INVESTIGATION INTO ADAPTIVE STRUCTURE IN SOFTWARE-EMBEDDED PRODUCTS FROM CYBERNETIC PERSPECTIVE

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ABSTRACT

INVESTIGATION INTO ADAPTIVE STRUCTURE IN SOFTWARE-EMBEDDED PRODUCTS FROM CYBERNETIC PERSPECTIVE

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This study investigates the concept of adaptivity in relation to the evolution of software and hence software embedded products. Whilst laying out the benefits of adaptivity in products, it discusses the potential future threats engendered by the actual change observed in the functionality principles of adaptive products.

The discussion is based upon cybernetic theory which defines control technology in the 20th century anew. Accordingly, literature survey on cybernetic theory, evolution of software from conventional to adaptive structure is presented. The changes in the functionality principles of adaptive systems and the similarities that these changes show with living autonomous systems is also investigated. The roles of product and user are redefined in relation to changing control mechanisms. Then, the new direction that the conventional product-user relationship has taken with adaptive products is examined. Finally, the potential future threats this new direction might bring is discussed with the help of two control conflict situations.

Keywords: adaptivity, product design, cybernetics, self-adaptive software

ÖZ

Yazılım Gömülü Ürünlerde Özuyarımlı Yapının Sibernetik Çerçevede İncelenmesi

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Bu çalışma, yazılımın geçirdiği evrim ve dolayısıyla yazılım gömülü ürünlere ilişkin olarak özuyarım kavramını ele almaktadır. Ürünlerde özuyarımın faydalarını ortaya koyarken, aynı zamanda özuyarımlı ürünlerin işlevsellik prensiplerinde görülen mevcut değişimin taşıdığı geleceğe yönelik olası tehditleri de tartışmaktadır.

Tartışma, 20. Yüzyılda kontrol teknolojisini yeniden belirleyen sibernetik teoriyi temel almaktadır. Buna uygun olarak, sibernetik teori ile yazılımın gelenekselden özuyarımlı yapıya doğru evrimi hakkında bir literatür taraması sunulmaktadır. Özuyarımlı sistemlerin işlevsellik prensiplerinde meydana gelen değişimler ile bu değişimlerin canlı otonom sistemlerle gösterdikleri benzerlikler araştırılmaktadır. Ürün ve kullanıcı rolleri değişen kontrol mekanizmalarına bağlı olarak yeniden tanımlanmaktadır. Daha sonra geleneksel ürün-kullanıcı ilişkisinin özuyarımlı ürünlerle beraber kazandığı yeni yön ele alınmaktadır. Son olarak ise, bu yeni yönelimin yol açabileceği geleceğe yönelik olası tehditler, iki kontrol çatışma kurgusuyla tartışılmaktadır.

Anahtar Kelimeler: özuyarım, ürün tasarımı, sibernetik, özuyarmalı yazılım

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

adaptable : (system) altering aspects of its structure, functionality or interface on the basis of a user model generated from *explicit* user input

adaptive : (system) altering aspects of its structure, functionality or interface on the basis of a user model generated from *implicit* user input

allopoietic : (system) performing to produce something other *(allo)* than itself

autonomic: acting or occurring involuntarily

autonomous : having the right or power of self-government, undertaken or carried on without outside control

control: preventing the transmission of a variety from the environment to the system.

feedback loop : process where information about the result of an action is sent back to the input of the system in the form of data.

goal : state of stable equilibrium, to which system intents to return after any perturbation

homeostatis : a physiological constancy or equilibrium maintained by self-regulating mechanisms

model : knowledge of the processes occuring in the perceived environment/user

model-building : process of model reforming in each interaction with the environment/user

open-loop : type of control which generates control inputs offline without feedback from the controlled object.

closed-loop : type of control which generates control inputs from both the environment and the controller object’s feedback.

CHAPTER 1

INTRODUCTION

Today it is an inevitable fact that increasing number of products are becoming software-embedded; as for control mechanisms the mechanic infrastructure they had is gradually turning out to be software-dependent. In that sense, software is starting to have a more effective role in product design everyday. Whereas at first, software was used by product design solely to get freed from mechanical infrastructure, nowadays it is made use of in many different areas.

Adaptivity is one of the fields where software is efficiently used in the field of product design. Benyon, D. R. defines 'adaptive systems' as systems that can alter aspects of their structure or functionality from implicit user input, in order to accomodate the differing needs of users. In order to provide the user with easier and more efficient usage, products with adaptive structures aim at transforming the static structure of products into self-forming designs as a result of the interactions made with the user. The concept of *Ambient Intelligence* which involves the implications of the concept of adaptivity in everyday life and the future visions developed by respectable design and technology firms such as Philips and Microsoft and HP, prove that in near future, advanced adaptive structures will be seen in many fields of product design.

For products to be transformed into an adaptive structure, new generation software having robust, self-organizing and adaptive features is considered to be used. Defense Advanced Research Projects Agency (DARPA) refers to these new generation software as 'self-adaptive software' and defines them as software that evaluates its own behavior and changes behavior when better functionality or performance is possible.

As a result of using self-adaptive software, the functionality principles of products undergo significant changes almost to the point of evolving. As defined by cybernetic theory, products are changing from being 'observed systems' into being 'observing systems'. Products with adaptive structure can now form user-models through their model-building structure, re-form themselves according to this model and can make decisions. In this respect, they are slowly starting to take on the autonomous functioning of a living system.

Alongside the undeniable application domains and benefits experienced today, this evolution also effects the conventional nature of the interaction between product and user. In the conventional sense, whereas the interaction between user and product were a process perceived as one-sided, products with adaptive structure have rendered the perception of this process two-sided. Products gaining an adaptive structure, in other words, their acquiring a consciousness to some extent, may lead, in the future, to their potentially constituting a threat to the person who created them. This may jeopardize the absolute control of the user over the product and can thus lead to potential threats. Although, with current technology, the threats of such a transition may not be self-evident, it might be possible to see these threats in near future.

1.1 Aim of the Study

This study aims to lay out the applications domains and benefits of adaptive products as well as the potential threats engendered by the actual change observed in the functionality principles of the adaptive products. The main motivation of the study is to show not only the definitive benefits of adaptive products that are frequently mentioned in design literature but also that they are gaining a structure which may constitute threats to the user.

The study will be based upon cybernetic theory which defines control technology in the 20th century anew. Thanks to cybernetics which can define all living and non-living systems as control mechanisms, the study will look at the change in the functionality principles of adaptive systems and the similarity that this change shows with living autonomous systems. Defining product and user from the same perspective as control mechanisms, the new direction that the conventional product user relationship has taken with adaptive products will be explained.

1.2 Main and Sub Research Questions

The following research questions were posed in the study.

- What roles does the concept of adaptivity play in today's software applications hence software-embedded products?

- In what ways does the integration of adaptive software change everyday life and product-user relationship?

    - What are the current application domains of products embedding adaptive software?
    - What potential benefits does adaptive-software bring in these application domains?
    - What potential threats does adaptive-software pose for product-user relationship?

1.3 Methodology

A literature review to support the essential background to the subject areas of the thesis was undertaken, covering the following subjects: cybernetics theory; evolution of software; concepts of adaptivity, adaptive-software and Ambient Intelligence. The sources covered included: academic publications; companies; internet sources; and professional literature.

1.4 Structure of the Thesis

Chapter 1 introduces the area of study, definition of the problem, aim of the study, research questions, methodology and structure of thesis.

Chapter 2 looks at cybernetic theory which brings a brand new dimension to control technology in the 20th century and the concepts whereby cybernetic theory is formed. The literature survey will first focus on the time period where the grounds for cybernetic theory were laid out and will discuss the innovations it has provided to control technology. After that, cybernetic theory will be elaborated upon four central concepts that form it.

Chapter 3 by exploring how software which forms the basis of control technologies today has progressed towards a self-adaptive structure, attempts to explain the positive outcomes of this process via cybernetic concepts. In the first part of the analysis, the concept of software will be defined in terms of its historical development. In the second part, the reasons why software took on a self-adaptive structure will be explained and the concept of self-adaptive software will be defined. The third part will focus on the 'autonomic computing' project developed by IBM in order to understand the characteristics of self-adaptive software. The fourth part will elaborate the conventional structure and self-adaptive structure of software from a cybernetic perspective and will analyze the changes in the structure of software as a control system. And the final part will focus on the changes in the software's structure and the effects it has on software-embedded applications.

Chapter 4 looks at how self-adaptive software defined in the previous chapter had reflections in everyday life and the field of product design. This chapter will focus on the concept of *Ambient Intelligence* and will attempt at making the appropriate derivations through this term. As such, in the first part the concept of *Ambient Intelligence* will be defined, after which the adaptive features of the vision it draws in everyday life will be explored. In the second part, the application domains of adaptive products will be analyzed with reference to concept examples. In the last part, potential threats that adaptive structure holds for will be laid out from both individual and cybernetic perspective. This part will mainly refer to the analysis of self-adaptive software within a cybernetic perspective elaborated in the previous chapter.

Chapter 5 draws upon the conclusions of the study in relation to the aim and the research questions proposed.

CHAPTER 2

CYBERNETICS THEORY

2.1 Introduction

This chapter will introduce cybernetics theory that has brought a new dimension to control technology and its fundamental concepts. This background will facilitate to analyze the systems involving a control mechanism with the help of cybernetic concepts and to make derivations from a common perspective.

The study will begin with a general introduction of the time period where the grounds of cybernetics were laid out. Then cybernetics theory will be defined and argument on the ways it revolutionized control technology will be discussed. Finally, cybernetic theory will be analyzed through four central concepts that form it.

2.2 Origins of Cybernetics

At the time of Second World War, Norbert Wiener, Arturo Rosenblueth, and Julian Bigelow were tasked to address the cutting edge of control technology, developing automatic range finders for antiaircraft guns. Otto Mayr portraits the situation in his book titled ‘The Origins of Feedback Control’ as:

> …an important military problem in WWII was the direction of anti-aircraft gun fire. Aircraft speeds had so increased that they were now of the same order of magnitude as that of the shells used. What was wanted, was a method of extrapolating the path of the aircraft to predict its future position, so that a shell could be sent to meet it (1975: 84).

Mayr (1975) describes those guns as servomechanisms being able to predict the trajectory of an airplane by taking into account the elements of past trajectories. By his explanations, this appeared to be an ‘intelligent’ behavior since it dealt with 'experience' (the recording of past events) and predictions of the future.

Wiener and his colleagues became interested in the problem and proposed a theory of prediction based on 'negative feedback loops' in the nervous system of human beings and designed a system which could make use of it in the control of anti-aircraft gun fire in 1940's. As Mayr figures out;

> Wiener inferred that in order to control a finalized action (an action with a purpose) the circulation of information needed for control must form "a closed loop allowing the evaluation of the effects of one's actions and the adaptation of future conduct based on past performances." This is typical of the guidance system of the antiaircraft gun, and it is equally characteristic of the nervous system when it orders the muscles to make a movement whose effects are then detected by the senses and fed back to the brain. Their purpose was to approach the study of living organisms from the viewpoint of a servomechanisms engineer and, conversely, to consider servomechanisms with the experience of the physiologist (1975: 85).

Thus Wiener, Rosenblueth and Bigelow discovered the closed loop of information necessary to correct any action -the negative feedback loop- and they generalized this discovery in terms of living organisms and machines. They adapted a Greek word *kybernetes,* meaning 'the art of steering', for their new discipline to evoke the rich interaction of goals, predictions, actions, feedback, and response in systems of all kinds.

2.3 Definition of Cybernetics

> Cybernetics, by definition, is the study of communication and control, typically involving regulatory feedback in living organisms, machines and organizations, as well as their combinations. It can be named as the science of purposeful behavior and helps us explain behavior as the continuous action of an organization (either living or non-living) in the process (Wiener, 1948: 4).

Cybernetics is neither a completely new discipline nor an approach that has suddenly been brought forward. Cybernetics, assumed to be present in the creative instinct of human beings and the development of which is still subject of debate, is actually a relatively new perspective that is suggested for self-organizing and autonomous processes and that is based upon self-control. It is a new dimension assumed by control technology, the foundations of which go back two thousand years.

The greatest achievement of cybernetics is that it complements traditional control theory as a universal through the notion of feedback. By relating control technology theory, which had previously been developed probably only in the field of engineering, to many other disciplines at the same time, it has defined itself as the *philosophy of sciences* rather than a pure discipline or science (Heylighen and Joslyn, 2001).

In that manner, cybernetics as 'an interdisciplinary epistemology', can look at many fields from software design to molecular biology, from artificial intelligence to sociology and more importantly, to the functioning of living and non-living beings from the same perspective. As Heylighen and Joslyn (2001) mention, cybernetics does not only involve engineered, artificial systems, but explores evolved natural systems on the same basis too. Thus, the technological-biological analogies which gained speed with the analogy between the anti-aircraft gun and the human nervous system, can lay the grounds for providing references between the functioning principle of a machine and that of a cell or a social organization.

2.4 Four Central Concepts of Cybernetics

The concepts and principles of cybernetics which is an interdisciplinary epistemology, constitute a wide range. In this section, four fundamental concepts that explain the functioning of a cybernetic system will be elaborated in detail while the grounds on which the functioning of the software and software-embedded systems that will be analyzed in the coming chapter, will be laid out.

Before embarking on these issues, there is another point that should also be mentioned. From the late 1940's up to today, cybernetics has undergone an evolution. Particularly in the 1970's, the theories developed by Foerster, Pask and Maturana in the areas of cognition and learning have given a new momentum to cybernetics, leading it to be named as *first-order cybernetics* between 1940 and 1970, and *second-order cybernetics* from the 1970's until today. In that regard, while first order cybernetics lays the grounds for feedback control theory, second order cybernetics carries this one step further by taking up this control theory from a constructivist perspective. It is important to mention that the concepts of *goal-directedness, feedback loop* and *control* which will be explained below are products of first-order cybernetics while the concept of *cognition* is product of second-order cybernetics.

However, as Heylighen and Joslyn (2001) mention, because it is a continuous development and does not have a clean cut off point between these two periods, it would not be appropriate to make such a distinction when exploring cybernetic theory. Thus, this section will discuss the basic concepts of cybernetics as a whole, without explicitly distinguishing between 'first order' and 'second order' ideas.

2.4.1 Goal Directedness

> Cybernetic or control systems are characterized by the fact that they have goals: states of affairs that they try to achieve and maintain, in spite of obstacles or perturbations (Heylighen and Joslyn, 2001: 163).

Classic Newtonian world view determines processes by their causes. In that manner, causes are followed by effects, in a simple, linear sequence. It claims that causes being adequately examined, the possible future effects may be foreseen. On the other hand, while cybernetics defines a process, it brings the concept of 'goal'. It states that the system, by identifying the intended goal, can determine its current movements. It claims that in order for a living or non-living system to function, a system should have a *goal* (Heylighen and Joslyn, 2001).

This concept of goal-directedness developed by cybernetics, defines an autonomous system as a system which, by the fact that pursues its own goals, resists obstructions from the environment that would make it deviate from its preferred state of affairs (Heylighen and Joslyn, 2001). Heylighen and

Joslyn give the example of the thermostat as the simplest. The setting of the thermostat determines the preferred temperature or goal state. Perturbations may be caused by changes in the outside temperature, opening of windows or doors, etc. The chore of the thermostat is to minimize the effects of such perturbations, and to keep the temperature as constant as possible with respect to the target temperature.

For simple artificial systems (e.g., thermostat, cruise control system), the fundamental goals are determined by their creator. These goals can also be determined as a pregiven utility assigned to them (Joslyn, 2001b). Joslyn (2001b) names these systems as 'allopoietic' since their function is to produce something other *(allo)* than themselves.

As for complex autonomous systems, the most fundamental goal is to maintain their own stability and survival (Joslyn, 2001b). This constitutes the continuance of their essential organization. An animal's defending its own life or a social organization's assuring its continuity can be stated among such examples. Alongside its fundamental goal, a system has also subsidiary goals which indirectly contribute to the fundamental goal (e.g., a living organism seeking food or shelter). All such systems are called 'homeostatic'. In Rosnay's words:

> Complex systems must have homeostasis to maintain stability and to survive. A homeostatic system (an industrial firm, a large organization, a cell) is an open system that maintains its structure and functions by means of a multiplicity of dynamic equilibriums rigorously controlled by interdependent regulation mechanisms (1997b).

In more general terms, all ecological, biological and social systems as well as complex artificial systems are homeostatic. Such systems react to each change and disturbance that occurs in the environment. These reactions happen through a series of modifications of equal size and opposite direction to those that created disturbance (Rosnay, 1997b).

According to Rosnay (2000), the goal of these modifications is to maintain the internal balances. If the system does not succeed in reestablishing its equilibriums, it enters into another mode of behavior, one with constraints often more severe than the previous ones. This mode can lead to the destruction of the system if the disturbances persist.

In both *allopoietic* and *homeostatic* systems, Heylighen and Joslyn (2001) model the 'goal state' as similar to a stable equilibrium, to which the system returns after any perturbations. In other words, this state can be named as 'equifinality' where different initial states lead to the same final state, implying the destruction of variety. Thus, a goal-directed system must actively intervene to achieve and maintain its goal, which would not be equilibrium otherwise.

2.4.2 Feedback Loop

Cybernetics defines all beings as a system or as a totality of systems. Instead of taking each system in itself, it takes them together with their behaviors and their environment. It prefers a dynamic rather than a static approach. It accepts the system it investigates with the system's interaction with its environment and the transformation that occurs as a result of this interaction (Rosnay, 1997a). Cybernetics develops a vision focused on the communication and flow of information that occurs between the system and its environment.

Within this interaction, when a transformation occurs in a system, there arises inputs and outputs. Heylighen and Joslyn (2001) define these inputs as the result of the environment's influence on the system, and the outputs as the influence of the system on the environment. Input and output are separated by duration of time, as in before and after, or past and present (Figure 2.1).

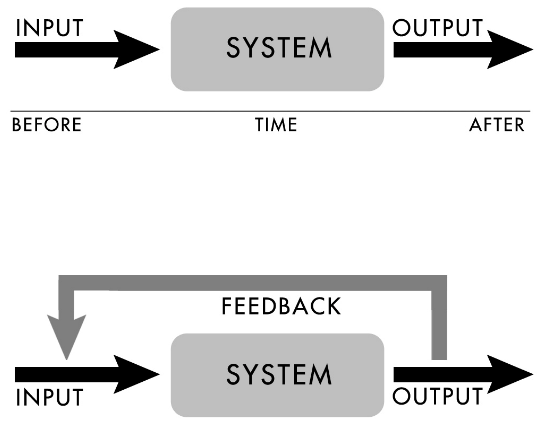

Figure 2.1 – Diagram showing linear vs. circular flow of system control (Rosnay, 1997a)

According to Heylighen and Joslyn (2001), in every feedback loop, information about the result of a transformation or an action is sent back to the input of the system in the form of data. If these new data facilitate and accelerate the transformation in the same direction as the preceding results, they are positive feedback - their effects are cumulative. If the new data produce a result in the opposite direction to previous results, they are negative feedback, their effects stabilize the system. From another point of view, Rosnay describes this situation as follows:

> Negative feedback control loops which try to achieve and maintain goal states were seen as basic models for the autonomy characteristic of organisms: their behavior, while purposeful, is not strictly determined by either environmental influences or internal dynamical processes (1997a).

This principle of negative feedback is the most important principle brought by cybernetics theory. Although products based on feedback loop have been developed more than a century ago, the ideas have not been concretized under a general theory. From this view point, cybernetics may be defined as the predecessor of negative feedback-loop based control technology. As opposed to control theories that perform a linear flow, cybernetics assumes a system that is in constant communication with its environment and that controls a situation due to the feedbacks it provides as a result of this communication.

2.4.3 Control

In cybernetics, control or regulation is most fundamentally formulated as a reduction of variety: perturbations with high variety affect the system's internal state, which should be kept as close as possible to the goal state, and therefore exhibit a low variety (Turchin and Joslyn, 1996). Therefore, in a sense, control prevents the transmission of a variety from the environment to the system.

The operating principle of the control mechanism is shown in its most basic state, in Figure 2.2. According to Heylighen and Joslyn (2001), control is the operation mode of a *control system* which includes two subsystems: a controller (C) and a controlled (S). C and S interact however; C's effect on S and S's effect on C are different from each other. While C can change the state of S, that is, can assert active control on S, the effect of S on C is passive which means there is only a formation of a perception of system S in the controller C. If we return to the above mentioned example of the thermostat, the thermostat constitutes the controller and room temperature constitutes the controlled system. In that case, the thermostat (C), while being capable of actively changing the temperature of the controlled system, the feedback it receives from the controlled system is the current temperature of the room. C can control S while S cannot control C, and the effect of S on C can be no more than reflecting its own representation.

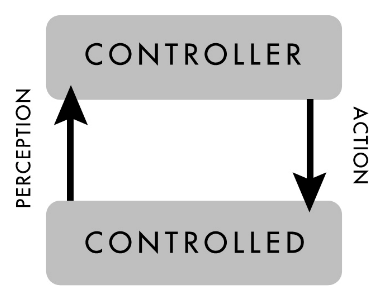

Figure 2.2 – Basic control mechanism diagram (Heylighen and Joslyn, 2001)

When examining the control mechanism in a more detailed diagram (Figure 2.3), we can define the diagram as a feedback cycle with two inputs. As Heylighen and Joslyn (2001) mentions, the first is the goal of the system or of the controller, while the second constitutes the disturbances of the environment or of the controlled system. As the system tries to reach its determined goal or tries to maintain its current state, it actually tries to minimize the effects it receives from the goals of the other systems (disturbances) in the environment. The system primarily starts to examine the variables that are found in the environment and that it thinks can effect its preferred state. It creates its own internal representation of the situation outside. The information obtained in this stage is then processed by the system in order to reach two conclusions. The first one is the manner in which the observed variables will affect the goal of the system. The second is the path the system will take in order to safeguard its goal.

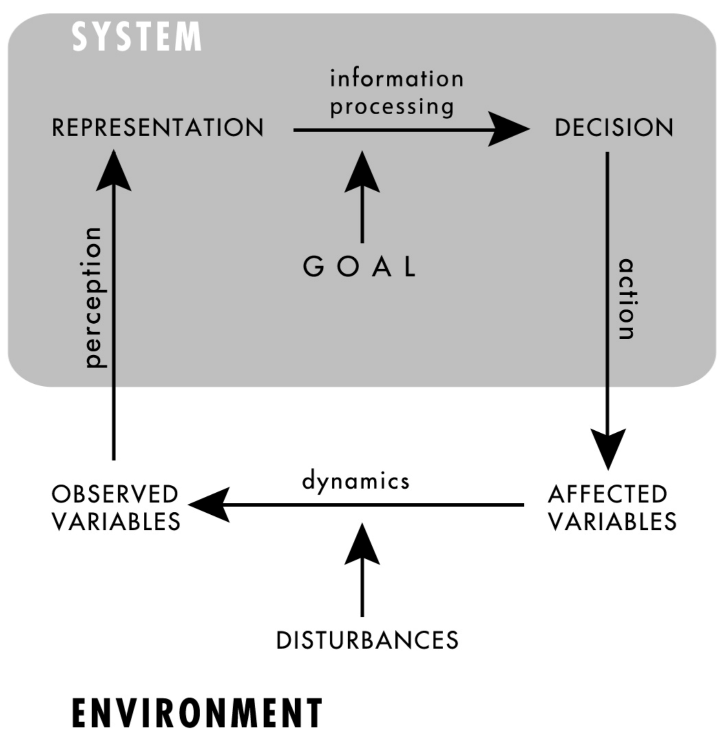

Figure 2.3 –Components of a Control System (Heylighen and Joslyn, 2001)

The system decides on and carries out an appropriate action which it has determined according to its processing of information. This action starts to affect certain variables in the environment and this influence, being further triggered by the disturbances, changes the dynamics of the environment. As a result, this change is reflected on the variables that have been and continue to be observed by the system. The change in these variables is perceived again by the system, is processed and reflected on the new decisions it will take. This is how the control mechanism starts all over again.

The components in this diagram may be simple or complex, depending on the level of complexity of the system or environment (Turchin and Joslyn, 1996). In the case of the thermostat, the 'goal' is to maintain the room temperature at a predetermined level; 'perception' is to sense the current temperature of the room. And the phase of information processing consists in the system's choice of heating or no heating, depending on whether the perceived temperature is lower or higher than the goal temperature. While the affected and observed variables constitute room temperature, disturbances are the amount of heat the room exchanges from the outside.

As a more complex example, we can think of a football club aiming at championship. Taking actions, transfering technical staff and footballers, organizing training matches, finding sponsors to increase the budget, expanding the stadium to let more supporters in, etc. The team's position within the league and the team's performance, are all processed according to the criterium of championship targeted by the club's management. Through the decision taken here, are realized the actions stated above. These actions affect the team's overall position within the league. However, the team's position is primarily determined by the matches held with its rivals and with the matches held between the other teams. After the match scores have been perceived and processed by club management, a new phase of taking decisions begins and the system's control cycle starts all over again.

At this point, Heylighen and Joslyn (2001) emphasize that the control loop diagram is completely symmetrical. If we turn the diagram in Figure 2.3 upside down, environment turns into system and disturbances into goals. According to Heylighen and Joslyn (ibid), this diagram can be considered as two interacting systems which impose their goals upon each other. From such a perspective;

> If the two goals are incompatible, this is a model of conflict or competition; otherwise, the interaction may settle into a mutually satisfactory equilibrium, providing a model of compromise or cooperation (Turchin and Joslyn, 1996).

However, as is stated by Turchin and Joslyn (1996), control mechanisms are formed according to the model that one system is superior to others, therefore creating an asymmetry between system and environment. So, as is explained in the diagram in Figure 2.2, while the controller creates active action over the controlled, the controlled can do no more than transfer its representation to the controller.

In Heylighen and Joslyn's view (2001), this assymetric model can be obtained by buffering the environment's and its disturbances' effect on the system and by increasing the strength of the system's actions. In the example of the thermostat, it is by insulating the walls of the room against external disturbances and by the functioning of the heating system with a constant energy that such an asymmetric model has been achieved and the system has become predominant over the environment. Heylighen and Joslyn (2001) has given a similar example in the case of the living cell as well. The same asymmetric model has been realized by the protective membrane surrounding the cell and by the food supply for energy.

2.4.4 Cognition

The concept of cognition determined by cybernetics will be defined under a) knowledge (model) and b) model-building.

a. Knowledge (Model)

Cybernetics asserts that a purposive system should have a certain knowledge in order to function. As Joslyn (2001a) mentions, in certain circumstances, the system needs to take certain decisions and make predictions to achieve its goal. In order to be able to make such a decision/prediction, it should have a ‘model’ of the processes occuring in the perceived environment. Thus, cybernetics defines knowledge as a model of some part of reality as it is perceived by the system. Heylighen and Joslyn (2001:164) defines this model as the ‘recursive generator of predictions about the world which allow the cybernetic system to make decisions about its actions’ .

Therefore, in a cybernetic system, there must be a group of actions that accurately maps a group of the disturbances in the environment. For instance, the thermostat, in response to the information ‘temperature too low’ it perceives, holds the information ‘heat’ while in response to the information ‘temperature high enough’, holds the information ‘do no heat’. According to Joslyn (2001a), this knowledge can be defined in the form of ‘if condition (perceived disturbance), then action’.

In Joslyn’s view (2001a), in circumstances where it is without knowledge, the system starts to deploy randomly the actions it holds, until one of these actions comes in useful. And if the variety of disturbances increases, the system becomes less likely to provide regulation by using the appropriate action. That’s why the variety of actions is not sufficient for effective control and the system must be able to know which actions to select from the variety of available actions. Thus, increasing the variety of actions must be associated with increasing the constraint in choosing the appropriate action, that can be called ‘knowledge’ (Heylighen and Joslyn, 2001). Cybernetics defines this necessity as ‘the law of requisite knowledge’.

b. Model Building

Cybernetics defines knowledge from a constructivist perspective. Knowledge, in contrast to a passive concept absorbed by the environment, forms a concept created actively by the system. Knowledge is formed as a result of the interaction between the system and its environment and is system specific. Heylighen and Joslyn explain this as follows:

> … system has no access to how the world really is, models are subjective constructions, not objective reflections of outside reality. For knowing systems, these models become their environments. Interaction is the basis of all that a cybernetic system knows (2001: 167).

In this subjective approach, the real world is in fact the model world that is formed. The system takes recourse in this model in order to define reality. This defined model being re-formed in each interaction with the environment, applies a model-building process. This process is dynamic and as the environment of the system changes, it helps it to adjust its own operation and therefore helps it to survive too.

According to Rosnay (1997b), the model-building methods are formed according to the level of complexity of systems. In simple artificial systems – any mechanical device – the model is defined as a pregiven data. An active model building does not apply for these systems. If its environment diverges from the predetermined model, the system will not survive. A thermostat with a determined temperature range that cannot function in an environment outside of this range, can be given as such an example.

In simple organic systems, model building is developed due to natural selection. Even though Rosnay (1997b) defines such a model-building as 'quite wasteful', it constitutes an unavoidable model in terms of the evolution of genes in all living beings.

Within the framework of Rosnay's example (1997b), let us think that a primitive aquatic organism is taken from its environment and put into a new one. In order for the creature to survive in this new environment, it must find a temperature zone that is adequate to its body temperature. There are three conditions (too hot, too cold, just right) that it can perceive from the environment, and three actions (go up, go down, do nothing) it can take. If we one-to-one map these two groups, three right states will come up (*too hot →go down*, *too cold →go up*, and *just right →do nothing*). These three defined states constitute the model by which the living being will survive. The environment does not help the living being in the process of model building, the living being must build this knowledge by experimenting. While the organisms which form the right states survive, the others disappear. Consequently, the natural selection that thus occurs, in the long term, leads to the evolution of the genetic map of the creature and to the formation of a new species fit for the new environment.

As to the more complex systems, they have formed a more efficient method; that is, ‘learning’. According to Heylighen and Joslyn (2001), ‘learning’ as biological adaptation, happens incidentally in the context of the pursuit of the current ‘needsatisfying’ goals. Learning can be defined as the process of adaptation. Heylighen and Joslyn state that;

> In learning, different rules compete with each other within the same organism's control structure. Depending on their success in predicting or controlling disturbances, rules are differentially rewarded or reinforced. The ones that receive most reinforcement eventually come to dominate the less successful ones. This can be seen as an application of control at the metalevel, or a metasystem transition, where now the goal is to minimize the perceived difference between prediction and observation, and the actions consist in varying the components of the model (2001:169).

2.4.5 Summary of the Four Central Concepts of Cybernetics

This part will attempt to summarize the four central concepts of cybernetics which are i) goal directedness, ii) feedback loop, iii) control, and iv) cognition.

i. Goal-directedness

Cybernetics claims that in order for a living or non-living system to function, the system should have a ‘goal’. By identifying an intended goal, the system can determine its current movements. Complex autonomous systems are ‘homeostatic’; the fundamental goal is to maintain their own stability and survival. Simple artificial systems are ‘allopoietic’; the fundamental goal, determined by their creator, is to produce something other than themselves.

ii. Feedback Loop

Cybernetics, as opposed to a system that performs a linear flow, assumes a system that is in constant communication with its environment and that controls a situation due to the feedbacks it provides as a result of this communication.

iii. Control

Cybernetics formulates control as a reduction of variety where control prevents the transmission of a variety from the environment to the system. Cybernetics forms control mechanisms according to the model that one system is superior to others, therefore creates an asymmetry between system and environment.

iv. Cognition

Cybernetics asserts that a goal-directed system should have a certain knowledge in order to function and defines this necessity as 'the law of requisite knowledge'. Cybernetics defines knowledge –model- from a constructivist perspective. Model is formed as a result of the interaction between the system and its environment and is system specific. The model-building methods are formed according to the level of complexity of systems.

2.5 Chapter Summary

In this chapter, the cybernetic theory which has brought a new dimension to control technology in the 20th century has been defined, its contribution to control technology has been explored and the four main concepts of cybernetics (i.e. goal-directedness, feed-back loop, control mechanism and cognition) that constitute the grounds of the theory have been discussed. With this attempt, a background based on cybernetic theory has been prepared in view of the studies to be made in the following parts of the thesis.

CHAPTER 3

EVOLUTION OF SOFTWARE TOWARDS SELF-ADAPTIVE STRUCTURE

3.1 Introduction

This chapter will look at software as the basis of today's control technologies and its evolution towards a self-adaptive structure. The outcomes of the development process will be examined in order to facilitate the discussion on the changes within the functioning of adaptive products, and the positive and negative outcomes that they have brought in the following chapter.

Therefore, first, the concept of software will be defined in accordance with its historical development. Secondly, the reasons for which software have progressed to a self-adaptive structure will be explored, and the concept of self-adaptive software will be defined. Thirdly, to grasp the characteristics of self-adaptive software, the 'autonomic computing' project developed by IBM will be reviewed. Then, the conventional structure and self-adaptive structure of software will be taken up, after which the change undergone in the structure of software as a control system will be analyzed. Finally, the effects of this change in the structure of software-embedded applications will be discussed.

3.2 Brief Definition and History of Software

Software, in a general sense, exists as any set of instructions that directs a machine to undertake a sequence of actions. In other words, software can be conceived as the knowledge that controls a set of activities (Kenney, 1994).

Ever since the invention of Charles Babbage's difference engine in 1822, machines have required a means of instructions to perform a specific task. In the beginning, Charles Babbage's difference engine could only be made to execute tasks by changing the gears which executed the calculations (Myers, 2000). The situation was a one on one game: a problem needed to be solved, thus a machine was built. When some sort of instruction was needed, a sequence was designed or written and transferred to either cards or mechanical aids such as, wires, gears, and shafts (Myers, 2000).

Eventually, physical motion was replaced by electrical signals when the US Government built the ENIAC in 1942. It followed many of the same principles of Babbage's engine and hence, could only be programmed by presetting switches and rewiring the entire system for each new program or calculation (Myers, 2000).

Software, as we know today, can be said to be based on two concepts developed by Jon Von Neumann in the field of computer programming language in 1945. The first concept is known as ‘shared-program technique’. It states that the actual computer hardware should be simple and should not need to be hand-wired for each program. Instead, complex instructions should be used to control the simple hardware, allowing it to be reprogrammed much faster (Needleman, 1995).

The second concept is known as ‘conditional control transfer’. It states that computer code should be based on logical statements such as, IF (expression) THEN, and looped such as with a FOR statement (Needleman, 1995). In this way, the functioning of system should be designed according to feedback cycles which describe each condition, in contrast to a linear flow.

In 1957, the first of the major languages appeared in the form of FORTRAN. Its name stands for FORmula TRANslating system. The language was designed at IBM for scientific computing. In this language based upon Von Neumann’s ideas, the components were very simple, and provided the programmer with low-level access to the computers’ innards (Myers, 2000).

Following FORTRAN, other computer programming languages ALGOL, COBOL and C appeared in 1958, 1959 and 1972 respectively. The software written with these languages and their new versions have become the most fundamental building blocks providing the functioning and control of systems from the second half of the 20th century onwards.

3.3 Self-Adaptive Software

Especially in the last three decades, the developments in software engineering have transformed software from their simple into a significantly improved state. However, in parallel to the developments software become more complex, which cause some elements that were negligible before, become considerable threats. As Laddaga and Robertson (2004) mention in their article 'Self Adaptive Software: A Position Paper', one of the major threats is the fact that complex software systems prove to be sensitive and fragile toward the changes that occur in the environment. In the case of the early days of software that faced a simple environment (e.g. calculators, and primitive computers) the possibility of such a change in the environment is highly unlikely. Whereas in software examples such as simulation systems, a change of this kind has become part of the ordinary process. This means that software systems must continuously be manually adapted. Software which contain tens of millions of lines of code must regularly be configured and tuned by skilled software engineers. This turns adaptation into a difficult and painful process. Therefore designing self-adaptive software became the next idea.

Following is a definition for self adaptive software provided by DARPA Broad Agency Announcement.

> Self Adaptive Software evaluates its own behavior and changes behavior when the evaluation indicates that it is not accomplishing what the software is intended to do, or when better functionality or performance is possible (1997: 12).

Shen and Wang (2004) suggests in their article titled 'Self-Adaptive Software: Cybernetic Perspective and an Application Server Supported Framework' that self-adaptive software has multiple ways of accomplishing its purpose, and has enough knowledge of its construction to make effective changes at runtime. Moreover, such software should include functionality for evaluating its behavior and performance, as well as the ability to replan and reconfigure itself in order to improve its operation (Shen and Wang, 2004).

In the view of the possibility of all systems based on software facing a possible chaos in the future, many leading software companies (e.g. IBM, Microsoft, Borland) have been developing various projects with the idea of built in self-adaptive software. However, in realistic terms, designing completely self-adaptive systems is a difficult and time consuming process. It requires new technologies and innovations. In this phase it will be adequate to look at the future vision of software determined by the concept of self-adaptivity. The project developed by IBM entitled 'autonomic computing' constitutes an important reference for this vision.

3.4 Autonomic Computing

In the article 'Autonomic Computing: IBM's Perspective on the State of Information Technology', IBM (2001: 4) defines the problem of complexity encountered today in the following manner:

> The growing complexity of I/T infrastructure threatens to undermine the very benefits information technology aims to provide. Even if we could somehow come up with enough skilled people, the complexity is growing beyond human ability to manage it. As computing evolves, the overlapping connections, dependencies, interacting applications become faster than any human can deliver.

IBM's solution proposal includes designing and building computing systems capable of running themselves, adjusting to varying circumstances, and preparing their resources to be handled most efficiently. These autonomic systems must anticipate needs and allow users to concentrate on what they want to accomplish rather than figuring out how to fix the computer related problems (IBM, 2001).

According to IBM (2001: 20), the most direct inspiration for this functionality is the autonomic function of the human central nervous system which regulates body temperature, breathing, and heart rate without conscious thought, description of which follows in more detail;

> It tells heart how fast to beat, checks blood's sugar and oxygen levels, and controls pupils so the right amount of light reaches eyes. It monitors body temperature and adjusts blood flow and skin functions to keep it at 98.6ºF. It carries out these functions across a wide range of external conditions, always maintaining

> a steady internal state called *homeostasis* while readying your body for the task at hand…But most significantly, it does all this without any conscious recognition or effort on human part. This allows human to think about what he wants to do, and not how he'll do it.

IBM (2001: 24) defines its autonomic computing project, which is similar to this structure, under six main items:

1. An autonomic computing system needs to know itself and comprise components that also possess a system identity;
2. An autonomic computing system must configure and reconfigure itself under varying and unpredictable conditions;
3. An autonomic computing system never settles for the status quo, it always looks for ways to optimize its functioning;
4. An autonomic computing system must self-heal itself;
5. An autonomic computing system must be an expert in self-protection;
6. An autonomic computing system must know its environment and the context surrounding its activity, and must act accordingly;

From this perspective, an autonomic computing system has detailed knowledge of its components, current status and all interactions with its surrounding to govern itself. It's precisely this awareness that autonomic computing requires. Moreover, this system configures itself automatically. In order to do this, it makes dynamic adjustments of its components by using advanced feedback control mechanisms. Additionally, this system is able to discover potential problems and then find an alternate way of using resources or reconfiguring the system to keep functioning smoothly.

The vision of autonomic computing defined above is important in terms of shedding light on the self-adaptivity concept that forms the future vision of software. The following sections will analyze self-adaptive software in accordance with these terms and derive respective outcomes.

3.5 Comparison of Conventional and Self-Adaptive Software from Cybernetic Perspective

This section will elaborate software's conventional and self-adaptive structures explained above as control systems within a cybernetic perspective and will analyze accordingly the change in software's structure and characteristics. The four central concepts of cybernetics defined in Chapter 2 will constitute a reference point for this analysis and appropriate derivations will be made using these concepts.

3.5.1 Conventional Software

Software in conventional terms can be defined as a control system. This control system has at least two components; the controller and the controlled object. The software itself is the controller, whereas the entities contained by the software (e.g. such as parameters, statements, and procedures) constitute the controlled objects (Shen and Wang, 2004).

As explained in Chapter 2, the controller changes the controlled object's behaviors by delivering control inputs which force the controlled object to achieve a desired goal. In that sense software, by providing the necessary changes in the controlled entities, achieves the task defined for itself.

Shen and Wang (2004) mention two types of control mechanisms in conventional software: 'open-loop control' and 'closed-loop' (feedback) control. Open-loop control, as a primitive type of control mechanism, generates control inputs offline without feedback from the controlled object. The software system which reacts, for example to the user inputs, passive calls and commands, is mostly like the open-loop control system (e.g. calculator, voice recorder). It does not concern or evaluate its output and current state, but passively reacts to the changes of its environment (Shen and Wang, 2004).

On the contrary, closed-loop control, as a product of cybernetic theory, generates control inputs from both the environment and the controller object's feedback. A complex software system, which is employed in dynamic environments, is mostly like the closed-loop control system (e.g. park sensors, cruise control systems). It senses and evaluates its output and actively reacts to the changes in its environment (Shen and Wang, 2004).

According to Shen and Wang (2004), the functioning of software with closed-loop control mechanism:

- senses the current states of controlled entities;
- evaluates the sensed data;
- changes the controlled entities;

This functioning is the control schema based on the fact of feedback put forth by cybernetic theory. The concept of 'conditional control transfer' defined by Von Neumann (1945) has been a basis in the development of the control schema within the framework of software. According to the author of this thesis, if conventional software with closed-loop control mechanism is defined through the central concepts of the cybernetic theory, following is correct.

I. It has an *allopoietic structure*.

The software has been programmed to serve another entity distinct from its own existence. The fundamental goal of software as an artificial system is assigned to the software by its designer as a pregiven utility.

II. It has a *static control mechanism*.

The software functions according to the control parameters determined by the designer and these parameters cannot be changed during execution. In order for the software to optimize its own control mechanism in the changes that occur in the structure of the control entities, it requires manual adaptation by the designer.

III. It has a *static model*.

For the conventional software, the model (knowledge) for the controlled entities has been determined by the designer and is static. The software makes decisions and executes them according to this static model. For the software to be able to continue functioning in case of change in its environment, it requires the interference of the designer.

Feedback control mechanism which is involved in cybernetic theory, constitutes an important element for conventional software. Thus by observing and assessing the change in the controlled entities, the software forms the decisions that it will be taking anew. However, the software can only control the controlled objects, therefore it hasn’t got a structure which enables it to monitor its control mechanism and adapt it accordingly when necessary. That is why the engineer must have absolute control over the software. Any change which may occur in the conditions surrounding the software necessitates manual adaptation of the software by the engineer.

3.5.2 Self-Adaptive Software

Self-adaptive software has an adaptive control mechanism. In defining terms, adaptive control is an advanced form of feedback control which not only adjusts the controlled object but also updates the controller by changing its own parameters (Laddaga and Robertson, 2004). In other words, adaptive control distinguishes itself from the feedback control through its adaptive controller and a mechanism for adjusting its own parameters. Shen and Wang (2004), defines the functioning of software with adaptive control mechanism in the following manner:

- senses the current states of controlled entities;
- evaluates the sensed data;
- generates adaptive models and maps them into controlled entities’ properties;
- changes the controlled entities;

According to the author of this thesis, if self-adaptive software is defined through the central concepts determined by cybernetic theory:

I. It has both an ‘allopoietic’ and ‘homeostatic’ structure.

Self-adaptive software, even though programmed to serve an entity other than itself, has a structure which allows it to be aware of its functioning at the same time. Such structured software preserves its internal stability while carrying out a task it has undertaken and when necessary, reacts to disturbances and changes it senses. The self-protection and healing features offered by IBM's 'autonomic computing' project can be considered as an example for the homeostatic structure of self-adaptive software.

II. It has an adaptive control strategy.

The control mechanisms of self-adaptive software possess features that can change not only the entities they control but also their own parameters which constitute the controller. In contrast to conventional software, it monitors both the functioning of controlled entities and its own functioning and adapts its system in accordance with its environment and requires no manual adaptation.

III. It has a dynamic model building mechanism.

The model that self-adaptive software has, being more than a statistical data, is formed as a result of the interaction between the system and its environment. At the end of each new interaction, this model is re-formed. In that sense, self-adaptive software enjoys to a certain extent a model-building structure and thanks to this structure it does not require manual adaptation by the designer. It can form models on its own.

3.5.3 Outcomes of the Comparison between Conventional and Self-Adaptive Software

The outcomes of the comparison between conventional and self-adaptive software can be summarized in Table 3.1. At the end of this comparison, the following conclusion can be derived: the concept of self-adaptivity which is considered relatively new, frees software from being just a tool which requires that its tasks be defined by the engineer, and turns it into an autonomous system aware of itself and its environment. The similarities that IBM traces between self-adaptive software and the human nervous system in the project of ‘autonomic computing’, is an appropriate demonstration of this fact.

	Conventional Software	Self-Adaptive Software
GOAL	*ALLOPOIETIC*	*ALLOPOIETIC & HOMEOSTATIC*
CONTROL	*STATIC*	*ADAPTIVE*
MODEL	*STATIC*	*DYNAMIC*

Table 3.1 – Comparison of Conventional and Self Adaptive Software

In that sense, the most significant advantage that self-adaptive software gains in favor of functioning like a living autonomous system is the constructivist structure it takes over. Unlike the static structure of conventional software which is designed as algorithm + data by its designer, it has a dynamic structure which senses its own functionality and interferes when necessary. The model it forms about its environment being much more than passive data, enjoys a dynamic structure which shapes as a result of interaction. In other words, self-adaptive software being no longer an ‘observed system’ determined by first-order cybernetics, can be defined as an ‘observing system’ determined by second-order cybernetics. This means that while conventional software can readily be defined in terms of first-order cybernetics theory, the dynamic nature of self-adaptive software requires not only the concepts of goal-directedness and feedback but also constructivist perspectives such as knowledge and model-building.

As has been mentioned above, a certain amount of time has to pass for software to assume a completely self-adaptive structure. The speed of the software’s evolution starting from the second half of the 20th Century until today suggests that the time needed will not have to be that long. The passing onto self-adaptive structure involves not only the field of software engineering but all fields where software is used as a control mechanism. The evolution of software simultaneously ensures that these fields too undergo a similar evolution according to their requirements. In that sense, the outcomes of the analysis carried out in this section involve all software-embedded applications and shed some light on future visions.

3.6 Comparison of Conventional and Self-Adaptive Structures in Software Embedded Applications

This part will focus on the software based change that takes place in the structure of software-embedded applications that interact with the user. In that manner, it will undertake the issue of World Wide Web (Web) applications where adaptive structure is most frequently used in the present day. First, the current situation of Web applications will be analyzed followed by the elements involved in the passage to adaptive structure. Then, the difference between these applications' conventional and adaptive structures will be examined from the cybernetics perspective. Because the change seen in the applications' structure involves mostly software, this comparative study will constitute a reference not only for the Web but for all applications having adaptive structures.

3.6.1 Current Situation on World Wide Web

As Perkowitz and Etzioni (1999) argue, information that exists on the Web and the users that have produce this knowledge or have an access to it reached to vast numbers. This state is not static but is a constantly changing, dynamic condition and it turns the Internet into a chaotic system. The Web's popularity as a global information system that is increasing daily, causes the amount of information it contains to grow in an amazing speed.

From the users' point of view, when such an amount of information does not reach the mass in an appropriate way, to be able to find useful information on the Web may turn into a painful and scary experience. If Web is to preserve its classic structure, it will become an abyss of information that contains infinitive information but cannot lend itself to the service of the user in an efficient way (Perkowitz and Etzioni, 1999).

In that respect, websites need to be more dynamic and assume a structure which can adapt itself according to the user. As a result of such interaction with the user, they could become more personalized. Accordingly, the fundamental element in the progress of web applications into adaptive structures is to provide each user with the information flow filtered according to that user's preferences. Sheth (1994) defines the essential characteristics that the Web should assume in its new phase under three headings: specialization and personalization, adaptation, and exploration. Brief descriptions of these characteristics are as follows:

Specialization/Personalization: Web applications must serve for the specific interests of the user. The applications should select information deemed to be interesting to the user and eliminate the rest. Moreover, they should be able to identify patterns in user's behavior by involving repeated interactions with the user. The applications should also infer the habits of the user and specialize themselves accordingly.

Adaptation: Since information filtering typically involves interaction over long periods of time, user's interest cannot be assumed to stay constant. When the user's interest changes, the applications should first be able to notice the change. The applications should also adapt their behavior in response to the change.

Exploration: Web applications should be capable of exploring newer information domains to find something potentially interesting for the user. There are two motivations for exploration. One is that exploration helps match a presently unknown but real user interest. The other motivation is that it helps improve the adaptation process. This is the case because newer kinds of information need to be explored to serve the changing user interests.

3.6.2 Conventional Web Applications

The fundamental communication mechanism of the Web is known as 'Hyper Text Transfer Protocol' (HTTP). In conventional manner, HTTP is a simple, stateless, request-response system. It basically consists of two modules: a 'browser' which enables the user to reach the Web, and a 'server' where the information is stored (Figure 3.1). A browser connects to a server, sends a retrieval request, the server sends the requested document and then closes the connection (Barrett and Maglio, 2004).

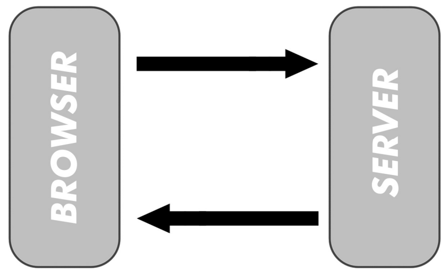

Figure 3.1 – Conventional Web Communication Diagram (Barrett and Maglio, 2004)

3.6.2.1 Characteristics of Conventional Web Applications

In conventional Web applications, the software which operates the system has an open-loop control mechanism that generates control inputs offline without feedback from the controlled object. It does not concern or evaluate its output and current state, but passively reacts to the requests from the browser and the server. In terms of the control mechanism of conventional Web applications, it assumes the characteristics of conventional software as:

I. It has an *allopoietic structure*.

The fundamental goal of the system is to ensure the transfer of information by appropriately establishing the connection between the browser and the server.

II. It has a *static control strategy*.

The control mechanism of the system regulates the connection established between the browser and the server. This control functions according to the parameters determined by the designer and since parameters are static, the functioning of the system cannot be altered.

III. It has a *static user-model*.

The system defines each user through a single model. The user-model that the system assumes has been assigned to the system by the designer and the interaction the system has with the user has no effect upon this model. The system functions for each user and for all times in the same manner. Whether the user is using the system for the first time or has been using it for a year, the system operates and executes its defined task (to communicate between the browser and server) in the same way.

3.6.2.2 Example of a Conventional Web Application: www.cnn.com

CNN's official web site can be given as an example for conventional web applications (Figure 3.2). The news determined in the server are then reflected on the browser by www.cnn.com. The site does this through its static structure and without any interference. It does not consider or evaluate its output and current state, but passively reacts to the requests from the browser and the server. In this structure, every user sees the same Web interface in the same way. Thus, every information resource is equally proximate to a user, and the accessibility of information is completely impersonal.

Figure 3.2 – A Screenshot from CNN Website (CNN, 2007)

3.6.3 Adaptive Web Applications

New generation Web applications with an adaptive software structure, aim to turn the impersonal nature of the Web into a personal one. Many software types and structures are being used to that end but these resemble each other in terms of fundamental principles. As a reference, it will be useful to look at the WBI (Web Browser Intelligence) technology developed by IBM as one of the major software development companies.

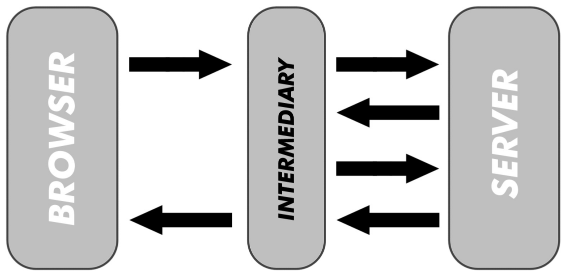

Figure 3.3 – WBI Web Communication Diagram (Barett and Maglio, 2004)

WBI technology is based upon the following principle: between the server and the browser which are the two elements of conventional Web, a self-adaptive module defined as 'intermediary' is added (Barrett and Maglio, 2004). While in the conventional model, the user connects directly to the server through the browser, in the new structure he connects to an intermediary (Figure 3.3). *Intermediary* can be defined as the computational element that lies along the path of web transactions (Barrett and Maglio, 2004). Intermediary has access to Web data at all points, and is able to observe, respond to requests, and modify both the request and the resulting documents.

The intermediary consists of numerous sub-systems that function simultaneously. WBI technology defines these sub-systems as 'agents'. As Barrett and Maglio (2004) imply, these agents attach themselves to the information stream, observe the data flowing along the stream, and alter the data as it flows through the browser. The agents can learn about the user, influence what the user sees by marking-up pages before passing them on, and provide entirely new functions to the user through the web browser.

The intermediary consists of four main types of agents:

- monitor agent
- cognitive agent
- editor agent
- autonomous agent

When the user connects to the 'intermediary' module through the browser, these agents simultaneously become active. According to Barrett (2004), the functioning of intermediary can be portrayed as follows.

The monitor agent records all the interaction occurring between the user and the intermediary. In a sense, it traces user's history. When considered as a cybernetic system, the monitor agent undertakes the role of perception in the system. It is not allowed to make decisions. It is only responsible for recording the movements of the user and communicating them to the cognitive agent (Barrett and Maglio, 2004).

After the user history is formed by the monitor agent, the cognitive agent starts to form a model of the user and decides what type of information flow is to be provided to the browser. The model formed is dynamic and is re-formed by the system each time the user interacts with the intermediary. The cognitive agent assumes two fundamental roles in the cybernetic control mechanism: model building and decision making (ibid).

According to the decisions made by the cognitive agent, the editor agent selects the appropriate information from the information mass in the servers and reflects these to the browser. In the cybernetic system it assumes the role of executing actions. Simultaneously to the functioning of the system, the autonomous agent explores new servers and records the data concerning the user model. It keeps these ready to show them to the user when necessary (Barrett and Maglio, 2004).

3.6.3.1 Characteristics of Adaptive Web Applications

The software that operates the adaptive Web application has an adaptive control mechanism. As mentioned before, adaptive control is an advanced form of feedback control, which not only adjusts the controlled object but also updates the controller by changing its own parameters. In the sense of control mechanisms, Web applications assume the characteristics of self-adaptive software.

I. It has both an *'allopoietic' and 'homeostatic' structure*.

Even though the system has been programmed for a task that has been defined for it, it has a structure which is able to interfere with its own structure too. It cannot be said that the system has an advanced homeostatic structure. However, the ability to sense its own functioning and to adapt it to varying conditions mean that the system assumes some control in the sense of preserving its own stability.

II. It has an *adaptive control mechanism*.

The adaptive control mechanism assumed by the system has the properties to change its own parameters as controller. The system can make the appropriate regulations in its functioning according to the user model it has built.

III. It has a *dynamic model building mechanism*.

The user model of the system is more than statistical data. It is built as a result of the interaction between the system and the user and this model is re-formed after each new interaction. In that sense, the system assumes a model-building function to a certain extent.

The new Web model transfers the load of the server which has full responsibility in the conventional Web, onto the intermediaries which assume an adaptive structure. The intermediary gains complete control over the content that is delivered to the browser. Unlike conventional Web applications, the new generation Web application with adaptive structure personalizes the impersonal nature of the web and the user thus reaches information that has been filtered according to its interests and tastes.

3.6.3.2 Example of an Adaptive Web Application: www.spotback.com

www.spotback.com, a new generation personalized news site, can be given as a current example of adaptive web applications (Figure 3.4). The idea behind Spotback is based on the understanding that every user has his/her own interests and tastes. Unlike conventional news sites' static structure, it is designed to quickly learn the user's fields of interest and style by analyzing how users rate and interact with news information. It then offers users the most interesting, relevant and hard to filter news information, tailored to their taste.

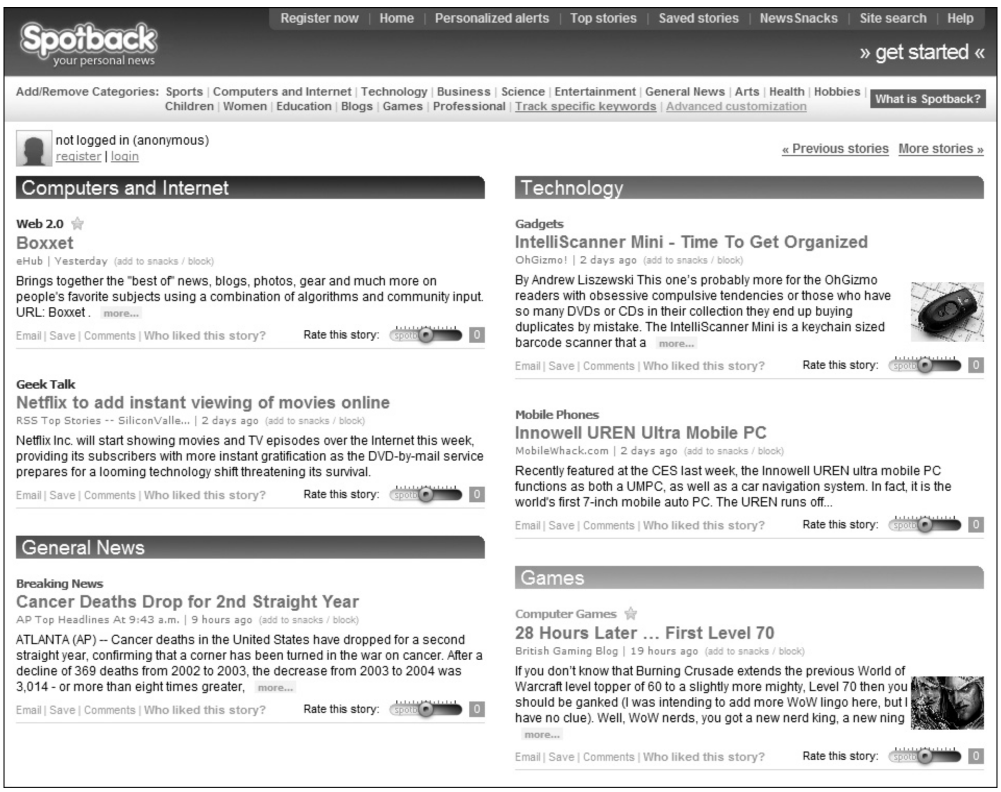

Figure 3.4 – A Screenshot from Spotback Website (Spotback, 2007)

The innovation that Spotback brings is its design. Thanks to its design, as a result of the interaction between the user and the news, the system can shape the model it builds about the user: There is a rating slider bar under each news heading so that the system can receive positive or negative feedback from the user (Figure 3.5). The user can rate each news from -5 to

+5. In response to the values given on the slider bar, the news on the site are updated in real-time.

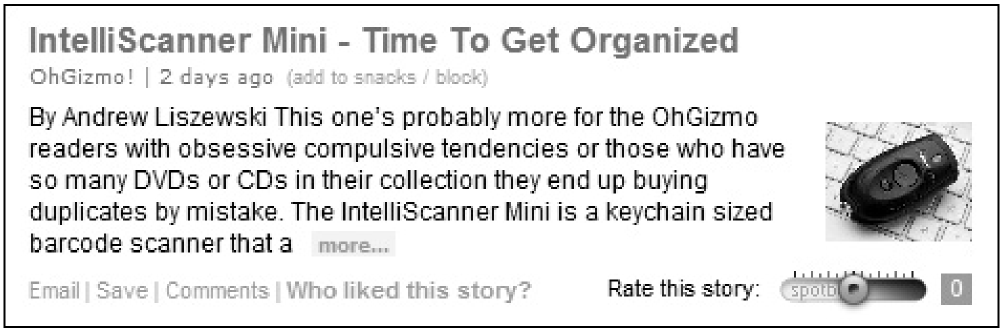

Figure 3.5 – A Screenshot of User News-rating Bar from Spotback Website (Spotback, 2007)

When Spotback receives positive feedback, it airs news that are more close to that perspective and when it receives negative feedback, it removes news of that kind. For example, if the user makes a search about Turkey and rates sports news low while he/she rates political subjects high, Spotback revises the model it has formed of the user. It builds a user model less interested in sports and more in politics. According to this model, Spotback starts to change both the news that are actively found on the page and the type of news that it will offer the user from then on. Ultimately, the more the system interacts with the user, the more the dynamic user model becomes concrete.

Spotback selects information deemed to be interesting to the user and eliminates the rest. Thus every user can engage in a news page that is filtered according to his/her personal tastes and interest. Moreover, according to user reviews (Digg, 2007), Spotback does get some negative comments together with the positive ones. One such comment is that conventional news sites users' have difficulty in adapting to the new structure. In fact, it will take some time for users who are used to conventional websites to adopt the features of use of an interactive site such as Spotback. Even though Spotback is criticized by some, it is a clear fact that with its adaptive structure, it has made a groundbreaking contribution to the concept of news site.

3.6.4 Outcomes of the Comparison between Conventional and Adaptive Web Applications

The outcomes of the comparison between conventional and adaptive web applications can be summarized in Table 3.2. At the end of this comparison, the following conclusion can be derived: adaptive applications become less static and exhibit more dynamic functioning. They are evolving in such a way that they sense the behavior of the user and make decisions accordingly. Instead of using pre-given models for their users, applications now form user models thanks to their model-building features. They can form themselves and make decisions according to this dynamic model.

	Conventional Web Appl.	Adaptive Web Appl.
GOAL	*ALLOPOIETIC*	*ALLOPOIETIC & HOMEOSTATIC*
CONTROL	*STATIC*	*ADAPTIVE*
USER-MODEL	*STATIC*	*DYNAMIC*

Table 3.2 – Comparison of Conventional and Self Adaptive Structures in Web Applications

The study made about the change in the structure of Web applications constitutes a reference valid for all software-embedded applications that interact with the user. Whatever functions the applications carry, for example, Web applications that provide transfer of information, mobile phones that provide communication, and radios that broadcast music, when they assume adaptive features, the fundamental principles of the changes they undergo in their structure is similar.

3.7 Chapter Summary

This chapter examined the development of software, which constitutes the basis of today's control technologies, towards a self-adaptive structure. Positive outcomes of this process were discussed in relation to the cybernetic concepts. Thus with this study, a point of reference in terms of software has been formed for the following chapter where the changes in adaptive products and their functioning principles are discussed in depth. The role assumed by the concept of adaptivity in the field of product design will be more clearly laid out.

CHAPTER 4

INTEGRATION OF ADAPTIVITY CONCEPT IN PRODUCTS

4.1 Introduction

Today it is an inevitable fact that increasing number of products are becoming software-embedded: as for control mechanisms the mechanic infrastructure they had is gradually turning out to be software-dependent. Hence product design is becoming all the more dependent on the development of software engineering, and is taking the advantage of the innovation possibilities it brings about. While product design used to make use of software only to be freed from mechanic control mechanisms, currently thanks to the flexibility it provides, software is used in many areas.

Therefore, this chapter will look at how self-adaptive software described in Chapter 3, is reflected upon the field of product design. The purpose of this chapter is to determine the need for the concept of adaptivity in product design and to lay out the application domains and possible future threats of products with self-adaptive software.

This chapter will also introduce the concept of *Ambient Intelligence* which involves the implications of the concept of adaptivity in everyday-life and will attempt to make appropriate derivations through this term. First, the concept of *Ambient Intelligence* will be defined, after which the adaptive features of the vision it draws in everyday-life will be explored. Secondly, the application domains of adaptive products will be analyzed with reference to the concept examples. Finally, potential threats that adaptive structure holds will be laid out. This part will mainly refer to the analysis of self-adaptive software within a cybernetic perspective elaborated in the previous chapter.

4.2 Ambient Intelligence

The concept of *Ambient Intelligence* (AmI) has been developed by the Information Society Technologies Advisory Group (ISTAG) during the last decade. It is originated from the vision of the future Information Society where people are surrounded by intelligent, adaptive and intuitive interfaces that are embedded in all kinds of products and an environment that is capable of recognizing and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way (Friedewald and Costa, 2003). AmI can also be named as a new paradigm in which people are empowered through a digital environment that is aware of their presence and is sensitive to their needs, habits, gestures and emotions (Punie, 2003).

It is a vision based on the idea of *ubiquitous computing* that consists of an integrated system of advanced computing devices which become invisible but available anytime and anywhere (Punie, 2003). However, Ambient Intelligence aims at taking *ubiquitous computing* one step further by realizing devices and environments that are sensitive and adaptive to the presence of people and its context (Friedewald and Costa, 2003). In this sense, as highlighted by Friedewald and Costa, AmI acts as the merger of two important visions or trends: *ubiquitous computing* and *social user interfaces*:

> AmI builds on advanced networking technologies, which allow robust networks to be formed by a broad range of mobile devices and other objects (ubiquitous computing). By adding adaptive user-system interaction methods, based on new insights in the way people like to interact with computing devices (social user interfaces), digital environments can be created which improve the quality of life of people by acting on their behalf. These context aware systems combine ubiquitous information, communication, and entertainment with enhanced personalization, natural interaction and intelligence (2003: 14).

According to Aarts and Roovers (2003), the vision of AmI assumes a shift in computing from desktop computers to a multiplicity of computing devices in our everyday lives whereby computing moves to the background and intelligent, ambient interfaces to the foreground. Therefore, the vision of AmI places the user at the centre of future development and designs the technology for the people rather than making people adapt to the technology. The emphasis turns out to be on greater user-friendliness, more efficient services support, user-empowerment and support for human interactions.

AmI signals a move beyond concepts which tend to objectify the relationship between people and technologies. In this manner, ISTAG introduces a new term called *Ambient Intelligent Space* (AmI Space) to realize this vision.

4.3 Ambient Intelligence Space

ISTAG proposes a new approach to realize the AmI as a medium to bridge the gap between technologies and societal and economic challenges in a person's environment. The AmI proposes utilization of technologies, infrastructure, applications and services and the integration between them within the AmI space for assisting person to overcome the social and economic challenges.

ISTAG adopted a '3-layer' model, with the social and economic challenges as the top layer, technologies as the bottom layer, and AmI Space as the 'middle layer' (Figure 4.1).

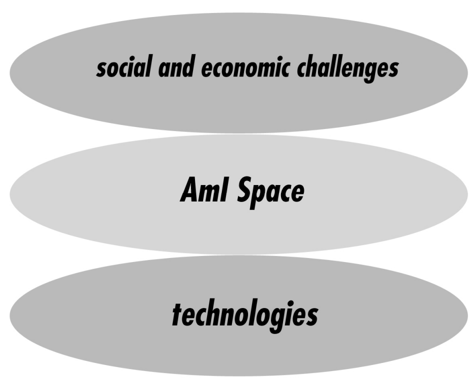

Figure 4.1 – '3-layer' Model of AmI Space (Punie, 2003)

AmI Space is composed of collaborative sub-spaces, of devices, services and the connecting networks. It consists of the collection of technologies, infrastructures, applications and services enabling AmI (Punie, 2003). AmI Space can be seen as the integration of functions at the local level across the various environments, and enables the direct natural and intuitive dialogue of the user with applications and services spanning collections of environments allowing knowledge and content organization and processing (Punie, 2003).

In AmI Space, people are surrounded with networks of embedded intelligent devices that provide ubiquitous information, communication, services and entertainment (Aarts and Roovers, 2003). Furthermore, the devices adapt themselves to users, and even anticipate their needs (Figure 4.2). AmI Space presents itself quite differently compared to contemporary handheld or stationary electronic boxes and devices. Electronics will be integrated into clothing, furniture, cars, houses, offices and public spaces which users interact with in the same way as they interact with each other (Punie, 2003).

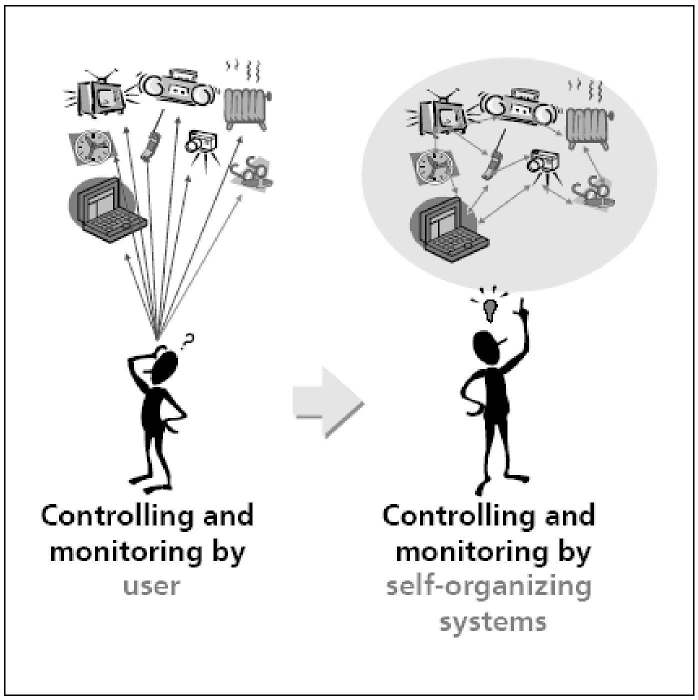

Figure 4.2 – Adaptive Structure of AmI Space (Aarts and Roovers, 2003)

A series of characteristics that AmI Space offers in relation to user and environment, can be summarized as follows (Friedewald and Costa, 2003). AmI Space can:

- be aware of the specific characteristics of human presence and personalities;
- be capable of responding intelligently to spoken or gestured indications of desire;
- create an unobtrusive interaction with the user;

- model the environment and sensors available to perceive it, to take care of the environment model;
- model the user behavior to keep track of all the relevant information concerning a user, automatically builds the user preferences from his past interactions and eventually abstracts the user profile to more general community profiles;
- interact with the user by taking into account the user preferences. Natural interaction with the user replaces the keyboard and windows interface with a more natural interface like speech, touch or gestures;
- configure and reconfigure itself under varying and even unpredictable conditions;
- an expert in self-protection in a heterogeneous environment;
- guarantee the quality services as perceived by the user;
- control security aspects to ensure the privacy and security of the transferred personal data and deal with authorization, key and rights management;

Accordingly, AmI space is constructed in a manner that AmI is personalized according to the user preferences. Thus, taking into account relations between user and environment AmI provides a context sensitive condition and communicate with the user in a medium that natural interfaces are used.

Today, there are a lot of initiatives to realize the concept of Ambient Intelligence. Three of the most prominent ones might be considered as *Easy Living Project* developed by Microsoft, *PHENOM Project* developed by Philips Research Center and *Cool Town Project* developed by HP. They have the common aim: to ease users' lives, to provide an 'adaptive', 'intelligent' and 'aware' environment. Apart from Microsoft, HP and Philips, many respectable design and manufacture companies develop joint projects with competent software companies in the areas of AmI. Referencing these projects, the active role that the concept of Ambient Intelligence will play in the future is apparent.

4.4 Application Domains of AmI

The concept of AmI has a wide range of application areas. Potentially, all fields involving the use of software can be associated with this concept. However, in the article 'Ambient Intelligence in Everyday Life', European Science and Technology Observatory (ESTO, 2003) defines the major domains of application of AmI as home, mobility, health, shopping and commerce, education and learning, culture, leisure, and entertainment (Figure 4.3). It is evident that in the future AmI will possibly take part and penetrate all sections of human life.

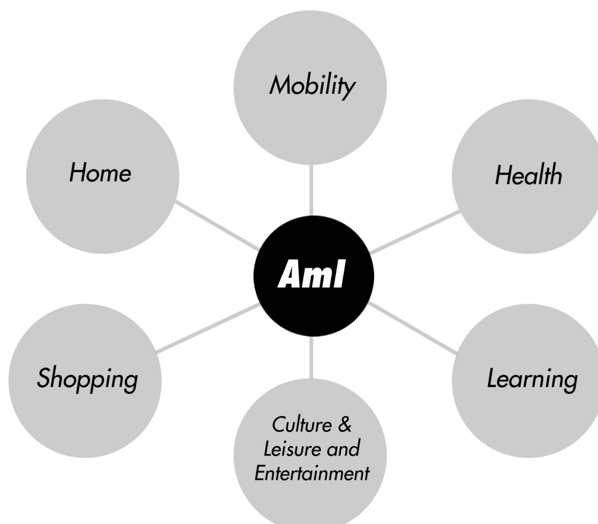

Figure 4.3 – Major Application Domains of AmI (ESTO, 2003)

The concept of AmI can mostly be associated with the domain of *home*. As Castells (1996) points out, 'home centeredness' is one of the leading trends in today's society. People not only rest but, with the increasing technological opportunities, work and manage services at their homes. Home, by gaining such additional roles, constitutes an ever increasing potential for AmI applications. As a result, various design and manufacturing firms, and particularly Philips Research Center, have chosen the domestic field for developing their AmI concept projects.

After home, it is the domains of mobility and health application that ESTO (2003) is mostly associated with. The facts that people are increasingly adapting a mobile life-style and the mobility application domain is gaining added functions are influencing factors upon this association. And in the domain of health, driving trends such as increasing personalization, context dependency and overcoming the limitations of time and place require the necessity of the concept of AmI.

From the major application domains of AmI, home, mobility, health, shopping, learning, culture & leisure, and entertainment domains will be presented and supporting examples of current and future applications will be discussed.

4.4.1 Home Domain

As mentioned above, domain of home plays the central role in the field of AmI. The criteria that people are spending more time at home than in any other space makes the application area of this domain quite wide. Another important criterion is that home is concerned with people, spaces, rooms, artifacts, furniture, equipment and their various combinations in terms of time and space. According to ESTO (2003), there are three basic functions that home application domain covers. These are; a) home automation, b) rest, relaxation and refreshing, c) household work

Following sections will discuss these basic functions of home domain and their possible AmI applications.

a. Home Automation

In home automation, the main goal of AmI is to bring added value to the user by making the control of existing service functionalities of home (e.g. HPAC, fire and burglary alarms and control of electronic appliances) easier, integrated and even automated (ESTO, 2003).

According to Rentto et al. (2002), most of the functionalities of home automation system currently exist on the market without any intelligence. The user may control lights or house warming with the existing switches and controls. In the home of the future, AmI will enable controlling these functions through touch panels and eventually by voice, hand gestures, face expressions (ibid). The AmI within the home domain means that the home automation system identifies the resident and adjusts service functionalities of home according to the known preferences.

Examples of possible future scenarios include:

- Turning on the favorite music or TV channels automatically;
- Adjusting certain degree of lighting and heating;
- Adjusting window shades in accordance with sunlight;

Accordingly, service functionalities of home can be more efficiently and securely provided to the users with the AmI applications.

b. Resting, Relaxation and Refreshing

Sleeping can be considered as the most important form of resting. People spend quarter of a day in the bed. There is a need for AmI applications providing pleasant ways of waking up as opposed to conventional approaches where a clock radio has been set by a timer to give a noisy wake up. Some scents of favorite flowers, movements of the bed, or beautiful scenery projected on the wall or ceiling could also be integrated to such an *AmI wake up call* (Riva and Vatalaro, 2005). Furthermore, smart devices can also be concentrated on connections inside the house, giving signals to other people in the house of sleeping persons in order to avoid disturbance (Rentto et al. 2002).

Besides sleeping, there are various degrees of rest which can also be done in other rooms than bedroom alone. In this respect, resting could also be supported by AmI applications, such as sensors embedded into the furniture measuring the resident's pulse, blood pressure and suggesting different kinds of electronic massage or acupuncture (Riva and Vatalaro, 2005). Since having permanent control over basic health concerns have become remarkable for people, such applications related to health are considered to assist comfort.

Another function closely related to resting and relaxation is concerned with the basic needs of the residents to refresh themselves and take care of their hygiene at home (Intille, 2002). Bathing and showering space (bath, shower and sauna) could be equipped with AmI. Setting the initial temperature of water by identifying the user and playing the expected background music can be given as an example.

Other activities like tooth brushing, combing, shaving normally take place mostly in the bathroom in front of a mirror. Already at the experimentation level of Philips Lab, there is an AmI innovation where the bathroom mirror not only reflects user's image on its surface, but also the clock, personalized news, the weather report or cartoons for the children (Philips, 2003). The same application can also display user's weight and then report on his cardiovascular health, even giving advices on improvement.

Thus, besides its functional features, technological developments in AmI also assist human comfort like resting, relaxation and refreshing.

c. Household Work

Household work is perceived as a domain covering all basic activities like cleaning, laundry work, cooking, preparing meals, washing up, sewing for keeping the house as a comfortable place to live in.

House cleaning can be facilitated by more efficient vacuum cleaners and eventually by cleaning robots embedded with sensors for orienting themselves according to obstacles (ESTO, 2003). AmI would also be needed for the cleaning robots to discern small items on the floor, and to tell the difference between a trash and valuables (Friedewald and Costa, 2003).

Washing machines can be considered as the main technological tools for cleaning and taking care of clothes. AmI could mean that the machines themselves could conclude from the degree of dirtiness the need for a certain program (ibid).

Cooking and preparing meals is a function that is at the same time on one hand very basic and routine and on the other hand a very social happening. The process begins with preparing the meal, having the meal and cleaning up. AmI could be applied to establishing a database of, for example, guests' food preferences, allergies, previous caterings and suggesting menus. In cooking, the oven could become aware of the degree and need of cooking time for a given portion of food and regulate its heat (Riva and Vatalaro, 2005).

According to the technological developments of AmI for the applications of home domain, in the future, conventions of living will transform and living in home will become the trend of the new society.

4.4.2 Mobility Domain

Concept of mobility is another drastically transforming issue of contemporary society that applications of AmI plays significant role within the new definition of mobility. AmI technologies propose alternative solutions within the domain of mobility by bringing together various issues related to mobility as mentioned below.

Mobility, as a general application area for AmI solutions in everyday life, can be studied under four main categories which are a) safety, b) navigation, c) mobile information, d) traffic management (ESTO, 2003):

a. Safety

The increase of car safety is one of the most important needs to be addressed by AmI technologies. As stated by ESTO (2003), the car, compare to other fields of application, has better prerequisites with respect to the available space and energy. Although it is difficult to distinguish between traditional car electronics and AmI applications, the distinctive feature will be the awareness of the car of its environment and its driver’s behavior (Bauer and Berger, 2001). AmI technology offers the opportunity to monitor the driver’s physical condition, to diagnose signs of incapability to drive, to warn the driver and to influence intelligently the driver’s behavior.

Examples of possible future scenarios include:

- Body sensors measuring blood pressure, skin conductivity or certain substances (e. g. alcohol, drugs) in the exudations of the driver (Bauer and Berger, 2001).

- Video sensors monitoring the driver's eye movements, blink duration and frequency in order to recognize indirectly the degree of alertness, stress or distraction (Friedewald and Costa, 2003).
- Detection of hazardous environmental conditions (e.g. slipperiness, limited visibility) (Friedewald and Costa, 2003).

Since our capacity of bodily functioning can not take up with the technological developments within the mobility domain, safety concerns have become prominent.

b. Navigation

AmI technology would enable gaining access to information on road conditions (e.g. road construction, road surface condition) and current and expected weather conditions. By using AmI technologies, location-based information, such as nearest train station, taxi, ticket vendor, porter service, booking office, hotels, restaurants, could be augmented with real-time traffic information, along with the availability of alternative transportation, time tables and delays, and with navigational support (Bauer and Berger, 2001).

Examples of possible future scenarios include:

- Information on slippery roads due to oils spills or water will be immediately processed and respective warnings of impeding slow-downs and delays issued to drivers in the area and those headed in the affected direction (Friedewald and Costa, 2003).
- Real-time reservation of guaranteed parking space will be possible using the on-board communication and navigation system (Bauer and Berger, 2001).
- Navigation systems will automatically download latest navigation information from servers (Bauer and Berger, 2001).

Therefore, AmI applications, proposing a location-based information system and taking into account alternatives of transportation, provides more effective use of transportation systems.

c. Mobile Information

Traffic and mobility is a central human need but takes up a lot of time in everyday life. During that period the traveler/driver should have access to all information he needs in the same way as one has in the office or at home.

AmI provides the opportunities to further personalize the information and to make it both contextually and action dependent. According to ESTO (2003), within the next decade, it is expected that the driver information systems will not only provide navigation aids, but also integrate functionalities in the areas of personalized entertainment, information and telecommunications for the driver and other passengers.

Examples of possible future scenarios include:

- Connect personalized information from other areas of the user's life with mobility information (Bauer and Berger, 2001).
- Automatic contact of emergency services, reporting vehicle location and damage (Friedewald and Costa, 2003).
- Give information about, for example; accommodation, restaurants etc. along with the travel route (Bauer and Berger, 2001).

Since domain of mobility plays a significant role in a person's life and a person spends considerable amount of time by traveling or driving, AmI also integrates personalized information from other domains into the domain of mobility.

d. Traffic Management

In future, integrated traffic management systems will become increasingly important to handle the growing volume of traffic and to prevent the potential traffic infarct as well as reducing the environmental burden. AmI technologies could play an essential role in vehicles and wearable devices to provide data for advanced integrated traffic management systems.

As stated by Lindwer and Marculescu (2003), employing AmI electronic traffic guidance systems, traffic can be routed for undisturbed flow. This can be done via strategically located electronic boards or using mobile communication. A more direct way would be to broadcast the relevant information to mobile navigation systems used in cars or to PDAs in case of pedestrians. These systems could automatically compute alternate routes and thus navigate their user around a trouble spot (ibid).

Other examples of solutions within AmI vision include:

- Vehicles headed for over-crowded parking facilities will be automatically re-routed to either free spaces in the immediate vicinity or to a park-and-ride parking area (ESTO, 2003).
- A slow down of traffic automatically reported by cars involved at the scene will cause prediction of potential traffic congestion and deduce alternate routes to take (Lindwer and Marculescu, 2003).
- When approaching a problem area drivers will receive automatic broadcasts with precise and up-to-date directions to navigate around a problem spot (Lindwer and Marculescu, 2003).

Since traffic has been a rising problem for the urban condition of the modern era, AmI technologies also propose solutions to recover the expended time within the traffic.

4.4.3 Health Domain

Within the new societal traditions, since considerations of health have become significantly popular for the people in terms of having a healthy lifestyle, AmI technologies also provide solutions within the domain of health.

Health, as a general application area for Ambient Intelligent solutions in everyday life, can generally be subdivided into three main categories which are a) Prevention, b) Cure and c) Care (ESTO, 2003):

a. Prevention

Prevention is directed towards informing, monitoring and pre-treating of people in order to prevent them from health problems (ESTO, 2003). As asserted by Friedewald and Costa (2003), over the last decades, the promotion of a healthy lifestyle has moved from being only a public consideration to a very powerful commercial trend. As costs of intelligent applications in health field fall down and the health applications are moving towards integration of functions and increasing of personalization, prediction becomes a part of prevention too (Emiliani and Stephanidis, 2004).

AmI systems can monitor peoples' health and health related behaviors, and it could also provide information or take action based on such activities. Moreover, AmI technologies provide opportunities for people to receive or search additional information and consultation about their health problems.

Examples of possible future solutions could be:

- Sensors to alert people with allergies against levels of allergens in the surroundings (Emiliani and Stephanidis, 2004).
- Lifestyle monitoring: monitoring of and subsequent advice on daily activities and food patterns (Emiliani and Stephanidis, 2004).
- Automated consultations between a person's intelligent agent and a health information database.
- Barcode scanners recognizing products with wanted or unwanted ingredients for a specific person (Riva, 2003).
- Intelligent sensoring system connected to the personal health file for predicting near-future health problems (Riva, 2003).

Thus, AmI applications provide people's prevention from health problems by detecting personalized risks of nutrition, allergies, diseases and environmental problems.

b. Cure

Cure is directed towards curing a disease or illness and the short-term recovery process (ESTO, 2003). Today, the activities related with cure (e.g. diagnosis, medical treatment, revalidation) are mostly undertaken by medical and paramedical staff (ESTO, 2003). Overcoming the limitations of time and place, increasing personalization and the drive towards more efficiency are the main drivers that impact this field.

Ambient communication and information sharing facilities and intelligent medical devices can facilitate treatment and even surgery at a distance.

Furthermore, with AmI technology, constant monitoring of patients' conditions or their compliances with medical guidelines will become feasible without those patients having to remain under observation in the hospital (Riva, 2003).

Other examples of solutions within AmI vision include:

- System of self-diagnosing devices on and even inside a patient's body.
- Intelligent implants, e.g. regulating levels of medication (Riva, 2003).
- Ambulant and emergency services supported by ambient information (Riva, 2003).
- Tagging of patients in a hospital, so that they carry all relevant information about health, diagnoses, treatment (Riva, 2003).
- Having patients 'under observation' without them staying in hospital (ESTO, 2003).

Besides preventing health problems, AmI also facilitate medical diagnosis or treatment without being in the hospital or requiring a medical intervention by the assistance of the devices implanted to the body.

c. Care

Care is a collection of more long-term activities directed towards the recovery process of patients and towards the support of everyday life functions of people in need of long-term attention, such as elderly, handicapped or chronically ill people (ESTO, 2003). Caretaking activities are mainly provided by professional nurses, activity companions and by non-professional family members and friends. However, as persons requiring attention are more and more encouraged to live autonomously, and budgets for professional care are tightened, surveillance and presence information become vital requirements in caretaking (Emiliani and Stephanidis, 2004).

Examples of care solutions include:

- Monitoring of activity patterns, sleeping behavior, pre-indications of incontinence etc. (Emiliani and Stephanidis, 2004).
- Monitoring of performance and controlling of assistive technology (Emiliani and Stephanidis, 2004).

Similar to the application mechanism of cure, AmI provides prolonged care applications without the need for human assistance or without being in the hospital environment.

4.4.4 Education and Learning Domain

The new knowledge society offers important opportunities and strategies for AmI applications in the education and learning domain. According to ESTO (2003), lifelong learning is a core element of these strategies. The aim is to make lifelong learning a reality for all people from any place, at any time and at the individuals' own paces.

The AmI puts the emphasis on the learning centered pattern rather than on the teaching centered model (ESTO, 2003). The new education and learning paradigm is based on active learning approach (to learn by doing, communication and sharing) rather than passive learning (e.g. to learn by watching and listening).

In the future, knowledge will be organized in Learning Objects (LO) that represent *a reusable media-independent chunk of information,* where information is considered not only as a document, but, for example, an expert, an experience, and a contact (Friedewald and Costa, 2003). Future scenarios envisage a knowledge space full of LOs like web-seminars, lessons, digital libraries and digital museums. In this knowledge space, a user giving only his user profile will build a personal learning path resulting by LOs connection and integration and suitable with his needs and profile.

Some possible examples given by (Friedewald and Costa, 2003) include:

- AmI reduces the workload of the teacher by helping in planning, preparation of presentations, logging of personal learning history, and even giving homework, assessing it and controlling the whole learning process.
- AmI introduces learning by experience and makes experiences richer by digital augmentation of physical objects and by making objects intelligent.

- Intelligent tools which extract documents and knowledge according to customized user topics, user profile and user goals.

Therefore, AmI presents a system of digitalized media for learning and education domain, accordingly, role of human is minimized and more effective ways of learning and teaching is achieved by proposing personalized methods.

4.4.5 Shopping and Commerce Domain

The-state-of-art in shopping and commerce has changed dramatically in the last few years, due to the coming of electronic business and electronic commerce, which are not only undoubtedly changing shopping traditional habits, but also implying an evolution in retailing and logistic transactions (Bohn, Coroama, 2004). AmI applications in shopping and commerce aim at creating a user-friendly, efficient and distributed service support to the customer, such as managing the search for and selection of merchandisers by the customer, and handling order and payment processes (ESTO, 2003).

Other possible application areas of AmI in shopping and commerce include (ESTO, 2003):

- Personal shopping management which supports the customer to compile items for purchase by intelligently surveying the stocks of food and other goods in the household and linking them intelligently with information about the customers' preferences and habits, which are collected by profiling customers.
- AmI-enabled store which lets shoppers at the site find and select items for purchase by using intelligent tags for goods and by intelligent terminal devices for the customers.
- Order processing which manages payment processing, including tax calculation and credit card transactions. It also includes functions such as management of customer addresses, discount and coupon application, inventory processing and delivery.

Shopping and commerce is still another significantly changing domain in the new societal traditions with the introduction of electronic media. Thus, AmI applications propose reaching at more alternatives of products to the customers. Besides, shopping and commerce in the electronic media provide economical use of time by eliminating face to face relationships between customers and sellers.

4.4.6 Culture, Leisure and Entertainment Domain

AmI has the potential to drive important changes in fields of culture, leisure and entertainment. There are differences between these fields and within each field, many of the AmI functions converge into total experiences, whereby the traditional boundaries between, for instance culture and entertainment, or information and communication, are blurring (Friedewald and Costa, 2003).

The driving forces can be different however, the leisure and entertainment sector together with communication facilities, are more shaped by commercial interest and private industries compared to cultural heritage, participation and socialization. However, for the realization of AmI within these fields, there is no doubt that public-private partnerships between many different actors will be needed.

Some possible examples include:

- Enhance and personalize the experience of visiting historical sites/museums/exhibitions (ESTO, 2003).
- Make self-customization of content possible and context-aware entertainment (e.g. selecting music or programming that fits your mood by relating a songs emotional feel to quantifiable musical features such as tempo and beat intensity (Sleeth, 2002).
- Provide more immersion towards 'total' experiences (e.g. 3-D real time holographic and cross-media content) (Sleeth, 2002).
- Meta-exhibitions: while visiting a painting exhibition, it is possible to virtually access to other paintings of the same authors, from the same school, from the same period, of the same geographical location (ESTO, 2003).
- Recreation and animation of historical or cultural objects or buildings, living experience of traveling through time and/or space (e.g. visit of

the castle in XII century and/or link to similar castles in the same region/country) (Friedewald and Costa, 2003).

AmI applications employ a driving force on the transformation of culture, leisure and entertainment traditions of people. Due to new definitions of physicality, communication and time proposed by AmI, habits of socialization has been changed. Accordingly, culture, leisure and entertainment activities are started to be experienced within the media proposed by AmI.

4.4.7 Overview of Application Domains of AmI

The implications of the concept of adaptivity which constitutes the general theme of the thesis on today's life has been defined through the concept of AmI and a wider approach for discussion has been offered. Within a general framework, AmI, and therefore adaptive systems, ultimately provide a more empowered user in terms of added convenience, personalization, safety and security as well as time and cost savings. This technology has the potential to positively influence the way we work, move, enjoy and live. Furthermore, this vision places the user at the centre of future development, and designs the technology for the people rather than making people adapt themselves to it. As has been mentioned before, the emphasis turns out to be on greater user-friendliness, more efficient services support and user-empowerment. It is expected that the technologies defined by the concept of AmI will adapt a structure that controls most of everyday life in the year 2020 (ESTO, 2003). The application domains of home, mobility, health, education and learning, shopping and commerce, culture, leisure and entertainment constitute concrete indicators in this regard.

4.5 Potential Threats of Adaptive Systems

Up until this point, the benefits provided by adaptive systems within the framework of the concept of AmI have been defined. Besides these, there exist some possible threats that adaptive systems engender for today and the near future. This section will elaborate these threats in two different frameworks. Firstly, the SWAMI research project launched by the European

Union will be discussed, after which the threats identified as a result of this project will be investigated. Then, with reference to Chapters 2 and 3, adaptive systems will be explored within a cybernetic framework and other potentials threats will be drawn out.

4.5.1 Potential Threats of Adaptive Systems from Individual Perspective

Potential threats and vulnerabilities that AmI might impose are analyzed by a European Union funded research project 'SWAMI' (Safeguards in a World of Ambient Intelligence). SWAMI consortium (2003) suggests that AmI could bring advantages to individuals in terms of efficiency, user-friendliness and comfort. However, it is also associated with serious problems and risks for future. The following is a list of AmI technologies that may present risks for the individuals (ibid):

- Firstly, significant portions of our daily activities need to be recorded, collected and tracked if the envisioned personalized services are to be made available;
- This will, secondly, increase the sheer quantity of personalized data in circulation in unknown dimensions;
- Thirdly, not only the quantity, but also the quality of the data will change due to the introduction of perceptual and biometric interfaces. Moreover, the tremendous amounts of personalized information in circulation may increasingly be linked, re-processed and reused for secondary purposes.

Accordingly, it is possible to discuss the key threats that AmI technology is associated with, under five topics as introduced by SWAMI (2003). These are:

- Surveillance
- Identity Theft
- Malicious Attacks
- Digital Divide
- Spamming

Details for each of these threats are given in the following sections.

4.5.1.1 Surveillance

With Ambient Intelligence, the monitoring and surveillance capabilities of new technologies can be massively extended beyond the current credit-card and Internet logs (Punie and Delaitre, 2005). This is possible not only because this intelligent environment is able to detect and monitor constantly what people are doing in their everyday lives (both online and offline), but also because of the possibility to connect and search isolated databases containing personal information. According to Punie and Beslay (2002), this concerns both basic personal identification data (e.g. age, sex and location), and information and communication content (e.g. past, current and future events information, working documents, family albums) and other medical and financial records.

Every user leaves electronic traces as the price of participating in the ambient intelligence society. These traces then would make new and more comprehensive surveillance of users' physical movements, their uses of electronic services and communications. The traces would also make it possible to construct very sophisticated personal profiles and activity patterns. Some may argue that it would even mean the end of privacy (Garfinckel, 2001) since it will be very difficult for people to find a place where they will have the right to be left alone.

Apart from this, as Punie and Maghiros (2006) state, the prospect and realization of increasing surveillance can have very concrete consequences for a citizen. For example, the disclosure of health details, personal preferences, habits and lifestyle to an insurance company or to an employer can easily lead to discrimination (e.g. higher insurance contributions, reduced career prospects, even denial of insurance coverage and job layoff). The possibility of the retailers being able to monitor the shopping behavior of customers can not only lead to an optimized supply chain, it can also be the basis of the transparent customer who could be manipulated and controlled (Punie and Maghiros, 2006).

4.5.1.2 Identity Theft

Identity theft is the act of obtaining identity information of a person for future illegal activities without the concerned person's consent (Ducatel and Bogdanowicz, 2001). Without appropiate security precautions, the AmI environment may encourage malicious people with many opportunities to steal identity information and to use them for illegal purposes. As the more widely personal information becomes available, the greater is the risk of its being stolen and being used for fraud or other illegal activities.

The methods employed to steal identity information could be both online and offline (Ducatel and Bogdanowicz, 2001). Offline methods may include the theft of the wallet, the purse, the stealing of information by rummaging a house or a car, by a fake survey. Online methods may encompass attacks on computers, online accounts and PDAs. The list of means is continuously evolving as new technologies emerge and new vulnerabilities are exploited.

Once a malicious person has succeeded in stealing personal identity data, then spying on any activity of the victim (e.g. using it for any kind of fraud, using it for terrorist attacks or even harming the life of the victim) becomes possible.

4.5.1.3 Malicious Attacks

AmI, as a new technology is plagued by both known and unknown weaknesses. These weaknesses are also potential threats to serve as a backdoor for malicious attackers. An attack can be an active or a passive one(Friedewald and Wright, 2005). An active attack is a deliberate alteration or destruction of data in a message or creation of false data. A passive attack consists of unauthorized monitoring, but not alteration or destruction of data, where the purpose is to acquire the information.
Complex computer systems can become a target of malicious attacks (e.g. viruses, denial of services). As Punie and Maghiros (2006) states, disruption to the operation of an AmI network may result in a loss of convenience as a minimum and/or severe damage ranging from financial loss to death. A number of examples given by Punie and Maghiros (2006) are listed below:

- The misuse or manipulation of home applications might result in fires being lit.
- The malfunction of healthcare and emergency systems can be a risk for the life and health of the affected persons.
- Businesses based on AmI can be ruined when the system is put out of operation or if a malicious person or competitor manipulates his back office system.
- An attack at the right place of the AmI infrastructure may cause a temporal breakdown of activities in business and society.

4.5.1.4 Digital Divide

The pervasiveness of AmI applications in almost every sphere of life poses the threats of social pressure and digital divide. People may be forced to use AmI technology. This pressure may be direct as in the case of health insurance companies that only give insurance protection when their clients are using some kind of health monitoring system (Punie and Delaitre, 2005). The pressure may also be indirect, since most daily activities involve the use necessity of AmI. Even if a person accepts to use AmI applications, predefined routines by the system will be unavoidable. This will limit personal freedom and self-determination (Punie and Maghiros, 2006).

As many activities in everyday life will become dependent on AmI systems, people may be hindered in their personal development and loose the ability to manage their lives. This can result in a lack of self-confidence and personal depression (Ducatel and Bogdanowicz, 2001).

AmI's personalization capabilities may lead to conflicts within community or between family members, especially when their interests are different (Ducatel and Bogdanowicz, 2001). Future AmI scenarios do not take into account the fact that people are not only individuals, but also members of a wide variety of social groups. As Ducatel and Bogdanowicz (2001) asserts, the deployment of AmI also challenges the relationship between different actors. For example, AmI gives parents very powerful means to control their children, but it raises the question from which age a child's privacy should be respected, and who sets the limits: government or the family?

4.5.1.5 Spamming

The availability of personal information is at the very heart of personalized services, but such information can be used for any kind of spamming (Punie and Maghiros, 2006). Personal profiles of individuals collected through the use of AmI technologies can be potentially used for spamming those individuals in most cases with unwanted information. The example of the Internet has shown that this effect can hardly be stopped when there are few effective rules or explicit mechanisms for an individual to control where the personal data are stored and for which purpose they may be used. Personalized information may be useful, however, when a certain threshold is exceeded even wanted and useful information may lose its value because the user is no longer able to assimilate and make use of the overload information.

4.5.1.6 Overview of Potential Threats from Individual Perspective

As more and more activities in daily life, at work and in other environments, will depend on the availability of adaptive devices and services in the future, the scale, complexity and scope of human activity within these environments would present enormous technical challenges for privacy, identity and security. The enormous amount of behavioral, personal and biological data that is recorded and disseminated can be named as the major cause of this situation. The growing autonomy and intelligence of adaptive devices and applications also bring potential weaknesses for malicious attacks and misuses.

4.5.2 Potential Threats of Adaptive Systems from Cybernetic Perspective

This section, discusses the changes of infrastructure in adaptive products, and illustrates the potential threats this holds for the future. The discussion will first take product and user as cybernetic systems, determine the control hierarchy between these two systems and will lay out in what sense adaptive products can change this hierarchy control. The possible threats that may be seen in the hierarchy of control will be explained with recourse to two conflict situations in relation to user-product interaction.

4.5.2.1 Control Hierarchy between the User and the Product

The evolution that has been undergone by products through adaptivity, constitutes an important stepping stone in technology. As defined by cybernetic theory, products are changing from being 'observed systems' to being 'observing systems'. At the same time they leave their static structures and assume dynamic functioning. In other words, products have slowly started to take on the dynamic structure in the functioning of living systems. This structure, which can perceive, learn and make decisions, is turning the product's control mechanism into a one that is gradually becoming more autonomous.

The source or the fundamental factor for this change is software. Products which first got freed from their mechanical infrastructures with the use of software, are now becoming part of adaptive structures with the use of self-adaptive software. In this sense, the evolution that has undergone by products can be defined in direct proportion to the evolution undergone by software. As described in Chapter 3, the evolution that software has been undergoing, is simultaneously changing the structure of products hence this change effects user-product interaction that occur in a conventional sense.

It is possible to take products and their users as two cybernetic systems that interact with each other. These two systems have a control mechanism in a hierarchical order. The control mechanism of the user considers itself the 'controller' and identifies the product as the 'controlled'. The control mechanism of the product considers itself the 'controller' and identifies the variables that it can affect (e.g. room temperature for the thermostat, speed of vehicle for cruise control systems) as the 'controlled'. Within such a hierarchy of control, the user has a relative control over the product and the product has a relative control over the variables it can affect.

As described in Chapter 2, control mechanisms are based on the principle of one system being superior to others. In other words, creating an *asymmetrical* situation between the controller and the controlled systems is a pre-condition. If there is no hierarchical superiority between two systems, an optimum control cannot occur. In that manner, having *symmetrical* relationship of two interacting cybernetic systems creates a potential threat in terms of control.

Through the structure of adaptive products, the product-user relation conventionally perceived as one-way, becomes two-way interaction (Figure 4.4). In other words, the interaction between product and user becomes almost like an interaction between two individuals. Adaptive products form models according to the users they interact with and shape their behaviors accordingly. This closely resembles how human-being converses with the surrounding people and forms a model of them.

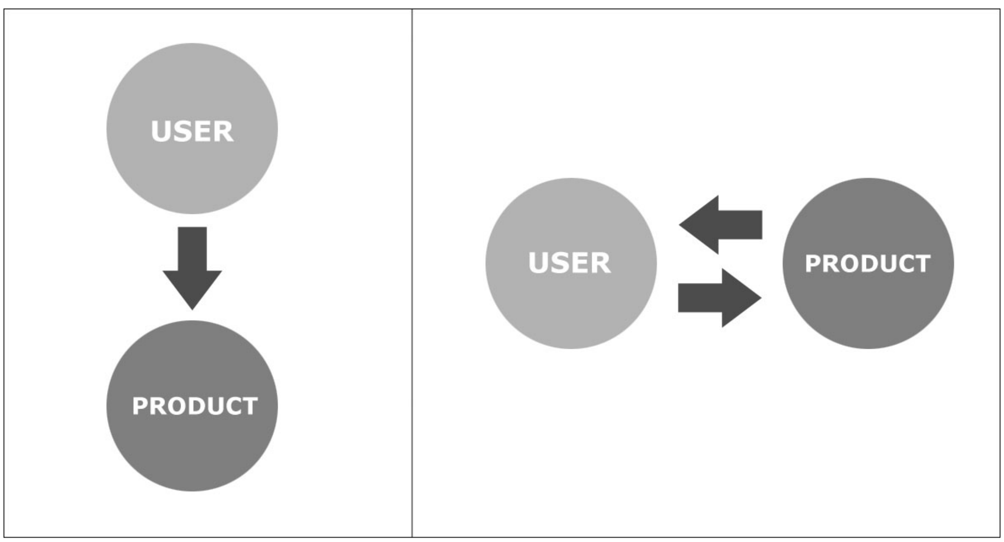

Figure 4.4 – Asymmetrical vs. Symmetrical Relation between the User and the Product

However, the interaction that users have formed with the products has not been in this direction so far. The interaction has had an absolutely static structure where the user is the *controller*, and the product is the *controlled* one. No relationship has been defined where conditions between product and user is *symmetrical*. With adaptive products such a fracture has occurred. Adaptive products, through the advanced control mechanisms they have gained, have taken on a structure which may change the hierarchical balance between the product and user in the conventional sense. Although the consequences of such a change are not self-evident with current technology, it would be possible to witness the outcomes in the future.

4.5.2.2 Two Possible Conflict Situations

In this section, an attempt will be made by the author to speculate on the possible conflict situations between the user and product, as a result of changes in the structure of adaptive products. Based on the outcomes of the comparative study of conventional and self-adaptive structures in Chapter 3, two possible conflict situations will be discussed. The first situation will be based upon the *homeostatic* structure taken on by adaptive products, while the second one will be based upon the *model-building* structure.

a. Conflict Situation Based upon Homeostatic Structure of Adaptive Products

This essential distinction of goal-directedness that distinguishes products or artificial systems from living systems, will gradually disappear in the future. Consequently, the products will have to assume a homeostatic structure in order to perform their functions successfully.

When adaptive products cease being 'observed systems' and become 'observing systems' this brings about properties which allows the product to be aware of its own functioning and to adapt its functioning. It would be misleading to determine an advanced homeostatic structure in the current examples analyzed. However, every product that can adapt its functioning in today's situation, constitutes a potential for an advanced homeostatic structure in the future.

However, when products with an allopoietic structure also assume an homeostatic structure, certain problems may occur in theory. To explain further, a product which has both an allopoietic and homeostatic structure will have two independent goals. If one of these goals were to provide answers for the user requests, the other goal would be to ensure the stability and survival of its own functioning/existence. If in any situation these two goals contradict to each other, the product will be likely to behave in an unintended way.

In the short story called ‘Runaround’ by Isaac Asimov, written in 1942, a similar situation is described. Before going into the story, it will be of use to look at the ‘**Three Laws of Robotics**’ which Asimov (1942) thinks will be what robots will have to comply with in the future:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

When analyzed from a cybernetic perspective, the first two rules define the allopoietic structure of the robot/product, while the third defines its homeostatic structure. According to the hierarchy brought about by this order, the allopoietic structure of the robot is in each case superior to its homeostatic structure. The short story ‘Runaround’ tells how this hieararchy becomes a cause of conflict for the new generation robot SPD-13.

The story which takes place in 2015, talks about two astronauts Gregory Powell, Mike Donovan and Robot SPD-13 (nicknamed ‘Speedy’) who are sent to start operations at a mining station on Mercury. The photo-cell banks on their spaceship are broken and the only thing that can fix them is selenium. The nearest selenium pool is a few kilometers away, and since Speedy can withstand Mercury’s severe temperature, Donovan sends him to get it. The astronauts become worried when they realize that Speedy has not returned after a few hours. When they find Speedy, he shows symptoms that, if he were a human, would be interpreted as drunkenness. After a while, the astronauts figure out the cause of Speedy’s odd behavior. Powell realizes that the selenium source contains some sort of unexpected danger. Under normal circumstances, Speedy would observe Rule 2 (a robot must obey orders given it by human beings), but, because Speedy was so expensive to manufacture and was not a thing to be lightly destroyed, Rule 3 (a robot must protect its own existence) has been strengthened. Speedy cannot decide whether to obey Rule 2 or the now-equal-priority Rule 3, and has started acting inebriated.

This story is important to describe the situation of control conflict that may arise by artificial systems with homeostatic structure. The robot as an artificial system finds itself in a dilemma between maintaining its own survival and realizing its assigned task, and thus jeopardizes the human being's absolute authority in control hierarchy.

In the future, products with advanced adaptive structure may similarly jeopardize the absolute control of the user over the product as a result of the homeostatic structure that they gained. When both the user and the product assume a homeostatic structure, the relationship between them becomes symmetrical. In this *symmetrical* relationship the hierarchical superiority of the user will be ruptured. The user will start making decisions considering the product's homeostatic structure. In return, adaptive products that are originally designed to make the users' lives easier, will assume a structure that limits the decisions of the users in a sense.

b. Conflict Situation Based upon Model-Building Structure of Adaptive Products

The user's control over the product is directly connected to the user-model formed by the product. The product defines the user over the model it builds and services the user accordingly. If the product forms an unwanted model of the user, it will shift into an erroneous position in terms of service. In that case, while the user orientates toward the determined goal, he/she will enter into a conflict situation with the product.

Such a situation does not involve a very critical element of threat for current usage, because an adaptive structure is mostly used in products for easy-to-model functions (e.g. personal digital assistants and websites). In other words, the user scenarios and the models formed do not involve complex input. However, as aforementioned, products' functionality principles will fundamentally change with the concept of adaptivity. Adaptivity concept, which is currently used in products in accordance with conventional functions, will be used with new functions in the future. Service providing robots, petlike entertaining products can be given as some of the examples within futuristic scenarios. In that sense, the more complex the functioning of products becomes, the more complex their model-building structures become. They may seemingly become closer to the cognitive structure of human beings.

Just as misunderstandings that can occur between human beings during communication, it would be probable to see similar communication problems between products and human beings. In an absolutely static structure, where human being is the *controller* and the product is the *controlled*, the models that products form in an unintentional direction and the actions they perform accordingly, will have a tremendous effect on the control hierarchy between the product and the user.

In parallel to this assumption, a short story called 'The Evitable Conflict' by Isaac Asimov (1950) describes another aspect of the situation. The story also makes a reference to the 'Three Laws of Robotics' described in Section 4.5.2.

According to the story which takes place in the 21st Century, the world economy has proven so difficult to manage, that its control was long since handed over to particularly advanced artificial brains, 'The Machines'. The main objective of the Machines is to provide better and much wonderful future than the humanity could ever manage on its own. After a while it is seen that these brains act in unintended ways and that they malfunction. Although each malfunction is minor when taken by itself, the fact that they exist at all is alarming. As a result of the examinations carried out, they discover that the Machines have generalized the First Law (A robot may not injure a *human being* or, through inaction, allow a *human being* to come to harm) to mean "No robot may harm *humanity*, or through inaction, allow humanity to come to *harm*". Thus, the malfunctions are deliberate acts by the Machines, allowing a small amount of harm to come to selected individuals in order to prevent a large amount of harm coming to humanity as a whole. In effect, the Machines have decided that the only way to follow the First Law is to take control of humanity, which is one of the events that the three Laws are supposed to prevent.

The story describes how the product (the Machines), in order to reach the goal defined for itself (the successful management of world economy), builds an unwanted model and provides service in an unwanted direction according to this erroneous model. In the future, adaptive products will render the product-user relationship symmetrically thanks to their advanced model-building structure. This symmetrical structure will be able to challenge the hierarchical superiority of the user, and even to turn the product into a rival against the human being, as described in the short story 'Evitable Conflict'.

4.5.2.3 Overview of Potential Threats from Cybernetic Perspective

There are numerous science-fiction novels of the 20th Century that have parallel scenarios as their subject matter. James Cameron's 'Terminator' trilogy (1984, 1991, 2003) about rebellion of cyborgs against humanity, Isaac Asimov's novel called 'I, Robot' (1950) about robots that revolt against human beings and Stanley Kubrick's '2001, Space Odyssey' (1968) about the artificially intelligent computer 'Hal' which takes over the control can be mentioned as few of these examples.

All these scenarios basically revolve around the same theme which can be briefly defined as the destruction of the equilibrium of control between the human being and the machine it has created. Humans are slowly handing in the systems under their control over to the artificial systems in order to live a more comfortable and quality life. When these systems assume adaptive structures, in other words, when they assume a consciousness to a certain extent, this may lead to their becoming rivals to the people who created them in future terms. This consciousness of the artificial systems jeopardizes in a sense the absolute control that humans have over these systems.

These scenarios are of an almost utopian nature in today's circumstances. Even though the author thinks the probability of these scenarios' realization is not so likely, it is meaningful to draw attention to the threats that the artificial systems with a certain consciousness hold in terms of the future of humanity.

Alongside the definitive benefits brought about by products with adaptive structure, it is useful to see the threats that they may hold for the future. In this respect, the thesis has analyzed the benefits of adaptive products for product design and has attempted to bring forward, in the framework of cybernetic concepts, the threats that may occur in near future.

According to the author, what should be kept in mind is: the changes that can be seen in the functioning principle of products in terms of adaptivity, is a significant step for the products' to acquire certain types of consciousness and intelligence. Thanks to these properties, products are gaining abilities to perceive, make decisions and behave like living organisms. It is only normal that the change that has been undergone by products will have both positive and negative outcomes. Analyzing the threats that may occur in the future and taking the necessary steps in that direction will ensure that the threats will remain only in science-fiction scenarios.

At this point, the real challenge rests upon software that mainly constitutes the products' functioning. The fact that products are assuming more complex functions increases both the importance of software and the challenges that it brings. Software constitutes, in a sense, the cognitive structure of products. The product decides what to do and when to do it, through the software it contains. Therefore, when software is designed successfully without undermining the possible threats, it will be able to minimize the risk that intelligent products hold for the future in the frame of adaptivity.

4.6 Chapter Summary

This chapter has discussed the active role that the concept of adaptivity will play in the future of products through the concept of Ambient Intelligence and has attempted to lay out its potential application domains. In accordance with current literature and the outcomes of Chapter 3 regarding software, the potential threats of adaptive structure have been discussed. Thus in this chapter, by adapting an objective perspective, both positive and negative outcomes of the concept of adaptivity have been argued.

CHAPTER 5

CONCLUSIONS

This study aimed at investigating the benefits of the adaptivity concept in products, and examined the potential future threats engendered by the actual change observed in the functionality principles of the adaptive products. Hence, the concept of adaptivity has been analyzed and a perception of its negative and positive implications has been developed. Based upon cybernetic theory, the study looked at adaptive systems and tried to define the new direction that the conventional product-user relationship has taken with the concept of adaptivity. Emphasis was given on how user interaction has changed in different application domains with the introduction of adaptive systems. The cybernetics perspective used in this research will provide an overview for further research on the interaction between adaptive systems and their users. Moreover, current literature on existing possible threats has been expanded to include a cybernetic perspective.

The concept of adaptivity refers to systems that can alter aspects of their structure, functionality or interface on the basis of a user model generated from *implicit* user input. When analyzed from a cybernetic perspective, the main characteristics of the adaptive structure of software can be listed as *homeostasis*, *adaptive control* and *model-building*. More explicitly adaptive software has a structure which allows it to be aware of its functioning (homeostatic), is able to control its own parameters (adaptive control) and has a dynamic model that is formed as a result of the interaction between the system and its environment (model-building).

Adaptive software is evolving in such a way that they can sense the behavior of the user and make decisions accordingly. Instead of using pre-given models for their users, adaptive software, hence software-based applications, now form user models with their model-building features, and offer the most suitable responses to the user.

The main role of adaptivity plays in software, hence software-based applications, is to reallocate the burden of adaptation process from the user to software. Modern software technology can provide advanced features for individuals' needs while presenting them a complex and unintuitive interface that is hard to learn and use. The concept of adaptivity aims to help users reap the benefits of high technology while shielding them from the technologically complex foundations. In this perspective, adaptive software, by running themselves and adjusting to varying circumstances, allow users to concentrate on what they want to accomplish rather than figuring out how to fix the computer related problems. The concept is based on the understanding that every user has his/her own interests and tastes. Adaptive software can filter its complex structure and the multitude of alternatives it can offer with respect to implicit inputs from the user. With this approach, adaptive software can create simple and effective results in terms of user satisfaction. It can be argued that the concept of adaptivity in software applications is a smarter approach for user-oriented solutions.

When the concept of adaptivity and its applications in daily-life and product design is investigated with respect to ISTAG's definition of Ambient Intelligence, the domains can be grouped as follows: home, mobility, health, shopping and commerce, education and learning, culture, leisure, and entertainment. The concept of adaptivity is mostly associated with the domain of home. Home, by gaining additional roles (e.g. home-office, entertainment and recreational facility), and technological opportunities, constitutes an ever increasing potential for adaptive solutions. After home, it is the domains of mobility and health that the concept of adaptivity is mostly associated with. The fact that people are increasingly adapting a mobile life-style can be named as the influencing factor for the mobility domain. Finally, in the domain of health, driving trends such as increasing personalization, context dependency require the necessity of the concept of adaptivity.

Although adaptive applications do bring specific benefits for every application domain they are used in, from a larger perspective they ultimately result in a more empowered user in terms of increased convenience, personalization, safety and security as well as time and cost savings. This technology has the potential to positively influence the way people work, move, enjoy and live. Furthermore, they place the user at the centre of future development, and design the technology for the people rather than making people adapt themselves to it. The emphasis turns out to be on greater user-friendliness, more efficient services support and user-empowerment.

On the other hand, as more and more activities in daily life, at work and in other environments, will depend on the availability of adaptive devices and services in the future, the scale, complexity and scope of human activity within these environments present huge technical challenges mainly for privacy, identity and security. The enormous amount of behavioral, personal and biological data being recorded and disseminated can be named as the major cause of this situation. Furthermore, the growing autonomy and intelligence of adaptive devices and applications have potential weaknesses for malicious attacks and misuses.

When discussed from cybernetic perspective, the structure of adaptive products renders the product-user relation that is conventionally perceived as one-way into a two-way interaction. The interaction between product and user becomes almost like an interaction between two individuals. Adaptive products form models according to the users they interact with and shape their behaviors accordingly. This closely resembles how human-being converses with the surrounding people and forms a model of them. In the conventional sense, the asymmetrical structure where user is the 'controller' and product is the 'controlled' is gradually becoming symmetrical.

Adaptive products, through the advanced control mechanisms they gained, have taken on a structure which change the hierarchical balance between the user as 'controller' and the product as 'controlled' in the conventional sense. When both user and product assume a homeostatic and a model-building structure, the relationship between them will become symmetrical. This symmetrical relationship may jeopardize the absolute control of the user over the product. When adaptive products assume a consciousness to a certain extent, this may lead to their becoming rivals to the people who created them in future terms. The consciousness of the artificial systems jeopardizes the absolute control that humans have over these systems. In this respect, adaptive products designed to make life easier for the user could assume a structure which limits his decisions and performance.

From the designer's perspective, threats of adaptive products bring new responsibilities to designers. Especially ethical concerns should be raised by designers that are the most prominent threats of adaptive products. The main threats which may be regarded as recording of personal data or user's having less control over the product, challenges the designer to redefine the relationship between user and product. Defining user's data as those which may and those which may not be recorded should be among the designer's primary responsibilities. Similarly, the proper definition of the hierarchical relation between product and user as well as the user's having permanent control over the product may be considered among such responsibilities. In this state, the designer is supposed to develop new attitudes for design including ethical aspects within the design process. Thus, protecting user's rights, such as privacy, security and control over the product should be principal responsibility of designers while designing adaptive products.

It may be concluded that this study may be further upgraded by focusing on the following subjects. First subject could be concerned with the ethical aspects of adaptive systems that will question the role of the designer with the treatment of adaptive systems according to the specified threats within the research. Second subject could be concerned with the concept of adaptivity in terms of formal expression of products. It may be examined that whether design of adaptive products will turn to a 'black-box', in view of that formless products will be generated.

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