Universal Design in Ambient Intelligent Environments

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Abstract. Ambient Assisted Living is normally how reference is made to Ambient Intelligence (AmI) environments when used to support old people in living independently and remain active, thus contributing to their physical and cognitive well-being (eInclusion). The main purpose of the paper is to show that the house is a particularly difficult environment, due to the variety of activities to be carried out in it and of abilities and preferences of people. Therefore, it is necessary to set up integrated infrastructures able to "reason" about the present status, physical and emotional, of the inhabitants and to offer them suitable support services.

Keywords: Ambient intelligence · Ambient assisted living · Artificial intelligence · ICT services · Active and Assisted Living

1 Introduction

Ambient intelligence (AmI), mainly its application in the house environment, normally identified as Ambient Assisted Living (AAL) up to 2014 when in EU documents the meaning of AAL was updated to Active and Assisted Living [1], is a concept hopefully leading to a new generation of products integrated in the living environment and controlled by services, which will offer functionalities able to support people in living more comfortably. Therefore, it is a good opportunity to start their design using a Universal Design approach defined as: "The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design".

Even if, the word "usable" in the above definition is a hint to the environment where the definition was developed (i.e. the field of eInclusion, i.e. of activity on behalf of people with some limitation of ability[1]), the definition itself does not make explicit reference to any lack of abilities. It only aims to the design of products and environments usable by all as they are. Unfortunately, it gives for granted some important aspects that have a fundamental impact in the real uptake of the use of technology in general and of ambient intelligence in particular.

[1] According to the WHO definitions, the locution people with limitations of abilities is used instead of people with disabilities or disabled people.

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First, it is necessary that what is designed and produced is useful, i.e. addresses real and relevant needs of users. Obviously, most of proposed products and environments address some need. However, the problem is if the offered advantage is perceived as sufficient to account for the economic investment and the cognitive effort of learning new form of behaviour in the environment. If this is not the case, it is very likely that the proposed innovation will not have the foreseen success.

Then is must be taken into account that usable does not mean only accessible as is normally assumed when people with some limitation of ability are considered. It also means that it is possible to carry out the addressed activity without too many efforts. For example, in Italy, many Web sites of public administrations or service providers are accessible, but not easily usable. It is sometimes very time and effort consuming to find out how simple actions may be carried out.

Ambient intelligence, in addition to the use in professional environments, as hospitals, offices, schools, has immediately been considered an opportunity for the creation of environments for the independent living of people with limitations of abilities and mainly for older people. In Europe, for example, programmes in the AAL field have been active from 2009.

The model behind the approach is that the user is surrounded by intelligent objects, through which functionalities are made available (Fig. 1). They may be useful: (i) to control her physical status from a health care perspective; (ii) to control her activities in order to monitor possible accident (e.g. falling) or to avoid dangerous situations (e.g. water spilling in the kitchen); (iii) to help her with activities (e.g. using home appliances); (iv) to connect her with the outside world. The facilities may be made available by technology available at home (e.g. sensors or home appliances) or from outside (service providers or carers). A controller is instrumental in collecting information about the user and her activities and to adapt the environment to avoid dangerous

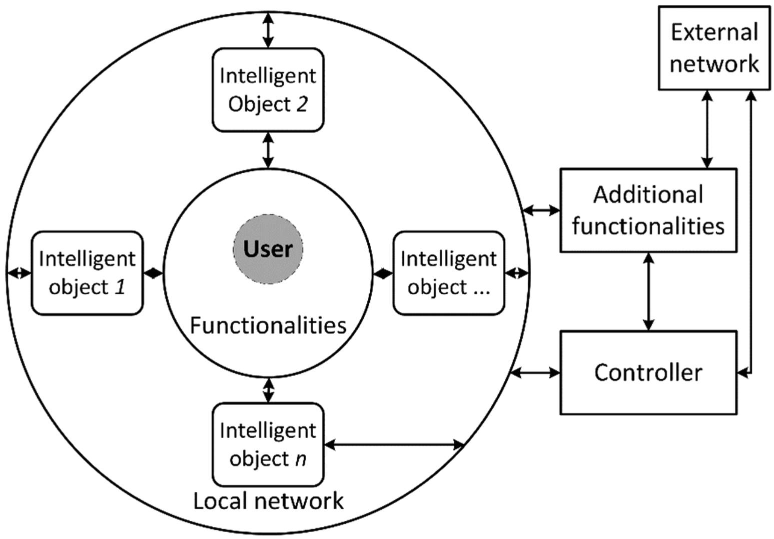

Fig. 1. Architecture of an ambient intelligent environment

situations, send alarms, when necessary, favour home activities (for example, preparing food), and connecting her with people and remote services. Adaptations are considered essential because in most studies users are supposed to have some form of limitation of ability (disability) and the environments needs to be adapted to cope with this situation.

The reality is that whilst points (i) and (ii) have been sufficiently developed and corresponding applications are spreading, the support of people in home activities and in the creation of suitable networks for social interactions are not reaching the market. Obviously, this is due to general market problems, for example, to the fact that home appliances are goods developed on very big scales and not changing rapidly. However, there are also problems connected on how the work on universal design has been carried out so far. Some of these reasons will be briefly discussed in the following.

2 The First Problem - Usefulness

As maintained in the introduction the first requirement for any ICT technology and/or application of is that it must be useful. This may seem a trivial observation, but in the following it will be made clear that it is not so.

2.1 Ambient Intelligence in General

If applications of ambient intelligence concepts in professional environments are considered, as the hospital, the office or the school, their usefulness is evident a priori. The usefulness of an operating theatre is clear to everyone and any increase of its efficiency that can be obtained favouring the integration of the equipment, increasing the information available to doctors and nurses and making easier their communication is clearly welcome. In addition, the health care field is not particularly cost sensitive and is open to innovations.

The same is true for offices. The administration of a big multinational company or of a branch of the public administration can find obvious advantages in the diffusion of ambient intelligence facilities in the working space. Again, the scale of applications is such that it is possible to take full advantage of the amount of resources to be invested for the increase in efficiency due to the deployment of new technology.

It may also be that some of the technology and applications are difficult to use, both intrinsically and/or because the available interactions may not be optimised. However, it is given for granted that in these professional environments people already know how to cope with technology and are able and willing to learn in order to improve their efficiency.

2.2 Ambient Assisted Living

The same is not true if an ambient assisted living environment is considered. In relevant documents [1], it is written that AAL applications should promote independent living, social interaction, particularly with carers, and preserve physical and cognitive well-being. In principle they appear to address very useful goals, but what does independent living, social integration or, more difficult, well-being mean? Any person working in the field or financing activity in it uses different definitions and different interventions are considered important. Due to the fact that many of these activities are meant to support old people, the only common idea is that the most important goal is to reduce costs for the public administrations.

According to the prevalent model and as a fundamental component of the motivation for intervention, it is given for granted that an old person has some form of limitation of ability. Therefore, in addition to the main purposes of controlling the persons from the health care perspective, avoiding dangerous situations, helping them with some simple reminder (e.g. remember to take the pill for hypertension) and making available a simple communication (help) channel, a further constraint is that this must be guaranteed in a way to be accessible, possibly with an universal design approach.

This model, at least in the case of old people, does not work anymore. Due to the demographic development, an increasing number of people is becoming old without any specific loss of abilities, but with only a general minor degradation of them. They are "normal" old people, who often live alone. Most of them do not need support for problems of medical relevance or for fear of dangerous situations. One of the main problems is that they tend to feel alone and segregated, irrespective of the support of relatives, friends and carers, and need to be supported in communication and social integration, because they tend to suffer for loneliness. Loneliness must be avoided because it is associated with:

- Increased mortality risk (by 26% in a recent analysis);
- More physician consultations resulting in health care costs;
- Depression that can be countered by social support.

What must be emphasized is that with "normal" old people the necessary complexity of the environment increases, because, in addition to the functionalities up to now considered for the deployment of an environment as the one sketched in Fig. 1, it is necessary to find out all activities a person must carry out to live comfortably and to appreciate the subtle differences of the users, also related to their emotional situation, implying needs, sometimes unconscious, of social contacts. On the other side, the consideration of possible support by intelligent environments to the society at large can increase the potential market and favour the uptake of the new technology. Probably, for some new technology and applications, a young couple is more open to spend than an old person living alone.

2.3 Living Situation

In order to make the discussion less abstract, some typical life situation and possible supports by the environment can be considered. The system is supposed to offer functionalities at three different levels. At the first level it offers some "conventional" ambient intelligence functions to the user. Her room adopts her 'personality' as she enters. For example, room temperature and default lighting are automatically set. A range of video and music choices are displayed for selection on a video screen.

Parameters of medical interest are monitored and advice is offered when appropriate or requested. If necessary, alarms are sent to the doctor or public assistance and her children are informed to be aware of her situation. This is understandable and completely transparent. She may feel comfortable that some form of smart technology is constantly monitoring her wellbeing and overall health condition.

At the second level she has access to a lot of information regarding communication with people and socialization in general. She can call people in her social group and outside it using general purpose social network services and be contacted by them. For example, while taking her breakfast coffee, she can list her shopping according to suggested recipes. The system is able to highlights the ingredients that are missing and she can confirm by voice the quantities she needs. She can be informed during the day on her shopping list, agree with what has been found, ask for alternatives, and find out when they will be delivered. She can call up her son living away on the phone or start a videoconference with him. While talking she uses a traditional remote control system to browse through a set of webcast local news bulletins that her son can discuss with her. They watch them together.

The amazing features of the system are at the third level. She has been told by her son that in addition to the network of people she is interacting with, in the background another network is active, a network made up of the intelligent agents representing her and all other people in her social group. Apparently, her agent is both a learning device, learning about her from her interactions with the environment, and at the same time an acting device offering communication, processing and decision-making functionality. For example, it is able to deal with a call of a member of the group asking for more information about a recipe. Mary is not able to reply in this moment. But her agent, with a nice reproduction of her voice and typical accent, can give all the necessary information regarding ingredients and execution. Obviously, her friend is able, if she like, to know that the information has been given by Mary's agent and call again when she becomes available. Even more surprising is that the system is able to sense her emotions and mood and the emotions of moods of the members of the social groups.

2.4 Increased Difficulties

In order to understand the difficulties connected with the creation of an environment able to support people as outlined above, it is necessary to consider the activities that they must carry out in their everyday life at home. Fortunately, this analysis has been carried out by WHO and reported in the ICF document [2]. WHO ICF is a widely accepted document, produced through the agreement of people around the world. It is well structured and, therefore, usable in mechanised procedures. Some important classes and subclasses are reported in the following list:

- d2 GENERAL TASKS AND DEMANDS
  - d220 Undertaking multiple tasks
  - d230 Carrying out daily routine
- d3 COMMUNICATION (receiving and producing)
- d4 MOBILITY

- d5 SELF-CARE
  - d510 Washing oneself
  - d520 Caring for body parts
  - d530 Toileting
  - d540 Dressing
  - d550 Eating
  - d560 Drinking
  - d570 Looking after one's health
- d6 DOMESTIC LIFE
  - d610 - d629 Acquisition of necessities
  - d630 - d649 Household tasks
    - d630 Preparing meals
    - d640 Doing housework
      - d6400 Washing and drying clothes and garments
      - d6401 Cleaning cooking area and utensils d6402 Cleaning living area
      - d6403 Using household appliances
      - d6404 Storing daily necessities
      - d6405 Disposing of garbage
- d7 INTERPERSONAL INTERACTIONS AND RELATIONSHIPS

Most of the above listed activities are complex in themselves and very often have interconnections at different levels with other activities. This can be clarified with an example whose details have been thoroughly examined in the Italian Design4All project [3]. A set of services have also been already implemented to prove the soundness of the analysis. In the Web environment there are many Web applications offering recipes. They are surely very useful for a young person who know how to cook and is able to control all aspects of the procedure. But let us assume that it is necessary to support an old man whose wife died recently. He does not know how to cook. Correspondingly, he does not know how to organize his pantry and tends to forget what he has in the fridge. A service meant to help him should be able:

- To know his medical status, in order to suggest suitable food;
- To know what is available in the pantry and in the fridge, together with the best-before date;
- To have a diary of what he ate in the preceding days in order to suggest suitable variations of the diet, on the basis of what is available and trying to use first what is near to the bet-before date;
- To suggest the menu and ask for acceptance, offering, if possible, alternatives;
- To control, on the basis of the choice, if all the necessary ingredients are available;
- If this is not the case, to prepare a list if the person is able and willing to go shopping;
- Otherwise, to help him in shopping from home or directly buy what is necessary, if authorised;
- To help in cooking, taking into account that normally it is necessary to cook more than one dish;

- Therefore, to divide the activity in elementary tasks, to be suggested with the right sequence and synchronisation and with information of the different tools to be used (for example, what knife to cut the meat?)
- …….

Obviously, the system must control very strictly all operations not only for security reasons, but also because the person can be interrupted for some other task or can forget to switch off the gas even if so advised.

3 A Possible Solution - Intelligence

Even if it is obviously difficult to influence the development of basic technology, its integration in complex environments should be organised in a structured procedure, starting from the identification of suitable combinations of functionalities (services), potentially useful to favour activities that people need to perform in the different environments. Then these services should be implemented in a way that allows them an evolution according to the varying user needs and the availability of new technology.

Very often, the identification of activities and functionalities to support people is made on an ad hoc way, for example with interviews with end users, often in an inadequate number. In fact, as shown above, activities to be carried out in order to live have been widely investigated and the corresponding knowledge has been made available in a structured form in the WHO ICF document.

After the definition of activities and sub activities, the identification of functionalities and their combination (services), necessary to support these activities, is necessary. They include technological functionalities in the house and remote and human support. This must be done (see examples from Design for All project [4, 5]) taking into account the abilities of the different people who are supposed to use the kitchen. So far, no interaction aspect needs to be taken into account, but only functional ones: for example, the use of complex descriptions of recipes can be difficult for older people with decreased cognitive capabilities. The produced knowledge must be formalised in an ontology to be available to reasoning components. It can be pointed out that ICF is also available as an ontology and that a number of ontologies about food are available (see example in [6, 7]). Moreover, information coming from social networks and any other application such as a forum, if conveniently processed, can contribute to the ontology construction.

Several technologies may be available for the implementation of the selected functionalities. The features of the technologies must be described in a formalised way together with the communication protocols. After a careful selection, they need to be integrated in the environment. This must be carried out under the control of a reasoning system (intelligence in the environment) able to use the knowledge in the ontologies.

In conclusion, designing for eInclusion is not only a problem of accessibility, but it implies the re-design of the entire living environment that needs to be under control by a reasoning system. This must be able:

- To identify needs (activities to be carried out) from available formalized knowledge and preferences about the way of implementing them from single users;

- To select and implement the functionalities necessary for carrying them out within the limitations and preferences of the single person with all their interconnections;
- To select the technology and develop interfaces for its interoperability;
- To make available the suitable interactions.

From the users' perspective, the main perceived features of an AmI environment are probably its adaptability to their requirements and preferences and adaptivity to the changes in their behaviour or in the context, as already claimed by Universal Design for accessibility. However, the situation is more complex. Adaptability and adaptivity should not only be limited to the interaction and based on simple deterministic rules as: if the user is blind then use voice and sound interaction. Instead, AmI needs real reasoning capabilities for identifying the goals of the users and helping users in fulfilling them using the available resources.

The quantity and quality of intelligence necessary can be made considering the requirements expressed in the ISTAG document [8], where the main high-level design requirements of an ambient intelligence environment are listed. It must be:

- Unobtrusive (i.e. many distributed devices are embedded in the environment, and do not intrude into our consciousness unless we need them);
- Personalized (i.e. it can recognize the user, and its behaviour can be tailored to the user's needs);
- Adaptive (i.e. its behaviour can change in response to a person's actions and environment)
- Anticipatory (i.e. it anticipates a person's desires and environment as much as possible without the need for mediation).

It is evident that these necessary features require real intelligence. The implementation architecture of the core of an AmI system can be described with reference to Fig. 2.

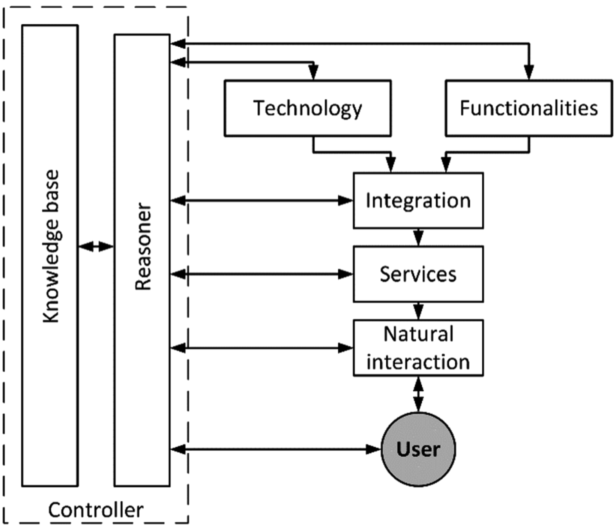

Fig. 2. Implementation architecture of an AmI system

The control part is made of two main blocks. The first is a knowledge base where information is available in a formal representation about:

- Activities to be carried out in the environment;
- Functionalities, whose individual use or cooperation with other functionalities in complex services is necessary to carry out the activities;
- Technology, whose basic functionality and embedded intelligence can be used to implement the functionalities;
- Interoperability, i.e. description of interfaces and communication protocols to use technology in an integrated form;
- Users: abilities of individual users and their requirements and preferences about functionalities to be used to support them in carrying out the necessary activities with the preferred interaction;
- Interactions: available interaction capabilities and possibility of integration.

Information is made available to a reasoning system able to:

- Enrich the knowledge base acquiring and integrating information already received in a formal representation, extracting it from informal information (for example expressed in natural language), and observing the behaviour of the users;
- Use the information in the knowledge base to construct in an unobtrusive and anticipatory way the services themselves and adaptability and adaptivity in the functionalities made available.

Finally, applications that appear trivial to most people instead require a lot of intelligence. Let assume that a person is diabetic. In the Applications markets, hundreds of applications are available aimed to suggest a correct diet. But, this does not simply depend on knowing if some ingredient is present in the available food as in the case of allergies, but on a set of conditions: the type of diabetes, the real time measurement of the present status, what the person ate the previous day, what will probably be available today and tomorrow, the activities to be carried out. The problem is so complex that an expert system is necessary to decide about the diet [9]. The expert system uses a lot of knowledge about the illness, the characteristics of food and the interrelations between the illness and the food, fortunately already available in a formalized form.

As a summary, it is clear that it is not possible to reason in terms of single technologies and/or services. The intelligent environment should be essentially a platform able to accommodate any technology and/or service through the ontological description of their functionalities and interconnection protocols and their integration under control of the intelligence in the system in order to produce an environment as useful to the single user as possible and able to mediate among the needs of people living in the same environment.

4 The Second Problem – Interaction

A second fundamental problem in ambient intelligence environments, of particular importance in the home environment, is the interaction with the environment itself and the services made available by it. In this context there is an emphasis about "natural" user interfaces. Even if this is not the place to discuss in details the meaning of this locution, the problem can be simplified by assuming that this includes interactions based on modalities and media used by people when interacting with other people (e.g. using speech, the body language, gestures, facial expressions and so on).

Once more there is a fundamental difference between professional environments and the home environment. As, for example discussed in [10], in a professional environment it is difficult to think to interactions more efficient of GUIs, with direct manipulation of menus and other objects useful to organise and summarise information. It is not very likely that an administration employee will interact with an Excel sheet moving the head or showing a puzzled face for an unexpected result. Maybe that she could use a spoken word instead of looking for the corresponding menu item, but it is more likely that in this case she will use a keyboard shortcut. She is used to this type of interface, which is common to most applications in use (for writing, access to mail, access to database and so on.) In this case the main emphasis is on the efficiency of the interface, more than on the interaction itself that almost unconsciously is supposed to be with a screen, using a keyboard and a pointer.

For a long time, this has been the case also in the home environment, because of the work in assistive technology, according to which interaction was looked for using an adaptation of interfaces already available on equipment and applications. The interfaces had to be made accessible to all potential users, including people with activity limitations and old people. Several generations of home equipment have been designed with “accessible” interfaces, some of them “normal” interfaces with some form of multimodal interaction. Sometimes they are so simplified not to allow an efficient use of the appliance. The same is true for many applications, whose interfaces, based on the conventional GUIs concepts and recently with tactile interactions with the diffusion of tablets, are often so simplified to allow only trivial operations of limited interest for the users (see discussion about usefulness).

In the house, as discussed in previous sections, there is a fundamental problem. The technology to be used and the activities to be carried out are so many and so interlaced, that it is impossible to think in terms of interfaces of single equipment and/or functionalities. For example, in the living room of one of the authors, with only a video equipment and a high fidelity system, nine different remote controls are present. The only simplification is that the DVD player and the TV set are from the same producer and therefore these two remote controls are similar.

In principle, as shown in Fig. 3, there should be a separation between the home infrastructure with its embedded technology and services and the interaction. The intelligence in the environment should be able to use any media to offer the interaction that the single person considers “natural” in her present situation. For example, a person, probably not living alone, could consider natural to interact with the house in the same way she interacts with other people, i.e. speaking and listening to answers, using the body language and facial expressions. If images and videos need to be shown and she does not want to go through the house with a tablet, they could be projected on any flat surface near her. Obviously, if needs and/or likes, for example for reasons of privacy, all information should be transferred to an equipment as a tablet accessible only to her.

The interaction should be, if desired, consistent through the entire apartment so that she can start speaking with a friend about food in the kitchen and continue through the

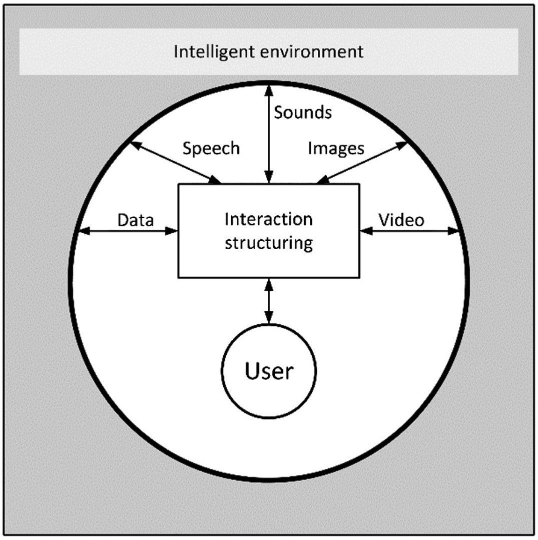

Fig. 3. Real-time structured interface

corridor and the living room, where she wants to find additional information on a book. The house, if she forgets, should immediately switch off all TV cameras if she enter the bathroom or is not properly dressed.

In the case of interaction, the intelligence in the environment should essentially be used to “understand” what the meaning of “natural” for each individual user is, on the basis of some initial information, but essentially of a continuous observation of how the individual user behaves. Moreover, it should also be able to mediate among the preferences of different users living together.

5 Conclusions

The main conclusions of the discussion can be summarised as:

- Any effort of transforming the living environment into an intelligent environment should address a significant set of functionalities, adequate to show the achievable advantages to the possible users and therefore to convince them to invest their resources or to accept the technological support;
- It is not convenient to think only in terms of people with activity limitations or old people, but the advantages of transforming the house into an intelligent environment may be of interest, in principle, for any person even if for different reasons;
- There should not be intelligent environments with prefixed features, but general purpose architectures where reasoning techniques are used to construct the right environment around any single person;
- Correspondingly, the interaction with environment should be constructed by the intelligent architecture for each particular user in a way that she consider natural.

References

1. Strategy 2014–2020 for the Active and Assisted Living Programme (2014) http://www.aal-europe.eu/wp-content/uploads/2015/11/20151001-AAL-Strategy_Final.pdf
2. World Health Organization. International Classification of Functioning, Disability and Health: ICF. World Health Organization (2001)
3. Sacco, M., Caldarola, E.G., Modoni, G., Terkaj, W.: Supporting the design of AAL through a SW integration framework: the D4All project. In: Stephanidis, C., Antona, M. (eds.) UAHCI 2014. LNCS, vol. 8513, pp. 75–84. Springer, Cham (2014). doi:10.1007/978-3-319-07437-5_8
4. Burzagli, L., Baronti, P., Billi, M., Emiliani, P.L., Gori, F.: Complete specifications of services in an AAL environment. In: Cavallo, F., Marletta, V., Monteriù, A., Siciliano, P. (eds.) ForItAAL 2016. LNEE, vol. 426, pp. 51–60. Springer, Cham (2017). doi:10.1007/978-3-319-54283-6_4
5. Burzagli, L., Gori, F., Baronti, P., Billi, M., Emiliani, P.L.: Elements of adaptation in ambient user interfaces. In: Miesenberger, K., Bühler, C., Penaz, P. (eds.) ICCHP 2016. LNCS, vol. 9759, pp. 594–601. Springer, Cham (2016). doi:10.1007/978-3-319-41267-2_85
6. Eurocode2 Food Coding System. http://www.ianunwin.demon.co.uk/eurocode7
7. LanguaL™ - The International Framework for Food Description (2012). http://www.langual.org/Default.asp
8. Ducatel, K., Burgelman, J.-C., Scapolo, F., Bogdanowicz, M.: Baseline scenarios for Ambient Intelligence in 2010, IPTS Working paper (2000)
9. Lee, C., Wang, M., Li, H., Chen, W.: Intelligent ontological agent for diabetic food recommendation. In: Proceedings of IEEE International Conference on Fuzzy Systems (FUZZ 2008), pp. 1803–1810 (2008)
10. Norman, D.: Natural user interfaces are not natural. Mag. Interact. **17**, 6–10 (2010). doi:10.1145/1744161.1744163