SMART PRODUCTS:
TECHNOLOGICAL APPLICATIONS vs USER EXPECTATIONS

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ABSTRACT

SMARTPRODUCTS: TECHNOLOGICAL APPLICATIONS vs USER EXPECTATIONS

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This thesis focuses on the technological trends in smart products, and analyzes their conformity to the user expectations. The advances in computation technologies have totally revolutionized the product concept, and with the integration of microchips, software and sensors into the classical everyday objects, smart products, able to sense the context, reason about the sensed data and act according to the situation, have emerged. This new way of computing basing on the ubiquitous and calm computing visions, has distributed the digital information into the surrounding environment, and once freed from the limited resources provided by the classical desktop based computing, attempted to enhance user product communication and collaboration in everyday environments. Via their sensing - decision making - acting process and advanced interaction capabilities**,** smart products have gained the ability to better interpret user needs and intuitively communicate with users through simplified interfaces involving the majority of the senses without even disturbing or overburdening their users. The study first, throughout a literature review, examines these improvements in computation technologies and determines the trends related to smart products. An empirical research is then conducted to find out to what extend user expectations from smart products overlap with the ongoing researches in this area.

The findings including users' conception about smartness and expectations from different types of smart products are analyzed regarding to the technological trends to deduce the coherence between literature's orientation and user preferences. The study considered the technological trends as a database and takes the user expectations as the design motivation.

Key words: Smart product, ubiquitous computing, calm computing, user expectations, technological trends

ÖZ

AKILLI ÜRÜNLER: TEKNOLOJİK UYGULAMALAR - KULLANICI BEKLENTİLERİ

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Bu çalışma akıllı ürünlerdeki teknolojik trendleri ele almakta ve kullanıcı beklentilerine ilişkin uyumluluklarını incelemektedir. Bilgisayar teknolojilerinde süregelen gelişmeler ürün kavramını tamamen değiştirmiş, mikroçip sensor ve yazılım gibi donatılarla zenginleştirilen sıradan gündelik objeler, çevresini ve etrafındaki kullanıcıları algılayabilen, içinde bulunduğu duruma yönelik bir şekilde düşünüp, bu duruma uygun olarak hareket edebilen akıllı ürünlere dönüşmüştür. Dağıtık ve dingin bilişim anlayışlarından beslenen bu yeni yaklaşım sonucu günlük yaşam alanlarına yayılan akıllı ürünler, masaüstü bilgisayar anlayışının sağlayabildiği sınırlı kaynaklara yetinmektense kullanıcı beklentilerini en iyi şekilde karşılamayı hedef edinmiş ve ürün - kullanıcı arasındaki iletişim ve işbirliğini geliştirmeyi amaçlamışlardır. Bilgisayar destekli bu ürünler, algılama, karar verebilme ve uygulama mekanizmaları ile ileri etkileşim kabiliyetleri doğrultusunda kullanıcı ihtiyaçlarını daha iyi yorumlayabilen ve kullanıcı duyularının çoğunluğuna hitap edebilen, dikkat yoğunluğu gerektirmeyen basitleştirilmiş arayüz biçimleri ortaya koymuştur.Çalışma süresince, ilk olarak akıllı ürünlere yönelik araştırmalar taranmış bu ve alandaki teknolojik gelişmeler saptanmıştır. Ardından elde edilen içeriğin kullanıcı beklentileriyle ne derece örtüştüğünü belirleyebilmek amacıyla amprik bir çalışma yürütülmüştür.

Çalışma sonucu akıllı ürünlere yönelik kullanıcı beklentileri belirlenmiş ve bulgular teknolojik trendler doğrultusunda analiz edilerek literatür çalışmasındaki sonuçlar ile olan bağlantısı sorgulanmıştır. Çalışma, ürün tasarımında teknolojik trendleri bir veri tabanı olarak görmekte, kullanıcı beklentilerini de tasarımı yönlendirebilecek nitelikte bulgu olarak değerlendirmektedir.

Anahtar kelimeler: Akıllı ürün, dağıtık bilişim, dingin bilişim, kullanıcı beklentileri, teknolojik trendler

To My Grandmother

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INTRODUCTION

1.1 Problem Definition

The application of digital technologies is radically changing the nature of today's consumer products. New developments are constantly improving hardware, software and interaction technologies, and their inevitable proliferation in everyday objects, totally diversifies the product concept. However no one could precisely know the limits or the effects of this diversification into daily life. Once equipped with the capacity to compute and communicate, these everyday objects may provide different functionality and interaction possibilities to the users. An ordinary coffee cup could transform into a mobile device where we can check e-mail, call friends or download music and video, our refrigerator could suggest alternative menus relative to our taste, automatically order food, or even our carpet could change color and pattern based on our current mood.

The functions provided by digitally augmented everyday objects are limited only by the imagination of their designers who continuously face challenging design questions such as "what to and how to digitally augment traditional objects". Designing such everyday artifacts becomes a very different and more and more complex task. The actualization process of a technology integrated desired product, not only requires to master perfectly the technology they include, but also necessitates to discover the "appropriate" digital functionalities to include and to envisage the simplest way of interaction with users.

Many products with digital properties called as ‘smart’ or ‘intelligent’ have already been in the market. The Pocket PC’s, mobile phones, digital photo frames, sensor based heating and lighting controllers, interactive TVs, car navigation systems etc. are some of the examples of these digital products.

The exponential growth of computerized devices is obvious; however the increase of these new products, loaded with multiple features, is often interrupted with failures in marketplace. The technology driven mentality combined with market competition engenders speedily developed products comporting numerous technological properties. The human-centered product development stage is generally skipped and products are pushed at the consumer faster than the users could adopt.

Whereas, in order to succeed in the market digitally augmented products which utilize the state of the art technologies should satisfy consumer expectations. To determine appropriate design strategies which minimize the risk of failure of smart products in the market, designers need to gather information about the daily needs, expectations, and motivations of the consumers regarding digitally augmented everyday objects.

1.2 Scope of the Study

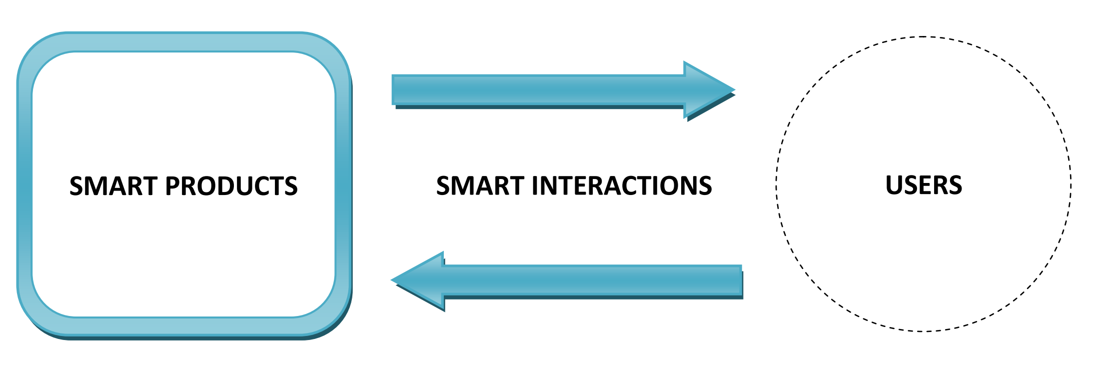
The goal of this study is to discover user expectations from smart products and determine to what extent these expectations overlap with current technological trends in the area of interest.

The study will review the trends in smart products and will collect data about “why” and “how” people would use a smart object. The data will then be analyzed according to the current trends in smart products to understand users’ expectations regarding to this new product segment, determine their priorities and define the most appropriate functionalities and interactions susceptible of satisfying their needs.

1.3 Structure of the Thesis

The study examines smart products from three perspectives. First it focuses on the current technological trends from product perspective. Technologies permitting different level of intelligence as well as the current examples of smart products are presented. Then it deals with the smartness from user-product interaction perspective. New interaction styles providing richer input and output modalities supposed to improve the interaction between users and smart products are described. Finally smart products are handled from user's perspective. User's understanding about smartness and their expectations from smart products are questioned. The diagram below (Figure 1.1) illustrates the questions which will be answered in each chapter.

Chapter 2 Smartness from product perspective	**Chapter 3** Smartness from user - product interaction perspective	**Chapter 4** Smartness from user perspective



What are the technological and conceptual background of smart products? What are the current technological trends on smart products? Which kind of smartness do the current smart products embody?	What are the technological and conceptual background of smart interactions? What are the current technological trends on user-smart product interactions? What are the different interaction types and technologies which can be used by smart products?	What are the user expectations from smart products? What type of smartness do users expect from smart products? Which kind of interactions do users envisage with smart products?

Chapter 5 Conclusion:
To what extend do the current technological trends meet user expectations from smart products?

Figure 1.1 Structure of the thesis

Chapter 2 starts with a look at the foundations of smart product idea. In order to mention the motivation and underlying vision of the idea, first, it presents the technical and conceptual background of the smart products and ubiquitous computing. Second, a deeper explanation of the term smart product is provided and the technologies permitting a product to become 'smart' are described.

The important studies dealing with the integration of computational power into common daily products are reviewed and current examples of the smart products are examined.

Chapter 3 concentrates on smart interactions assuring the communication between the users and the smart products. An overview of current technological trends in this field is provided after introducing calm computing vision and describing the technical and conceptual background of smart interactions revolutionizing the human-computer interaction completely. Following, new interaction styles permitting to establish an adequate interaction with smart products are described. The improvements concerning user- smart product interaction are elaborated and the different examples of products enhanced with smart interaction technologies derived from literature are presented.

Chapter 4 focuses on user understanding from the term of smart product and their expectations from this new category of product. Concepts such as technology driven design and user centered design are elaborated to reveal the importance of satisfying user expectations to determine the marketplace success of a product. Through an empirical study, how the term of smartness is conceived by users and what kind of smartness they expect from these products are determined.

The study concludes with a comparison between the findings of the empirical study and the technological trends mentioned in preceding chapters. By comparing current trends with user expectations, it is intended to examine, to what extent the smartness attributed to the products from the user perspective overlaps with the smartness vision provided by the current technological background. Users' expectations will construct a guideline to evaluate current trends in this area and determine the appropriate 'smart' functionalities and interactions satisfying user needs.

CHAPTER 2

SMARTNESS FROM PRODUCT PERSPECTIVE

The integration of Internet and Web technologies added new dimensions into human living and working models in the last century. A huge network consisting of interconnected supercomputers, clusters, workstations, servers, personal computers, PDAs (Personal Digital Assistants), and many other digital devices formed the basis of a digital information world (Ma, 2005, Kunii, 2004). Another revolution bringing the computation from this cyberworld into the real world has emerged by the end of the last century. According to this new way of computing, computers were supposed to support people ubiquitously in their daily activities through common everyday objects and environments (Figure 2.1).

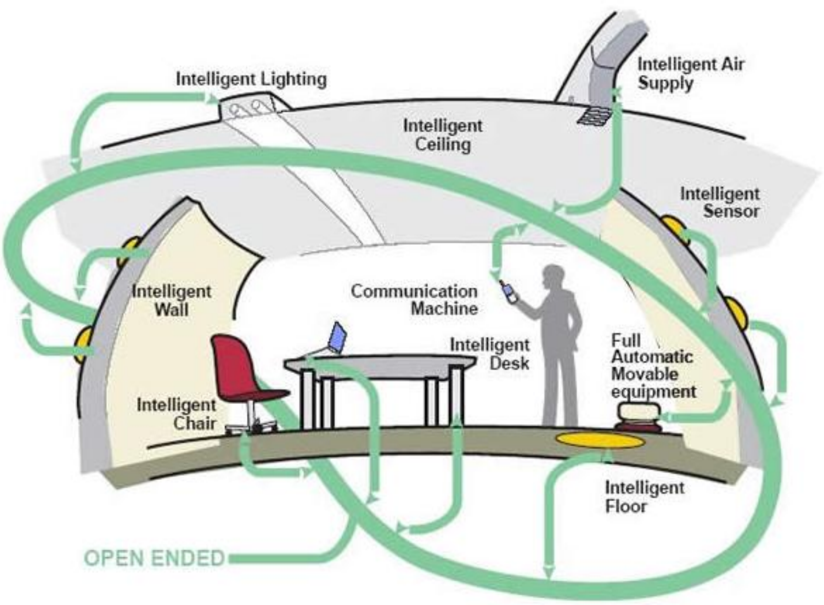


Figure 2.1 Ubiquitous Computing Vision

(Source: www.u-tokyo.ac.jp)

As mentioned by Weiser et al. (1991, pp: 694) Ubiquitous computing is a “new field of computer science, one that speculated on a physical world richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives and connected through a continuous network”. The idea envisaging such a computation is the consequence of both a technological and conceptual background.

2.1 Technical background

The technological advances permitted the integration of a great number and variety of computers with different sizes and functions in everyday life. The integration of digital technology into the daily objects is the result of two fundamental technology trends, according to Ma et al. (2005): the continuing miniaturization of more and more powerful electronic chips, and their interoperability toward wireless networks. Computation has become increasingly such smaller and unobtrusive that its proliferation into physical objects was inevitable. In addition to these advancements in computational power and communication technologies, Mattern (2001) mentions also the emergence of new materials, and the progress in sensors and tracking technologies as important inputs.

Computational power

The continuing technological progress of information technology starts in the late 1960s with the exponential growth of microelectronics, storage capacity and communication bandwidth. In 1965, Gordon Moore observed that the number of components per integrated circuit doubles approximately every year. He predicted that this trend will subsist and the power of microprocessors will double about every 18 months (Moore, 1965). His prediction also known as Moore’s law has been proved to be valid for more than 40 years. Besides, Moore’s law is not only applied to the microprocessors; a similar progress in the storage capacity, and the bandwidth of communication network has also occurred (Siegemund, 2004). Finally, as a result of the increasing computation speed and much more powerful, smaller, and cheaper computer processors and storage components; large amounts of computing devices are integrated into everyday environments.

Communication capabilities

In addition, the bandwidth of communication technologies and the wireless communication supporting mobile computing, have improved rapidly. Thus efficient wireless systems assuring communication between mobile everyday objects and also enabling the necessary data transfer with background infrastructure services were established (Siegemund, 2004; Bohn et al., 2004). Especially the developments in wireless communication technologies, with the establishment of protocols such as, Bluetooth, WLAN, GSM, optical communication, RFID protocols, powerline communications, or body area networks (Want et al., 2002) provided a variety of means both for long and short distance communication.

New materials

On the other hand the development in microsystem technology and nanotechnology had a great impact on smart products (Mattern, 2001). With the use of these new materials intrinsically emitting light, changing color or shape, the integration of computation into everyday life gained a new dimension permitting users to manipulate everyday things by providing additional features that enrich existing interaction patterns (Dourish, 2004).

Sensor technology

Another interesting development is tracking and sensors technologies. The integration of sensors into everyday objects permitted to have context-aware and also context-adaptive products (Bohn et al.,2004).

The technological advancements, resulted finally in the development of digitally augmented everyday objects with powerful processors, huge storage capacity, communicating with each other, equipped with sensors, providing a completely different product experience and enabling the development of ubiquitous computing vision.

2.2 Conceptual background

The motivation behind the vision of ubiquitous computing was the fact that the silicon based information technology was not well suited to the environment surrounding us. General purpose computers were such isolated from the overall situation that, rather than being just a tool supporting people in their daily activities, they were necessitating permanent attention of users and technological skills to use them. As an alternate to the technology-centered computing view, ubiquitous computing was introduced promoting a new way of thinking about computers, bringing the technology to the background, and letting people to focus on the task rather than the tool.

Ubiquitous computing vision aims consequently to benefit from information technology, without limiting users to their desktops or laptops, by providing them convenient and comfortable services in their everyday environment with right means at right place and in right time through a continuous, natural and implicit interaction requiring less pre-knowledge and fewer computer skills (Weiser, 1993, Norman, 2007). “The challenge is to create a new kind of relationship of people to computers, one in which the computer would have to take the lead in becoming vastly better at getting out the way, allowing people to just go about their lives” stated Weiser (1993, pp: 73) while introducing this new computation vision.

Ubiquitous computing could be regarded as the opposite of cyber computing consisting of the implementation of information technologies in digital or virtual world where physical things in the real world were transferred into the virtual world. Books became e-books, money became e-money and even environments such as classroom are transformed into e-classroom (Ma, 2005). Contrarily in ubiquitous computing the sensing, communicating and processing abilities are embedded into real things. Ubiquitous computing envisions a complete integration of information technology into the daily environment in order to support people in their daily activities. The human centered view even necessitates that the computational power become invisible to the users, disappearing in the background. The omnipresent information should be unobtrusive and perceived as an integral part of existing objects. However at the background all ubiquitous computing technologies have to be connected, aware of each other and permanently sensing their environment and surrounding users. First examples of ubiquitous computing have been the proliferation of devices at varying scales from hand held personal devices such as pads, tabs to wall-sized shared devices as electronic whiteboards. However, as pointed out by Weiser (1993), tabs, pads and boards were just the beginning of ubiquitous computing. In light of the ongoing advances in hardware, software and communication technologies, following developing research areas are mostly concentrated on integrating computational power into everyday objects. Smart products linking the real world to everyday things with the information technology emerged as a result of these researches and exemplify to the full extent the vision of Ubiquitous Computing. The following section will give a definition of smart product and present its technical properties in detail.

2.3 Smart Products

In order to be considered "smart" those products should include numerous features enriching or enhancing their existing capabilities. They can have similar physical properties to any everyday objects as a table, mirror or a cup, however what makes them smart, is their digital capabilities.

The word 'smart' is an abstract and vague term that can cover different meanings relative to the context. Besides "smart", there are a lot of researches named, with other terms, such as intelligent, context-aware, active, reactive, proactive, informative, assistive, adaptive, automated, sentient, perceptual, cognitive etc. However, in most of the cases the words "smart" and "intelligent" used interchangeably and with almost equivalent meanings, seem to embody all of the terms mentioned above.

2.3.1 Definition

The smart product definitions existing in literature cover different level of smartness, Kintzig et al. (2003, pp: 23), for example, define smart object simply as a "physical device equipped with a processor, memory, at least one network connection, and various sensors/actuators". Siegmund (2004, pp: 15) adds a specific dimension to this definition and defines smart product as an "everyday object" consisting both from an everyday thing and information technology that augments it. While according to Ma (2005, pp: 147) a "smart ubiquitous thing" besides being a real physical object that could sense, compute and communicate should also take some responsive or automatic actions/reactions/proactions according to its goals, situated contexts, users' needs, etc.

Finally Cook and Das (2005, pp: 80) extend the smart objects capabilities by attributing them in addition the ability "to acquire and apply knowledge about an environment and to adapt to its inhabitants in order to improve their experience in that environment".

Altogether, they lead to the following 'early' definition: Smart product is a physical everyday thing equipped with digital technologies, which could sense, compute communicate and take some responsive actions in order to improve users experience.

The term 'product' is subtle and could cover multiple things in the real world. Therefore different terms such as smart object, smart every day object, smart ubiquitous thing, smart environment are used in literature. In this study, as illustrated in Figure 2.2, the term 'smart product' will cover the totality of smart objects, smart environments and smart systems.

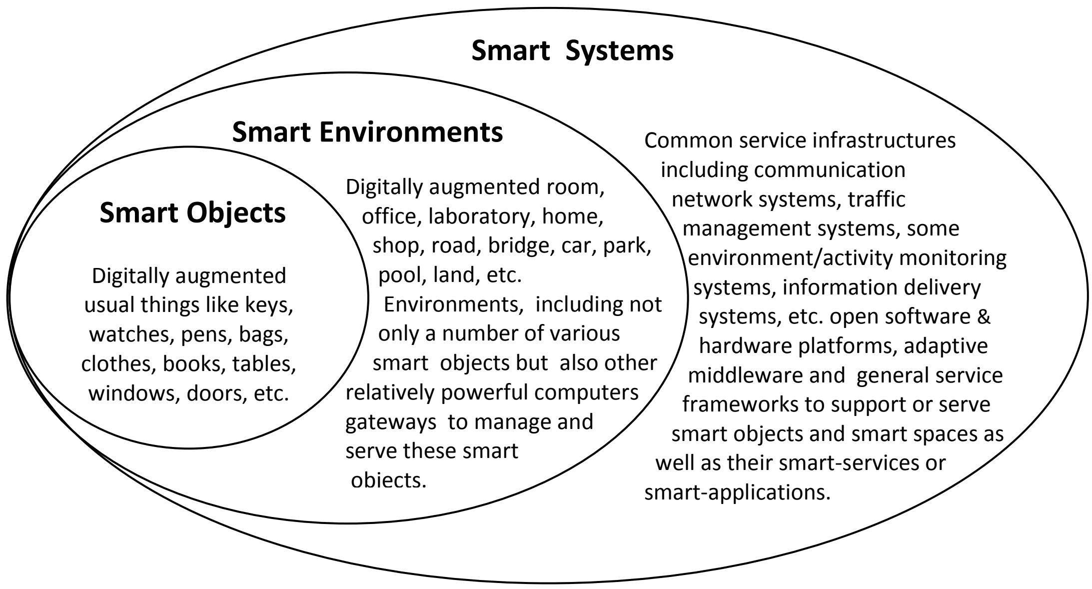


Figure 2.2 Smart Products

(Adapted from Ma, 2005)

In addition to smart product definitions, the Artificial Intelligence literature provides multiple descriptions concerning "smartness" feature. Those descriptions enclose different characteristics that products or entities should include in order to be considered as smart.
Different descriptions emphasizing certain capabilities of smart products are derived from the literature. Table 2.1 provides a comparative outlook to the main characteristics of smart agents and reveals the smartness understanding within the literature.

Table 2.1 Smartness characteristics according to different authors

	CONTEXT AWARENESS	COMMUNICATION CAPABILITIES	INTERACTION CAPABILITIES	AUTONOMY				OTHER
				AUTONOMY	REACTIVITY	PROACTIVITY	ADAPTABILITY	
Maas et al.(2008)	**Situatedness** -recognize situational and community contexts	**Network ability** -communicate and bundle with other products				**Pro-activity** -anticipation of user's plans and intentions	**Adaptiveness** -change behavior according to buyer's and consumer's responses to tasks **Personalization** tailoring of products according to buyer's and consumer's needs	**Business-awareness** -consideration of business and legal constraints -products are used in compliance with constraints that are defined in contracts.
Mühlhauser et al. (2008)	**Context aware**	**Self organized embedding** - establish an optimal product to product interaction	**Multimodal natural interfaces** -has improved product to user interaction; interacts with the user by relying on modalities and devices that are adequate at a given moment in time, depending on the user's preferences, context and current task.			**Proactive behavior**		**Support the entire life-cycle** -simplicity during the entire life-cycle of the product, to support manufacturing, repair or use.
Smartproducts cons.	**Situation & context aware** -sense physical info.,virtual info. and to infer higher level events from this raw data.	**Self organized embedding in smart products envir.** -embed itself into an existing smart product envir.and automatically build a smart product environment. **Distributed storage of knowledge** -outsource their knowledge to other smart product	**Multimodal interaction** - provide a natural interaction. -make use of the different input and output capabilities (e.g., speech, pointing, networked displays, microphones, speakers, etc.).	**Autonomy** - operate on its own without relying on a central infrastructure. -interact with each other and the user without the need of central control.	**Support procedural knowledge** -recognize when the user or another smart product has completed a step in the procedure, determine how the user needs can be involved in the different steps and how implicit interaction can be integrated	**Proactive** -proactively approach user -situation info. is used to decide when to proactively approach user, or interact with other products.	**Emerging knowledge** -learn new knowledge from observing the user, incorporating user feedback and exploring other external knowledge sources like Wikis - able to gather a more accurate user model and to learn new procedures.	**Support the user throughout whole life-cycle** -sense the user context, provide information about itself and its usage history while is needed during the usage or recycling phase.
Rijsdijk and Hultink(2007)		**Ability to cooperate** -cooperate with other devices to achieve a common goal	**Humanlike interaction** - communicates and interacts with the user in a natural, human way. **Personality** -shows the properties of a credible character	**Autonomy** - operate in an independent and goal-directed way without interference of the user	**Reactivity** -ability to react to changes in its environment. -the reactions to the environment are merely direct responses (reflexes).		**Adaptability** -able to improve the match between its functioning and its environment -able to respond and adapt to the envir.(the user or the room) over time, which may result in better performance.	**Multifunctionality** a single product fulfills multiple functions
Bradshaw (1997)		**Collaborative behavior** -can work in concert with other agents to achieve a common goal	**Flexible multimodal communication** -interprets user needs and select appropriate modalities of communication. **Personality** -manifests the attributes of a "believable" character such as emotion	**Autonomy** -show goal-directed, proactive and self-learning behavior **Collaborative dialogue** -have specific or abstract goals based on embedded knowledge	**Reactivity** -ability to selectively sense and act .	**Inferential capability** -ability to act on abstract task, specification using prior knowledge or general goals and may have explicit models of user, situation and/or other agents	**Adaptivity** -able to learn and improve with experience	**Engagement** Sensing and influencing capability of user engagement **Temporal continuity** persistence of identity and state over long periods of time
Jennings and Wooldridge (1998)		**Social ability** - interact with other agents (and possibly humans) via some kind of agent-communication language		**Autonomy** -show reactive, proactive behavior; operate without direct intervention of humans, and have some kind of control over its actions and internal state[...], a specific outcome is not guaranteed in advance **Goal-oriented**	**Responsive** -ability to perceive the environment, (the physical world, users, other agents, the Internet), and respond fashion to changes that occur in it.	**Pro-activeness** agents do not simply act in response to their environment, they are able to exhibit opportunistic and goal-oriented behavior by taking the initiative	**Adaptiveness** change behavior according to buyer's and consumer's responses to tasks	

The smartness accorded to products could vary from one source to another, however as it can be observed in Table 2.1, some major characteristics are commonly mentioned by multiple sources. The foreground features of smart products in literature are:

- *Context-awareness*: the ability to sense context.
- *Communication capabilities*: the ability to form and join networks with other products, establish the necessary communication to share information or act collaboratively to achieve a common goal.
- *Autonomy*: the ability to act on its own without any interference of user.

  Bradshaw (1997) as well as Jennings and Wooldridge (1998) mention reactive, proactive and adaptive behaviour among the subfeature of the autonomy characteristic. (Similarly in this study rather than a separated characteristic, autonomy is treated as the result of reactivity, proactivity and adaptability capabilities.)
  - *Reactivity*: ability to provide direct responses to the changes occurring in a certain environment. Reactivity could be merely considered as a basic reaction like human's reflexes: the perception of some inputs triggers some outputs.
  - *Proactivity/Predictivity*: the ability to show a goal oriented, opportunistic behavior by anticipating user's plans and intentions. In addition to the reactive behavior that could only furnish some well defined responses according to the contextual data, proactive products are able to make an assessment of the situation, and chose the most optimal solution among all possible actions they envisaged.
  - *Adaptability*: the ability to learn from the environment and improve itself over time. Context information is used to update product's internal models related to the user profile or the environmental characteristics. The product could then provide a better performance by adapting itself to changing conditions or responding according to the user preferences.
- *Multimodal interaction capabilities*: the ability to interact through natural input and output capabilities, communicating with the user in human way. Personality feature which consist of the ability to show the properties of a credible character, mentioned by Rijsdijk and Hultink(2007) and Bradshaw (1997) is also treated among interaction capabilities in this study.

In summary, based on the literature, a smart product could be defined as an entity: tangible object, environment, software, or service,

- linking everyday physical surrounding with information technology by augmenting ordinary objects or environment with unobtrusive embedded computing platforms in different shapes, size forms and functions;
- perceiving users' existence and surroundings , reasoning about the situational context, and taking proper actions in its own or even collaboratively by communicating with other smart products;
- automatically reacting to the changes occurring in an environment, attempting to predict and anticipate users' plans and intentions, changing processing according to user's responses and tasks, and adapting its application behavior automatically based on users' need and affect in order to improve their experience in that environment;
- interacting with users implicitly, in a natural, humanlike way.

2.3.2 Technical properties

Smart products can be conceived as interactive products which combine a physical interface and a software interface. Cook and Das (2007) conceptualize smart environments in four layers: physical, communication, information and decision (Figure 2.3).

The information sensed at the physical layer is communicated through the network, to the information layer where it is processed into a more useful knowledge. Once the necessary user or environment models are constructed, the processed data is presented to the decision layer. The decision concerning the action to be performed, resulting from the decision making algorithms is then transferred through services to physical components. Basing on this smart environment description of Cook and Das (2007), three main capabilities of smart products consisting of:

- perceiving the state of the environment and users with sensors,
- reasoning about the data considering task goals and envisaging the outcomes of possible actions by using a variety of Artificial Intelligence techniques ,
- acting upon the environment to change its state according to its intended goal,

will be examined throughout this section.

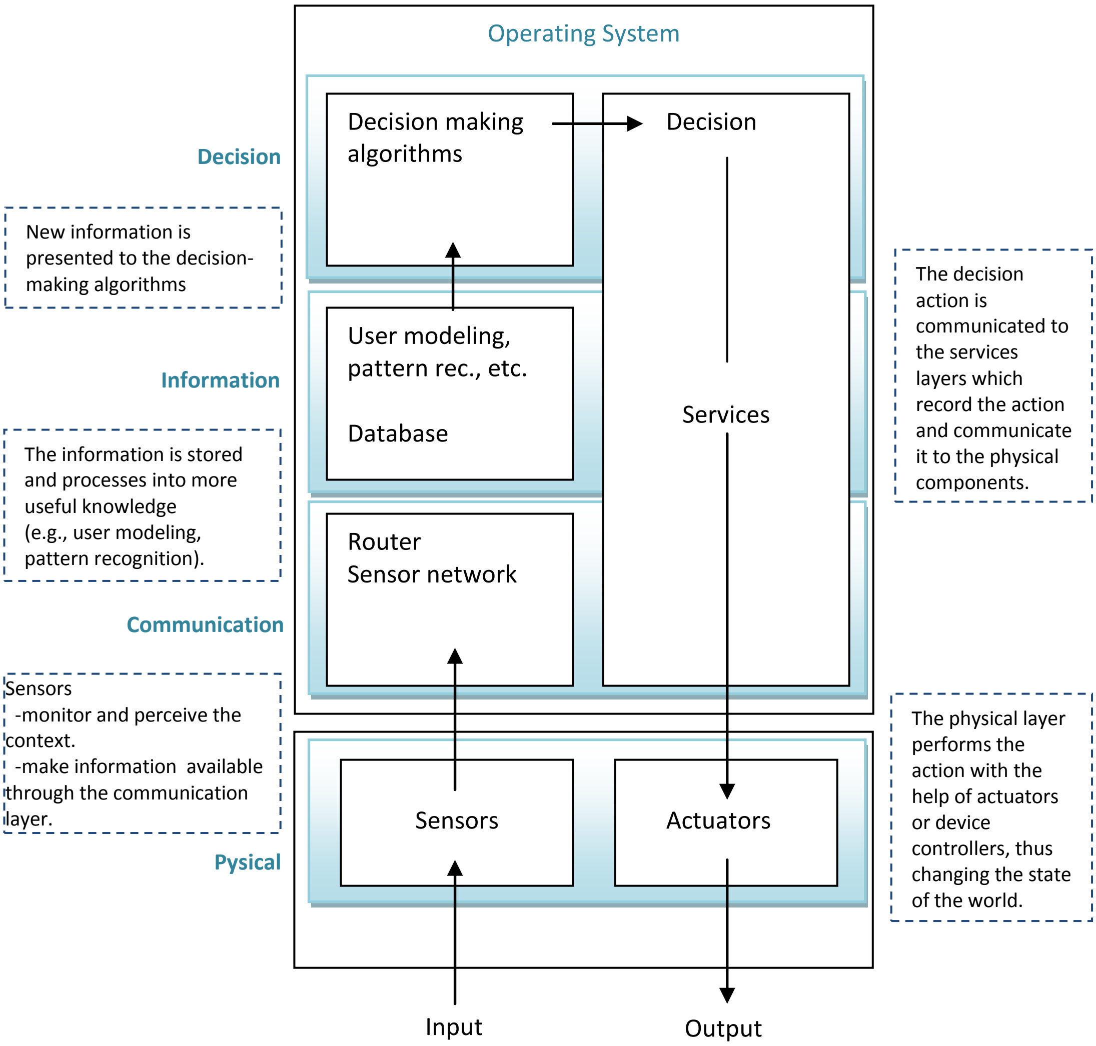


Figure 2.3 Smart product's physical and software interface

(Adapted from Cook and Das, 2007)

2.3.2.1. Perceiving

In order to respond with the most appropriate actions when necessary, user centered smart products need to construct a successful model of the context. However the context, embodying multiple variables is an abstract concept. Therefore establishing perfect context awareness is a difficult task and requires advanced sensing capabilities.

Context information

Schmidt (2002) proposes the following model (Figure 2.4) to structure the concept of context:

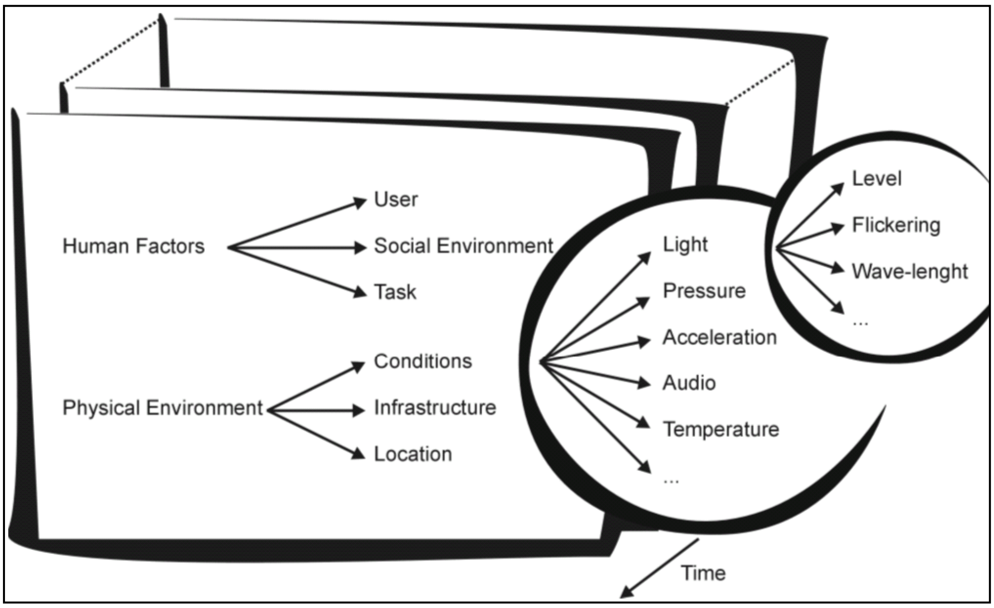


Figure 2.4 Context dependencies (Schmidt, 2002)

According to this view, all of the features constructing the context are organized hierarchically.

Context related to human factors is dependent on features about:

- user: knowledge of habits, emotional state, bio-physiological conditions, etc
- user's social environment: co-location of others, social interaction, group dynamics, etc.
- user's tasks: spontaneous activity, engaged tasks, general goals, etc.

Context related to physical environment embody:

- location: absolute position, relative position, co-location, etc.
- infrastructure: surrounding resources for computation, communication, task performance, etc.
- physical conditions: noise, light, pressure, etc.

(Schmidt, 2002).

Capturing human factors and physical environment states is essential to understand the situations in a context. Designers decide on the appropriate sensing technology to recognize some useful context, while implementing a context aware smart system. An abstraction of the real life is generally required to capture the current situation by making some assumptions on specific sensor values indicating that user is in a certain situation. According to Schmidt (2001, pp: 2) to construct sensor-based context awareness, it could be assumed that "in a certain situation, specific sensor data will be frequently similar to sensor data of the same situation at different times". The assumptions that can be made on specific sensory inputs, based on the occurrence of a certain type of situation are presented in Table 2.1:

Table 2.2 Real-world situations related to sensor data (Schmidt, 2001)

Situation	Sensor Data
User sleeps	It is dark, silent, type of location is indoors, time is "nighttime", user is horizontal, specific motion pattern, absolute position is stable
User is watching TV	Light level/color is changing, certain audio level (not silent), type of location is indoors, user is mainly stationary
User is cycling	Location type is outdoors, user is sitting, and specific motion pattern of legs, absolute position is changing.

Various perceptual technologies are needed to gather information about an ongoing scene. As shown in the table, a combination of different sensor data is required to define what is happening in a certain situation: for example, whether the user sleeps or not, information about light, location, time, position and motion should be collected. Even if it is difficult to obtain a complete definition of the context, Abowd et al. (2000) proposed exploring the "five W's" (Who, What, Where, When, Why) of a context to infer a minimal set of necessary data:

- Who?

Identifying people is important to define the role played by a person within the context which consists one of the major data related to an ongoing scene. To determine "who" the person in question is, different identification methods such as voice and face recognition, or iris, retina and fingerprint tracking could be used. People's identification permit not only to establish efficient security applications but it also provides an important data which could strongly affect the action to be taken relative to the user preferences.

- What?

The recognition of user activities is fundamental in order to provide appropriate help when required. However, interpreting user's activity is a difficult problem, to understand what is happening in certain scene multiple data concerning the location and number of people, their identity, their speech activity, location and surrounding state of objects should be considered. Methods such as speech recognition and language analysis enable to understand what is being said, what a conversation is about, and what the decisions or conclusions are. The interaction of people with objects and the way they are interacting provide considerable cues about what the user is doing; their movements, gesture, posture, and orientation of head could all be analyzed to answer the question of "what".

- Where?

Components for detecting and locating people or objects give strong cues about the activity and permit the system to anticipate the eventual needs of users. Detecting user's presence in a certain space could considerably restrict the probabilities concerning his next activity and facilitate to anticipate his intentions.

Similarly proximity and contact sensors could help to detect the objects in use or to anticipate the device that will be operated in near future and enable better understanding of user's intentions at a specific instant.

- When?

The association of activities with time is necessary to understand how an environment is evolving. Interpreting people's activity by considering the time intervals could provide additional information about user's intentions or interests. Knowing when exactly a user performed an action and how long it lasted could include other information then the simple nature of the action: a brief glance to any object could be indicative of a general lack of interest, along with any action deviated from the usual routine could be sign of a particular interest. By tracking long term activities, determining routines and considering the eventual deviations, the system could deliver commonly required services in specific locations at a particular time.

- Why?

After perceiving what the user is doing, understanding why the user is doing such a thing is an even more challenging problem. Inferring and understanding intentions and goals behind people's activities will permit to anticipate needs and serve users in a sensible way. People's attitudes, affections, or emotions could be helpful in determining the reason behind their actions. Some tracking techniques have been developed to interpret the state of users from their speech, facial expression, hand gestures, body temperature, heart rate or galvanic skin response.

Constructing a successful model of the context necessitates intelligently choosing the most appropriate sensors which will provide useful information according to each situation. Even to be able to answer some basic questions such as "who", "where", "when", "what", and "why", numerous sensors and various tracking techniques need to be employed. Over the past few years, considerable effort has been put into developing sensing technologies. The following section provides a brief overview of different sensor technologies that could be used by context aware smart products.

Sensor technology

Components such as sensors or microcontrollers permit smart systems to observe, monitor and interact with the real world. To support ubiquitous computing concept these sensors are embedded into the surrounding everyday products transparently to the users.

All available sensors share the captured information with each other to collect maximal data about the status of the environment, its inhabitants and the ongoing activities in the environment and accordingly to construct a successful model of the context (Cook, Augusto and Jakkula, 2009). A variety of light, motion, location, proximity, touch and bio sensors are used to gather information about the environment or the users and establish context aware systems able of perceiving the state of the real world. Some of the environmental properties that can to be captured via sensors and the data processing techniques developed to transform the sensor data into a useful knowledge about the context, are detailed in Table 2.3:

Table 2.3 Sensor types and data processing techniques (Cook and Das, 2006; Schmidt and Kranz, 2005; Ramos, Augusto and Shapiro, 2008)

Sensors	Types	Information Obtained	Data Processed
Audio	Microphones Amplifiers	Volume Spectrum	• Speech recognition (signal processing and pattern recognition to identify words) • Natural language processing (syntax and semantic analysis to construct a logical representation of the data directly collected from spoken language) • Discrimination (noise, music, speech) • Voice recognition (identification)
	Multiple interconnected, spatially distributed microphones	Location of an audio source	• Context identification related to distributed sound sources • Location tracking • Motion tracking
Vision	Camera modules	Color Motion	• Color histogram generation • Image acquisition • Image processing • Scene and image flow analysis • Geometric reasoning • Shapes, markers, objects, and people recognition (face, facial expression, eye, retina, fingerprint tracking) • Motion tracking • Gesture tracking
Light	Optical sensors Photo-diode Color sensor InfraRed UltraViolet-Sensor	Light intensity Density Reflection Color Temperature of the light (wavelength) Type of the light	• Deducing cues about the environment from pattern in light (e.g. 50 Hz flickering or light emitted by a TV) • Reasoning on movements and further context from the information about the light distribution (direct light, indirect light, device placed on a surface, etc.)
	Passive Infrared Sensors	IR light radiating from objects	• Detecting a moving heat source (e.g. humans, animals, etc.).
Movement and Acceleration	Mobile wearable sensors: motion switches, accelerometers, gyroscopes	Movement, Acceleration Orientation Angular velocity Angle Shock Vibration	• Motion tracking (accelerometers, gyroscopes and orientation sensors are combined to obtain 3-dimensional tracking) • Gesture tracking • Shock detection

Table 2.3 (continued)

Location **Position**	Long distance: GPS, dGPS, Cellular network-GSM base stations, Radio beacons Short distance: InfraRed-beacon system, RFId, Tags Ultrasonic location system	Position, Geometric location information Co-location, Proximity Distance from audio source	• Realizing co-location (by making the communication range of radio beacons adjustable, the degree of co-location can be selected) • People, object recognition • Motion tracking (e.g. RFId tags coupled with an RFId reader to monitor the movement of the tagged objects, or ultrasonic pulse sent out and the reflection measured to track the moving object)
Proximity **Touch** **User interaction**	Capacitive sensor, Humidity sensor Light sensors, Temperature sensors, CMOS-cameras, Conductive surfaces, Sensitive resistors, Strain gauges	Humidity changes Skin conductance Muscle tension Transition resistance	• Detecting proximity and contact (humidity rises when users approach an artifact, resistance change according to the force applied, heats up from the body heat, light sensors are covered when a user holds the device) • Gathering information about force applied (how strong the users grip on the artifact is determined from skin conductance, muscle tension, and transition resistance also the minimal deformation of artifact can be measured from user's grip)
Temperature **Humidity** **Air Pressure**	Thermal resistors Humidity Capacitive and resistive Air pressure	Temperature level Humidity level Altitude barometer	• Identifying the type of environment • Measuring transitions between situations • Getting indications on the usage patterns, and changes in whereabouts of an artifact. • Detecting changes in an environment for fire fighters, cold storage rooms • Detecting presence (people that are in spaces also change the humidity, e.g. when people are entering a room the humidity will increase). • Deducing certain actions (e.g. a closing door in a room or vehicle will change pressure minimally, similar changes happen when driving through a tunnel).
Chemical	Gas sensors, Electronic Noses Multi-gas sensors	Gas concentration in the air.	• Recognizing a particular smell or a variety of smells (e.g. detecting food or alcohol, could be used for specific tasks by security forces or fire fighters).
Bio-sensors	Bio-sensors	Heart rate at different body points Skin resistance Muscle tension Blood pressure	• Gathering medical feedback. • Recognition of the emotional state (the pulse or heart rate indicates how calm, excited, or exhausted someone is). • Gesture and movements recognition (muscle tension can be used in order to determine users' action)
Weight	Weight sensors	Absolute weight Distribution of weight	• Discrimination of objects • Detecting hierarchies of load cell arrangements • Detecting presence: analyzing the change of load when an action occurs can reveal further information, such as who is walking over a floor

2.3.2.2 Reasoning

The voluminous data collected through the sensor network needs to be processed into useful knowledge. Different data modeling and knowledge representation methods as conceptual graph (Figure 2.5) and semantic network (Figure 2.6) are used to conceptualize the specifics of the environment and users.

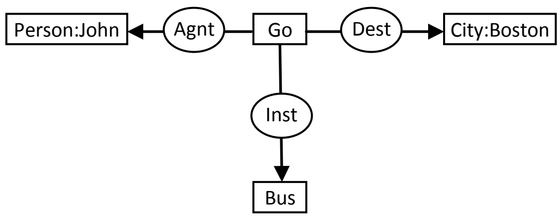


Figure 2.5 Conceptual graph
Novak and Gowin (1984)

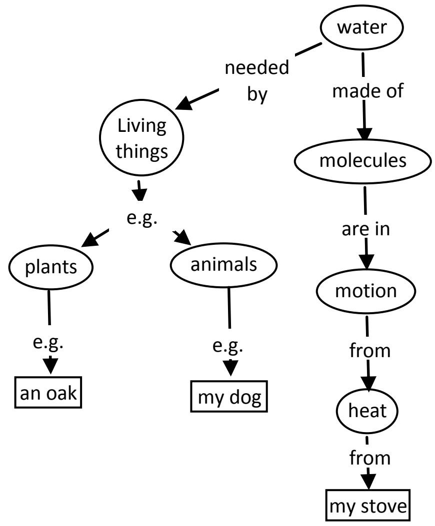


Figure 2.6 Semantic network
Novak and Gowin (1984)

If the sensory data could be abstracted into a context representative model, reasoning about the environment and selecting the action to be executed become possible (Garcia, and Herrera, 2008).

Once the context is perceived, and understood, automated decision making process begins in order to execute the proper actions, reactions and proactions adapted to users' and environment's requirements. The decision making task is defined as "the process of determining the action that should be taken by the system in the given situation in order to optimize a given performance metric" (Huber, 2005, pp: 230). To make a decision, smart products rely on tools from artificial intelligence such as expert systems, prediction algorithms and learning algorithms. Within smart products, this process could embody different levels of intelligence. On the basic level, it can consist of making a single decision, based on a limited set of local observation. In such a case the system reacts to the changes occurring in the environment in a specific way that doesn't necessarily follow users' prospects. These systems are called reactive and rely on the knowledge based or expert decision making algorithms:

Reactive Systems

Decision making process could be triggered by any changes occurring in an environment. In other words the system reacts when the predefined necessary conditions are met. Decisions are based on a set of rules derived from expert knowledge. The rules could be considered as a set of condition-action mappings, if and then system applies the corresponding rules chosen from the database relative to the conditions of current state. Reactive rule based systems are used to make automated decisions as:

IF SITUATION → DO ACTION

e.g. IF user leaves the home THEN stop fan.

Expert systems codify the best practices into a set of rules and shift amongst all data to provide best responses to a specific situation. However rules should be designed carefully to not activate multiple rules for a given situation and also to cover a maximum number of context (Huber, 2005). Expert systems try to match current situations with predefined conditions. However, in real life, diverse complicated and imprecise situations may occur where predefined conditions could stay incompetent.

Algorithms working with fuzzy logic additionally map the current situations to a multiple set of condition to produce more than one possibility. In conventional set theory an object is a member of a set or not, given the example above, the user is present at home or not, fuzzy set member could take any value between 0 and 1. Thus fuzzy models can deal with imprecise or incomplete data and describe vague statements as in natural language logic. This approach permit a more instinctive reasoning by applying more flexible rules better fitting to the situation.

IF VARIABLE **IS** PROPERTY → DO ACTION

e.g. IF temperature IS very cold THEN stop fan
IF temperature IS cold THEN turn down fan
IF temperature IS normal THEN maintain level
IF temperature IS hot THEN speed up fan

Presence is a precise situation, user is present in home or not, however, “temperature” is a relative notion, the room could be very cold, cold, normal or hot. Both of these systems are considered as supervised, which imply that a human still makes the final decision. In fact, rule based systems provide simple guidance for more conventional responses. They are generally used in relatively simple decision making cases with limited variables, where solutions have to be predefined in advance by the user or by a programmer.

To develop systems that truly “reason”, more advanced modes containing algorithms that mimic human decision making capabilities are necessary. These capabilities rely upon effective prediction algorithms which are explained below.

Predictive Systems

Smart environments must be able to acquire and apply knowledge about the context in order to meet the goals of comfort and efficiency (Fogel, 2006; Ramos, Augusto and Shapiro, 2008; Mülhauser, 2008). Systems anticipating human needs or interests in real time, after constructing the model of the environment, use planning and prediction algorithms to determine autonomously necessary actions to be taken. Once the potential activities of users are predicted and hypothesis developed from the constructed model, prediction algorithms could decide on actions to be taken in order to support and improve the activity.

Different prediction algorithms exist, for systems could reason from previously observed user actions to determine user’s next action and therefore automate some selected repetitive tasks. In daily life users typically interact with various devices to accomplish some routine activities. The order and purpose of these interactions remain generally the same. For example while leaving home people do almost the same actions every day (e.g. take keys, take wallet, turn off heating, wear shoes, etc.). The repeatability could be explored in multiple ways by different prediction algorithms. Sequence matching algorithms consider user’s actions as a sequence of events, and use this historical event information including some inherent pattern of recurrence to predict the next event in the sequence. Some of them deal with the likelihood of new events and give higher probability to occur to recently observed events than the older ones (Davision and Hirsch, 1998) while others work with the pair of events and tend to look through the entire event history to find sequences that match current situation (Gorniak and Pool, 2000).

The next actions could be dependent from current or past observations but also from other factors that cannot be directly observed as the emotional state of the user. Hidden Markov models (Rabiner, 1989) are used to improve the activity prediction by modeling the uncertain effects of an action. The algorithm selects an action to execute from Markov chain of events, relative to the probability distribution developed considering the current observable states but also the hidden states that are most likely to generate a specific action. An example of Markov chain of event is presented in Figure 2.7:

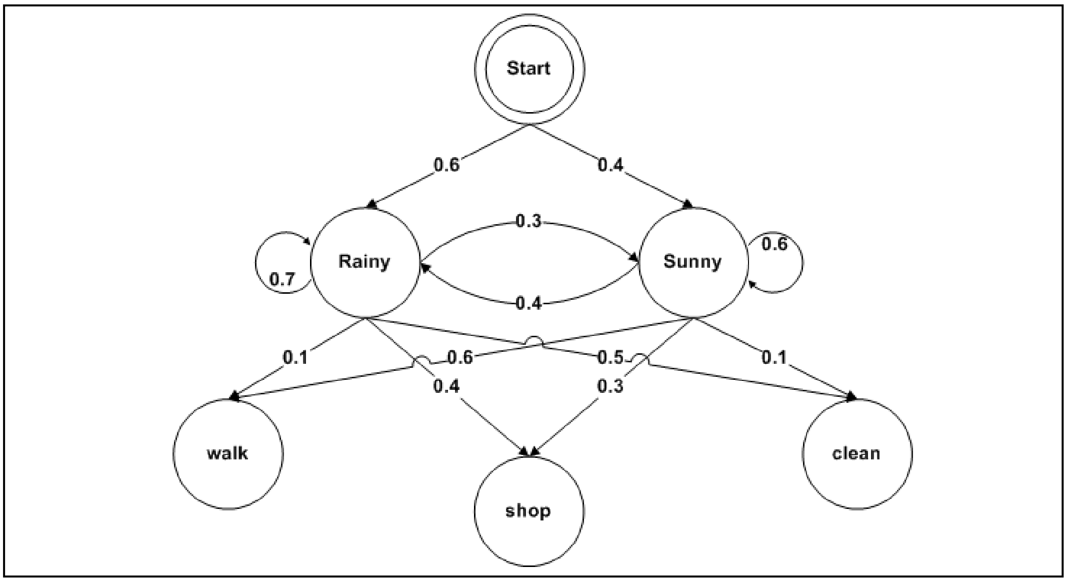


Figure 2.7 Markov chain of event

e.g. three activities that could be performed are walking, shopping, and cleaning. The choice of what to do is determined exclusively by the weather on a given day. No definite information is known about the weather. The weather operates as a discrete Markov chain. There are two states, "Rainy" and "Sunny", but, they are hidden: they cannot been observed directly. Based on general trends, algorithm tries to guess what the weather must have been like and the activity that will be performed. (Rabiner, 1989)

In cases where smart products are supposed to achieve a particular set of goals plan recognition algorithms are used to identify the possible plans, or sequences of actions that are known to achieve those goals. The model of the environment and the descriptions of effects are used in order to predict the next action of a particular sequence by considering its eventual outcome. It is essential to assure minimal error rate with minimal delays for computation to avoid user permanently supervise and reverse smart product decisions.

Along with prediction algorithms anticipating user needs, to improve user experience with smart products some adaptive learning algorithms permitting to adapt their user and environment have been developed.

Adaptive systems

A decision made by a smart system should meet user expectations in order to be optimal. Users' preferences are hard to be determined by a simple observation or sensing data. Thus learning algorithms are used to improve decision making process of smart systems (Ramos, Augusto and Shapiro, 2008). For example temperature and lighting preferences may vary for different users. In previously described approaches as expert systems, to acquire the proper action, users or programmer should construct customized models in advance; in contrast of the ubiquitous computing vision, which will highly decrease the usability of the system and consequently increase the workload of the user. However, machine learning algorithms permit smart systems to autonomously adapt themselves to the users, suppressing the necessity for the user to manipulate or manage the system.

Learning algorithms contain vast amount of data that are sorted and put through extensive trial and error pattern recognition that is known as 'training' (Mozer, 2005). Neural networks based learning algorithms are frequently used in smart environments (Figure 2.8).

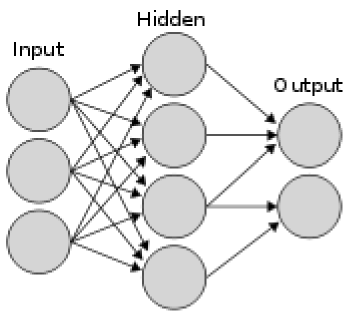
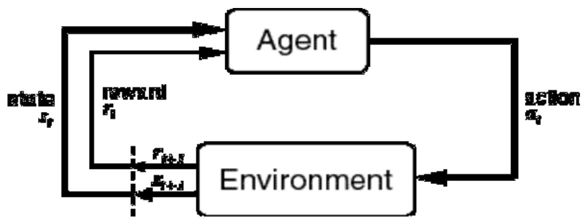


Figure 2.8 Neural network (Addington and Schodek, 2005)

This method inspired from human brain's neural processing, has the capability to generalize the training set to novel situations and to make a judgment when unexpected data are encountered or unexampled situations arise (Addington and Schodek, 2005). As illustrated in Figure 2.8, the input provided is mapped into a number of hidden states in neural networks.

The hidden states depend on the inputs and consequently the outputs depend on the hidden states. The given information (input) is analyzed deeply by providing projections (hidden) given new situations of interest and answer "what if" questions.

Neural networks are capable of developing learning skills by altering the strength of certain connections in network according to desired action (output). Neural networks algorithm is a supervised learning method requiring knowledge about the appropriate control actions, it extrapolates to the unknown by interpreting the current situation according to the training set. Besides neural networks, there exist also various other supervised learning algorithms working with same principle as the decision tree classifiers, nearest neighbor algorithms, etc. More detailed information about those algorithms could be found in Mitchell's (1997) Machine learning book. Another learning method consists of reinforcement learning (Figure 2.9). Instead of reasoning upon a predefined training set including knowledge about the appropriate controls, reinforcement learning algorithms rely on feedback loops permanently allowing the system to change responses according to the context. To adapt, the reinforcement learning algorithms explores the effects of their actions over time and uses this experience to construct control policies that optimize the expected future action (Huber, 2005).



Agents and environment t interact at discrete time steps: t=0,1,2,…

Agent observes state at step t

Produces action at step t

Gets resulting reward: r_{t+1}

And resulting next state: s_{t+1}

Figure 2.9 Reinforcement learning principle (Tuyls, 2006)

Once perceived the context through their sensors and reasoned about the action to be taken via reactive predictive or adaptive decision making algorithms, then smart products execute the corresponding actions and affect their environment.

2.3.2.3 Acting

Smart products tie their reasoning process to the real world through acting. The decisions given by their reasoning algorithms are in turn used to intelligently drive the actuators. A smart product could act and affect the state of the physical world in various ways. Auditory and visual feedback provided by the speakers and displays constitute the most common acting examples (Cook and Das, 2006) also the actuators providing tactile and force feedback are increasingly used among smart systems' sensory modalities. Ubiquitous computing vision broaden the acting possibilities considerably, digital technology integrated smart products able to respond their users in multiple ways, permitted to establish a richer user-product interaction. To give an idea about smart products' different acting capabilities, various examples from houses automatically adjusting their heating or lighting systems to the shoes adapting the tread's cushioning level according to the terrain conditions are presented below:

Multiple smart environment researches have been conducted in order to observe users' interactions with a fully computerized environment containing various smart object prototypes (Figure 2.10). Besides researches focusing on private spaces such as smart homes, (e.g. Georgia Tech's Aware Home, the University of Colorado's AdaptiveHouse, University of Texas' MavHome, Interactive Institute's ComHOME, MIT 's House_n, Microsoft' easyliving project, Gator Tech's Smart House, IBM's PvC Technology Lab; Philips' Home Lab, etc.), also researches observing users in public spaces such as meeting rooms (NIST Smart Space and Meeting Room Projects) workplaces (Stanford University's Interactive Workspaces, HP's CoolTown, IBM's BlueSpace) and classrooms, (Georgia Institute of Technology Classroom 2000) have been developed.

Home labs enable researchers to simulate and accordingly evaluate user experience with state-of-the-art technologies and evolve their designs to better fit user needs. The technologies described throughout previous sections concerning perceptual and reasoning capabilities are applied to the home and everyday objects in order to provide inhabitants an assistive home agent enhancing their quality of life. Besides ensuring users' comfort, also minimizing the cost of running the home is considered among the major aims of smart homes.

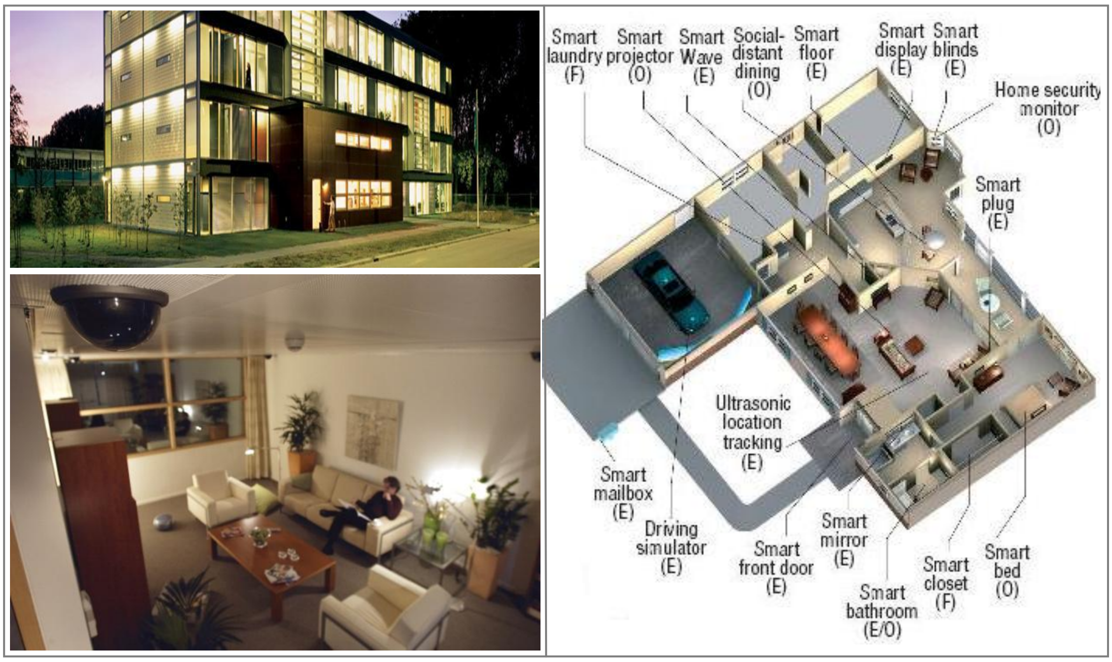


Figure 2.10 Smart home projects

(Philips' Home Lab, source:www.research.philips.com, retrieved 10, August 2009; Gator Tech's Smart House, Helal et al.,2005)

The Adaptive House agent perceives the state of the house through a sensor network, reasons about the most efficient ways to respond via decision making component and acts on the environment through device controllers. The agent tries to predict its inhabitant's actions, learn and adapt to their preferences after observing them over a period, to automate and even optimize some basic functions such as air or water temperature regulation, lighting and aeration. The house is equipped with over 75 sensors monitoring the users, along with the various aspects of the environment such as the room temperature, ambient light, sound level, motion, door and window positions, outside weather and insulation. The actuators control ambient air temperature, via central heating and cooling, electric space heaters, water heating, lighting, and ventilation (Mozer, 2005). The agent increases the comfort of the inhabitants by reducing the number of tasks that the inhabitants have to perform. Instead of programming in advance, the users could let the house program itself by monitoring the environment, observing the occupancy and users' behavior patterns, sensing inhabitants' actions and learning to predict their next actions or future states of the house.

The users can indicate their preferences manipulating light switches or thermostats, or simply turning on the hot water when the predictions are not meeting their expectations. Users' interventions are communicated to the system that tries to adapt itself progressively to all feedbacks via the reinforcement algorithms.

The decision making algorithms should also consider the most optimal scenarios for energy saving while performing according to the user preferences and goals. However, user action sequences may often not meet the optimal strategy for an automated home. Thus MavHome agent, instead of a blind automation basing on users' potential action and preferences, reduces energy usage, evaluates periodically the state of the house also and learns autonomously from the feedback of its own actions without any interference. The effects of the agent's actions are communicated back through delayed rewards which allow the agent to construct the appropriate control policies with the intent to optimize its next action and consequently the future reward. The agent could take new decision whenever a change in the state of the home occurs. Figure 2.11 illustrates the knowledge encapsulation and training procedure of the home agent:

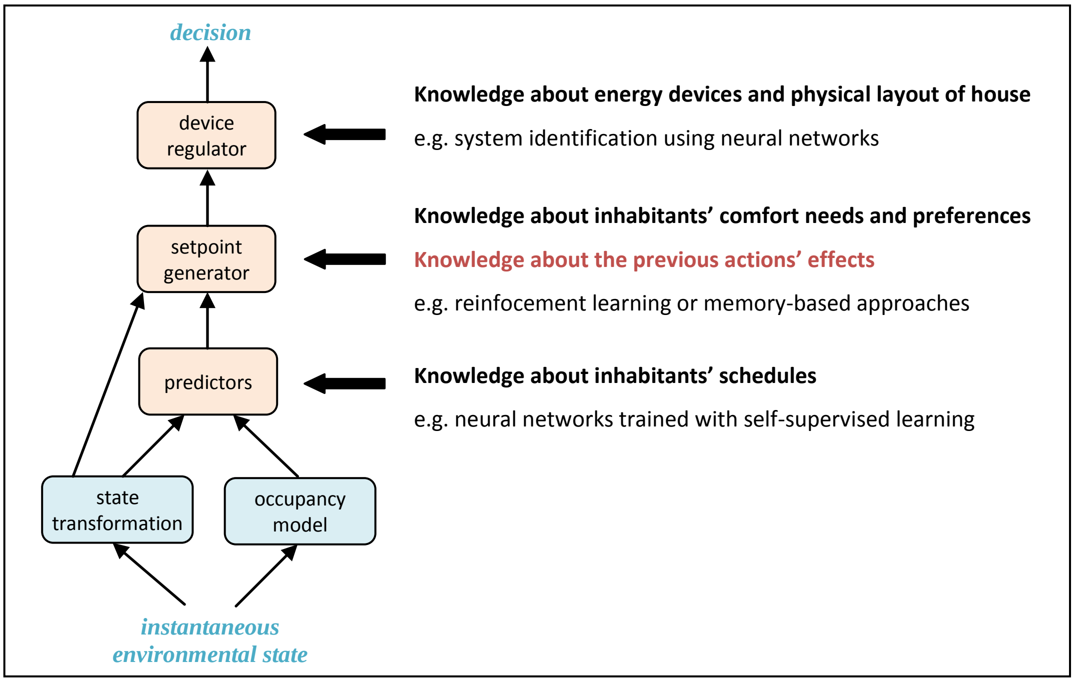


Figure 2.11 Home agent's decision making process (Cook and Das, 2006)

Multiple context aware smart products that could assure a similar assistance have been developed besides smart environments providing users reactive, predictive and adaptive responses through a unique centralized decision making system.

The Ambient Umbrella (Figure 2.12) alerts users to upcoming rain, snow, drizzle or thunderstorms and reminds taking the umbrella. When the probability of fall precipitation gets over 60%, the handle starts illuminating. The handle's illumination pattern changes according to the fall precipitation intensity; for example, soft, intermittent pulses indicate a light rain, and rapid, intense patterns are signs of thunderstorms. The umbrella communicates wirelessly with an ambient information network and acts according to the weather data received from "Accuweather.com" database. The product doesn't react as response to any sensory input, the reaction is triggered through the information communicated by the system, and the umbrella reacts relative to the data received.

Figure 2.12 Ambient Umbrella
(source: www.ambientdevices.com, retrieved 7, July 2009)

As well as reactive products, which immediately provide the necessary actions when the predetermined conditions occur, there exist also smart products predicting the most appropriate action that could be taken according to a certain situation. To improve the "blind" wash cycles, Maytag and Honeywell's Micro Switch Division designed a dishwasher that could automatically adjust the washing programming according to the state of the dishes (Figure 2.13).

The dishwasher can determine how dirty the dishes are by checking periodically the quality of circulating water, which is dependent on the quantity of food particles within, and consequently a closed-loop feedback adjusts its programming for the washing cycle. This will not only save water and energy by recognizing the dishes that don't require much cleaning, but it will also permit to save time by stopping wash cycle when the sensor output indicates that the water is clean.

Figure 2.13 Dirt-Sensing Dishwasher

(source: www.honeywell-sensor.com.cn, retrieved 7, July 2009)

In addition to reactive and predictive smart products also diverse adaptive product prototypes able to learn user's preferences and changing behavior according to the changing situations can be found in the literature. Ubiquitous computing enables the application of new technologies in various different scenarios such as face recognition technique generally used in access control applications or in digital cameras extended its use beyond the bathroom.

SmartFaucet (Figure 2.14) able to recognize its user, can deliver the appropriate water flow and temperature that would suit the user's individual taste. Each family member may have different preferences about the water's heat and flow rate, thus the faucet, once learned the users' preferences, identifies the person standing in front of the sink, and acts according to his preferences hence it provides a maximum comfort to its users. SmartFaucet also informs users about the weather, allows them to check their email and agendas while brushing their teeth.

Figure 2.14 Smart faucet

(source: www.home-designing.com, retrieved 7, July 2009)

Adidas's smart shoe (Figure 2.14) which is equipped with sensors and microprocessors enables to automatically and continuously adjust itself relative to the different running or walking surfaces. The smart shoe senses the cushioning level on each step and evaluates it according to the terrain's conditions. If the cushioning level calculated is too soft or too firm, then the shoe dynamically adapts itself to provide users a better running experience by protecting their feet when stepping ground with the most suitable level of cushion. The smart shoes automatically adapt to the environmental conditions and increase users' comfort and performance considerably while users are interacting naturally by simply wearing them and walking or running as they do with any other traditional shoes.

Figure 2.14 Smart shoe (source: inventorspot.com, last visited 08.07.2009)

Besides smart products that reason through sophisticated decision making algorithms, there are also some products which can directly react to the changes occurring in the environment trough their smart materials. Products enhanced with smart materials carry out tasks not as a consequence of signals or impulses passed from one component to another but as a result of their intrinsic properties.

Some of the outputs resulting from the sensory data are presented in Table 2.2:

Table 2.2 Smart materials (Adapted from Addington and Schodek, 2005)

TYPE OF SMART MATERIAL	INPUT	OUTPUT
Type 1 Property-changing		
Termomochromics	Temperature difference	Color change
Photochromics	Radiation (light)	Color change
Mechanochormics	Deformation	Color change
Chemochormics	Chemical concentration	Color change
Electrochromics	Electric potential difference	Color change
Liquid crystals	Electric potential difference	Color change
Suspended particle	Electric potential difference	Color change
Electrorheological	Electric potential difference	Stiffness/viscosity change
Magnetorheological	Electric potential difference	Stiffness/viscosity change
Type 2 Energy-exchanging		
Electroluminiscents	Electric potential difference	Light
Photoluminescents	Radiation	Light
Chemoluminescents	Chemical concentration	Light
Thermoluminescents	Temperature difference	Light
Light-emitting diodes	Electric potential difference	Light
Photovoltaics	Radiation (light)	Electric potential difference
Type 2 Energy – exchanging (reversible)		
Piezoelectric	Deformation	Electric potential difference
Pyroelectric	Temperature difference	Electric potential difference
Thermoelectric	Temperature difference	Electric potential difference
Electroresistive	Electric potential difference	Deformation
Magnetorestrictive	Magnetic field	Deformation

Numerous products, capable of changing color, viscosity or transparency when exposed to light, due to a temperature change, or when a voltage is applied can be imagined. Two examples of the products enhanced by smart materials consisting from a smart fabric changing color relative to the user's skin temperature and smart glasses able to regulate their transparency according to the daylight properties, are presented below:

Babyglow is a baby suit that changes color with temperature (Figure 2.15). It is designed by Chris Ebejer, to help parents to recognize immediately when their child temperature rises to a dangerous level. The colorful (pastel green, blue and pink) cotton baby suits' smart fabric material contains an ink pigment with heat sensitive molecules such that they begin turning white when baby's temperature attains 37C.

Figure 2.15 Color changing fabric

(source: www.babyglow.uk.com, retrieved 11, March 2009)

The smart glasses permit users to control the amount of light, glare and heat passing through a window with the help of SPD (suspended particle device) technology developed by Research Frontiers Incorporated (Figure 2.16).

Figure 2.16 Transparency changing windows

(source: www.refr-spd.com, retrieved 11, March 2009)

The suspended particles absorb the light and block it from passing through the glass. However, when electrical voltage is applied, the microscopic particles within the glass align and let light pass through. By regulating the voltage, users can then precisely control the level of windows' transparency. Besides windows, variables products such as skylights, doors, sunroofs, visors and eyewear can also benefit from this technology.

2.4 Conclusion

Each level in the development of Artificial Intelligence (AI) has progressively reduced the human participation in the real time activity of decision making. Improved computation capability enhanced products with sensing, reasoning and acting capabilities. Smart products' "sense-reason-act" process mentioned throughout this chapter is recapitulated in Figure 2.17:

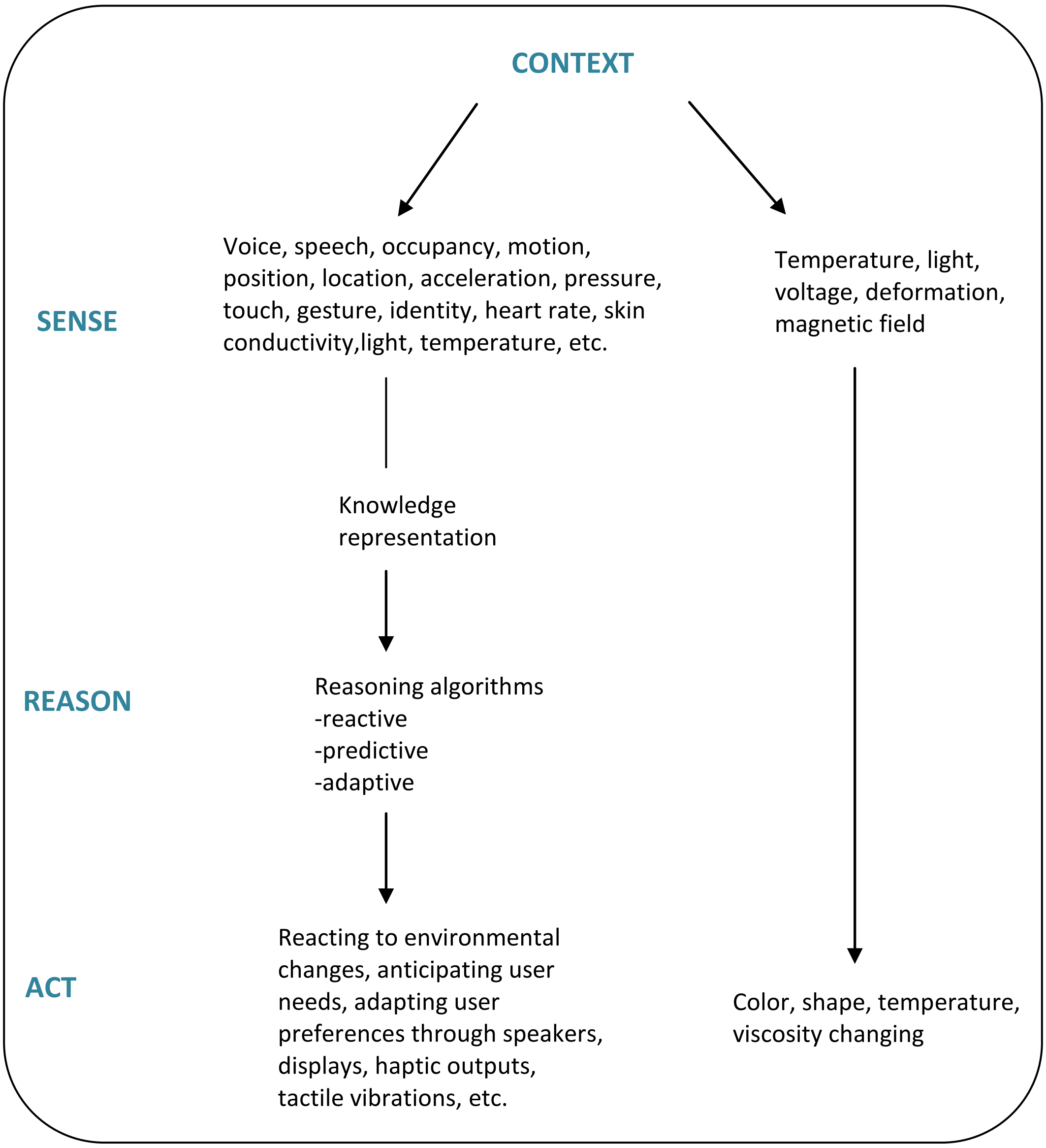


Figure 2.17 Product smartness

Equipped with sensors and computational power, smart products have gained the ability to capture context information, and set the best possible actions to be taken according to the situation. Along with expert, rule base systems working on well defined, structured decision making conditions, the systems supporting imprecision and uncertainty as fuzzy logic, neural networks, probabilistic reasoning algorithms and reinforcement learning techniques permitted smart products to deal with new situations and adapt changing conditions by generalizing, associating, and abstracting the context information. Reactive, predictive and adaptive smart product applications automatically reacting to the changing environmental situations, predicting the most appropriate solutions or learning from their actions and improving their reasoning algorithms has emerged. In addition to diverse decision making capabilities, products are also equipped with smart materials able to directly respond by a color, shape, temperature or viscosity change, without necessarily passing the sensor data on to a running software.

However as Norman (2007) states, although machines are good in thinking and logic, superior in speed, power and consistency they are bad at physical activities, emotions, social skills, creativity and imagination.

The complex system of perception and action, emotion and cognition is not yet present in machines and cannot be easily generated by changing the reasoning algorithms or adding sensors. They can partially understand the user and reason in a limited way about the action to be taken. However even a human could not perfectly predict the intentions of a user, they could only reason on the right action through communication, therefore establishing humanlike interactions with machines are essential. Many researches about natural interaction as tangible interaction possibilities or interfaces based on speech, vision, and gesture are constantly improving. New ways of computing and interacting as emotional computing or affective interaction arise by considering different ways of thinking of the human mind, and to mimic its emotional process.

The forthcoming part of the study will explore the smartness notion from a user-product interaction perspective by focusing on those trends aiming to construct a more intuitive and direct communication between humans and machines.

CHAPTER 3

SMARTNESS FROM USER-PRODUCT INTERACTION PERSPECTIVE

As a consequence of ubiquitous computing vision focusing on computation and digital information accessible to everyday environment, smart products augmented with computational power have emerged and multiple products with digital capabilities have proliferated into the physical world.

However, as affirmed by Weiser and Brown (1996, pp: 2), "If computers are everywhere they better stay out of the way", computers should not overburden people in their everyday lives. Basing on this assumption, Weiser (1996) has complemented his ubiquitous computing vision with a new approach putting the importance on the need of building a harmonious human-computer interaction. He introduced the notion of "calm computing" dealing primarily with interaction design rather than the hardware or software technologies.

Calm computing evaluates the technological trends from a user perspective instead of focusing on sensor capabilities, computing algorithms or wireless networking possibilities, all handling smartness from product perspective. In a world where computing has gained a new dimension changing the relationships between people and computers, such that the approach envisions a world of serenity, where information appears when needed and effortlessly disappear into the periphery when it is unnecessary.

Technical and conceptual background leading to this new computing approach presenting a totally different interaction with computers, are explored in the following sections.

3.1 Technical background

Four separate computer era could be distinguished in the history of human computer interaction (Figure 3.1) and each era is marked with specific interface styles according to the hardware and software possibilities available at the different time periods (Dam, 1997).

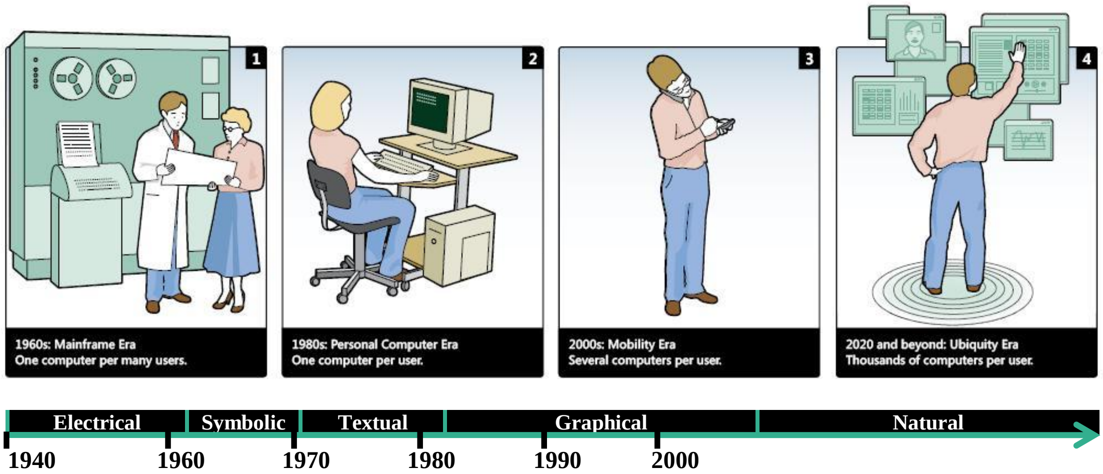


Figure 3.1 History of human computer interaction

(Adapted from jeanseok.com, retrieved 15, May 2009)

First corresponds to the era when computers were considered as sophisticated machine and used only by experts to solve specific problems. Experts should reconfigure the machine and thus have a strong knowledge of electronic to set up a new experiment. In the early 60’s a transition from electrical to symbolic interaction has occurred where programming languages permitted experts to control the system through a set of rules and instructions, independently from precise electronic details of a specific computer. However multiple users still were working with a single machine having no user interface and communication could be only established with punched cards inputs and line printer outputs (Dam, 1997; Moggridge, 2007).

Then come mainframes and minicomputers having mechanical or alphanumeric displays where users interact with the computer by typing commands with parameters. Textual interaction consisted of continuous back-and-forth instruction and response between the user and the system. In this regard, textual interfaces were considered as the origin of ‘interactive computing’ as they allowed an interactive loop to be established between computer and users (Moggridge, 2007).

The third age is marked by graphical user interfaces based on windows, icons, menus and pointing devices allowing users a two-dimensional interaction rather than one-dimensional textual input entering. The most significant step in terms of the development of user interface models was the transition from textual to graphical interaction. The graphical user interface was founded in 1970 by Xerox PARC and popularized with the commercial success of the Apple Macintosh and later copied by Microsoft Windows on the PC (Ishii, 2008) applications. Today they are still largely confined to GUIs and based on the same principles with the early examples.

The color displays have appeared, the graphic quality has improved and animations increased the realism, however 'point and select' principle has remained the same (Dam, 1997). The interface was apparently sufficiently good for conventional desktop tasks, and from wall sized electronic whiteboards to small handheld computers a variety of GUI devices could be distinguished in the marketplace (Dourish, 2004; Ishii, 2008). Personal computers, handheld computers, and cellular phones are currently among the most common GUI devices in the market. Today's technological advances allow to complement traditional GUIs with multiple features. Technologies as handwriting capture, voice recognition, motion tracking, biometric sensors, and various other sensing and reasoning capabilities (previously mentioned in Section 2.3.2 Technical Properties) opened up alternative modes of interaction enabling a richer interaction between humans and computers.

3.2 Conceptual Background

In parallel with technological advances, the vision of computing has also considerably evolved. In the first few decades of computing, engineers were only concerned with the functionality and performance of applications. However then in the 1970's, human factor studies encouraged with the improved understanding of human psychology, have focused on human cognitive psychology and have examined psychological methodologies to follow throughout the design and evaluation process of human computer systems.

In this period, the pioneer studies of HCI investigating in 'software psychology' (Shneirderman, 1980) conducted researches about software design, programming and the use of interactive systems with the goal of motivating and guiding system developers to consider characteristics of human beings (Carroll, 1997).

After a decade when personal computers began to be used by millions of people, it was realized that besides the functionality and performance of the systems, their ease of use also plays a major role in the success of the products. Users were frustrated because of the performance centric machines that could not handle error and error recovery, ignorant about individual differences, preferences, work context or collaborative tasks, etc. The idea that computer systems and software should be designed and developed according to the needs, abilities and preferences of their potential users, has gained importance.

Human computer interaction (HCI) study has emerged as an intermediate discipline between psychology and social science, on the one side, and computer science and technology, on the other. HCI specialists focus on users to understand the need for new products, the development and evaluation of prototypes, the quality and ease of use of products, design of documentation and installation of user support, to improve the interactions between users and computers hence the usability of computer systems (Carroll, 1997).

To make user-friendly products and applications that people can effortlessly use, a development process centered on user, attaching the primary importance on the usability of the system has been established. Technology development has improved with the strong integration of human- computer research in the process.

HCI remain as an important area in computer science and continues to broaden as an area linking design and use of technology. However once computers migrated from desktop into everyday objects and environments, new interaction constraints far beyond from two dimensional GUI usability problems arose. Concerning this fact, Bannon (2005) claims that since computational devices become a part of the environment instead of simply remaining as functional items for accomplishing tasks, the designs built on the GUI interface and the standard PC can no longer be valid.

Although the technological advances increasing the number of computerized devices in the everyday environment have facilitated accessing the digital world and improved the quality of service, they also disturbed, and created frustrations from the user perspective. If this “excitement of interaction”, as defined by Weiser (1997), persists in an era envisioning thousands of computers per user, dispersed all around the environment; human-computer interaction will undoubtedly take an exhausting and even enraging form.

This problem applies from computers having graphical user interfaces to all other sort of digital devices even having no interface. Today’s digital products try to catch the attention of their user with lights, beeping signals or alarms Norman (2007) says, and if the trend continues the future will be a cacophony of many distracting, irritating, and potentially dangerous alerts and alarms he affirms.

Alternatively, calm computing proposes a more humanistic interaction vision by encouraging people to live in a simple and natural environment. The difference between encalming and infuriating technologies depend on the way they engage the attention of the users. Ubiquitous computing accompanied with the calm computing vision keep the computers in the background, out of the focus of attention and place emphasis on the natural human environment. The information vanishing at the periphery, as part of the environment, moves from the periphery to the center only when it is required. Without provoking any information overload, digitally enhanced environments could by this way “calmly” increase user’s knowledge and assist them in their tasks (Weiser and Brown, 1996).

Peripheral presence is also described with the term of ‘implicit interaction’ in literature. Systems working with implicit interaction are not noticeable and they do not address the users explicitly to complete a task (Postland, 2009). The sketch (Figure 3.2) by Philips Design CEO, Marzano (1999) sets out Philips' latest design philosophy aiming similarly to simplify people’s lives by implicit interaction. According to Marzano, the home of the future will contain objects having both cultural and technological use and will look more like the home of the past than the home of the present. The technology will disappear into the background and will not constitute a focus of attention as today's technological devices; digitally empowered products will not be distinguishable from traditional objects. Televisions will be part of the walls, stereos disappear into bookcases and today's cluttering technology standing at the center of attention and demanding a permanent control will become more quite and calm at the periphery, disturbing users only when necessary.

Figure 3.2 Home Simple Home The Past, Present, and Future home
(source: www.businessweek.com, retrieved 15, May 2009)

Calm technology vision aims to establish a humanlike interaction with embedded and interconnected ubiquitous computers by trying to diminish disruption, distraction and overwhelming at maximum. Existing forms of "silicon-based information technology" (Weiser, 1991) are in contrast, far from having encalming interaction possibilities. Since a very restricted human action and perception abilities are exploited, interaction becomes even more effort demanding when users have to communicate with multiple computers rather than one. Humans' communication style with computers is much different from their communication manner with each other. To compensate this dissimilarity, users have to learn new commands to adapt themselves to their computer processing. However, as mentioned by Abowd (1994), “Humans speak, gesture, and use writing utensils to communicate with other humans and alter physical artifacts. These natural actions can and should be used as explicit or implicit input to ubicomp systems”. Instead of 2D widgets as icons, menus or toolbars, new interaction styles exploiting those natural communication skills and therefore supporting common forms of human expression should be established.

3.3 Smart interactions

The emerging technologies raised new challenges and opportunities for human-computer interaction besides opening up new form of computing. To establish a ‘calm’ ubiquitous computing based upon natural interactions between computerized devices and people, new interaction styles were developed. The following section gives an overview of those interaction trends providing users a much more implicit and natural interaction than traditional user interfaces.

3.3.1 Natural interaction

The vision of building smart environments, attempts to create a human-centered system, embedded in physical spaces, and communicating with users intuitively through natural interfaces. According to Valli (2007), ‘natural interaction’ is defined in terms of experience. He affirms that “people naturally communicate through gestures, expressions, movements, and discover the world by looking around and manipulating physical stuff”, and he defends that “the key assumption here is that people are meant to interact with technology as they are used to interact with the real world in everyday life, as evolution and education taught them to do” (Valli, 2007, pp:2). To describe similar interaction thinking, also umbrella terms as “post wimp (windows-icon-menu) interfaces”, “reality based interfaces”, “humanlike interactions”, and “enactive interactions” are used in literature. All of those new interaction styles aim to minimize the cognitive distance between user’s intent and execution of that intent (Dam, 1997).

Human cognitive development studies focusing on human perception and learning skills have been a source of inspiration for natural interaction styles diminishing the necessary mental workload for dealing with an interface. Verplank (2003) asserts that Piaget's (1971) vision involving three iterative stages of cognitive transformation, could guide engineers and designers in their task of devising new types of interaction. According to this vision, people have innate enactive or kinesthetic skills, they know how to grasp and manipulate, they are born with simple reflexes and develop rapidly controlled actions, to achieve their goals. Then they begin to observe the environment and take an interest in how things look and develop their iconic thinking capabilities. And while they start to understand conversations and use words to communicate their knowledge, their symbolic thinking is henceforth establised (Piaget, 1971). The evolution of human computer interaction styles has been in reversed order: it is starts with a symbolic teletypes (TTY) interaction assuring communication between computer and user through inputs and outputs constituting a dialog of symbols. Then the iconic graphical user interfaces (GUI) become dominant. According to this evolution process, the succeeding interface technology should be based on enactive skills putting people's natural interaction capabilities to the foreground (Verplank, 2003).

The sketch from Alan Kay (1996) (Figure 3.3) shows the opposite path followed between the development of human computer interaction and humans cognitive transformation.

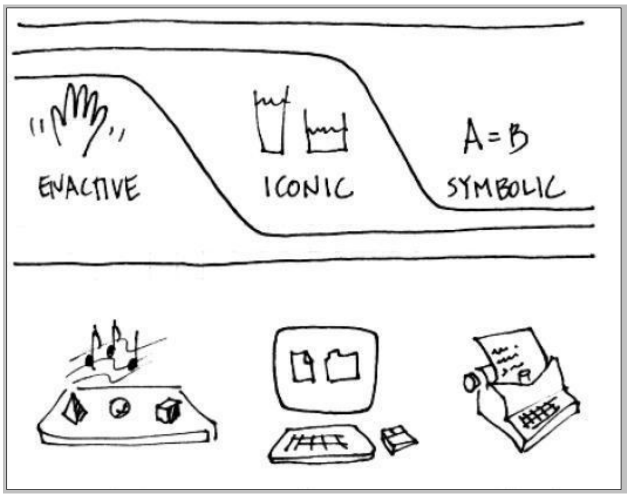


Figure 3.3 Humans cognitive transformation vs. human computer interaction development (Kay, 1996)

Considering the cross connection between these two development processes (Figure 3.3), exploring users' innate interaction skills is expected to enable designers to develop more intuitive interaction styles. To avoid users focusing on the interaction required to accomplish a task rather than the task itself, existing interaction skills of the users with the real world are exploited.

3.3.1.1 Exploited skills

Natural interaction provides multiple interaction possibilities based on users' preexisting knowledge about everyday world:

- Their understanding of naïve physics is exploited with physical metaphors like gravity, mass, velocity, rigidity and inertia simulating physical conditions of the real world that are included into the interfaces.
- People's body skills like gestures, body movements are integrated as inputs into the interfaces. Interfaces supporting whole body interaction have emerged. Besides people's skills to manipulate such as picking up, positioning, altering, and arranging objects are simulated to intensify the reality illusion of new interfaces. People could interact with the digital world simply by moving from one place to another or manipulating a virtual object by grasping it as they habituate in the physical world.
- Accordingly environmental awareness skills like the sense of space created by the combination of sights, sound, smells and feeling that surround them, the sense of orientation, location information and navigation capabilities, and their capability to rapidly identify events and objects are exploited and tried to be integrated into the interaction with digital products.
- Finally social awareness skills enabling people to be aware of other people's presence, the ability to collaborate, exchange information or physical objects are explored and applied.

(Norman, 2007; Jacob et al., 2008).

New generation interaction styles based on users pre-existing skills free users from developing interface specific skills. Exploiting people's intuitive interacting skills provide an easy and fast learned communication with computerized products and even reduce the mental effort and time given to familiarize with a new interface. As a consequence, users' performance increases while their frustrations decrease.

According to Japanese product designer Fukasawa (2008) "the best designs are those that dissolve in behavior," the products should be such an integral part of the action that they would disappear while accomplishing the task and provide an effortless and almost subconscious act to use the product. Furthermore Castells (2004) affirms that the divide between real world spaces and digital spaces constitutes a fracture in our information processing capacity. An extra mental process is required to assure the transition between thinking in virtual and thinking in real world. And trying to unify these two distant spaces could help to the establishment of more natural interfaces.

The relation between digital and physical world could be enhanced by making digital data tangible or augmenting physical objects with supplementary information. New interfaces based upon people's pre-existing skills and taking into consideration their learning process in a unified physical and virtual world could assure an intuitive and natural interaction between humans' and computers.

3.3.1.2 Types of natural smart interfaces

As defined by Ziegelbaum (n.d.), new interaction styles "where people will no longer have to learn multiple new commands for every interface, and where instead they will use a universal physical/gestural language that is body/space centric and not device/screen obsessed" are emerging. These correspond to 'Gesture based interaction', 'Tangible interaction' and 'Augmented reality' trends.

To formalize current user-product communication, numerous research examining these new gesture based, tangible and augmented interaction possibilities is conducted. One of their major goals being to provide a richer experience that investigates many more senses in the interaction between user and product, the necessary communication is tried to be established throughout natural methods such as gestures, touch, or body movements. Natural interaction, freeing people from desktop based interfaces, provided a body centric interaction possibility exploiting users' already existing skills. While intensifying the sensual perception it is also aimed to simplify the interaction at a cognitive level by diminishing the mental workload needed to interact with a product. The user should easily recognize the potential action of a certain product and realize how to interact with it. Gesture based, augmented and tangible interfaces, by bringing virtual into the real world and minimizing the divide between these two worlds, established an intuitive interaction that avoids the extra mental workload required to assure the transition between virtual thinking and real thinking; and consequently allowed users to focus on tasks rather than developing interfaces specific skills to accomplish a task.

Gesture based interfaces

Saffer (2008) defines gesture as "any physical movement that can be sensed and responded to, by a digital system without the aid of a traditional pointing device such as a mouse or stylus." According to this view, a wave, a head nod, a touch, a toe tap, and even a raised eyebrow could be all considered as gesture. People already use gestures for communication; they could even empower their gestures and give them further meaning to communicate with computer interfaces and as Saffer (2008, pp:2) argues "the best, most natural designs will be those that match the behavior of the system to the gesture humans might already do to enable that behavior".

An interface capable of recognizing and treating these gestures as input is characterized as a 'gesture based interface'. Rather than interacting with traditional pointing devices transferring the two dimensional input to the screen, through gesture based interfaces, users can communicate with the digital environment via their own body and hand movements. Gesture based interfaces may rely on tangibility, and entail users directly to interact by touching the device containing the digital information. They can also support remote interaction permitting users to control the interface from distance with body movements. According to the gesture recognition technology that has been chosen, users can interact simply by their own body without using any intermediate controller, but also they can even wear or manipulate some sensor based devices (e.g. finger sensor, glove, etc.) with the intent to facilitate motion tracking or gesture recognition process.

Hand movements differentiating these two gesture based interaction styles are shown in the Figure 3.4 and Figure 3.5:

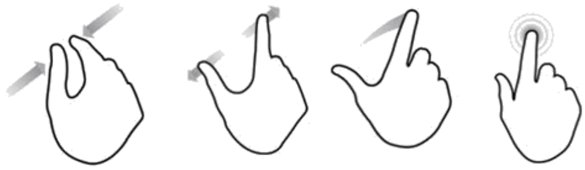


Figure 3.4 Touch based gesture recognition

(Gestures of a touchscreen interaction: "pinch", "spread", "drag" and "point" controls are respectively communicated, source: graffletopia.com, retrieved 9, June 2009)

Figure 3.5 Remote gesture recognition

(Gestures used in the interaction with photos projected onto the screen: "bring up more photos", "randomize photos", "make photo wall" and "reset view" controls are communicated, MIT lab's g-stalt project, source: zig.media.mit.edu/Work/G-stalt, retrieved 9, June 2009)

Touch based interface necessitating a direct contact can be more restrictive in terms of gesture possibilities compared to the remotely controlled interfaces allowing all sorts of three dimensional gestures involving whole body into the interaction.

Different applications based on people's preexisting interaction skills such as body movements or gestures have been effectively developed to make interfaces more natural and easy to use:

Oblong's "G-Speak" (Spatial Operational Environment) is one of the most advanced gesture based interaction platforms that can track users' hand motion without necessitating to touch on screen. Its development began in the early 1990s at MIT's Media Laboratory and continues in Oblong Industries founded in 2006, with the purpose of building "G-Speak" as a broadly useful platform. The platform consists of a visually immersive environment where direct manipulation techniques enable a new kind of dialogue between human and machine (Figure 3.6). Users can easily control the interface from distance by wearing a set of gloves and remotely manipulate digital data, using their both hands. The interface can support multiple users and can capture their 3-dimensional gestures including hands movements from up and down, side to side and even forward and back. An image on the screen can be moved from one wall to another or onto the tabletop with a simple hand orientation. These possibilities make "G-Speak" an ideal interface to manipulate large amounts of data in large and wide displays by collaborating with others (Kramer, 2008).

Figure 3.6 G-Speak interface

(source:www.impactlab.com/2008/11/16/g-speak-the-minority-report-style-operating-system/, retrieved 3, June 2009)

Duke University's "Multi-Touch Collaborative Wall" provides similar interaction facilities through a touch based interface (Figure 3.7).

Figure 3.7 Multi-Touch Collaborative Wall

(Source: http://www.renci.org/resources/computing, retrieved 1, July 2009)

'Collaborative wall' permits users a multi-touch 'surface computing' and supports an 'always hands-on' interaction: users can simply touch the item they want to manipulate on the screen, and then move it easily by running their hands over the screen, magnify it, scroll it, etc. (Lynn, 2008).

Touch based or not, in contrast to the classical input devices having limited control capabilities, gestural interaction styles using human body skills can convey much more subtlety and permit user to control the system in a more efficient and precise way. Human gestures contain subtle information that could add multiple details to the input entries than a click on the mouse or a key tap on the keyboard. For example, even just an eye movement such as eye blinking, widely opening eyes, or raising an eyebrow can have very different meanings from each other. In addition to being a natural interaction style that imitates interaction with physical objects in the real world, gestures, permit users to acquire a more flexible and nuanced control over digital information. Interacting directly with digital displays allows designers to integrate multiple different configurations depending on the functionality requirements (Saffer, 2008), the totality of the control set could change dynamically with a simple gesture and display the most appropriate user interface which provides a considerable flexibility comparing to the static physical controllers.

Multiple products possessing gestures based interfaces are already present in the market. Nintendo's Wii and Wii-fit, Apple's iPhone and iPod Touch, Microsoft's Surface are some of the recent examples. Users control iPhone by touching on the screen and manipulate the digital objects with a tap of fingertip. Figure 3.8 illustrates zoom in and zoom out gestures permitting to control a digital image.

Figure 3.8 iPhone, zoom in zoom out gestures
(source: www.apple-touch.com, retrieved 1, July 2009)

The Wii-fit is an exercise console consisting of activities such as yoga, strength training, aerobics or balance games. Users stand out on a balance board and hold a set of wireless controller to play the games. Their movements is then reflected on the screen and repeated by their avatars. Figure 3.10 illustrates Wii-fit's free form interaction:

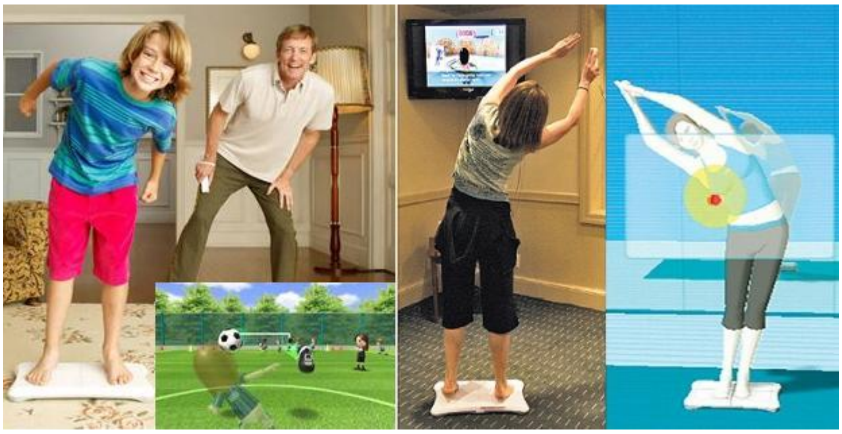


Figure 3.9 Wii Fit whole body involving interface

(source: www.apartmenttherapy.com/uimages/chicago/Wii-Fit-2.jpg, last visited 09.06.2009www.coralphones.co.uk/F2SImages/Nin_Wii_Fit.jpg, retrieved 9, June 2009)

The interaction becomes more involving and entertaining for users. Gestural interaction adds fun and encourages improvisation and exploration.

Similarly, 'Helsinki City Wall' developed by the Ubiquitous Interaction group at the Helsinki Institute for Information Technology and Multitouch Company, is an interactive wall, showing pictures and movie clips and allowing people to interact with the content by touching on the screen. It is aimed to provide an engaging, collaborative and playful installation where passer could manipulate media and learn about anniversaries, events and festivals (Vanderbeeken, 2007).

Figure 3.10 Helsinki City wall

(source: citywall.org, retrieved 9, June 2009)

Inamo Restaurant in London designed by Blacksheep company provide customers an exceptional food ordering experience throughout menus projected onto tabletops (Figure

3.11). Customers can select their food and beverages interactively, change their table top's pattern, and even play games or benefit from local information and services.

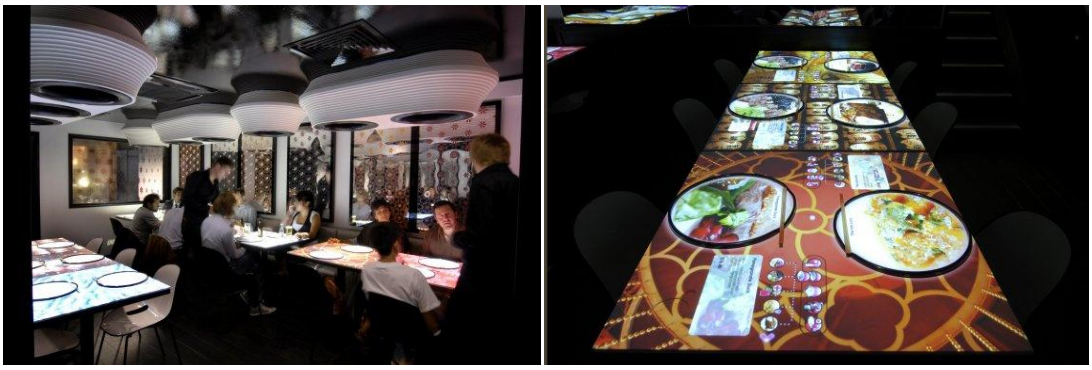


Figure 3.11 Interactive restaurant

(source: http://www.inamo-restaurant.com/gallery-photos.php, retrieved 8, August 2009)

Augmented reality interfaces

Augmented reality is a new form of interaction between people and technology permitting virtual objects to be inserted into real scenes in order to enhance the real image. By this way, the digital information becomes part of the real world.

Azuma, in his definition (1997) states that augmented reality,

- combines real and virtual
- is interactive in real time
- is registered in 3D

According to Vallino (1998, pp: 1) "the goal of augmented reality systems is to combine the interactive real world with an interactive computer-generated world in such a way that they appear as one environment."

Virtual reality vision deals with virtual objects in a computer generated world, by isolating the user totally from the real world. Augmented reality in contrast, brings the virtuality into the real world and allows users to interact with virtual objects or entity in their everyday environment and aims to enhance real world capabilities with computational power: it supplements reality rather than completely replacing it.

In this regard augmented reality could be considered as the middle ground between virtual and real as illustrated in Figure 3.12.

Figure 3.12 Reality-Virtuality continuum (Milgram and Kishino, 1994)

According to the reality-virtuality continuum proposed by Milgram (Milgram and Kishino 1994), augmented reality is closer to the real world end of line and lies in the middle region called ‘mixed reality’. Augmented virtuality is a term created by Milgram; situated in the mixed reality region in a more close manner to the virtuality, it defines virtual systems containing some real world simulations and giving the reality illusion to the virtual elements (Milgram et al. 1994).

Augmented reality integrates computational power into the reality of the user. In an augmented environment, computational devices are used to improve people perception and interaction in the physical world (Streitz et al., 1999). It consists of linking the physical objects already present in our physical environment to a virtual environment. The real scene is augmented with the virtual scene that adds additional information to the environment. Through a natural interaction both with real and virtual objects, the user benefits from the information and assistance provided by the enhanced physical environment. To make the user experience more realistic, augmented reality integrates all sorts of digital information into the physical world and allows multiple senses to be engaged in this experience. Graphical features, sound effects or even haptic devices providing tactile responses are used to intensify the virtual presence of objects.

Research on augmented reality systems have explored multiple augmentation possibilities in various domains. Azuma (1997) identified six classes of potential applications as medical visualization, maintenance and repair, annotation, robot path planning, entertainment, and military aircraft navigation and targeting. Today these application domains are considerably extended with many additional researches conducted upon areas such as education, psychology, publicity, sports training, urban planning, etc. (Boj and Diaz, 2008). However the common intent remains always the same: to enhance users' perception of the world and improve their performance (Vallino, 1998).

Augmented reality has a great potential to guide users in complex tasks. For example in order to assist people in the assemblage, maintenance and repair of sophisticated machines; 3D images, writings, or even animations appear all around the machine. A variety of information can be provided through the system: annotations may identify the name of parts, describe their functions or give information about their maintenance history while a voice record is explaining in detail each task to be accomplished during the maintenance process. Figure 3.13 corresponds to the illustration of a car maintenance process augmented through the glasses developed by BMW Company.

Figure 3.13 Augmented car maintenance process

(Source: www.designboom.com/cms/images/-andy01/bmw1.jpg, retrieved 9, June 2009)

BMW's glasses highlight the part that should be removed and replaced to assist mechanics. They explain how to extract them via an audiotrack describing the repair steps of the repair and even by pointing out the screws that need adjustment. Their future work consists of extending the usage of these glasses through BMW service to assist the staff in their technical work. Through this way technical information would be accessible in the workshop and as well as in the vehicle. The service staff can easily get assistance anywhere and anytime needed (Zeiss, 2004).

Besides assisting people in the maintenance and repair of complex machines described above, augmented interfaces can be also distinguished in medical applications. Augmented reality gives surgeons access to the necessary medical information during the surgery. The computer vision group of MIT Artificial Intelligence Laboratory has developed an augmented reality application that enables surgeons to visualize internal structures of the human body in the form of 3D reconstructions of internal anatomy (Figure 3.14).

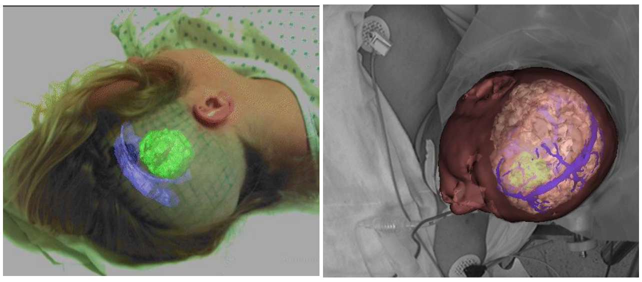


Figure 3.14 Augmented surgery

(source: http://groups.csail.mit.edu/vision/medical-vision, retrieved 6, June 2009)

Furthermore, augmented reality applications also aim to support collaborative tasks which are difficult to accomplish with screen based interfaces. Arthur project is an augmented reality application developed by Fraunhofer FIT supporting collaborative tasks and permitting architects to review the final presentation design and planning decisions (Figure 3.15). Users can sit around an augmented round table and via their see through displays, they can discuss the model that appears on the table. They can even remove existing buildings, add and manipulate new ones in 3D (Broll et al., 2004).

Figure 3.15 Augmented urban planning

(source: http://www.vr.ucl.ac.uk/projects/arthur, retrieved 10, June 2009)

Augmented reality has a wider range of application possibilities in everyday tasks along with assisting people in their work, in collaborative or complex tasks. As an example the "NoteScape Project" developed by Microsoft's Human Computer Interaction research team, enables users to have a permanent access to their important sticky notes. Virtual sticky notes accompanying users, become visible when the user looks through a head-mounted display on a display surface such as a laptop or a mobile phone screen (Figure 3.16). In contrast to the ordinary sticky notes which are location dependent, virtual ones follow the user in every physical context, float around the users' body and allow users to create, organize and browse through them anywhere they like (Edge and Min, 2009).

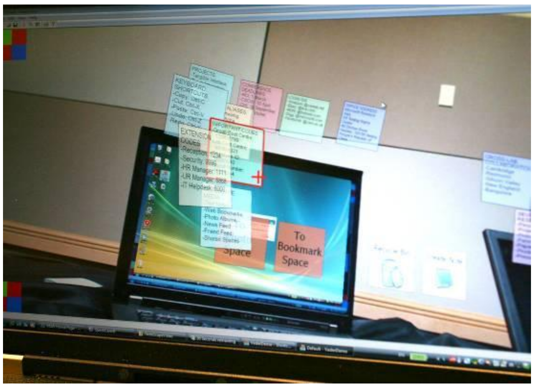


Figure 3.16 Augmented "sticky" notes

(Source: http://research.microsoft.com/en-us/projects/ncci, retrieved 13, August 2009)

A history book illustrating the history of the American's Cup course is another example for the everyday usage. The 'BlackMagic Kiosk Project' developed by HIT Lab NZ provides an innovative reading experience by augmenting the book with 3D images and animations. As illustrated in Figure 3.17, when readers look through a handheld display at the pages of a physical book, they see graphic models leaping out the pages and overlaying to the real world (Woods et al., 2004; Blackmagic Book, 2002).

Figure 3.17 Augmented book

(source: http://www.hitlabnz.org/wiki/Black_Magic_Book, retrieved 13, August 2009)

As well as everyday objects, everyday environments also can be totally augmented by digital information, in the scope of 'Counter Intelligence Project' conducted by MIT Lab. An ordinary kitchen is augmented with the intent to guide and assist users in their everyday tasks. As seen in Figure 3.18, various digital information is projected on kitchen appliances and surfaces. Augmented refrigerator gives spatial information about its content on its door and reduce the number of time that the door is opened for that purpose (Bonanni , Lee and Selker, 2005).

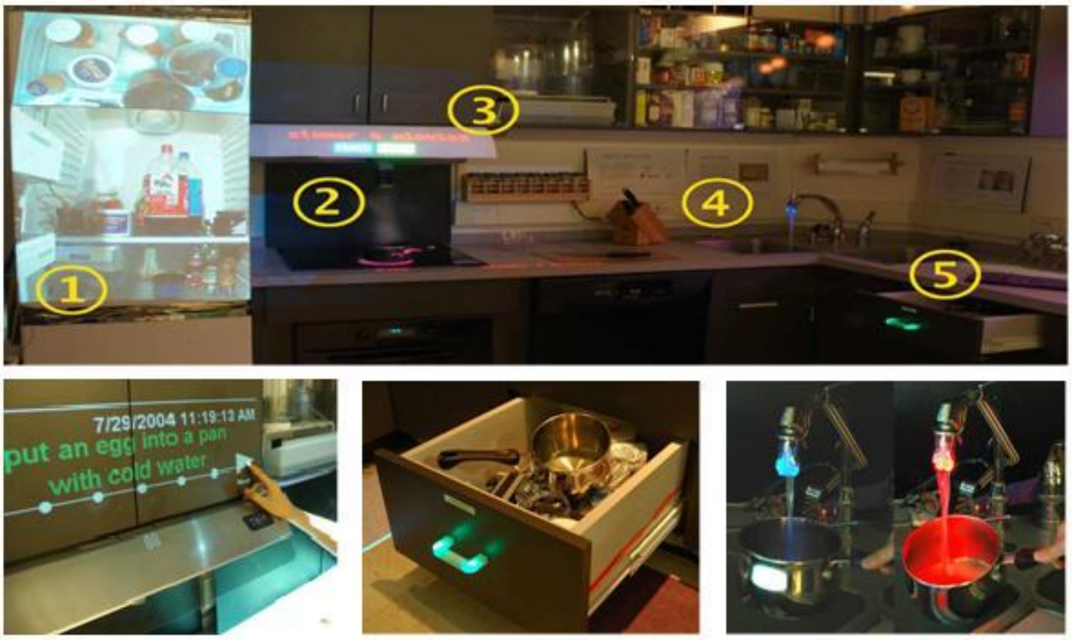


Figure 3.18 Augmented kitchen

(information projection on the refrigerator (1), the range (2), the cabinet (3), the faucet(4) and drawers(5); Bonnani, Lee and Selcker, 2005)

Virtual recipe guides users through a recipe step-by-step, the cookware indicates the food temperature and cooking time, also it informs when food reaches a desired temperature. Cabinet handles illuminate according to the indications given by the virtual recipe to help user in locating the necessary ingredients in the kitchen. And finally the faucets indicate the temperature of the water by projecting colored light onto the stream of water.

Tangible interfaces

Within Computing and HCI literature, 'Tangible User Interface' (TUI) term was first proposed by Hiroshi Ishii and his group at the MIT Media Lab in 1997 as an alternative to the graphical user interface. From HCI perspective, "Tangible User Interface" was considered as a new type of interface bringing computing from virtual into the real world. "Tangible User Interface" could overpass the discomfort created by traditional GUIs and even newer approaches such as virtual reality requiring a complete involvement into the virtual world (Ishii and Ullmer, 1997).

Ishii and Ulmer (1997) mentions that the variety of components such as windows, menus, or icons provided by GUIs are always represented in intangible pixels and remotely controlled with mouse or keyboard, as a result he claims that, most of the sensing and manipulating skills of users were neglected. TUIs, in contrary, are built to exploit those skills. In GUI, there is no direct relation between general purpose remote controllers and the virtual representation on screen. The mouse cannot be considered as a tangible representation of any data on the screen. The key idea of TUI is giving a physical form, a tangible representation to digital information (Ishii, 2008). Tangible user interfaces couple digital data with graspable controllers, which imply that the digital data is represented through tangible objects that can be directly manipulated by users. An appropriate input device is designed for each application and the digital content is directly controlled through this controller which reciprocally becomes the representations of digital information in the real world.

Through this way, TUIs allow users to unify representation and control units; nevertheless, the tangible representation of the digital data cannot immediately react as virtual pixels on a screen. The reaction is often supplemented with an intangible, virtual representation as sound or video projection to create permanently a dynamic feedback. This virtual representation should be closely coupled with physical objects to strengthen the reality illusion. The applications described below, provide different examples associated with this coupling of digital information with physical objects:

One of the first examples consists of a prototype of the 'Urban Planning Workbench' (URP) developed by MIT's Tangible Media research Group (Figure 3.19). The system tries to simulate the effects of building placement on sunlight and wind flow. Digital data is coupled with the real world throughout some physical models of buildings. The tangible models of building can be manipulated by users, and virtual shadows are projected on the surface. Time of the day and season properties can be set additionally with the help of some rotary controls. Any problem of overlapping due to the position of a building, or its size and shape can easily be determined. Similarly air flow can be simulated in streamlines projected on the surface to visualize the air currents around the building such that any undesirable flow scenario can be avoided (Underkoffler and Ishii 1999).

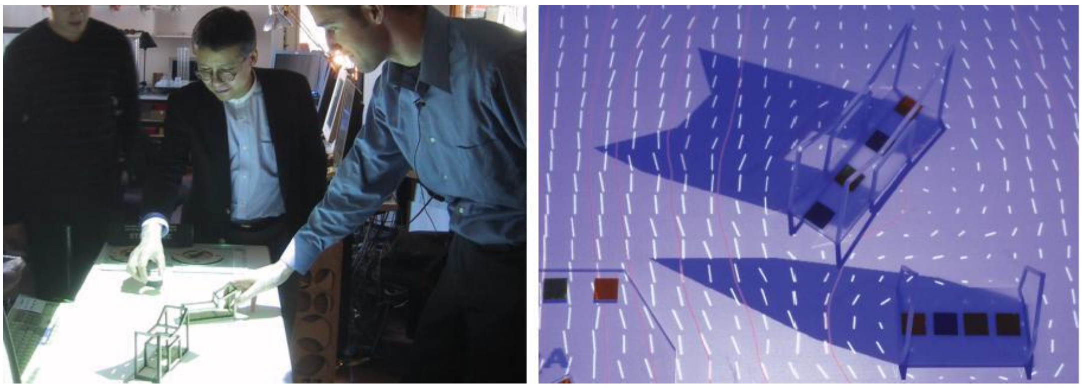


Figure 3.19 Urban Planning Workbench
(Underkoffler, Ishii, 1999)

A similar interface is also established through 'Music Bottles' project (Figure 3.18). In this case, an ordinary everyday product is chosen as tangible representation of digital data. Simple glass bottles are utilized as controllers of digital information. The physical meaning of a bottle which consists of being 'a container' was extended into the digital domain: instead of wine, juice or water the bottle can contain musical information and when opened it can liberate a sound of piano, bass or drums (Ishii, Mazalek and Lee, 2001). Digital background make possible to integrate every sort of data into ordinary everyday product “some bottles contain stories, some bottles contain a genie, and you can also imagine perfume bottles that contain a chanson, or whisky bottles which can contain story of Scotland, for example” explains Ishii (Moggridge, 2007, pp: 533).

In another application (Figure 3.20) a wine bottle depicts its virtues on the surface of the table it is placed (Valli, 2004).

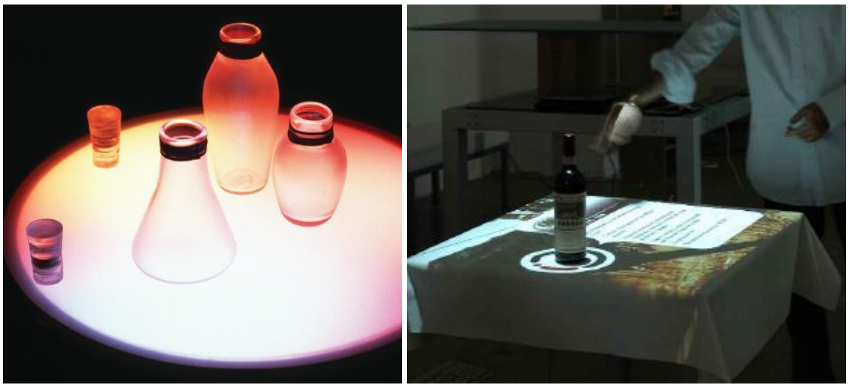


Figure 3.20 Bottle controllers: Music Bottles and Wine Bottle controller

(source:tangible.media.mit.edu/projects/musicbottles, retrieved 19, August 2009; Valli, 2004)

Apart from task specific tangible user interface as mentioned above, there exist also multiple table-based tangible applications permitting people to accomplish various tasks by manipulating directly the digital content. Table based applications combine tangible input of physical object with multi-touch interaction on the surface, users can directly manipulate projected images, or they can interact with physical tokens, as they can also manipulate graphics on a large scaled touchscreen. Pompeu Fabra Univeristy - Reactable Project, Microsoft’s Surface Computer and Light Blue Optic’s Light Touch are some of the examples of these table based tangible interfaces (Figure 3.21).

Figure 3.21 Reactables, Microsoft Surface, Light Touch,

(source: www.reactable.com, www.microsoft.com/surface, retrieved 4, July 2009 www.psfk.com/2010/01/light-touch-turn-any-surface-into-a-touchscreen.html, 12, August 2009)

Over the years, the vision of tangible user interfaces is developed and expanded upon different domains. Many research groups not only from HCI and computing but also from product design and arts focused on this new type of interaction with the purpose of building new experiences. The term “Tangible User Interface” is than shifted to a more inclusive term as “Tangible Interaction”, placing the accent on the design of interaction rather than visible interface (Hornecker and Buur, 2006).

As argued by Hornecker and Buur (2006), the term of Tangible Interaction prioritizes some principles of design as: tangibility and materiality, physical embodiment of data, bodily interaction and embeddedness in real spaces and contexts. From industrial design perspective, tangible interaction was a requisite of the new technological developments giving the possibility to integrate digital properties into the products. Product’s digital process has generally no inherent relationship with the products form, Tangible Interaction was seen as a promising way of establishing this relationship (Hornecker, 2006). Marble Answering Machine developed by Bishop (1992) in Royal College of Art (Figure 3.22) is one of the product design concept processing digital information throughout a physical interaction.

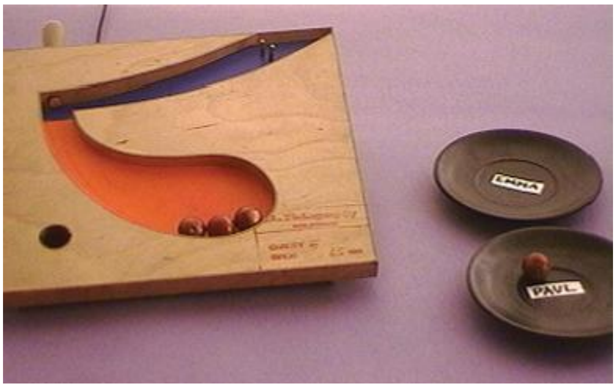


Figure 3.22 Marble answer machine
(Moggridge, 2007)

Incoming messages are represented by marbles. For each voice message leaved, a marble is falling out of the machine to play the message, the user could than take the marble and put into a special play indentation on the machine, the message can be deleted or the user can also choose to store messages, outside of the machine in a receptacle. By this way the user can categorize or organize messages from various people (Smith, 1995).

Similarly the Digital Shoebox (Figure 3.23) designed by Banks in Microsoft's Research Laboratory aims to make the storage of digital photos more tangible (Banks and Sellen, 2009).

Figure 3.23 Digital Shoebox

(Harper et al., 2008)

Photos can be sent wirelessly to the box, and users can browse through them by running their finger across the top of the box. Most households have shoeboxes full of paper photos; digital shoebox accordingly refers to this typical usage of empty boxes as a photo container and tries to provide a similar tangible interaction throughout a digital shoebox containing digital photos (Banks and Sellen, 2009).

The major aim of tangible interfaces, being to harmonize the interaction between the virtual and real world, the applications are only limited with the imagination of their designers. Besides applications linking digital information to the physical environment via tangible tokens or physical objects, also developing new applications that mimic real life activities considered as a way of unifying virtual and physical thinking as mentioned in section 3.2.1 Natural Interaction. Likewise the Marble answer machine and the Digital Shoebox projects, "Virtuo Digital Palette" project concept developed by Klimava (2008) has a great potential to decrease the mental workload while learning a new interface. The interface mimics the activity of painting with physical canvas. The real paint mixture effect is provided by a digitally enhanced palette that displays the colors through LED lights. The amount of paint "picked up" by the tool is determined by the amount of time that tool spends on the mixed color. Users don't have to learn interacting with the painting program because it simulates their already known painting capabilities with a canvas, palette and brush (Figure 3.24).

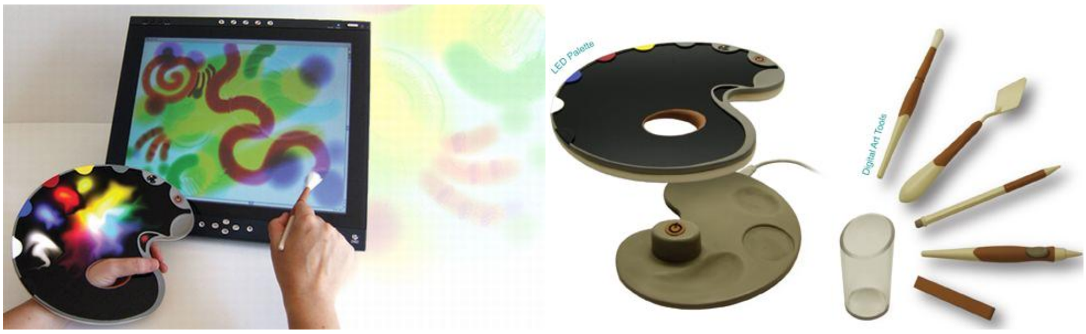


Figure 3.24 Virtuo digital palette

(source: www.yanaklimava.com/, retrieved 12, September 2009)

Application areas for Tangible Interaction have been widely diversified. In addition to provide a more natural interaction with user interfaces and digitally augmented products, tangible interaction is extended over the environment and allowed people to interact with whole body movement in interactive spaces. Interactive floor, interactive museum concept and interactive graffiti wall are some of the examples that could illustrate the evolution of tangible interfaces from small objects that users could grasp and move around a table to large spaces such that users can move around the interface by themselves.

Interactive floor track users' presence and respond according to their movements on the floor (Figure 3.25).

Figure 3.25 Interactive Floor

(Valli, 2007)

The “Graffiti Wall” (Figure 3.26), with same principle, could engage large groups of people at parties or festivals, and encourage them for a common activity, such that users can digitally "paint" a surface in the same way that they can tag a wall with traditional spray paint:

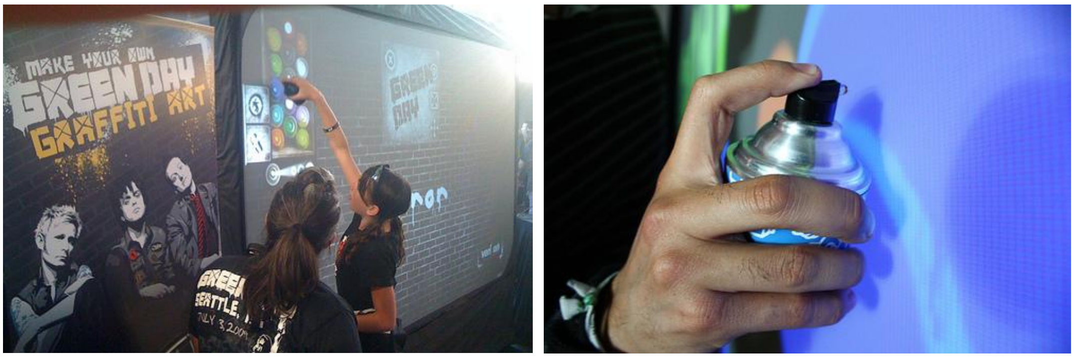


Figure 3.26 Graffiti wall

(source: www.tangibleinteraction.com/gallery/digital_graffiti_wall, retrieved 14, September 2009)

In parallel to the diversification of applications’ area the boundaries between the gestural interfaces, tangible interfaces and augmented reality interfaces become blurred. Gesture based interfaces include tangibility, similarly augmented reality application also could support a tangible interaction, the “SixthSense” project developed by MIT Media Lab, bridges the gap existing into different interactions style into one unique device (Figure 3.27).

Figure 3.27 SixthSense

(source: www.pranavmistry.com/projects/sixthsense, retrieved 14, September 2009)

SixthSense is a wearable gestural interface that augments the physical world with digital information and let people to control the digital content tangibly via natural hand gestures. The visual information is projected on walls and other physical objects that could be used as interfaces and user's hand gestures are tracked using computer-vision based techniques.

The prototype implements several applications that demonstrate the flexibility of the system: the drawing application lets the user draw on any surface by tracking the fingertip movements of the user's index finger, also a newspaper for example could be augmented by digital information and can show live video news or provide dynamic information on an ordinary piece of paper, in the case of the dial pad application, numbers are projected on the user's hand and in order to dial a number user taps on the projected numbers (Mistry and Maes, 2009).

Natural interaction styles have received a considerable attention and multiple applications in diverse area have been developed. Conventional computation understanding restraining people in the virtual world gained a new approach and had taken steps into the physical world. As pointed out by Fishkin (2004), this approach implies a further step that "leads away from computer-human interfaces into the realm of human interfaces in general". To improve the communication and to diminish the cognitive distance between humans and computers natural interaction styles brought computation to the real world and make it more sensitive to human's communication skills. However, besides improving the communication through diverse input and output modalities, also developing an understanding concerning the cognitive process of humans where both logic and affect plays an essential role, is required.

Norman (2004) examining the relations between affect, behavior and cognition discovered that people's attitude, behavior and action results from the interactions between their emotional and cognitive systems. Emotions could change the way that cognitive system functions. People possess emotions which effects considerably their actions. To improve the human-computer interaction accordingly, interfaces need to understand people's affective state and even to include emotions in their decision making process.

3.3.2 Affective Interaction

For a long time emotions were treated independently from rational thinking and even consciously neglected in decision making processes. The affect was hard to measure and therefore generally misunderstood. However studies in neuroscience and psychology revealed that emotions were an important part of multiple cognitive processes and intelligence in general. Perception and organization of memory, categorization and preference, goal generation, evaluation, judgment decision-making and problem solving capabilities, strategic planning, focusing on, attention, motivation, performance, intention, communication, and learning are indeed all highly influenced by emotions (Damasio, 1996, Lisetti and Nasoz, 2005). Humans establish affective relationships with the environment since birth and their emotions play a crucial role in their development. People couldn't completely neglect their emotions while making a decision. Even some of their actions might not have any 'logical' explanation. They could establish affective relations with certain products while they could stay neutral with others and correspondingly certain actions might make one group of people smile while the group gets disappointed.

People naturally emote also while they are interacting with computers (Reeves & Nass, 1996), however computers do not naturally perceive their emotions. Assuming that emotions play an essential role in people's interaction with each other, and trying to simulate human-human communication methods to obtain a more natural human-computer interaction and enhance everyday digital products, it is indispensable to study affect and design systems that are able to recognize, interpret and process human emotions.

Affective computing has emerged as a branch of the study of artificial intelligence and aims to improve the human-computer interaction, by making emotion sensitive computers. It is originated with Rosalind Picard's paper (1995) on affective computing where she argues that computers should be able to infer information about users' affective state, build computational models of affect and respond accordingly. The words 'affective' and 'emotional' are frequently used indistinguishably however the term affective is more wide ranging and embraces all of the psychological states such as moods, feelings, passions and sentiments in addition to the emotions.

The ability to recognize emotions will permit a computer to better understand its user's cognitive process and actions. The computer will be able to adapt itself to the emotional state of the user and respond him accordingly. On the other hand the computational intelligence complemented with emotional intelligence will allow the computer to observe, interpret and act likewise a human. Integrating artificial emotions into the reasoning process of computers which will not only provide a better understanding of their human users but also provide human like reasoning and acting capabilities. As a result, increasing quality of communication makes plausible to improve the human-computer interaction. A harmonious human-computer interaction could be established and computers could interact naturally with their user by imitating everyday human communication.

3.3.2.1. Affect recognition

Throughout facial, body and vocal expressions, people could easily communicate their affective states. For humans, recognizing that a person gets distressed, relaxed, happy, sad, angry or anxious is not too difficult. Various expressions related to different affective states could be almost intuitively determined and interpreted. In contrary for machines, recognizing the affective states of humans is a difficult task. Humans could express their emotions in multiple ways and a similar action could include different meanings according to the temporal and situational context. For example a smile could indicate that the user is content about the situation as well as it could be a smile in a forced manner revealing his reaction to the absurdity of the situation and denoting his total disagreement.

As the affective states could be expressed in a multiple different ways from speech to body gestures, various techniques are employed to sense and recognize them. Machines interpret the affective information through visual, acoustic and tactual inputs captured via different modalities and approaches, such as behavioral cues and signals (e.g. speech and voice intonation, facial expressions, body gestures, posture or movement), physiological signals (e.g. respiration, heart rate, temperature, galvanic skin conductivity and salivation, brain and scalp signals, thermal infrared imagery) and situation evaluation (Paiva,2000, Gunes, Piccardi and Pantic,2008).

Speech may deliver some clues about the emotional state both through the explicit meaning of the word spoken but also the implicit meaning hidden behind the way that the words are spoken. Discourse information involving word selections and phrase formulations is linguistically and semantically analyzed, and different acoustic features and pronunciation styles are detected from parameters such as pitch, energy, frequency and duration to determine the affective state.

Basic emotions as happiness, sadness, surprise, fear, anger and disgust, but also more subtle expressions such as fatigue or pain and mental states like agreement, disagreement, unsure, concentration, interest, or frustration are tried to be tracked throughout facial features and bodily expressions (Hong et al., 2005; Cohn, 2007; Stock and Righart, 2007). Facial components such as eyes, nose, eyebrow, mouth, lips, ears, and also texture characteristics as wrinkles, bulges and furrows are captured continuously to detect any change. Consequently body gestures postures or movements could help to determine the affective states of the users (Ball and Breese, 2000, Kleinsmith and Berthouze, 2007, Cran and Gross, 2007). An upright posture could sometimes communicate the aggression, leaning behind could connote relaxation, head and hand movement could convey diverse meanings to enhance the facial expression, etc.

The affective interaction embodies in general, coordinates of face hand and other body movements and even generates some biological signals that manifests as variations in respiration, heart rate, pulse, skin conductivity, salivation or temperature conditions. The advances in affect recognition techniques permit machines to acquire information from multiple sources constituting each a part of the multi-modal affective system. And as well as independent approaches exist to capture different signals, all of the user's expressions are correlated with one another. An interpretation considering the combination of different inputs would provide better results about user's state than treating each signals separately. The low level signal recognition should be accompanied with higher level reasoning process which evaluates user response and interpret it relative to the situation in order to have better understanding of the affective information carried out with the behaviors, decisions and even the choice of words of the user most of the time. Once the emotional state is recognized, to establish affective interactions, machines should then analyze, interpret the affective information presented by users and reason them. With the help of an affect model built from the data captured throughout physiological, behavioral and even situational clues, computing system tries to recognize the emotions, moods or sentiments latent behind these inputs in order to identify the affective state of the user and also predict which affection is likely to occur next. Then the computing system evaluates the model to determine the most appropriate action to be taken according to the user's actual state. Machine learning algorithms, could take into consideration the affect information presented by the user, remember user's previous affective reactions given under certain conditions and establish a personalized decision making and choosing actions process.

Furthermore, machines themselves could develop their own affect models to express in a humanlike way by complementing their actions and decisions with affective behavior. Picard (2000) differentiates the recognition process from the simulation of affective states. She argues that recognition is possible with the analysis of the inputs concerning user actual state while affect simulation results from a synthesis of agent's goals, contextual knowledge, user's goals, user' emotional states, etc. (Figure 3.28) Some analysis could then give rise to a state in a computational system.

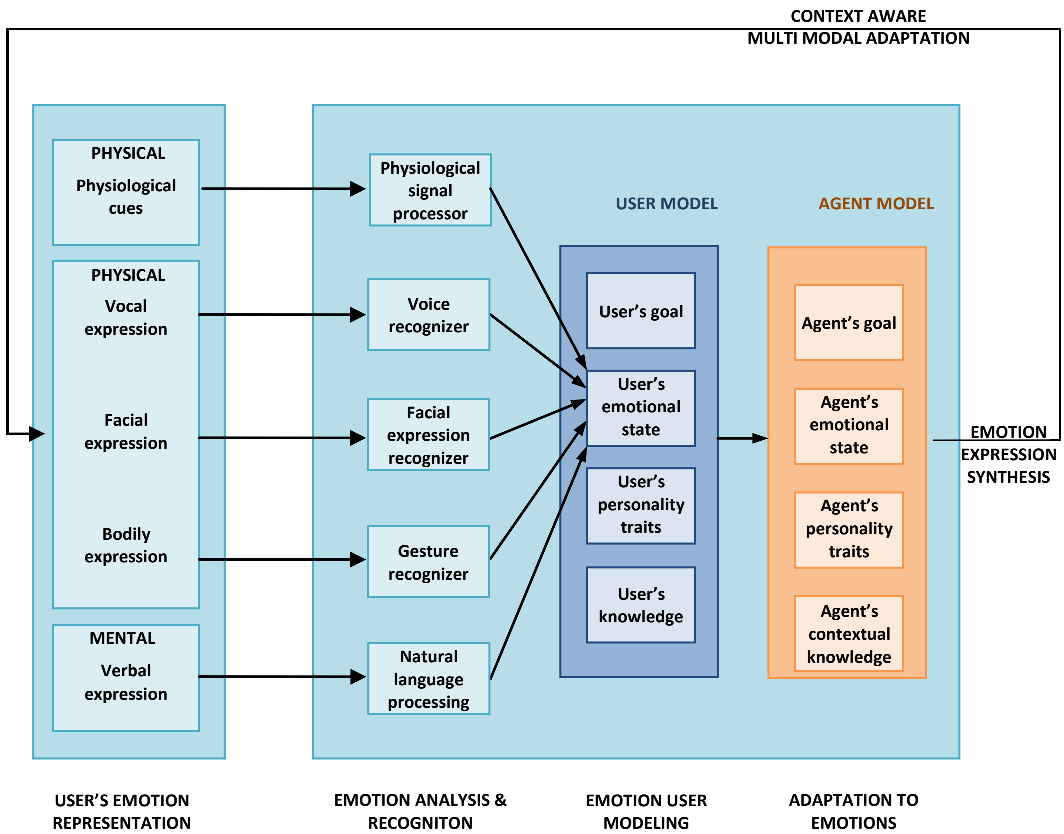


Figure 3.28 Affect recognition & simulation process
(Adapted from Lisetti and Nasoz, 2005)

The affect model is generated with the goal to interpret user's emotion properly and adapt computer's reactions to the changes of the user's emotions. However neither modeling user's affective state nor building computers' own affective states is a simple task. Tao and Tan (2005) claim that most of the affective information capturing systems are present in labs or studios where researchers have to deal with a very limited number of inputs comparing to the natural scenarios. In real environment more continuous and complicated interactions occur and they transform the affective states recognition process into a more laborious task.

Although there is a growing interest on emotion theories between research communities, as mentioned by Paiva (2000), there has not been yet a clear consensus on what emotions are and what theories are better to obtain computer emotions. Currently researchers generally work with simplified model of emotions corresponding to a well defined scenario. Different approaches of modeling and simulating emotions exist: The OCC model (Ortony, Clore and Collins,1990) classifies people's emotions as a result of events, objects and other agents in three categories. People are happy or unhappy with an event, like or dislike an object, approve or disapprove an agent. These 3 categories comprehend 22 detailed emotions each that the system tries to map every one of the affective information presented to one of them. However, in real environment more than one emotion could be experienced with a single reaction, an event could reveal all of the emotions in the three categories. Even though it has some limitations, OCC model is an important attempt in building personalized computing systems that are able to perceive their user's feelings and give friendly responses and multiple affective products based on OCC principle (Zong, Dohi and Ishizuka, 1995, Liu, 2006, Parunak et al., 2006).

Accordingly, Elliot's (1992) empathic machine "affective reasoner" is designed as a friendly computer tutor that could listen people's emotional problems and respond them like an understanding friend. The agent tries to recognize people's emotional state from the sentences they formulate, and respond appropriately by dynamically updating its facial expression from the database containing a number or cartoon-like faces, in order to display different emotions relative to the situation. Elliot (1992) describes the agent's reasoning principle as follows: ''I can say to an agent in the program, 'Sam, I'm worried about my test,' Sam will recognize what 'worried' means, and might respond, 'Clark, you're my friend. I'm sorry you're worried. I hope your test goes well.' Right now Sam's emotional acuity is more advanced than his language ability: he doesn't know what a test is, but he knows how to respond when you're worried.'' Although it understands the sentences partially, and respond with limited number of facial expression, the agent could play the caretaker. Minsky (2006) defends that emotions as well as rationality are a way of thinking. He argues that “each of our major "emotional states" results from turning certain resources on while turning certain others off-—and thus changing some ways that our brains behave”. According to the type of problem faced, human mind selects an appropriate “way to think” (Figure 3.29). The emotions are "ways to think" for different "problem types" that exist in the world. The selectors of human mind turn on emotions to deal with various situations when necessary.

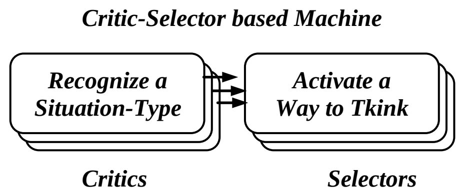


Figure 3.29 Critics – selectors mechanism (Minsky, 2006)

The basic emotional states such as hunger or thirst are triggered via some neuronal agents sensing the chemical properties of an organism, and similarly fear or wrath result from increasing concentrations of different hormones in the organism against certain external events.

However over the years with the growing mental abilities, the simple If and Then rules triggering those basic emotions are replaced with a “Critic-Selector” type of machine. “Critic” resource, besides recognizing the external world events, also deals with problems or obstacles inside the mind. Critic-Selector machine is not confined to just reacting to external events, it could even direct itself to switch to a different way to think. It generally considers several reactions before deciding which one to proceed (Minsky, 2006, pp: 29). “Thus, an adult who encounters what might be a threat need not just react instinctively, but can also proceed to *deliberate* on whether to retreat or attack—that is, to use higher-level strategies to choose among possible ways to react” affirms Minsky while describing the thinking process of mature minds.

Minsky recognizes either that a further work to discover more specifically the functioning of each "ways of thinking" must be carried on to better understand and simulate people' emotion. People's affective states are closely related with their personalities, environment, and cultural background and only a combination of all of this information could lead to an efficacious affective model as presented above in Figure 3.26. Similarly Picard (2003) defending that there are always some methods to handle and progress in understanding of any complex modeling problem, recognizes that researchers are limited in modeling affect because of lack of knowledge about affect at the neuronal signaling level. How such molecules communicate among the organs in human body is not entirely discovered and the real-time sensing of local molecular activity is not easily accomplished. As the affect phenomenon is not entirely understood, any system able to accurately process the emotional information in a human-like manner has not yet been developed. The theories about affect and emotion concepts have not still reached any conclusion

The limited affect data resources and the complexity of natural scenarios transform the multimodal affective computing and relevant learning and controlling algorithms into a laborious task. Even that a real effective affect interaction couldn't be established with today's knowledge about the subject, multiple applications exist. Current researches about smart technologies are able to sense at a certain level affective states of people and establish some affective relationships with people.

3.3.2.2 Affective smart interfaces

Affective computing give rise to the development of many smart technologies establishing different affective interactions with people. Once people's affective state is captured and interpreted, the affect information could then be used to develop applications that respond accurately and effectively by taking into consideration the perceived states of the user and even by trying to predict user's potential reactions that could be given against their actions. Applications interacting with users according to their moods, applications displaying user's affective state, and facilitating the communication of emotional information, or applications that synthesize or simulate human-like emotions are as well developed to simplify reciprocally the human-computer understanding, to establish a natural interaction and to provide better services to people.

Affective interaction makes computers less artificial and even more intelligent, besides provides user a humanlike interaction experience closer to the real life. There exist multiple affective interfaces examples reducing user frustrations recognize their user emotions, share their feelings and help computers to develop social-emotional skills.

Interfaces sensing user emotions

Likewise most of the HCI researches, affective computing studies aim to help reducing user frustrations during an interaction. Affective computing could improve the interaction with daily products by capturing people's affective states and handling decision making algorithms to respond in an intelligent, sensitive and friendly way. Product which can detect human's feelings could assist people only when needed; when the user feels stressed and frustrated the system could take the control or act in a way to relax its user. In this context, affective vehicle interfaces are developed to simplify, facilitate and accordingly establish a more natural interaction between the drivers and their car. Affective cars could monitor their users' emotional state during driving, recognize their frustrations and take the necessary precautions to avoid any reaction capable of endangering driving safety. Besides improving safety, affective cars that are aware from the stress level of their users could act in a way to abate their frustrations and provide them a more comfortable driving.

AIDA (Affective Intelligent Driving Agent) is an affective car interface developed by MIT Media Lab with the goal of making the driving experience more effective, safer and enjoyable (Figure 3.30). Among the researches trying to ameliorate the communication between the car and the driver, by taking the basics of human social interaction as model, AIDA is one of the prototypes having the ability to perceive and interpret the affective state of driver or passengers. Furthermore, AIDA merges knowledge about the city with an understanding of the driver's priorities and needs. To provide an efficient assistance in the accomplishment of his tasks by predicting his intentions or eventual actions in advance, AIDA analyses driver's mobility patterns and learn his favorite routes, and locations, even permanently monitors the environment to suggest optimal routes by considering the traffic conditions or alternative destinations which may interest its driver or passengers. According to the goals of the driver, AIDA could also give real-time information about environmental conditions, commercial activity, tourist attractions, or residential areas.

However the most important aspect of the interface, differentiating it from the other intelligent car systems, is that AIDA realizes this assistance in a very natural and simplest manner: it simulates human facial expressions and could communicate with the driver through a smile or the blink of an eye accompanied with physical movements and voice information. Humans could intuitively understand facial expression, and communicate through speech; therefore the interpretation of the information giving by AIDA could be easy and quick. AIDA providing a natural interaction facilitates then the driving process by preventing distractions and allowing the driver to concentrate on the road. It could capture people's emotion via their facial expression or skin galvanic conductance and respond them in a socially appropriate manner. It could sense when user is stressed, or recognize driver's distraction, and alert him to focus on driving or recommend him to lean back and relax etc.

The creators affirm that they aimed to create the illusion of an informed and friendly companion guiding people during the drive. Drivers would feel as there is a real person in the car that assists them permanently during the drive (MIT Media Lab Personal Robot Group, n.d.).

Figure 3.30 AIDA

(Source: robotic.media.mit.edu/projects/robots/aida/overview/overview.html, retrieved 21, August 2009)

Norman (2004) affirms that sooner or later machines will be equipped with emotions in order to establish a better interaction, cooperation and learning. Smart designs able to process the affective information captured from user, provide a high flexibility and an efficient assistance especially in critical and complex tasks.

However affective computing has also a great potential of application in mundane everyday tasks. Various companion devices emerging in recent years, try determining user's mood or affections before deciding on their actions to enhance realism. They create the illusion of a personalized caretaker and even to provide a higher degree of autonomy. For instance, the alarm clock designed by Wensveen (Figure3.31) as a part of his PhD project about the emotional intelligence in products, aims to wake up its users according to their affective mood (Wensveen and Overbeeke, 2001). The clock uses 12 sliders to set the waking time. The display window on the top shows the period of sleep that has been set. Users slide them all the way for a full hour's sleep. As well as each slider could be operated one by one people could also use both of their hand to operate multiple sliders at the time. According to the number of sliders moved at once, the speed of sliding, the length of the move and the waiting time between the actions based on the pattern that the user form with the sliders (e.g. whether they are vertically and horizontally symmetrical, centered or not etc.) the clock tries to figure out the degree of arousal, valence and urgency for the user. Then combining this information with the amount of sleep set, it predicts how the user will feel the following morning and chose an appropriate signal accordingly. The clock's assumption is that the resulting pattern of the sliders and the way which they are moved indicate user's affective state before going to sleep, and to determine his mood while awaking. However if the user respond differently than predicted in the morning, the alarm clock recognize that the signal was not chosen appropriately and try to gradually adapt to its user by selecting another sound next morning. "This lets you train your alarm clock by a system of reward and punishment, just like you would do to a dog." affirms Wensveen.

Figure 3.31 Alarm clock

(source: www.delftoutlook.tudelft.nl/info/index58a9.html?hoofdstuk=Article&ArtID=4241, retrieved 21, August 2009)

Besides caretaker affective products that expand considerably the relationship between humans and machines, facilitating the interaction by providing a better understanding of each other, affective computing could also improve human to human emotional communication. Smart products capturing user's affective state through diverse sensors and tracking technologies, could share this information with other people, and help users in delivering their emotions.

Key Table and Picture Frame developed in the scope of the Equator project by the Engineering and Physical Sciences Research Council at Royal College of Art envisaging to alert cohabitants about the user's emotional state, is one of these products that transform the affect information captured from the user into easily recognizable emotion patterns(Figure 3.32).

Figure 3.32 Key Table and Picture Frame

(Moggridge, 2007)

The key table deduces people's emotions from the way they put their stuff on it. With the help of weight sensors, user's mood is predicted according to the force with which something is dumped onto the table. If a user is in a bad mood the table assumes that he will violently throw objects, in contrast while everything is okay, and the user is in good mood it envisages that he will gently place them. The emotional state captured is then transmitted to the picture frame wirelessly.

According to the information communicated, if the table has detected an extraordinary state, the picture tilts at an angle to alert other inhabitants to tread carefully. The bad mood of the user communicated through an aggressive behavior could also be recognized by other people. However although an explicit affective behavior is captured, the table and picture frame could warn the inhabitants in advance about user's state.

Philips design work with more intrinsic feelings that are not especially revealed by explicit gestures, speech or facial expressions. People naturally diffuse multiple affective signals implicitly. The electronic sensing jewelry concept uses biosensors to recognize and display these affective states (Figure 3.33). Philips' jewelry include flexible sensors that capture and interpret bio-activity, and actuators that simulate and display the affective information by changing color or even shape according to the user's mood. Multiple biometric signals could be captured by this way and communicated to the entourage with a playful simulation.

Besides facilitating the communication of affective states, and even becoming a way of expressing emotions this kind of products permit users to experience a more vivid interaction with unique designs that reflect their personality.

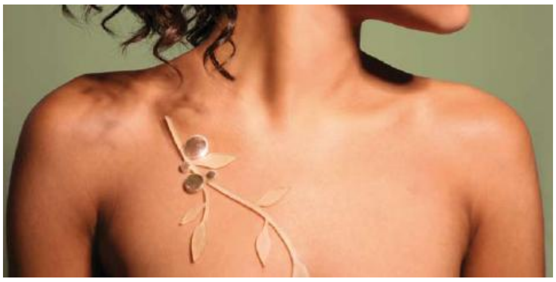


Figure 3.33 Mood sensitive jewelry concept

(source: www.design.philips.com/probes/projects/electronic_sensing_jewelry/index.page, retrieved 12, October 2009)

Interfaces developing social-emotional skills

Computers capture people's emotions, and use this information to determine their priorities and interpret their expectations better. As a consequence, computers understand their users better and act in way to satisfy them: human computer interaction is enhanced.

However this is a one-sided enhancement. Computers don't display any emotions, thus is still difficult for humans to understand them. In this extent, many of the current researches aim to augment computers with human-like social emotional skills. Researches about interfaces containing animated characters that could vocally, facially or even bodily express their emotions are conducted with the intent to develop an affective human computer interaction, and assure a natural communication. With such characters answering user's requests in real time, speaking directly to the user, having realistic voices, and complementing their conversation by mimics and gestures, it is intended to increase the believability as well as the efficacy of the interaction. Once the traditional modalities of human-human communication cited above are used in human-computer interactions, Zanbaka et al. (2004) defend that people respond to virtual humans similar to the way that they respond to real humans. Emotional attitude gives a semblance of empathy that permit user to conceive the machine like another person reacting naturally to his emotions.

Humanlike features create the illusion that the machine has a personality and convey to the users some degree of believability (Cassell et al., 2000, Paiva et al., 2005) that positively influences users' performance (Raij et al., 2006, Babu et. al., 2007). Brave and Nass (2002) mentioned that interactions ignoring people's emotional states are defined as being cold, socially incompetent and even untrustworthy by users. However, interactions with emotional machines are mentioned as much more natural and pleasant. And when the behavior and attitude of an interface agent is similar to a real human, users achieve tasks efficiently (Takeuchi and Katagiri, 1999).

Garcia and Marve (Figure 3.34) are two examples of interactive virtual human interface agents. Officer Garcia is used as a real-time embodied agent for an eyewitness application's interface. He's designed to guide the eyewitness trough the identification procedure. Similarly Marve, is a part of a messaging application. He's taking and delivering messages to the concerned persons. He uses movement and face tracking techniques to detect and recognize people and eventually inform about their messages automatically. Both of the agents are able to interact via speech, eye contact, facial expressions, gestures and even master humanlike social communication protocols such as turn taking, feedback, and repair mechanisms.

Figure 3.34 Interactive virtual human interfaces

(Daugherty et al., 2007; Babu et al., 2005)

Building an interface that recognize emotions and simulate human behavior in real-time is a challenging task. Multiple techniques from a variety of disciplines are needed to be used simultaneously to establish a virtual human interface. A framework including speech recognition, animation and rendering, planning and discourse modeling, user identification and tracking, and real-time speech synthesis are required.

Virtual agents using natural methods of communication have a great potential to improve human computer interaction. The intuitiveness of the interaction avoids users from being exposed to a high level of mental workload while communicating their intents and understanding the responses given by the system. Although they are challenging to develop, virtual agents could considerably change the common usage and understanding of computers and completely revolutionize the accessibility, usability, and applicability of computerized devices in everyday life (Babu et al., 2005).

Human to virtual agent interaction is seen as a promising technology especially for future interfaces of social or collaborative applications, thus researches about agent systems, animated characters, user emotions, or conversational interface agents, (Isbester and Doyle, 2002) are increasingly proliferating and spanning from virtual characters into robotic agents. Besides animated characters living in virtual environment, sociable robotic systems are beginning to assist people in their everyday environments. Multiple ongoing researches include the development of socially intelligent robot partners that establish a natural interaction with humans. Kismet, Nexi, and Alberthubo could illustrate the evident progress in the development of affective robots having humanlike features (Figure 3.35).

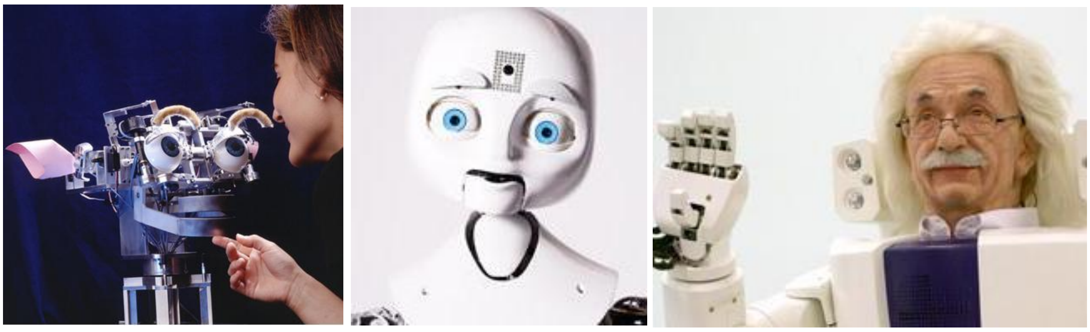


Figure 3.35 Humanoid robots (Kismet, Nexi, and Alberthumo)

(Source: www.ai.mit.edu/projects/kismet/; robotic.media.mit.edu/; www.hansonrobotics.com/vision.html, retrieved 14, September 2009)

These projects are trying to model the human behavior and movements in robots. The prototypes are able to recognize people, display facial expressions, communicate verbally with their users by maintaining the eye contact, and even mimic some of the human emotions. Kismet was a project developed by MIT Media Lab in order to explore a natural caretaker interaction throughout an affective robot. Similarly Nexi was designed to experiment the non verbally communication methods with humans. And Alberthumo is one of the biologically-inspired robots developed by Hanson robotics, a research group investigated in the development of realistic humanlike behaving creatures. In future these robots will be ultimately able to work with humans as peers, as explained by Hanson robotics' researchers, while humans continue to push technology forward, and related technology improves, robots will evolve into socially intelligent beings, capable of love and they will earn a place in the extended human family.

As well as it is easier to imagine humanlike characters such as the interface agents or robots to display affective behavior via facial expression, gestures or voice intonation, all of the ordinary everyday product have in fact the possibility of establishing affective relationship with people in different ways. Throughout "Living interfaces" project conducted by the research group of Potsdam University for example (Figure 3.36), an affective interaction is established by integrating personality features into the everyday products. The impatient toaster and intimate door lock are two prototypes developed throughout this project consisting from a series of experiment aiming to explore the benefits of reduced life like movements for human-machine interaction.

Figure 3.36 Living interfaces: affective toaster and door lock

(Burneleit, Hemmert and Wettach, 2009; Roy, Hemmert and Wettach, 2009, retrieved 12, October 2009)

In the scope of the project an ordinary toaster is augmented with humanlike behavior to motivate user to eat in regular intervals. The toaster has no handles or buttons, instead a speech and gesture based interaction is required. Periodically to remind user about the meal time, the toaster signalizes its "hunger" by shaking nervously. When the user "feds" the toaster with bread, it becomes satisfied and calms down. It continues moving gently during toasting task to signalize activity, and once the breads are toasted, it excites again to communicate the end of the toasting task. The toaster only calms down when user takes care of it, pats it or when he takes the slice of bread out of the slot. The door lock also waits for affection from its user, an ordinary door again augmented with humanlike affective expectations remains locked until the user gives a kiss to it. The intimate human-human interaction is tried to be simulated with this prototype. A camera-augmented mirror is assimilated to a door lock and the kiss is conceived as a key. The user then should kiss the mirror to open the door, which connote besides that the act of kissing himself is opening a door.

As research indicates, humans tend to like what is similar to themselves (Otto, Euler and Mandl, 2000). Accordingly simulating the intimate human-human interaction between people and everyday objects increased user's sympathy for these objects and has positive effect on their interaction experience (Burneleit, Hemmert and Wettach, 2009; Roy, Hemmert and Wettach, 2009).

3.4 Conclusion

Ubiquitous computing totally revolutionized the traditional way of interacting with computers, smart devices ranged far and wide into all forms of everyday products led to the development of more "natural" and "humanistic" interaction styles.

The new interaction trends mentioned throughout this chapter are recapitulated in Figure 3.37:

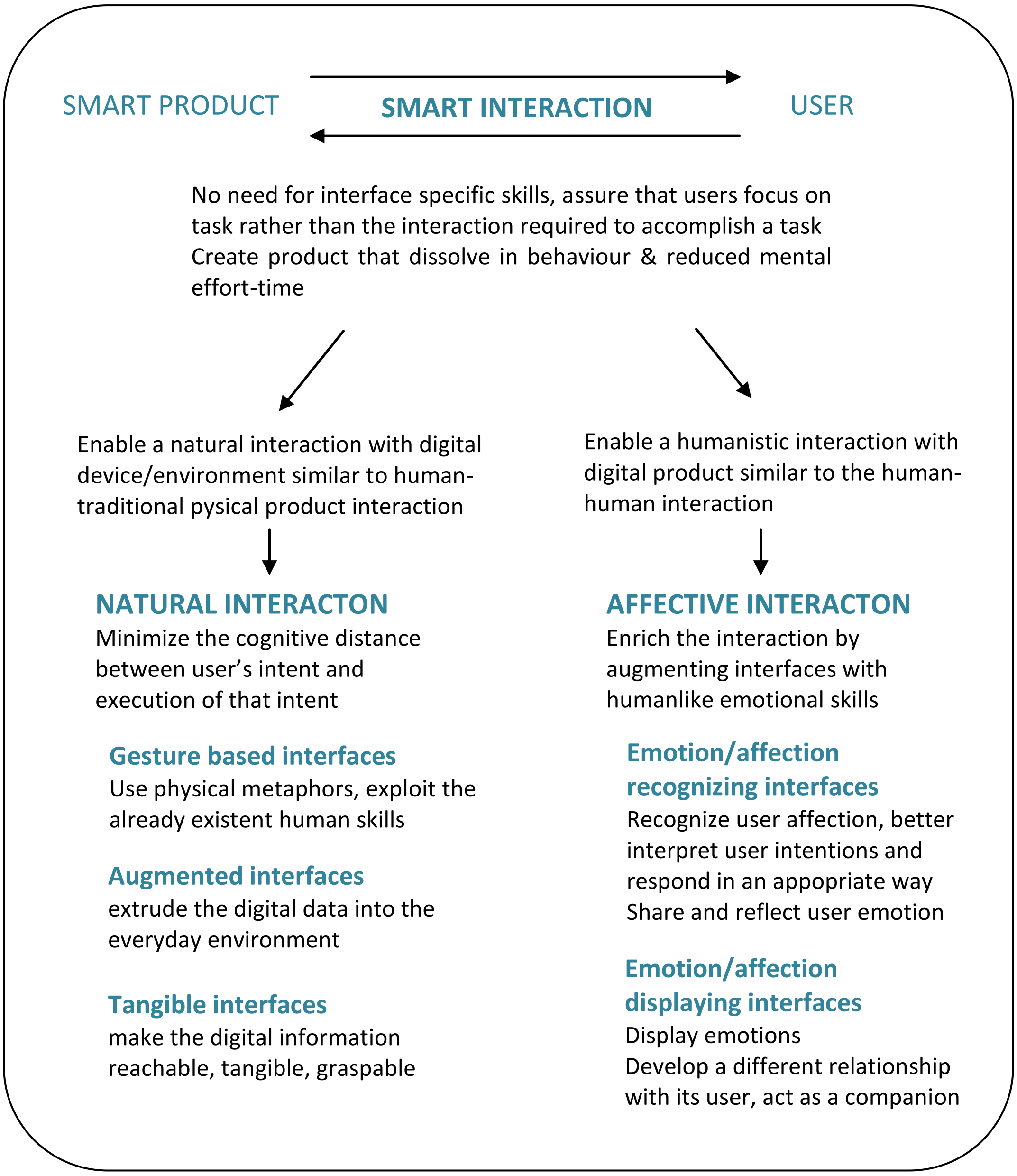


Figure 3.37 Smart interaction

As the result of the new computing approach where people have to interact with multiple digital devices ubiquitously, new human-computer interactions solutions providing people a much more intuitive interaction than the traditional user interfaces become mandatory. In order to attenuate the barriers between the virtual and the real world toward “natural”, “humanlike” interaction approaches, various interfaces exploiting users’ already existent body skills, social and environmental awareness were developed. Freed from diverse traditional pointing devices users were allowed, through gesture based interfaces, to communicate with the computers by their own gestures or body movements.

Furthermore via the new approaches such as the tangible interaction or augmented reality, that are extracting the digital data into the everyday environment and letting this digital information to be reachable, tangible, graspable, the cognitive distance between the user environment and the digital world were minimized and the complexity coming from the necessity of transferring the knowledge into this to separated world was overcome.

Natural interaction approach attempts to establish, with the digital products, an interaction similar to the one existent between users and the traditional objects. It mimics the interaction that the users have with the physical products and help them to perceive the digital information intuitively. Users could interact with the digital devices as they were interacting with a bottle, a pen, a table or a palette etc. in the real world, with their own body skills, by touching, holding or grasping them.

In addition to the natural interaction, the affective interaction enriches the human-computer communication by adding a human specific emotional dimension. These humanistic interfaces recognize their user’s affections, share this affection and even give some affective reactions. They mimic especially the human-to-human interaction with the goal of better interpreting user expectations and responding them with proper actions. To establish a common language and give the message that they understand and share their user’s feelings, affective products, capture people’s emotional clues and respond them in a humanlike manner by displaying an affective behavior similar to the human species, easily recognizable by the users. Even some of the affective products, wait for affection, ask to be treated compassionately, caringly such as an adopted pet and try to establish a communication through one of the most basic human interacting way, through emotions.

This time not only it permits to interact naturally as if they were interacting with the traditional objects, it also mimics the human to human interaction. This humanization of interfaces, become possible with an agent that recognize the users' feelings and act in an appropriate way to satisfy their emotional state. The agent by giving the message of understanding and sharing the user's emotions and also by responding him in a humanlike manner through some affective behavior easily recognizable by human species, aims to develop a common language with his owner.

From algorithms permitting products to have advanced decision making capabilities or to improved human computer interaction techniques leading to the development of gesture based, augmented, tangible and even affective interfaces, many technological advances revolutionizing the product conception as well as the user-product interaction are detailed throughout the two precedent chapters. However to what extend these technological trends overlap with the users' expectations from smart products still remains as a challenging question.

After treating smartness from product perspective in Chapter II and from user-product interaction perspective in Chapter III, the following section focuses on users to discover their expectations from smart products.

CHAPTER 4

SMARTNESS FROM USER PERSPECTIVE

4.1 Introduction

Different examples of smart products containing digital properties have been presented throughout the previous sections. Weather forecasting umbrellas, face recognizing faucets, dirt sensing dishwashers, gesture recognizing game consoles, augmented books, mood sensitive alarm clocks, nervous toasters; all of them constitute different approaches to smart products. They include various technologies enhancing/complementing their capabilities or adding them extra functionalities.

However to what extent do these technology integrated novel products satisfy user needs and expectations? Do users really expect that their faucet recognize them or their toaster begin to shake periodically to indicate their meal time? This chapter investigates user expectations and to what extent integrated smart technologies overlap with user needs.

Technology driven design & smart products

A priori, for the products that have followed a technology driven development process, it could not be assumed that all of them overlap with the user expectations perfectly. Once a new technology is emerged, designers and engineers envisage multiple diverse scenarios in which it could be applied. Facial recognition techniques first developed within the context of security applications are then integrated for example into a faucet to suit each user's individual tastes regarding water temperature. Similarly heart rate sensing methods frequently used in medical examinations are expected to guide products through user's emotional state, and enable them to give the most appropriate responses.

Multiple research groups from academia, as well electronics, computing and communication companies have established smart environment laboratories where they could implement diverse smart product concepts (see Chapter 2, 2.2.2.3). However these smart product researches are still a case of technology push (Abowd and Mynatt, 2000; Chen and Kotz, 2000; Huang, 2000). The invented smart object prototypes and smart system applications are restricted to some previously defined contexts of use. And the user groups are mainly composed of people from university and business environments. Consequently the prototypes are generated without a solid understanding about the everyday needs,expectations, or motivations of users related to future technologies (Lucero et al., 2007). Even researchers claim that current smart home systems are not valued by users (Haines et al., 2006; Howard et al., 2007). According to Venkatesh (1996) it cannot be assumed that what the technology can do in the household is the same as what the household would like to do with the technology. As household priorities and circumstances might change, in certain households, certain activities might be performed while some others might not. Similarly Taylor et al. (2006) suggest that in order to understand how to design technologies that are valued by users in domestic life, designers should first examine the context of home.

Technology driven design vs user centered design

Once new materials and devices having as objective to profit military or industrial production are developed (Cockburn, 1997), an appropriate market to which applies this technology is regarded (Ulrich and Eppinger, 2000). Technology driven design is one of the results of this mentality considering technology as the source of marketable commodities and new products (Jamison and Hard, 2003). Finally it is rather the demand that has been determined by the availability of new technology (Bauman and May, 2001).

The integration of information technologies into daily life has followed a similar progress and consequently, sophisticated products having complex interfaces accompanied with multiple usability problems, far from meeting user expectation appeared in the marketplace (Norman, 1998; Haines et al., 2006).

Whereas, to be user-friendly, and successful in market, contrary to the technology driven mentality, products need to follow a human-centered product development stage (Norman, 1998; Taylor et al., 2006). Technology driven products not only had complex interfaces which cause usability problems but also they did not fit user expectations. The increasing complexity of products required then consequently being accompanied with an increasing awareness of customer needs: "Good design happens only when designers understand people as well as technology" affirmed Hackos and Redish (1998).

Studies show that the more customers are integrated into the development process of a project, the more likely it is going to be successful (Keil, 1995; Shao, Berman and Wolski, 2000). Once organizations realized that meeting customer needs and expectations was one of the key factors of succeeding in the marketplace, an increasing amount of research has focused on user centered design process. Multiple studies concerning users expectations were conducted, the customer needs questioned and finally various user centered design heuristic were developed.

However as mentioned by Abowd, Mynatt and Rodden (2002) existing theories that inform design and evaluation has been developed to provide human factor guidance and to establish a better human computer interaction which tend to focus especially on the needs and demands of designing desktop computer interface such as graphical displays, direct manipulation interfaces, multimedia systems, or Web sites. As mentioned by Moran and Dourish (2001), designing smart products for the "complex, dynamic real world" possesses challenges while the "well-understood" desktop environment does not. Thus existing design heuristics (Nielsen, 2005) should be revised before their application in the design process of smart products.

User centered design & smart products

To discover everyday needs, expectations, and motivations of users related to smart objects and consequently to determine some design strategies that can benefit the innovation of product concepts; a qualitative user research with conform data gathering methods to this new type of products is certainly required.

Various studies mainly focusing on the development and/or evaluation process of specific prototypes or concept projects have been carried out in order to discover user's needs. Some of them were based on the usage of a specific product (e.g., Sensitive table, Kranz and Schmidt, 2005; InteractiveTV, Choi et al. 2003; Fridge companion, Böhlen, 2002; Smartsink, Bonanni et al., 2007) and others on monitoring inhabitants' life in real smart spaces (e.g., The Smart Home Usability and Living Experience project, Koskela and Matilla, 2004, Smart-It, Holmquist, Maze, and Ljungblad, 2003).

Those studies have been effective in revealing users' preferences among existing solution and options, however as well as achieving evaluative data, conducted by already developed smart products or environments, they remained insufficient to collect generative knowledge about smart products. Users' expectations should be taken into account in the early stages of the product development process. According to Kankainen and Oulasvirta (2003), only an early focus on users could transform the design process from trial and error to an informed activity.

Therefore discovering needs, expectations and preferences of users before starting the design process is essential. To support their argument, Kankainen and Oulasvirta (2003), give the following reasons:

- **Human needs are opportunities waiting to be exploited, not guesses at the future,**
- **Human needs provide a roadmap for development,**
- **Human need lasts longer than any specific solution: empirical data wherefrom the needs are interpreted is valuable in all later stages of user-centered design process.**

Constructing a data pool concerning user needs and expectations, enable in fact to determine the necessary strategy and objectives guarantying the user satisfaction. Developers could then envisage multiple solutions relative to these objectives and improve them iteratively. Instead of trying to predict the future, or find different application domains to adapt new technologies, designers could exploit users' expectations because a crucial part of the future already exists in this empirical data in the form of human needs/expectation (Patnaik and Becker, 1999). It is only by this way that the "technology push" approach could leave its place to a "demand pull" development process (Lucero, Lashina, and Diederiks, 2004).

In this scope this chapter focuses on users' understanding from the term of smart product and their expectations this new product segment. Literature surveys so far has provided limited insight into the challenging design question: "what/how to digitally augment traditional objects?". This study, rather than asking users to select some household tasks at which they look for an assistant from a list (Dautenhahn et al., 2005, Oestreicher and Eklundh, 2006), asking them to evaluate and rank some fictitious smart object scenarios (Röker et al., 2006), or demanding them to complete a questionnaire about their expectations (Copleston and Bugman, 2008), aims to discover in which tasks users expect what kind of smartness, focusing throughout a semi structured interview on users' everyday activities. Without limiting the scope with household activities or orienting users in their answers by giving predefined tasks or some delimiting questions, as were in the case of previous studies, the study will pursue an activity-centric interview method to reveal user's expectations.

Activity centered design & smart products

To diminish the lack of knowledge about the goals and motives of people and the circumstances surrounding any set of activity, the visions of ACD- Activity centered design- (Gay and Hembrooke, 2004) and accordingly, AOC - Activity oriented computing -(Kimani, et al., 2008) focus on the activities of user to better fit their intention in contrast of the previous application centered visions. Applications generally contain a set of pre defined functionalities concerning a specific domain. However "user activities may require much diverse functionality, often spanning different domains, and which functionalities are required to support an activity can only be determined at runtime, depending on the user needs, and may need to evolve in response to changes in those needs" affirm Kimani et al. (2008). In order to orient design toward human needs, ACD uses a larger unit than the traditional approaches, long-term, high-level activities such as "staying fit" are defined instead of simple tasks as "using a treadmill" (Li and Landay, 2008). Norman (2007) comparing HCD to ACD claims that "many of the systems that have passed through HCD design phases fail to support the sequential requirements of the underlying tasks and activities". However, activity-centered methods focus upon especially this aspect of behavior.

Producing activity centered solutions for human-smart product interaction is important to establish an efficacious and persistent human-machine communication. Each level in the development of AI has progressively reduced the human participation in the real time activity of decision making. Improving computation capabilities provided a smart system that has the ability to automatically decide, predict and learn to deal with new situations by generalizing, discovering, associating, and abstracting. However it is important to recognize that all these techniques are still in their infancy and at research state. As Norman says (2007), "the goal of attempting a complete automation is not yet possible because of technical limitation and cost constraints". Smart products could be only partially automated and require generally to be monitored by user. So being capable of identifying their needs and taking action with the purpose of optimally supporting their activities is essential.

Similarly the vision of AOC places activities to the main stage and consider that user activity encompasses user needs and preferences. AOC relies on the principle of making the computer environment aware of user activities. The action will then be taken to optimally assist the user according to his intentions. Users could be assisted in various ways in their daily activities, AOC focuses on the ongoing activities and examines how the activities could be best supported depending on user's needs and context changes by questioning "which activities a user may want to carry out in a particular context; what functionality is required to support an activity; what are the user preferences relative to quality of service for each different activity; which activities conflict; which have specific privacy or security concerns, and so forth" (Sousa et al., 2008).

Considering the promises of activity centric approach, to reveal the smartness needs and expectations of users from products, an empirical study, centered on user activities is implemented.

4.2 Method

Throughout a semi-structured interview, how the term of smartness is conceived from the part of users and what kind of smartness they expect from these products were tried to be determined. To discover why, for what and how people would use smart products, respondents were induced to imagine life with smart products and 'day dream' interactions with these products. To gather information about uses of a new type of product that is not existing before, 'information acceleration' methods are used (Urban, Bruce and John, 1996), by projecting users into the future at a time when the capabilities of technology are only limited with their imagination, the expectation from the new type of everyday product augmented with digital capabilities were questioned.

The interview concentrates on users' daily life and asks them to describe their everyday activities in the companion of smart products. Considering this principle, the expectations from the objects and environments during the whole day are questioned in seven steps:

1. While waking-up,
2. After waking-up until leaving home,
3. While leaving home,
4. While going to work,
5. At work,
6. While entering home,
7. After entering until sleeping.

In each step what kind of smartness do they expect from the products they mention and how they conceive to control these products are questioned. The respondents are induced to describe their daily routine activities following a chronological order and the interview is deepened respectively to their answers. By beginning from the time they wake up, users detailed their actions and when necessary they were encouraged via subquestions (e.g. What are you doing when you entering the bathroom/kitchen/car/bus/office/etc.? Do you expecting some specific smartness form the bathroom/kitcken/car/bus/office/etc. appliances?) to remember their house, outdoor or office routines. By projecting them into some specific environments and time intervals it is aimed to gather the maximum information. 30 users have been interviewed to obtain significant data about user expectations and the number of male-female users is assumed to be equal in order to achieve coherence. The sampling age interval has been chosen such as 'under 35 year old working people' and people who have routine daily activities and belong to the new generation of young workers growing up with computers have been interviewed. The following section presents the results of the empirical study by describing what users understand from the term smartness, and what they expect from a smart product.

4.3 Results and analysis

The smartness capabilities expected by users are compared by literature findings and analyzed according to smart technologies presented throughout the previous two chapters.

4.3.1 Users' smartness understanding

Regarding user expectations about smartness, first, what signify a 'smart product' to the users, how they conceive and define smartness was questioned. The properties that a product should include in order to be considered as 'smart' according to the users, are presented in Figure 4.1. Users' answers were multi-layered, they described various smartness criteria at different levels. Figure 4.1 presents the responses given by users according to a hierarchical order: at the top users expect products that facilitate their life and fasten their activities. They look for products that could diminish their workload in simple routine everyday tasks. While, they expect those products to be able to help them in laborious tasks or assist them when they feel incapable of accomplishing certain tasks, they could also ease their mental workload.

Then they describe how these products could facilitate and fasten their activities: by realizing their requests, helping them in decision making, guiding them, alerting, reminding when necessary, also acting and deciding in their place and finally by responding to them interactively. They mention obedient products which will unconditionally try to fulfill all of their requests, they describe also assistive, persuasive and preventive products giving the right decisions always based on user's interests and helping them permanently in their tasks. Furthermore a dynamic interaction is expected from these products. Users wish that smart products easily understand them and immediately respond to their needs.

They deepen their description by listing the technological capabilities that a smart product should have or the different process that it could follow to accomplish previously mentioned tasks: a smart product could decide on its own simply through pursuing a predefined program, or could try to predict users' requests, evaluate different probabilities to find the most convenient solution. Even it could learn over time and try to respond relative to users' preferences. Besides smart products should be aware of their features, their dependencies and their environment; they should also have the capability of dynamically adapting themselves to the changing situations.

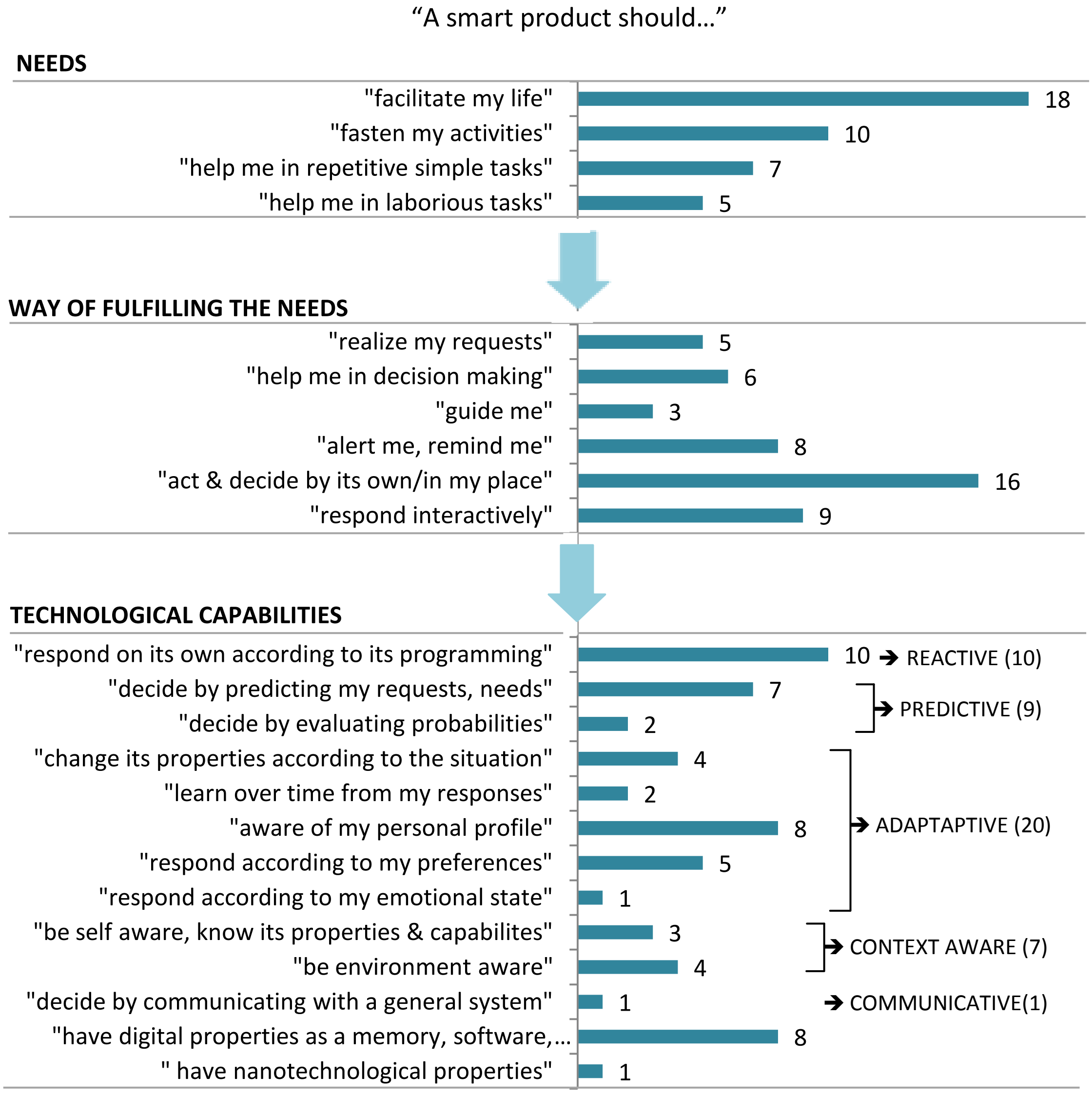


Figure 4.1 Smartness characteristics

Some of the smart product characteristics presented in the literature could be distinguished among users' smart product descriptions: Users insisted on decision making capability and mentioned reactive, predictive and adaptive products. They accentuated context awareness as well by describing products able to sense user's and environment's states. Communication capabilities were mentioned only by one user and multimodal interaction capabilities seem to be neglected. Although they mentioned their expectation about dynamically interacting products, users didn't precisely mention their wishes for improved interaction capabilities. Related with material smartness notion, users affirmed that, for a product to be called smart, it should integrate some nanotechnological capabilities, in addition to its digital properties.

4.3.2 Users' smartness expectations

To depict users expectations about smart products in detail, following the first introductive question aiming to reveal their smart product conception in general, users were asked to state their expectation according to the time intervals and imagine a whole day, from getting up to going to sleep that they live in companion of smart products.

Users' smartness expectation varies a lot according to the objects, activities or time intervals, and it's important to categorize the smartness expectation into several dimensions to discover which dimension fits to which object, to which activities or to what time of the day. The smart product capabilities relative to user expectations were grouped into six different categories as illustrated in Figure 4.2:

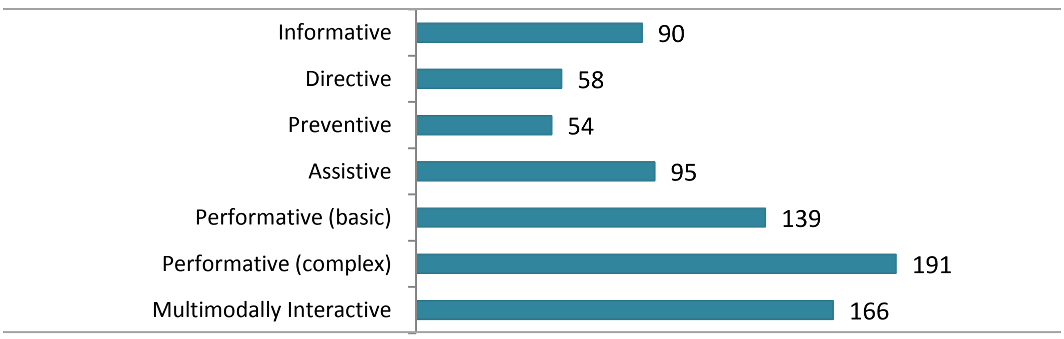


Figure 4.2 Users' smart product expectations

- *Informative*: Provide user the desired information when/where asked.
- *Assistive*: Simplify user tasks, make estimations, optimized adjustments, settlings, diminish their intervention by an automated decision making process.
- *Directive*: Guide user in decision making by proposing various alternatives, suggesting or recommending solutions.
- *Preventive*: Alert user when necessary to avoid undesirable or dangerous situations,
- *Performative*: Help user in accomplishing task, totally automate certain task or diminish user intervention.
- *Multimodally interactive*: Use different input and output modalities, provide advanced interaction capabilities.

These categories were derived from the collected data and were not pre-decided at the beginning of the research. Once the user information is gathered, the data is then analyzed relative to frequencies of answers including the same similar smartness expectation (e.g. informative product) which were characterized by specific sentences (e.g. “I want to be informed about x”, “I want that it display x”, “It should be able to provide me the x information”).

The frequency of similar sentences and the frequency of different objects mentioned in these sentences are depicted and grouped according to the environments in which users were projected throughout the interview to describe their actions. The following part includes the expectations of users from each category.

Informative

Respondents expect their smart product be part of a network, communicate permanently with other products, databases or users and enable them to access any type of data wherever and whenever they need. Precisely via which objects and about which topics users expect to be informed are presented respectively in Figure 4.3 and 4.4.

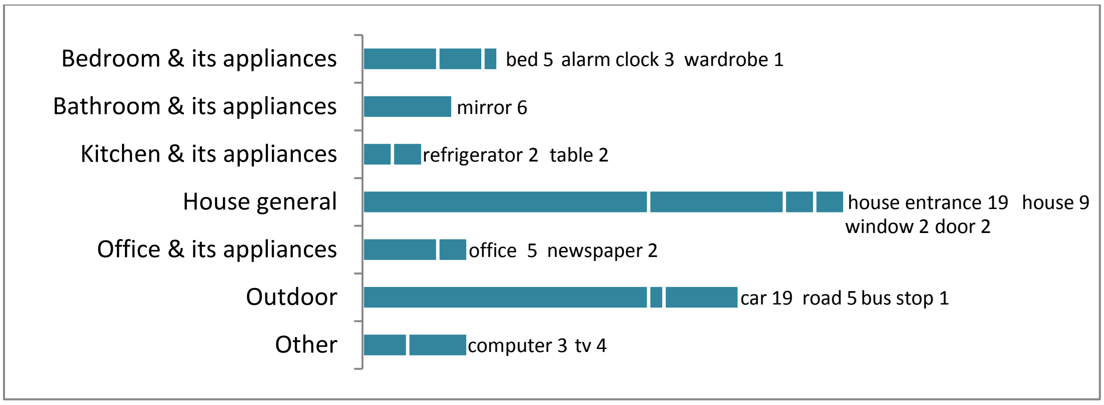


Figure 4.3 Informative products

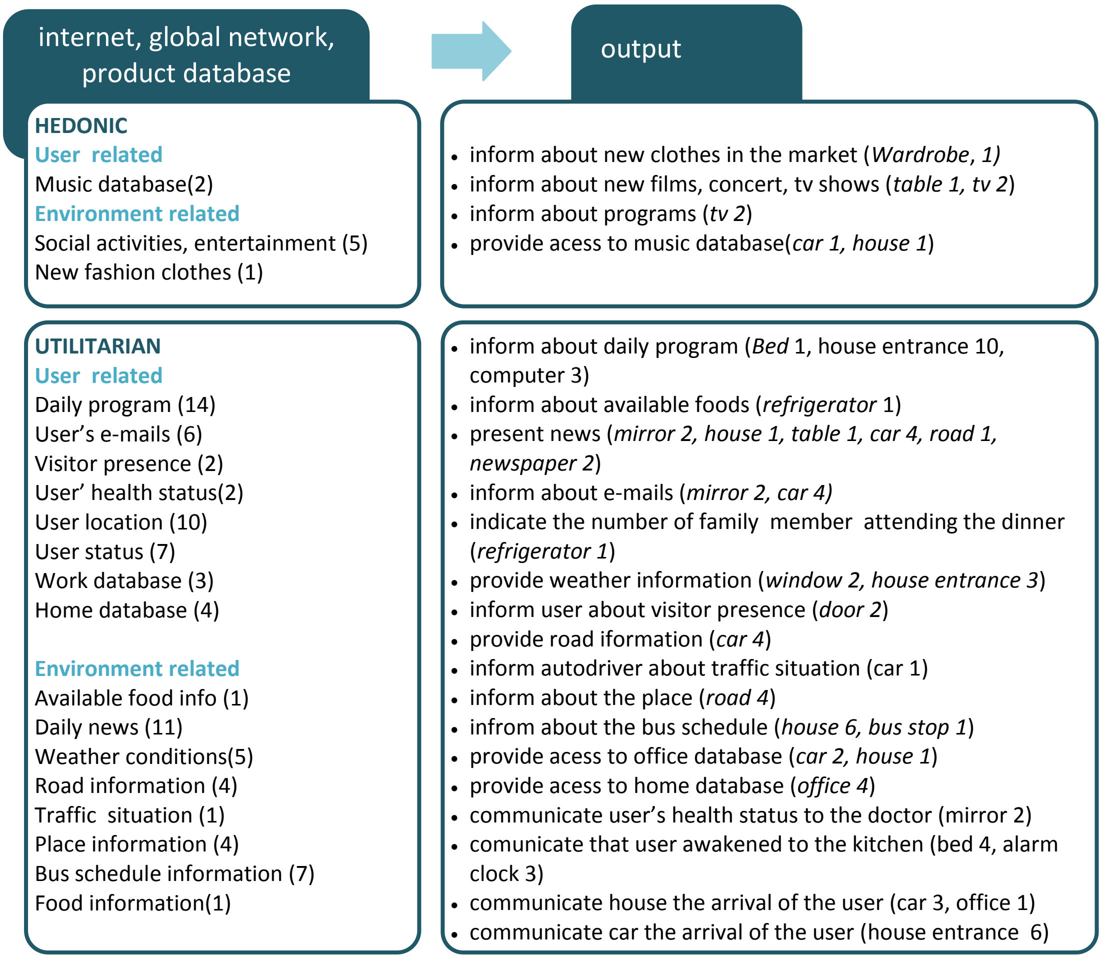


Figure 4.4 Expectations from informative products

Users need informative smart products that communicate with the internet or other products to provide them some general information while beginning a new day, they describe windows informing the about the weather conditions, walls displaying the daily news, bed citing them their daily programs, wardrobes giving the details of the forthcoming fashion and tables listing them the possible cultural activities of the day.

Also some specific information dependent on the context is expected; before starting the meal preparation for example, they would like their refrigerator to inform them about the number of family members attending dinner, or in the market, when they are shopping, they wish it communicates them its contents to avoid buying redundant foods. Just while leaving home, they describe a door or a general gate system listing them their daily tasks to do, providing them the bus schedule information and letting them know in advance when exactly the bus or metro will be on station. Otherwise if they travel by car, they would be informed about the road information or the traffic situation.

Furthermore, users wish their personal data (home database, office database, music archive, etc.) to be accessible from anywhere/anytime. They look for a system linking and unifying all of their physical environments (home, office or outdoor) under a single virtual environment. Besides smart objects providing them a variety of information, they also describe smart environments communicating with each other and interacting with people. In their opinion, smart products should be able to share the data gathered from any context with the other products in the network and, by the way, inform the concerning products about user's status and activities. To increase comfort and save time, the house heating and aeration systems should start in advance, according to the users' arrival information communicated via the office agent. Similarly the car should be heated and its windows defrosted before the user gets in signal from the gate system a or the necessary breakfast preparations should begin by the bed's stimuli indicating that the user has woken up. To assure the healthcare of the user, the mirror should communicate with bascules and houses' different web cameras in order to collect data and notify periodically their medicine. From the road information to the content of their refrigerator, users expect being informed about a variety of subjects. In correlation with communication capabilities that smart products are supposed to integrate, they express their wishes for a connected network including their everyday smart products providing them a permanent access to any source of information, which increases their situational knowledge and affects their decision making capabilities. Being accompanied with informative products, users could increase their own context awareness and better manage-monitor diverse situations and maintain control over their environment.

Directive

Users look for directive products capable of providing recommendations and motivating them when necessary or helping them to concentrate on the task performed. Figure 4.5 and 4.6 present especially through which everyday products users expect to be directed and provide users' expectations about directive products.

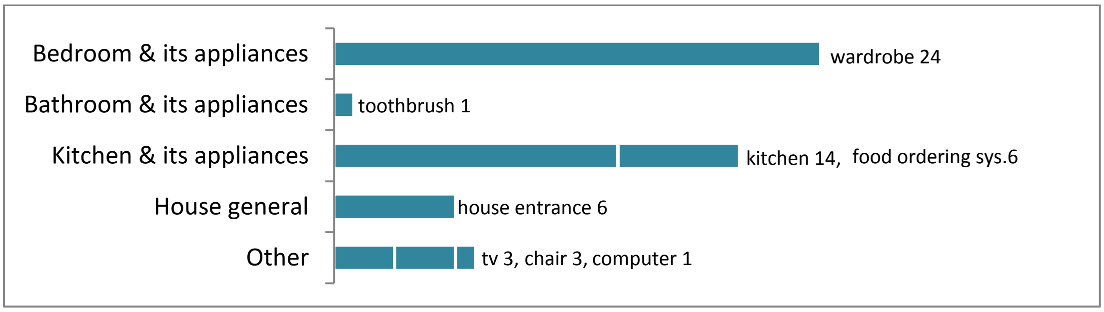


Figure 4.5 Directive products

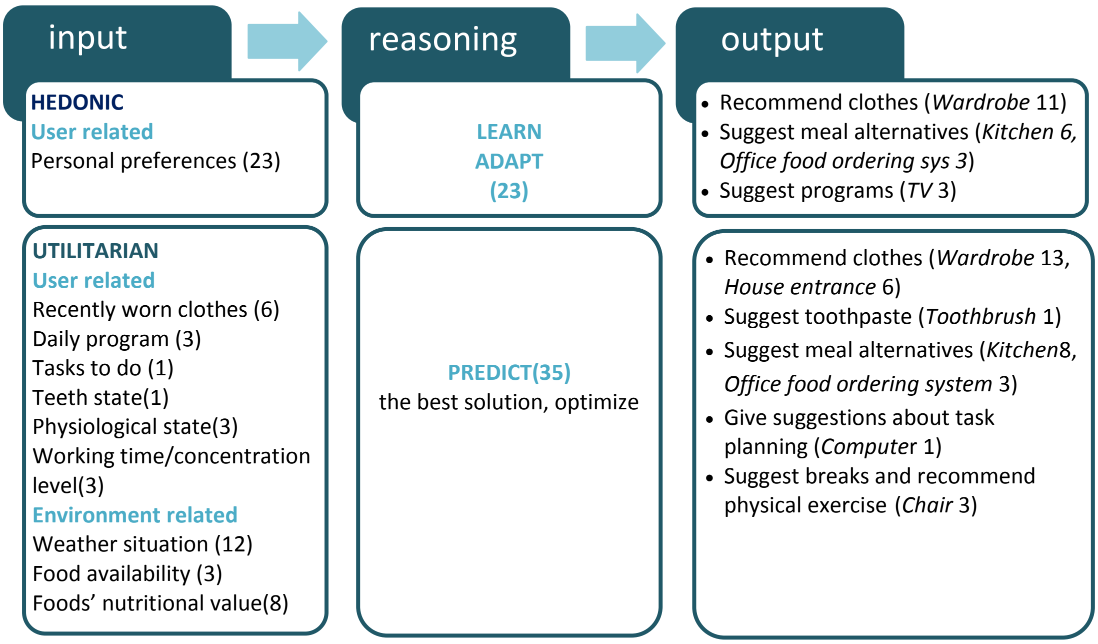


Figure 4.6 Expectations from directive products

Users need some recommendations especially from the wardrobe while dressing up and from the kitchen while preparing meal. They expect a variety of well balanced meal suggestions that conform to the users' individual tastes and different attire combinations appropriately chosen relative to the weather constraints and personal preferences.

Even, to assure the necessary motivation and concentration while working, study chairs which can suggest users a break by considering that they have worked enough are mentioned.

Directive smart products include the dimensions of predictivity and adaptability which are both among smart product characteristics in the literature. To provide recommendations or suggestions, products should be aware of the personal profile of the users, learn their preferences over time and adapt their responses according to their owners' personal exigencies. They should be aware of user and environment states, consider situational constraints, and predict from all possible actions the optimal ones that would fit to the current context most.

Users expressed their wishes for products that follow their interests, suggest them multiple options and recommend them the best solutions. This kind of smartness diminishes the mental workload and user activity by helping them for decision making by considering multiple criteria (e.g., weather conditions, user's daily program, user's preferences). The high expectations from wardrobe during the morning preparation period, reveals the importance of time constraints in decision making activities. People require to be oriented when they are under time pressure.

Preventive

Users mentioned preventive products able to alert or avoid any unwanted situation. The products from which user expect a preventive behavior (Figure 4.7) and tasks they need to be alerted of (Figure 4.8) are listed below :

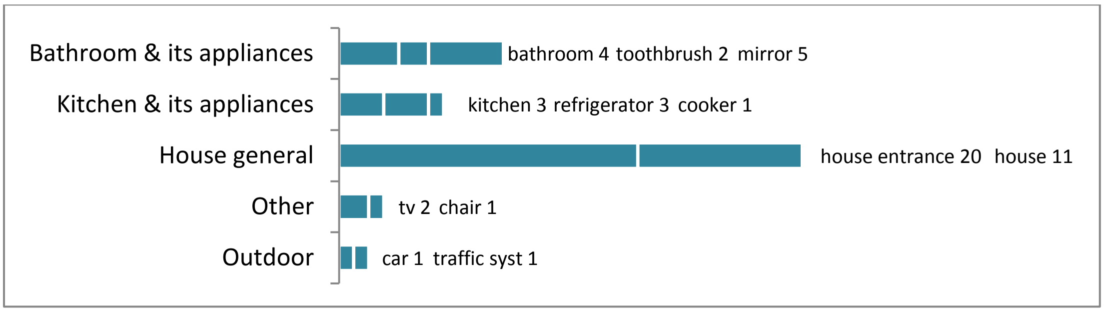


Figure 4.7 Preventive products

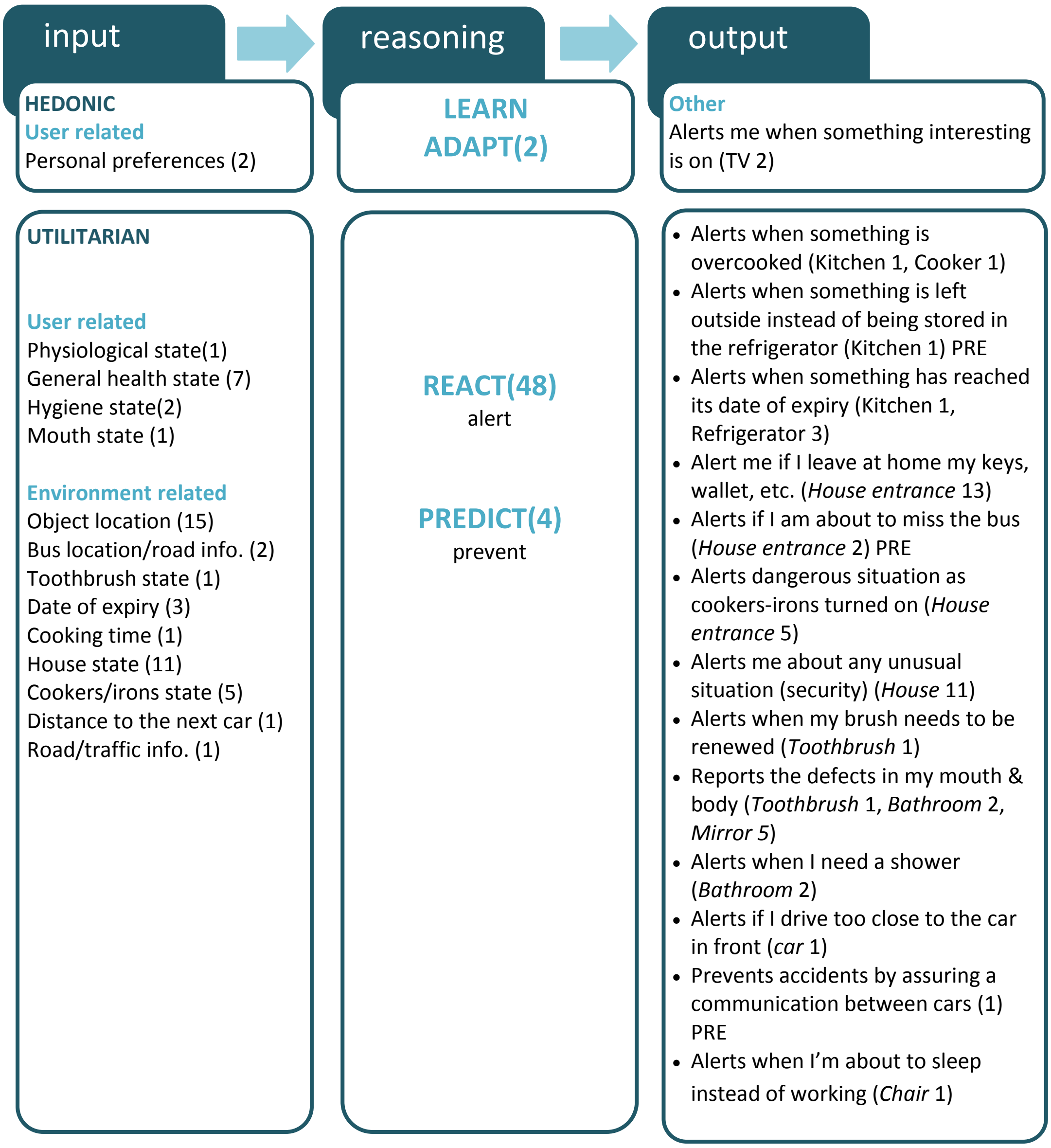


Figure 4.8 Expectations from preventive products

Users expect to be warned in advance against any critical situation that could have harmful consequences. They want smart products to be vigilant and alert their activities. They describe products aware of people's action, permanently monitoring the environment. They expect being averted about their health status, their mistakes, or toward unusual situations and potential household accidents. Users would like their bathroom to be able of making a sanitary control during their personal care activities and report them any defects on their body.

Users wish evenly to check out that everything is okay in house before leaving, thus they look for a reactive system which will control the house and alert about any unusual situation or any dangerous situation as cookers and irons forgotten to be turned off. Additionally, they describe a gate reminder that will alert them if they leave at home something they shouldn't have, such as their keys, their wallet, their mobile phone or an important document they should absolutely take to their office. Similarly, they expect a smart kitchen that could alert if they forget something on the cooker or leave outside a food which needs to be stored in the refrigerator or if something has reached its date of expiry.

Reactivity expectation dominates preventive products. Users have mentioned reactive products observing the context and alerting them when any suspicious or dangerous situations are recognized. Also predictivity and adaptability dimensions could be distinguished among preventive products. Users have described products which can predict that something will go wrong, after analyzing the actions of user (e.g. missing the bus, leaving food outside of the refrigerator), and even products that could arrange this situation by taking the necessary precautions (turn off cooker, or iron). Preventive products could increase their performance and avoid the mistakes or unwanted situations.

Assistive

Another smartness dimension expressed by users, concerns assistive products having the ability of making some adjustments, settlings or estimations in order to optimize product processing. The assistive products mentioned by users and the smartness assigned to those products are presented in Figure 4.9 and 4.10.

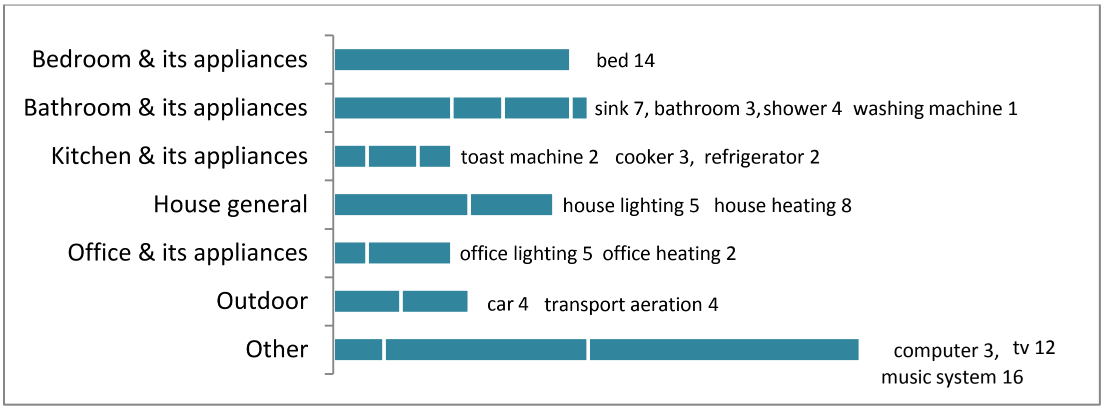


Figure 4.9 Assistive products

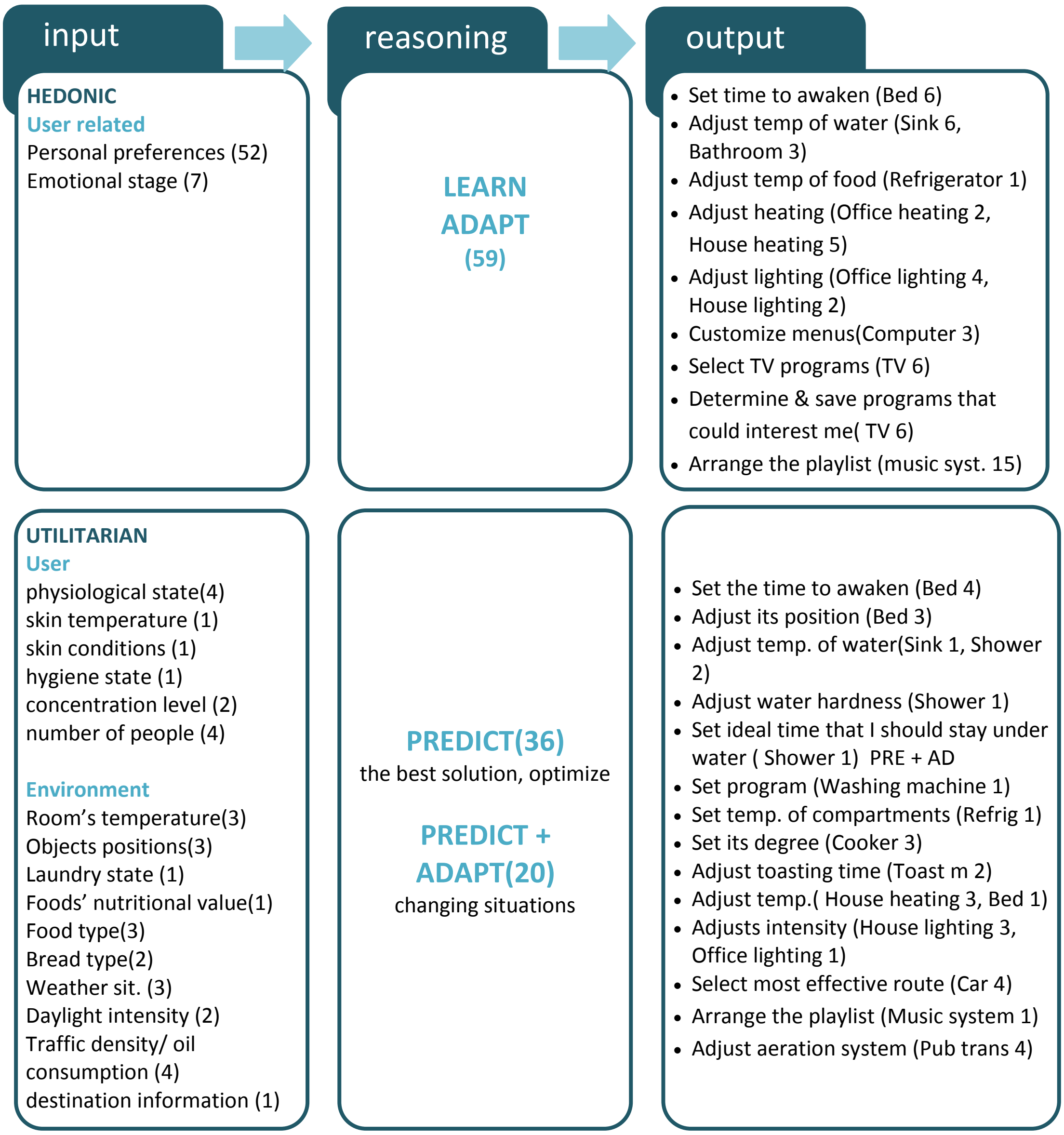


Figure 4.10 Expectations from assistive products

People expect such kind of smartness especially during the morning preparation, from their bathroom and kitchen appliances, while travelling to work, from their car or public transportations and during their leisure time, from their music player, in order to, save time, relieve mental workload, optimize their activities by avoiding errors, as well as to obtain highly customized products. They look for smarter products which will enable them to act by considering different constraints or comparing different criteria.

They wish their smart products; automatically adjust the temperature relative to the weather conditions, set the cooking time limit conform to each food type, start the air conditioning when needed according to the number of people in the environment, or estimate the most efficient route considering time, oil consumption and traffic density.

However besides a toaster which will set the toasting time according to the type of bread, a refrigerator that will arrange the temperature in its compartments according to the nutritional value of each food, a kitchen agent which could automatically assure the meal shopping by ordering the expiry date reached food, or a lighting system adjusting its intensity according to the daylight, users also look for more customized products able of considering their preferences and personal exigencies. They wish their music player arranges the playlist according to their preferences and their TV automatically select channels and save the programs that could interest them. Similarly, a shower adjusting water temperature and hardness relative to user skin properties, a bed taking the shape of user’s body to maximize comfort and increase the sleep quality and additionally waking up considering user’s physiological and emotional state, or even a bus or metro able of automatically recognizing users are mentioned.

Assistive smart products necessitate being highly adaptive in order to make settlings and adjustments relative to their users’ preferences; even they should be predictive to determine the most advantageous solutions and optimize their adjustments. In some cases, assistive products need in addition to update their adjustments regarding changing contexts, which necessitates, in addition to predictivity, some adaptability capabilities. This type of autonomy is required to facilitate user tasks in which they could encounter some difficulties contrary to the routine activities.

Performative

Besides informative, assistive, preventive and persuasive products supporting people in mental activities, a considerable wish for performative products helping users in task accomplishing is also expressed. Users describe multiple smart products diminishing their physical workload by automating diverse tasks. However, the activities mentioned by users involve very different levels of smartness: from automatically starting and ending products to the ones equipped with nanotechnological properties or having sophisticated mechanical capabilities, various expectations are expressed concerning performative products. In Figure 4.11 and 4.12, automatically start and stopping products are presented.

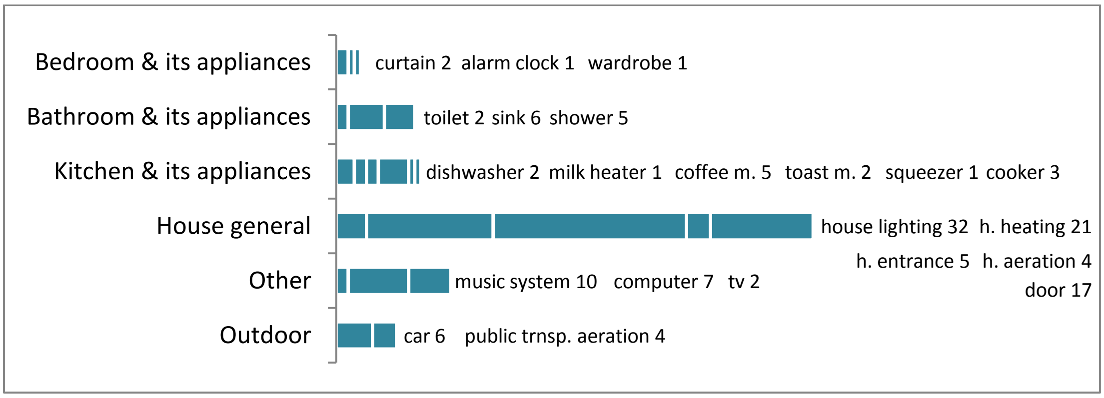


Figure 4.11 Basic perfomative products

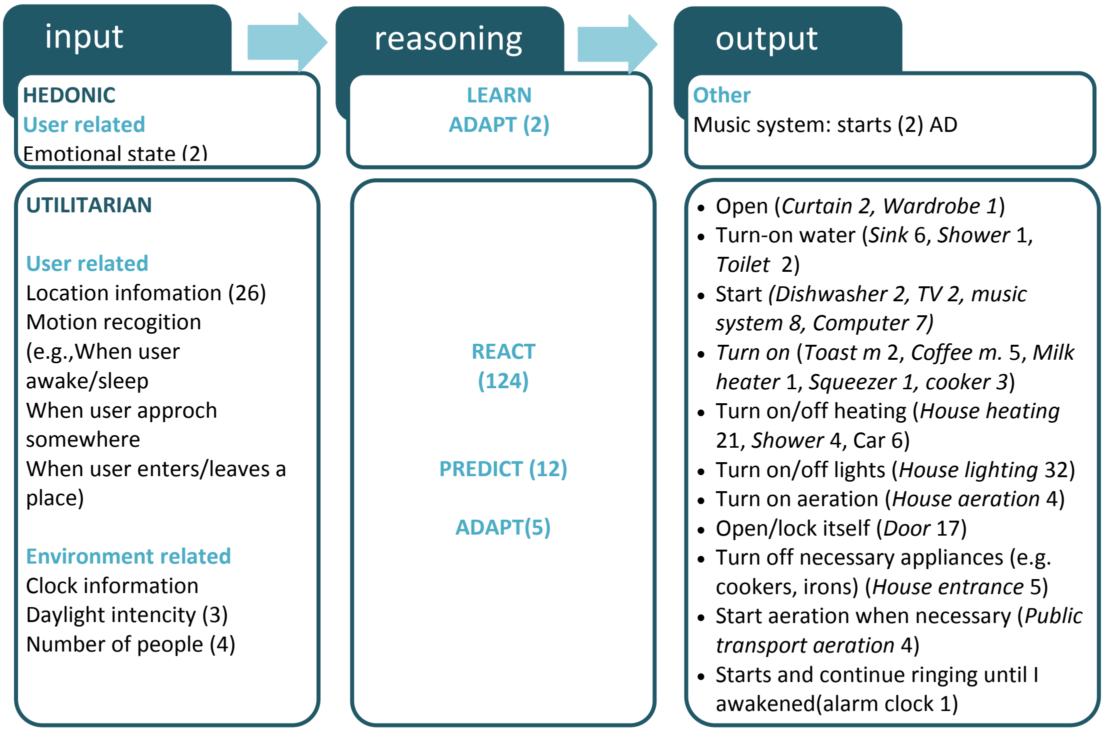


Figure 4.12 Expectations from basic perfomative products

As low level of automated products people expect self starting and ending systems. Especially in waking up, leaving home, entering home and sleeping periods, users have expressed their wishes for automatically turning on/off lighting, heating and air conditioning systems, or curtain, door, and electronic appliances. Also during the morning, for routine simple activities such as personal care and breakfast preparation, automatically opening sink, shower, or automatically starting coffee/ tea machine, milk heater etc. are desired.

Generally users describe reactive systems like products that sense user's location or movement and act when user is awake or asleep, enters or leaves an environment. Some predictivity expectation could be also observed throughout users' descriptions pointing out products that could predict their actions according to contextual situation after analyzing environmental conditions. Adaptability dimension is also distinguishable among products starting according to the user's emotional state and products updating their state according to the user response or changing situations (e.g. public transport aeration system the amount of oxygen in the air). Users look for their workload to diminish through automatically turning on/off systems, their preparation process becomes faster, energy and water saving becomes more efficient as well as the security is maintained. Besides basic perfomative products, users expect also sophisticated performance which implicates mechanical tasks. The objects and tasks involving complex perfomative behavior are listed in Figure 4.13 and 4.14.

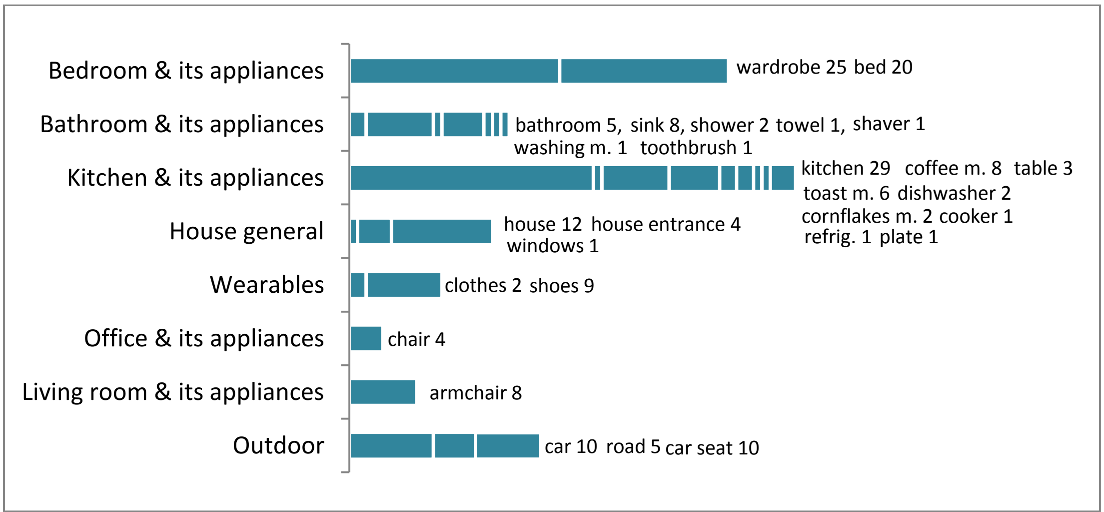


Figure 4.13 Complex performative product

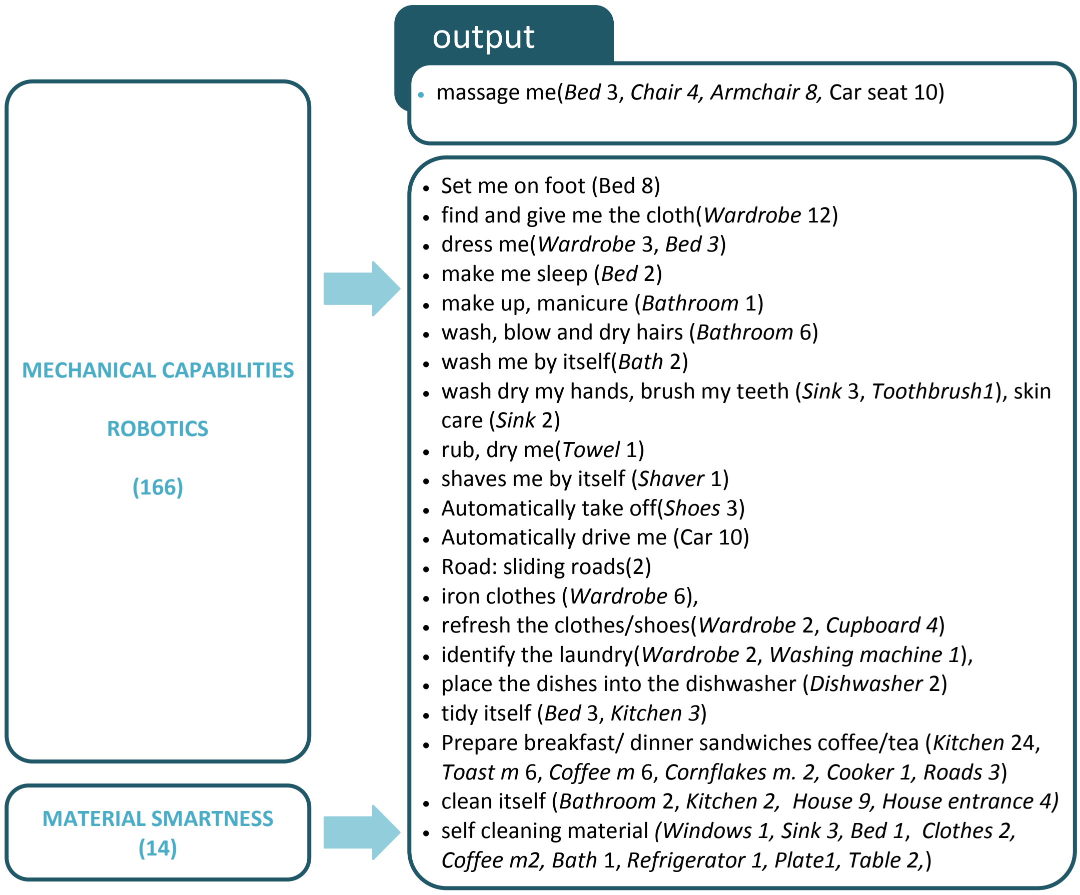


Figure 4.14 Expectations from complex performative products

Fully automated systems are described by users such that smart products do everything for them. They begin their jobs by awaking user and setting him on foot, then tidy the bed, wash user, blow his hairs, find and give him his clothes, and even dress user, prepare his breakfast, check the house before leaving, drive the car, prepare his dinner once returned home, clean the table and finally make user sleep. However it can be observed that this automation doesn't accompany user at work. In fact, users already have an assistant which help them at work: their computer. They mentioned that they would be embarrassed if smart products could do their job better than they do.

The way smart products realize these tasks was not described by users, they expressed their wishes as if there were a servant following them. However, the articulated tasks require advanced perceptual skills and complex mechanical capabilities that are not necessarily mentioned among smart product characteristic in the literature.

Along with products accomplishing mechanical tasks, also self cleaning products such as sinks, showers, dishes, clothes or bed sheets which could automatically clean themselves, and non wrinkling, bacteria resistant fabrics have been mentioned. Users even have an expectation of material smartness, this implies that the products, besides digital properties, have also nanotechnological capabilities.

Performative behavior expectation is mainly observed in personal care and housework activities. Users frequently expressed their wishes for a servant like system that follows them, automate and fasten their everyday routines as dressing, bathing, shaving etc., and even reducing the load of housekeeping chores as meal preparing, house cleaning or tidying, ironing refreshing clothes, etc.

Multimodally interactive

As well as smart products, people also have described smart interactions. They were very outspoken in their desire to have multimodal inputs and outputs. The products from which they expect advanced interaction capabilities and different input/output are recapitulated in Figure 4.15 and 4.16.

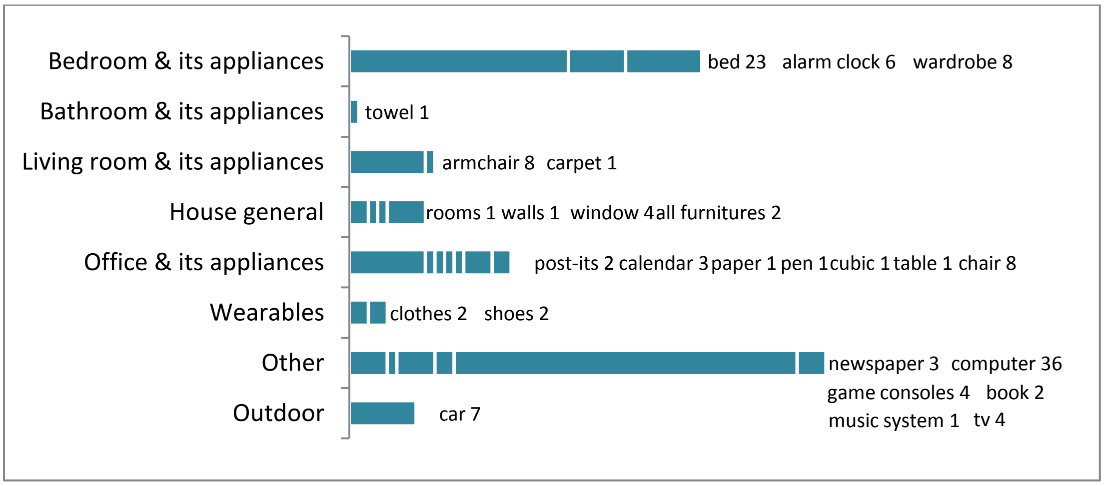


Figure 4.15 Multimodally interactive products

input

HEDONIC
Emotional state(10)
UTILITARIAN
Speech recognition (car 6 , tv 1)
Speech recognition, handwriting, eye tracking, gesture recognition (computer 23)
Identity recognition for acess control (chair 4)

NATURAL INTERACTION (133)

AFFECTIVE INTERACTION (32)

otput

Advanced Visual Capabilities- Augmented reality
Shows the clothes in 2D or 3D (*Wardrobe* 8)
Displays virtual images, provides virtual dream(*Bed* 2)
Virtually changing environments(e.g. dinner at Bahamas) (*House* 1, *Game consoles 4*)
Display virtual images(e.g. a sunny day instead of rainy) (*Window 2*) 3D display, virtual reality (*Computer 2, TV 3)*

Tangible screen technology & Cooperation, communication capabilities
Digital book(2),Digital newspaper(3),Digital pen(1),Digital paper(1) Digital calendar(3),Digital post its(2)

Haptic tangible olfactory outputs
Awake by rise (Bed 6), by vibrating poking (Bed 6), by giving a sensation of wetness, coldness, hardness(Bed 3), by a song(alarm clock4), by a coffee smell (alarm clock 2)
Warn by vibrating (Chair 1)

Transformation Capabilities - Nanotechnology
Change color, patterns , texture (*Bed* 1 Armchair 3, Clothes 1, Shoes 2, carpet 1, window 2 furniture 2)
Walls: could slide and create different living spaces (1)
Furniture gen.:their color, places, and type of fabric (2)
Change form (*Bed 1, Chair 2, Table 1 , Cubic 1, armchair 4*)
Change heat(*carpet 1, bed 4, towel 1, clothes 1)*
Foldable screens *(1)*
Screens that could be magnifying and miniaturizing when needed *(3)*
Flexible materials *(4),* little tiny-multipurpose devices*(3),*
Projectors instead of screens *(1)*

Affective behaviour
Wake up, caress *(Bed 2)*
Guide like a mother*(Wardrobe 1)*
Motivate them (Computer 5)
Put some restrictions: permit only five or ten min breaks such as a co-worker Computer 3)
Home assistance service having a specific voice ready to serve them whenever they need (House 11).
Receive speak-out orders as if they were workers (Computer 4)
Read them the news through the author's voice (Newspaper 1),
Display virtual orchestra & with virtual players(Music system 1)

Figure 4.16 Expectations from multimodally interactive products (1)

After waking up until sleeping respondents expect different interaction capabilities from their smart products, they wait for tangible and performative interfaces that stimulate the majority of their senses. In the morning, they describe a bed awaking them by vibrating or by giving a cold sensation also accompanied by their preferred song or the smell of coffee. Similarly while working they imagine computers that are able to warn its user against errors by vibrating his seat.

Furthermore, at work they look for computers that communicate and interact with them in a humanlike manner, speech recognizing and producing interfaces, as well as handwriting, eye tracking, gesture recognizing and motion tracking interfaces are among the requested technologies. Users would like to create a 3D model, or generate html codes of a web site simply through description by speaking. Even tangible interface allowing user to model in 3D by shaping mock-ups with their hands, or transforming the sketch of the user into a technical drawing are expected.

Users think that their office gets overcrowded by electronic devices such as PCs, printers, fax machines, telephones, photocopiers, and many others, so they propose to make invisible these devices by distributing their functionalities into daily objects. They would like their study table be enhanced by personal computer capabilities. Users expect to interact with this smart table as they were interacting with their study table in the real life: some documents will be dispersed all over the table, there will be a notebook, a calendar etc. as usual, and they will write on documents with pens. However, all of those office appliances cited above would have digital properties and would be able to communicate with each other. Users prefer to work with hardcopies than virtual ones, they wish to work with documents which they could handle. They expect their calendar to be physically present on their table, but also expect to combine different projects' planning into a unique calendar with a simple touch, similarly they wish to see the post-it notes as virtual images on screen or as 3D holograms attached to the board, they expect physically present digital objects able to supply the facilities of digital world into the everyday environment.

A wish for affective interaction has also been observed. They have assigned various human specific properties to the smart products they described. They have asked for beds that will wake up by caressing and wardrobes that will guide what to dress up as "like a mother" guides her child. Similarly they express their wishes for a digital newspaper vocalizing them the news through the author's voice, they even describe a smart music system enabling them to perform music along with a virtual orchestra composed by virtual musicians.

Besides, users look for a home assistance service having a specific voice tone and following them permanently, even after leaving home, in their car, remembering them their daily program, informing them about the latest news, reacting to their commands and answering to their questions. They wish that their computer assist and help them in planning their tasks such as meeting, travels or holidays, etc., and motivate them. They also would like their computers put some restrictions like permitting only five or ten minutes breaks such as one of their co-worker will do. Similarly they want to interact with computers by speaking and by giving some orders as if they were workers.

They expect also some changes in hardware technology, flexible materials, little, tiny, multi-purpose devices, projectors replacing screens and 3D displays are requested. They look for advanced visual capabilities from smart products. At their leisure time, users expect a more realistic experience with their TV or computer games throughout virtual reality or 3D displays bringing the virtual image into the real world. Or in the morning while awaking for example, they want their window displays a shiny landscape. When dressing, without being obliged to try clothes they selected, they expect to see their virtual reflection on the mirror or as a virtual 3D model turning in front of them. While dining, they imagine a relaxing landscape, and finally while sleeping they expect to be involved into a virtual scene provided by their room and begin dreaming through this scene.

Furthermore, users look for various smart products equipped with smart materials and having different transformation capabilities: self heating as well as color and shape changing products such as self-heating clothes, teapots, glasses and beds or color changing furnitures, pattern or texture changing clothes and shoes are among mentioned products by users. Even, some users envisage foldable computers with tiny, flexible screens having stretching properties and capable of magnifying or miniaturizing when needed.

Users' multimodally interactive product descriptions include also predictivity, adaptability and reactivity dimension of smartness (Fig. 4.17).

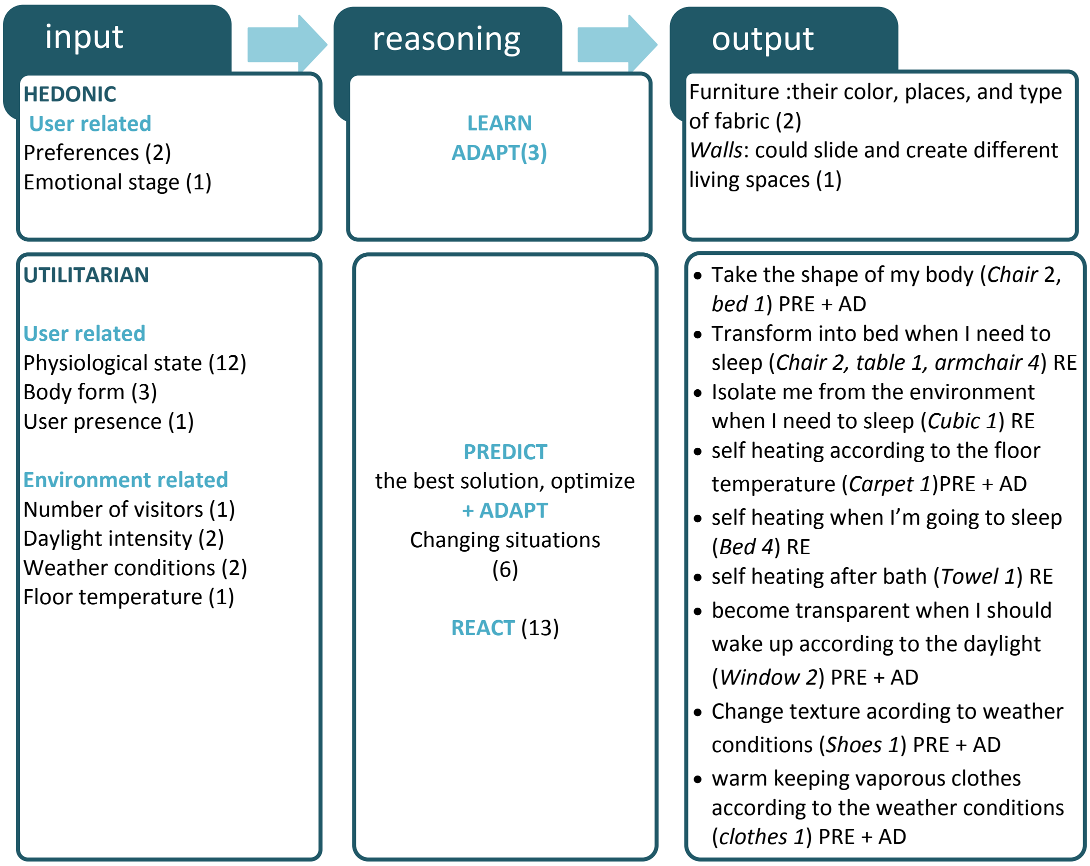


Figure 4.17 Expectations from multimodally interactive products (2)

The color of the furniture as well as their places and their type of fabric could be changed according to the emotional stage of the user, even the ergonomics could be optimized according to user's body and their ideal temperature could be predicted according to the weather condition. The ambiance could be adapted to the user wishes, the walls could slide and create completely different environments, lighting and music systems could work synchronically and create impressive interiors.

The armchair could perceive that the user has slept and then transform into a bed by gaining a soft texture if needed which implies a reactivity dimension. It could even give a massage, a good smell, or somehow relax the user.

4.4 Conclusion

There are in fact two types of tasks the smart products could do for the owner: tasks fulfilling the utilitarian wishes of the user and tasks satisfying the hedonic wishes.

According to an opinion, technology is a mean to achieve practical ends and therefore must be viewed in utilitarian terms (Escobar, 1994 referred in Venkatesh, 1996). In contrast to this utilitarian approach, some researchers propose that information technology should also be assessed in terms of the social context in which it is embedded. (Kling, 1980 referred in Venkatesh, 1996). Adoption of technologies may be a hedonic decision rather than a purely utilitarian decision. Hedonic goals are multisensory and provide for experiential consumption, fun, pleasure, and excitement. Utilitarian goals, on the other hand, are primarily instrumental and their purchase is motivated by functional product aspects (Khan,2004).

Similarly in this study these two types of goals are mentioned by the users. The utilitarian wishes include especially tasks decreasing the workload of daily routine activities or helping user in difficult/laborious activities, whereas the hedonic ones concentrate more on tasks enriching or embellishing user's life (Figure 4.18).

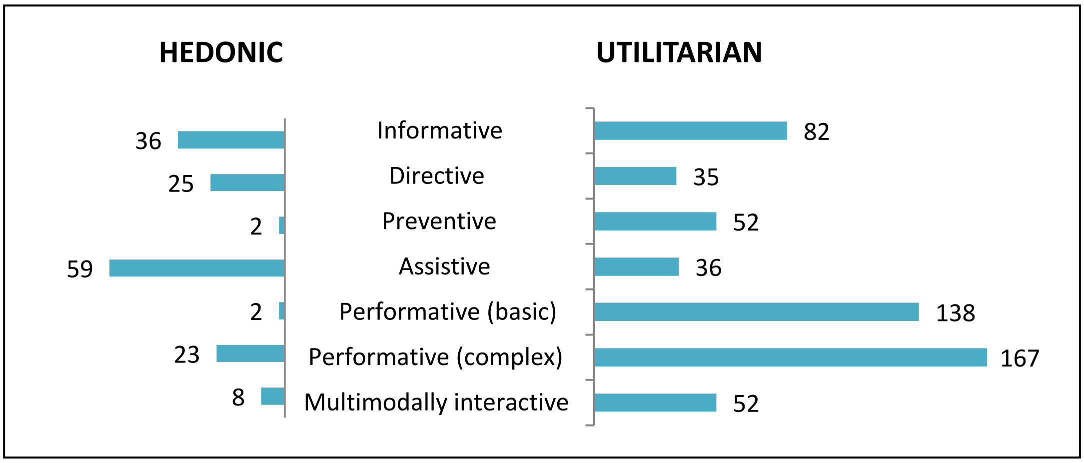


Figure 4.18 Hedonic & Utilitarian wishes

Utilitarian wishes dominate especially informative, preventive and basic performative product expectations. In those type of smart products, users instead of focusing on their personal preferences or fun, they aim to be well primed by useful information which will facilitate their decision making process, they wish to be alerted when something goes wrong, and expect that simple routine activities are done without their intervention.

Similarly from directive, assistive and complex performative products users have utilitarian expectations; they wish to be guided when they are faced with difficult situations, or when they need to give critical decisions, and they expect to be assisted, when they feel incapable of overcoming some tasks.

They ask to be informed about the weather information, the road situation, they look for their smart product recommend healthy foods, optimize their use of diverse devises, alert them about their health situation, their security or accomplish all of the fatigue duty tasks.

Utilitarian expectations are frequent during the preparation period of the morning, especially before leaving home, hence the time and efforts saving intentions could be clearly distinguished among these products.

As well as utilitarian wishes, hedonic expectations are quite frequent in directive, assistive and performative products. Users wish that products make recommendations, furnish an assistance and even serve them according to their preferences, their emotional states.

Hedonic expectations are mostly seen in entertainment activities, after entering home until sleeping period, but they are also frequent during whole day. Users wish that products consider their emotional stage, and preferences, while awaking, while suggesting clothes combinations, or meal alternatives. Similarly they expect that products select for them the appropriate music or TV shows. Furthermore they have a permanent comfort expectation, they want to be awaken comfortably without being troubled by a warning beep, then expect a shower with restful smells and refreshing vapor therapy. Even in their car, they would like to read their newspaper, or book, watch TV, eat, drink and relax through a massage session provided by their seat.

In addition to the hedonic and utilitarian aspects, compared to smartness dimensions mentioned throughout the technological trends in Chapter II and Chapter III, - context awareness, communication capabilities, reactivity, predictivity, adaptability, natural and affective interaction- it could be concluded that the users' understanding of smartness and expectations from smart products are not too divergent from the literature content.

Figure 4.19 illustrates the distribution of the smartness expectations from different types of products cited by the users:

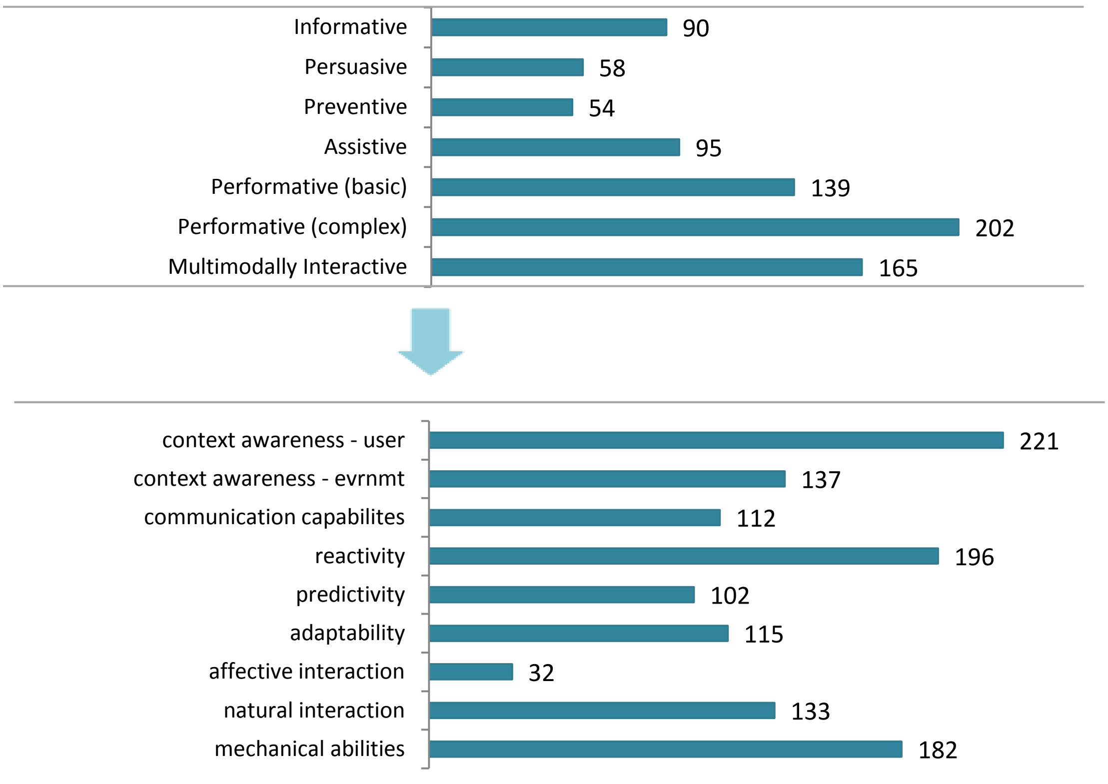


Figure 4.19 Smartness criterias included in users' smart product descriptions

Context awareness is the most commonly expected ability among the different types of smart products examples given by users. First of all, the smart products they will own, should possess the ability to sense their users' status and capture data related to the environment. Then they should be reactive, they should detect any evolution susceptible to change the inputs of the actual context and appropriately respond to it. They have to, to a certain extent, include predictivity and adaptability capabilities to better deal with different scenarios and easily keep pace with the unenvisaged situations. And they should be able of doing all of these actions by communicating and cooperating with each other.

Furthermore, users expressed their wish for enhanced human-computer interaction and more than the affective interfaces providing a humanistic interaction based on the communication of the emotions, they described products having natural interaction capabilities. And finally, differently from the technological trends detailed throughout the literature review, users mentioned also some advanced mechanical capabilities as the indicators of product's smartness.

Context awareness

In every smart product type described by user whatsoever informative, predictive, assistive, directive, performative or multimodally interactive, the context awareness property is mentioned. Users expect products that sense the environment, that are able to consider all of the eventual situational exigencies and that are permanently aware from any change or any modification concerning the current context. The context described, is either related with the human factors and the physical environment. Users mention products able to understand when somebody approach, leave, sit, walk or sleep. They imagine products that sense their emotional state and that have an idea about their personal preferences, or aware from their physiological state and health status. Similarly, in term of environmental awareness, physical and virtual information concerning the weather situation, daylight intensity, bus schedule, traffic density are expected to be inferred. From people's presence or the location of objects to the food types and their nutritional value, various contextual data is demanded to be recognized.

Communication capabilities

As well as independent, self sufficient smart objects, users expressed also an intense wish for informative smart systems communicating with each other through a network. This expectation is in correlation with the human centered view of ubiquitous computing necessitating the computational power become invisible to the users, disappearing into the background. Users need informative products capable of accessing any type of data whenever and wherever they need, houses communicating them their daily task planning, windows informing them permanently about the weather conditions, mirrors presenting the daily news or cars providing the necessary information about the traffic and road conditions are among the given examples.

Furthermore in term of networking capabilities and ubiquitous computing, users also declared their expectations to make invisible the office products by distributing their functionalities into daily object and assuring their intercommunication. The omnipresent information should be unobtrusive and perceived as an integral part of existing objects. A similar processing is expected from kitchen appliances, especially in the morning time to prepare the breakfast, and also while leaving home, from all of the house components to control and check the home status.

As pointed by Weiser while introducing ubiquitous computing vision in (1991), at the background, all technologies are supposed to be connected, aware from each other and permanently sensing their environment and users. One of the major properties of smart systems, which consist of distributing tasks into specialized objects cooperating with each other (Norman, 1998), seems to be adopted by users.

Reactivity

Users' reactivity expectation can be clearly distinguished in preventive and basic performative products. Reactive products, aware from the context, respond to the environment with direct reflexes (Rijsdijk and Hultink, 2003) are expected.

Reactivity including preventive products, aware from the environment, are mostly mentioned during the preparation period in the morning and especially while leaving home. Users expect reactivity from products such as mirrors, toothbrushes, doors, that are able to warn immediately their users when something goes wrong: if any modification in the user's health status is detected, any unusual situation is encountered in the house or anything has been forgotten to be kept by user while leaving home, it is expected from those products that they react by predicting their user or they act in a way to prevent those undesirable situations.

Reactivity expectation from basic performative products is especially revealed in awaking/sleeping periods and while leaving/entering home. Automatically opening bathroom and kitchen appliances when they perceive users, or when users wake up;

automatically turning on lights, opening doors when user enters at home or shoes putting off themselves; and armchairs transforming into bed, lights turning off when user sleeps are between mentioned reactive products.

Predictivity

Predictivity is essentially expected from assistive and directive products, it is mentioned as a necessary smartness dimension which could improve users decision making capabilities with the help of algorithms competent in foreseeing their expectation, their needs and providing the appropriate services. From directive products including predictivity, users expect that they furnish them multiple alternatives about the best actions to be taken once after evaluating different possibilities and selecting the most appropriate ones.

Users expect assistive smart products that are able to select the most optimal solutions according to the situational context, they describe products making predictions about their needs and increasing in a way their possibilities and even enriching their foreseeing capabilities.

Predictivity is especially expressed in awaking, home leaving and home entering periods. Users look for products furnishing them the optimal solution according to the environmental state, providing them some recommendations about the suitable clothes, according to the weather conditions or selecting the meal alternatives considering their nutritional value.

Adaptability

People expect that products before processing, consider their personal preferences and emotional stages. In other words, they look for customized products which recognize their users, learn their preferences, anticipate their reactions and also which could select their responses according to their users' actual emotional states.

The adaptability dimension is mostly seen in directive and assistive smart product expectations. Users would like their products make coherent suggestions or settling with their personal profile. They wish to listen their preferred song while awaking, bathing, driving, working etc. They want that their kitchen prepare them their favorite meal, and that their clothes change color according to their preferences. They want in fact a personalized interaction with products; everything should be done in a special way that will be appreciated by its owner. Product should adapt itself to the user, by learning over time their preferences and attempting to anticipate them. They should also adapt themselves to the environmental situations, or other persons accompanying user. Selecting the music according to the destination in car, or according to the passengers, considering room's temperature while heating or the weather situation while suggesting some combination of clothes are some of the examples of this environmental adaptation.

Natural Interaction

In correlation with the literature, natural interaction capabilities allowing the product to communicate and interact with the user in a natural, human way (Rijsdijk and Hultink, 2003) consists one of the properties expected from smart products. Users expect to establish easier and more realistic interaction with products and described speech, gesture or identity recognizing products. These wishes are especially mentioned for work period, during the interaction with computers and after entering home throughout the leisure time.

Even if users describe full automated systems during the course of the day; they abstain from automation in their work. This fact could be due to the belief of the user that smart products could trivialize their job. Here again it can be seen that, users don't expect that smart products facilitate their jobs related to their work. Contrary they are displeased from the help of smart products at work. They just wish that the interacting way with these products ameliorates in order to increase their performance.

Especially in leisure time, while entertaining activities they expect really advanced outputs. Three dimensional visual capabilities, provided by virtual images as well as materials physically changing their visual properties and also haptic, tangible outputs are mentioned. They described 3D displays, virtual landscapes, vibrating beds, color and pattern changing armchairs, carpets. Their smartness expectations encompass augmented reality, tangible interaction and the material smartness characteristics. Augmented and tangible interfaces by bringing the digital world into the everyday environment aimed to harmonize the transition between these two worlds and provide a more natural interaction with computers. Users seem to be agree with this objective and even give some outputs examples which strain the limits of today' technology.

Also with the use of new materials intrinsically emitting light, changing color or shape, the integration of computation into everyday gained a new dimension permitting users to manipulate everyday things by providing additional features that enrich existing interaction patterns (Dourish, 2004); and this impact of the development in microsystem technology and nanotechnology could be clearly distinguished from users' product descriptions.

Affective Interaction

Some properties of affective interaction as the ability to recognize human emotions and to show, in a way, the properties of a credible character, are also mentioned by users as a sign of smartness. Users would like their products sense their emotional state and react according to this captured input in order to provide the most coherent responses. Emotion recognition wish is especially expressed in assistive products where users expect that their product realize some adjustments or settlings by taking into the consideration their emotional state.

They would like to interact with their smart products as like interacting with a companion, a colleague or an assistant. However, their affective output expectation doesn't go further than a robotic agent description. They do not envisage multiple different everyday products trying to communicate with them through emotional signs and by showing affective behavior.

Mechanical abilities

In addition to the smart products capabilities mentioned throughout the literature review, users also expressed their wish for products having complex mechanical task accomplishing abilities. Especially in their performative products descriptions, users mentioned products that are able of doing multiple mechanical ability requiring tasks, from the beginning of the day until they are going to sleep they expect "something" that will awake them, dress them, wash their hands, prepare breakfast, tidy and clean the house. They describe a robotic agent, as like an assistant, following them during the day, accomplishing voluntary all of the fatigue duty jobs and permanently taking care of them. Whereas, those mentally uncomplicated tasks necessitate improved robotic capabilities that are not especially handled in the smart products researches.

CHAPTER 5

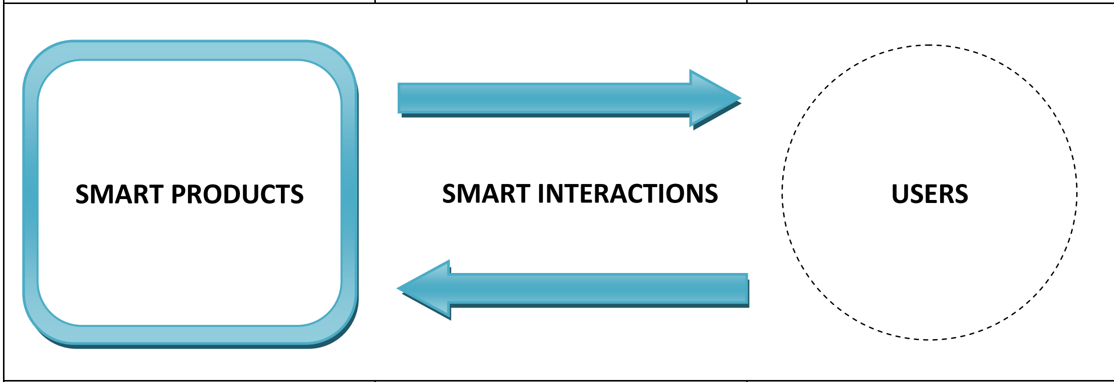
CONCLUSION

The vision of building smart products, attempts to create a human-centered computing that is embedded in physical spaces. This study investigated in this novel line of research that combines sensing, reasoning, acting/interacting capabilities with the ubiquitous calm and affective computing visions.

The integration of microchips, software and sensors technologies has added a range of new abilities to the traditional everyday products. Products equipped with computational power become able to collect data about the context, process this information and accordingly produce the appropriate responses. These abilities differentiating smart products from traditional ones constitute the "product smartness" and considerably revolutionize the interacting ways with products.

To further elaborate product smartness, two different sources of information are consulted throughout this study. A literature review focusing on smart products' capabilities and an empirical research concerning users' expectations from smart products are conducted. In the first part of the literature review smartness is handled from product side, and the technologies permitting a product to become context aware and take action autonomously according to the surrounding situations are explained. In the second part, smartness is discussed from user-product interaction perspective and technologies envisioning to improve this interaction are investigated, multimodal communication possibilities between smart products and users are discovered. Finally the empirical study handled product smartness from user perspective in order to reveal users' expectations concerning smart products' capabilities. Figure 5.1 illustrates the literature review and the empirical study findings, and recapitulates the answers of the research questions (see Chapter 1, Figure 1.1).

Chapter 2 Smartness from product perspective	**Chapter 3** Smartness from user - product interaction perspective	**Chapter 4** Smartness from user perspective



Powerful microchips Wireless technologies Sensor technologies New Materials + *Ubiquitous computing vision* ↓ Sensing user and environment state Reasoning autonomously according to the decision making algorithms or through responsive materials Acting appropriately according to the situational context ↓ Communication capabilities Context awareness Reactivity Predictivity Adapability	Electrical interactions Symbolic interactions Textual interactions Graphical interactions + *Calm computing vision* ↓ Exploring user preexisting skills Diminishing cognitive distance between virtual and real world + *Affective computing vision* ↓ Enriching the interaction by adding an affective dimension considering user emotions ↓ Natural interaction (gesture based, augmented, tangible interfaces) Affective interaction (affect recognizing, sharing and simulating interfaces)	Informative Directive Assistive Preventive Performative Multimodally interactive products ↓ Communication capabilities Context awareness Reactivity Predictivity Adaptivity Natural interaction Affective interaction *+Advanced visual, tangible and olfactory outputs* *+Humanoid robot interfaces* *+Advanced mechanical, robotic abilities*

Figure 5.1 Conclusion

The improvements in microchips, wireless networks, sensors and material technologies accompanied by ubiquitous computing vision, led to the integration of digital data into daily objects and generated a new way of computing dispersed all over the surrounding. This approach freed completely from desktop's limited resources was able to get more detailed inputs, thus better interpret users' expectations and generate the appropriate outputs. Ubiquitous computers equipped with sensors, diverse tracking capabilities and enhanced by reactive, predictive, adaptive decision making algorithms or smart materials, have gained autonomy in their actions**.**

They become smart products, aware of the users and their environment, communicating with each other and sharing information, reacting to the changes occurring in an environment, anticipating their user's need, adapting themselves to the changing conditions and learning their user's preferences.

In parallel to the developments in computing, the way of interacting with computers also changed. Ubiquitous computing complemented with calm computing vision not only distributed computation into everyday products but also aimed that these digitally empowered products would be not distinguishable from traditional objects. Rather than bringing to the focus of attention, the technology is left to vanish at the background, and appear only when it is required without disturbing or overburdening users.

With the new computing understanding, the ongoing evolution leaving behind respectively the electrical, symbolic, textual and graphical user interfaces stages let its place to a transition toward natural and affective interfaces. In contrast to the effort demanding desktop based graphical user interfaces exploiting a very restricted human action and perception abilities and where users have to learn new commands and adapt themselves to their computers processing, the new interaction trends attempted to develop intuitive and implicit user interfaces. This "smart" human-computer interaction approach that follows the smart product trend aimed to establish a natural and humanlike interaction between users and their ubiquitous computers. By exploiting users' preexisting communication skills and in addition by bringing digital data into the physical environment and allowing this abstract and unreachable virtual world to be tangible, natural interfaces expected to diminish the cognitive distance complicating even more the interaction between real and virtual worlds. On the other hand, affective computing vision tended to integrate human specific properties into the machines. Through affect recognition models, computers become able to "share" at a certain measure their users' emotions and respond to them with the most appropriate actions. Similarly by affect simulation communication with users is tried to be enhanced and the intuitiveness of the interaction be intensified. Users could capture, naturally the emotional clues given by their products and interact humanlikely with them.

The extended literature review about the smart products' technological trends permitted to gain an overview about smart products' capabilities, and by dismissing variations introduced by different views, to determine seven major smart product characteristics: context awareness, interconnectivity, reactivity, predictivity, adaptability, natural and affective interaction capabilities.

The findings related to the different smartness criteria mentioned in the literature are then completed with an empirical research focusing on users' expectations from smart products. To reveal user understanding concerning smartness, throughout an exploratory face to face interview, 30 users were asked to day dream their routine actions with smart products and detail their expectations from those products.

Users described informative, directive, assistive, preventive and performative products capable of supporting them in simple routine everyday tasks (e.g. waking up, dressing, personal care, food preparing, housekeeping) as well as helping them in laborious or critical tasks where they feel incapable and need help (e.g. health caring, assuring home security, driving safety) through user friendly, multimodal interfaces.

They expressed their wishes for products aware from the contextual conditions, permitting them to access any type of data whenever and wherever they need, contributing to their decision making process, helping them to deduce the optimum solutions among the different choices, smart systems capable of making adjustments, settlings, estimations as well as providing suggestions considering their users' personal preferences and emotional states, giving recommendation or motivating, warning them against potential risks and full-automated robotic agents accomplishing the majority of their routine, fatiguing daily chores.

They expect a multimodal interaction with these products where most of their senses will be involved. Through a direct and effective way of communication, they would like their smart products to capture their intentions and respond to them via diverse output modalities. Instead of desktop's limited interaction patterns, they expect to manipulate products enhanced with three dimensional, tangible or olfactory physical outputs.

They have also tendency to attribute personal characteristics to their smart products and treat them like a companion or order as if they were their worker or assistant.

Within the smart products expectations described by users it was possible to recognize the smartness dimensions detailed throughout the literature search. The capabilities they assigned to smart products include interconnectivity, context awareness, reactivity, predictivity and adaptability dimensions and are in accordance with the smart products trends. Similarly their description about the interacting way with smart products reflects the aspects of natural and affective interaction.

However differently from the literature, users described also robotic products having advanced mechanical properties. Instead of smartness abilities complementing the functionality or adding new dimensions to the traditional usage of the everyday products, users expressed an intensive wish for smart products able of repeating their activities. Full automated system accomplishing essentially their household and personal care activities were mentioned. And even if these tasks are considered as simple routine everyday jobs, they require complex mechanical abilities that current smart products research does not especially prioritize.

In terms of natural interaction also, users expect some advanced output capabilities that strain limits of today's technology. They described products producing physically enhanced responses, various sophisticated material smartness and transformation capabilities. Similarly, their affective interaction expectations revolved around a robotic assistant carrying them permanently like a companion or as a mother as affirmed by users. They regard affection from a more limited perspective and imagine more than everyday products, a totally humanlike agent. The degree of humanization described by users differs from the literature's ubiquitous computing approach and requires some advanced affect recognition and simulation capabilities that are not envisageable with today's affect knowledge.

Results indicate that except some aspects such as mechanical ability, the advanced multimodal output expectations from products and the degree of humanization envisaged for the interfaces, the majority of user expectations are coherent with the technological trends in smart product and overlap with the literature research findings: although users do not explicitly mention all of their smartness criterias, their smart products descriptions included context awareness, interconnectivity, reactivity, adaptability, predictivity properties and natural, affective interaction abilities.

In summary, our framework is capable of providing a reasonable depth of knowledge about the smart product trends and permitted to determine to what extend users' expectations concerning the abilities that a smart product should include overlap with these trends.

However in term of interaction compared to the findings recapitulating users' conception of smartness, this study provides limited information. During the interviews, users had difficulties in expressing their interaction expectation from inexistent products. They concentrated more on the functionality of smart product rather than the way of interacting with them. In order to ovecome this limitation and to gather useful information for designers a further study mainly focusing on the interactions expectation can be carried out.

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