwelling.

*Domonovus*’ API can exist locally (in a computational unit within the domestic environment) or, more likely, in a remote server on the cloud, where all related code and databases are stored (as in the case of the Heroku application presented in Chapter 5). Within this digital space, all accumulated data extracted from the environment and the inhabitants (biological information, interactions, settings and preferences, and micro, meso, and macro events) become a digital replica of the domestic world. The cloud facilitates universal access from any geographical location, establishing the domestic avatar as mobile and universally accessible; a cloud I.P. is where the home is.
The invisible and remote servers of the cloud now become a fundamental extension of the domestic interior, loyally following their owners and automatically personalizing when required. With location-based sensing technologies the preferences of the identified user can be used in a home’s interior space, no matter where this place may be. If access is granted, instant customization based on the user’s information shapes the empty house accordingly, and content is directly fused into the interior – spatially mapped, personalized, and instantly configured. This is similar to a web browser that becomes a frame to accommodate upon authorization the personalized data space of the user’s social media content; the cyberspace becomes an inspirational source for the transformation of our validated reality.

The modular nature of an API enables the implementation of computational engines to become part of the household’s activities, helping to configure physical or virtual extensions, analysing events and interactions, or assisting inhabitants in personalizing and controlling the domestic space. The integration with other APIs offered by companies and open-source communities makes it extremely convenient and beneficial to accommodate a range of services that accurately fit the lifestyle, desires, and perceptual qualities of the inhabitants. To understand the API features of DomoNovus, as well as other aspects that have been mentioned in the manifesto and its analysis, in the following page there is a system diagram that displays its main units and functions in more detail. The diagram intends to show how the API can be structured and organised as a system that contains the aforementioned processes. The accompanying USB flash drive contains a full resolution version of the image below (folder Chapter 7 –DomoNovus System Diagram).
Figure 68: Stavros Didakis – System Diagram for Domonovus (2016)
Chapter Summary

_DomoNovus_, as presented in this chapter, is a speculative concept that demonstrates a future of the computationally-enhanced domestic environment. As transhumanism and posthumanism amplify concerns related to anticipated scenarios of biological modifications, man-machine symbiosis, artificial intelligence, and so on, similarly, the domestic space is imagined using concepts and ideas extracted from the theoretical and practical work of this research, as well as current studies in arts, science, literature, and academic research. The purpose of _DomoNovus_ is to provide a basis for further discussion in relation to the topics presented and analysed here, such as the hybridization of domestic objects, properties, and events, the implementation of computational units responsible for reasoning, analysis, memory-keeping, multisensory interfaces, and network of things, open-source and DIY ideology, sustainability strategies, as well as computational media practices that transform the interior space into a mesmerizing cosmos.

Considerations related to _DomoNovus_ are analysed, as it is necessary to understand limitations that could constrain aspects of its development or pose threats and dangers to the domestic environment and its inhabitants. In particular, it examines whether humans could co-exist with this proposed environment, how it would affect the architectural development, and also the operation and maintenance responsibilities that inhabitants need to be aware of. Furthermore, it is discussed why _DomoNovus_ needs to extend safety and security not only on physical but also digital domains, so that its residents feel safe and protected. The privacy of the household needs to remain intact at all times, unless the owners decide to share specific aspects of the household’s data, media, and settings to social circles, research companies, or even the
Another consideration that is examined relates to the level of automatism that DomoNovus can provide, making sure that its functions become a collaborative discussion that it is mutually calibrated between the domestic space, the inhabitants, and the computational machines. The applied automations have to be configured delicately in order to avoid the consequences of paralyzing the domestic life and numbing its human beings.

The last part of the chapter proposes a conceptual model for the development of DomoNovus, which is inspired by Le Corbusier's famous Maison “Dom-Ino”, an architectural framework that has redefined residential development since the beginning of the 20th century. Based on the fundamental principle of Dom-Ino, where its basic structural core is provided so that owners and inhabitants can configure the space by themselves using the Five Points of Architecture, similarly, an Application Program Interface is suggested that could assist the dwellers of DomoNovus to set, configure, and personalize the functions and content of their domestic space. By having all API preferences stored in a remote location on the cloud, it is argued that the properties of the house become mobile, extendable, transferrable, and always present in time and space.

Based on the work presented in the previous chapters, the theoretical and practical explorations provide a framework related to the domestication of ubiquity, as analysed from different perspectives: the contextualization of essential properties, layering of the physical space using transparent media compositions, the identification of micro, meso, and macro aspects that directly relate to the ecological system of the household, the networked manifestations of all physical and computational things contained in the house, and the symbiotic relationship that has to be accomplished in order to
successfully reach all goals and objectives. Through the discussion and analysis of *DomoNovus*, this research concludes the speculation concerning the future of the domestic environment and the practices involved for the domestication of ubiquity. As Martin Dodge and Rob Kitchin explain (Dodge & Kitchin, 2008), computational processes are not only going to be built into the objects of the domestic space, but also into the fabric of the dwelling itself (ibid: 23), resulting in a mesh of biological, immaterial, invisible, virtual, and hybrid things.
Chapter 8: Conclusion

Modes of the imaginary follows modes of technological evolution, and it is therefore to be expected that the next mode of technical efficiency will give rise to a new imaginary mode. (Baudrillard, 2005: 127)

Thesis Summary

This practice-based research investigates the role of computational media technologies within the home environment, proposes frameworks and methodologies for their domestication, and speculates on the possibilities that emerge from the implementation of hardware and software systems within daily interactions. With the addition of computational practices such as ubiquitous computing, ambient intelligence, and the Internet of Things, the house is transformed into a multi-dimensional process that spans across time and physical dimensions, extending to the memory of the databases, and the simulations and interfaces of the digital and virtual space. The purpose of the research, therefore, is to investigate the domestic transition and anticipate the following steps of this ecological evolution.

Moreover, this work demonstrates specific methodological processes to help us better understand the domestication of technological developments, including, but not limited to speculative investigations using open-source computational media resources. The theoretical and applied experimentations that are presented, investigate the possibilities of the design of technologically-activated architectural and domestic spaces that provide and promote configuration to personalised preferences using a range of sensorial and media extensions.

The arrangement, orchestration, and synthesis of media elements (such as lights, sounds, and visuals) have been studied to illustrate how the
ethe real (but nevertheless) effective properties they contain, merge with static and inanimate structures of the domestic space. As the functional and aesthetic needs of the house shift in real-time according to inhabitants’ preferences, media modules as expressive extensions are applied so that meaning, information, and interaction assist the transformation of the domestic experience.

Another important aspect of this research is the collection of information from the domestic ecology. This has been carried out on a range of scales using software and hardware sensor interfaces, scanning in real-time a large set of variables that are important in understanding the household in molecular detail. All logged recordings are stored, processed, and can be retrieved and used when necessary. The processing algorithms allow the household to be viewed and understood from a range of perspectives, facilitating the exploration of unseen patterns, or indicating contrasts and trends, which together expand the awareness of the household and challenge what is considered as home.

Information, media content, and data visualisations are some of the elements that can be spatialized within the domestic interior. Such diffusion practices are necessary to demonstrate the possible fluidity of the environment, as well as illustrate how personalization and interaction with the content and processes can be more easily adjusted. The importance of middleware and interfacing solutions is critical, and for this reason, practical investigations are developed, used, and examined.

By blending media layers, sensorial capabilities, and diffusion practices with intimate and personalized aspects of inhabitants, new conditions of
symbiotic dwelling are made possible. Physical structure, biological organisms, virtual spaces, and digital systems they all collide, merge, and mutually co-evolve. Consequently, requirements for co-existence are analysed, demonstrating important aspects of the computationally-enhanced home.

Finally, DomoNovus is presented, a speculative model consisting of design fiction, sketches, a visual map, and a system diagram; combined these illustrate ideas and concepts for an anticipated alternative future of the domestic space. The main intention of DomoNovus is to visualise a future where the house becomes a cell for symbiotic mutualism, blending personal preferences with shifted structures and algorithmic processes that facilitate a wide array of experiences and possibilities.

**Revisiting Objectives**

The aim of this research, as specified in Chapter 1, is to speculate on the possible futures of the domestic environment through technological and artistic developments that investigate alternative possibilities, and to experiment with a range of practices, methodologies, technologies, and media. For this reason, home has been examined from various perspectives, such as architecture, sociology, ecological systems, art practices, technological developments, as well as on several scales, from micro to macro, which has assisted in identifying significant aspects for the fusion of computational technologies in the domestic environment. The practices that are demonstrated include quantitative and qualitative research, software programming, sensor electronics, systems development, mobile and cloud
applications, interface design, and design fiction (manifesto, sketches, diagrams); Chapter 1 lists the practical elements of this work in more detail.

The developed computational and sensor interfaces examine the domestic ecology by sensing, collecting, sharing, and diffusing data related to the interior and exterior environment, its domestic interactions, and personal and affective properties of the inhabitants. To understand the domestic space in greater detail, it is important to register information and conditions that assist accurate personalization, and with the use of appropriate resources, such as functions, automations, and media, to propose new possibilities for the domestic life.

As demonstrated in the case studies, by registering the captured information on the cloud, users are able to access recorded values, extract sets of data, and link them with properties of the household (i.e. to control media elements for aesthetic purposes). Moreover, it is possible to create real-time synthesis and compositions of audio-visual material according to sensed interactions, to diffuse and spatialize data in physical, digital, and hybrid spaces of the domestic interior, and to analyse and visualise a range of properties that indicate valuable aspects of the household to provoke and enhance domestic consciousness.

The presented case studies require us to view the domestic object as a non-static space of creative possibilities that can be well-adjusted to the instantaneous configurations of computational systems, communication protocols, and cyberspace. It is necessary to respect and understand the sensitive nature of the domestic environment, but at the same time to expand
its functions by fusing physical and digital worlds, transforming it into a collective hub that accommodates a broad range of needs.

The methodology of this research consists mainly of five points, which are explored in detail in the individual chapters; however, they all supplement each other at various practical or conceptual levels. Context, Media Layers, Invisible Matter, Diffusion, and Symbiosis are critical aspects that propose theoretical and practical concepts in order to achieve the objectives of this research. These points are used to study the domestication of computational media technologies and how they can transform the home, dwelling, and domestic life.

It is, therefore, important to (a) contextualise the domestic environment and understand its functions, aesthetics, personalization demands, and poetic dimensions, (b) explore the range of possible media layers that can be added to the household to create engaging compositions, (c) examine the house as an ecology that consists of numerous elements and record, analyse, and distribute information that assists in a higher level of domestic awareness, (d) provide diffusion strategies that spatialize information within physical and virtual surfaces of the house, as well as to explore the possibilities that emerge from the universe of the domestic objects, and finally, (e) establish the house and its inhabitants as partners in a mutual symbiosis.

The inductive nature of the process leads to *DomoNovus*, a speculative concept presented in Chapter 7. The fictional speculation becomes an essential ingredient in this research as it links the theoretical, practical, artistic, and technological dimensions, explored in the previous chapters, and it pushes further the boundaries of imagination, while establishing a
comprehensive realisation of the domestic anticipations. This development
intends to provoke speculation and criticism, but also to invite and initiate new
research methods and practices for understanding the next steps in the
evolution of the domestic space.

Critical Reflection

One of the main concerns of this research is that its multi-disciplinary nature
makes it difficult to establish precise methods for achieving concrete results
that can be easily accepted in a specific subject field. The different subjects
that collide here, such as architectural design, computer science, engineering,
sociology, and art, usually have certain evaluation and research criteria that
often contradict other disciplines (i.e. practices applied in engineering may not
be acceptable in art, and vice versa). However, the methodologies of this
study have been developed to align with the multiple disciplines mentioned,
and to investigate the subject matter from different angles to reveal answers
and solutions that assist the speculative demands of this work.

The home is an incredible object for observation, as it can provide rich
information concerning the activities of the household, the lifestyle of
inhabitants, and the qualities of the domestic life. In contrast to the complexity
of the public space, the conditions and parameters of the home are simpler to
measure and control (in regards to implementation, cost, environmental
variables, and so on). Nevertheless, some practices of this study, such as the
interactive artworks Plinthos Pavilion and AFU, have been exhibited in public
spaces with the intention to extract properties, ideas, and concepts from the
public space and its occupants, assisting and contributing to this current investigation.

The sensorial interfaces created to monitor the house on micro, meso, and macro scales should be considered as practical explorations of the sensing possibilities of the domestic space, and not as a definitive instrumentation, as the main point is to individually assist the needs of each space, and promote customization according to the inhabitants’ requests. Therefore, the presented sensing mechanisms aim to suggest and highlight the DIY and open-source philosophy, which must be adopted in the development of computationally-enhanced domestic spaces, where modularity becomes priority in physical, digital, and virtual domains.

Although platforms and middleware were suggested to mix the modular units of the household that reconfigure, process, and spatialize data, content, and media, further research is necessary to explore more advanced technological possibilities that facilitate intuitive and functional interactions and interfaces. However, for the purposes of this research, the suggested solutions sufficiently portray the concepts involved and provide the necessary means to contextualise and support the practical developments.

The projects presented in Chapters 5 and 6, such as the Cloud, DataBlobs, Memorabilia, and HexSpace, demonstrate how captured values from sensor applications can be filtered, processed, or visualised to support personalization and accommodate user demands. Despite this, more detailed investigation is required to establish computational facilitation in the processing stages of the recorded data. Such data are extracted from the sensorial interfaces of the house to demonstrate further possibilities of
computational processing that can help attain precise personalization and context-aware applications.

For example, cloud applications provided by major technology companies (Google, 2016; Microsoft, 2016; IBM, 2016) allow users to access state-of-the-art Artificial Intelligence and Machine Learning platforms. A range of practices can be accommodated by these services, such as to index and analyse data and metadata collected from the household, to filter, classify and train algorithms, to perform cluster analytics for identifying correlations and anomalies, or even to identify trends and psychological traits. These practices facilitate deep learning methods for exploring the domestic environment using a large range of “optics”. This aligns with the modular nature of DomNovus in Chapter 7, as the implementation of systems with the use of an API within the computational processes of a particular environment, assists personalization and provides the technology for the inhabitants to set their domestic interior according to their views, needs, and desires.

The manifesto that is presented in Chapter 7 intends to illustrate how certain computational and media technologies are going to affect the domestic environment in the near future. DomNovus does not intend to predict the transformations of the home over the coming years, but rather to engage the imaginaries of the reader, and to demonstrate how conceptualized practices of this research can be advanced. Nevertheless, many of the proposed hypotheses of DomNovus are based on scientific, technological, and artistic practices that, although are being investigated at present, are not directly linked to the domestic space. However, as there is a substantial level of uncertainty surrounding the domestication of these practices, their implementation and uses need to be seriously considered.
Future Directions

In this research many issues have been raised that attempt to question and explore the speculative and anticipated futures of domesticity, including: the definition of dwelling in our shiftable present; the intrusion of sensor technologies and digital artefacts that scan the environment on all possible scales; the multiple diffusions of the retrieved data that are defined by processing algorithms; as well as the practical implications computational media technologies bring to our personalized habitats and to the domestic consciousness.

Although some of the aforementioned issues have been explored from a variety of perspectives, a larger inquiry is needed in order to register in detail these practices and understand their consequences for the domestic life. For example, more work needs to be done concerning the sensing abilities of
the domestic space, which will provide a spectrum of detection methods in order to accurately map all properties of its ecology. As suggested in Chapter 4, it is critical to provide a technological facilitation that scans and monitors numerous properties of the interior space, such as air quality, chemical analysis, and environmental properties. As mega-cities around the world (and especially Asia) become over-saturated with excessive urbanization (resulting in a dystopian environmental future), it is vital to raise awareness concerning these conditions, allowing main courses of action to take place that will be able to activate sensible behaviours and responses from the citizens.

With the threat of urbanization and environmental change looming, one of the priorities for the development of domestic space is to protect its inhabitants from harmful (and at times deadly) chemicals, bacteria and carcinoid elements, and allow sensing devices, as for example the DataGrid, presented in Chapter 4, to become a domesticated part of the household and lifestyle of occupants. Public awareness needs to be raised concerning this vital issue, as well as to motivate inhabitants to use and develop personalised solutions using open-source and modular computational units for their individual needs. Further research is required to suggest and develop not only monitoring systems but also systems that propose functional and accessible solutions to the maximum benefit of the household. The security of the house merely depends on its physical construction elements (cement, steel, wood), as the sensitivity and responsiveness of the sensor and monitoring interfaces can suggest better qualities for safety, protection, and well-being.

Therefore, it is important to explore the monitoring abilities of a house and the incorporation of an array of sensing devices, not only for collecting data from its interior space, but also from its external physical environment.
and the cyberspace. It is fundamentally important to combine computational processing using a range of methods (such as machine learning, indexing, data mining, cluster analysis, and so on) with the sensorial infrastructure of the house and construct meaning from the unseen interactions and properties of the ecology, not only to support functional and mundane tasks, but also to enhance the awareness about the surrounding space, and to propose engaging and imaginative spaces for exploration. For this reason, in Chapter 7, an Application Program Interface is suggested to link together the computational units of the house and allow them to connect to remote services for further processing, providing a structural core for the personalized elements.

Finally, a future direction for this work is to develop artworks and speculative designs that further explore the facilitation of interfaces and interactions within the daily domestic environment, and to suggest possibilities for playful engagements, imaginative structures, and personalised extensions that span across spectra and dimensions. It is necessary to see the interior space as a reconfigurable object that accommodates hybrid functions of variable realities, and provides users the tools to navigate and explore a range of alternative experiences. Overall, additional research is needed to examine the association of ubiquitous technologies with home environments, and how this is going to define inhabitants' lifestyles in the near future. It is important to research what this means for the habitual experience, how lifestyle is affected, altered, violated, and what are the philosophical inquires that are implicated through particular associations.
Conclusion

This research investigates the transformation of the home environment according to the domestication of computational and media technologies, which should not be viewed as efficient, sustainable or trendy gadgets, but as essential properties that assist in reimagining dwelling and the domestic life. The practices presented in this work, which consist of speculative designs, artefacts, installations, and computational developments, make an effort to explore the house as an environment full of creative possibilities; a house that is not static and unresponsive, but understands multiple scales and realities, has a memory and processing facilitation, expresses itself through spatialized media, and intents to co-exist in symbiosis with its inhabitants. Similar to the views of Merleau-Ponty and Heidegger discussed in Chapter 2, here it is demonstrated that home and inhabitants are unified in a more immediate way, as the environment transforms into a transparent extension that responds, assists, and accommodates at all times.

Thus, the domestic space provokes us to study, implement, test, and analyse the networked relationships between inorganic, biological, and digital entities. In contrast to Kurt Schwitters’ Merzbau, the cartography of behaviours, actions, and sensed interactions do not only emerge in the physical space, but also in digital, hybrid, and virtual domains (as for example in DataBlobs, presented in Chapter 5). It is possible therefore to witness the domestic space transforming into a tool of distributed authorship, a cybercerption and telematics portal, a cluster of participation of objects, bodies, and avatars. Unseen and buried datasets that are collected from the sensorial and algorithmic agents, as discussed in Chapter 2 with Nickolson’s Kleptoman, need to be organized and connected with the daily actions of the
household through computational tools that bring awareness, link to practices, enhance context-awareness, and allow the house to be viewed through multiple timeframes and scales.

In 1914, Corbusier conceived of *Dom-Ino*, a standardized system for the development of prefabricated houses that consists of only a structural core, which permits a great flexibility to suit individual demands based on aesthetics, climate, composition or view. One hundred years later, home takes a similar direction, as it transforms into an Application Programming Interface (API), offering the main structure and protocols for the users to implement content, functions, processes, and media that properly suit the needs of their households. *DomoNovus*, a speculative concept presented in Chapter 7, develops an intimate and affective relationship with its inhabitants, as it can deeply and efficiently understand their needs, while suggesting and offering precise responses accordingly. The invisible and remote servers of the cloud become a fundamental extension of the domestic interior, loyally following their owners and automatically personalizing when needed. The “New Home” has a memory of all recorded events of the past, which allows it to define the range of interactions that may take place in the present, and to assist, predict and co-create content concerning future incidents that might occur. As also discussed in Chapter 1, the *Blur Building* by Diller Scofidio and Renfro suggests an architectural structure that evaporates and transforms into a cloud. Similarly, *DomoNovus* evaporates the home, its physical structure diffuses into ubiquity through the use of the technological materialization.

In conclusion, the main finding of this research and its contribution to knowledge is that, to properly analyse, investigate, and understand the contemporary domestic environment, a methodological framework that
respects the complexities and additional dimensions of the space needs to be devised and applied. The methodological process that is proposed in this case consists of five points (Context, Media Layers, Invisible Matter, Diffusion, and Symbiosis) and demonstrates the importance of merging a range of disciplines to accomplish a new understanding concerning the home, which is viewed as an ecological system that contains multiple spectra of information, events, objects, and organisms, spanning across micro, meso, and macro scales. Experimental and speculative practices are important elements in the development of this research as they reveal alternative futures of the domestic world, giving us the option to critically reflect on positive and negative effects of the relationship. From the investigation of this research, it is apparent that the household transforms into a hybrid and collective organism that facilitates navigation and interaction of the multiple dimensions of its extended environment (real, virtual, augmented), enhancing consciousness and perception of what constitutes a personal and intimate setting (Umwelt). The case studies have assisted in the development of DomoNovus, a concept that suggests a technological infrastructure that accommodates the computational units of the house – an Application Program Interface. According to DomoNovus, a range of systems, devices, and technological frameworks facilitate the complex demands of the house, utilizing the cloud and its servers to become an integral part of the system, storing preferences, modules, databases, and distributing upon authorization, raw or processed data; the fragmented and diffused units that synthesise the layers of the domestic space, enhancing our understanding of the complex system we call “home”.

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One of the main aims of this research is to question whether computational media technology can be domesticated, and explore ways, methods, and practices that assist in achieving this purpose. Part of this question is covered from the practical explorations that have been demonstrated and analysed during this thesis. There is a great possibility that the speculations that are presented in this study are going to assimilate the domestic realities of the near future; technology will be tamed and fully domesticated, and blend its users with their environments. However, the question that emerges at this final point is not whether technology can be domesticated, but rather, if the unpredictable, often radical and nonsensical machine we call human, can become part of our computationally-enhanced homes.
Appendix 1

Survey

For this survey, a questionnaire was designed that comprises of 40 questions – split into ten questions into four parts (Demographics, Interior Design / Decoration, Psychology / Mood / Wellbeing, Technology). One hundred samples were collected, analysed, and cross-referenced to give insights concerning domestication, design, and media and technology. The form created in Google Docs was distributed in social network websites where responders could locate the file, complete, and send the results back to the database. The questionnaire was designed in a particular order with a formalized set of questions. A simple and concise vocabulary was used for the syntax so that it could be understood by groups of different age, culture, and education background. No particular requirement for participating in this research was needed, as well as any prior specific knowledge. For expressing the questions properly without causing any confusion, ambiguous words/concepts were eliminated. Also, leading or biasing questions were excluded as they can blur the responses accordingly without any further helpful outcome. Due to the reason data need to be internally consistent and coherent for analysis, Likert Scales and Balanced Categories were used. A system of 5 gradations was applied; this number makes it easier to locate a trend, and same time it is possible to use cross-tabulation between different answers to detect further information on a particular area.

The responders’ majority were women (60%), and almost all were within the age of 18 and 34 (89%). These numbers represent well the target group of this research - young, independent people (most probably with a home of their own) that know and understand well digital and computational technologies. Almost half of the responders are single, and the other half either in a relationship or married, and most of them well educated. Half of them live in a residence that has a maximum of 2 people, and only 10% are part of a larger household of 4 people and more. As many responders are university students, not many of them are employed, but those that they are employed say they are satisfied with their current jobs.

Most of the responders (60%) consider home an important part of their lives, and they pay close attention to the area/location, interior design, and hygiene of their home. The decoration of the interior is mainly done by themselves, or sometimes together with a member of their household, but rarely assigned to a person outside of their home or a professional designer, which shows the need to personalize themselves their interiors, a fundamental consideration in the definition of home. An astonishing 65% say they like to change their home decoration every time they have the need for it, clearly indicating the desire for shiftable interiors that respond to dwellers’ needs, although the economic factor for these changes is considerable enough (16% of them think that this is a crucial factor). Aesthetics, comfort, and practicality, are important aspects of their homes, but not cost or technology. However, there is a slightly difference in opinions between men and women, as 30% of men believe that entertainment and recreation needs are important, in contrast to 5% of the women. Women seem to prefer their
homes to suit better their social needs/obligations. In general, it is demonstrated that home needs to be a comfortable place for calm, relaxation, and personal expression. Furniture, wallpapers/wall colours, and lighting are the most popular things for the decoration, and music is mainly selected to convey a particular mood. However, it is interesting that women consider more strongly the importance of lighting, plants, and perfumery in contrast to men.

18. (Male) Indicate how much your residence supports the following:

- Entertainment/ recreation needs: 68.00%
- Social needs/ obligations: 30.00%
- Need for calm and relaxation: 10.00%
- Practical needs: 3.00%
- Aesthetic needs: 2.00%

18. (Female) Indicate how much your residence supports the following:

- Entertainment/ recreation needs: 50.00%
- Social needs/ obligations: 45.00%
- Need for calm and relaxation: 10.00%
- Practical needs: 5.00%
- Aesthetic needs: 2.00%

19. Do you think that the following are important for the decoration of your residence?

- Extremely
- Very much
- Moderately
- Slightly
- Not at all

19. (Male) Do you think that the following are important for the decoration of your residence?

19. (Female) Do you think that the following are important for the decoration of your residence?

20. Have you ever used the following for altering the atmosphere of your interior space?

- Always
- Frequently
- Often
- Rarely
- Never

Colors/Wallpapers
Lighting
Music
Aromatherapy
Feng Shui
Mood, behaviour, emotion, health, intellectual performance, comfort, calmness, relaxation, and creativity are all extremely affected by the domestic environment as the responders say. Light, music, smell, and temperature and powerful properties that directly affect people’s positive attitude, demonstrated in Question 26. Concerning the uses of various media to provoke happiness, pleasure, and calmness, from the replies it is evident that watching documentaries, nature, music videos, or using social media and video games this can be easily achieved. Another parameter affecting the domestic experience to a large extent is the positive and adverse effects a house may cause to inhabitants’ health. The greater percentage of the responders are aware of the cleanliness and purity of the domestic interiors. More than half of the responders believe that technology could assist them to achieve a healthier lifestyle.

![Chart 23: How much do you believe the following are affected from the interior design of your residence?](chart23)

![Chart 26: The following properties of the interior space of your residence can affect your positive attitude.](chart26)

![Chart 29: How aware are you concerning the cleanliness and purity of your domestic space?](chart29)

![Chart 30: Computers and technology can help you develop a healthier lifestyle.](chart30)

Most of the people that took part in the survey have an excellent relationship with modern technology such as electronic and digital devices, computers, Internet, and so on (men are more attached to technology than women). The responders consider technology a significant influence on their
lifestyles and that it has become a fundamental tool for their creativity, productivity, and their social life. However, only 31% of them consider that lack of technology can result in boredom and dull moments. The responders seem to spend daily much time on the computer (working, studying, or for entertainment), listening to music, and surfing the Internet, and less time on the TV or playing video games. Most of them think that the technological devices they have in their homes are attractive enough, and they are satisfied with their performance, as they do not create many problems or make their life difficult.

35. How much time do you spend daily for the following?

39. Technological devices that exist in your home are uninteresting.

40. Computers and technology create a lot of problems and make your life difficult.

The analysis of the data also includes a cross-reference between various categories such as education, economics (based on income), and household members of different questions of the questionnaire to identify trends. However, nothing particular was found. All material related to this survey are provided in the accompanying folder (Appendix 1). The online form can be found at the following web address:

https://docs.google.com/forms/d/1rYvyWh2aBAHTpMRiAAnC2nd9VbmHy9rvekL3UGlvg5Q/formResponse
Appendix 2

Workshop – Computational Technologies & Domestic Environments

The workshop that took place in MBS College (franchise of Nottingham Trent University, UK) in Heraklion, Greece, consisted of a presentation, delivered by the author, video screenings, group discussions, sketching, and written responses that were given by the presenter. In the accompanying folder (Appendix 2), you may find the presentation of the workshop that displays in more detail the content that was delivered during the two sessions that lasted for 8 hours. The sessions have been video recorded, however, because of the reason that the presentation and the discussions were made in the Greek language, they are not included in the Appendix 2 folder.

Here is the documentation of three main questions, together with participants’ responses:

Question 1: Would you like to have a “smart home”? Write the main benefits and problems of it.

Aimee: I would like to have a “smart home”. A smart home can bring us a lot of conveniences. We can do whatever we want very efficiently. But the problem is that we will be lazy because of the overdependence on the smart home. But I still would like to have one. I believe that technology can bring love and more emotion to us.

Alex: No, I think it’s not safe enough.

Bella: I would like to have a “smart home”, but it has both advantages and disadvantages. Life will become easier if we have a smart home,
we don't need to do things all by ourselves and we will feel more comfortable. Home will be more suitable for us to live in, and there will be more possibilities and more changes for our lives. But on the other hand, there will be some problems, the more technology we use, the more possibilities we will have, but these possibilities may not all be good ones. They might be out of control. How can we ensure that they won’t start to hurt people like in science fiction films? And if we have a smart home, we will be lazier and have less communication with other people.

Davika: Of course I would like to have a “smart home”, but for “smart home” I keep a neutral attitude. “Smart home” is an efficient home. It’s automatic, remote, controlled. It’s high-end technology. The benefits are that it can be a comfortable environment, have many modern facilities, accommodate a fast pace of life, and keep people healthy and safe. If technology fails, (i.e. you lose access to a room or the house) you will be trapped. It can be expensive, and make people lazy.

Eachie: I would like to have a “smart home” because the house will bring us more convenient and comfortable life, however it may also leads to an information leakage. Smart house is able to get all the information of you and your family about their names, health condition and blood types and take care of you and your family with the information so that you don’t need to go to the hospital to check your health condition. Nevertheless, if the computing system in your house is hacked by government, company or other people, they may be able to control you by controlling your house.

Elaine: I think “the smart home” will become the main trend in the future. The main benefit is that the intelligent furniture will make our life more automatic and convenient. In the future, people can access everything from the house with high technology without going out. While these intelligent systems are controlled by network communications, if there is hacker attacking the computer system and tampering with the system programming, he/she may cause the system of intelligent furniture to disorder and even personal information to be stolen. So, smart systems may be not very safe.

Frank: Sure, I want to live in a smart house.

Potential Benefits:

- Time will be saved from trifles. Since the house will take care of everything, people will never have to bother running their homes on their own, thus being able to focus on something more important.
- Inhabitant experience will be improved. The house itself will change the condition according to the owner’s needs, mood, state of health, etc. Living in a home has never been more comfortable.
- A smart home provides brand-new ways to access Internet. With each component connected to the network, information can be uploaded, fetched or pushed anywhere in the house.
A smart house is energy-efficient and sustainable. Energy can be collected from solar energy, air energy, bio energy (e.g. using human waste to produce bio-gas) and even people’s motion. Plastics, metals, paper, etc. can be recycled.

Smart home is an eco-friendly lifestyle. All rubbish released will undergo harmless disposal.

Possible Problems:

- A large quantity of electronic components might produce more radiation, which does harm to our health.
- The thorough data collection of the owner and the ubiquitous Internet access jeopardize a person’s privacy.
- A domestic system, namely an intelligent system, runs the risk of being hacked. If the system collapses, the house can become a total mess.

Jessie: Yes, I’d like to.

Benefits:

The intelligent machines in the smart home can work instead of the people. It improves the efficiency and saves a lot of time at the same time. The smart home raises the quality of people’s life. So “Smart home” will make our life more intelligent, more convenient and more comfortable. And it will make our life more beautiful and more colorful. I think it will also promote the development of the society.

Problems:

The price of a “smart home” will be very high; maybe not everyone can afford it. In the future, once the “smart home” blends into the life of people, human will gradually rely on them, and finally they cannot do anything if there is a trouble with it. A threat is that maybe intelligent machines will completely replace human beings.

John: I would like to have one. The advantage is that we can improve our life. The disadvantage is that we may worry about the high-end technology surrounding our lives.

Lee: I would like to have, absolutely. It will be able to help a lazy person like me doing a lot of things. In my opinion, the “smart home” could do anything! But technology is not very advanced nowadays; the idea we think is still a dream and the high expenses is a problem.

Nicky: Yes, I would like to. A smart home can be more convenient and help people live better. When we are busy the room can free our hands and help us to save water and electricity - save time and money.

Roo: Yes, I want to have a smart room. To be frank, I am afraid of the darkness and if I have one, I can open the light before I go into my house. Second, a smart room can prevent our house from dangers to some extent. Third, nowadays human become lazier and lazier, a smart room is the result of our laziness, it can make our life more easy and comfortable.
Sukii: I would really like to have a “smart home”. I think “smart home” can make our life more convenient and our time will be well used. It maintains the traditional residential function, and gets rid of passive mode which become a powerful modern intelligent tool. Sometimes we can’t find the remote-controller, the “smart home” can easily handle this situation. Besides, it can help us not to be a home servant, we don’t have to arrange our time tightly and give ourselves time to clean the house etc. Of course technology has both advantages and disadvantages. When we are lying on the sofa and enjoy the smart home prepared, we might feel lonely cuz we don’t have to do things by ourselves and don’t need anyone’s help. Meanwhile, when our house becomes a “smart home”, safety risks will be increased.

Z.X.: In my opinion, I want to have a “smart home”, but if it has high intelligence, I might be afraid. Because I cannot control my house, it is very dangerous. I prefer A.I. to improve my living quality, rather than controlling everything.

Z.Z.: I want a smart home. Basically, because I am a lazy person. And I will be dying of having a house that will make my life easier and more convenient. The main benefits I guess are about energy source recycling, which is extremely important. Saving energy and changing the waste into fuel will come true sooner or later, actually it’s been realized partly, and I guess smart houses will work better in this field.

**Question 2: Can you trust computers to control your house and access all of your private information?**

Aimee: I can trust a computer controlling my house but I cannot accept it will access all of my private information. Private information is the secrecy that you will never show to others although some information is not very important. But it’s dangerous to make someone control your information, as they will know what you want and what you like. As a result, the computers will control all of our lives.

Alex: No.

Bella: I’m not 100 percent sure about this. Because in nowadays, steal other’s information sometimes happens. The private information we put on the Internet is not safe now, things only will become worse in the future. Also we have AI now, if the computer really have its own mind and consciousness, it will be a big danger.

Davika: I can trust computers controlling my house and accessing all of my private information, because the future is the era of science and technology.

Eachie: I don’t think that I can trust them. If every movement of you could be recorded by the computer, then those who want to know your private information such as bank code and identity will get this information more easily. And if the computer makes a wrong judgment about the weather and even your health conditions, you will be led to a bunch of troubles.
Elaine: No, I don't think so. Because as the in science fiction films, the robots many times are controlled by the humans first, but slowly when it have its own thinking, it will not be trapped in the bondage of people. So I think one day the intelligent computer will go beyond human intelligence, and it may be a great threat to the human society.

Frank: There's hardly anything totally reliable. Even a person is likely to make mistakes, which can lead to serious problems. But it doesn't mean we no longer trust anything or anyone. My point is, the computers that work as our housekeepers must be equipped with better security mechanisms, given that they deal with every aspect of our life. After the strong firewall and secure protection system are established, the computers managing our home deserve to be trusted equally, just like we trust our smartphones and PCs with different accounts and passwords.

Jessie: No. Because once there is a problem in the computer program, the security of the private information won't be safe, some people may steal them. Even these intelligent machines also need electricity to support their operations, if there is no electricity in the home, the computer can not control our house, and all the machines that are controlled by the computer will stop working.

John: No, because it can be damaged by someone.

Lee: Yes, I would trust. Computers were designed to serve people and this must be their role. If we do not trust them, how can we still use computers and why we design them? We should trust what we do.

Nicky: I am not convinced. Maybe the computer system will face a hacker intrusion, because it is smart doesn't mean that others can't control it.

Roo: No. While I want to have one, I don't trust the computers completely. Nothing is absolutely safe.

Sukii: It's very cool to use a computer to control my house, but I can't totally trust this. Because when our private information becomes a part of electronic systems, it is not private anymore.

Z.X.: I could never trust AI. Because most of computer thinks using code, every code has specific rules, they don't have mood like humans, so they cannot control our life efficiently. A critical mistake might cost a life.

Z.Z.: No, I cannot trust computer entirely. Things like Google leaking private information of celebrities have happened more than couple of times. And even though we are going to put computer in charge, it shouldn't and never ought to be our last tap; there must be some human having access to the information.
Question 3: Write down one way computers/technology can understand your needs.

Aimee: Write all the facial expression in the computer, and them the computer and recognize what you want to do.

Alex: When you watch videos online, (i.e. YouTube) the part that registers if you like this or not, could be used to identify preferences.

Bella: Computer can test our heart beats and recognize our expression and change the home into different styles. Because there will be changes on our heart beats and expression when we feel in different ways. And maybe we can wear a hat which can notice our mind and transfer it to the system.

Davika: Remote communication technology.

Eachie: Let the computer log in all your web accounts to select what you are interested in. Or put on a helmet that can detect your body temperature and other health conditions so that those data can be transferred into the computer and it may be able to get you some advice about your health condition and help you live a healthier life.

Elaine: Code or Processing

Frank: (Before we move to numerous details, one thing must be noted — the whole domestic system must be a self-learning system. From the cybernetics point of view, calibrators are involved.)

1) All components at home, smartphones, computers and wearable devices are connected.
2) Collect physical and mental condition, along with people’s hobbies, preferences, etc.
3) Analyze our possible needs
4) Change the house condition (temperature, lighting, etc.) to a certain degree
5) Measure people’s reaction to such condition
6) Adjust the condition till the most ideal state

Jessie: Perhaps there will be an app that each family member has in their phone. It needs to connect the computers or technology in our smart home. So we just need to connect the Internet to manipulate them. And the computers or technology can understand our needs.

John: Sensor technology

Lee: A very smart A.I.

Nicky: I want like to be able to have a good the temperature. Let me not feel too hot when i asleep. I hope the room can change, because I think the same I can feel tired.

Roo: Put some sensors under our pillows and the ground at the bed, so that the computer can understand that to turn on the light on the way to toilet if we get up in the midnight to go to toilet.
Sukki: Remote control can help me to control electrical equipment that i forgot to turn off. Besides, if i want to have dinner or hot bath at the moment i got home, remote control can make the electric cooker and water heater start to work in advance.

Z.X.: I think one way is induction. We use kinds of sensor to computer, like they can catch our face, and to respond and catch gestures. For example, if we do finger snap, computer will know it means we have some problems and it needs to come here and ask what happened.

Z.Z.: We can communicate with computers by identifying blood sample and computer Cookies, and after identity verification, we act normally, and computer tracks our behavior trace and habits, after analyzing the data, computer predict our next movement, correct, save in the system file, incorrect, track again, we train computer like training a pet, I guess it will be more effective.
Appendix 3

Plinthos Pavilion

Please find in the accompanying folder Appendix 3 a video time-lapse of Plinthos Pavilion’s construction, and a video demonstrating the final installation work. Below there is a selection of media publicity this project generated. Plinthos Pavilion has been published in the following international magazines:

“Plinthos Pavilion”, Space Magazine, No. 522, pp. 68, May 2011, Hong Kong
“Plinthos Pavilion”, Monitor Magazine, No. 64, May 2011, Berlin
“Plinthos Pavilion”, Frame Magazine, February 2011, Amsterdam

Also, it has been published in the following online blogs:

http://www.archdaily.com/109217/plinthos-mab-architecture/
http://blog mauriluceprogetti.it/plinthos-pavilion/
http://arcfreeze.com/plinthos-mab-architecture/
http://www.fastcodesign.com/1663172/brick-building-is-a-transparent-interactive-light-painting
http://www.delood.com/architecture/plinthos-pavilion-mab-architects
http://www.arch-times.com/2011/02/06/plinthos-mab-architecture/
http://architecturelinked.com/video/plinthos-by-mabarchitects
List of References


Conference Papers / Presentations


Didakis, S. (2012), Visualizing Environmental Information, System Presentation, Data Ecologies Symposium, 10th November, i-DAT, Plymouth University, Plymouth, UK.

Workshops


Didakis, S. (2014) *Processing & Collective Sentiment*, Workshop, 2 weeks, April, Shanghai Maritime University, Shanghai, China.

Didakis, S., Ewais, Z., & Phillips, M. (2013) Sensorama Workshop, 16 hours, German University of Cairo, 1st & 2nd April, 16 hours, Cairo, Egypt.


iDAT (2012) *IBM Smarter Planet Workshop*, November, Plymouth University, Plymouth, UK.


iDAT (2012) *Data Ecologies Symposium*, Workshop, 4 hours, Plymouth University, Plymouth, UK.

Didakis, S. (2012) *Media Technology and Interior Design*, Workshop, 2 weeks, MBS College (franchise of Nottingham Trent University, UK), Heraklion, Greece.

iDAT (2011) *Bio-OS, Research & Development*, Workshop, 10 hours, Plymouth University, Plymouth, UK.

iDAT (2011) *Eco-OS, Recording and Visualizing Nature*, Workshop, 10 hours, Plymouth University, Plymouth, UK.

Didakis, S. (2010) *Processing Programming Language*, Workshop, 6 hours, MBS College (franchise of Nottingham Trent University, UK), Heraklion, Greece.

Didakis, S. (2010) *Processing Programming Language*, Workshop, 6 hours, MBS College (franchise of Nottingham Trent University, UK), Heraklion, Greece.
Awards & Commissions


Didakis S. (2013) *Pulse Mode*, Catalyst Award, Code Control Festival, Leicester Arts Centre & Arts and Humanities Research Council, Leicester, UK.

Didakis S. (2013) *This City’s Centre*, Commissioned Installation, Arts and Humanities Research Council, Exeter, UK.


Artistic, Design-Based Work / Exhibitions

The following works demonstrate practices developed by the author during the time of that relate to the topic

System Development

Name: This City’s Centre
Venue: Exeter Phoenix (Exeter, UK)
Date: September 2013
Media: Programming, video, streaming, network, audio
Description: This City’s Centre is a digital performance that introduces new ways of creating and experiencing new media performances. For the demands of this work it was important to develop a technological framework that assists creative aspects of the storyline and enhances parts of the performance space that relate to the exposition of this artwork. A trans-disciplinary collage generates a surreal experience that offers an invitation to examine daily urban life in local and remote locations simultaneously. This City’s Centre was made possible with the help of more than 30 people, and with main funding from AHRC.
**Art Installation**

**Name:** Pulse Mode  
**Venue:** Phoenix / Leicester Arts Centre (Leicester, UK)  
**Date:** March 2013  
**Media:** Programming, visualizations, sonification, projections, 3D, data, EEG sensors, web development

**Description:** Pulse Mode allows participants to interact in real time with the audiovisual mix and trigger events that represent social engagement and mirror aesthetic preferences of the collaborative interaction. The installation space consists of a fragmented 3D screen of 7 irregular rectangular shapes, an info-screen (tablet), a Mindwave sensor, and a tablet for settings and visualization. Mobile devices of the participants can be used to select preferences and adjust properties of the system in real time using a web interface, which is installed on a server in order to communicate with the processing units. A live set, which includes all audio tracks, is controlled by programmed devices and responds to the incoming information – extracted from the participants. The visual processing unit controls the composition and the projection mapping, and a Processing sketch reads the Mindwave interface and shares its data within the network. Pulse Mode raises issues of authority and control of the media content, allowing participants to define the environment and gain direct access to its functions (or not), and presents a complex audiovisual system that allows multiple automations and interactions to take place with the use of various protocols, programs, and platforms.
Art Installation

Name: The Source

Venue: Gezira Art Centre (Cairo, Egypt)

Date: March 2013 – April 2013

Media: Programming, visualizations, sonification, projections, 3D, data
Description: This installation becomes a virtual space of sonic and visual compositions created in real time based on information captured from various locations around the world. XML and other data feeds from environmental sources are used by the system to define the score according to random events such as solar wind speed, earthquakes, or average temperature of specific geo-locations. The composition consists of layers/channels that exist from macro to micro structures, manifesting as granular noises, high-pitched frequencies, or low-bass resonances for the audio domain, and as spectrograms, streaming data text, or colorized planes for the visual domain. Moreover, streaming audio is received from various sources around the globe, and 3D objects morphed and animated according to specific events. A computer vision system is implemented within the space to track visitors' position and movement, as this is the interaction method to interpolate between the different composition layers. When in stasis, the composition returns to a static and almost inactive position. This installation was co-created with Mike Phillips and Ziad Ewais, iDAT, Plymouth University.

Technical Director
Event: Roy Ascott Exhibition
Venue: Shanghai Biennale 2012, Powerstation of Art (Shanghai, China)
Date: October 2012 – March 2013
Media: Tabletop, Projections, Computers, Network, Video, Animation, 3D
Description: Installation of tabletop, mounting and creating visual imagery to be shown on projections and LED screens, setting up the sound system, ensuring proper connectivity and equipment functionality, maintenance, support, programming and development.

Artwork Programming

Name: Journey to the West. Re-activating Roy Ascott’s “La Plissure Du Texte”

Venue: Shanghai Biennale 2012 (Shanghai, China)

Date: October 2012 – March 2013

Media: Programming, Animation, 3D, Text

Description: “Journey to the West” is an installation that re-activates “La Plissure Du Texte”, a seminal work of distributed authorship created by Roy Ascott in 1984. For this 2012 version, a system was developed that enables similar characteristics of the original work, but with current communication technologies. Skype was used as a platform to enable authors from around the world to contribute to the narrative of a planetary fairytale. All the conversation is collected from a main computer that visualizes the messages in a 3D space. Participants in Shanghai Biennale can navigate with the help of a
controller inside the virtual space and explore the narrative in real time.

(Conceptualized by Roy Ascott, Juliette Yuan, and Stavros Didakis. Design, programming and development by Stavros Didakis).

Installation

Name: Data Ecologies
Venue: i-DAT, Plymouth University (Plymouth, UK)
Date: October 2012
Media: Programming, visualizations, data, architecture
Description: This system was developed to provide a case study for intelligent buildings from a creative and artistic perspective. For this reason, a number of environmental sensors were used in a large architectural space (Portland Square building, in Plymouth University), previously installed for the Arch-OS framework, developed by i-DAT. In this scenario, the data are used to create real-time visualizations that relate to the observed natural phenomena. Moreover, the system uses various APIs to extract data for a number of different goals - defined by the user. For example, Twitter messages can control the visualization process, or sensor data feeds can be streamed in social networks. The system was presented at the Data Ecologies Symposium (i-DAT, Plymouth University).
Installation

Event: Final Year Student Exhibition
Venue: MBS College (Heraklion, Greece)
Date: September 2012
Media: Multitouch Interaction, Programming, Animation, Video, Sound, Text

Description: For the final year student exhibition in MBS College (franchise of Nottingham Trent University), I developed an application that is used together with a multitouch tabletop system. Fiducial markers have been implemented into circular tangible objects. Each object corresponds to the ID of a specific student. By placing the object on the top of the table, the ID is recognized by the system and brings on that specific position relevant information of the student’s assignments, such as videos, pictures, slideshows, and many more. Thus, the table becomes a collective virtual space of memory where the users can interactively use it and receive the requested information.
**Multi-touch Tabletop Development**

Event: Totally Summer Tour  
Venue: Palm Beach Club (Hersonissos, Greece)  
Date: August 2012  
Media: Multitouch Interaction, Programming Animation, Sound  

Description: For this event, a Reactable-like multitouch tabletop was created. Tangible objects with fiducial markers were used, in order to control a live music set with hundreds of recorded samples. The objects are used to navigate within the sample database, and also to control other parameters of the live set such as volume, effects, and many more. The installation is provided to the participants to create collaborative performances in a joyful and innovative way.
Installation

Venue: Status Nightclub (Hersonissos, Greece)
Date: June 2012
Media: Projection Mapping, Video Animation, Programming, System Development

Description: This installation consists of a media system that provides projection mapping, multiscreen configuration, automation, sound synchronization, and more. In general it is a complete solution for the media demands of a nightclub as this one. I have been responsible in delivering this complete solution (programming, development, media design, installation, and maintenance). The system is in permanent use.

Installation

Venue: Matrix Nightclub (Hersonissos, Greece)
Date: June 2012
Media: Projection Mapping, Programming, Multi-Screen System, Video Animation, System Development

Description: In Matrix Nightclub I created this installation of a complex audiovisual processing system. There is a real-time analysis engine that processes various events (camera input, audio levels, musical key), and based on these parameters the visuals are automatically generated and mixed. Moreover, the system has a multiple keystone correction method to be used in mapping projections. The system is in permanent use.
Presentation – Talk

Title: “The Myth of Symbiosis, Psychotropy, and Transparency Within the Built Environment”

Venue: Ionion Centre for the Arts and Culture (Kefalonia, Greece)

Date: April 30 – May 2, 2012

Abstract: “Based on earlier studies of J. C. R. Licklider, this paper translocates the context of symbiosis between man and the machine into the built environment, and more specifically into contemporary methods for the design of domestic/residential spaces. According to this, a discussion is made concerning the implementation of media and sensor technologies within the architectural DNA that initiate the emergence of psychotropic spaces of Ballardian Architecture; structures that are capable of becoming extensions of the inhabitant’s mood, emotion, and psyche. Furthermore, this paper presents Plinthos Pavilion, a collaborative artwork that confronts issues of transparency, ubiquity, and invisibility; an example of synergy between the primary notions of architectural and media design, which blend with the use of electronic and digital technology, transforming a physical structure to an organism that breaths, reacts, and communicates.”

Workshop

Name: Bio-OS Workshop

Venue: Institute of Digital Arts Technology, University of Plymouth (Plymouth, UK)

Date: November 2011

Media: Bio-OS
Description: Bio-OS is a collection of prototype technologies used for sensing biological processes such as heart rate, breathing rate, body temperature, and galvanic skin response. It has been developed by i-DAT (University of Plymouth), and in November 2011 I participated in this workshop and presentation that explored various issues raised from these interfaces (interface design, e-health, ubiquitous computing, interactive art, social networking, data visualization, and more).

Workshop

Name: ECOIDs Workshop
Venue: Institute of Digital Arts Technology, University of Plymouth (Plymouth, UK)
Date: November 2011
Media: ECOIDs

Description: Eco-OS is an infrastructure developed by i-DAT (University of Plymouth) that is used to create a network of wireless sensor interfaces (ECOIDs) distributed in outdoor spaces with main concern to gather environmental data for further use and analysis. The ECOIDs are able to transmit data through one another, and collect all the results to the main server database. The raw data can be used as basic material for artistic practices (visualization, sonification, and many more), or they can be used by environmental scientists in order to study closer the behavior of ecologies or related physical events. In November 2011 I participated in this workshop that presented topics related to this technological infrastructure and its artistic practices.
Installation

Venue: Rafinaria Nightclub (Heraklion, Greece)

Date: October 2011

Media: Projection Mapping, Video Animation, Programming, System Development

Description: This is an installation of a projection mapping system. Large rectangular cubes with multiple dimensions have been connected together with iron tubes and act as a screen that receives on their white surfaces video projections. The software that was designed for this specific installation uses projection-mapping methods to create a complex visual space that enhances the dimensionality of the environment and suggests a novel way of experiencing the “screen” on 9 surfaces.
Installation

Name: FaceWall
Venue: Rafinaria Nightclub (Heraklion, Greece)
Date: October 2011
Media: Projection Mapping, Video Animation, Programming, Social Media

Description: In this project, the system uses data that are extracted from the participants' social media (profile pictures), and creates a photographic collage in real-time. The system has been programmed in Processing, and it is based on algorithms for the manipulation of image data. The projection screen is comprised of three rectangular vertical banners installed in different height and depth positions. The installation exhibits fragmented pieces of fused virtual spaces.
Presentation – Talk

Event: Pech Kucha Heraklion#2
Venue: Vitouri Gate (Heraklion, Greece)
Date: September 2011

Description: Following is a part of my presentation at Pech Kucha in Heraklion, Crete: "[…] New digital media technologies can be integrated into the architectural space and transform it into a digital canvas enabling direct alteration and modification. For example, animated graphics that are projected inside the space can create a new perception in social, economic, and cultural matters. The architectures we knew until now expand with the use of interactive systems as well as with the implementation of four dimensional design parameters, such as sound, music, and animation. We witness the genesis of a new hybrid partnership that allows fluidity, kinesis, and transformation. It is important to discover new ways to
affect memory, experience, and feelings, and to ignite the spark that may provide an utopious and prosperous lifestyle. [...] "

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**Installation**

**Event:** Pecha Kucha Heraklion#2  
**Venue:** Vitouri Gate (Heraklion, Greece)  
**Date:** September 2011  
**Media:** Projection Mapping, Multi-Screen, Interactive Animation, Programming  
**Description:** A multi-screen projection on a medieval fortress presents fragmented pieces of the event that float within the visual boundaries. As participants approach, the pieces are pushed away to reveal hidden messages that need exploration and decoding.
Installation

Venue: RAI Nightclub (Hersonissos, Greece)
Date: May 2011
Media: Projection Mapping, Multi-Screen, Video Animation, Programming, System Development

Description: This is a permanent multiscreen installation that consists of eight projection spaces, and a software program that controls the processing and automation of the visual material. The software provides real-time audio analysis of various frequency bands that control the visual synthesis of sampled material, effects, and 3D models that are generated from the program.