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Ambient Systems and Taxonomy Approaches

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About the authors

Mr A. Konios received his Bachelor degree in Computer Science from the University of Piraeus in 2009. In 2010, he graduated from Newcastle University, where he did his Master degree in Computer Security and Resilience. Currently he is studying for his PhD in Modelling and Synthesis of Ambient Systems under the supervision of Dr Marta Koutny. Other research interests include Formal Methods and System Validation.

Suggested keywords

Ambient Systems and Taxonomy Approaches

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This work presents the main features of the ambient systems and how they are interpreted by their designers. Looking back to the literature, definitions that have been given to the ambient systems up to this day are presented. This paper introduces a generic definition of the ambient systems that tries to combine and cover the majority of the different definitions that have been given by other researchers. In addition, some examples of developed ambient systems and their evaluation techniques are briefly mentioned. Thereafter, we raise the problem of the behavioural analysis (synthesis problem) of the ambient systems which we are going to address during this PhD project. Furthermore, we propose two examples of ambient systems that could be used as case studies for our research topic. Finally, in the last part of this paper, some of the existing taxonomy approaches are analysed and a comparison of two of them is conducted by classifying the two case studies.

1 Introduction

The rapid development of ambient systems, which are increasingly related to the use of advanced technology, leads more and more researchers to deal with these more complex environments. The need of exhaustive understanding of these systems resulted in the creation of different definitions of these systems. Despite the fact that the researchers, through their definitions, focus on different aspects of ambient systems, these systems have some certain characteristics that dominate their functionality. These characteristics are presented in the next section.

Wanting to achieve a more comprehensive and easy understanding of what ambient systems are, except their different and various definitions, we also present some taxonomy methods that will help us to become familiar with the notion of this kind of systems more quickly. Moreover, we describe two of the case studies that will be used for analysis during this project.

Users that interact with this kind of systems usually require a sufficient and effective behaviour from them. In other words, they expect the appropriate response or reaction of the systems. In order to achieve this goal, the designers analyse their systems using a variety of evaluation methods, such as formal methods. Some examples of formal methods that deal with the verification of the systems are: Petri nets [1], Visual Event Grammar [2], Modal Action Logic [3], Social Network Analysis [4], Interaction Walkthrough [5], etc. As was mentioned above, these methods have the intention to analyse the system behaviour by checking if the prevailing properties of the system hold or not; if these properties do not hold, they may cause the defective function of the system. Each of these methods takes into account different or similar properties during the verification process.

In this project, we are going to use Petri nets, especially classes of Petri nets with localities [6, 7, 8], in order to analyse the behaviour of the ambient systems. To be more specific, we shall try to sort out the synthesis problem, which is defined in [9] as the construction of a Petri Net for a given transition system in such a way that the reachability graph of the net is isomorphic to the transition system. Currently, the detailed description of the synthesis problem is out of the scope of this paper. We just intend to explain the ambient systems that will be used for the analysis purposes.

2 Ambient Systems

Nowadays, humans are looking for systems that will make their lives easier and more pleasant with respect to the fulfilment of their everyday obligations or transactions. The tremendous advance of technology has contributed to the construction of such systems, which incorporate both ubiquitous and pervasive computing. Their main purpose is to serve their users so that they will not be charged with additional and time-consuming tasks in order to achieve their primary goal. In fact, the aim of these systems is to act in the background in a silent way that will not distract or interrupt the user from his goal, but only will inform him when is needed. In addition, they usually facilitate the user's tasks by tracking down or predicting his potential actions. Ambient systems were named after their ability to be completely embedded in the environment in which they act.

In the next paragraphs, we present some definitions that were given to the ambient systems, which specify exactly what these systems and their main characteristics are. At the end of this section, we develop our generic definition for the ambient systems and we mention some examples of implemented systems.

2.1 Definitions of Ambient Systems

Luca Cardelli and Andrew Gordon [10] define the ambient system as a bounded place where computation happens, can be nested within other ambient systems, can be moved as a whole, has a unique name and a collection of agents. The

notion of the boundary determines what is inside and what outside an ambient. The second characteristic allows an ambient to be used as part of another ambient. The "move" property implies that a device can be connected (disconnected) to (from) a system automatically without causing problems to the system. Finally, the name of the ambient is used to control the access to the systems and the collection of agents characterises the ability of the system to run computations.

Iliasov et al in [11] define ambient systems as systems that have mobile elements, need to be context-aware and are open. Mobile elements can be code, devices, data, services and users. Context-awareness mentions the ability of the system to be adapted to the information changes. Finally, the openness refers to the fact that system components can appear or disappear.

Kristensen et al in [12] define ambient systems as environments where "users participate in several ongoing computations. Aspects as time and space are central in the systems. The systems usually identify users, collaborate intelligently, and support users in their ongoing activities. In ambient systems the participants can have the initiative. The goal is not to provide information per se, but to support activities directly in the physical world".

Russ et al [13] define ambient systems as: "An ambient information system is a system which offers its user mobile and pervasive access (mediated by sensors and effectors of their immediate environment) and which is capable of adapting itself to the particular user needs and profiles".

After having looked at some definitions of the ambient systems, we present our definition, which incorporates all the characteristics that were defined by the above definitions, in order to provide a more descriptive and comprehensive statement of the ambient systems.

So we define an ambient system as a system that acts in a silent way at the background of the environment (i.e. allows the user to have the initiative), does not distract the user from his goals, predicts or tracks down the potential actions of the user, informs/alerts him periodically or when is needed and has the following characteristics:

- Is context-aware, namely it adapts itself according to the information changes. These changes can be change of location / position of an object (device) or a subject (user), change of time, temperature etc.
- Consists of output devices and mobile elements, such as private displays (PDAs, mobiles, laptops) and public displays (boards, screens), where the (updated) information is displayed,
- Has advanced technology, like robotic technology, sensors, effectors etc., which makes it capable of identifying, tracking down and interacting with the user or the system components/devices,
- Is a bounded place. The dissemination and use of the data/ information is restricted by the boundary of the system,

- The information is always available (depending on the access level of the user). Each user has access only to the information that he is eligible for. In addition the availability of the information requires continuous connectivity to the system,

- Devices can be automatically and directly connected (disconnected) to (from) the system without affecting its functionality.

In the next part, we briefly present some examples of existing ambient systems.

2.2 Examples of developed Ambient Systems

Harrison and Massink [14] have modelled a Guidance system and an Out-patient system. The first one aims to guide the visitors that are unfamiliar with an office building to a particular location in it. The Out-patient system is similar to the previous one but is located at a hospital. This system provides information to the patients that is relevant to their appointment, the waiting times and finally helps them through the guidance system to get to the suitable doctor or report for the appropriate medical examinations.

Kray et al have developed an Airport model [15]. That system simulates the steps of the airport system. In more details, it senses the location of the user and informs him about his flight, the possible next steps that he has to do and all the relating information. This model works by using sensors that identify the user and his current location.

Finally, *Luis Silva et al* have implemented a system that simulates the functionality of a smart Library [16]. This model informs the user of the books that are in stock and then guides him to the place where the book that he wants is. Firstly, the user requests a book through the library webpage and then goes to the library entry gate where a display shows his request. He enters the library and the guide system of the library leads him to the shelf where the book is located. The system points out the exact position of the book by a light of a specific colour. The user picks up the book and he can leave.

3 Case Studies of Ambient Systems

Having mentioned the basic features of the ambient systems in the previous sections, the following ones present two ambient systems that could be used as case studies in order to examine their behaviour using different classes of Petri Nets, such as Elementary Net Systems and Place-Transition Systems with localities. These two ambient systems fully comply with the generic definition of ambient systems that was presented earlier in this paper (see section 2.1).

The two case studies refer to systems that were developed by students of the University of Piraeus and Newcastle University during their undergraduate and postgraduate studies respectively.

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3.1 Ambient Parking Garage

Starting with the description of the first case study that will be used for the elaboration of that specific PhD project, it should be mentioned that the Ambient Garage, which is presented below, is an extended version of an application that was developed by Konstantinos Konstantopoulos, Dimitrios Salogiannis and Alexandros Konios during their undergraduate studies. That system was implemented in VRML (Virtual Reality Modelling Language) language. The behaviour of the system is presented in the form of scenario in the following paragraph.

3.1.1 Scenario of Ambient Parking Garage

The Ambient Garage, as is logical, is a bounded place and its capacity is limited. For sake of simplicity, it is assumed that this particular garage can host up to fifteen cars and is equipped with two entrances that can be also used as exits. In addition, the Garage is always in operation and when the system reaches its maximum capacity, the cars that request access to the building have to wait in a queue until a parking space is released. The drivers that wait for a space are informed that the garage is full by a message on their mobile device. Each of these drivers can leave the queue anytime he wants without taking any further actions. The maximum length of the queue can be two for each entrance.

The drivers (users) can have access to the Garage only by using a prepaid ticket. This ticket can be bought either online or from the kiosk of the garage where the users fill in a form with personal details like name, surname, address, mobile number etc. The user can buy three different types of tickets, a one-hour, a daily or a monthly ticket. If a user buys a ticket, a confirmation message is sent to his mobile device (this process will be described later). The type of the ticket corresponds to the sectors/area where the car can be parked. Each sector has five parking spaces and each ticket corresponds to one specific space of that sector. Each space of the garage is equipped with sensors in order to allow the administrator of the system to know if a car is parked at the appropriate position or not. If that car is parked in a wrong place, a visual message is activated alerting the driver to move his car to the correct position. This message is depicted by a flashing light(which is located over the parking spot) that has the same colour as that of the instructions indicating the correct place where the car should be moved. Moreover, the cars have equipment that allows the sensors of the garage to acquire the appropriate information each time that is needed. This equipment is used as the ID of each car. Finally, it is assumed that each driver always carries a mobile device (e.g. PDA, mobile phone) with him, where he receives all the relevant information.

Continuing the description of the system, it should be mentioned that the garage is fully equipped with sensors that recognise the position of each car anytime. The ambient garage also has a guidance system (or signage system) that gives instructions to each driver of how he can get to the parking space that is allocated to his car. All these instructions are shown on the public displays

(boards) of the garage, assigning a specific colour for the signage (e.g. arrows) of each car. In case that a driver misses the target by following wrong instructions, the system redirects him by finding his current position and changing the relevant signage on the public displays (update of the data). When the driver finds his space and successfully parks his car, the sensors recognise that the suitable car has been parked to the space by scanning the ID of the car. Then the system sends a message to the mobile device of the user informing him about the remaining time that he has in his disposal (by showing a timer that counts down the time). Fifteen minutes before the time expires, the system transmits again an alert or notification message to the user reminding him that he has to leave the garage within the remaining time or that he can renew the ticket. If the user does not leave the garage within that time, a fine is imposed by the system. On the other hand, if the user renews the ticket, the same procedure as that of buying a ticket is repeated, i.e. the system sends a message to the mobile device notifying him with the remaining time.

Until now, we have described the procedure that takes place when the car is in the garage but we have not discussed yet what happens when a car/driver requests to enter or leave the building respectively. In the former case, the car approaches the bar of the garage, where a sensor scans the ID of the car finding out if the ticket is paid or not. In case that is not paid, the access is denied to the car and a message is sent to the mobile device of the driver, informing him that he has to buy a ticket. Otherwise, the access is permitted and the system lifts up the bar. When the bar is lifted up, the system automatically assigns a parking place to the car according to the type of its tickets and guides it towards that place. In the latter case, the car/driver that wants to leave the building approaching the exit bar. Another sensor identifies the car and checks if it is authorised to leave. If not, the system sends a message to the driver notifying that the fine must be paid. When the fine is paid, the driver is free to leave, otherwise the bar remains down.

3.2 Conference Room Smart Environment

The following system is an application that was developed by Antonis Petrou during his thesis in the MSc course of Computer Security and Resilience at Newcastle University [17]. This application simulates an ambient environment of a conference room. The conference meeting room is a place where the conference committee decides which of the submitted papers will be accepted or rejected in order to be included or not in the conference. The detailed description of the functionality of that environment will be explained in the following paragraphs through the presentation of the scenario, on which the implementation of the application was based.

3.2.1 Scenario of Conference Room

The behaviour of this system is presented by following a scenario that consists of sub-scenarios that cover all the possible cases that could occur in the conference

room. This environment requires authorized members that can have access to the conference room using a smart card that corresponds to their ID. Each of these cards is unique and it is supposed that the user always carries it with him. The users can enter the room only if they swipe their cards through the card reader that is located on the door. The same process is repeated when the users want to leave the room. The system, using the cards can identify who is in the room at any time.

The room is equipped with stationary personal displays, sensors that are embedded in the personal displays and a public display. Furthermore, each personal display uses a role based access control system to identify the authorised users. This access control system is working by using a password and a username. Each time that a user enters his credentials, the system allows him to gain access to the information that corresponds to his role. The roles that can be assigned to the members of the conference are: author, spokesperson, temporary reviewer, reviewer, committee member, stand-in chair manager and chair manager. Some of the authorized members of the conference meeting can be assigned with more than one role.

Prior to the beginning of the conference meeting, the chair manager, who also has administrative privileges, can have access to the database in order to initialise the registered members, their roles and the appropriate data (submitted papers, initial decisions) that are needed for the conduct of the conference. An assumption that all the submitted papers have already been graded (by two reviewers each) is made; that is called an initial review. According to the scores of the initial reviews, the system makes a suggestion about the initial decision for each paper. This initial decision will be used during the main phases of the conference (e.g. first phase).

The conference meeting consist of three different phases and a break phase. During the first phase, all the authorised members can participate in the conference meeting (are in the room) and the information about the submitted papers and their initial reviews is shown on the public display. In phase one, the only personal displays that can be used are these of the chair manager and the spokespersons. The display of the chair manager shows the review information of all the submitted papers and allows the chair manager to take actions, such as making/changing initial decisions for the papers (accepted or rejected). On the other hand, the displays of the spokespersons enable them to see information about the reviews of the papers that are assigned to them (each spokesperson can acquire information only for the papers that are assigned to him). If an unauthorised person gets in the room (during phase one), the system hides all the information of the public display and shows it again when that person leaves the room. The same thing happens when that person gets close to an activated personal display. In former case, the system identifies the unauthorised user by his smart card (when he swipes it, the card reader sends a signal to the system that someone enters the room and the system scans the database to check if he is a registered member or not). In the latter case, the sensor of the personal display senses that another (unauthorised) person is within the range of the

private display and hides all the information of the display. In addition, it does not matter if the authorised user is in front of the display or not, the system will hide all the information from everyone that is within that range. The first phase ends when the chair manager has assigned all the papers to the temporary reviewers and a decision about which of the papers will be reviewed in the next phases has been concluded. At the end of the first phase, the system forces the members that cannot participate in the next stage to exit the room immediately in order to permit the remaining members to carry on with the procedure of the conference.

The completion of the first phase is followed by that of the break. The members that can be present in the room during the break phase are all the members that have one of the following roles: chair manager or temporary reviewer. During that phase, the temporary reviewers can see (on their personal displays) information about the list of the papers that must be reviewed and can also score them. Each temporary reviewer can only receive information about the papers that are assigned to him. In contrast to the private displays, the public one displays the list of the papers under review and a timer that shows the remaining time until the end of the session. If a reviewer submits his scores for the relevant papers, the system does not let him change his mark or any other detail. As in the first phase, an unauthorised person could get in the room unexpectedly. In such a case, the timer will be automatically stopped due to the interruption of the session and will start again when that person leaves the room. If all the reviews have been submitted or the time expires, the break phase is terminated and the conference proceeds to the next phase.

Phase two is held after the end of the break phase. In this phase, all the members of the conference, except the chair manager, the spokespersons and the committee members that can attend the meeting, should leave the room; when only the authorised persons remain in the room, the second phase can start. The public display of the room presents all the updated information about the paper reviews that were carried out during the previous phase and their scores. The committee holds a session to make a final decision for each paper. In this case, some conflicts between the roles can emerge. For instance, a member of the committee can also be an author of a reviewed paper. Even the chair manager could be in this situation. Thus, the elimination of these phenomena is achieved by removing the privilege from the member who is closely related to the paper which is currently examined. That member must leave the session until a final decision is made for that paper. After that, each "banished" member can return to the session. If that member is the chair manager, the system sends an alert message to him through his private display and deactivates his role until the final decision of that particular paper is made. In the meantime, another predetermined member temporarily replaces him as the stand-in chair manager. Conflicts can occur even if the authors of the reviewed paper are from the same institute or organisation as some of the committee members. Once again, the system forces the members that are in conflict with the currently examined paper to exit the room, otherwise the session cannot continue. It is

also assumed that an unauthorised user can interrupt the process by entering the room, as in the previous phases. The system reacts to that interruption as in the previous phases. When all the conflicts and the interruptions have been solved and all the final decisions have been made, the second phase is finished.

Finally, the last phase of the conference allows everyone to be present in the room. During that stage, the final decision for each paper is announced and all the relevant information is displayed on the public screen. In this phase, the personal displays cannot be used and it is assumed that interruptions by unauthorised users cannot affect or change the conference procedure. After the announcement of the decisions, the conference meeting is completed and all the participants leave the room.

4 Taxonomy Approaches of Ambient Systems

The primary intention of the following paragraphs is to briefly present some of the developed taxonomy approaches that were found during the literature review that we have carried out. Furthermore, we use two of these taxonomy approaches to classify the ambient systems that were described above.

It is worth pointing that despite the rapid growth of the ambient systems and their embodiment in our lives, their classification is in early stages yet. This fact is justified by the difficulties that emerge during the development of such a taxonomy approach. These difficulties could consist of the motivations, the goals, the range of the examined dimensions, the efficiency of the approach etc. As has been noticed from the literature, only a few different approaches have been developed or published to date.

4.1 Ames' and Dey's Taxonomy Approach

Ames and Dey introduce a classification for ambient information systems that derives from their experience in developing such systems [18]. Their suggestion is based on eleven system dimensions that are used to assess the quality of the classified systems. These dimensions are: intrusiveness, notification, persistence, temporal context, overview to detail, modality, level of abstraction, interactivity, location, content and aesthetic.

The dimensions mentioned above are described in [18] as follows:

- Intrusiveness: displays do not demand attention, but provides information with a level of intrusiveness appropriate to the information's importance

- Notification: devices display information constantly, but alert with a more salient cue when a certain state is reached or when information changes - they do not demand the same amount of attention all the time

- Persistence: displays show information at an appropriate time scale and an appropriate refresh rate

- Temporal context: if comparison with past or prediction of future is important, displays show it, reducing cognitive demands on user by not requiring them to remember other states

- Overview to detail: displays show the right amount of detail: get an overview at a glance, and more detail if one pays attention

- Modality: displays show information in a mode (that is, using a sense) that is not already overloaded

- Level of abstraction: displays do not show information directly, but rather in an abstract or indirect manner. The method of displaying information should be clearly linked to the nature of the information

- Interactivity: displays are appropriately interactive (or not), without demanding too much from the user

- Location: displays reflect sensitivity to location and their surroundings in general, such as a quiet room vs. a noisy public plaza

- Content: displays show information that the user cares about, or are flexible in content

- Aesthetics: apart from being useful or valuable as information sources, the displays are also pleasing

4.2 Matthews et al. Taxonomy Approach

Matthews et al. have implemented a taxonomy that focuses on three basic dimensions for the evaluation of the ambient systems: notification level, transition and abstraction [19]. The notification level refers to the importance level of the data that is disseminated within the system. Notification level is divided into five levels that depict the importance of the data: Ignore, Change Blind, Make Aware, Interrupt and Demand Attention. These levels are sorted in an ascending order (from low to high). The transition dimension represents the programmatic changes to the displays that result from the data updates. Transition is assessed using the following enumeration: interrupt, make aware and change blind. The last dimension (abstraction) describes the process that transforms the input data to any types of perceivable information that can be displayed on the screens of the ambient systems (e.g. sign, picture, caricature, letters or numbers). The abstraction is measured using two categories: feature abstraction or degradation.

4.3 Pousman's and Stasko's Taxonomy Approach

Pousman and Stasko define a new set of dimensions to analyse the ambient systems [20]. These dimensions are: information capacity, notification level, representation fidelity and aesthetic emphasis. Information capacity refers to

the throughput of information that can be displayed by an ambient system. Information capacity is rated using five levels: low, somewhat low, medium, somewhat high and high. For instance, systems that depict only a single piece of information are characterised by low information capacity and systems that display more detailed information could belong to upper levers depending on the throughput of information that they deal with. Notification level characterises the intrusiveness of the system. In more details, a system alerts the user according to the importance of the information. At this point, Pousman and Stasko adopt, with a slight difference, the levels that are defined by Matthews et al. Pousman and Stasko have changed the lower level from Ignore to User Poll. Representation fidelity deals with the different ways under which the information can be presented by the system. The display of the information calls for representational accuracy and easy perception of the meaning of the presented information. In order to analyse these notions, Pousman and Stasko introduced the categories as follows [20]:

- INDEXICAL: measuring instruments, maps, photographs, text

- ICONIC: drawings, doodles, caricatures

- ICONIC: Metaphors

- SYMBOLIC: language symbols (letters and numbers)

- SYMBOLIC: abstract symbols

These categories have been sorted from high (indexical) to low (symbolic). Systems that cannot represent the information accurately and the user is not able to comprehend the meaning of the information easily belong to the lower layers of this categorisation. Finally, the last dimension that has been proposed is the aesthetic emphasis. Aesthetic emphasis focuses on the intention of the developer to produce a visually pleasing system. This dimension can be rated only in a subjective way. This occurs due to the fact that the evaluators of a system may have different opinion of what is aesthetically pleasing or not. The grading scale that is used in this case is identical to that of the first dimension.

Pousman and Stasko also suggest four design patterns that aim to provide a generic categorisation of the ambient information systems. These patterns derive from four different combinations of the dimensions of their proposed taxonomy. These four patterns are: Symbolic Sculptural Displays, Multiple-Information Consolidators, Information Monitor Display and High Throughput Textual Display. The following figure shows the graphs of these patterns (adapted from [20]).

These patterns will be described thoroughly in the following paragraphs.

Symbolic Sculptural Displays: this pattern consists of ambient systems that provide few information to the users and their information is displayed in an abstract way.
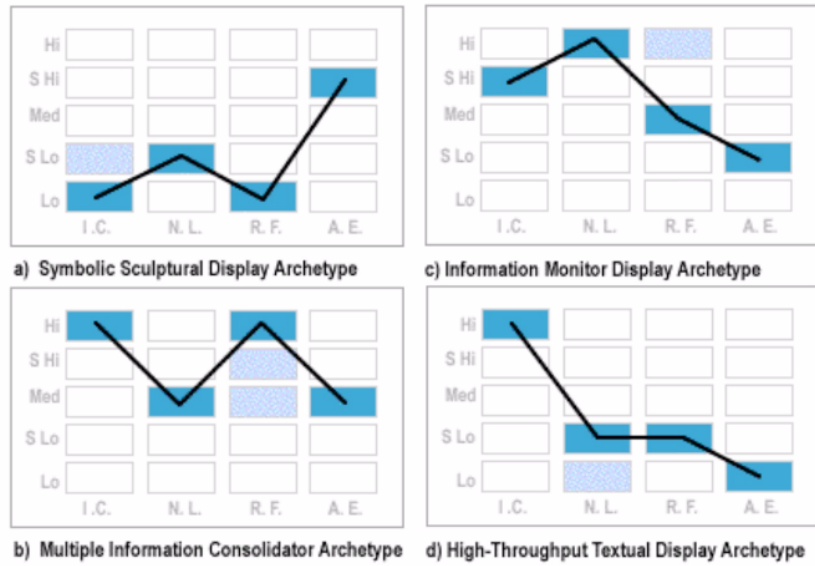
Figure 1: The four design patterns of Pousman and Stasko.

Multiple-Information Consolidators: this pattern contains systems that can supply the user with much more information than that of the Symbolic Sculptural Displays. Finally, they make the users aware of the information changes and could be characterised as aesthetically elegant systems.

Information Monitor Displays: this pattern includes ambient systems that can provide too much information but in an iconic way (usually information displayed by metaphors). They can notify the user of the context changes in an efficient manner. As regards the aesthetic emphasis, these systems could be classified either in the medium or in the somewhat low level.

High Throughput Textual Display: this pattern consists of all the systems that can deal with huge throughput of information. They represent the information with very simple graphics. Furthermore, the notification level of these systems can be either user poll or change blind, which means that these systems are possessed by low intrusiveness. Finally, their low aesthetic emphasis ranking proves that the primary goal of the designers of these systems is not the elegancy.

At this point, it should be mentioned that these design patterns do not cover all the ambient systems that can be analysed by this taxonomy approach. For example, there exist systems that could be classified to a different combination of dimensions or could belong to more than one pattern.

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4.4 Tomitsch et al. Taxonomy Approach

The last taxonomy approach was developed by *M. Tomitsch, K. Kappel, A. Lehner and T. Grechenig*. The intent of this group of scientists was to present a taxonomy approach that would have more descriptive power than that of the existing ones [21]. Therefore, they developed a taxonomy that contains all these features that have the greatest influence on the design of the ambient systems. These system features correspond to the following dimensions: abstraction level, transition, notification level, temporal gradient, representation, modality, source and dynamic of input. Each of these dimensions uses different metrics in order to be analysed.

Abstraction level describes how the encoded data is represented by the system. This dimension can be measured using three different levels of abstraction: low, medium and high. Systems that belong to the low level represent the information in a direct and comprehensive way. Medium level systems depict the information in quite comprehensive way. Finally, high level consists of systems that use a symbolic representation of the information.

Transition refers to the state changes of the system that result from the update of the information. More precisely, transition measures the velocity of the state changes that may occur during the operation of the system. Transition can be measured as slow, medium and fast. A system that is characterised by a slow transition does not make the user aware of the state change directly. Medium transition systems change the state of the displays faster than the slow transition systems. Finally, fast transition systems are able to immediately change the state of the display.

Notification level discusses the way under which the system alerts or notifies the user as regards the information changes. In this approach, the developers have adapted the same metric features as these in the taxonomy approach of Matthews et al in order to analyse the notification level of the ambient systems.

Temporal gradient refers to whether the system displays a record of all the state changes of the information or not. The metric of this dimension is either history (all states are displayed) or current (only the current state).

Representation deals with the nature of the output displays, i.e. the type of the displays. This dimension uses three classification categories of the output displays: physical, integrated and 2D representation. Physical representation refers to output displays that are design to be ambient information systems. Integrated representation includes systems that use object with embedded technology that function like ambient displays. 2D representation category consists of systems that use typical screen technology.

Modality describes the forms under which the information can be presented to the users of the system. Metric of this dimension can be: visual, tactile, olfactory, auditory, and movement.

Source refers to the locality of the information in relation to the source. In other words, it describes if the displayed information and its source are within the same environment or not. The metric features of this dimension are classified

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as local, distant and virtual. Local source implies that the position of the displayed information is the same with that of the source. Distant source systems allow the dissemination of the information to mobile devices that are located in a large distance from the source. Finally, in virtual source systems, information can be provided using virtual networks like internet or mobile networks.

Location, as it is described in [21], refers to the location or context of the output devices. Three common classes of location are used: private, semi-private and public.

Dynamic of input describes the frequency or the velocity to which the data changes in relation to the source of that data. Dynamic of input is quite similar to the transition of the system. It uses the same metric features as these of transition. Slow dynamic describes rare data changes that in their turn result in rare updates of the output displays. Medium dynamic refers to frequent changes of the input data. Finally, fast dynamic implies direct and fast data changes.

Using this taxonomy, its developers try to relate the used dimensions to each other so as to identify possible patterns that could be useful for the analysis of the examined ambient systems. For instance, they have concluded that the majority of the systems with slow transition must also have a change blind notification level.

4.5 Comparison of Taxonomy approaches

In the next part of this section, we demonstrate two taxonomy examples using the last two approaches that were mentioned above. In these examples, we classify the case studies of paragraph 3. The goal of this illustration is to identify if we could draw precise and useful conclusions about which taxonomy is more effective.

Starting with the first taxonomy example, we classify the two case studies using the approach of Pousman and Stasko. Firstly, we examine the information capacity of our systems and can claim that the ambient garage can have somewhat high or high information capacity. This decision derives from the fact that the system can represent a huge amount of information on its public displays (i.e. boards). On the other hand, the ambient conference room belongs to the medium class due to the fact that it can depict limited information either on the public or private displays.

The next dimension is the notification level. As has been mentioned above, notification level has the following classes: User Poll, Change Blind, Make Aware, Interrupt and Demand Attention. The ambient garage is positioned on the Make Aware notification level. This results from the fact that the system always makes the user aware of the state changes (information changes) without interrupting or demanding attention. Contrary to the garage, the conference room sometimes notifies the user of a state change by interrupting him from his primary goal. This occurs when an "intruder" enters the room or gets

close to a private screen. At these occasions, the system hides all the information and does not permit the completion of the task. So, its notification level can be defined as Interrupt.

Analysing the two ambient systems in terms of representation fidelity, we conclude that both systems represent the information in a direct and comprehensive manner. Both of them use textual information. In addition, the ambient garage also uses iconic representation like coloured arrows. Although it uses iconic representation, it will be included in the indexical class, because the majority of the information is represented by text. Conference room also belongs to the same class.

Finally, as regards the aesthetic emphasis dimension, we have subjectively assessed both the garage and conference room and classed them in the medium class. We believe that the systems that support LCD screens as output displays, could be characterised as aesthetic good looking systems, therefore we put them in the medium class.

The classification that was explained above is also presented in the following table:

	Information Capacity	Notification level	Representational fidelity	Aesthetic emphasis
High/ Demand Attention/ Indexical			Ambient Garage, Conference Room	
Somewhat high/ Interrupt/ Iconic	Ambient Garage	Conference Room		
Medium/ Make Aware/ Iconic	Conference Room	Ambient Garage		Ambient Garage, Conference Room
Somewhat low/ Change Blind/ Symbolic				
Low/ User poll/ Symbolic				

Table 1: Rousman and Stasko taxonomy

As we can notice from the above table, these systems do not match to one of the four patterns that Pousman and Stasko have introduced, but we could claim that ambient garage and conference room are close to Multiple Information Consolidator and Information Monitor Display respectively.

Continuing with the second taxonomy approach [21], we try to classify the two systems using all the dimensions and the corresponding metrics of the approach.

The abstraction level of both systems can be characterised as low because both system support textual representation, thus there is no or very low abstraction to the representation of the information. Examining the transition, we notice that both systems have a fast transition. That means that the users of

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these systems can recognise state changes immediately on the private or public displays. For example, the garage immediately notifies the user when he loses his way by redirecting him through the change of the arrows that lead to the parking space. In conference room, a kind of fast notice is observed when an unauthorised user enters the room. The notification level in this approach is almost the same as in the previous approach, so the garage and the conference room belong to Make Aware and Interrupt class respectively. Next step is the assessment of the temporal gradient. Both systems do not keep record of the previous states, so they are included in the current class. After that we examine the representation and the modality of the systems. Both systems use LCD screens and represent their information in a visual way (text, symbols), therefore we classify them as systems with 2D representation and visual modality. The last three dimensions that will be analysed are: Source, Location and Dynamic of Input. As regards source, the garage gives the opportunity to the users to retrieve information through mobile or wireless networks, so it is characterised as virtual. On the other hand, the conference room is characterised as local because the information is available only within the room. Location of both systems can be described as a combination of public and private classes. This happens because these systems use both types of context. Finally, the dynamic of input for both systems is fast due to the fact that they use dynamic changes of input.

Having used these two different taxonomies for the above ambient systems, we have concluded that these approaches analyse and focus on different aspect of the systems. To be more specific, the first one is a simple method that does not cover a huge spectrum of system design issues. On the other hand, the second approach is more descriptive and allows the designers to understand the importance of some system features that could improve the functionality and the effectiveness of the systems that they want to develop. For that reason the second method could be employed for the creation of more useful and effective taxonomy patterns.

The second comparison is summarised in the following table:

Systems	Abstraction level			Transition			Notification level					Temporal gradient		Representation			Modality					Source			Location			Dynamic of input		
	Low	Medium	High	Slow	Medium	Fast	Ignore	Change Blind	Make Aware	Interrupt	Demand Attention	History	Current	Physical	Integrated	2D	Visual	Tactile	Olfactory	Auditory	Movement	Local	Distant	Virtual	Private	Semi-public	Public	Slow	Medium	Fast
Ambient Garage	*					*			*				*			*	*							*			*			*
Conference Room	*					*				*			*			*	*					*					*			*

Table 2: Taxonomy of M. Tomitsch, K. Kappel, A. Lehner and T. Grechenig.

5 Discussion

In this paper we have discussed a variety of issues that are related to ambient systems. The main aim of this paper was to explain what an ambient system is and how we can classify ambient systems by using some taxonomy approaches. Throughout the writing of this paper and the investigation of the literature as regards the classification of the ambient systems, we concluded that further taxonomy approaches of ambient systems could be applicable. For example, a future work could be a development of a taxonomy approach that will be based on notions related to Petri Nets, i.e. the causality and concurrency of system's behaviour.

References

[1] Wolfgang Reisig. "Petri Nets - An Introduction", EATCS Monographs on Theoretical Computer Science, Springer-Verlag, 1985.

[2] Berstel, J., Reghizzi, S.C., Roussel, G. and Pietro, P.S. A scalable formal method for design and automatic checking of user interfaces., ACM Transactions on Software Engineering and Methodology, May 12-19, 2001, p.453-462, Toronto, Ontario, Canada.

[3] Campos, J.C. and Harrison, M.D., Systematic analysis of control panel interfaces using formal tools. In T.C. Nicholas Graham and Philippe Palanque (editors) Interactive Systems: Design, Specification and Verification (DSVIS 2008) Springer Lecture Notes in Computer Science 5136 pp. 72-85, 2008.

[4] H. Thimbleby and P. Oladimeji, Social network analysis and interactive device design, 2009, ACM SIGCHI Symposium on Engineering Interactive Computing Systems, EICS'09, pages 91-100, Pittsburgh, Pennsylvania, USA.

[5] H. Thimbleby, Interaction Walkthrough: A usability evaluation method for critical systems, Department of Computer Science, Swansea University, Wales, www.cs.swan.ac.uk/ csharold/tick/cs-uem.pdf (Last accessed at 2th May 2011).

[6] Koutny, M., Pietkiewicz-Koutny, M.: Synthesis of Elementary Net Systems with Context Arcs and Localities. Fundamenta Informaticae 88 (2008) 307-328.

[7] Koutny, M., Pietkiewicz-Koutny, M.: Synthesis of Petri Nets with Localities. Scientific Annals of Computer Science 19 (2009) 1-23.

[8] Koutny, M., Pietkiewicz-Koutny, M.: Synthesis of General Petri Nets with Localities. University of Newcastle upon Tyne, Computing Science, Newcastle upon Tyne, March 2010.

[9] Pietkiewicz-Koutny, M.: The Synthesis Problem for Elementary Net Systems with Inhibitor Arcs. Fundamenta Informaticae 40 (1999) 251-283.

[10] L. Cardelli and A.D. Gordon. Mobile Ambients. Theoretical Computer Science, 1(240):177-213, 2000.

[11] A. Iliasov, A. Romanovsky, B. Arief, L. Laibinis and E. Troubitsyna, On Rigorous Design and Implementation of Fault Tolerant Ambient Systems, 10th IEEE International Symposium on Object and Component-Oriented Real-Time Distributed Computing (ISORC07), Santorini Island, Greece, 7-9 May, pp. 141-145, 2007.

[12]] B.B.Kristensen, D.May, P.Nowack. Collaboration and Modelling in Ambient Systems: Vision, Concepts and Experiments. Proceedings of 44th Hawaii International Conference on System Sciences (HICSS), 2011.

[13] A. Russ, W. Hesse, D. Muller: Ambient information systems - do they open a new quality of IS? In Proc. 3rd EuroSIGSAND symposium 2008, Marburg/Lahn. LNI 129, pp. 87-101. Koellen-Verlag, 2008.

[14] Harrison, M.D. and Massink, M. (2010) Modelling interactive experience, function and performance in ubiquitous systems. Electronic Notes in Theoretical Computer Science Vol. 261, pp 23-42 Elsevier B.V., 2010 ISSN 1571-0661. Notes : 10.1016/j.entcs.2010.01.004 Paper originally presented at the 4th International Workshop on the Practical Application of Stochastic Modelling (PASM 2009), Imperial College London, September 2009.

[15] Harrison, M.D., Kray, C., Sun, Z and Zhang, H. (2008) Factoring user experience in the design of ambient and mobile systems. In Gulliksen, J.; Harning, M.B.; Palanque, P.; Veer, G.C. van der; Wesson, J. (Eds.) Engineering Interactive Systems Springer Lecture Notes in Computer Science. Vol. 4940. pp. 243-259.

[16] J. L. Silva, O. R. Ribeiro, J. M. Fernandes, J. C. Campos, and M. D: Harrison (2010) The APEX framework: prototyping of ubiquitous environments based on Petri nets In R. Bernhaupt, P. Forbrig, J. Gulliksen and M.K. Lrusdttir, editors, Human-Centred Software Engineering, volume 6409 of Lecture Notes in Computer Science, pages 6-21. Springer.

[17] A. Petrou. Exploring Privacy and Security in Ubiquitous Systems, Master Thesis in Computer Security and Resilience, Newcastle University, September 2010.

[18] Ames, M., and Dey, A. Description of design dimensions and evaluation of ambient displays. Techn. Report CSD-02-1211. UC Berkeley, 2002.

[19] Matthews, T., Rattenbury, T., Carter, S., Dey, A., and Mankoff, J. 2002. A peripheral display toolkit. Tech. Report IRB-TR-03-018. Intel Research Berkeley, 2002.

[20] Pousman, Z. and Stasko, J. A taxonomy of ambient information systems: four patterns of design. Proc. Of AVI 2006. ACM Press, New York, NY, 67-74.

[21] Tomitsch, M., Kappel, K., Lehner, A. and Grechenig, Th.: Towards a Taxonomy for Ambient Information Systems. In.: Workshop at Pervasive 2007: Designing and Evaluating Ambient Information Systems. 5th International Conference on Pervasive Computing, Toronto, Canada, pp. 42-47, 2007.