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# *Design Patterns in Ambient Intelligence*

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*Abstract:* **The paper is dealing with the problem of design pattern application in the area of ambient intelligence. Design patterns are one of today's phenomenon, come out from practice and offer solutions for commonly appearing problems in application design. Their usage in the area of ambient intelligence offers the possibility to use existing and proofed techniques in a newly developing area, where there is certain need for standardization and specification of basic principles. The paper inquires into several model situations in the area of ambient intelligence and creates simple scenarios of solutions for basic problems, that exist in this area.**

***Keywords: ambient intelligence, design patterns***

## I. INTRODUCTION

Ambient intelligence (AI) is an area, which is being researched as a theoretical basis for devices that shall be developed in the future. There have been many analysis and research projects. On basis of these projects, we can however examine the proposed solutions, search for new relationships and also seek similarities when solving various situations and cases.

Thanks to the miniaturization of devices, the area of ambient intelligence is developing very fast. Such miniaturization provides the possibility of introducing devices which are invisible to man, but fill the roles necessary for the basic functionality of AI systems. This provides the possibility of building solutions for different areas of AI. It is mainly the area of home environment, because the aspects of AI are most often presented on examples from this area. These systems have been described as physically embedded intelligent systems [9].

A lot of these solutions emerge lately. In order for scientists to be able to orient themselves among these solutions, it would be convenient to standardize them in some way. We will try to search for an abstract solution, that may be the base for others to build on. It would then not be necessary to make up new solutions of already researched situations, instead an existing one only needs to be implemented using available resources. It would also be good for the various components of AI systems to operate on the same or at least similar interface, so to that they can be interchangeable. The internal system components must carry a identifier, which signals that they are a part of the system. If a component without the identifier tries to connect with the system, the user must authorize it, otherwise it shouldn't have access to any part of the system.

It this paper we will research existing solutions or solutions that are under development. We will look for common aspects, among which sufficient level of abstraction can be reached in order to prepare general solution for a specific problem.

The paper describes the areas of design patterns and ambient intelligence in the first three sections. It concentrates on the interconnection of these themes. In Section V we describe few selected problems and highlight their common aspects, those are then turned into new design patterns in Section VI, which is followed by the conclusion.

## II. RESEARCHING DESIGN PATTERNS

Design pattern is a generally usable solution for a repeating problem, which occurs when developing software applications. The term „Design pattern" is a term for a wide area of solutions of problems which appear when designing software. There are also various other types of patterns, for example architectural, behavioral etc. When researching other possible patterns it is thus necessary to emphasize on the fact, that the problematic should fall within the area of design patterns. Many new design patterns emerged with the arrival of service oriented architecture, others are invented as complements to new programming techniques or other areas of software development.

Design patterns are connected with the expansion of object-oriented programming and application design. It is the basis for their existence and they provide effective solutions for problems from these areas. They are defined by basic thesis which is that they provide general and reusable solution for commonly appearing problems in the area of application design and development. These solutions are effective thanks to them being tested in practical use and also thanks to the fact, that they simplify the overall process of application design and development. The idea of design patterns is well captured by Erich Gamma in [1] - „Program to an 'interface', not an 'implementation'".

We shall now try to think about few areas in which the problematic of design patterns is not clearly defined, let alone closed.

Design patterns usually develop from often used solution for a specific problem. In ambient intelligence it is a bit more abstract problematic. We are trying to solve more general problems, which concern practical usage of devices in ambient intelligence. Design patterns in this case are more similar to architectural patterns. These solutions are in addition abstracted to even higher level than when speaking

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about classical design patterns. We do not solve the specific programming problems anymore, but rather try to find a general way of solving a specific problematic. For example the primary initiation system, system of movement tracking, system of content analysis etc. We will look into these systems more in the following sections.

Design patterns in ambient intelligence emerge based on solutions that are in early stages of development, not implemented at all, or their functionality is only partial. There is however a general way of solving a problem, which may or may not be tied to a specific implementation or product. Due to the exclusivity of this problem individual solutions are often tied to a specific company, which develops the solution. It is difficult to directly develop and test the proposed solutions without support. Thanks to the practical implications of these solutions, a company can have a project, that is interesting from scientific, business and marketing point of view. As an example, a support system for houses for the elderly may be presented.

## III. Ambient Intelligence

Ambient intelligence is a term, which denotes areas, that are capable of being aware of the presence of people and somehow react to this presence. It is a concept, that assumes, that people will be surrounded by various electronic devices without fully embracing their presence and that these devices are intelligent and able to react to a variety of impulses. As all devices get smaller and are integrated into the surrounding area, people start to perceive only the interface of the device they works with. As described in [7], the system function should be independent of human beings and serve as a guide through the intelligent area.

Ambient intelligence has the potential to provide the user with a virtual space, allowing him to communicate naturally with the intelligent environment or through it with other users. It can receive commands and react accordingly by utilizing all the available communication channels, while optimizing system resources [8].

Systems in the area of ambient intelligence should fulfill the following functions [2]:

They should contain integrated devices - there is a lot of small devices in the area, which all have specific functions and they communicate with each other. The devices are invisible to man.

The systems are tied to a person - the system knows who is it communicating with. It can separate users into various groups and provide different services to each group. Examples of such groups can be parents, children, inhabitants of a home or visitors.

The systems can adapt - they change their activity based on the changes in the overall environment and the requirements of humans. They can react to expectable events (sound the alarm for example).

The systems can predict events - they can expect and predict the wishes of a human being (order missing food etc).

With the coming of ambient intelligence system, new security threats emerge as well. In [6], the authors ran several tests of system security in AI, considering not only the safety of the system itself, but also the legal readiness of state law for the coming of these systems. It seems that there is still a lot of issues, that need to be addressed in this area.

## IV. Searching for Patterns

Searching for patterns in existing solutions is a complex problem. It is necessary to find solutions, that concern the same or similar problem. That is not easy because it may not be clear which problems have common aspects. Within some we might see the connection only when we get similar patterns from them.

It seems, that some design patterns can be used in other areas apart from software design. These are mainly patterns, which concern the whole application design, such as Inversion of Control in [4], facade, which we discover in many places, and others. It is obvious, that the area of design patterns is connected with ambient intelligence and it will be useful to analyze the problems connected with it.

We will present several sample solutions. First we will describe the problem in general, then its processing and at last we will search for common aspects in that solution. In the end we will try to connect these common aspects and search for patterns within the design of appropriate applications.

## V. Resolving Problems

In this section, we will first examine existing solutions of problems within ambient intelligence. We will outline the basic questions and explain how the problems are solved. We will then analyze individual solutions and search for common aspect from which we will try to build several design patterns as a solution of a specific part of the whole problematic. The final step is backward application of these new patterns on the original solutions and examining if they apply correctly.

### *A. Using ambient intelligence for voice control of home environment*

One of the primary tasks of ambient intelligence is natural interaction of human beings and intelligent devices. This means voice communication, through which one can simply give commands as if he was talking with someone else.

In this part, we will emphasize on a home environment in which intelligent household appliances are controlled through a central system, which can analyze human speech and accept commands on the level of natural speech. The user can control heating, security systems, musical or video players and other intelligent devices through interaction with the system.

#### *1) General solution*

The user communicates with the interface in a suitable fashion (hologram, robot) using a microphone, which records the user's commands. The microphone can be portable or there can be sound sensors in all the rooms, so the communication becomes more natural, because it abstracts from the device the user must have on him all the time.

The user activates the system using a keyword. The interface then records user commands, executes them and

reports back to user. In case of uncertainty, the system asks the user if it understood his command correctly.

*2) Maior-Domo*

A. Gárate, N. Herrasti and A. López in their study [3] describe solution for this problem based on devices from Fagor Electrodómesticos, which allow the user to control all the devices in home environment by one called Maior-Domo. User communicates with this device by voice commands, picture is provided by TV screen on which the Maior-Domo can inform the user of its activities.

*3) Behavioral patterns*

Even in this proposal, we can see some basic aspects of behavior, which will probably repeat themselves. Those are, for example, beginning the communication with Maior-Domo based on a keyword, maximum usage of existing devices, or different levels of abstraction.

### *B. Care for the elderly*

The fast aging of population is a reason of usage of intelligent systems in the area of care for the elderly. We will as in the previous example focus on home environment. In this case the target group are the elderly, for whom it can be difficult to learn how to control new devices.

In this case it is not only about basic interaction with intelligent devices in the home environment, but also about watching and reacting on certain events. The whole system must be partially autonomous and must be able to correctly and quickly react to changes in the environment.

*1) General Solution*

The basic principle is similar to the one when controlling home environment. In addition there is a component of agents, which autonomously take care of the security of users. The system must be able to react to events such as fire, but also analyze current situation as whole, it should be able to localize the user, other robots and react to the overall situation in the environment. It is a very complex problem, where it is necessary to prepare a knowledge base, on which the system will base its decisions.

*2) RoboCare*

RoboCare is a system which attempts to implement such a care for the elderly. It comprises of many software and hardware agents, each providing different services, which are implemented by means of e-service oriented middleware [4]. These services are used by the central unit, which coordinates the work of individual agents. The system implements the Inversion of Control pattern [1], which allows loose coupling of individual agents, but also the system as whole. In [4] the authors present the function of the system on two agents.

The first one is the people and robot localization and watch agent. This agent uses cameras in watched rooms. It analyzes captured images and tries to localize users based on these images. It can also localize robots and devices which are located in the area. It can send commands to the robots based on their current position.

The second one is the plan execution monitoring agent. It analyzes events in watched environment, controls the fulfillment of planned events, reacts to predictable events and tries to prevent unpredictable events.

The agents can interact by providing services to each other. This is basically the implementation of the Inversion of Control design pattern. The components are loosely tied by eliminating mutual dependencies.

Such system can be improved by implementing an existing framework, that handles the basic functions of the environment and already has a knowledge base to build upon. An example of such a framework can be found in [10].

*3) Behavioral patterns*

We can see here behavioral signs similar to the Maior-Domo. The agents constantly monitor the environment and based on this monitoring control commands are sent back to specific system parts.

In addition, there is the prediction of unexpected events and communication between agents on the same level.

### *C. Games in ambient intelligence environment*

We will now try to look into a different possibility for ambient intelligence environments which is the area of gaming. These games offer new possibilities for players due to a new level of user interaction.

*1) General solution*

Computer games are still a favorite entertainment. There are two possibilities of using ambient intelligence environment for gaming.

First it is the possibility of using ambient intelligence interface to control existing games. This provides closer user interaction and a better connection with the game.

The second one are games based on ambient intelligence environment. AI environment can track user movement and accept voice commands. By focusing on goal achievement, the game can teach its players cooperation, increase game difficulty or provide different tasks for different users. It can gain all the information it needs based on its sensors and analysis of achieved tasks.

The game begins by a specific command. The system then sets difficulty for the game and explains to the players their first task. The simplest solution is by voice or video presentation. This can be for example a specific position of players etc. By achieving the goal, players continue to the next level. They can be rated by the time in which they achieve their goal, by the way they do it or by exactness of answers.

*2) Socio-e(c)ho*

In [5], the authors are trying to implement such a system for simple games on the ambient intelligence platform. It is a system called socio-e(c)ho, which provides the possibility of monitoring and viewing game status, creating user made models and interact based on the game structure.

The goal is to find out how AI systems support many players and research the players' interaction with intelligent environment.

There are seven levels of increasing difficulty. The players receive a word puzzle at the beginning of each level. This is a hint for them to achieve the desired position or movement.

User tracking is done by the means of motion-capture techniques, so that the system can monitor them and watch their progress through the game. The players can orient

themselves in the environment based on light and sound. The changes in light or sound indicate a change in the progress of current level.

The reasoning engine provides the intelligence for the system. It must interpret the input data from motion capture in real time, process it and indentify the level of completion of the body states or movement. It must also interpret group data and the sequencing of body states in the game.

The display engine has audio and light components, through which the system informs the users of their progress in the current level.

*3) Behavioral patterns*

Similar situations as in previous examples appear here as well, even though this is a very different implementation of AI system. There is the reaction on player movement and communication between system devices on the same level.

## VI. New Design Patterns

In the above examples, we can see a lot of situations which repeat. We will try to focus on a few of them and try to transform them into general form, so that they can be used in the future. It will be only a first concept of these patterns and they need to be examined further.

### *A. Primary initiation system*

The first pattern is initiating event of AI device or the whole environment. It can be triggered by user as it is with Maior-Domo, or automatically by an event in the environment as it is with a system for care for the elderly. One of the simplest examples may be turning on the light when a users enters room.

*1) Description*

A simple schema may look like the one on Figure 1.

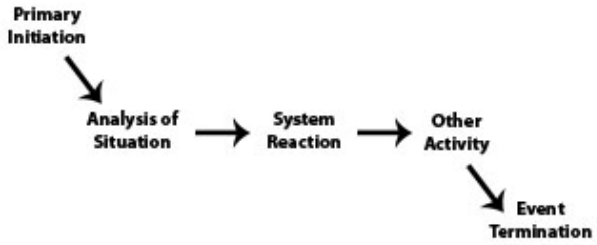


**Figure 1:** Primary initiation system

The primary initiation is either user command or an event of the environment. System processes the data and reacts appropriately. Other activities vary based on the different systems. When all commands are executed, the system returns to passive mode.

*2) Pattern application example*

We will demonstrate the usage of the Primary initiation system pattern on the simple example of turning on the light, when a user enters a room. In Figure 1, we can see, that the execution of the pattern starts with the Primary initiation. In our case, it is the user entering a room. Then we have to analyze the situation. The core shall ask the environment agents if the room is dark. The sensors will send a reply. If the room is dark, the system reacts accordingly, in this case, turning on the light, but it also may be rolling up the shutters etc. That is the System reaction. There is no need for any other activity in this case, so the event terminates. It may start again once the user leaves the room, so that the lights go off again.

### *B. User tracking*

In all above described systems, the environment can track user movement. This can be done by video cameras, intelligent floors, motion tracking sensors or heat sensors. The goal is to react appropriately to user movement.

*1) Description*

The situation may look like the one on Figure 2.

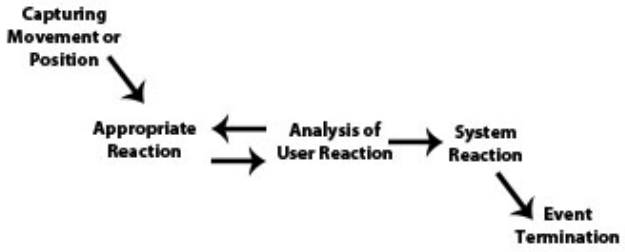


**Figure 2:** User tracking

At the beginning the system captures the position or movement of the user which is connected to some reaction. This can be the start of communication, calling for help etc. Based on the activity of the user, the system analyses if it reacted accordingly and reacts further if needed. When no other action is required, the system may do some finalizing activities and the event terminates.

*2) Pattern application example*

We will apply the User tracking pattern on a scenario from a home environment. The situation is that a user we will call Adam falls unconscious. The system detects, that Adam has fallen on the ground and is not moving. Based on this fact, the system calls for an ambulance and tries to communicate with Adam. If available, it can also send a robot to assist or try to wake Adam somehow. While Adam is unconscious, the system uses any resources available to help him and determines if his status has improved. Once an ambulance arrives, the system provides the doctor with all information it has gathered about the situation and then the event terminates.

### *C. Command*

In most environments we examined a possibility for a user to enter a command to the system he works with appears.

*1) Description*

Schema of such a situation may look like the one on Figure 3.

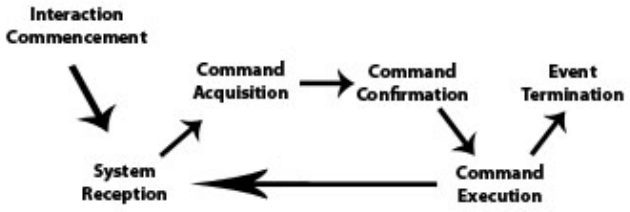


**Figure 3:** Command

We will try to illustrate this on voice commands. The user initiates the system by a specific keyword. The system reports, that it is ready to receive commands. After receiving user command, the system asks the user, if it understood his command correctly. Based on the user's answer the system executes the command. It can then either continue receiving commands or end the communication with the user.

*2) Pattern application example*

Application of the Command pattern will be demonstrated on a common situation in the home environment. A user, whom we will call Barbara will communicate with the home central system. Start of the communication may be implemented using the Primary initiation pattern. In this example, we will only handle the consecutive process. The environment in which this example scenario takes place is a home computer system, that allows voice communication with the user and provides text input on a TV screen. It is equipped with microphones integrated with the environment.

First, we will describe the scenario and then show the implementation of the Command pattern on this scenario.

Barbara would like to watch a movie. She doesn't know which movie exactly yet, so she asks for a list of movies. The computer can offer her movies listed by ratings, latest movies, various genres etc. Barbara wants to watch a romantic movie, so she asks for a listing of romantic movies. There is a lot of movies from this genre, so they are listed on several pages. Barbara "turns" the pages until she finds a movie she would like to watch and asks that the movie be played. She sits down on her sofa and enjoys the movie.

Now for the Command pattern implementation, it is obvious, that Barbara is giving commands to the computer system, thus we will apply the respective pattern.

The Interaction Commencement phase may implement the Primary initiation system pattern by capturing a keyword, using which Barbara starts the communication. The whole Command pattern implementation is hidden under the System Reaction phase in the Primary initiation system pattern as shown on Figure 4.

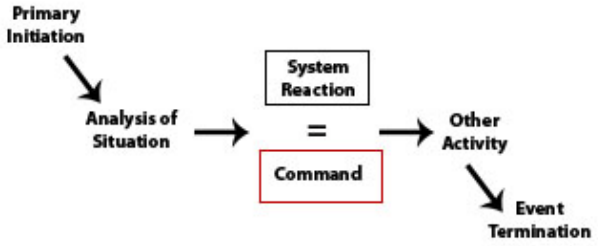


**Figure 4:** Command as System Reaction

We will show the implementation of the Command pattern on the specific example of Barbara wanting to watch a movie, but it can be any other command given to the central system.

Interaction with the system starts when Barbara asks to watch a movie. The system receives the command, which is the implementation of the System Reception phase. Command Acquisition processes it and as it is a clear command, it understands it, skips the Command Confirmation phase and acts further. When the Command Execution phase comes up, the system determines, that Barbara did not specify the movie, so the system asks her what kind of movie would she like to watch, which brings the current phase back to System Reception. Barbara asks for a romantic movie, the system receives the command and lists the romantic movies it has in its database. Barbara asks for the next page of the list by another command and the system presents it to her. She picks one of the movies and asks the system to play it.

In this phase, the User tracking pattern may be implemented for maybe a bit advanced case, that Barbara would pick the movie by pointing at one of the listed movies and perhaps saying: "That one!". In this case, the system would have to determine where is her finger pointing and ask her to confirm the movie by saying the movie's name or highlighting it on the screen.

As the system knows this is the final step, it asks Barbara in the Command Confirmation phase to confirm the movie that is about to be played. The above is a repetition of the loop from the System Reception to the Command Execution phase while there are still further instructions needed. When Barbara confirms, the system starts playing the movie and the event terminates.

### *D. Implication of new design patterns*

The proposed design patterns may be used when building new solutions in the area of ambient intelligence. They offer a good base for solving situations that appear in these systems frequently. It is then not necessary to solve the same situation over and over again, but a general process is available. It is however vital to research further and confirm the effectiveness and real applicability of these patterns and analyze more example situations.

## VII. CONCLUSION

In this paper we described selected example situations of behavior of AI systems and general solutions of a few problems. Of these general processes three often repeated situations emerged. The main goal of these model situations is that these basic problems need not be solved again. They offer a simple process of solving classical situations and come out of existing systems.

Ambient intelligence concerns mainly the home environment and so most model situations are from a home environment. User interaction system is described and also his way of communicating using natural human interaction.

One of future goals is the analysis of more model situations and searching for common aspects so we can better specify the abstract patterns and also confirm the above. Another might be searching for newly appearing situations and proposing further solutions for problems. The area of ambient intelligence develops quickly and it is thus probable that there will be a lot more resources available.

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