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APPLICATION OF OBJECT ORIENTED THINKING IN PRODUCT DESIGN: DESIGN PROCESS OF PERSONAL DIGITAL PARTNER

Bijan Aryana[1] , Seyed Javad Zafarmand [2], Sardar Hajati Modaraie [2], Caro Lucas[3], Somayeh Naghibi[4]

[1] Design Department, Shiraz Municipality, Shiraz, Iran, aryana@mail.iust.ac.ir

[2]Industrial Design Department, Faculty of Fine Arts, University of Tehran, Tehran, Iran, zafarmand@ut.ac.ir, modaraie@ut.ac.ir

[3] Institute of Electro Technique, University of Tehran , Tehran, Iran, lucas@ipm.ir

[4] M A student, University of Tehran , naghibi@parstarh.com

ABSTRACT:

Object oriented thinking is one of the most effective paradigms in computer science area which has important influences on software engineering and design. While industrial design and computer science have common domains like Human Computer Interaction (HCI), industrial design could benefit from advantages of object oriented thinking too. In this study an object oriented design process which is based on a correspondence between the object oriented

paradigm and a typical industrial design project, is proposed. In the next step, this design process has been applied in a product design project about Personal Digital Partner, a cutting edge portable digital device. Analysis of the resulted product concepts shows the possible advantages of the object oriented design process and one of powerful object oriented tools, Unified Modeling Language (UML) in a multidisciplinary product design and development project.

Keywords: Product Design and Development Process, Object Oriented Thinking, Design Process

1. INTRODUCTION

In 1950s and 1960s, mechanisms were the most important agents in products, so function in industrial design was affected by mechanical parts and mechanisms. In addition, Aesthetics was influenced by Modernism style (Novack and Mustafa 2004). In 1970s and 1980s, initiation of the cumulative effects of electronics and computer engineering started and the products became smaller and economic. In that time, creativity was - and somehow still is - one of the most important factors in an industrial design process (Cross and Dorst 2001), while Minimalism was one of the most alive styles in design.

What about the present time? After 1990s, it seems that the products have more interactions with the users (Feiz et al. 1997). The processors caused many products to be semi-intelligent and have a more complex behavior than the older products. In style and Aesthetics, because of more manufacturing facilities, there is more freedom of creating new forms and hence Industrial design is going to be more artistic. However, there is a new problem with the new products - or new technology - and this problem lies in the high level of interaction between user and product.

Personal Digital Partner is a product with multiple user interfaces and a high level of interaction, a product that can unify different functions in communication and information categories and something more than today's Personal Digital Assistants (PDAs) or cell phones. Design process of this mobile computation age product would be multidisciplinary. One of the most important relationships in this design process is the relationship between industrial designers and computing engineers. That is why, in this research, the feasibility of using object oriented thinking and one of its powerful tools, Unified Modeling language (UML) in a product design process has been studied. Object oriented thinking firstly created in computer sciences domain and has been widely used in software engineering and design due to its ability of defining complex systems. Because

of the advantages of object oriented thinking and its adaptability this paradigm is going to be used in other disciplines too.

The emphasis of this research is on the design process and the final concepts would be used to evaluate the proposed process. The new product, Personal Digital Partner would be a computer anyway. It would have a central processor, an operating system and the essence of computer. Like most advance products design team is a multidisciplinary team. How can a designer consider this essence in his/her design and how can the multidisciplinary design team work together? One of the approaches is the application of the same methodology and the same language, so a member of multidisciplinary team could understand the others, and he/she doesn't need to know all details about other professions.

2. BACKGROUND

2.1. HUMAN-COMPUTER INTERACTION

As computer science grows, its effect on human and society has been considered too. Especially in the main convergence of human and computer, user interfaces. Because of the usability of computer and information systems, many researches are done about the relationship between Human and Computer.

"The goal of universal access to information and communications services is compelling. Enthusiastic networking innovators, business leaders, and government policymakers see opportunities and benefits from widespread usage. But even if they succeed and the economies of scale bring low costs, computing researchers will still have much work to do. They will have to deal with the difficult question: How can information and communications services be made usable for every citizen?" (Shneiderman 2000).

So, similar to physical environments, human should be considered in virtual environments. In the new products both of these environments are important. For instance, in the usage scenario of a mobile phone, the physical entity of this product is important, because it should be light, easy to handle and beautiful. Furthermore, its virtual entity is important too: the menus, the logical relationship between them, colors and symbols which appear on screen should be designed well

and useable. Today, HCI experts, Human Factors specialists and industrial designers should work together to design the products.

When the first Personal Computers were marketed, the producers of these new products like Apple Macintosh and IBM employed industrial designers in order to consider Aesthetics and Ergonomics in their products. In the early projects, industrial designers used traditional design processes, similar to design processes of the other product such as home appliances. But the results were not as well as their last works in the other industries (Figure 1). Finally, they found the reason: computers had a higher level of interaction with the users and they had a virtual entity in addition to their physical entity. So, only designing the physical parts was not enough and the virtual parts should be designed too (Spreenberg, Salomon and Joe 1995).

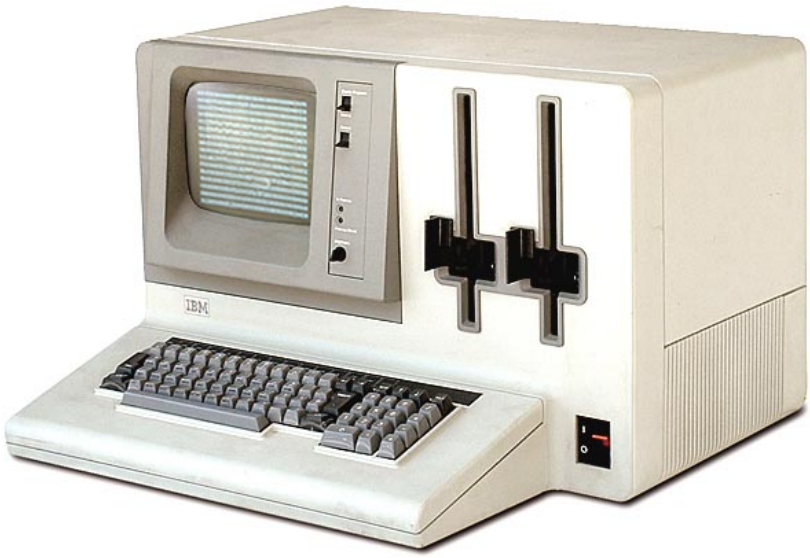

Figure 1: IBM 5110 model 3, introduced in 1980. An example of early PC designs.

2.2. OBJECT ORIENTED THINKING

The Object Oriented (OO) approach is a paradigm distributing representation over a number of active entities, called objects. The various benefits of using the Object Oriented Paradigm (OOP) for software engineering, such as modularity, maintainability, reusability, etc. make many professional and academic organizations use it in software and system design (Rumbaugh et al.1991). As the use of OOP grows, it increases the number of universities and business organizations interested on teaching/training students/employees to efficiently use it and to better apply the benefits of the paradigm (Booch 1994). This research is trying to use this paradigm in

an industrial design process to discuss about its advantages. The main reason of this methodology is to approach industrial design, HCI and computing engineers. As HCI came from Computer Science, Object oriented thinking is well-known for many HCI experts and it can be a common point for a multidisciplinary design project.

Furthermore, Personal Digital Partner, like many other cutting edge products, has many components, functions and interfaces, so there is an important similarity between this product and a complex software or management model. Object oriented thinking has benefited Computer Engineering and management in such a complex systems and it would be useful for a product design team in the same way.

3. CORRESPONDENCE BETWEEN OBJECT ORIENTED PARADIGM AND A TYPICAL INDUSTRIAL DESIGN PROCESS

In a typical industrial design project, there are major components like design parameters, standards and users' needs. All of these major components have relationships with other parts of the project. So, the project could be defined as a dynamic system. Because of the nature of object oriented thinking, study on a possible correspondence between its paradigm and a typical industrial design project and definition of objects and classes would be the first step.

- ☐ The objects could be:
- ☐ All parameters about new product entity which are defined from the problem definition phrase
- ☐ All solutions like new ideas and experiences
- ☐ All facts about new product, like standards
- ☐ All facts about users
- ☐ According to the correspondence, classes would be:
- ☐ Product Entity
- ☐ Solutions

- ☐ Product Facts
- ☐ User Facts

In most industrial design projects, the process starts with problem definition. As an example, a typical problem definition for Personal Digital Partner concept could be as follows:

Many products and many functions are concerned with Information and Communication: How can we unify them and create a portable, available, multifunctional and accessible product?

After reviewing the problem, classes (super classes) and their objects could be defined *as:*

A) Objects of Product Entity class: (functions of new product):

- ☐ Connecting to internet
- ☐ Tel communication
- ☐ Sharing information
- ☐ Storing information
- ☐ Using soft wares
- ☐ Multimedia functions

B) Objects of Solution class: (new ideas or experiences which can help us to solve the problem):

- ☐ Ideas which are created by Brainstorming
- ☐ Ideas which are created accidentally
- ☐ Experiences of designing similar products
- ☐ Experiences of solving similar problems

C) Objects of Product Facts class: (facts about new product)

- ☐ New feasible and marketable technologies
- ☐ Economic and technologic limitations

- ☐ Standards

D) Objects of User Facts class: (facts about Users)

- ☐ Suitable colors
- ☐ Suitable forms
- ☐ Suitable textures
- ☐ Ergonomic and HCI standards

By considering this correspondence, in a multidisciplinary team, industrial design process could be understood by the other professions. For example, a software programmer who is in charge of modeling the whole multidisciplinary product design process, in order to avoid faults and competitor activities, can understand the industrial design process and models it correctly.

Furthermore, because of the classified structure of object oriented paradigm, the designers would have a better control over their design activity. In object oriented thinking all of the entities should be defined as objects and all of the objects should be a member of a class. So, by using this system, there won't be any impertinent information in documents and an industrial designer can understand all of the relationships and interactions between the objects in design process. This design process is also more dynamic, but not linear or like a simple checklist.

4. UML: THE STANDARD LANGUAGE FOR MODELING OF SYSTEMS

UML stands for Unified Modeling Language. By using different types of visual diagrams, UML's major abilities are (Pinheiro da Silva and Paton 2000):

- ☐ Data modeling concepts (Entity Relationship Diagrams)
- ☐ Business Modeling (work flow)
- ☐ Object Modeling
- ☐ Component Modeling

UML is the standard language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system. It can be used with all processes, throughout the development life cycle, and across different implementation technologies as follows (Booch, Rumbaugh and Jacobson 1999):

- ☐ Display the boundary of a system & its major functions using use cases and actors
- ☐ Illustrate use case realizations with interaction diagrams
- ☐ Represent a static structure of a system using class diagrams
- ☐ Model the behavior of objects with state transition diagrams
- ☐ Reveal the physical implementation architecture with component & deployment diagrams

However, UML does not prescribe a standard process or method for developing a system. So, UML is more for modeling a real system - for example software - than modeling a process (Bennett, Skelton and Lunn 2001). In the last section, different classes of an industrial design process defined. But the best use of UML in this project is to model the real product as a system. When considering this important point, there are some difference between definition of classes in section 3 and classes that are used in UML diagrams of Personal Digital Partner. The classes of Personal Digital Partner (as a system) are different functions of this product and also the other important systems which have interaction with Personal Digital Partner.

Use cases are generally the starting point of *o*bject *o*riented analysis with UML (Popkin Software and Systems 1998). Use cases modeling is the simplest and most effective technique for modeling system requirements from a user's perspective, which is very important in an industrial design project. Use cases are used to model how a system or business currently works, or how the users wish it to work. It is not really an object oriented approach; it is really a form of process modeling. It is, however, an excellent way to lead into Object Oriented analysis of the systems.

The Use case model consists of actors and use cases. Use cases represent the behavior of the system; scenarios that the system goes through in response to stimuli from an actor. Actors represent the users and other systems that interact with the system. They are drawn as stick figures. They actually represent a type of user, not an instance of a user.

As an example, the actors in Personal Digital Partner system are User, Internet, Telecom net, Software and File. (Figure 2)

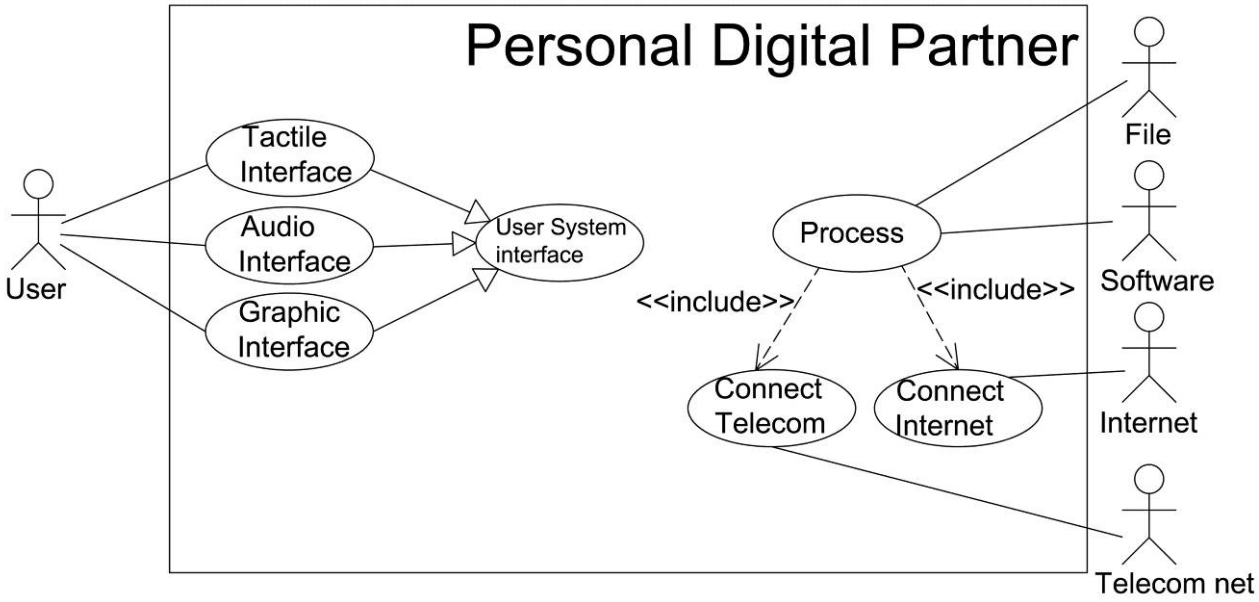

Figure 2: Use case diagram for Personal Digital Partner

Once participating objects have been identified, we use Class diagrams to describe the structure of the system. Classes are the abstractions that specify the common structure and the behavior of a set of objects. Objects are the entities that are created, modified, and destroyed during the execution of the system. Objects have the state which includes the values of its attributes and its relationships with other objects. Class diagrams describe the objects, classes, attributes, and relationships found in the system. Figure 3 shows the class diagram for Personal Digital Partner.

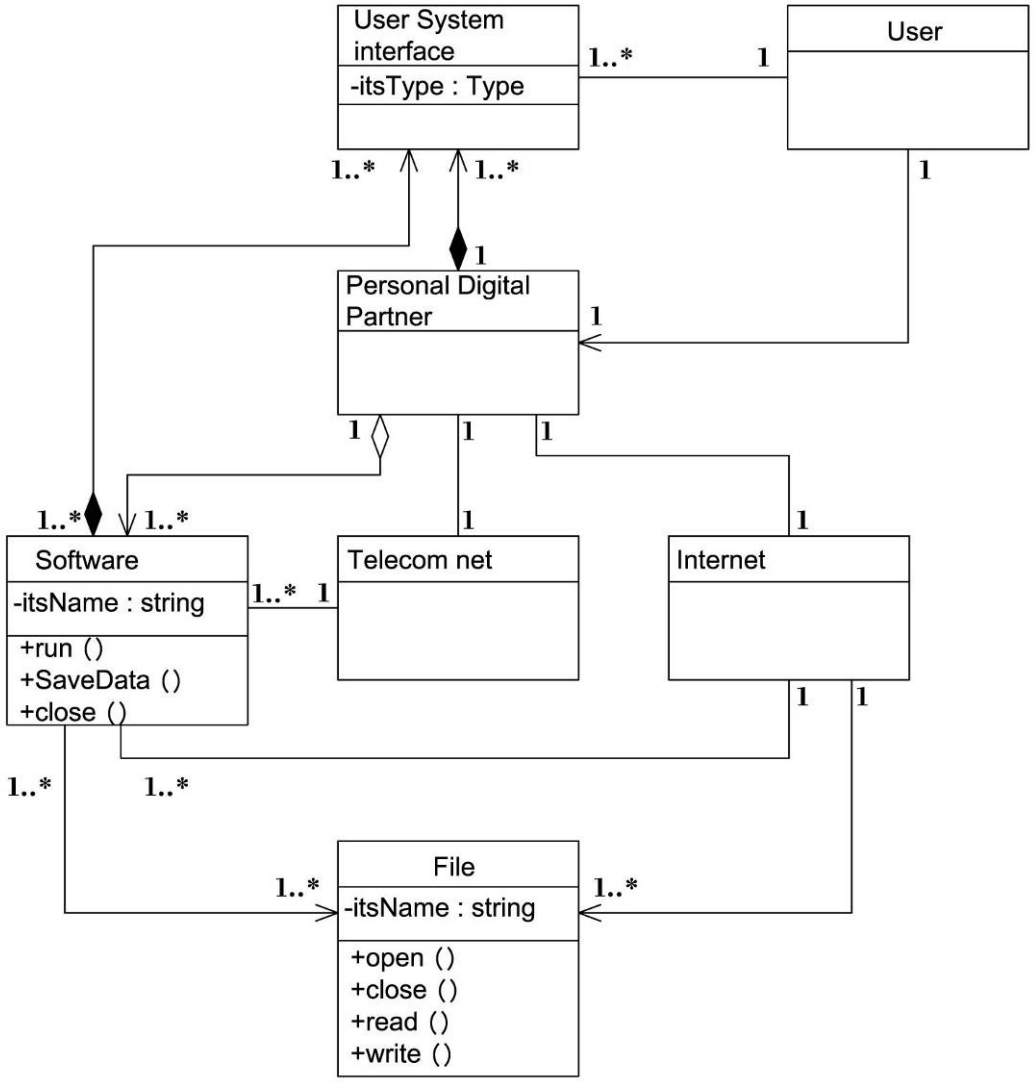

Figure 3: Class diagram for Personal Digital Partner

Moreover all UML designs can be separated into the static and dynamic components. The static design describes the software elements used, and the way they are structured. The dynamic design describes the details of the communications between those elements. Dynamic diagrams depict the communications between objects for a particular scenario. In an industrial design project the most important objective is to enhance the relationships between the product/system and the user/human. So in the dynamic design phase, there are many scenarios to be modeled, because only for one user, there are infinite behaviors and interactions. Figure 4 is an example of dynamic design (Collaboration Diagram) for Personal Digital Partner. Collaboration diagram messages show the sequence of messages between objects.

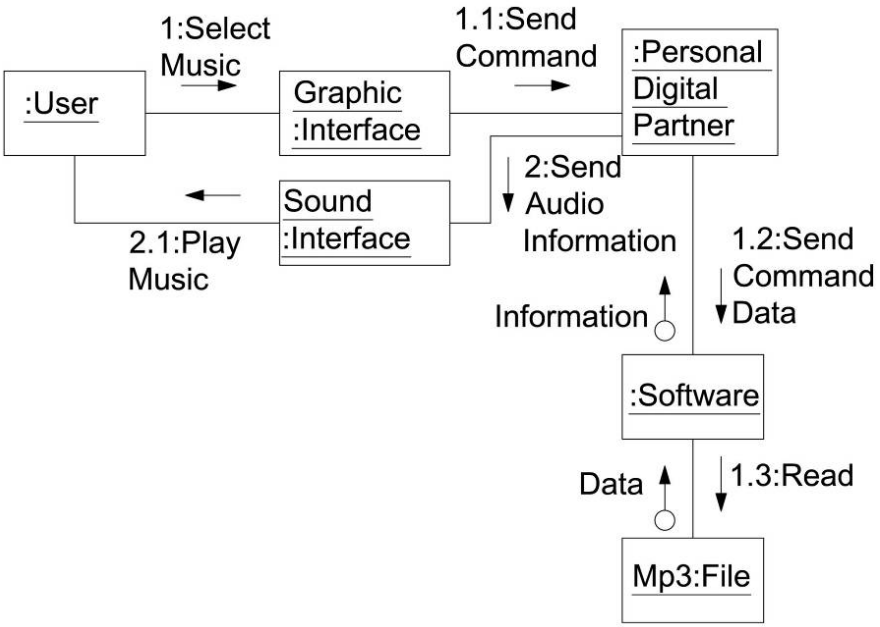

Figure 4: Collaboration diagram of playing a MP3 file with Personal Digital Partner

By modeling the product (system) with UML, the designer won't forget about any important external system or internal interaction, because he/she should define all of the objects and classes in the process of modeling and after modeling he/she can see all of the logical relationships in a visual model. So, designer has more control on the different aspects of design. Also before the product becomes a physical or virtual 3D model, the logical entity of product would be created. In the classic Industrial design processes, the first feedbacks of design appear after a physical or virtual 3D model. But by this new process, the designer can test the product before its physical form and accurate dimensions being defined.

Further, in a multidisciplinary team, this standard language would be understandable for all members with different professional backgrounds. The documentation will be also easer and many descriptions could be omitted.

6. DESIGN PRACTICE

The review of object oriented paradigm and one of its tools, UML, showed the potential advantages of using this thinking in a typical industrial design project. Thus, to evaluate the new idea in a real situation, an experimental phase is needed. So, this experimental phase was done as an applied research project (Personal Digital Partner) at University of Tehran. The project was

a collaborative research between the Faculty of Electrical and Computer Engineering and Industrial Design Department of University of Tehran. The most important achievements of this project were:

- ☐ Local target group's needs and lifestyle were considered in both concepts. The target users participated in brainstorming and idea generation, which makes the product more user-centered.
- ☐ Using object oriented thinking in an industrial design process.
- ☐ Product design modeling with UML, as an object oriented tool
- ☐ During PDP project two concepts were created, Booklet PC and Zodiac. Zodiac was one of the finalists in Toshiba Hard Disk Drive Revolution competition (March 2006)

Different phases of this project could be reviewed in the next subsections. In the first subsection, a summary of proposed object oriented design process is presented. Two product concepts, in the next subsection, is design by this proposed design process. Table 1 shows a summary of Personal Digital Partner project.

	Personal Digital Partner			
1	**Product Entity** *Main Functions Such as:* Connecting to internet ,Tel communication ,Sharing information ,Storing information ,Using soft wares ,Multimedia functions			
2	**Product Facts** *Feasible Technologies Such as:* - Context awareness - Standard systems for communication among digital devices - Multifunctional user interfaces (for example touch sensitive screens) - etc.	**User Facts** - Socio cultural trends among members of user group - Need for intuitive usage scenarios - Need for customized and adaptable features - Attention to social impact of digital devices	**Solutions** - 65 ideas by 15 users in brainstorming sessions - Review of 10 products in 3 different categories of portable digital devices - Study on 2 research/ design projects about similar subject	**Logical Design** *Static Design* Use case and Class diagrams for Personal Digital Partner (Figure 2, 3) *Dynamic Design* Typical Collaboration diagrams for main functions (Figure 4)
3	**Evaluation**			
4	**Booklet PC**		**Zodiac**	

Table 1: Summary of Personal Digital Partner project

6.1. SUMMARY OF PROPOSED DESIGN PROCESS

According to the sections about correspondence between object oriented thinking and a typical industrial design process and also application of UML, the phases of new process are:

1. Problem definition: Resolving the problem into basic statements which define the product entity

These statements can be the basic functions and behaviors of new product and also, the objects of class: Product Entity. As Product Entity class is defined, Product Facts and User Fact classes can be defined too.

2. Object definition for User Fact class:

In this phase use cases and scenarios are very important and helpful tools. The steps are:

- ☐ 2-1. Gathering information about general facts like standards
- ☐ 2-2. Definition of use cases, assumed users and scenarios. Observation can be used to know more about users and their behaviors.
- ☐ 2-3. Documenting the information which is obtained from 2-2 in order to be used in logical design

3. Object definition for product fact class:

There are two steps in this phase:

- ☐ 3-1.Gathering information about general facts like standards
- ☐ 3-2. Gathering information about specific facts for the subject of project, like:

  New technologies that will be marketable and can be useable in new product

  Economic and technical limitations

4. Object definition for solution class:

Two types of objects are identifiable in this class: ideas or new solutions and experiences or solutions which are used to solve similar problems.

5. Logical Design:

By using information of phase 2, especially steps 2-2 and 2-3, a Logical Design of product will be created. Logical Design has three steps:

- ☐ 5-1. New class definition for real product: Note that this class definition is different from class definition for Design process in phases 1, 2, 3 and 4. For example in Personal Digital Partner, classes are File, Internet, Telecom net, Software etc. (figure 3)

- ☐ 5-2. Static design that can be modeled with UML and visualized by using Class and Use case diagrams.

- ☐ 5-3. Dynamic design that can be modeled with UML and visualized by using Collaboration and Sequence diagrams: Some problems may found in this step (for example difficulties in using key functions by user) so new ideas or experiences, should be added to Solution class.

6. Finding the optimum solution:

By using a simple quantitative method (setting values for objects) objects of Solution classes can be evaluated in five steps:

- ☐ 6-1. Static design helps designer to find Use cases and classes in product with stronger relations with user. Ideas and experiences with better operation in these Use cases are given higher values.

- ☐ 6-2. Dynamic design helps designer to find problems or variances in use cases. Ideas and experiences with better solutions for these problems are given higher values.

- ☐ 6-3. logical design is done by using information of steps 2-2 and 2-3, so the objects which are defined in these steps affected evaluation, steps 6-1 and 6-2. But what about step 2-1: general facts? These facts can be used directly in evaluation; for example, solutions can be evaluated considering their adaptability with standards.

- ☐ 6-4. objects of product fact class can be used directly in evaluation too.

- ☐ 6-5. Finally, a total value for each solution can be determined by summing values of steps 6-1, 6-2, 6-3 and 6-4; although, values of each step may multiply in an importance ratio.

For example steps 6-1 and 6-2 have higher importance ratio than other steps, because they are about user and also they are about specific issue of project. Step 6-3 is about user too, but evaluation is done considering general facts, so has higher importance ratio than 6-4 but less than 6-1 and 6-2.Total value can help the designer find an optimum solution for new product.

Figure 5 is a collaboration diagram for this new design process, while figure 6 is an example of a classic industrial design process.

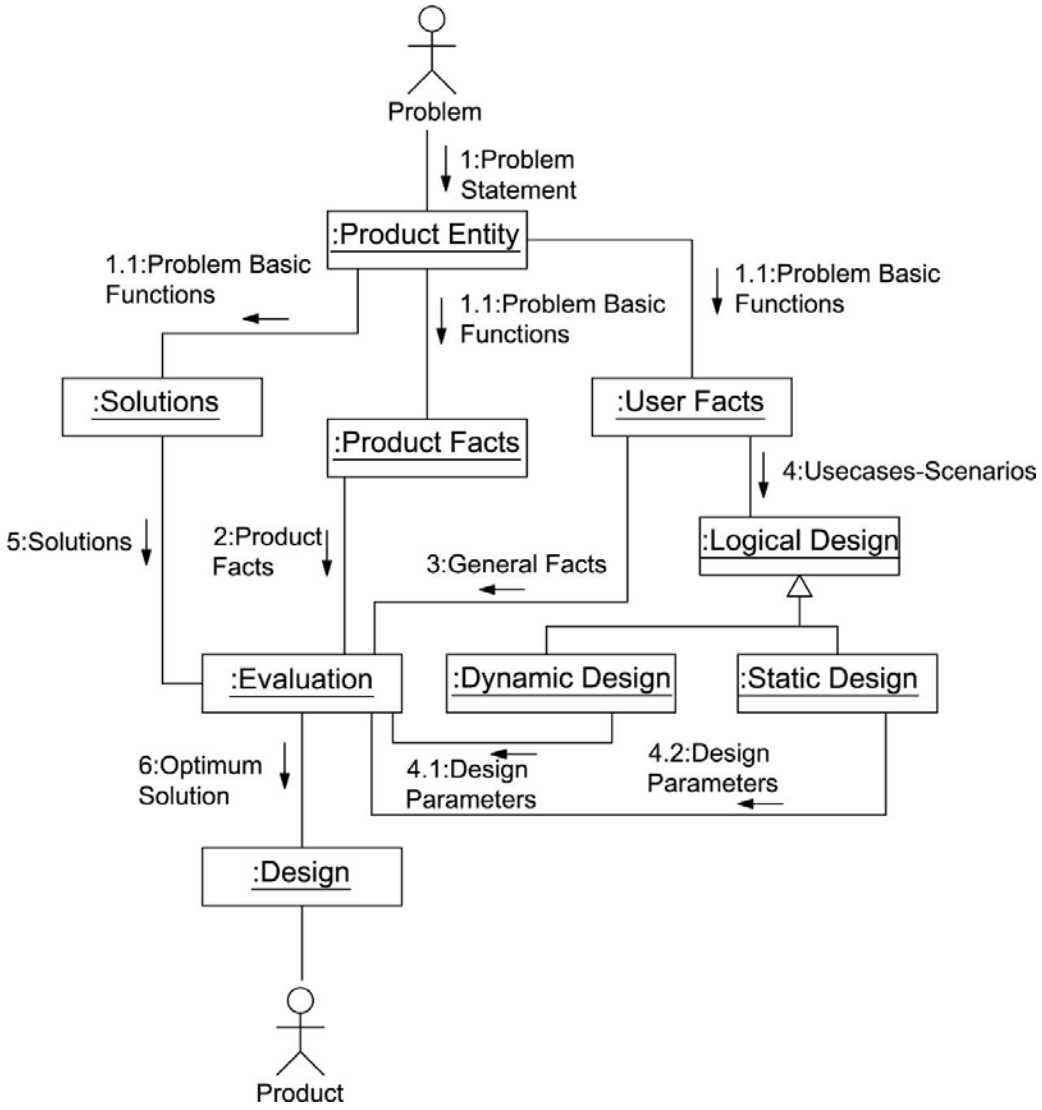

Figure 5: collaboration diagram for object oriented design process

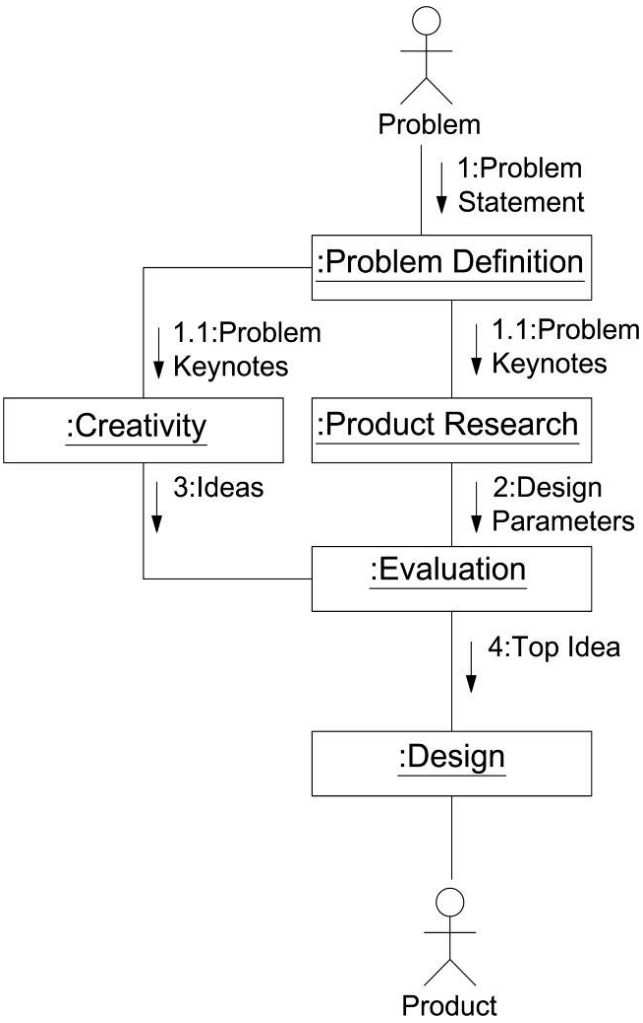

Figure 6: A classic industrial design process

6.2. DESIGN SUMMARY

Although the classification of information was a great help during the Personal Digital Partner project, the most interesting part of the new design process was the logical design phase. In this phase the logical relationships were designed before the physical design. So, the final concepts were designed by considering their context of use and not only as single objects.

For instance, Zodiac was not only a small portable digital device, but an important part of a products ecosystem. In contrast, Booklet PC was a dynamic multifunctional digital device and a combination of different products. The classification of user interfaces in this concept was one of the results of its object oriented design process.

6.2.1. BOOKLET PC, A MAXIMAL CONCEPT

Dynamic design by UML showed that, Personal Digital Partner users would face many functions and usage scenarios. So, the final design may have usability problems. One of the solutions is to classify user interfaces and functions in order to provide a more convenient usage. The classification is not only virtual (for example by menus), but also physical. This classification makes Booklet PC (Figure 7) a usable product while because of its maximal approach many functions and user interfaces can be found in the design. The features of concept could be explained in three areas:

- User and Context: The design is proposed for the users who have a digital-mobile lifestyle, the people, who want to access to information anywhere in order to do their jobs better, and are tired of various kinds of peripherals and problems of setting and connecting them. Booklet PC is designed to be adaptable. In a mobile lifestyle many situations are unpredictable, so in such a dynamic context user should be able to use product in different modes with different functions, physical positions and specific user interfaces. Because of this ability, Booklet PC is adaptable to its dynamic context of usage.

- Scenarios of Use: In today PCs, all user interfaces are accessible in only one condition, but in Booklet PC interfaces are classified. So, the user won't be confused and will be able to find the best way for any task. Many of the functions like playing music and making calls are available only through cell phone's user interface, when Booklet PC is closed. Also the cell phone can be detached easily by pulling its tab. If the user needs a larger display, he/she can pull the display tab. In this position he/she will be able to move cursor in vertical, horizontal and diagonal directions, select and type by cell phone's user interface.

- Classified interfaces: In Booklet PC, the users won't use any new interface; the new experience is that the users are using a device with the classified interfaces. There is a correspondence between this classification and physical position. Another point is that user can select his/her desired user interface or condition and change the PC without using puzzler menus, only by rotating and pulling its parts. An important advantage of using known interfaces in a new way is that the users will accept new product effortlessly: they don’t need to learn any thing new.

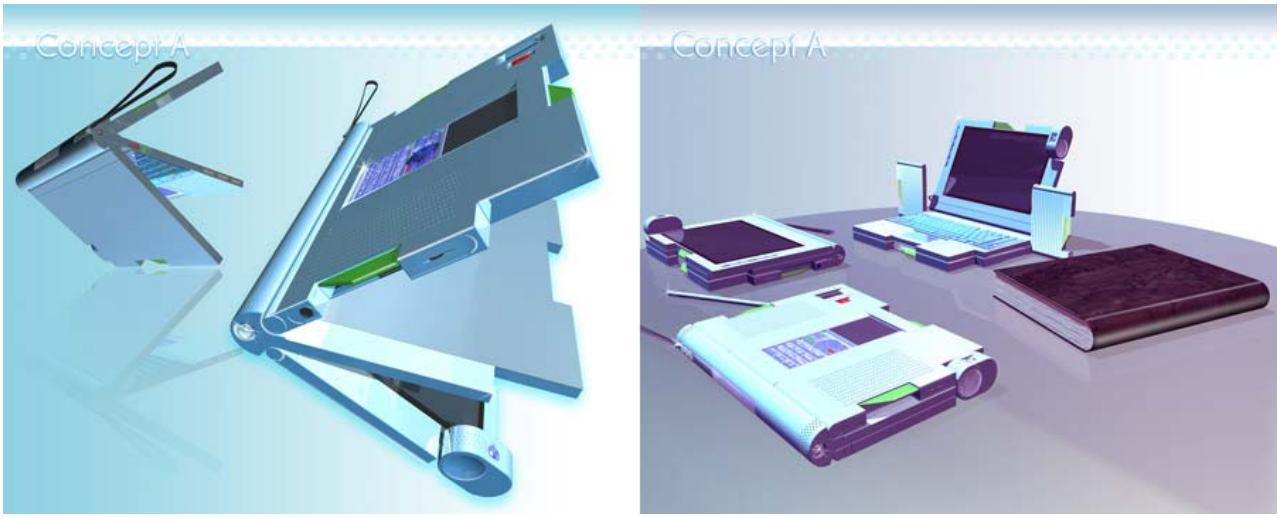

Figure 7: Booklet PC, a maximal concept.

6.2.2 ZODIAC, A MINIMAL CONCEPT

UML static diagrams (like class diagram in Figure 3) showed that the new product could be designed as a component of a system and many of its tasks could be completed by the other components (products or subsystems). This idea was the main reason of Zodiac's minimal approach. Zodiac was one of the finalists in Toshiba Hard Disk Drive Revolution competition and jury comments also show that some of the aspects of design, which were the results of object oriented design process, specially design of the whole scenario instead of design of a single product, have been noticed by jury too:

"I like this design because it looks at the need for developing an eco system of supporting products as well as examining how you would integrate new products with existing devices." (Chantalle Hamaide, Editor, Intramurous)

The main features of Zodiac (Figure 8) are:

- ☐ Zodiac is a small and portable device with a dynamic user Interface. Zodiac enables the user to take information anywhere and access it by different products. Because of its simple shape and small size, the user can use it in "Nomadic" situations. He/she only uses "one" product for several functions and shares information without using multiple derives. It is a context aware product. When the user wants to access information, Zodiac will change its user interface according to the usage context.

- The product has only two basic components: user interface and memory. The user interface can adapt itself to the usage context and the product can be used in different modes like dial, keypad and multimedia control.

- A USB port enables data loading and battery charging, also an integrated microphone act as a simple vocal interface. There is a small ring behind the device, so the user can wear it like a locket or attach it to a clip.

Figure 8: Zodiac, a minimal concept.

7. CONCLUSION

Cutting edge products are smart and complex and the smartness and complexity make them similar to software systems. Because of its ability to abstract and classify systems, object oriented thinking is one of the best solutions for design, engineering and management.

While, each advanced product uses diverse technologies, the industrial designers need more powerful tools to communicate with the other disciplines in design projects. Therefore, study on object oriented thinking and developing new methods based on this thinking would enable the designers to meet the contemporary high-tech industry, in which digital technology plays an important role.

Today's advanced products are not only the solid objects, as they have specific behaviors. So, the designers should be able to design their logical entities too. The design practice phase of this research was based on a proposed object oriented design process and demonstrated possible advantages of the object oriented paradigm in an industrial design project.

This preliminary design process could be extended to the new product design models. Moreover the other similar paradigms like agent oriented thinking could be considered in the next steps or future works too.

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