

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE
ENGINEERING AND TECHNOLOGY

**TECHNOLOGY-LED EVOLUTION OF INTERIOR SPACE: INTERIORS
BECOMING PRODUCTS**

M.Sc. THESIS

Sena SEMİZOĞLU

Department of Industrial Product Design

Industrial Product Design Programme

Thesis Advisor: Assoc. Prof. Dr. Çiğdem KAYA PAZARBAŞI

DECEMBER 2015

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

**TEKNOLOJİ İLE DEĞİŞEN MEKANLAR: İÇ MEKANLARIN
ÜRÜNLEŞMESİ**

YÜKSEK LİSANS TEZİ

**Sena SEMİZOĞLU
(502121911)**

Endüstri Ürünleri Tasarımı Anabilim Dalı

Endüstri Ürünleri Tasarımı Programı

Tez Danışmanı: Doç. Dr. Çiğdem KAYA PAZARBAŞI

ARALIK 2015

Sena Semizoğlu, a **M.Sc.** student of ITU **Graduate School of Science Engineering and Technology**, student ID 502121911 , successfully defended the **thesis** entitled “**TECHNOLOGY-LED EVOLUTION OF INTERIOR SPACE: INTERIORS BECOMING PRODUCTS**”, which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Assoc. Prof. Dr. Çiğdem KAYA PAZARBAŞI**
Istanbul Technical University

Jury Members : **Assoc. Prof. Dr. Çiğdem KAYA PAZARBAŞI**
Istanbul Technical University

Assoc.Prof. Dr. Emine GÖRGÜL
Istanbul Technical University

Assoc.Prof. Dr. Frederico FIALHO TEIXEIRA.....
MEF University

Date of Submission : 27 November 2015

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To my grandfather and Kerem,

FOREWORD

I would like to thank;

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My friends for supporting and encouraging me during this period,

My brother for teaching me that life is bigger than our perception and knowledge, and for making me think with a wide angle,

And to my parents for their endless support, and for helping me to become who I am.

November 2015

Sena SEMİZOĞLU
(Interior Architect)

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ABBREVIATIONS

AI	: Artificial Intelligence
AmI	: Ambient Intelligence
App	: Application
AR	: Augmented Reality
CUI	: Command User Interfaces
DIY	: Do-It-Yourself
GUI	: Graphical User Interfaces
HCI	: Human-Computer Interaction
ICT	: Information and Communication Technologies
IoT	: Internet of Things
JARVIS	: Just a Rather very intelligent system
MIT	: Massachusetts Institute of Technology
M2M	: Machine to machine
TUI	: Tangible User Interface
UI	: User Interface
WIMP	: Windows, icons, menus and pointers
VR	: Virtual Reality

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TECHNOLOGY-LED EVOLUTION OF INTERIOR SPACE: INTERIORS BECOMING PRODUCTS

SUMMARY

Information and Communication Technologies (ICTs) are widely used by crowds. These technologies, like their ancestors, change daily habits and alter space-product perceptions and designs. Human-Computer Interaction (HCI) is the field that investigates noble ways to integrate these technologies into daily life by offering subtle interactions. This field covers user interface research along with artificial intelligence, augmented reality research.

User Interface design stands as an important aspect as the mediums change but the need for a designed interface does not. To connect with the digital world there must be an interface; digital or physical, graphical or multidimensional. Thus the emergence of this area is important to understand the trends in the designed mediums. Another important aspect that should be taken into consideration in design is the notion of artificial intelligence. Though it is not possible to create a human-like intelligence in a short period, there are some finely programmed systems that can assist humans during their daily tasks. One other advancement in ICTs that affects products and environments is augmented reality. It brings the ability to add digital entities into everyday surroundings. Even though the interaction is achieved with head displays, this technology brings several advantages.

While the technological aspects of the ICTs are investigated under the field of Human-Computer Interaction, the relation between products and these technologies cannot be missed. ICTs are both changing the trends in the market, and the designing process along with the features of the objects. Do-it-yourself communities, Makers communities along with the free-knowledge sources on the World Wide Web changes the way people interact with design. Another aspect related to products is the immaterialisation. Though physical presences of ICTs were dominant for years, this dominance lose importance as they become embedded into each other and into surroundings. For several years of Human-Computer Interaction research, the interaction was through black boxes with screens and keyboards. With developments in related areas both the interaction and the host of these technology is changing, becoming more natural, more humane.

The way of interaction is changing from visual experience to total body experience, while the designed medium is shifting to environments from products. This shift leads to interdisciplinary collaborations. Though defining a discipline and defending their professionals' rights is important, in this changing world where the knowledge is reachable by anyone interested is possible, designers, engineers and craftsmen should be open about interdisciplinary work.

Rooms are becoming products and electronic products are being embedded to space. For architects and interior architects/designers it is important understand the dynamics of these technologies. The 'Smart' notion can offer many complementary features to homes other than adjusting lights/ HVAC/ locks of the house or tracking health of inhabitants. With the Internet of Things many household objects became able to communicate each other and the inhabitants, and with the developments in Artificial Intelligence research it would be possible to say homes will become personal assistants. Interior architects should combine their knowledge about human behaviour and space organization with Information and Communication Technologies (ICTs). Whole body experience has been used by architects for centuries as buildings and interior spaces are designed to embrace human body and senses. Their knowledge can lead to new possibilities in the user interface design. The ICTs and Interaction Design offer new ways of architecture, but to make use of these ways architects should learn about the delicacies of technology. ICTs are offering the mind, while architecture is offering the vessel.

To create subtle interaction between technology and humans and also to protect humans' rich attainments gained through centuries collaboration should be supported. While architects can offer their knowledge about human-space relation, product designers can offer their knowledge of product-human relation. Engineers as the developers of these technologies also have deep knowledge that can be a great contribution to these fields. Thus collaboration between the each related field should be supported as this would result in more successful and less harmful environments.

TEKNOLOJİ İLE DEĞİŞEN MEKANLAR: İÇ MEKANLARIN ÜRÜNLEŞMESİ ÖZET

Günümüzde Bilgi ve İletişim Teknolojileri (BIT) hayatın her alanında karşımıza çıkmaktadır. Bu teknolojiler kendilerinden önceki birçok teknoloji gibi hayata dahil olurken alışkanlıkları değiştirmekte ve değişen alışkanlıklar ve trendler doğrultusunda ürün ve mekan algıları ve tasarımları da değişmektedir.

İnsan-Bilgisayar Etkileşimi alanı gelişen teknolojiler doğrultusunda insanlara bu teknolojileri daha kolay ve verimli kullanabilmek amacıyla araştırmalar yapılan bir alandır. Bu alandaki çalışmalar arayüz, yapay zeka, sanal gerçeklik gibi birçok çalışmayı kapsamaktadır.

Kullanıcı arayüzleri İnsan-Bilgisayar Etkileşimi alanında önemli bir yer tutmuştur. Her bir işlem için ezberlenen komutların girilerek işlem yapıldığı komut tabanlı sistemlerden genel kullanıma daha uygun olan Pencere, İkon, Menu ve İşaretçi (*Windows, Icons, Menus and Pointers [WIMP]*) arayüzlerine geçilmiştir. Bu dönemde bilgisayarlarla etkileşim klavye, fare ve ekranlar aracılığıyla olmuştur ve Grafik olarak ifadeleştirme büyük önem kazanmıştır. Komut tabanlı kullanıcı arayüzlerinden sonra Grafik Tabanlı Kullanıcı Arayüzleri gelmiştir. Grafik tabanlı arayüzlerin insanların yüzyıllar boyu bilişsel olarak geliştirdiği duyu derinliğini karşılayamaması, teknolojiyle etkileşimi yapay bir hale getirmiş ve görme öncelikli olmak üzere görme ve duyma duyularını öne çıkarmıştır. Çeşitli teknoloji alanlarındaki gelişmelerle diğer duyulara da hitap edebilecek dijital algılama sistemleri geliştirilmektedir. Bunların da verdiği olanaklarla *Tangible* (Somut) kullanıcı arayüzleri geliştirilmeye başlanmıştır. Gerçek hayattaki objeler dijital ortamdaki modellemelerle eşleştirilerek eş zamanlı değişimlerin yapılması sağlanmaktadır. Bu arayüzlerde de gerçek hayatta varolan objelerin rijitliği, dijital ortamların esnekliğini karşılayamadığından zorluklar doğmaktadır. Bu alandaki araştırmacılar, yeni nesil kullanıcı arayüzlerinin malzeme, üretim vb alanlarda yapılan araştırmalarla birlikte daha esnek malzemeleri olası kılarak dijital esneklik ve somut rijidite dengesini kurmasını beklemektedir.

Arayüzlerden farklı olarak Bilgi ve İletişim Teknolojileri hayatımıza “akıllı” kavramını da getirmiştir. Akıllı olarak tabir edilen ürünler genellikle birden fazla işi yapmaya yarayan bilgisayar sistemleri gömülü ürünlerdir. Burada akıllı sıfatı kullanılırken gerçek bir zekanın doğaçlama ve hızla gereken bilgileri süzme yeteneklerinin karşılanmadığını belirtmek gerekmektedir. Bilgisayar sistemlerinin çevrelerini algılamaları sağlanabilmekle beraber gerçek akıl göstergesi olan hareketlerde bulunmaları şu an için gerçekleşebilir değildir, programlandıkları ölçüde zekilerdir. Yapay zeka araştırmaları ile insan gibi komplike ve basit düşünceleri bir arada üretebilen sistem tasarımları amaçlanmaktadır. Ancak insan zekasının esnekliği

ve programlanmadan da çeşitli hareketleri uyarlayarak çözümler sunma yeteneği henüz yapay olarak gerçekleştirilememektedir.

Bilgi ve İletişim Teknolojilerinin getirdiği bir başka kavram da ‘sanal gerçeklik’ tir. Dijital olarak var edilen bu gerçeklik, görsel algıların çeşitli kandırmacalar kullanılarak manipüle edilmesi ile inandırıcılık kazanmaktadır. 80 ve 90lı yıllarda bilimkurgu konseptlerinin de etkisiyle araştırmalarda ön planda yer alsa da, insanların yapay bir ortamla ilişkide bulunurken duyularını tam anlamıyla kullanamamaları ve gerçek dünyaya tamamen bir alternatif olarak sunulması bu alandaki çalışmaların arttırılmış gerçeklik gibi alanlara kaymasına sebebiyet vermiştir. Arttırılmış gerçeklikte kişiler gerçek hayata entegre edilmiş çeşitli dijital eklentilerle bilgi aktarımı hızlandırılabilir.

Bilgi iletişim teknolojilerindeki bu gelişmeler sanal dünya ile gerçek dünyaya giderek yaklaştırmak insanla yakından etkileşimde olan mimarlık ve ürün tasarımı gibi alanları da etkilemektedir. Bilgisayar teknolojilerinin sunduğu parametrik tasarlama programları ile tasarlama sürecinde büyük farklılıklar yaşanmıştır. Çok uzun süreler tutan çizimler, paylaşımda yaşanan güçlükler bu programlar sayesinde büyük oranda aşılmıştır. Tasarlama sürecine bilgisayar dahiliyetinin avantajlarının yanında dezavantajları da mevcuttur. 3 boyutlu ürün ve mekan tasarımlarının 2 boyutlu arayüzlerle gerçekleştirilmesi algılamada sorunlara yol açmaktadır. Ayrıca bütün bedenin algıladığı bir yapıyı sadece görsel algılar üzerinden tasarlamak bedensel algılamayı köreltmektedir ve mimarlık teorisyenleri tarafından bu durum eleştirilmektedir.

Tasarlama süreçlerine dahil olmanın haricinde, bilgi ve iletişim teknolojileri çeşitli elektronik ekipmanlarla ürünlere ve mekanlara dahil olmaktadır. Mekanlara özgü ilk kullanımlar daha çok mekanın fiziksel koşullarını düzenlemek üzerine olmuştur. Bu koşullar havalandırma, ısıtma/soğutma, aydınlatma, güvenlik mekanizmaları olarak genellenebilir. Isı, hareket, ses gibi çoklu algılayıcılar sayesinde mekandaki çeşitli aktiviteleri gözlemlemek mümkün olmaktadır. Bu teknolojinin bir getirisi yalnız yaşayan yaşlıların, ya da epilepsi gibi nöbetli rahatsızlıkları olan bireylerin tek başlarına yaşamalarını destekleyici entegrasyonlar yapılabilmesidir. Çeşitli eklentilerle kişilerin hayati fonksiyonları otomasyon sistemleri tarafından takip edilebilmekte ve acil durumlarda sağlık ekiplerine veya istenilen kişilere bilgilendirme yapılabilmektedir.

Ürünler mekanlara oranla çok daha uzun süredir bilgi ve iletişim teknolojilerine konak olmaktadır. Telefonlar, bilgisayarlar, tabletler hep bu teknolojilerin uzantısı olarak ortaya çıkmış ve zaman içinde fiziksel olarak değişime uğrasalar da bilgi ve iletişim teknolojilerine ev sahipliği yapmaya devam etmektedirler. Malzeme ve üretim tekniklerindeki kısıtlamalardan ötürü elektronik aletlerin yaygın olarak kullanıldığı ilk dönemlerde ‘kara kutular’ ın iç mekanlarda baskın olarak var olduğu görülmektedir. Mekanların ve ürünlerin temel özellikleri uzun seneler boyunca gelişmiş ve oturmuştur. Örneğin masa, sandalye, duvarlar, zemin vb. Kalıplaşmış temel elemanların yanında bahsedilen kara kutular mekanın bütünlüğünü bozmakta ve insanın doğal etkileşimini kötü yönde etkilemektedir. Ürünün çalışmasını sağlayan teknolojiyi anlamak ve kullanmak kimi zaman yorucu ve bezdirici olabilmektedir. Bu olumsuzlukları aşmak için bilgi ve iletişim teknolojilerinin mekanların asıl elemanlarına entegrasyonu çeşitli araştırmacılar tarafından önerilmiştir.

BIT ürünlerinin mekansallaşması mimari teorilerde de karşılık bulmaktadır. Teknolojinin hayatın her alanında gelişmekte olduğu açıkça belli iken, teknolojinin mekanlara ürünler üzerinden dahil olduğu da gerçektir. Bu ürünlerin mekansal anlamda getirdiği olumsuzluklar karşısında kullanımlarını reddetmek doğru bir yol değildir, gelişen teknolojiler ile mekana entegrasyon sağlanarak mekansal bütünlüğün tekrar oluşması ve bununla birlikte yeni olanaklar sunulması olasıdır.

2. Dünya Savaşı sonrasında askeri kökenli teknolojilerin tasarımcılar tarafından ürünlere uygulanması, ürün tasarımında yeni kavramların doğuşuna sebep olmuştur. Mimarlıkta da benzer bir şekilde, yıkılan hayatları ve şehirleri yeniden inşa etmek adına yeni kavramlar ortaya atılmıştır. Bu dönemde hafiflik, yeniden üretilebilirlik ve inşa edilebilirlik, farklı koşullara uyum sağlayabilir olma ve mobilite mimarlar tarafından önemli hususlar olarak dile getirilmiştir. Bu doğrultuda mekanlara ürünsel olabilecek özelliklerin eklendiği görülebilmektedir. Teknoloji ve mimarlığın yakın ilişkisi düşünüldüğünde 20. Yüzyıl mimarlığındaki bu kavramlar karşılıklarını malzeme ve inşaat teknolojilerindeki gelişmelerle karşılamaya çalıştığı söylenebilir. 21. Yüzyılda ise Bilgi ve İletişim Teknolojileri mekanları değişebilir kılmada farklı olanaklar sunmaktadır.

Mekanın bir anlam taşıdığı ve mimarlığın yapıdan ibaret olmadığı mimarlar tarafından çokça savunulan bir sav olmuştur. Daha önce de belirtildiği gibi bedensel bir deneyim sunan mimari yapıtlar BİT destekli tasarlama süreçlerinde görsellik diğer duyuların önüne geçecek şekilde değişmiştir. Algılamada ve duyusallıkta yaşanan kaybın BİT'lerin mekanlara doğru şekillerde entegre olması ile aşılabılır hale geleceği öngörülebilir. Kullanıcı arayüzlerindeki gelişmeler ve ürünleri kısıtlayan fiziksel zorunlulukların aşılması ile bunlar mekanlara dahil olmakta ve mekanların kullanımını değiştirmektedir. Bu değişim olumlu ya da olumsuz birçok farklı şekilde yorumlabılse de mimarlığın temelinde yatan insan-ürün-mekan ilişkisi ve mekansal bütünlüğün önemi unutulmamalıdır. Birçok mimar ve tasarımcı teknolojinin insan doğasına zarar vermeyecek şekilde hayata dahil olması gerektiğini savunmuşlardır. Bilgi ve iletişim teknolojilerinin fiziksel hayatı baskın bir şekilde etkilemesi, faydalarına gölge düşürmektedir.

Bilgi ve İletişim Teknolojileri günlük hayata dahil olurken duyuaal zenginliğimizde kayba yol açmış, alışkanlıklarımızı ve bağlantılı olarak ürünlerin doğasını değiştirmiştir. Algıda oluşan farklılıklar mimarlığı ve mekanları da etkilemektedir. Bu alandaki yeni gelişmeler, akıllı sistemler, arttırılmış gerçeklik vb gibi, bu kaybı azaltmak için öneriler sunmaktadır. Ürünler mekanlara entegre olurken, mekanlar ürünsel özellikler kazanmaktadır. Teknolojinin üretilmesi ve yaygın kullanıma geçmesi arasındaki zamanda bu teknolojinin insan-ürün-mekan ilişkine en az zararı verecek şekilde kullanılabileceği düşünülmelidir. Kara kutuların ve kabloların mekanları domine etmesi olumsuz bir örnek olarak düşünülebilir. Mekanların BİT'lere konak haline gelmesi ile ortaya çıkabilecek olumsuz durumların çok daha büyük ölçekli olabileceği öngörülebilir.

BİT gömülü mekanlar üretmek farklı uzmanlık alanlarından bilgi ve deneyim gerektirmektedir. Mimarların yüzyıllardır insan-mekan ilişkisini tartışması bu alanda derin bir birikime işaret etmektedir. Benzer şekilde insan-ürün ilişkisinin tasarımcılar tarafından derinlemesi incelendiği görülebılır. Teknolojiyi geliştiren taraf olarak mühendislerin katkısı unutulmamalıdır. Bu bağlamda birbirinden farklı alanların katkısının da farklı olacağı düşünülerek bu alanların deneyim ve bilgisinin birlikte daha zengin olanaklar sunabileceği öngörülebilir. Bu durumda da insan-ürün-mekan

ilişisini zedelememek adına mimarların, endüstriyel tasarımcıların, etkileşim tasarımcılarının ve mühendislerin bir arada çalışması desteklenmelidir.

1. INTRODUCTION

Emerging Information and Communication Technologies introduced us to a new realm of virtual world. This new non-physical dimensions presented new ways of executing actions without the physical restrictions. The virtual world entered daily life through computer systems; cases, keyboards, mice, screens and speakers, which happened to be virtual world's physical representation, while the digital representation happened to be user interfaces.

Virtual world brought many new concepts into life such as globalisation, sharing knowledge and experience freely, turning each user into a source of information. These concepts led to widespread use. However, physical and digital representations have certain limitations and disadvantages. User interfaces offered limited set of actions, and appealed mainly to eye instead of all senses, while the computer systems entered interior spaces in plastic boxes with wires. The integration of ICTs into daily life has consequences such as leaving out body-space-product relationship with loss in sensory diversity. The interior spaces became invaded by physical presence of ICTs, with limited attention on human attributes.

With ongoing developments the physical representation of virtual world is merging into the built environment, thus two worlds begin to share the physical space. It can be claimed that with the ongoing developments in ICTs interior spaces gain product-like features and become the medium where interaction between the two worlds takes place, as well as becoming inclusive and adaptive in this changing landscape.

As environments become embedded with digital artifacts, actualising these environments require specialised knowledge from different fields. The need for collaboration between scientists, engineers, architects and designers is emerging and should be supported (Ak, N., 2006; Akoğlu, 2010).

1.1 Importance of Thesis

With the developments in Information and Communication Technologies along with other related fields such as new materials and manufacturing techniques etc, the boundaries of space and products blur. While each profession deals with mediums in different scales, both architecture and product design aim for creating better lives. With this larger aim in mind, during the emergence of ICTs, architects investigate the causes and effects of computer-aided design tools' integration to designing process, while product designers investigated possible ways to create genuine interactions with and through computers.

Investigating the link between space, product and humans in adaptive environments will help to advance the knowledge needed to fulfil the needs to create technologically advanced and user friendly environments.

1.2 Structure of Thesis

While the first chapter introduces the context, the second chapter explains the methods used. This involves extracting keywords for literature review, the way of sample selection from each field (HCI, Product Design, and Architecture). HCI samples show development of user interfaces through time, also express space-related concepts such as ambient intelligence and augmented reality. Product design samples show the changes in ICT embedded products with technological advancements. Architectural samples express adaptive environment concepts. All these samples are compared with each other in their own category according to the keywords.

The third chapter analyses the features of ICTs through examining how these technologies are developed through time. This chapter gives a brief history of theoretical background of Interaction Design, then exceeds with examining changes in digital representation of virtual world through time by giving examples and explaining advantages and disadvantages of user interfaces. Also a brief introduction to research fields such as ambient intelligence and augmented reality is given as these fields offer necessary concepts for enhancing interactions.

The fourth chapter examines the changes in product design while this field become adaptive to the changing trends such as High Design, do-it-yourself production, and open source knowledge in practice related areas.

The fifth chapter defines architecture and space's meaning, and examines the theoretical background for the relevance of technological advancement. It goes on with examples from ICT embedded interior spaces to present concept environments, along with some example concepts from Sci-fi movies and forecasts ideas on the future of interiors.

In the last chapter, three main issues related to ICTs integration to interiors and products are discussed under the light of theoretical and historical backgrounds from both fields of architecture and product design along with the concepts of ICT evaluated in previous four chapters. These issues are; changing body-space-product relationship while losing gained sensory diversity, need of adaptive product design and spaces becoming adaptive.

1.3 Hypothesis

Products such as mobile phones, computers and televisions hosted ICTs for the first decades of their emergence, and the principles for designing interactions are mostly related with products. There are several researches to clarify the product related properties of designed mediums such as buttons, screens etc.

With the developments in ICTs such as tangible user interfaces and ambient intelligence, space began to host ICTs and gains features related to products. Thus it is now possible to claim that interiors are becoming products of ICTs that need to be designed not only with an architectural perspective but also in a perspective that makes use of the gained knowledge and experience of product designers.

With ICT related developments product design became adaptive and with the integration of ICTs in interiors, space should become adaptive to answer the needs of inhabitants better. Also designers, architects and computer scientists along with other related fields should work in collaboration to create mediums that suit the requirements of the Information Age for user-centered living.

2. METHODS

2.1 Literature Review

Literature review for this research is held under three main fields, Interaction Design, Product Design and Architecture. Online databases are investigated for the study, also to keep up with the technological developments in consumer products popular magazines and websites such as Popular Science magazine and TechnologyReview website, are followed since December, 2014.

To identify the development in ICTs, mainly these keywords were used for database searches: Interaction Design, User Interfaces, Human-Computer Interaction, Artificial Intelligence, Ambient Intelligence, Virtual Reality and Augmented Reality.

For Product Design mainly these keywords were used: Smart Products, ICT embedded products, High Design, Open Source Movement, Makers' Movement and additive manufacturing.

For Architecture mainly these keywords were used: Interactive Environments, Smart Environments, post-war architecture, adaptive environments, architecture and technology.

2.2 Sample Selection

To clearly explain the emergence of ICTs, wide variety of examples are given after examining these samples according to selected keywords. For product designs and user interfaces, commercial products and interfaces are chosen to explain today's use of these technologies. To explain the architectural relevance of ICTs theories and concept projects are examined. Detailed information about ICT related samples are given in Appendix B.

Literature review showed that several keywords gain importance for products and concepts related to ICTs. User involvement takes part in articles and concepts in two ways; physical involvement and involvement in the decision making procedure

during usage (ability to manipulate the interface). Several engineers, architects criticised the way humans interact with the digital world as the interaction was limited to 2 dimensional screens (Fitzmaurice et al, 1995; Ishii and Ullmer, 1997; Pallasmaa, 2005; Pask, 1969; Wellner et al, 1993). Based on this the body involvement is considered during the sample selection, by including samples that use different channels of body in the means of five senses and whole body interaction. Also the ability to manipulate the user interface; customising or ability to work simultaneously, is considered as a key point in the selection as this issue is discussed by several researchers such as Weiser (1991), Ishii (2008a, 2008b), Ishii and Ullmer (1997) and Myers(1998).

Another main research area in Information and Communication Technology is Artificial Intelligence which is explained in the chapter 3.3.2. Intelligence level of the product/interface/concept is taken into consideration during the sample selection. Also the ability to communicate (feedback levels) and response is discussed by several researchers such as Akman (1977), Bostrom (2014), Glanville (2007) and Wiener (1958/1973).

Being adaptive is considered one of the most important aspects by both architecture, HCI and product design. HCI researchers support the interfaces or designed mediums to be adaptive in regard to the changing features of real life and human beings (Alben, 1997; Fitzmaurice et al, 1995; Ishii and Ullmer, 1997). Similarly architects of the post-war era offered adaptive, lightweight and changeable environments to fulfil the need after the mass destruction (Ak, N., 2006; Chalk 1966/1999; Fuller, 1969/2007; Onbay, 2006).

To show the increasing awareness of the body and the involvement of the user, all the samples except from the ones in Chapter 5.2 are assessed with these keywords: (1) adaptive, (2) communicative/responsive and (3) manipulatable. Even though another keyword – intelligence – is emphasised on ICT related researches, as a result of the limited range of intelligent mediums this keyword is left out in the comparison charts (Appendix C). Assessments are made in each medium group of (1) user interfaces, (2) tools and systems, and (3) environments by the researcher for a comparative understanding of the existing examples as the background of the research. Therefore they can be regarded as subjective. Other researches may indicate different scaling.

Samples from Chapter 5.2 are left out in the assessments because they aren't embedded with ICTs even though they indicate theoretical background for ICT embedded environments.

Samples in the Appendix C can be examined in detail in Appendix A, which is consisting of identification tags of the samples. Short descriptions and keyword assessments of the samples along with the features, name, year and type of the sample are given in the Appendix B.

3. INTERACTION DESIGN

With the developments in computer sciences, and ICTs (information and communication technologies), computers became a part of daily life. As a consequence a need for designed interfaces arose. Research and design practice in Human-Computer Interaction (HCI) became widespread.

HCI stems from the combination of communication theories and technology. Initial HCI practice is based solely on technology. As technology became embodied in the built environment, its interaction with human and its bodily presence became a research subject.

While ICTs and computers became integrated to daily actions users' involvement with them increased. As a result of the material and manufacturing technologies of the time, ICTs and computers were presented in boxes which dominated interior spaces. ICTs' physical presence intervened the relationship between the body, space and product. The gained sensory diversity of body is degraded mostly to vision along with hearing, interior spaces are dominated by electronic devices in boxes, and products are designed to fulfil technological requirements instead of human needs (Akoğlu, 2010; Ishii and Ullmer, 1997; Marzano, 1999, 2003, 2005; Pallasmaa, 2005; Weiser, 1991, Wellner et al, 1993). However humans have a far richer array of senses and needs. On the other hand ICTs digital presence introduced the notion of virtual world which's nature is more fluid and flexible than real world.

ICTs are still under development. New projects offer alternative ways of interaction by merging digital and the physical representations of these technologies. As ICTs are in close relationship with daily life, examining the changes of these technologies is a reasonable way to understand the changing landscape and to create a natural way of interaction between human and the machine.

3.1 Interaction Design: From Function to Bodily Experience

Gillian Crampton Smith, who is one of the founders of the Royal College of Arts' Computer Related Design Department which is now called Interaction Design Department, stated in a 2002 interview that "If I were to sum up interaction design in a sentence, I would say that it's about shaping our everyday life through digital artifacts – for work, for play, and for entertainment" (2007, p. xi). But in the past ICTs were more task oriented.

When information and communication technologies first initiated in 1960s, studies in HCI were initially about technological and technical aspects, as it was more important to technically execute a function. There was scarce connection of these researches with everyday use, because technology was developed for specific tasks. As a result of limited use, the need for an easy-to-understand user interface was not present. The relatively late turn to user needs and designers's late contribution to ICTs can be explained by these arguments: (1) governmental and military support in pioneer technological developments, (2) development and usage stages of a technology, (3) and also perception of design among researchers.

Myers (1998) address the importance of research held in universities and labs about HCI by naming the milestone research projects of interfaces funded by major institutions such as NASA, US Navy and Air Forces, Central Intelligence Agency. Hence, one may suppose that most of the pioneer projects were funded by government and military forces. Bayazit (2004) claims that as a result of the technological developments in the Second World War designers became attracted to these design related developments such as new methods and techniques used in advancements of wartime equipments. Design research trends altered from the physical aspects to concerns about human needs (Bayazit, 2004). Both these arguments indicate a technical focus in the first generation research about ICTs, and also for a relatively late merge of ICTs to daily life. It is possible to assume for military applications the goal of the action is more important than the process of the action, thus technical aspects to execute the action are investigated more than the users' need in the first phases of development.

Similarly Smith (2007) explains David Liddle’s vision about the three stages of technological developments from functionality to technology becoming widespread. According to this vision, the first stage of a developing technology is enthusiast stage, where the user is a technology enthusiast whose priority is not the usability, but the technology. The second stage is professional stage in which the user has obligations to use the product whether it is easy to use or not. In the third and the final stage, which he names as consumer stage, the user is much more interested in the benefits of the technology and its ease of use is an important feature (2007). In Myers’ (1998) chronological chart (Figure 3.1), there is a gap of approximately 20 years between university research and commercial products. His findings indicate that technology reaches wide use in time. Therefore it can be argued that designers professionally involve in technological advancement after a certain time period after their invention.

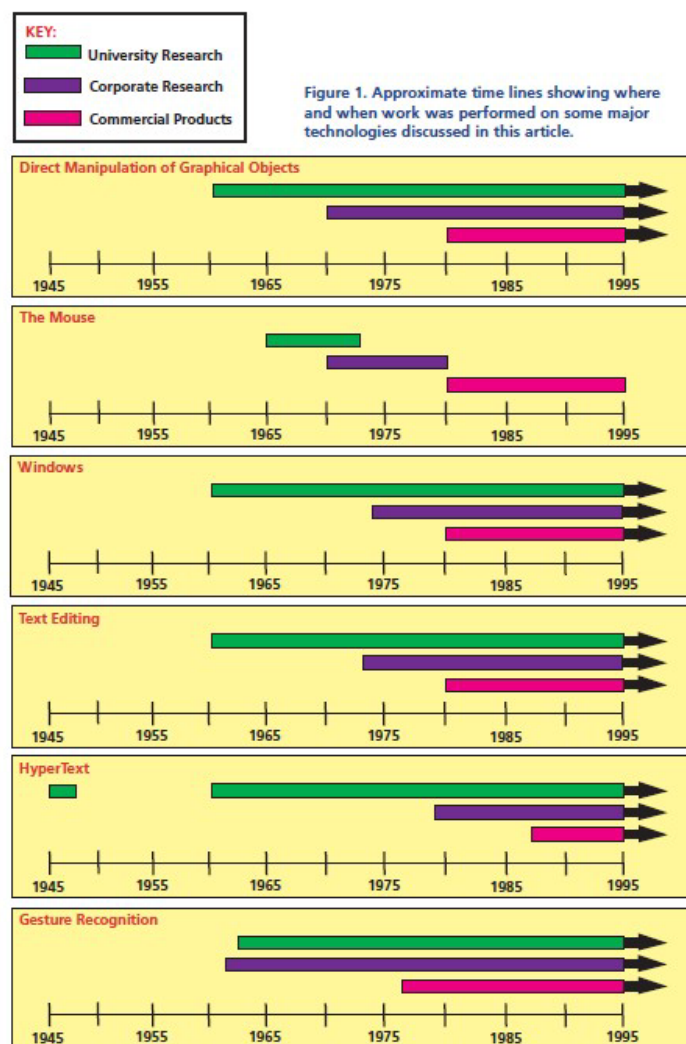


Figure 3.1 : Chronological chart of ICT related research (Myers, 1998, p.2).

Designers' relatively late contribution to HCI can also be explained by the perception of design among researchers. In their article about Interaction Design research in HCI, Forlizzi et al. claim that design's focus is mostly seen as aesthetics by several researchers in HCI field (2008). They also add that this restricted view is causing a distance between design and HCI, because researchers cannot foresee the possible outcomes from collaboration with designers (Forlizzi et al., 2008). However designers have a role not only in designing functions of interactions but also in the bodily experience.

As mentioned earlier, designers' late contribution to the field can be explained by affects of military support, developmental stages of technology, and misinterpretation of design and design research.

As the developed technologies are replaced by their superior ones they become feasible to be included in more personalised everyday products. A need for a way of communication between the person and the technology, an interface, occurs. Even though the designed medium changes, designers are bridging the two sides of digital and real worlds by designing the communication. This communication is not only a visual and functional communication but a multisensory and bodily experience thus a humane experience as indicated in Table C.4. Alben (1997) roots interaction design closely to human experience by explaining that users, designers, researchers and developers are all humans and they should create mediums that support humans instead of oppressing them.

3.1.1 Information system versus communication system

Communication plays a crucial role in Human-Computer Interaction, and the main element of the communication is data. It can be claimed that data underlies our existence. Even the most basic movements of our bodies come to life as results of series of data transfer. Every second each object – even the non-livings – spread data about itself; sense organs gather the relevant and irrelevant data and transfer it to the brain (Wiener, 1958/1973). Brain identifies, classifies and sorts it, and then sends it to the related body parts. Today scientists assert that DNA is a natural storage for data as DNA can be implemented with data as a result of latest developments in related technologies (Tibbits et al, 2014). All these examples indicate exchanging

data and evaluating data is important for existence. Thus for designing ICT embedded environments, systems or products, understanding the two-sided nature of data exchange and communication is important.

Cybernetics, as Akman (1977) explains, is a science which is specialised on investigating the data flow. The field was first initiated by Norbert Wiener in the Second World War era to manage systems and later cybernetics' theories spread to other fields like economics, information gathering and computer sciences. (Bayazit, 2004). Akman (1977) states Cybernetics can be shortly defined as “Communication, Control and Equilibration”, which contains three main actions. This indicates that just creating and gathering data is not enough for Cybernetics, to investigate and to draw out information there should be a process, a communication, a circularity and a system.

In his book, Akman (1977) explains the difference between information systems and communication systems as such: in information systems, the data is created and spread, but in communication systems data exchange occurs, data flow happens in both ways (Figures 3.2 and 3.3).

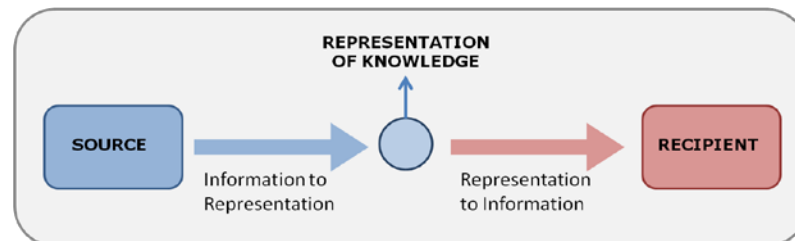


Figure 3.2 : Information Systems (Adapted from Akman, 1977).

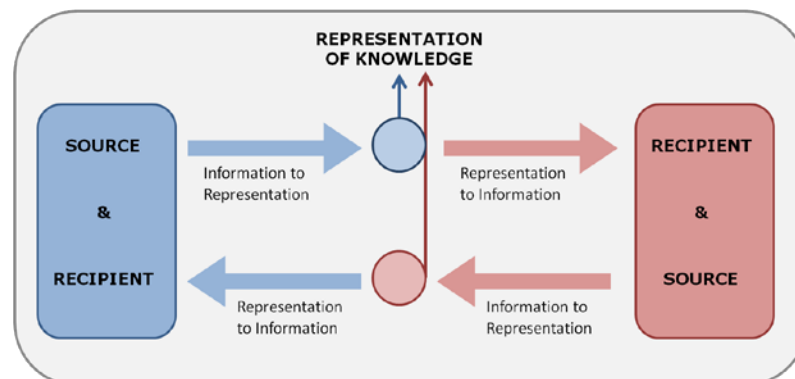


Figure 3.3 : Communication Systems (Adapted from Akman, 1977).

Wiener (1958/1973) states usually human-to-human conversation comes to mind speaking of communication. He explains that human-to-human conversation is not

the only way to communicate by giving examples from daily life. For example, if someone can transport the information of being awake to the household systems or products and products respond to this information by heating the coffee plate, or by shutting down the heating. According to Wiener, the sound of eggboiler when the egg is boiled is considered as a mutual conversation (Wiener, 1958/1973). In these examples tactile, visual or audio feedback is considered as a way of conversation. These feedbacks transmit data in response to whether the command or the situation is understood or applicable. Glanville (2009) states the mutual conversation between human and interfaces as such:

Conversation demonstrates several key cybernetic concepts. It is circular and iterative: a feedback loop. Two (or more) participants each hear what the other has to say, and repeat back their understanding to the other, in their own formulation. X talks to Y; Y listens, constructs his understanding and talks to X. X, in turn, listens and constructs her understanding. Differences (errors) may be corrected by comparing understandings before and after this exchange. Organisationally, a conversation is essentially the same as a thermostat: The difference is in how we understand the enhanced mentative abilities of the elements X and Y. (2009, pp 181-182)

According to Wiener (1958/1973), communication machines have similar two-sided working principles as living beings. In both, sensors are a part of the system and in both a special organ gathers the data and transmits it to an organism or a machine. In both, the data is not accepted directly, it is reformed by some living or non-living experiments; in this case, the data is processed for next steps. In both, this process helps altering the outer world. Wiener (1958/1973) also states that current machines of his time have sense organs, which means they can detect the data around (Wiener, 1958/1973). It is possible to assume that data exchange is as important for machines as it is important for living beings, and it is possible to claim that machines are systems that copy living beings in the means of data exchange. According to Glanville (2007), who identifies himself as a second-order cybernetician, the role of the observer in an iterative and circular interaction can be explained as such:

A way of summarizing what makes cybernetic systems different from (I have argued more general than) traditional ones is circularity. Circularity is embodied in the role of the observer in cybernetic systems: the observer cannot be inactive, or there would be no system. (...) In actuality, the observer is always present, always active in several ways (for instance, setting up experiments, choosing variables, arranging outcomes in the body of knowledge).

Consistency demands that we treat the observer of the cybernetic system in the same way that we treat the observer in the cybernetic system; and the observer in the cybernetic system must be active (to effect change), so the observer of the system should be treated as active, in just the same way. (Glanville, 2007, p. 1183)

The acceptance of the observer being active, as explained by Glanville, was new to the research mainstream. He argues that design – as a verb, not a noun – shares some features with cybernetic systems such as being circular and iterative. Bayazit (2004) states design theoreticians like Gordon Pask and Bruce Archer were among the methodologists and theoreticians who were inspired by the resemblance between cybernetics concept of organisms’ self-control and the act of design.

Gordon Pask argues that architects are forced system designers; as physical and psychological requirements of a building became more complicated through time. Architects become much more related with systems even though they don’t see themselves as system designers (1969). He also argues that as human beings are in a dialogue with the built environment, the designed medium such as cities, buildings, environments etc. should be dynamic and transformable (1969). It can be said that from Pask’s point of view, the designed medium should act like an organism, a living thing which is adaptive and learning.

3.1.2 Ubiquitous computing

As ICTs became more intergrated in daily life and interfered architecture through physically static computers, Mark Weiser from Xerox PARC came up with the term “ubiquitous computing” in 1990s, which he explains in these words: “This is different from PDA’s, dynabooks, or information at your fingertips. It is invisible, everywhere computing that does not live on a personal device of any sort, but in the woodwork everywhere.” (Weiser, n.d.)

With the idea of hidden computers that assist humans in ubiquitous computing, researchers focused more on the alternative ways of interaction. ‘Ubiquitous computing’ is critical in the field of HCI, because it created an understanding beyond limited product range. However, Haque (2007) mentions mainstream research is about hiding the mechanics of the technology and the user is often left out in decision making processes. As a result system designers may create stricted situations (2007).

In Pask's writings, as stated by Haque (2007), it is mentioned that as a result of the strictly defined circulation, random developments are not possible with the limited set of actions and formerly defined answers. Though Pask's arguments and Weiser's visions don't agree on the way of the implementation of system, they both offer a way to create a space that is not technologically overwhelming to people.

It is possible to say that – taking into account of Cyberneticians's view – designers/ researchers/ computer scientists should create a medium that can react to changes which are not pre-programmed in the system as an organism does, to have communication with the environment. They should create a medium that can improvise.

3.2 Between the Human and the Computer: User Interfaces

Designers play an important role as they create mediums for people to communicate through ICTs. As mentioned in Section 3.1, with the beginning of consumer stage of technology ICT embedded products became feasible and the user involvement is increased. As a consequence creating well-designed, easy-to-use user interfaces gained importance. To understand the loss in sensory diversity, and product designs which are limited by technology, and to be able to understand the necessity of mutual interaction between human and computer technologies, the emergence of interfaces, current trends and future visions about user interfaces, which are briefly compared in Table 3.1, are investigated and discussed. This section shows that including users has been a historical continuum.

Table 3.1 : Comparison of User Interface Genres

	Features	Advantages	Disadvantages	Physical Representation
Command UIs	- Command writing	<i>First computers used this type of UI.</i>	-Limited to the user's memory. -No feedback.	Keyboards Screens
Graphical UIs	- WIMPs - Graphical feedback	Ability to work on multiple tasks simultaneously.	-Too graphic. -Stuck at screens.	Keyboards Screens Mouse
Tangible UIs	- Haptic connection with the help of physical objects.	Closer to real-life interactions by copying the act.	-Physical stableness.	Any physical object attached to digital entities.
Next Gen.UIs	- Making use of organisms or flexible materials, products.	More body involvement	<i>-Unknown at the time.</i>	Body extentions. Biologic materials. Amorph materials, products.

3.2.1 Windows, icons, menus, pointers (WIMP) and graphical user interfaces (GUIs)

Graphical User Interfaces (GUIs) were the first user interfaces in commercial products, and they are still used in today's products. GUIs are the foremost used UI type; they determined the way humans interact with the digital world. Though GUIs opened the door to digital world, they caused some loss in gained sensory diversity and dominated daily environments through their physical presences.

As computer technologies became feasible for widespread use, designers developed 2-dimensional, graphical interfaces that are easy to use. By ease of use, being able to act through the digital world is meant. These 2dimensional interfaces are called Graphical User Interfaces (GUIs). For the first several decades of HCI, interfaces were GUIs and the interaction was just through windows, icons, menus and pointers (WIMP). In his article Myers (1998) captions "Basic Interactions" as "Direct Manipulation of Graphical Objects", "Mouse", and "Windows". The earliest examples of interaction concepts go back to 1960s (Myers, 1998).

For the first years of computing systems, black screens and command lines were crucial (Figure 3.4). If a user wanted to perform an action, she/he had to write a specific command for each step. She/he also had to write commands to check if the action was done properly. This means people had to know too many command lines to work with computers. As the capabilities of hardware and the possibilities of software increased new ways of interaction became possible. With the development of operating systems, which later turned into the main working software of computer, command lines became hidden. Alan Kay's idea of overlapping windows influenced the first operating systems (Myers, 1998). Ishii states the difference between writing commands and using WIMPs as such:

GUIs represent information (bits) with pixels on a bit-mapped display. Those graphical representations can be manipulated with generic remote controllers such as mice and keyboards. By decoupling representation (pixels) from control (input devices) in this way, GUIs provide the malleability to emulate a variety of media graphically. By utilizing graphical representation and "see, point and click" interaction, the GUI made a significant improvement over its predecessor, the CUI (Command User Interface) which required the user to "remember and type" characters. (2008a, p. xv).

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GRAFTABL COM      11237 03.02.90    13:00
GRAPHICS COM      19758 03.02.90    13:00
GRAPHICS PRO      21232 03.02.90    13:00
EXE2BIN EXE       8584 03.02.90    13:00
EXPAND EXE       14035 03.02.90    13:00
JOIN EXE        17934 03.02.90    13:00
LCD CPI        10771 03.02.90    13:00
LOADFIX COM      1273 03.02.90    13:00
INFO TXT       15690 03.02.90    13:00
ANWINFO TXT      10313 03.02.90    13:00
PRINTER SYS      18052 03.02.90    13:00
REPLACE EXE      20194 03.02.90    13:00
SUBST EXE       18574 03.02.90    13:00
TREE COM        6974 03.02.90    13:00
COMMAND COM      50031 03.02.90    13:00
DOSHELL INI      17830 28.05.06    21:18
      83 Date(en)      2147161 Byte
                   26421248 Byte frei

C:\DOS>ver

MS-DOS Version 5.00

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Figure 3.4 : Command User Interfaces, MSDOS (URL-1) .

Graphical User Interfaces (Figures 3.5 and 3.6) and its fundamental ways of interaction windows, icons, menus, pointers – the WIMP – helped users to understand the basics of this new computer world. A standart user won't have to write command lines for each step of an action, thus using computers became accessible by crowds.

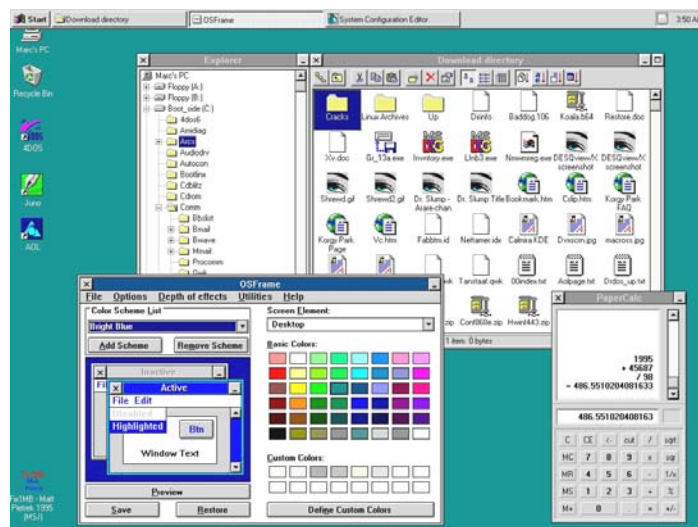


Figure 3.5 : One of the early examples of Graphical User Interfaces, Windows 3.2 operating system (URL-2).

Though GUIs made it easier to operate computers, they limited the interaction to 2 dimensional visuals and a limited set of audials. Wellner et al, criticise the way of computing by these words: “..our computing takes place sitting in front of, and staring at, a single glowing screen attached to an array of buttons and a mouse.” (1993). They also mention that humans are in a deep relation with their surroundings, and they interact with the digital worlds through screens, and these two worlds do not

have much in common (1993). Wellner et al (1993) see augmented reality as a way to merge these two worlds and as a future of computing.



Figure 3.6 : One of the late examples of Graphical User Interfaces, Windows 8 for Mobile (URL-3).

Several researchers criticised interactions that leave out senses other than visual and audio. As stated above in ‘ubiquitous computing’ interaction takes place not just in desktop, but as a part of the space (Weiser, 1991). Weiser envisioned that the computers’ physical features will be hidden so that the users won’t need to deal with them (1991). According to Ishii and Ullmer, even though Ubiquitous Computing has an important place, it lacks thinking beyond Graphical User Interfaces (1997). They criticised that GUIs interfered the relation between the user to the real world as such: “The interactions with these GUIs are separated from the ordinary physical environment within which we live and interact.” (Ishii and Ullmer, 1997, p 234).

Similarly van Dam addresses GUIs’ most crucial restriction as its lack of interaction with the human sensory channels other than touch and vision. He mentions that human beings use their whole sensory system to interact with the world while in digital world keyboards and mouse workstations are a must for WIMP GUIs (2000). Van Dam claims that the ultimate goal of HCI researchers should be creating natural ways of interaction that suit human features (2000).

3.2.2 Tangible user interfaces (TUIs)

Human beings not only gather information from what they are focused on, but they also gather information from their surroundings. Though GUIs were a solid base in

Interaction Design, limiting interaction into a little screen is not a righteous vision because it leaves out the opportunities of the flexibility the digital world offers, and also it restricts the bodily interaction by only having visual and audio representations of the digital world. On the other hand TUIs offer new ways of interaction by trying to consider all the human senses and abilities and answer related needs in the designing process. Hiroshi Ishii and Brygg Ullmer from MIT Media Laboratory, explains the world of GUI era by these words:

Current GUI-based HCI displays all information as “painted bits” on rectangular screens in the foreground, thus restricting itself to very limited communication channels. GUIs fall short of embracing the richness of human senses and skills people have developed through a lifetime of interaction with the physical world. (1997, p 240)

Ishii and Ullmer also indicate that people stand in between of two worlds: physical world and digital world (1997). Although GUIs seem to meet basic task needs, they restrict the physical interface into 2-D digital surfaces. They force people to use just a limited selection of their senses, while humans have peripheral cognition along with other senses, and abilities. Ishii (2008b), states that “However, when interacting with the GUI world, we cannot take advantage of our evolved dexterity or utilize our skills in manipulating physical objects (such as building blocks or clay models)” (p. 32). Ishii also criticises the GUI era as the only connection to the digital world is just through small pixels and flat screens (2008a). Ishii and Ullmer mentions historical instruments that our ancestors use to measure time, or investigate the sky, and how these artifacts were made from brass and oak, all before the invention of a computer (1997). They state:

Through grasping and manipulating these instruments, users of the past must have developed rich languages and cultures which valued haptic interaction with real physical objects. Alas, much of this richness has been lost to the rapid flood of digital technologies. (1997, p234)

Their argument is important for making sense of the reasons behind the damages in body-product-space relationship such as sensory diversity loss.

With the recognition of these limitations and developments in computer science, several researchers investigated ways to enrich the digital experience, and to bridge the physical and digital worlds. According to Shaer and Hornecker, one of the first works dated back to 1995 and was Fitzmaurice et al’s Graspable User Interface (Figure 3.7) in which he uses wooden sticks to manipulate graphical objects (2010).

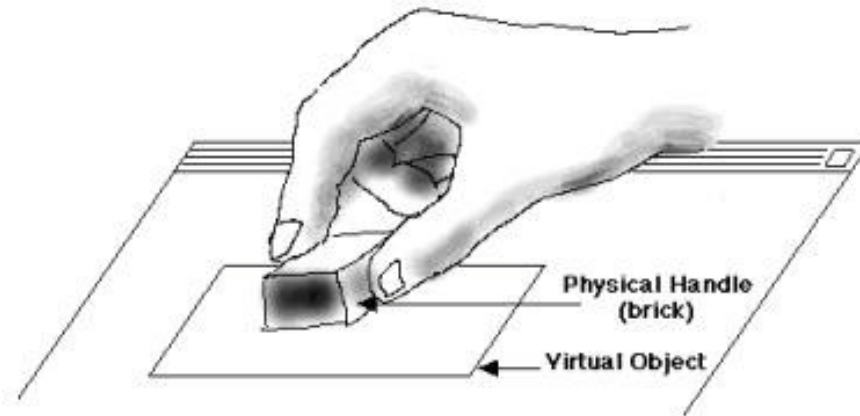


Figure 3.7 : Graspable User Interface (Fitzmaurice, Ishii and Buxton, 1995, p. 42).

2 years later Ishii and Ullmer came up with the idea of Tangible Bits, and their Tangible User Interfaces (TUIs) vision was to match bits to atoms, digital information to everyday objects and environments (1997). Shaer and Hornecker explain the shift from graspable to tangible as; “Whereas “graspable” emphasizes the ability to manually manipulate objects, the meaning of “tangible” encompasses “realness/sureness”, being able to be touched as well as the action of touching, which includes multisensory perception:” (2010, pp 8-9). All these visions predict an interface in which humans can use their senses and abilities completely, and have similar-to-real-life virtual experiences as indicated Table C.4 Unlike GUIs using limited senses and restricted surfaces, TUIs suggested body experiences in everyday environments. Thus it is possible to say that TUIs recreated 3d interactions.

Ishii explains that being able to alter the digital data physically, and to perceive it through peripheral senses is a key concept for TUIs (2008b). He explains TUIs’ main purpose as allowing humans to use digital technologies to collaborate, make decisions and learn without losing the benefits of being able to grasp and manipulate real physical artifacts (2008b)

With Tangible User Interfaces, the aim is to represent digital information with physical artifacts in which the digital model will change when the tangible model changes (Ishii, 2008a). Hiroshi Ishii, one of the minds behind Tangible User Interface, repeatedly mentions his childhood abacus as a well-designed TUI (1997, 2008a). One of the reasons behind Ishii marking a non-digital abacus as a TUI is its simplicity. Even without a written description, anyone can understand the capabilities of an abacus. Another reason is its ability to have both of

the tangible and intangible domains. Both input and output is created with beads and rods which symbolise ones, fives, tens, hundreds according to the need (2008a). It is possible to say that with abacus a broad selection of numeric quantities can be calculated through a limited physical quantity. In TUIs imaginary world, digital or analog, can be expressed through physical objects rather than intangible, physically non-existent graphics.

Game consoles with the capability of movement tracking are valuable consumer products with tangible user interfaces. In Figures 3.8 to 3.10 three leading game consoles' with movement tracking can be seen; Nintendo Wii Fit, Xbox Kinect and Playstation 3 Move. Though each has the ability to track movements and requires bodily interaction with the users, each has a unique way to recognize movements. In Nintendo Wii Fit (Figure 3.8) body movements are recognized through the balance board. The players should step up on the board to play games or exercise.



Figure 3.8 : Nintendo Wii Fit (URL-4).

In Xbox Kinect (Figure 3.9) there is no need for a board or a stick to be able to play games or exercise. Its camera is able to track body movements and execute actions according to these moves.



Figure 3.9 : Xbox Kinect (URL-5).

In Playstation 3 Move sticks with lightened ends are used to track movements (Figure 3.10). The joysticks have several buttons to execute actions in the menu, and they have to be adjusted before each game.



Figure 3.10 : Playstation 3 Move (URL-6).

These examples show ways to use tangible interfaces other than work related interfaces and also indicate that movement tracking can enhance entertainment. Though TUIs create new possibilities to interact through/with digital technology, connecting digital information to physical artifacts has its own limitations as a result of physics. As mentioned by Ishii (2008a) while it was possible to manipulate the pixels of GUI, it is not quite possible to manipulate tangible bits of TUIs. Physical features of existing materials do not allow fast – and in most cases efficient – changes like changing the color, shape, size etc.

3.2.3 Next generation user interfaces

With the developments in material, biological and programming technologies, scientists are able to overcome the limitation of GUIs and TUIs. Several Labs including MIT Media Lab are working on creating new and more innovative ways of interaction. The inventors of TUIs, Tangible Media Group of MIT, name this new concept as Radical Atoms, while there are some other research under the names; kinetic user interfaces, organic user interfaces etc. Next generation of user interfaces offer interactions that are integrated to daily life in a more subtle way by showing the cause and effect relation more explicitly. These interfaces include shapeshifting opportunities, non-digital biological implementations, and touchable mid-air holograms along with many others.

Lakatos and Ishii (2012) explain physical restrictions like the rigidity of real life objects in contrast to the wide range of digital fluidity can cause inconsistency between TUIs and the digital models. With the emerging technologies in other fields like nanotechnology, material etc., Lakatos and Ishii offer a new way of interaction to overcome the restrictions of TUIs as such:

To address this challenge, we presented our new vision, “Radical Atoms” [1]. Radical Atoms take a leap beyond Tangible Bits by assuming a hypothetical generation of materials that can change form and appearance dynamically, becoming as reconfigurable as pixels on a screen. Radical Atoms is a computationally transformable and reconfigurable material that is bi-directionally coupled with an underlying digital model (bits) so that dynamic changes of physical form can be reflected in digital states in real time, vice versa. (Lakatos and Ishii, 2012, p. 37)

To investigate and overcome the limitations of GUIs and TUIs, Coelho and Zigelbaum (2011) used shape changing interfaces such as mechanically supported shape changing surfaces. They claim the limitations of both virtual and physical world affect the solution for real-time shape changing interfaces as such:

Digital surfaces are unconcerned by gravity, construction, and traditional distinctions between surface and structure. In the physical world, things are quite different and physical surfaces are constrained by their topological and material imitations, as well as external forces such as gravity and user control. (Coelho and Zigelbaum, 2011, p. 166)

They also claim that an interface which designers can manipulate both physical and digital entities to create 3-dimensional models is not a hard-to-imagine futuristic vision (Coelho and Zigelbaum, 2011).

Another example of next generation interfaces indicates the integration of technology and human body for a multisensory HCI experience. In 2015 MIT Media Lab presented several projects to support their vision of Radical Atoms. *BioLogic* is a project where they collaborated with researchers and scientists from fields like art, design, science and engineering. In their official website, they state:

bioLogic is growing living actuators and synthesizing responsive bio-skin in the era where bio is the new interface. We are Imagining a world where actuators and sensors can be grown rather than manufactured, being derived from nature as opposed to engineered in factories. (URL-7, 2015)

Under the *bioLogic* research, the team developed “Second Skin” clothing (Figures 3.11 and 3.12), in which the fabric acts according to the wearer’s sweating conditions with the help of living bacteria that bio-printed to the fabric through nanotubes.



Figure 3.11 : Second Skin (URL-7).



Figure 3.12 : Second Skin when under humidity (URL-7).

Figure 3.11 shows how the fabric acts when first worn, the ventilation parts are closed. In Figure 3.12 dancer is seen after performed her choreography and as with

the action her body is warmed up, and the ventilation parts are opened. The team explains that the same technology can be used in other areas as such:

bio-hybrid flowers blossom and wilt reversible with both shape and color changing; a living tea leaf signals through transformation when the tea is ready; or a lampshade sculpts light activated by the light bulb. Imagination unfolds the power of the tiny bacteria. (URL-7, Retrieved November 2015)

Another project that highly adaptive and responsive like Second Skin, as indicated in Table C.3 is held under MIT Tangible Media Group named *LineFORM* which presents a multi-purpose interaction device. While Second Skin uses organic intelligence to adapt, this project consists of a line-shaped product that can transform itself into other shapes and fulfil different user needs. This line consists of series of tiny servo motors (Figure 3.13), that in collaboration they can create different shapes (Figures 3.14 to 3.17).



Figure 3.13 : LineFORM consisting of tiny servo-motors (URL-8).



Figure 3.14 : LineFORM creating a surface (URL-8).

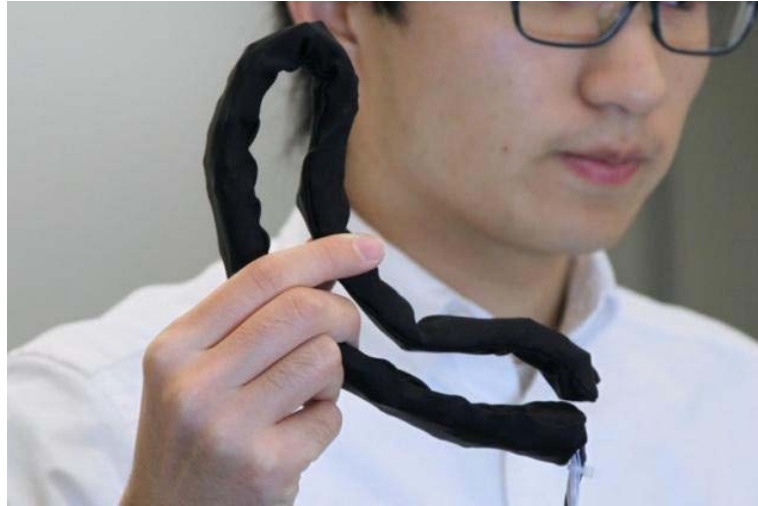


Figure 3.15 : LineFORM in the form of a phone (URL-8).



Figure 3.16 : LineFORM in the shape of a lamp that can be adjusted through its body instead of buttons (URL-8).



Figure 3.17 : LineFORM as a preprogrammed fitness tool (URL-8).

While Second Skin and LineFORM interfaces are adaptive and communicative at high levels, as indicated in Table C.1, another variation of possible next generation interaction is the Digital Nature Group's *Fairy Lights in Femtosecond* (Figure 3.18) project. Though this interface offers relatively low level of manipulation among its peers, this project actualises having a non-material but touchable interface. In this project the team managed to create mid-air touchable holograms that are not harmful to human body. This project offers the future possibility of creating half digital and half physical objects that can be projected or hidden as wished.

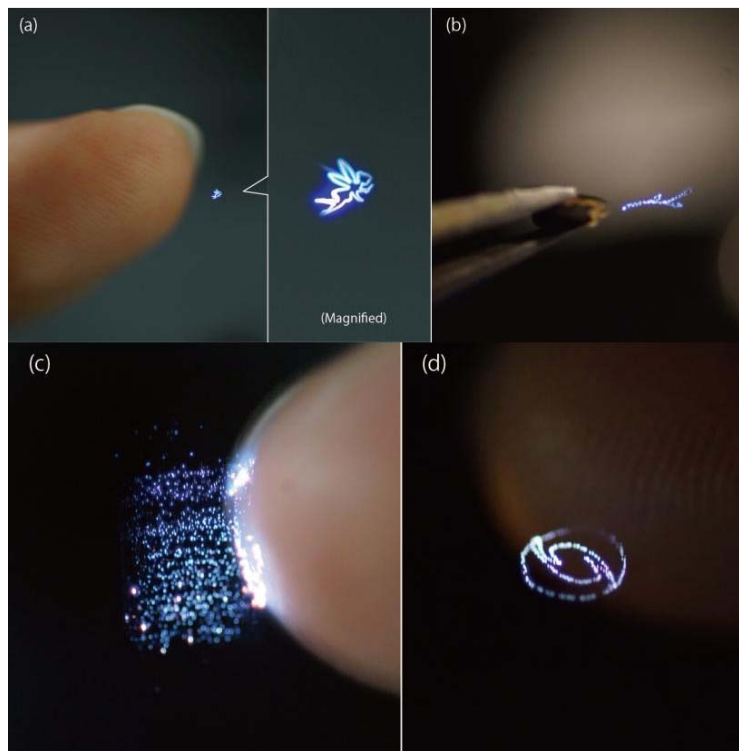


Figure 3.18 : Fairy Lights in Femtoseconds (URL-9).

These examples with many others under development, indicate more organic and natural forms of interaction and products, thus designing principles. Industrial design of a shapeshifting product would require different principles and processes than a static product, or with the emerging interfaces using real life organisms can be seen as a way to create interactive and responsive products. The restrictions on the physical representations of interaction are becoming easier, thus all the related fields that changed during the emergence of ICTs may change again.

3.3 Being ‘Smart’ in Virtual World

ICTs introduced new dimensions when first emerged: a virtual world where people can execute actions without the restrictions of the physical reality. While there was a limited set of possible actions, researchers are developing entities equivalent to human mind, to enhance the uses of the digital world.

Today most of the commercial products and even buildings are named as ‘smart’. Even though many different objects can be addressed under the name ‘smart’, how many of them are truly smart mediums is questionable because receiving information and acting through preprogrammed routes is not showing intelligence. In this thesis it is argued that a truly smart entity (mechanical, organical or digital) should have organic abilities such as adapting, thinking and improvising.

While creating intelligence is a critical topic in computing world, the physical presence of this intelligence also has importance. Digital world and physical world are merging into each other with new UIs thus reality is being manipulated. Researchers work on creating alternated realities, along with ways to manipulate reality by enhancing and diminishing entities digitally.

3.3.1 Alternative realities: Virtual reality, augmented reality

Though vision is preliminary in contemporary life, humans perceive and learn the world through their body (Pallasmaa, 2005; Kirsh, 2013). Vision can be misleading without the support of other senses, and this perception deficit brings the opportunity to create alternative realities and trick human mind. Virtual reality can be considered as digitally produced alternative reality. With the help of binoculars like Oculus Rift (Figure 3.19) etc. users are shown different realities. These systems are mostly used for entertainment purposes, while there are some simulation systems used by military for training purposes and by NASA for investigating planet surfaces virtually. Though the concept of creating virtual worlds was popular for the first years of computers, the lack of sensory diversity withheld the widespread use of these technologies, there are some researches to develop a multisensory virtual reality experience.



Figure 3.19 : Oculus VR Headset (URL-10).

Oculus Virtual Reality Headset can be seen in Figure 3.19, which is used by gamers to enhance the entertainment. Though VR has advantages for limited durations such as opening up new dimension, in long uses the disconnection of visual and bodily perception is uncomfortable as it causes conflicting feedback.

With the limitations and the unnatural interactions virtual reality offers, researchers investigated ways to implement digital entities into physical world. Augmented reality is intersection of two different worlds; virtual and real. Real life is embedded with information, and with the designed tools like HoloLens (Figures 3.20 and 3.21) and Google Glass (Figures 3.22 and 3.23), it is possible to interact with these virtual entities.

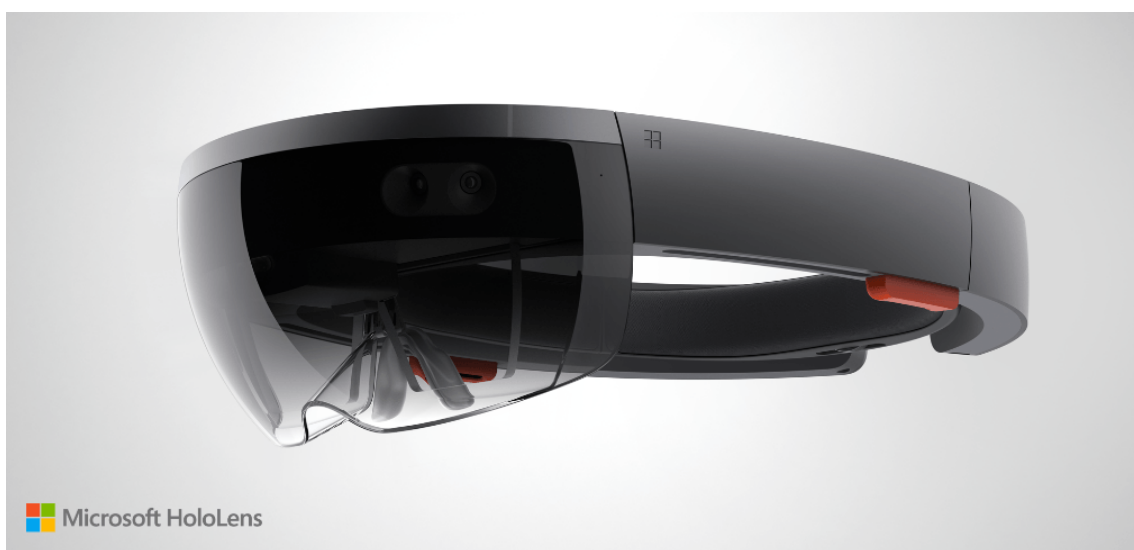


Figure 3.20 : Microsoft HoloLens (URL-11).



Figure 3.21 : Suggested Interface for HoloLens (URL-11).

HoloLens headsets offer bodily interaction with the surroundings. Though it is possible to act in the physical world with digital entities, HoloLens' presence is close to VR headsets, it interferes with the natural perception.



Figure 3.22 : Google Glass (URLs -12&13).

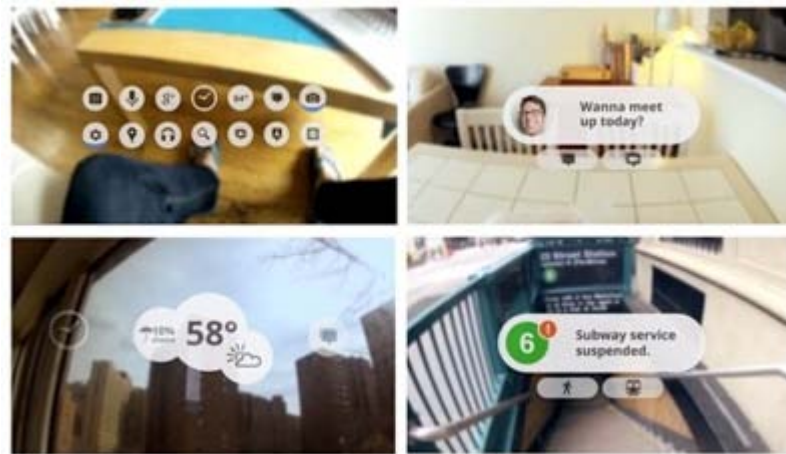


Figure 3.23 : Suggested interfaces for Google Glass (URL-14).

Similarly to HoloLens, Google Glass is adding entities in physical world. The suggested interfaces show 2-dimensional graphics in contrast to HoloLens' 3-dimensional model embedded interface. Also as indicated in the Table C.2 HoloLens is superior to Google Glass in the areas of adaptivity, being responsive and manipulatable, as HoloLens offeres whole body interaction while Google Glass acts according to eye gestures and movements.

It is possible to claim that these technologies are now in the enthusiast stage, which means they are still under development. It is also possible to claim that, when ICTs first emergence taken into account, these technologies are in a phase that their physical presence is close to plastic boxes, and with developments in related fields it is possible suggest that their physical presence will become more natural.

3.3.2 Creating “smart” mediums: Artificial intelligence, ambient intelligence

It is possible to say that something ‘smart’ has the ability to detect variables in a situation and to act intelligently according to these variables. In the washing machine case, the machine detects the load then adjusts the water level to avoid waste. Even though a washing machine is defined as smart because of its ability to weigh the load, it is pre-programmed to specific situations and this raises a question: Is it truly acting smart when all the possible activities are pre-defined?

As Haque (2007) mentions this kind of a system/machine has limited information, and people choose what suits their needs most. He claims that this information/data exchange has very little connection to a real conversation because choices are very

limited. He adds that in a system like that “...nothing novel can emerge, because all the possible responses are already programmed.” (Haque, 2007, p.58).

In his book, Kaku (2011/2015) briefly explains Artificial Intelligence’s (AI) history while noting the failed predictions. He claims in every thirty years AI field is improving, and gaining importance. The concept of AI was first introduced in 1950s, scientists claimed that computers will be able to solve problems, play chess etc., but the designed systems were much less capable than humans. In 1980s, AI field gained popularity, and though in late 1990s IBM’s Deep Blue – an AI that plays chess – won a game against the world champion, the lack of real intelligence was obvious (Kaku, 2011/2015). Similarly Nick Bostrom (2014) mentions the false predictions about the breakthrough developments in AI field, and gives some explanation to the ‘a couple decades’ time phenomena as ‘a couple decades’ is enough for seeing possible outcomes of a technology. He also mentions that even though the predictions fail about timing, the idea of having an AI which outcomes human intelligence is not a dream (Bostrom, 2014).

Donald Knuth, computer scientist, states “AI has by now succeeded in doing essentially everything that requires ‘thinking’ but somehow failed to do most of what people and animals do ‘without thinking’ – that, somehow, is much harder!” (as quoted in Bostrom, 2014, p.14). Also Michio Kaku (2011/2015) addresses two main problems while explaining the repeatedly failure of predictions about artificial intelligence; first is AIs’ inability to recognize patterns, second is they don’t have common sense. These arguments support the hypothesis that an AI, a truly ‘smart’ machine should be able to adapt, improvise and think subconsciously; not because it is programmed to do so, but as a result of its nature.

As mentioned by Bostrom (2014) there are several approaches to design a superintelligence, though they are not the subjects of this thesis. The important point for this thesis is that an artificial intelligence – in the means of something adaptive, learning, thinking on own – is possible. Even though this goal is not fulfilled right now, with the developments in the field, it can be said that research in this direction is vastly growing. Also as explained by Bostrom (2014) there are several AIs already embedded into daily life; speech recognition, face-gesture recognition, gameplay, medical assistants, industrial robots, personal assistant AIs that can answer simple

questions. Also there are several AIs that can learn from users' habits and interests, and guide users through the Web according to their needs (Bostrom, 2014).

Though AIs are most basically softwares, they meet users through a broad selection of mediums. Smart portable devices like phones and tablets host assistant softwares that are able to chat and even tell basic level jokes, while there are some embedded AIs into the web – mostly in search engines – that are able to learn from the user's interests.

While the host is mostly an object or a commercial product, with the emerging technical developments in sensors, cameras and actuators it is possible to create digitized environments. A digital environment should be able to assist people in a subtle but sensitive way, it should understand whether the user really needs help, or if she/he wants to be left alone with the task (Augusto, 2010).

It was explained in this chapter that with the computers and computer supported products entered homes, and became embedded in a wide range from basic systems like anti-theft alarms, fire alarms to more complicated systems like health tracking systems, the field of ambient intelligence emerged. Augusto (2010) states “Basically an AmI system has a real environment and occupants that interact with that environment in some typical way for that combination environment/occupants.” (p.6) when explaining the basic structure of ambient intelligence. Similarly Ramos et al (2008) states that “Basically, AmI refers to a digital environment that proactively, but sensibly, supports people in their daily lives.” (p.15).

There are several techniques and technologies to achieve ambient intelligence, such as Internet of Things (IoT), Machine-to-Machine (M2M) connection and sensor technologies. The IoT is about creating a network of objects that can be manipulated from distances while M2M is about making it possible for machines to communicate with each other. Feki et al (2013) explains the IoT as such:

The term Internet of Things (IoT) describes several technologies and research disciplines that enable the Internet to reach out into the real world of physical objects. Technologies like RFID, short range wireless communications, real-time localization, and sensor networks are becoming increasingly pervasive, making the IoT a reality. (Feki, Kawsar, Boussard, & Trappeniers, 2013, p.24)

One of the commercial IoT systems is PHILIPS' Hue system (Figures 3.24 and 3.25), which gives the users the ability to manipulate the lights in their homes from

anywhere with an Internet connection. It is possible to change the light colour to any colour from spectrum, or set lights to show the weather, or program lights to change when a mail comes. This project offers subtle ways to exchange data, and possible ways to adapt and change interiors according to human needs and feedback.



Figure 3.24 : PHILIPS Hue System (URL-15).

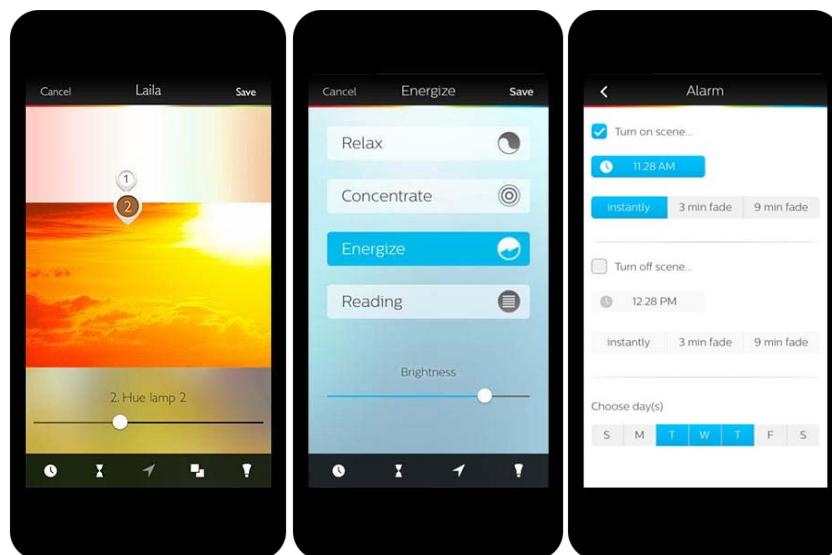


Figure 3.25 : Mobile App of Hue (URL-15)

Another commercial IoT product is Amazon Echo (Figure 3.26), a speaker named Alexa that respond to voice commands. This speaker device can be connected with many mobile devices and applications through internet. It can communicate with the

household items and notify the owner about supplies, so it is possible to claim it works as a personal assistant.



Figure 3.26 : Amazon Echo, ‘Alexa’ (URL-16)

As shown in Table C.2 all these examples indicate an awareness of the user, while suggesting ways of communication with the environments.

3.4 Interaction Design: Sci-fi Visions

In the movie series of Ironman (2000s series), Tony Stark aka Ironman has a personal assistant/companion called J.A.R.V.I.S. (Just a rather very intelligent system), which is an artificial intelligence that has the common sense and ability to answer the needs of Stark like a human being. While with the existing technology it is not possible to build such an AI and embed it to a space, many concept projects are developed to create smarter spaces or merge digital entities in the physical space. Shedroff and Noessel (2012) mention that sci-fi literature and media affect the developments of user interfaces as this literature and media offer possible ways of physical interactions. They investigated science fiction movies for interfaces and evaluated these user interfaces according to their relevance to technological developments. It was explained that technology and science fiction has a circular relationship as in the means of technology being the actuator and the science fiction being the dreamer (2012). In this section very few examples will be given as possible interaction ways that might become real with the developments in ICTs.

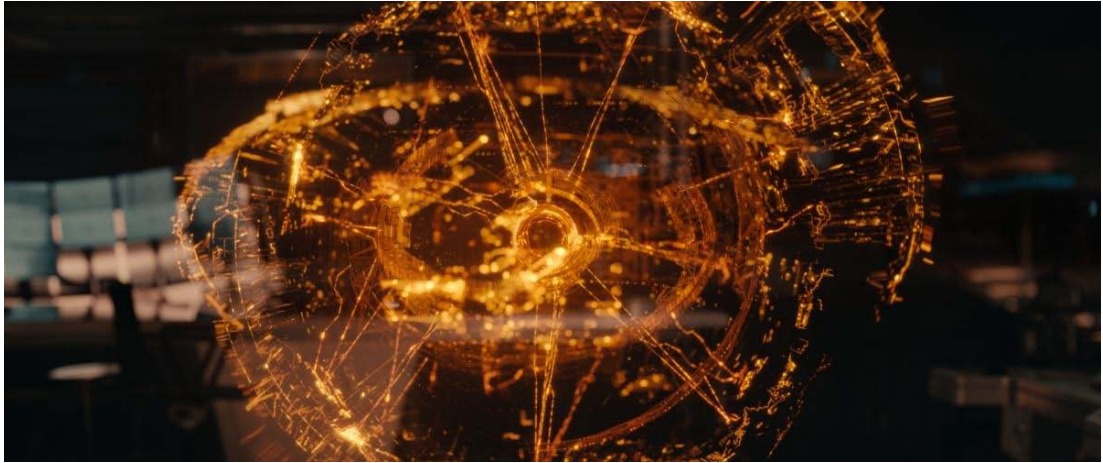


Figure 3.27 : Representation of J.A.R.V.I.S. from the movie Avengers: Age of Ultron (URL-17)

As mentioned above JARVIS (Figure 3.27) is an Artificial Intelligence that manages Stark's life as a real life assistant. It has the ability to improvise under emergency situations. It can track health and manage contacts along with the ability to use the industrial devices inside the mansion. It can be seen as a being that mastered the Internet of Things and Machine to Machine communication along with the capabilities of human intelligence. JARVIS acts both like a user interface and an artificial intelligence. Its relation with the surrounding space is much higher than its peers and though JARVIS cannot be seen as physical entity, the mansion stands as its limbs.



Figure 3.28 : A Holographic Interface from the movie Tron Legacy. (URL-18)

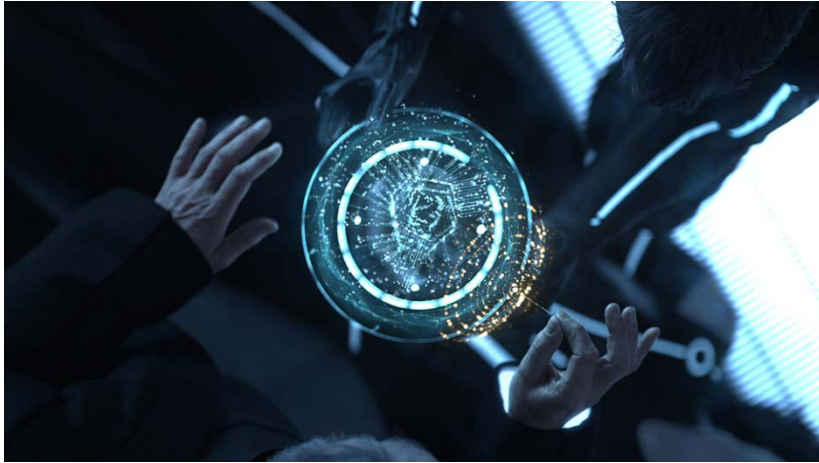


Figure 3.29 : A Holographic Interface from the movie Tron Legacy. (URL-19)

Another possible way of interaction is the Holographic Interface from the movie Tron: Legacy. It can be seen in Figure 3.28 and 3.29 that it offers direct manipulation of digital entities without the need of a specific design. Though it is possible to claim that this interface is in the Grid which is the actual digital world, and as a result of being in the Grid its manipulability cannot be achieved in real world, it is also possible to claim with regard to Fairy Lights in Femtoseconds project (Figure 3.18) which is a way of creating a touchable holographic entity, this interface can be achieved with further developments in the field. What this interface offers is being location-free. The needed interface and the information can be reached anywhere, there is no need for a specified environment.



Figure 3.30 : Interface from the movie Minority Report. (URL-20)

Another interface influencing the environment is the user interface from the 2002 movie Minority Report (Figure 3.30). This UI shows a way to manipulate digital entities with gestures and movements. It acts as a big window to digital world where

the mediums are not placed statically. In today's technology the digital representations of videos, songs and any other dynamic entity are static figures in computers. In contrast it can be seen in the movie that these digital entities are represented by their own dynamics even when they are not the subject of the user. Though this interface offers high levels of digital manipulation, it is strictly location-based.

All these movies with many other science-fiction movies, suggest ways to interact with technology even the technology mentioned is not available at the time. It is possible to claim that this movie genre is a way to imagine future and with the developments in ICTs and related fields this genre's offering gain importance.

4. PRODUCT DESIGN, ICTs AND INTERACTION DESIGN

As stated by Hight and Perry (2006) shifts in the economy, industry and technology affects the dynamics of product design world. They state about the effects of changes in these fields as such:

With the shift from the second machine age to that of information, the reflexive network has replaced the assembly line as a pre-eminent model of organisation even as media infrastructures have augmented physical transportation at multiple scales stretching from discrete sites of production and consumption, to economic, political and even social institutions. This nexus of computation, telecommunications and new organisations of economic and political power suggests that the 19th-century division of design into distinct professions might now be displaced by different organisations of knowledge and practices. (Hight and Perry, 2006, p.5)

ICTs came with paradigm shifts. The flexibility of virtual world affected design and related fields such as society, industry and economy. Frazer (1995) states about these shifts as such:

The emphasis has moved from product to process as Buckminster Fuller, John Cage and Marshall McLuhan all foresaw: and it has moved from forms, to the relationship between forms, to forms in their environment, to the relationship between forms and their users. (Frazer, 1995, p. 79)

With the emergence of ICTs and computers new ways of interactions became possible, and with developments in many product related fields these products and interactions altered or vanished. In order to get a grasp of this changing landscape, historical changes in product design is investigated. Also the changes in ICT embedded products is investigated with a brief history of these products' physical forms.

4.1 Designing Products: From Craftsmen to Makers, ICT related developments

While history of industrial product design began with Industrial Revolution, humans designed and manufactured objects for centuries. Before the game-changing

innovations of Industrial Revolution, mass-production and global business corporates, craftsmen were designing and manufacturing objects.

With industrialisation mass-production became possible as faster and cheaper manufacturing methods developed (Heskett, 1980). Mass-production brought the opportunity to create affordable designed objects for the masses, in contrast to crafting. It takes long time and effort to create a crafted object while with mechanisation it is possible to manufacture faster and cheaper. As a result of mass-production countries began to create new business models such as multinational corporates. With globalisation and world-wide transportation it became possible to have the same object at different locations on earth. It is possible to claim under the light of these arguments location lost its importance. Also manufacturing and possessing a product became more affordable and accessible.

On the contrary to increasing accesibility of products, uniqueness lost importance as it is impossible to mass-produce one-of-a-kind products. While crafted objects were site-specific, mass-produced objects were designed to answer the crowd's needs instead of individuals'.

Another change industrialisation brought into life is specialisation of knowledge. While in pre-industrial era, an object is made by a craftsman who knew all the techniques and details related to it, in industrial era an object is designed and manufactured by several people who have special knowledge in their own field. This resulted in collaboration between professions while bringing the opportunity to generate deeper knowledge in each field. While these were important innovations for the time, in time they resulted in an unholistic approach in productions as each field became more related to solve inner problems rather than creating a holistic approach. These drawbacks of knowledge specialisation are overcome as the ICTs emerged and Internet entered daily life, the Information Age began.

With the emergence of internet related social media channels such as Facebook, Youtube, Pinterest, Instagram and Twitter, individuals became the source of information. Also with online shopping stores such as Etsy it became possible for individuals to create virtual stores to sell individually produced goods. With the developments in the virtual world, individuals gain importance and they are offered with set of tools to fulfil their goals.

Internet is a big source of data. It creates a cultural flow worldwide with the social media platforms and developing websites by growing and gathering data from anyone in anywhere linked to internet (Mau et al, 2004). Other than offering the ability to create digital representations for individuals, internet also offered platforms for communities. Open-source community, as mentioned by Bonanni et al. (2008), “... depend on transparency and shared platforms to foster collective projects to resolve social needs.” (p. 2554). Individuals with similar goals can meet, and share their knowledge, which results in producer individuals. For example Stangler and Maxwell (2012) list some examples of DIY society and explain what this new realm brings to life as such:

... Each of these examples, quintessential embodiments of the new production economy, is marked by three concepts: a culture of DIY, new learning and teaching of knowledge, and the democratization of technology – and indeed of production and entrepreneurship. ...

... the concept is clear: activities like inventing, innovating, and starting a business are not reserved for a special set of “others” but are in the realm of you and me. One need not to be an expert to create something, and this shift in attitude and culture is one of the resounding lessons these programs are teaching us. In this sense, there is a very rich human element. (Stangler and Maxwell, 2012, p. 8)

Internet and related content changing the business models, while there has been a strong relationship with business and industry, it is possible to claim that industrial product design is also changing. Mau et al (2004) states on this changing landscape as such: “Prosumer: With the proliferation of digital networks the world over, the electronic marketplace has gone from empowering the consumer to supporting a global civic society. Power to the people.” (p. 139). The disadvantages caused by industrialisation are eliminated with the developments in ICTs.

Another result of widespread internet use is Makers Movement. As knowledge sharing and open-source community grown bigger day by day people began to create objects by learning from individuals on the internet. With easy-to-use programming platforms such as Arduino and Rapsberry Pi, it became possible for individuals, who don’t have detailed information about programming and electronics, to design responsive electronics. Thus interested individuals are now capable of creating objects.

Other than internet’s big influence on product-related processes, design procedures are affected with the development of 3d printers as they became affordable by

crowds. It became possible to customize a design without spending too much time and money on it. With relevance to open-source movement, 3d model libraries such as Tingiverse, Pinshape and Cubify emerged, and with the free models they offer along with one's personal ability to create digital 3d models, individuals with 3d printers became capable of producing and designing objects.

All these developments in knowledge sharing, personal online stores and manufacturing techniques offer customisation tools for individuals more than any time in history. Green (2007) explains the future of design as such: "In terms of how we interface and interact with the future, the implication is that it will be less about predicting it more about collaboratively designing it. The future will emerge through interaction and co-creation." (p.48).

In regard to mentioned developments and concepts in ICTs, it is possible to claim that the nature of product design is changing. As end users' involvement in designing process along with the ability of shaping and reshaping the product according to need increase products become more adaptive and customised. While ICTs brought changes to the nature of Product Design as a field, they also created a big industry when they first emerged. With the advancements in ICTs the physical presence of ICTs, products of this big industry, is also changing.

4.2 From ICT Dominant Products to Products with ICTs

ICTs entered daily life through products and offered new types of products, such as computers, mobile phones and headsets. While the first generation of these products can be mostly defined as plastic boxes, with the developments in new materials and manufacturing methods fields they altered. Advancements in touchscreen technologies along with advancements in electronics cause changes in the physical presence of products. While the first ICT embedded products were under the restriction of the technology, with the developments in the field many of these products vanish or merge into long-existing products such as watches.

PHILIPS Design's High Design vision explains these changes. While Stefano Marzano worked as a CEO in PHILIPS Design, he and his team came up with several futuristic ideas about technology and its use in domestic environments. He says that the future of human race is not determined by the technology but by the

choices people made about how to use it, and he also adds that the future is not free of outer impacts and people who are capable taking responsibilities and making decisions can alter it. (Marzano, 1999) It is also mentioned in the same book that designers and decision-makers have to merge technology into domestic spaces appropriately in order to have a house serving system that is not frightening its owners.

As stated by Marzano, in 1991, the company had an exhibition in Berlin, which is called *Ambiente Electronica*, which included several virtual environments and products. Marzano explains that these environments and products has a mutual feature about adding nobility to the house, making it more enjoyable, recreative and delightful, which aids developing a pleasant environment of communication and information, tranquility, safety and self-awareness. (1999)

Marzano argues that as a result of the limitations in processing materials, domestic environments are under the dominance of ‘grey and black boxes’, and these boxes will be penetrated into the environment. He states, there are some items, which are closely related to human life that have been around for centuries. Most basic items from these are chairs, tables, walls, and roofs etc. He emphasizes that the primary shape of these items have not changed through centuries and it will not change in the future, as these are answering basic human needs. He mentions that although a need for the basic functions of technological devices exists regardless of time, their physical attributes don’t suit human needs, as they happen to be boxes. He claims that in the future technological devices will be combined with the objects that human race own for centuries (Marzano, 2003).

These arguments became ground zero for a futuristic design perspective, which Marzano named as ‘High Design’ (Figure 4.1). Marzano (2005) states the main principle of High Design in these words: “...High Design focuses on people, from start to finish.” He, then, explains three other crucial features; being research based, including new skills, integration into the business process (Marzano, 2005, pp 65-66).

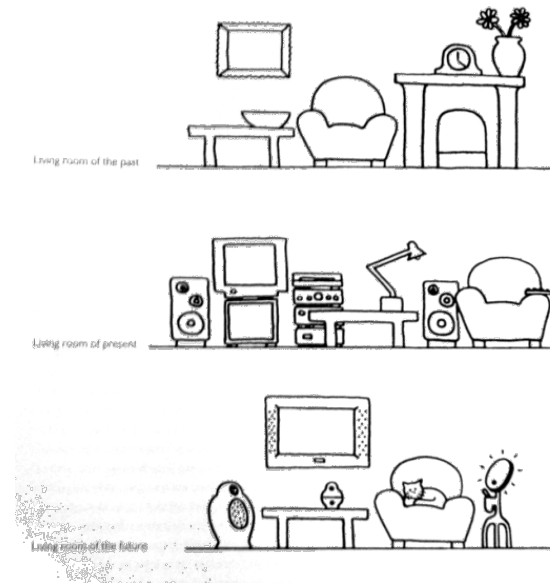


Figure 4.1 : High design sketch (Marzano, 2005).

In Figure 4.1, which Marzano drew as a part of High Design perspective, it is possible to notice the simpleness of objects in past and future visions, and it is also possible to notice the complexity as a result of dominant technological ‘boxes’. Marzano states “...in advanced societies the living space of the future could look more like that of the past than that of today.” (2003, p9)

4.2.1 Computers, mobile phones and touchscreen technology

Computers first entered homes through big boxes with screens, keyboards, mice and many wires. The physical representation of the digital world consisted of buttons, wires and screens. With the developments in user interfaces, manufacturing methods and emerging technologies such as touchscreen and motion detection, the physical representation of ICTs change. The impact of this change can be traced through computers and mobile phones.

Figures 4.2 to 4.4 show the changes in desktop personal computers physical attributes from 80s to today, while Figure 4.6 shows the milestone portable personal computers of IBM/Lenovo Company.



Figure 4.2 : One of the first personal computers, IBM 5150 dated 1980s (URL-21).



Figure 4.3 : Later example of PCs, from 1990s (URL-22).

It can be seen in these figures that first generations of computers are site specific, with several extensions in the space. On the contrary Figure 4.4 shows a new way of computing in which the physical device can be used both as a desktop PC and a tablet. It is possible to claim that through time physical aspects of the computers became more adaptive, thus it became possible to answer several needs in one device.

Figures 4.2, 4.3, 4.4 and 4.6 indicate developments in the physical presence of computers. While first generations of computers were bounded to a location as a result of hardware requirements, with technological developments latest generations can be used in various situations with ease. Also with the developments human-computer interaction is changing by gaining tactile features. In regard to these changes it is possible to claim that even though technical requirements restrict the

design of the product, some of these requirements lose importance with the developments in the related areas allowing giving priority to user needs. For example the first computer screens needed more space as seen in Figure 4.3 in which the screen covers the whole space over the computer case, while in the latest generations as seen in Figure 4.4 the screen and the case become one and can be easily carried around. This concept change increases users' ability to interact with the device under the users' preferences instead of technologies' restrictions.



Figure 4.4 : Latest example of desktop PCs with all-in-one concept (URL-23).

As quoted by Bruce Mau et al (2004), Bill Buxton (n.d) states about the interaction between humans and technology as such: “When we have problems interacting with technologies, it’s a direct result of our not having asked the right questions in the design process. To be effective, we must shift our focus from the techno-centric to the human-centric.” (p. 99). In Figure 4.5 several input devices can be seen. All these devices are experiments to create the best device to achieve qualified interaction for computer related tasks. As the ICT related tasks become varied, digital artefacts or their physical presence require different features. For example to sketch without loosing the flexibility of the hand one must use similar tools to centuries old pencils. Similarly as the tasks become complicated the need to use the physical capabilities becomes important.

All these arguments suggest that the physical existence of computers is changing with the touchscreen technology. While there have been buttons, wires and pointer devices, now many of these physical features are embedded in the touchscreens.

Similar to computers, mobile phones altered with the developments in related fields. Figure 4.7 shows mobile phone samples of each year's phones beginning from 1985 to 2015. It can be seen in the figure that mobile phones became smaller and screens eliminated buttons. Also it is possible to claim that new models are designed more aesthetically as they evolved from big black boxes with buttons on to simply products.



Figure 4.5 : “Assorted input devices, from the personal collection of Bill Buxton.”
(Mau et al, 2004,p. 98).



Figure 4.6 : Milestones of IBM/Lenovo Company's Portable PCs (URL-24).



Figure 4.7 : 30 years of Mobile Phones (adapted from URL-25)

Embedding touchscreens into the phones and tablets bring these devices new features suitable for entertainment purposes such as gaming and video playing. It can be seen in the Figure 4.8 that with the gained purposes screen size relatively grew bigger through time. Though this growth offered richer interaction with the digital mediums, physical existence of the device become harder to manage because of its size.



Figure 4.8 : iPhone's evolution from 2007 to 2015 (adapted from URL-26)

As mobile phones become multi-functional devices many other devices including wristwatches and headphones gained smart features to work in accordance with these mobiles. In Figure 4.9 Apple Watch can be seen, which can be adjusted according to

the needs and wishes of the user. Smart watches bring the opportunity to manage contacts, mails and mobile phone related actions without the actual need to touch the phone. It is now possible to call someone without even taking the phone out of the pocket. Under the light of these developments it is possible to claim that mobile phones are also vanishing or merging with other products, the basic action of a mobile phone can now be executed in other devices like smart watches.



Figure 4.9 : Apple Watch (URL-27)

All these examples show that ICTs are merging into life day by day and this merger is happening first through black boxes. With the developments in product related fields such as manufacturing, materials etc. these technologies take smaller space. This results in the incorporealisation of ICT related products which is supporting Marzano's (2003) vision that products will merge into surroundings and products that are essential or existed for centuries.

4.2.2 ICT embedded automobile: from radio to autonomy

ICTs entered the automobiles through the radio. Before computers, televisions and mobile phones became widespread radio technology was used vastly for entertainment and mass communication. While the first ever radio broadcasting dates back to 24th December 1906, first examples of radio mounted cars emerged in 1930s (Bull, 2004; Simaan, 1998). Brandt (2013) states that with the developments in the radio technology such as FM radio, Blaupunkt's AM-FM radio and explains the history of in-car music tools as such:

The progress of the car radio advanced with Chrysler and their music on demand radio system. This included a radio with a small turntable which started to be implemented in cars in 1955. In the 1960s the car radio advanced further with the transistor radio by Becker. In the 1970s the cassettes appeared and with them the first in-car cassette players. The music on demand concept continued to develop and in 1985 Becker introduced the first in-car CD player. This stable evolution of the car radio maintained its pace in the 1990s and 2000s with the LED display, the Radio data system (RDS), Bluetooth and even DVDs as a part of the radio. (Brandt, 2013, p.2-3)

As mentioned use of ICTs in the car began with radio, though later mechanical systems turned into electronical systems. With the integration of computers the complexity of the mechanical systems and the tools needed to adjust car features decreased. As a result the design of the ‘Center Fascia’(Figure 4.10) – which is in the middle of the Instrument Panel (Figure 4.11) (Kim & Han, 2014) – changed through time.



Figure 4.10 : Center Fascia (URL-28)



Figure 4.11 : Instrument Panel (URL-29)

In the center fascia there are several adjustment tools for air conditioning, radio and flashers. In the case of radio, for several years the radio was optional, which meant the user had to buy a radio and mount it in the designated area in the center fascia, though in the late years the radio system became a standart feature in automobiles. Figures 4.12 to 4.14 show examples of radio mounted car interiors from different decades.



Figure 4.12 : 1949 Porsche 356 interior, radio on the left (URL-30)



Figure 4.13 : Center Fascia of Opel Astra, 2000 (URL-31)



Figure 4.14 : 2014 Toyota Avensis Interior (URL-32)

As can be seen in Figures 4.12 to 4.14 the automobile radio evolved into a computer. While the first examples of center fascia are mounted with many buttons, it is possible to say that buttons are merged into the road computers in later examples. This change brings the opportunity to mount other driving tools for navigation, travel data observation and hands-free communication in the center fascia. Navigation tools help drivers without the need of constantly checking on the map, and verbally warns drivers when a turn is close or when the driver needs to slow down or change lanes (Figure 4.15).



Figure 4.15 : In-car navigation (URL-33)

With the integration of computers it became possible to observe travel data such as fuel consumption and average speed during the trip (Figure 4.16). Brandt (2013)

explains the relevance of these systems as such: “They [Vehicle Monitoring Systems] aim to provide the driver with accurate information about the status of the car as a whole, or individual components.” (Brandt, 2013, p.3)



Figure 4.16 : Tracking fuel consumption (URL-34)

Another change the computers bring into the car is the ability to communicate hands-free with the help of wireless technologies (Figure 4.17). As a result of the emerging dangers while using mobiles during drive, new ways of possible interactions are investigated. With the integration of computers into cars, it became possible to add new features such as wireless and bluetooth connections to enhance and secure the user experience.



Figure 4.17 : Hands-free talking (URL-35)

These innovations – navigation, travel data observation, hands-free communication – are now in the consumer stage. Recent developments in sensor technologies and user interfaces influenced designers and engineers to create future concepts. While augmented reality tools are used for enhancing driving experience and security, artificial intelligence methods such as machine learning and machine to machine communication are used for creating self-driving, self-parking thus automated cars.

AR technology can be used for creating a subtle environment that can inform and interact with the driver. Head-up Displays are extensions of AR technology, in which the windshield is added with relevant data. Figures 4.18 and 4.19 shows some example user interfaces for Head-up Displays.



Figure 4.18 : Head-up Display Interface Concept (URL-36)



Figure 4.19 : Head-up Display Interface Concept (URL-37)

Another ICT related concept is the autonomous cars. While machine learning and vehicle to vehicle communication self-parking cars are in consumer stage, self-driving cars are under development. Brandt (2013) explains the importance of vehicle-to-vehicle communication as such:

This not only plays an important role for the avoidance of rear-end collisions, but also in situations when the driver does not have a clear overview over the traffic situation, e.g. at highly frequented intersections. While the driver's attention is by nature restricted, V2V systems can sense threats and hazards with a 360 degree awareness of the position of other vehicles and the danger they present. They are also regarded as an important step towards reducing the danger from ghost drivers. (Brandt, 2013, p.5)

In their official website Audi states that their vision is to create a digital assistant to support the driver during the trip (Audi, n.d.). Autonomous car concept comes with several questions about what will the driver do when it's on auto-pilot, or what will be the future of transportation without the need for drivers. Though autonomous cars are under development stages, researchers and UI designers are investigating the possibilities. Figure 4.20 and 4.21 show some of these possibilities.



Figure 4.20 : Self-Driving Car Concept (URL-38)



Figure 4.21 : Self-Driving Car Concept (URL-39)

In both concepts the time during the drive is taken as a leisure time for the drivers. Each Figure (4.20 and 4.21) gives the drivers the opportunity to continue their work during the trip. While there are some critical issues that needs to be solved in order to create a self-driving car as mentioned by Brandt (2013), it is possible to say that ICTs integration in the car may cause massive changes in the action of driving.

As stated by Bull (2004) music-on-the-go systems (radios, portable devices etc.) caused a shift in the understanding of car interiors. Bull (2004) explains that the car itself becomes a machine for communication with the use of ICTs. He states as such: “The automobile becomes a mobile, privatized and sophisticated communication machine through which the driver can choose whether to work, socialize or pass the time.” (Bull, 2004, p.251).

Another important statement Bull (2004) makes is that with the use of music in the car, the space surrounding the driver becomes a specialised private space without losing the features of being public. This means even though music is an intangible medium it has the power to change the perception of users, as they create an ambient sound environment. ICT related changes in the car show the influence of these technologies on products and their surroundings.

5. ARCHITECTURE, ICTs AND INTERACTION DESIGN

Architecture is not only about seeing but about a full body sensory experience. When ICTs first emerged and entered interior spaces they caused some complications that changed the way architecture is perceived. While interior spaces became dominated by the physical presences of virtual world, the consequences of sensory diversity loss caused by the digital representations of virtual world also affected architecture implicitly. With the dominance of eyesight the relationship between the body and space weakened, thus the inhabitants become restricted by the visual features of modern spaces.

Technology becoming embedded and inclusive of people will have positive consequences such as enriching whole body interaction and multisensory experience. The developments in ICTs such as augmented reality, ambient intelligence and user interfaces bring the opportunity to overcome the mentioned complications. As technology becomes integrated into architecture more and more, and as virtual world merges with physical world the risk of technological predominance in interior spaces emerge. Understanding the nature of architecture along with architectural theories might be a reasonable way to avoid this predominance.

5.1 Architecture: Meaning of a Space

Architecture is related to science, art, technology and at most to human life. Throughout several thousand years humans lived in caves, tents, adobe/ wooden/ stone/ concrete/ steel houses, castles, palaces etc. Even though different kind of technologies – even today's basic tools were once revolutionary – are developed and the form of the shelter changed, the need for a shelter, a home did not. Architecture itself is inclusive to humans, while nature is inclusive to architecture and the meaning of architecture and body-space relevance is constant. Frank Lloyd Wright (1953), one of the founders of modern architecture, explains the close relationship between architecture and its inhabitants as such:

... the time is here for architecture to recognize its own nature, to realize the fact that it is out of life itself for life as it is now lived, a humane and therefore an intensely human thing; it must again become the most human of all the expressions of human nature. Architecture is a necessary interpretation of such human life as we know if we ourselves are to live with individuality and beauty. (Wright, 1953, p. 225)

Another pioneer in modern architecture Le Corbusier (1923/2013) explains how humans perceive beauty and claims anything beautiful should be in harmony with nature, thus architecture should be a reflection of nature. Yıldırım and Allmer assert that ordinariness and thus daily life is important in Le Corbusier's designs (2012, p. 70).

Glanville (2009) mentions Vitruvius who was an architect lived in 1st century BC, and his statements about creating successful architecture "Utilitas, Firmitas, Venustas" should be present, and Glanville also mentions one of the first English translations for these words is "commodity, firmness, and delight", also he translates these terms into today's language as "function, fabrication, form" (2009, p. 176). It can be seen that Vitruvius' values for architecture still has validity as their equivalents find place in modern time discussions. As mentioned by Glanville (2009), the first two values are easy to identify thus their requirements can be fulfilled accordingly, while on the other hand defining delight and relatively fulfil its requirements is difficult and as a result designers are leaving out delight or downgrading it. Pallasmaa (2005) states his understanding of architecture and its relation with human body as such:

Instead of creating mere objects of visual seduction, architecture relates, mediates and projects meanings. The ultimate meaning of any building is beyond architecture; it directs our consciousness back to the world and towards our own sense of self and being. Significant architecture makes us experience ourselves as complete embodied and spiritual beings. In fact, this is the great function of all meaningful art. (Pallasmaa, 2005, p11)

In regard to all these visions from architects it is possible to claim that architecture has a strong relationship with inhabitants. The building without inhabitants is meaningless while as stated earlier architecture is enriching the human experience of world and is a reflection of human nature. Thus it can be claimed that delight is important for architecture as it is closely related to humane values of architecture. As explained by Glanville (2009) delight is what makes a design unique. In the context

of this thesis 'delight' is taken as all the values that please human body and senses, values that create environments inclusive to the inhabitants. While as mentioned above 'delight' can be translated as 'form', it can be argued that combining the wide variety of human related values just in 'form' which is closely related to visualisation, is downgrading the rich nature of architectural design and human beings.

As vision gained importance among senses, contemporary designs became more interested in the visual aspects, and many architects criticised this change. Pallasmaa (2005) argues that in contemporary world, sight is too prioritised over other bodily senses, and because of this new generation architecture people feel alienated. Mallgrave (2013) states that recent researches show that humans experience their surroundings with on a multisensory level and adds: "Exclusively visual designs in this regard fall short of the mark" (p.114). Pallasmaa criticises the dominance of visual perception over whole body perception as such: "Instead of experiencing our being in the world, we behold it from outside as spectators of images projected on the surface of the retina." (2005, p. 30) All these arguments and criticisms support the importance of body-space relationship in architecture.

According to Ashley Montagu, as quoted by Pallasmaa (2005), all the senses comes from skin – it modified itself to taste, smell, hear and see – and touch is the 'mother of all senses'. (2005, p. 11). As an extension of this view, it is possible to say that human beings perceive the world through different channels of skin. This vision leads to the idea of the whole body being a sense organ. Humans do not perceive the world just through their hands, eyes, mouth, ears or nose, the whole body gathers data (Pallasmaa, 2005; Kirsh, 2013). For example if a place is dusty or moist, then the body knows, or else the body can sense the difference between the floor materials before the mind consciously investigates it. Similarly human body can sense dimensions of the environment with echoing sound or a particular smell that related to past experiences.

When considering that there is a relationship between body-space, space gains meaning. An interior space has many features; illumination might be dark or light, corridors might be narrow or wide, the ceiling might be high or low. Relatively an interior space has physiological effects on humans such as feeling depressed,

relieved, frightened etc. Mallgrave (2013) explains the embedded information in interiors as such:

Architecture, more so than in other arts, prompts not only the simulation of its materials and forms, but also the anticipation of wanting to move within it. In a very basic way, a building, or a city for that matter, invites movement – the ecological condition for Gibson’s perpetual psychology. The architect Steve Brubaker has noted this implied invitation to action in many commonplace architectural situations: “Stairs: I want to walk on them. Niche: I want to sit in it. Column: I want to lean against it. Newel post the size of a baby’s head: I want to pat it.”⁵³ One wants to pat a newel post, however, only when it has a particular dimension or profile that pleases the human hand; one is drawn to ascend a staircase only when it is gracefully configured and endows my efforts with a certain dignity. No one wants to lean against a roughly textured column that promises discomfort or pain. (Mallgrave, 2013, pp. 137-138)

The embedded data in interiors change the way humans perceive the space. Taşçıoğlu (2013) points out that each space has its own message which is defined after the physical space (‘essence’/ ‘töz’) and the contents (‘core’/ ‘öz’) of the space (p. 61). In regard to this, it is possible to say that a space is communicating through its design, while humans are perceiving through their body. Pallasmaa states on communication between human and space:

Our bodies and movements are in constant interaction with the environment; the world and the self inform and redefine each other constantly. The percept of the body and the image of the world turn into one single continuous existential experience; there is no body separate from its domicile in space, and there is no space unrelated to the unconscious image of perceiving self. (2005, p40)

Humans are already in a relationship with environment. They perceive the data/message of their surroundings. This relationship can be taken as an information system. As mentioned in Chapter 3.1.1 cybernetics theory explains that in information systems the source spreads information without having a feedback about the understanding of the recipient. ICT related developments such as AmI, IoT and M2M bring the possibility to alter this system from information to communication. To achieve communication between space and humans interaction should be circular and iterative (Akman, 1977; Glanville, 2007; Wiener, 1958/1973). As a second-order cybernetician and architect Gordon Pask (1969) supports the idea to achieve space-human communication designed mediums such as cities, buildings and environments should be adaptive to the inhabitants.

In regard to these arguments it is possible to claim that the message of the space gains importance and should be designed with care thus space should be designed with an holistic approach. Another indication of these arguments about interaction and communication between human and space is that space should be able to adapt to compensate the dynamicity of humans. Though systematic and holistic approaches are discussed in architectural history, these visions gained importance after the Second World War as a result of the technological influence on architecture.

5.2 Architectural Relevance of Technology: Architecture as a System

Architecture is closely related to the society therefore it is possible to say that any change or challenge that affect society, such as Industrial Revolution, World War or space missions, affect architecture. Peter Cook (1999) from Archigram explains this notion as such: “With every level of society and with every level of commodity, the unchanging scene is being replaced by the increase in change of our user-habits – and thereby, eventually, our user-habitats.” (p.16).

Industrial Revolution came with several changes, and one of them was specialisation. While this led to deepen knowledge in each field, it also caused a loss in holistic perspective among individuals. McDonough and Braungart (2002/2007) explain the mainstream vision after the revolution as such:

For obvious reasons, the design goals of early industrialists were quite specific, limited to the practical, profitable, efficient, and linear. Many industrialists, designers, and engineers did not see their designs as part of a larger system, outside of an economic one. But they did share some general assumptions about the world. (McDonough and Braungart, 2002/2007, p.425)

Though specialisation has several benefits, without the proper knowledge sharing channels between professions it limits the cross industry innovations. As explained by Vullings and Heleven (2015), it is possible to find a suitable solution to a specific problem in another industry or field thus interdisciplinary work should be supported without losing the benefits of specialisation.

Another important event in history, the Second World War, came with many consequences in terms of architecture. Several cities in Europe were destroyed and the old architectural methods did not meet the requirements of fast and productive ways of building. As mentioned earlier military based research and advancements in

engineering during the war era influenced designers and architects (Bayazit, 2004; Braham & Hale, 2007). According to Goodman (2008) space missions period, 'the Space Age' which began around late 1950s also affected daily life. The space vehicle concepts such as lightweight but durable materials or mechanical aesthetics are applied to architecture with the abilities of prefabrication (Goodman, 2008). Though pioneer architects such as Le Corbusier and Frank Lloyd Wright discussed architectural relevance of technology before the World War II and the Space Age, this topic gained importance after the war as a result of both the need of fast production and the influence of engineering amongst architects and designers. Many architects and groups including Richard Buckminster Fuller, Archigram and Mies van der Rohe emphasised the role of technology in the Space Age.

The need of specialised individuals' collaboration arose with the need of faster production and reconstruction. While specialisation has the advantage of gaining deeper knowledge about a subtopic, it also causes alienation from the general concept. Boyce (1969/2007) explains this issue as such:

Recent history thus suggested a strangling paradox: while we were increasing our detailed understanding of man and environments, we were apparently decreasing our capability to cope with the problems that man and environment inflicted upon each other. We could build a comfortable air conditioning system for a building but fail to air condition our cities. (Boyce, 1969/2007, p. 182)

Similarly Richard Buckminster Fuller (1969/2007) criticised the way society sees specialisation as such:

Of course, our failures are a consequence of many factors, but possibly one of the most important is the fact that society operates on the theory that specialization is the key to success, not realizing that specialization precludes comprehensive thinking. (Fuller, 1969/2007, p.178)

As mentioned in the last chapter, architecture should adapt to nature and it is possible to claim that nature is a big system and it works in harmony with billions of specialised assets. Marshall McLuhan (1964/2007) explains that humans were originally acting in harmony with the nature, and as the artificial interactions increased their relation with the universe weakened. He also states that flexibility in environments increased as a result of the developments in engineering and technology, and this flexibility is a way to enhance the human relation to the nature once again (McLuhan, 1964/2007). With regard to the order in nature and

interdisciplinary working architects' visions such as Gordon Pask (1969) who argues that architecture by its nature is a system design activity, systematic approaches gained importance in the postwar era.

Another aspect that was criticised during this era was the role of the inhabitant in architecture. While the buildings and environments are designed by architects, the inhabitants spend more time in it and they can effectively change environments according to their vision through time. Though inhabitants' contribution is crucial for architecture, this relation is mostly underestimated. Second order cybernetics, as mentioned in Chapter 3.1.1, offers that every asset of a system is an observer and even though each asset observes the same thing, their perception, observation and interpretation would be different. Pask (1969) and his student Glanville (2009) combined architecture and cybernetics by addressing architecture as a system and inhabitants as observers. Haque (2007) states Pask accepts and supports the users' contribution in architecture, thus he worked on responsive environments and products by using technology as a way to enrich the designed mediums. Similarly to Pask many architects offered responsive and adaptive environments to enhance human interaction with surroundings.

Most similarly to Pask's view, Warren Chalk of Archigram sharply criticises overlooking to user involvement in the design of environments, and explains how environments should be designed inclusive of the users as such: "The inherent qualities of mass-production for a consumer orientated society are those of repetition and standardization, but parts can be changeable or interchangeable depending on individual needs and preferences, and, given a world market, could also be feasible." (1966/1997, p. 17)

Adaptive and systematic aspects of environments also take part in Richard Buckminster Fuller's vision (1929/2007) as he explains that designers should consider time as the fourth and the most important dimension of all. It can be said that the changing affects of time was important for him and the environments should be malleable to these changes. Baldwin (1997) states that Buckminster Fuller's works are designed to be 'autonomous' which can be achieved by being systematic. It is possible to say that Fuller thinks the world as a whole and one with regard to his explanations about the first sailors' lives and Baldwin claims that autonomy stands as a crucial part in Fuller's perspective (Baldwin, 1997; Fuller, 1969/2007).

Mies van der Rohe (1950/2007) states that technology merges with the architecture when it matures and he explains the relation between architecture and technology as such:

Architecture depends on its time. It is the crystallization of its inner structure, the slow unfolding of its form. That is the reason why technology and architecture are so closely related. Our real hope is that they will grow together, that some day the one will be the expression of the other. Only then will we have an architecture worthy of its name: architecture as a true symbol of our time. (van der Rohe, 1950/2007, p.114)

In the post-war era these arguments about systematic and holistic approach to create adaptive to inhabitant environments gained importance and architects and groups including Buckminster Fuller, Cedric Price, Yona Friedman, Archigram and Superstudio designed several concepts supporting these ideas. Their designs suggest iterative and continuous systems that can be adapted to different situations, which indicated mechanism-like architecture.

Fuller offered Geodesic Domes as a way to create a systematic, location-free architecture. He designed the US Pavilion at EXPO'67 Montreal (Figures 5.1 and 5.2). He used geodesic dome as a facade of the habitat he created. Inside the geodesic facade there was a building. The dome brings the advantage to adapt to different climates easily.

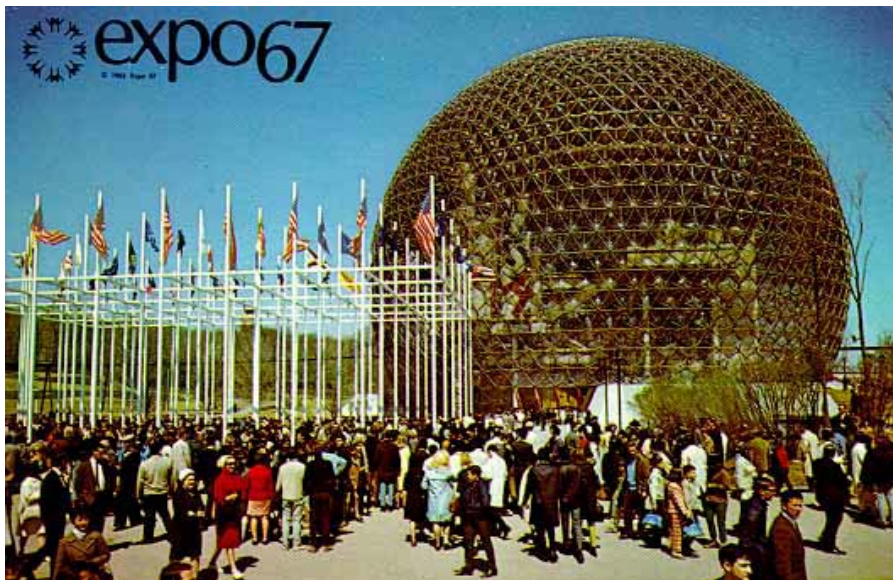


Figure 5.1 : US Pavilion at EXPO'67, Montreal. (URL-40)

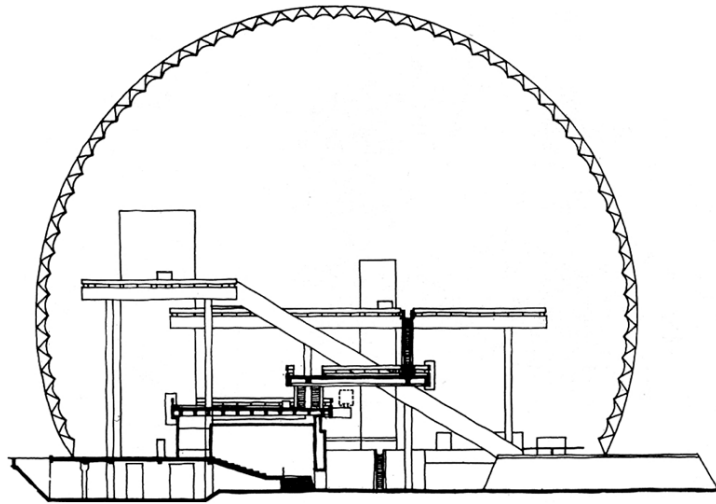


Figure 5.2 : US Pavilion section (URL-41)

Fuller also suggested to build a giant geodesic dome over New York to create a new habitat (Figure 5.3). Hatch explained the features of the dome as such:

Its skin would consist of wire-reinforced, one-way vision, shatterproof glass, mist-plated with aluminium to cut sun glare while admitting light. From the outside it would look like a great glittering hemispheric mirror, while from the inside its structural elements would be as invisible as the wires of a screened porch, and it would appear as a translucent film through which the sky, clouds and stars would appear. (Hatch, 1974, p.230)



Figure 5.3 : Geodesic dome as an urban facade. (URL-42)

Another architectural system that suggests buildings as mechanisms is Cedric Price's Fun Palace (Figures 5.4 and 5.5) project dated 1964. Price and Littlewood (1968) state that it is intended to create a short-life, open to change entertainment building to meet the changing dynamics of society. The building concept consisted of fixed load-

bearing elements and moveable or easy/fast-to-built elements such as activity spaces, screens and theatres. Price and Littlewood explain what this concept offered as such:

But the essence of the place will be its informality: nothing is obligatory, anything goes. There will be no permanent structures. Nothing is to last for more than ten years, some things not more than ten days: no concrete stadia, stained and cracking; no legacy of noble contemporary architecture, quickly dating; no municipal geranium-beds or fixed teak benches. (Price and Littlewood, 1968, p.130)

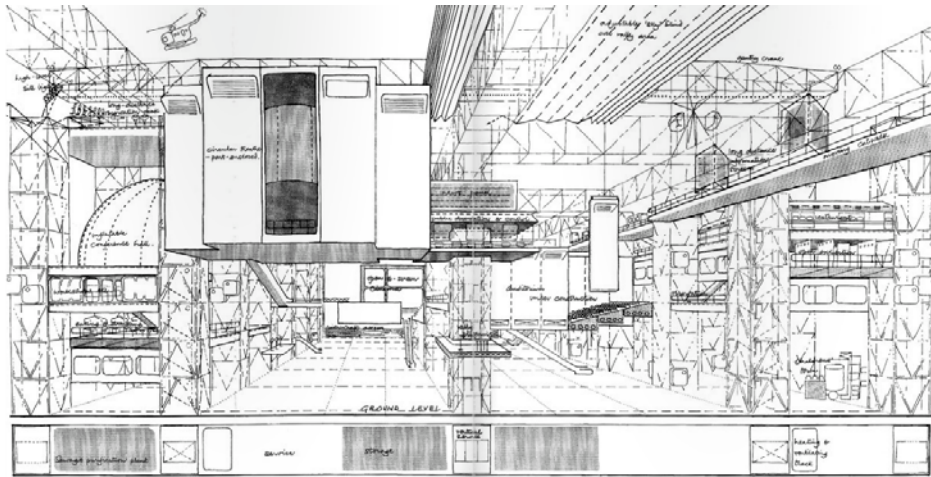


Figure 5.4 : The Fun Palace section (URL-43)

Mathews (2005) states that this concept is challenging to architecture and explains as such: “...for it was not even a conventional ‘building’ at all, but rather a kind of scaffold or framework, enclosing a socially interactive machine - a virtual architecture merging art and technology” (2005, p.75). Also Mathews (2006) states that even though the technological aspects of this concept seem to have priority, the whole project was about to create human-centered environment.

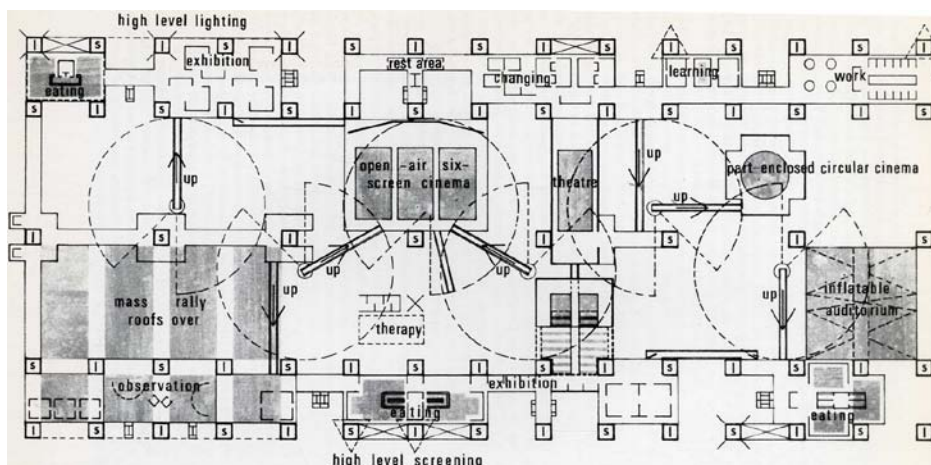


Figure 5.5 : The Fun Palace plan (URL-44)

A group of Italian architects, Superstudio created concept designs for future living as a way of criticising the role of modernist architect. As quoted by Quesada (2011), Superstudio explained their work in 1972 as such: “At that time it was obvious that to continue designing furniture, objects and similar household decorations was no solution to the problems of living, nor to those of life; even less was it serving to save the soul.” (2011, p.28). They criticised the way architecture lost connection to the human values, the way it became too oriented with technological aspects of modernism. According to Design Museum Kensington archives (2015), Superstudio emphasised the social impact of architecture, and criticised how technology overrides human needs.

Superstudio created The Continuous Monument (Figures 5.6 and 5.7) in 1969, and Quesada (2011) explains their criticism about the trends of architecture at the time as such: “For the authors, the monument is the definitive expression of human reason - the constructional reason and the symbolic reason - the ‘recovery’ of communicative architectural values, the loss of which produced a state of irony and disdain.” (2011, p.26). In the monument Superstudio offered a design modul that can be repeated to adapt different locations and situations and they explained as such:

The Continuous Monument is the culmination of a series of coherent project operations which we carry forward, from design to town-planning, as a demonstration of a theory stated a priori: that of a single gesture design. A transportable design that remains identical to itself, changing its scale or semantic area without trauma or inconvenience. (As quoted by Quesada, 2011, p.28)



Figure 5.6 : The Continuous Monument collage (URL-45)

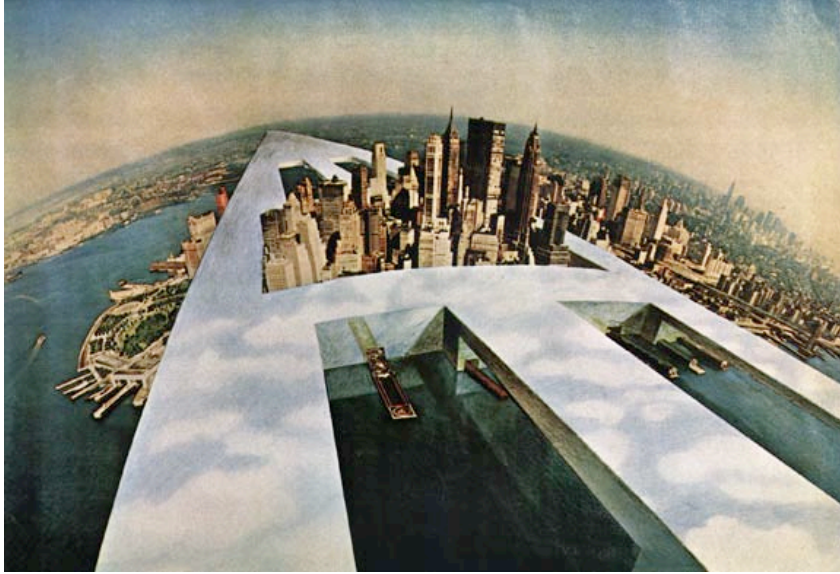


Figure 5.7 : The Continuous Monument collage (URL-46)

Another concept is Yona Friedman's *The Spatial City* (Figures 5.8 and 5.9). Friedman offered a master structure to contain homes and work places. This structure would cover the existing cities in a stacking manner to create more space without the restrictions of the land. In his vision it is possible to change the location of a living module regardless of interrupting or damaging the master structure.



Figure 5.8 : The Spatial City collage (URL-47)

Gürbüz (2009) states that Friedman foresaw the changes in the relationship between the inhabitants and the architects, and adds as a solution to these changes Friedman tried to offer new design methods to give inhabitants a role in designing. Similar to

Superstudio's Continuous Monument, these megastructures were designed to host flexible living modules.

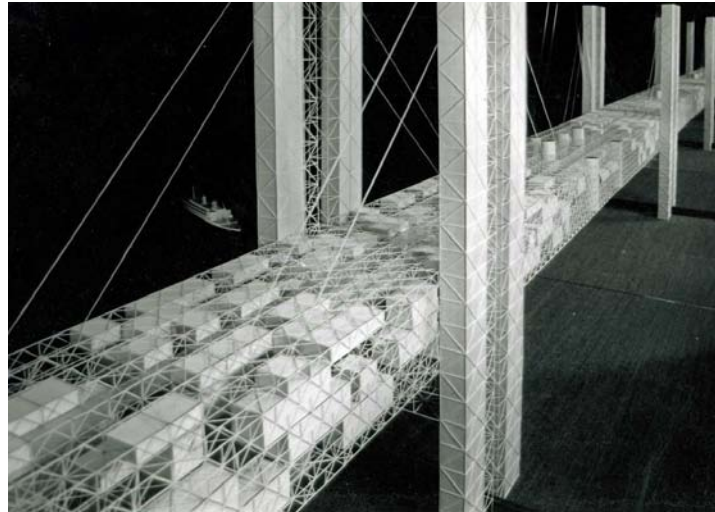


Figure 5.9 : The Spatial City model (URL-48)

Another mechanism-like architectural system is Archigram's the Walking Cities (Figures 5.10 and 5.11) vision. This utopian concept consisted of giant structures equal to cities which can travel around the World without the restrictions of land and countries. Sadler (2005) explains that even though Walking City concept raises questions about the physical limitations and psychological and sociological motivation, and emphasises the importance of the project as such: "Nonetheless, it was a bold memorandum of forgotten modernist ambitions: to make collective dwellings, transcend national boundaries, build machines for living in, extend human dominion, alter everyday perception, bring people into contact with the elements, and simply to excite the public about the future" (Sadler, 2005, p. 39).

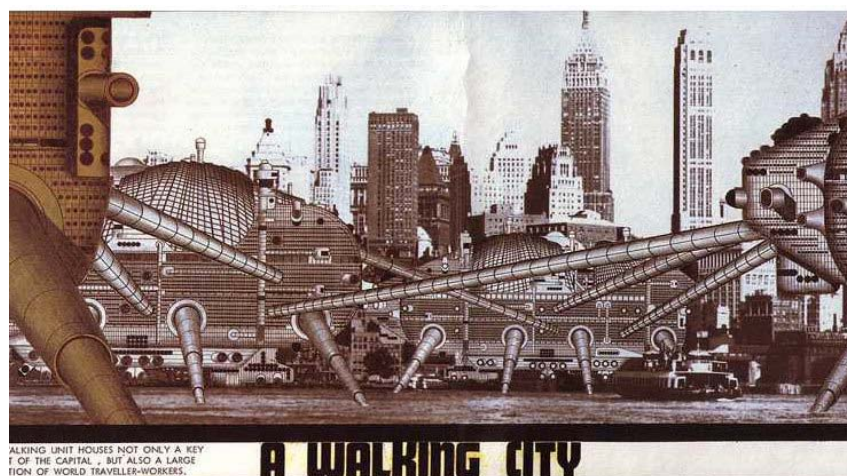


Figure 5.10 : Archigram's "A Walking City" vision (Onbay, 2006, p. 40)

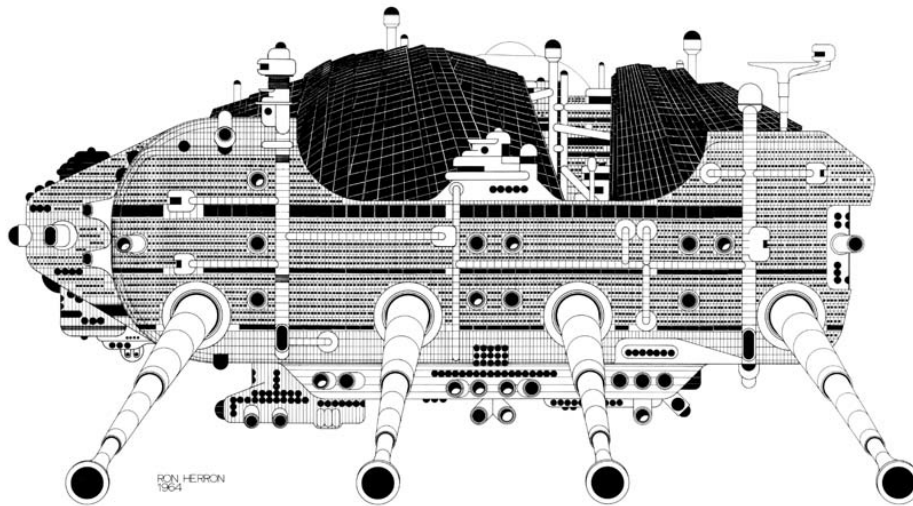


Figure 5.11 : Archigram’s “A Walking City” vision (Sadler, 2005, p. 39)

While these examples use repetitive modules to create architectural systems, projects such as Dymaxion House, Cushicle offered productised spaces. Buckminster Fuller designed a house which can be transported and constructed easily. The house was designed as a mechanism to offer sustainable living, its special design helps to reduce heating/cooling costs while water consumption is decreased with high-pressured plumbing systems. Dymaxion House (Figures 5.12 and 5.13) concept offered a wireframe for inhabitants to adapt the house as needed, also its autonomy led to sustainability (Onbay, 2006).

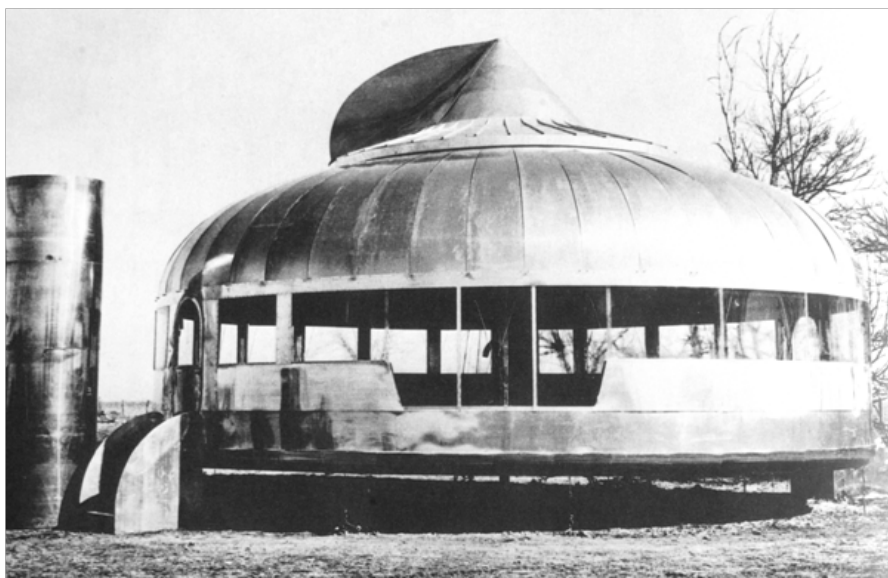


Figure 5.12 : Fuller’s Dymaxion House (URL-49)

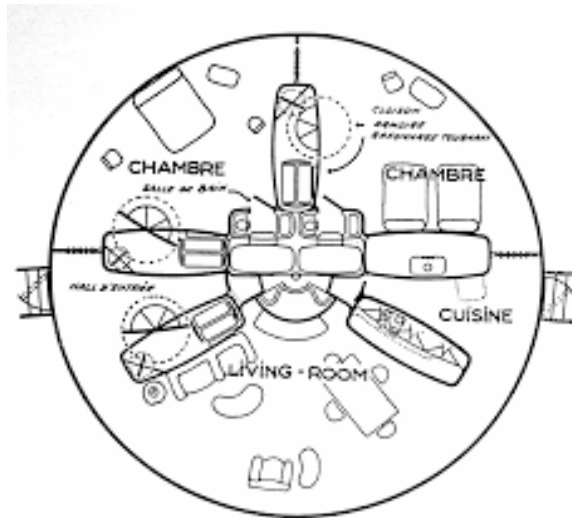


Figure 5.13 : Dymaxion House, plan (URL-50)

Archigram's Cushicle/Suitaloan (Figures 5.14 and 5.15) concept is a portable, inflatable mechanical system – a product – that creates a personal space at any location. This project indicates an understanding of space as an extension of the body. Sadler (2005) explains the concept as such:

As portable as a hefty haversack, the Cushicle (air CUSHion VehICLE) was designed as an armature unfolding to provide many of the amenities of the contemporary living room, including television; the Suitaloan was an add-on shell, inflated by the Cushicle to the size of a small room to accommodate its Michelangelesque occupant. (Sadler, 2005, p.114)

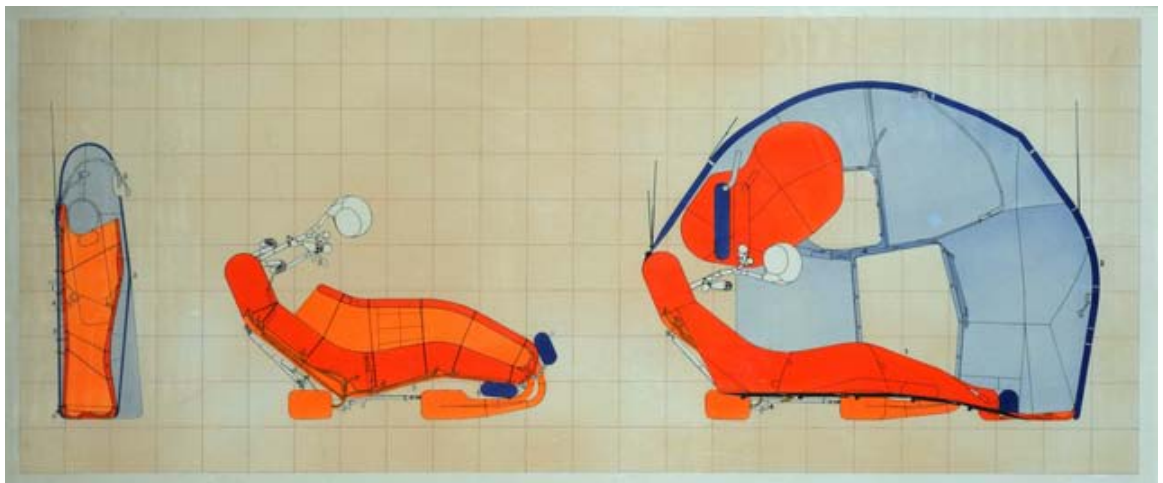


Figure 5.14 : Archigram's Cushicle/Suitaloon concept (URL-51)



Figure 5.15 : Working mock-up of Suitaloon (Sadler, 2005, p. 184)

All these projects foresaw the future direction of globalisation in the means of getting over the restrictions of location. They visioned the World as a complete land, and designed to meet the changing needs of society. Though many of these concepts are questionable in the means of construction, the ideas they contain such as the involvement of the inhabitants and being able to answer changes systematically are still up-to-date. Onbay (2006) states that the tendency to create customizable, product-like environments in post-war era affects contemporary architecture and 21st century architecture aims to fulfil this goal by combining new sensor technologies and building techniques. The importance of the inhabitants' preferences, and their active role in defining the space meet with the human-centered basics of Interaction Design. The emergence of ICTs gives architecture new tools to create adaptive, responsive and exclusive spaces.

5.3 Information and Communication Technologies in Architecture

Computers changed the experience of architecture and space, thus changed the relationship between the space and the inhabitant in a way that both these assets are dynamic (Ak, E., 2006; Bouman, 2005). Onbay (2006) claims that the future homes will be the connection medium to information flow, and they will have features of an industrial product along with the ability of being designed and customised by the end user.

Bouman (2002) explains that interaction between people become malleable and the core values of architecture are under threat by the digital era. He also explains that architecture should become the terminal and become inclusive of ICTs as such:

...What remains is a building profession that falls back on its core activity and is at risk of losing its cultural relevance. Unless architecture is able to redefine itself and to broaden the substance of its design activities. And that will only be possible when it no longer leaves the design of the digital environment to trained specialists but incorporates it into the design of the physical built environment. If the virtual world is threatening to usurp the cultural relevance of architecture, then it is logical that architecture should seek to connect with that world. (Bouman, 2002, p.7)

As criticised by Streitz et al (2001) "...the physical space around us provides rich affordances for interaction and communication that should be exploited. Research in HCI has neglected this larger context by limiting itself for a long time to the desktop computer." (2001, p. 555). They also claim that architecture should be inclusive of several fields such as HCI, AR, Ubiquitous Computing and 'Computer-Supported Cooperative Work' (Streitz et al, 2001). Information and Communication Technologies already entered interior spaces in many areas starting to include inhabitants. Many of the first applications of these technologies were about creating adjustable and traceable environments. Adjusting physical conditions became possible. An inhabitant can lock the doors without being in the home, or adjust the lights of a room from another country. Physical presence lost importance when it comes to adjusting these technical features of a space. Other than these adjusting features tracking health issues from distance became possible. Elderly people and people with disadvantages like epilepsy can be tracked by sensors and in an emergency medical crew can be informed. Gross and Green (2012) claims about the emergence of ICTs in architectural spaces as such:

In our Information Age, ICT is increasingly embedded into the physical fabric of the built environment in order to intelligently control heating, air conditioning, and lighting, as well as to transform building facades into vast computer displays. But while ICT can intelligently move temperature-controlled air through building interiors, and digital bits across building surfaces, it also promises to move physical building elements to create intelligent, adaptive built environments responsive to the challenges and opportunities of a digital society. (Gross and Green, 2012, p. 28)

Other than tracking spaces, and adjustable features assistive spaces with collective intelligence are under development. With machine learning, mimic and gesture

tracking and AIs that are able to understand human emotions; a new concept of interior spaces will be available. Oosterhuis (2002) states that “architecture is the programmable hyperbody..” (p.5) and explains his understanding of ICT embedded architecture as such:

It is fair to say that the building will find itself in a state of continuous operation. The building, consisting of numerous cooperating programmable elements, will behave like a swarm. The building elements will show flocking behaviour, always keeping an eye on the neighbouring actor, always ready to act and react. Hence we propose a new motto for the discipline of architecture: “Game, set and match”. To be played over and over again. (Oosterhuis, 2002, p.5)

Oosterhuis’ arguments support the idea that architecture should be organism-like thus should be adaptive and buildings should be designed as a whole.

5.3.1 ICT embedded spaces: More than securing buildings, adjusting features and tracking health

House automation systems are generally planned for safety, information, comfort and reducing energy consumption by the inhabitants and these systems fulfil only limited amount of these plans efficiently (Ak, N., 2006). Though computers and ICTs cannot fulfil every need in the house, one of the positive sides of the emergence of sensors and information and communication technologies is becoming able to monitor inhabitants without interfering to their life. There are several ‘elderly home’ researches for creating a safe environment for elderly people living alone. In case of an emergency like a heart attack it would be difficult for the person to call medical assistance while having an attack. Before ICT related tracking abilities elderly people mostly moved to care houses and change their lifestyle in order to get help in an emergency. Similarly there are specialised house complexes for people with epilepsy. ICT embedded spaces offer people to merge the assistive systems to their life without actually changing their lifestyle.

Other than the applications for tracking health, there are several applications of creating secure places. Theft alarm systems, track movements in the house and warn the owners in case of intrusion. Motion, heat and sound detection is possible. Also there are several locking systems that open themselves only for specific people by recognising their fingerprint, or voice, or retinal scan. These advancements in applications enhance the secure feeling in interiors, thus ease human life.

Another application area of ICTs in spaces is to adjust features like air conditioning, heating, lights, locks etc. Many of the contemporary homes have these adjusting systems such as PHILIPS Hue. Other than the commercial products mentioned in chapter 3.3.2, several companies' and universities' research labs worked on creating ICT embedded ambient environments.

One of the first works of ICT embedded spaces is PHILIPS Pavilion (Figures 5.16, 5.17 and 5.18) at the Brussels EXPO'58. As mentioned by Marzano (2005) PHILIPS was honoured to install a pavilion in the fair amongst countries. The pavilion was designed to show the latest technology PHILIPS produced, but instead of presenting the actual products design team – which consisted of Le Corbusier and Iannis Xenakis with few others – created an environment for visitors to experience the technology.



Figure 5.16 : Le Poème Électronique 1958, PHILIPS Pavilion, (URL-52)

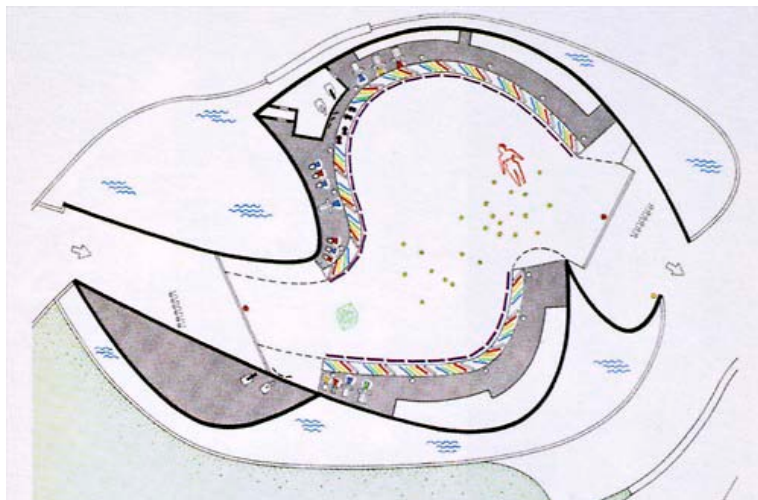


Figure 5.17 : Le Poème Électronique 1958, plan (URL-53)



Figure 5.18 : Le Poème Électronique 1958, video sequences(URL-54)

The pavilion was embedded with projectors, lights, speakers and sensors. All the media along with the structure of the pavilion was designed carefully to astound visitors (Marzano,2005). The exhibition was called “Le Poème Électronique” which meant “Electronic Poem”.

Though PHILIPS Pavilion was one the first works to create ambient environment, which dated back to 1958 thus a frontier, ambient intelligence and ICT embedded environment researches increased in the 1990s with the wide use of computers. One of important work in the field is the ambientROOM (Figures 5.19 and 5.20) which is designed by MIT Tangible Media Group. Ishii et al (1998) created ambientROOM as a way to investigate the possibilities of TUIs. They explain the concept as such:

The ambientROOM is a personal interface environment designed to provide information for background processing. It displays information through subtle cues of sound, light, or motion easily relegated to the periphery of awareness. Many of these “ambient media” displays are inspired by natural phenomena such as wind, sunlight, or the sounds of a rainforest. In addition, the ambientROOM uses graspable objects such as bottles to provide control of the ambient media. (Ishii et al., 1998, p.173)

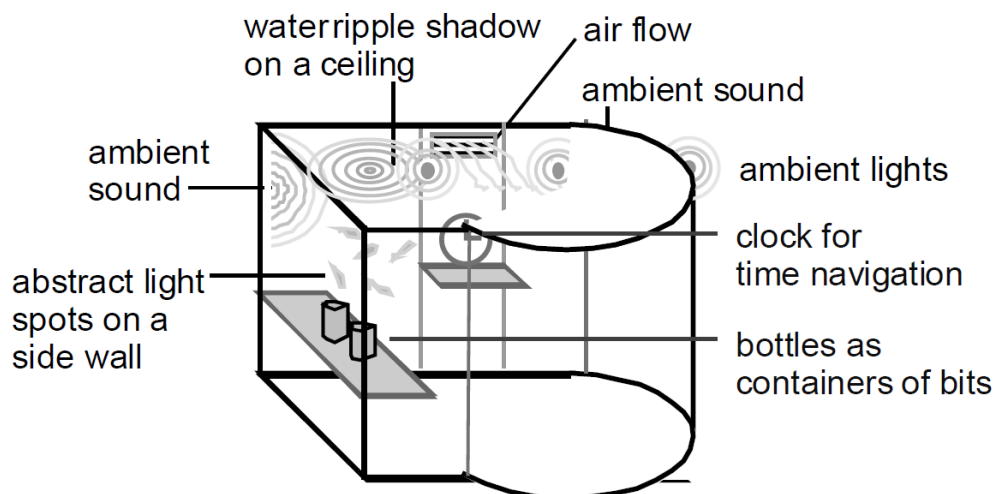


Figure 5.19 : “ambientROOM schematic diagram” (Ishii et al, 1998, p. 173)

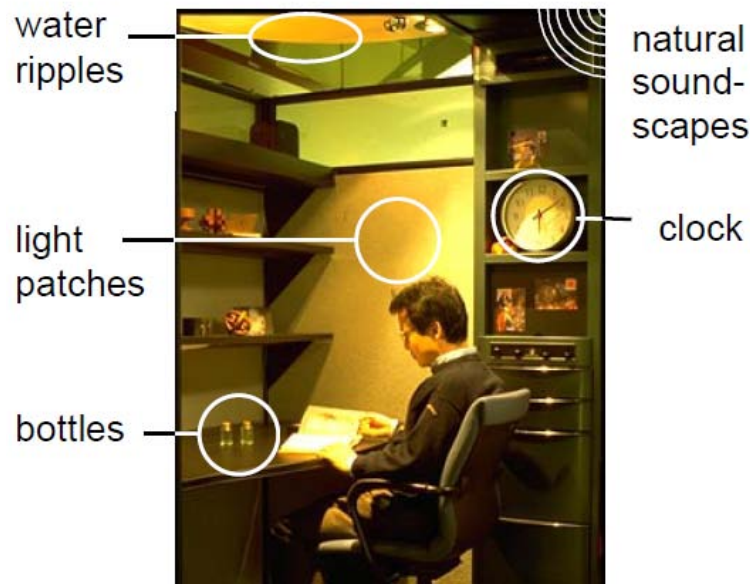


Figure 5.20 : “Ambient media displays and controls” (Ishii et al, 1998, p. 173)

While ambientROOM project was at a room-scale, House_n Consortium of MIT was at a house-scale. As mentioned by Onbay (2006) this project was held under the collaboration of multidisciplinary teams which include architects, engineers, scientists and health organisations along with companies. Project offers several research fields such as healthy living, user interfaces, air quality of interior spaces, energy preservation and accident prevention. Onbay also lists some of the projects held under House_n project which includes energy-producing wall units, a ring that can measure the oxygen level in blood and an augmented environment, KidsRoom (Figure 5.21) where the gameplay and imagination of the children is supported by projectors, sensors and interior entities. As indicated in Table C.3, in comparison to ambientROOM project, KidsRoom project offers a more responsive environment and also the surroundings are more adaptive to the users’ actions.

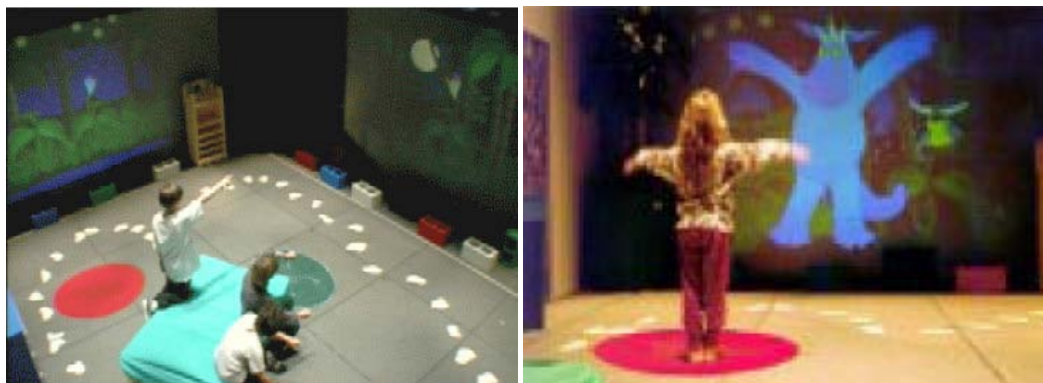


Figure 5.21 : The KidsRoom (Onbay, 2006, p. 86)

Another concept is PHILIPS' the Reading Room 2020 (Figures 5.22 and 5.23), in which dominance of the screens is eliminated by integration of the ICTs to walls and desks. In PHILIPS Design website it is stated that:

This design concept is an optimized environment for applying and sharing knowledge. Touch panel operation greatly simplifies procedures. There is simple interaction with other specialists in the hospital and beyond. The room is dark enough for concentrating on images, yet bright enough to write and discuss cases with colleagues. (URL-22, Retrieved November 2015)



Figure 5.22 : Reading Room 2020 Concept, dated 2007 (URL-55).



Figure 5.23 : Reading Room 2020 Concept,dated 2007 (URL-56).

This project shows the holistic design approach that makes all the entities work together to create a productive knowledge sharing space. It can be seen in the bottom right of Figure 5.4 that walls and desks are integrated with user interfaces to offer flexible working stations.

While these projects use ICTs as a way of enhancing daily tasks without the interference and dominance of technology, several concepts including Blur Building, Hyperbody Interactive Wall and deCOI's Hyposurface use ICTs as a way to create new experiences.

Blur Building (Figures 5.24 and 5.25) is designed for the 2002 Swiss EXPO by Diller Scofidio and Renfro. The lightweight structure was placed over the Lake Neuchatel and used lake's water to create a new atmosphere to give visitors a chance to experience the wall-free space with limited vision. People are tagged according to a questionnaire they fill at the entrance, and warned in the building according to their similarities and differences with encountered visitors (Picon, 2010). Architects explain their intention as such:

Upon entering Blur, visual and acoustic references are erased. There is only an optical “white-out” and the “white-noise” of pulsing nozzles. Contrary to immersive environments that strive for visual fidelity in high-definition with ever-greater technical virtuosity, Blur is decidedly low-definition. In this exposition pavilion there is nothing to see but our dependence on vision itself. (DSRNY, n.d.)



Figure 5.24 : Blur Building (URL-57).

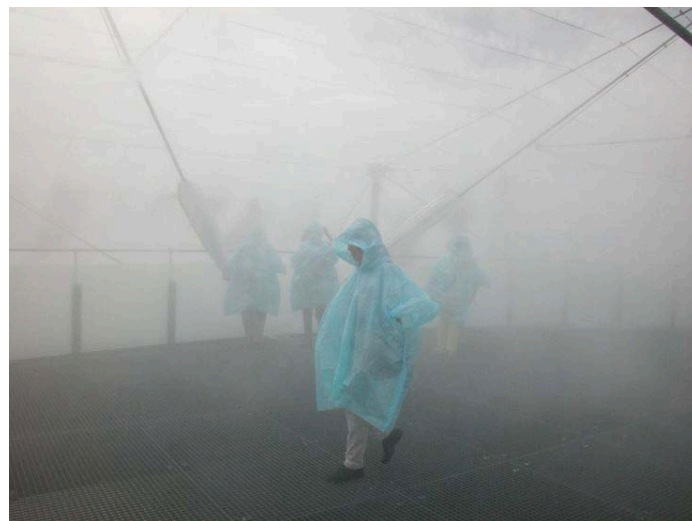


Figure 5.25 : Blur Building, inside the exhibition. (URL-58).

Another project is InteractiveWall (Figure 5.26) installation of Hyperbody at the Hannover Messe industrial trade fair in 2009. The wall, which contains of seven separate divisions with hydraulic and pneumatic systems, reacts to people by creating movements, sounds and lighting. Hosale et al (2010) describes the process and output of the project as such:

Starting from a clear interactive design concept, we developed a one-to-many interactive system that exhibited emergent behaviour and performed liked a living system. The result is an independent system built on synchronous behaviour that is interrupted by the game-like response of multiparticipant interaction. This layered system encourages the intended cycle of observation, exploration, modification, and reciprocal change in the participant, reinforcing believability in the system, and providing a sense of agency to the user. (Hosale et al, 2010, p.81)



Figure 5.26 : InteractiveWall, 2009 (URL-59).

Similar to Interactive Wall, deCOi designed the Hyposurface (Figures 5.27 and 5.28), a reactive wall, which interacts with passers by changing its shape according to the changes in the environment such as sound, light and movement (Picon, 2010).



Figure 5.27 : Hyposurface, 1999-2001 (URL-60).

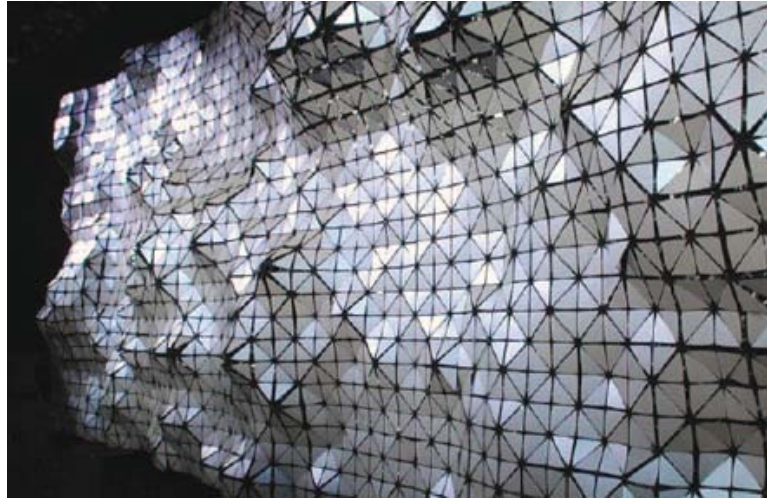


Figure 5.28 : Hyposurface, 1999-2001 (URL-61).

In regard of the mentioned projects it is possible to claim that ICTs have opportunity to enhance the relationship between the human and the space along with the ability to create new experiences. As mentioned in Chapter 5.2, ICTs offer new ways to design, live and change the space. Though these examples can be identified as the prototypes or experiments of ICT related concepts, they indicate possible ways to create adaptive and responsive spaces that reflects the inhabitants.

6. CONCLUSIONS AND RECOMMENDATIONS

ICTs altered the world in many aspects; the way of communication changed, locations lost importance and new business models emerged. They offered new mediums to interact, create and communicate thus became irreplaceable for living. As these technologies become widespread, they also affected the way people do and perceive things. Widespread use of these technologies despite their limitations caused loss in sensory diversity, domination of black boxes in interior spaces and techno-centered designs instead of human-centered designs. Though ICTs' physical and digital representations brought such disadvantages, developments in the related fields offer ways to overcome these disadvantages.

Recent developments in the field of ICTs bring the opportunity to create multisensory, space integrated and user-centered designs. In this chapter these opportunities are discussed to have a better understanding of emerging interactive interior spaces and products.

6.1 Changing Body-Space-Product Relationship: Loosing the Sensory Diversity

Design – both architectural and product design – is an act of creating better living, which is closely related to the human body because the body acts as the interface between the world and the self. As mentioned in Chapter 5.1 humans perceive the world through their whole body. With the emergence of ICTs perception channels altered, vision is prioritised over other senses. This resulted in a loss in sensory diversity.

The offered possibilities such as connecting people regardless of location, reaching information about millions of things and managing business all over the world etc, were so irresistible and promising that they overcame the disadvantages of ICTs' digital and physical presence. User interfaces played an important role in the loss. WIMPs and GUIs limited the interaction to 2-dimensional visuals and a limited count of audials. They offered a graphically rich environment without taking other

senses into consideration. Technology restricted the wide variety of sensory channels human body possess, limiting the perception of the body to vision.

When vision became prior to other senses architecture and product design outputs altered. Many architects and designers along with engineers criticised the exclusion of sensory channels other than vision, as 3-dimensional features of architecture and design are reduced into 2-dimensional graphical arts. With the recent advancements in ICTs, several concepts are developed to fulfil human needs. In UI field researchers work both on enhancing the existing interfaces, and offering new ways of interaction, while in VR field several concept projects are developed to create advanced realities. Also in AI field, the aim is to create an entity which can be the virtual equal of human mind. Though the aim of each field is higher than what projects offered, researches in these fields are already changing the way of interaction.

As mentioned GUIs' limitations are responsible for the loss of sensory diversity. To overcome the GUI related limitations such as being bounded to screens, Tangible User Interfaces were offered. TUIs bring the opportunity to create closer relationship between the real world and physical world as they connected the physical objects to digital representations thus became able to manipulate digital bits with physical atoms. Though TUIs offer richer ways of interaction than GUIs; they fall short at the point of creating in-time changes. While the virtual world is flexible, the rigidity of the physical world is limiting the interaction. There are several concept UI projects that can be examined as next generation UIs, which offer integration of technology to body extensions such as clothing and prosthetics, or products that are able shapeshift according to the task, or mid-air holograms that are half digital, half physical. Next generation of user interfaces bring the opportunity to support body-product-space relationship as it became possible to use the flexibility of the digital world through physical world. Though researchers have developed several projects under the names of TUIs and the Next generation of UIs, the existence of all the user interfaces should be thought together. GUIs offer simple and well-known ways of interaction, and with the support of TUIs and Next generation of UIs these interactions can be enhanced. It is possible to claim that all the developments in user interfaces are about enriching the way of interaction, not about losing the habits gained with GUIs.

Virtual and Augmented Realities also offer new concepts to meet the extensive sensory diversity of human body. While VR is mostly used for gaming or military

related situations, AR concepts offer real life interaction with the virtual entities. As a working principle both Realities use perception of the eye, thus they are both strongly related to vision. Though it raises the question of how to increase whole body interaction when all is related to eye, these realities – especially AR – offer social interactions with digital entities which means even though these entities are not physically touchable, they are able to response the users' actions in a 3-dimensional grid. With AR it is possible to wander around the virtual objects, thus it would be fair to state that virtual entities gain some features of physical entities. They are perceptually carried to the physical world to have a better understanding and feeling of the digital models/entities.

Another important field that should be taken into consideration is Artificial Intelligence along with Ambient Intelligence. As mentioned earlier AI field aims to create human-like intelligence that can improvise and adapt like a human does. Experts in this field state even though fulfilling this aim is not possible in near future, there are many attempts to create task-oriented, learning-oriented etc. intelligences that able to improvise at subtle levels. Many of the smart phones and user interfaces have virtual intelligences to assist users. These intelligences/software can answer tasks and some even make pre-programmed jokes. While AI is offering a mastermind for the implemented medium, which can be a house, a computer or a phone, AmI is offering a network of objects that can communicate with the inhabitants of a space. Ordinary household objects can gain responsive features with implementation of sensors and actuators. Also these objects can communicate with each other. Though it may not be necessary or feasible to do so but as an example it is possible to program a carpet to send signals to vacuum cleaner when it becomes dirty.

Though the emergence of ICTs interfered with the relationship between the body, surroundings and product, with the developments in ICTs negative effects can be inverted. Environments and products gain intelligent features to communicate with users. All these concepts turn the interior into a systematic entity: a mechanism with a mind, or an organism. In chapter 5.2, the resemblance of architecture, systems and mechanisms is discussed. The arguments of architects support the idea that to create an environment which is addressing human needs, and to ease human life, design should adopt a holistic perspective similar to nature in which the relationship of the

parts and the whole is very mutual. Thus the designed environment should swathe in human and act dynamically in accordance.

All the developments in Interaction Design support the idea of creating an organic environment, while user interfaces give environments tools to perceive the world, augmented reality offers environments a possible way express itself through, while artificial intelligence along with ambient intelligence gives the ability to think and act accordingly. Thus it is possible to claim that the interiors will become such entities that interacting with them won't require specialised knowledge of technology, instead interaction will happen in a subtle way allowing to restore the lost sensory diversity.

6.2 Design Needs to be Adaptive

As mentioned earlier, Product Design is closely related to industry and humans. The changes of dynamics both in industry and human habits affect product design very closely. With the developments in ICTs, which include physical representations, digital representations and offerings of digital world, human habits and industry are under change.

ICTs changed the nature of daily habits. While before ICTs the action of writing included pens and papers, now it can be executed just by pressing buttons. Similarly to writing, many other actions including drawing, singing, playing changed. Though many people master the needed skills to execute these actions without specific tools, with the developments in user interfaces and detection systems for computers, many specialised tools are developed such as touchpads and their pens to draw. It can be said that with the developments it became possible to benefit from the experience gained from both worlds. People became able to use their experience of physical world in the flexible virtual world, thus became able to manipulate their work faster and easier.

ICTs offered new fields for design, the need to create physical features of a valuable interaction designers worked on keyboards, mice and other input devices. Several designed input devices can be seen in the Figure 4.4, it can also be seen in the same figure that very few of these devices are similar to daily objects such as pens while others offered totally different ways of interactions for the time. It can be seen that

technical aspects are prioritised over design in these examples. As criticised by several designers, design is under the restrictions of industry and techniques of the time. As mentioned earlier in Chapter 3.1, even though the way of interaction and the medium changes it is interaction designers' job to connect digital world to physical world.

As mentioned, design is under the restriction of technology. Material and manufacturing technologies affect designs, and with the emergence of ICTs hardware requirements caused products to be designed as plastic boxes. These resulted in a loss in human priority in design and products dominated the interiors instead of merging into the environment to create natural interaction.

The physical representation of the digital world, products, changed with the developments in material and manufacturing technologies. It can be seen in the Figure 4.6 that, in 1980s first samples of mobile phones have bigger dimensions and several buttons to manage the phone. Also it can be seen in the same figure that through 30 years mobile phone became smaller and buttons are merged into the touchscreen. It can be seen that the black boxes turned into elegant products through time.

Touchscreen technology changed the electronic devices. With the widespread use of touchscreen displays in mobiles and tablets, these devices gained other uses such as gaming, document editing and entertainment. These new uses they changed the devices pocket-size computers or televisions. With the gained features sizes of the screens grow bigger with each model and mobile phones became a-few-centimeter smaller versions of tablets. Another result of this merger is buttons' integration into the screens. With the widespread use of tablets and phones with touchscreen technology the nature of actions changed again. Earlier the action of writing was given as an example to show the changes in actions. The action of writing also changed without the buttons. While with the buttons the act of pushing a button gives a tactile and an audio (audio depended on the model) feedback, the act of touching a screen to virtually push buttons needs different feedback that will remind the accustomed action. While this is also a cause for sensory diversity loss, it also changes the channel of interaction. Designers worked on this problem to create a considerable feedback and resulted in adding some audio feedback similar to a typewriter's and some visual feedback such as bigger visuals when pressed.

Another consequence of widespread use of touchscreen embedded devices is the merger of products into each other. While this merger has many other causes related to hardware of electronics such as new manufacturing methods that make it possible to create microscopic electronic entities, changes in user habits and consumer products affects this merger as well. Though this topic is a challenge of this decade, it has been discussed by many authorities. Mark Weiser offered Ubiquitous Computing vision in early 1990s which suggests that computers should be hidden in the background of living and release humans from dealing with technical details of how technology works. Similarly to this vision in 2000s Stefano Marzano from PHILIPS Design introduced his and his team's vision 'High Design'. They claimed that the ICT embedded products, electronics, dominated daily surroundings and should become embedded to the interiors. They offered that these technologies should merge with the interior entities such as tables, seating units and walls which have been around for centuries.

Both 'Ubiquitous Computing' and 'High Design' visions suggest merging products as a solution to technologies' domination over humans. On the contrary Pask's approach is to create entities that don't need to be hidden such as his MusiColor machine which acts like a performer. Thus it is possible to claim that in Paskian systems machines are the mechanical or digital equivalents of humans in real life. Also it is possible to claim that these different arguments about technology led to different paths. While ubiquitous computing and high design visions can be fulfilled by technologies such as IoT (Internet of Things) and M2M (machine-to-machine) communication, Pask's vision is being investigated in the field of artificial intelligence.

Other than the changes in physical representation of digital world, also the developments in user interfaces altered products as the interaction between digital and physical worlds happen in user interfaces. As mentioned earlier people gained motor skills for centuries, and actions became advanced with each tool developed. When all the inventions throughout history are taken into account, it is possible to claim that the variety of these skills and senses is enormous. Also as mentioned earlier with the emergence of ICTs many of these skills and senses were lost or left out. The widespread use of graphical user interfaces is among the reasons of this change. As the graphical and visual representation became more important than

physical existence, design customisation became more related to the changes in visual features.

As mentioned earlier with the embedding of many actions to the screens phones and tablets gained the features of computers and televisions, and to be able to execute these actions with ease screen sizes grew. This change can be seen in Apple's iPhone example in Figure 4.7 in which shows the evolution of the serie since its first production in 2007. This growth in size indicates the increasing importance of visual representation. While this growth offers more effective interaction when the phone is used as a television or a computer, it interfered with the interaction between phone and the user as it became harder to use the phone with one hand, place it in the pocket or else. As mentioned before technology has limitations over products. Though these restrict the way designers' involvement, these limitations bring new opportunities. In Figure 4.8 Apple Watch can be seen, these smart watches can be used in accordance with the phone and earbuds, and can be used without the need to touch the phone. Mails can be read through these devices while it can also be used to reach contacts along with other abilities such as fitness tracking etc. These advancements are related to the High Design vision, as they offer technologically dominant products merge with centuries-old products. While High Design vision is mostly about the surroundings, the resemblance is evident.

New technologies enter daily world through boxes, mobile phones are an example along with the reality-headsets. Virtual reality and augmented reality both offer new representations to the digital entitites, but to be able to see and percept these entities special tools are needed. Reality headsets are designed to fulfil this need. Figure 3.19 shows s reality headset. While virtual reality headsets have to cut the connection between the user and the surroundings to be able to offer close-to-real interaction, augmented reality devices should merge into daily objects as mush as possible. As mentioned all these devices are manufactured in black boxes, and with the developments such as Google Glass – although its efficiency can be argued – it is possible to claim that these devices will also merge into life through centuries-old products.

In all these examples, such as smart watches and glasses, it can be seen that the actual product that hosts the technology is something that humans use for long times. It means that these products adapted into daily life so well that even if their form

changed their use did not change. Another resemblance of these products is that they are body extensions; watches are placed on arms and glasses are placed on our face. They merged into body in a way that frequent users mostly don't recognize their existence. They can be, as mentioned earlier, accepted as a righteous interface.

Other than the changes in the physical end products, also the way of producing and consuming is changing as a result of ICTs offerings. With Internet and related movements such as Open Source Movement, Makers Movement along with the developments in manufacturing methods such as 3d printers, it became possible to print designed objects from smaller entities such as jewellery to bigger entities such as cars. 3d printers offer faster production of customisable products with a wide range of materials such as metals, plastics, bones and tissues etc. While to be able to use these printers users should create their imagined products in 3d modelling programs, with the open source websites and model libraries it is possible to print out the needed products without modelling. These platforms offer designed 3d objects that can be printed without the need of a change, thus can be used by many people who doesn't have any knowledge of 3d modelling programs.

The changes in producing and consuming bring the opportunity to create sight-specific, unique products, thus it is possible to claim that end users become able to create products that suit best to their needs and the need to consume will be decreased. Instead of humans adapting their needs to the design and the technology, design would be adaptive according to their needs. With the ability to create unique solutions and products, the surroundings would become adaptive and interior spaces will gain the ability to be customisable by the inhabitants.

6.3 Space Becoming Adaptive and Communicative

As indicated in Chapter 3.1 and Chapter 5.1 humans gather data from surroundings unconsciously, thus it can be claimed that environments are embedded with information already. Even without architectural spaces and human interference, nature is embedded with information. In nature bright colours suggest poisonous creatures and plants, and leaves change colours in autumn. All these along with many embedded others suggest that our surroundings – natural or man-made – are already information systems.

The emergence of Information and Communication Technologies increased the importance of communication and data. As mentioned earlier these technologies entered interior spaces through products such as televisions, computers and mobile phones etc. which brought many changes to interior spaces as they change the way people execute actions. Products changed the actions, thus changed their space, and also dominated interiors by their black-box presence.

ICTs changed the nature of actions, architectural blueprint drawing can be given as an example. Before computers entered the workspace architects were using pens and rulers to draw blueprints, and they had specialised angled tables for drawing. With the emergence of Personal Computers and digital tools for parametric drawing space organization changed. Angled tables with pens and rulers were outed by desktop computers with keyboards and mouses. Afterwards with the laptops becoming feasible and affordable for common use, it became possible for architects to work anywhere with a connection to power and Internet. Similarly actions including writing, painting, drawing and many others changed along with their spaces.

As stated earlier ICT related products entered interiors spaces through box shaped computers which have many extensions such as keyboards and wires. This resulted in the dominance of box shaped plastic products as mentioned in the High Design vision. To overcome the dominance of technology in interiors, several suggestions were made. While some including Marzano and Weiser offered hidden computers in interiors, some including Pask offered that computers should be designed equally to beings thus should not be hidden. As mentioned earlier it is possible to claim that these visions lead to different paths. Hidden/embedded computers vision lead to ambient intelligence in which smart objects can communicate among themselves and act according to their presets, while organism-like computers are being investigated under the fields of artificial intelligence.

Ambient intelligence helps creating smart environments by using the communication between products. Though it was possible to gather data from each digital/mechanical component in the house, with the developments in ambient intelligence field it became possible to communicate with the surroundings. IoT - Internet of Things and M2M- Machine to Machine communication bring the opportunity to create a network of machines that can be adjusted according to the users need without forcing the user to deal with technical details of the technology.

These technologies offer assistive features such as ability to secure buildings from distance or track the inhabitants' health which are mentioned in chapter 5.3.1. Thus it is possible to claim that with the further developments in this field, inhabitants would be able to have conversations with their homes and surroundings.

One of the offerings of ICTs is augmented reality in which digital entities (that can be perceived and seen through special tools) are embedded to the physical reality. Figures 3.24 and 3.26 show some tools for ambient intelligence. While glasses and screens are offering more graphic digitals, Fairy Lights concept is offering tactile feedback for the embedded digitals. As mentioned earlier Fairy Lights project shows the opportunity to create half digital half physical entities that can be perceived and be interacted with more naturally. With further developments it might eliminate the need for embedded screens for some tasks similarly to the buttons' merger into screens. Also related advancements in holographic technologies might bring the flexibility and manipulation ability of the digital world into the physical world. Thus the physical world might become more adaptive with the embedded digital tools.

Developments in Augmented Reality and Ambient Intelligence fields along with advancements in user interfaces suggest that interior spaces gain product-like features, and they shift from informative systems to communicative systems. As discussed earlier design needs to be adaptive in order to answer the needs of the time. Similarly architecture should be adaptive and communicative to answer these needs.

Though it seems like a contemporary challenge, as mentioned in Chapters 5.1 and 5.2 architects sought ways to accomplish natural interaction with technologically advanced environments. After the Second World War several concepts were developed, many of them offered systems that consisted of iterative modules to create adaptive, transportable, location-free and user-oriented environments. Though the malleability of the concepts were closely linked to the material and manufacturing technologies, ideas behind are still current as they were about thinking the world as a whole and giving priority to inhabitants' preferences instead of technical requirements. It is criticised in the projects that architecture lost its connection to human values, instead of inspiring people architecture was restricting them. These visions meet with today's issues of technological dominance and user-centered design.

It can be claimed that with the emergence and dominance of ICTs in interior spaces, natural interaction between humans and their surroundings is damaged. Loss in sensory diversity is an example to this damaged interaction. The suggestions of the architects mentioned above lead to an understanding of space as a being, as an whole. Though ICTs dominated interiors for several years, the developments in the field along with the developments in materials and manufacturing bring the ability to create adaptive environments. The flexibility of the digital world now can be transferred to the real environments. Examples in Chapter 5.3.1 show the integration of ICTs into physical world. This new concepts of responsive walls and environments indicate more than just restoring the natural interactions, they offer new ways of interactions by turning static elements into dynamic entities.

It is possible to claim that with advancements in sensors and actuators along with the concepts of ambient intelligence such as IoT and M2M, environments gain tools for perceiving and reacting like an organism. Also with the developments in artificial intelligence field, as mentioned in Chapter 3.3.2, homes and devices might gain assistive abilities similar to a human's. Advancements in ICTs suggest that products and environments gain abilities like natural organisms, and these organisms have the tools to communicate which is a new concept for humans.

With regards to the changing trends and emerging technologies, communicative environments offer more natural, subtle and easier interactions. As mentioned earlier interaction designers' job is to design the bridge between the technology and humans. For many years technology was hosted by products, and product designers contributed to the interaction design field with their experience and knowledge. As the technologies' host is becoming spaces, it can be claimed that it is architects' turn to work in collaboration to achieve the task of creating a human-centered environment instead of technological dominance.

6.4 Recommendations

Interaction Design is under development, and it is possible to claim with regards to the importance of Information and Communication Technologies that Interaction Design is gaining importance. As ICTs brought challenges, limitations and drawbacks in many fields such as perception, physical and digital representations,

they also opened up new dimensions for the humanity. And with the increasing importance it is crucial to design this new world compatibly to the physical world.

Each profession of product design and architecture gained wide knowledge about human life and habits. All this gained knowledge is very important for ICT related research as human priority is sought. ICT related devices affect daily habits and surrounding at a high pace thus designing these artefacts with the gained knowledge in both product design, architecture and computer sciences is important. The very nature of architecture and product design is human-centered, and it can be claimed that architects and product designers along with engineers have the ability to create technologically sophisticated but human-centered spaces.

As products physically merge into the environment, interior spaces gain product like features. For further studies, it is recommended to find ways to transfer knowledge between the related fields. While there have been already several researches in each area mentioned in this thesis – such as user interfaces, augmented reality, ambient intelligence, product design and architecture etc. – their close relationship should be taken into consideration, thus it is recommended to work in collaboration for an environment without the technological domination. It can also be claimed that with designers' late contribution to the HCI resulted in technological dominance in interiors and loss in sensory diversity, architects' late contribution might lead to similar effects. Thus architects should be aware of the emerging technologies such as ICTs as these are closely related and adaptive to the inhabitants' habits and daily life.

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APPENDICES

APPENDIX A: Legends for Appendices B and C

APPENDIX B: Sampling Information Tag Tables

APPENDIX C: Comparison Tables

APPENDIX A

Table A.1: Legend for Information Tags

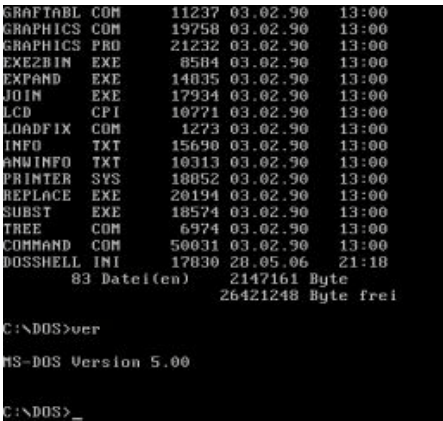
En 3 90s	Short Description: ICT embedded environment for kids Features: This environment is designed for Kids' game time. It reacts to the kids' movements thus joins the gamaplay. In contrast to AmbientROOM, technology is not used subtly. Though the interface cannot be understood at first glance, it is designed as an entity that reacts and plays with kids so it is not hidden in the background. It offers full body interaction.	 The KidsRoom    
Colour of the circle	Content	
	Code of the sample: EN: Environment; T/S: Tools and Systems, UI: User Interface	
	Sample Feature Tags	
	Sample Description and Features	
	Sample Figure and Name	
	Sample's Interaction Channels	

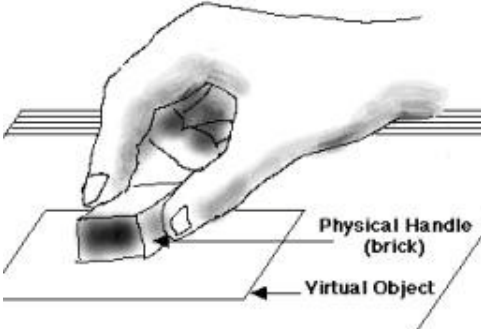
Table A.2: Legend for Icons

ICON	MEANING	ICON	MEANING	ICON	MEANING
	Produced between 2010-2015		Visual Interaction		Next Generation UI
	Produced in 2010s		Audial Interaction		Virtual Reality
	Produced in 2000s		Tactile Interaction		Augmented Reality
	Produced in 1990s		Whole-body Interaction		Ambient Intelligence
	Produced in 1950s		Command UI		
	Fiction		Graphical UI		
	Shows some level of intelligence		Tangible UI		

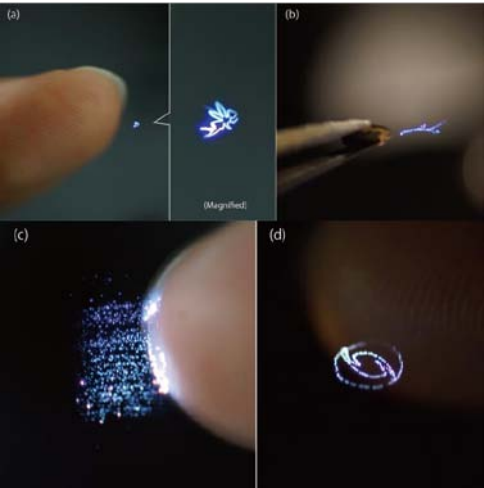
APPENDIX B

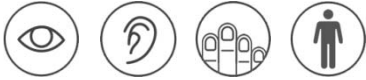
Table B.1: Information tag table of UI samples.

UI 1 90s 	Short Description: This user interface show the first interaction with the digital world. Features: This user interface is one of the first user interfaces. It's very limited as the user has to remember each command to execute actions, thus it is hardly open to manipulations. Also the interaction is very limited as there is very little tactile and audio feedback.	 MSDOS 
UI 2 90s 	Short Description: This user interface shows the Windows, icons, menus and pointers (WIMP) concept. Features: This user interface is one of the first widely used GUIs. Though it offers limited interaction, it has more options than Command UIs. Actions are limited and the interface can only be manipulated through WIMP. This user interface offers visual feedback along with limited set of audio feedback. Direct perception of the executed actions is an important development for UIs.	 Windows 3.2  

UI 3 10s	Short Description: This user interface shows the GUIs' use with touch screen technology. Features: Mobile Phones and Tablets share their user interfaces. This mobile UI can be altered according to the user's preferences thus it is possible to manipulate the interface. This interface offers visual feedback higher than its predecessors, along with enhancements in audio feedback. Also with vibration options, a limited tactile feedback can be given to the users.	 Windows 8 for mobile  
UI 4 90s	Short Description: In this user interface wooden sticks are used to manipulate graphical objects. Features: This UI is more adaptive than the GUIs of its era, as it offered more direct manipulation of digital entities. Graspable UI presented a new way of interaction by giving the opportunity to manipulate digital entities with physical objects. This user interface offers direct visual feedback along with the tactile feedback of the physical object and the movements of the hand.	 Graspable User Interface  
UI 5 00s	Short Description: Body involvement in gameplay. Features: Nintendo Wii Fit offers several tangible tools that can be used equally to fitness equipment. It can track balance, movements and create a full body experience. Though it offers full body experience, it needs several specialised tools such as balance board or joysticks to measure movements.	 Nintendo Wii Fit    

UI 6 10s 	Short Description: Body involvement in gameplay. Features: Xbox Kinect is a game console that offers full body experience without the need of a specialised tangible tool. Its camera can track body movements and move the digital persona to act according to these movements. Though Kinect has the advantage of being tool-free, limited game and graphics are criticised among users.	 Xbox Kinect   
UI 7 10s 	Short Description: Body involvement in gameplay. Features: Playstation 3 Move use motion detection for gameplay. It uses two lighted joysticks to detect motion. It is more tool-bounded than its peers (Wii Fit, Kinect). Though interaction is mainly through the controller, as a result of the games' interface design whole body interaction is possible.	 Playstation 3 Move    
UI 8 15  	Short Description: In this project, bacteria are used to create interactive fabric that reacts to the users' body temperature and sweating level. Features: This clothing has the ability to adapt to different situations as it hosts organic homophobic bacteria. Though this fabric is highly adaptive, users are incapable of affecting its change. Feedback as in the means of sensory channels is limited though the fabric uses natural intelligence of the bacteria and communicate by opening and closing the vents.	 Second Skin  

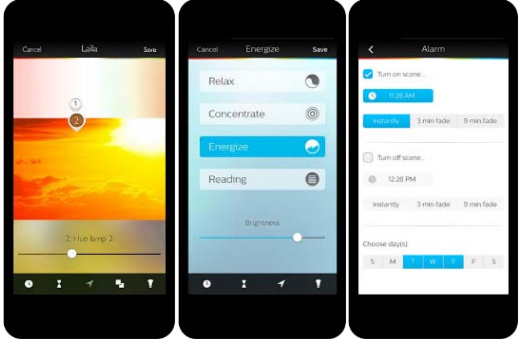
UI 9 15	Short Description: A line shaped interface that can create many shapes according to needs. Features: This product/interface can change its shape regarding of the action. It can learn designated movements and repeat them when needed along with the programmed actions. It can be manipulated freely by the user. It offers whole body interaction.	 LineFORM   
UI 10 15	Short Description: Holographic digital entity that can be touched. Features: This interaction medium offers tactile feedback although it is immaterial. Even though the physical interaction is limited to a short period, it is digitally flexible at most. Also the ability to create mid-air, non-material but touchable medium is new among user interfaces. This ability comes with the advantage of being location free. If technical requirements are fulfilled than it is possible to create these holograms at any location. This interface answers visual and tactile sensory channels.	 Fairy Lights in Femtoseconds  
UI 11 15  	Short Description: Human like AI that is in charge of the whole Stark Mansion and Iron Suits. Features: This AI is highly adaptive, personal assistant that can sometimes act as a friend with its own mind. It has the ability to improvise and act on its own during emergency situations. It gives feedback through several channels including spoken language, visual and audio channels. This AI shows how it might be to have a superintelligent home assistant.	 JARVIS   

UI 12	Short Description: A location-bound interface to detect criminals before they commit crime. Features: This interface offers adjustable screen-like interface that can be manipulated by the user's movements and touch. It hosts data as a living entity. It offers tactile, visual and audio feedback along with whole body interaction. This interface shows a specialised environment example which is highly integrated with technology.	 Minority Report 
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UI 13	Short Description: Portable Holographic Interface Features: This interface offers the flexibility of the virtual dimensions in the physical world, thus it is an highly adaptive interface. It gives the ability to directly manipulate the features and also gives direct feedback. It uses visual and tactile channels to interact with users. This interface shows a possible way of interaction as it offers tangible but immaterial entity which is location-free thus can be used anywhere to customise the surroundings.	 Tron Legacy 
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Table B.2 : Information tag table of Tool and System samples.

T/S 1 15 VR	Short Description: Virtual Reality Headset Features: This headset interferes with space perception. It works in collaboration with specially designed videos. Interaction is through visual and audio channels.	 Oculus VR  
T/S 2 15 AR	Short Description: Augmented Reality Headset Features: This headset uses real-life to mount digital entities that can be manipulated freely. It doesn't cut the relation between the users and their surroundings by just adding digital entities to physical world.	 Microsoft HoloLens 
T/S 3 15 AR	Short Description: Augmented Reality Headset/Glass Features: This glass uses small screen on the right eye side to augment information to real life. Though it is embedded to a widely-used object – glasses – Google shut down the project due to privacy concerns as these glasses also shows social media accounts of people it encounters.	 Google Glass 

T/S 4	Short Description: Ambient Intelligence System for lighting Features: PHILIPS Hue system offers M2M connection between lights and related household features. If programmed it can warn inhabitants about incoming mail or emergency situations. It is possible to adjust lighting from distance with the mobile app and users have full opportunity to manipulate its features.	 PHILIPS Hue   
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T/S 5	Short Description: Ambient Intelligence System for Household. Features: Alexa, as it answers this name, acts as a personal assistant at home. If connected to the other household items it can detect which products are over and order these products online.	 Amazon Echo, Alexa  
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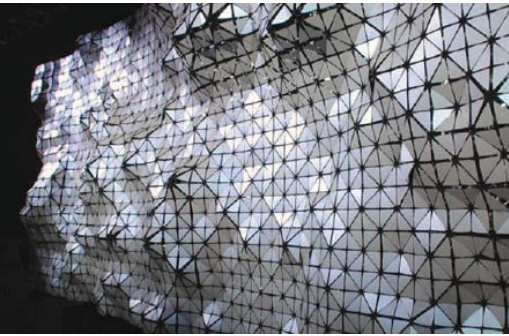
Table B.3 : Information tag table of ICT embedded environment samples.

En 1 50s Aml	Short Description: ICT embedded environment Features: The Pavilion was built by PHILIPS and Le Corbusier for the EXPO'58 Montreal. It was designed to promote ICT related products of PHILIPS the Pavilion did not designed as way to present the products in a classical manner. The concept was to create an ambient environment to express the possibilities of the new technologies and to create a new kind of experience for the visitors.	 PHILIPS Pavilion   
En 2 90s Aml	Short Description: ICT embedded environment Features: This environment is embedded with information. It uses subtle natural references such as wind, waterdrop etc to give information subconsciously. It shows a concept that closely related to High Design vision as it uses daily life objects to embed the technology.	 AmbientROOM   
En 3 90s Aml	Short Description: ICT embedded environment for kids Features: This environment is designed for Kids' game time. It reacts to the kids' movements thus joins the gamaplay. In contrast to AmbientROOM, technology is not used subtly. Though the interface cannot be understood at first glance, it is designed as an entity that reacts and plays with kids so it is not hidden in the background. It offers full body interaction.	 The KidsRoom    

En 4	Short Description: An ICT embedded working space for Radiologists which offers that the whole space is a tool for the interface.	
 	Features: This concept is an example of merging two worlds in a room. Flexibility of the digital world can be used at a high level as all the surfaces can act as a digital interface with projection and sensor technologies. The room reacts to the body movements and sound. Also the room completely acts as a communication tool though it is not creating communication.	PHILIPS Reading Room 2020 

En 5	Short Description: Ambient environment	
 	Features: This building is designed for the Swiss EXPO in 2002. It is raised above the lake, and use its water to create a new kind of ambient environment by suppressing the senses. With the foggy atmosphere visual and audial senses are restricted to enhance the whole body interaction with the space.	Blur Building 

En 6	Short Description: An interactive and adaptive wall	
 	Features: This project offers a wall system that can react to the visitors. It uses light, sound and movement to interact with people. This projects offers new dimensions for adaptive architectural design in the scale of building elements.	Interactive Wall 

En 7	Short Description: An interactive surface installation Features: This installation reacts to sound, light and movement of the people passing by. It offers an interactive and responsive surface design that can be used in interiors.	 Hyposurface    
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APPENDIX C

Table C.1 : Comparison of User Interface samples according to keywords.

USER INTERFACES	ADAPTIVE	UI1:MSDOS	UI2:Win 3.2	UI3:Win 8 UI4:Graspable UI UI13:Minority Report	UI5:Nintendo Wii Fit UI7:PS 3 Move UI6:Xbox Kinect	UI8:Second Skin UI9:LineFORM UI10:FairyLights UI12:Tron UI UI11:JARVIS
	RESPONSIVE	UI1:MSDOS	UI2:Win 3.2 UI4:Graspable UI	UI3:Win 8 UI13:Minority Report UI12:Tron UI	UI5:Nintendo Wii Fit UI7:PS 3 Move UI6:Xbox Kinect	UI8:Second Skin UI9:LineFORM UI11:JARVIS
	MANIPULATABLE	UI1:MSDOS	UI2:Win 3.2 UI8:Second Skin	UI3:Win 8 UI4:Graspable UI UI10:FairyLights UI5:Nintendo Wii Fit UI7:PS 3 Move	UI13:Minority Report UI11:JARVIS UI6:Xbox Kinect	UI9:LineFORM UI12:Tron UI

Table C.2 : Comparison of Tool and System samples according to keywords.

TOOLS/SYSTEMS	ADAPTIVE		T/S5:ALEXA T/S3:Google Glass T/S1:OculusRift	T/S2:HoloLens T/S4:PHILIPS Hue
	RESPONSIVE	T/S1:Oculus Rift	T/S5:ALEXA T/S4:PHILIPS Hue T/S3:Google Glass	T/S2:HoloLens
	MANIPULATABLE	T/S5:ALEXA T/S3:Google Glass	T/S2:HoloLens T/S1:Oculus Rift	T/S4:PHILIPS Hue

Table C.3 : Comparison of ICT embedded Environment samples according to keywords.

ENVIRONMENTS	ADAPTIVE	En2:AmbientROOM En1:PHILIPS Pavilion	En5:Blur Building En4:Reading Room 2020	En7:Hyposurface En6:Interactive Wall En3:KidsRoom
	RESPONSIVE	En2:AmbientROOM En4:Reading Room 2020	En5:Blur Building En1:PHILIPS Pavilion	En7:Hyposurface En6:Interactive Wall En3:KidsRoom
	MANIPULATABLE	En1:PHILIPS Pavilion En4:Reading Room 2020	En2:AmbientROOM En5:Blur Building En3:KidsRoom	En7:Hyposurface

Table C.4 : Comparison of UIs' Interaction Levels

INTERACTION CHANNEL/ USER INTERFACE	VISUAL	AUDIAL	TACTILE	WHOLE BODY/ IMMERSIVE
MSDOS				
Win 3.2	 			
Win 8	  	 		
Graspable UI	  		 	
Nintendo Wii Fit	  	  	 	  
Xbox Kinect	  	  		  
PS 3 Move	  	  	 	  
Second Skin				
LineFORM				 
FairyLights				
Minority Report				 
Tron UI				
JARVIS	 	  		



CURRICULUM VITAE

Sena Semizoğlu

21.04.1990 / İstanbul

Email: sena_semizoglu@hotmail.com

EDUCATION:

B.Sc.: Interior Architecture, ITU (2008-2012)

High School: HASAL (2004-2008)