On the Design of Ambient Intelligent Systems in the Context of Assistive Technologies

J.L. Sevillano[1], J. Falcó[2], J. Abascal[3], A. Civit-Balcells[1],
G. Jiménez[1], S. Vicente[1], and R. Casas[4]

[1] ETSI Informática, Universidad de Sevilla, Av. Reina Mercedes, s/n, 41012, Sevilla, Spain
`{sevi,civit,gaji,satur}@atc.us.es`
[2] CPS, Edificio A, Universidad de Zaragoza, María de Luna, 3. 50015, Zaragoza, Spain
`jfalco@unizar.es`
[3] LIPCNE. EHU-UPV, Manuel Lardizabal 1, 20018 Donostia-San Sebastián, Spain
`julio.abascal@si.ehu.es`
[4] DEE-UPC, Av. del Canal Olímpic, s/n, E-08860 Castelldefels, Spain
`Roberto.Casas@upc.es`

Abstract. The design of Ambient Intelligent Systems (*AISs*) is discussed in the context of assistive technologies. The main issues include ubiquitous communications, context awareness, natural interactions and heterogeneity, which are analyzed using some examples. A layered architecture is proposed for heterogeneous sub-systems integration with three levels of interactions that may be used as a framework to design assistive AISs.

1 Ambient Intelligence

The concept of *Ambient Intelligence* (AmI) is one of the main guiding principles for the Future Information Society [1]. It defines a set of properties of a responsive and proactive environment to enable individuals and devices to interact easily. There are a number of key research areas in the development of AISs [2], including components related to ambience (smart materials, sensor and embedded systems technologies, ubiquitous communications, adaptive software, etc.) and intelligence (natural interactions, context awareness, emotional computing, etc.). Efforts should also be made to integrate and converge these specific components.

A new challenge is the development of complex distributed systems that integrate many heterogeneous digital devices and services and their networks into everyday environments [2,3]. In this paper, we consider how existing and future devices and subsystems could be integrated to design AISs in the context of assistive technologies. First we identify the key components of an AIS [4]:

- *Ubiquitous communications:* access at anytime and from any place or (mobile) device. In this case, mobile does not only mean that it is carried by the user, but that it is actually “on the move”. Guaranteeing ubiquitous access is the most important infrastructure to support AmI. Wireless connections now permit low-cost commercial solutions for this type of communication.

- *Context awareness:* defined as the *use* of information to characterize the *situation* of an *entity* (person, place, object) [5]. The *situation* may have several “dimensions” [6]:
    - Location awareness (the most studied issue); adaptation to changing geographical positions, location-based services, etc.
    - Temporal awareness; including time schedule of events.
    - Personal awareness; dynamic adaptation to user needs, abilities or preferences.
    - Other dimensions; device (processing power, battery) or physical environment (noise).

  Finally, the correct *use* of this information involves taking the appropriate actions autonomously [7], although current systems fall short. The problem is probably that AmI requires common sense decisions about everyday situations, but this apparently modest reasoning is the most difficult to emulate [8]. On the other hand, several experimental studies have reported that users are willing to be active [6]. These two considerations suggest that in some cases a simpler solution would be to let the users provide context information (location, personal) and configure or select the most appropriate service. Furthermore, the information provided by one user may be useful for another with similar characteristics or abilities. So, we could develop useful AISs with a limited intelligence.
- *Natural interactions*: AISs should be based on a user centered approach (the user is *the* single master device) instead of a device centered approach. This is a somewhat more technological version of the ISTAG *holistic citizen-centered* view, which also includes other factors like culture and business [2]. Obviously, the approach is especially important in the context of assistive technologies. Smooth integration between user and all subsystems requires natural languages (speech, gestures, etc.), reduced learning effort and services that are easy to find and use.
- *Heterogeneity:* A major problem with AIS design is the integration and interaction among heterogeneous subsystems. A common channel is needed to communicate all subsystems, the latter were probably not designed to interact with each other. Services and information from a given subsystem should be described using common languages and media formats to be accessible to other subsystems. This issue also affects previously described components. For example, interaction between context-aware subsystems requires common context representations that are independent of the applications. But it is not just a simple problem of using a common *format*. Further issues are how this context information is interchanged among subsystems, how services are discovered or offered, and how they are integrated in user interfaces.

Other research issues like smart materials and device and sensor technologies are more related to individual "components" than to the integration of components into AISs. Advances in these individual technologies (mainly related to "ambience" rather than to "intelligence") would improve some aspects of these systems, providing smaller, cheaper and more powerful devices, but may not represent significant achievements towards real AISs.

2 AISS and Assistive Technologies

2.1 Ubiquitous Access

Ambient intelligence requires ubiquitous access when the user is the master and main element of the system. Generally speaking, ubiquitous communication allows access to services that are not restricted by the location of resources/users. This is particularly well suited for people with mobility restrictions, but it may also be useful for the handicapped who want to access assistive services through personalized interfaces in unfamiliar environments. For instance, a visually impaired mobile user should be able to access audio descriptions ubiquitously or alternatives to semaphores or warning light signals. Moreover, support is greatly improved if the user can access services from different locations. One example is a common remote control for TV, answering the phone from a wheelchair, turning lights on or off and opening the door. More advanced systems include monitoring user location in terms of safety (falls), support or comfort, or informing about tasks to be performed at a certain time due to cognitive disabilities. All of these require ubiquitous access.

2.2 Context Awareness

For systems that adapt their function in terms of the environment, the first aspect that seems to be taken into account is physical position. Location awareness requires external inputs regarding the geographical (absolute/relative) position of the user, which is particularly useful in special situations (e.g. unfamiliar environments). Typical applications track user location, including assisted navigation (e.g. semi-automatically guided wheelchairs in structured environments: hospitals, airports, etc.), care for people who may get lost (e.g. elderly residences [9]), etc. Another situation is location based services [6] where the definition of user location is less accurate and the question is what services are offered at specific locations. For instance, visitor guides and information at the entrance of hospitals or residences or facilities for wheelchair users. For a mobile user, these services may change and, more importantly, the infrastructure and even the positioning system may vary when users move from one place to another.

With personal awareness, services and information can be adapted to user needs, abilities, preferences, privileges and state. This is especially useful for people with limited physical and/or cognitive abilities. For example, the timing of automatic doors may depend on user mobility restrictions or a tourist guidance system may propose alternative routes for wheelchair users. In this context, one of the main issues is a generic and universal description of personal abilities and characteristics.

Personal parameters may be *static* or *dynamic*. Static parameters include abilities and limitations, special needs, type of interface and personal preferences. The system could memorize user-preferred options for frequently visited locations to propose a default (room temperature, music, light level). Dynamic parameters include mood or anxiety levels that are sensed or inferred from user response. Depending on the system intelligence, it could learn from user behavior (e.g. infer voluntary movements from uncontrolled tremor) and adapt these dynamic parameters. Once the system has learned to detect the situations, it can take palliative actions, such as playing relaxing music.

Other aspects of context awareness include time of the day or week, special dates, sequencing of events (e.g. time orientation for the mentally disabled), technological awareness (bandwidth, display resolution, battery capacity, computational power), and environmental (weather conditions), building or outside conditions (restricted areas, crowded areas).

All of these context dimensions should be used together. For example personal location-based services and information (e.g. audio environmental description for visually impaired people) can be combined with avoiding useless content (e.g. alternative wheelchair routes for a non-wheelchair user). On the other hand, personal preferences or privileges depend on location. Available location or personal information may be time dependent, e.g. if the user wants to plan his/her subsequent activities when privileges or available services are time-limited.

2.3 Natural Interactions

In AmI, technology should be enabled by simple and effortless interactions [3]. Current research focuses on so called *Natural* interactions through speech, gestures and facial expressions. These general advancements can benefit assistive technologies provided that accessible human-machine interfaces are designed following the Design-for-All policy [10]. Since these new technologies may present accessibility problems, user interfaces should be able to cope with diversity, including the disabled. A mixed approach can be used to guarantee universal access while considering specific interaction devices for people with special needs [11]. Another problem with AISs is that interactions between the user and the rest of elements usually occur with little or no advance planning. In other words, there is a need for spontaneous and occasional use [6]. Therefore, natural interactions are not only a problem of using advanced/ accessible interfaces, but also of interfacing devices or services without *a priori* knowledge of what type of device we may encounter.

2.4 Support for Heterogeneous Subsystems and Service Interaction

The whole system should be able to support the interaction of heterogeneous networks, services and applications. Assistive technologies are very heterogeneous when attending needs due to individual and temporal variations. Moreover, devices were designed by different manufacturers using different technologies for heterogeneous applications [14]. The Design-for-All concept considers the lack of simplification usually made when considering a standard user. At the same time, this lack of standardization and individual diversity and variability increases heterogeneity in subsystem development, both in terms of applications and services, in a kind of vicious circle.

3 Layered Architecture for Sub-system Interactions

Here we consider the integration/interaction of heterogeneous sub-systems, and propose a layered architecture.

In previous studies, the term *interoperability* refers to mean interactions among systems at higher levels [2,12,13,14,15]. Usually, a reduced version of the OSI standard of layers is used, sometimes including non-OSI levels like *Internetworking* (including the routing and internetworking components) and *Middleware*, which could be defined as an interface among applications and the network operating system, equivalent to session and presentation levels of OSI [16]. However, from the point of view of subsystem interactions, a three level definition may be more useful, including the *Application level* (the classical one defined in OSI model), the *Middleware level*, and the *Internetworking level*, with all the lower level functions in our model (transport, network, data link and physical layer).

The systems to be connected are also distributed. The three levels help to model the interaction among systems with different types of interactions depending on the level. The interactions are named *Interconnectivity*, *Interoperability* and *Interfunctionality* at the Internetworking, Middleware and Application levels, respectively. In the next section we revise and reformulate these concepts.

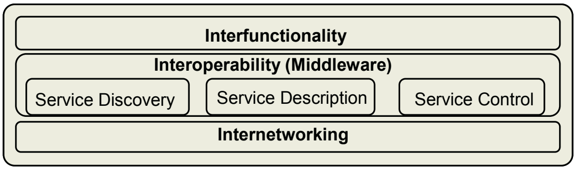

Fig. 1. Layered architecture for sub-system interactions

3.1 Interconnectivity

The *interconnectivity* between heterogeneous systems is defined as the ability to interact at the internetworking level. A good example is the Internet, which has a robust and contrasted solution based on the IP protocol [14], and other advantages such as direct Internet access in *home automation* through *Residential Gateways* [17]. This configuration permits environmental control in a remote mode via a web page [18,19,20]. Other solutions for interconnection include HAVi, most domotic systems and the *Simple Control Protocol (SCP).* None of them are based on IP, but they all involve the interaction of devices in somewhat homogeneous environments. In some cases a combination of these two approaches is the best solution. Most devices can be connected through IP networks while secondary (maybe simpler devices like sensors), are connected using non-IP communications. In this case a gateway is used to interconnect IP and non-IP subnetworks.

There are two options regarding the gateway development to link different media, depending on the context. A centralized system can be used for interconnectivity [13], such as in home automation where the *residential gateway* interconnects all heterogeneous networks at home and supports Internet access [15,17]. In other contexts a system of several interconnected gateways could be used, as in large buildings (airports, hotels). But more problems remain, such as finding the most adequate access point or handoff for mobile systems [21].

3.2 Interoperability

The concept of interoperability is widely used to describe interaction among devices at all levels [14], including control, configuration and information sharing in different formats [15]. To distinguish this term from *interconnectivity*, we consider *interoperability* related to the sharing services at the middleware level, such as import/export services [13]. Interoperability can provide a set of services to all elements. In the literature there is a general agreement about the functions that should be related with interoperability ([16, 22]), including dynamic service discovering (periodically or triggered by determined events [17]), service description (including actions that may be performed, properties that may be useful, even devices for which connection was not planned), and service control (actions and modifications of state or attributes of a service in a sub-network from another device connected to a different sub-network). The usefulness of this interoperability will be greater for mobile devices, changing environments and pervasive computing.

A number of architectures can support these functions (Jini, UPnP), but not all of them are useful in the environments and applications for Ambient Intelligence. There are three basic issues to take into account in systems with several heterogeneous networks that include mobile devices with wireless connections [16]:

- Mobile devices usually have limited resources (computing power, bandwidth, memory). The complexity needed or desired for some functions should be placed in fixed systems.
- Interconnectivity cannot be guaranteed at any time. Wireless connections may suffer frequent connection losses, that forces *asynchronous* communications.
- Mobility and environmental variability in systems that require *context dependent computation* (which is central to the Ambient Intelligence concept, see above).

3.3 Interfunctionality

There is an interaction among subsystems at the interoperability level. As a result, the services can be discovered and shared as a *syntactic* interaction, without considering their “meaning”. We propose a higher level of *semantic* interactions, similar to those described in the literature for other fields [10,23,24]. Obviously the usefulness of the service and its applicability should be described in more detail. Several languages have been proposed, such as RDF (Resource Description Language) [25] and future work will address the issue of which language best suits AmI applications.

Interfunctionality would add two main values for subsystem interactions. First, the semantic descriptions allow us to pre-select the services previewed as useful for the applications of a particular subsystem. This allows a selection for limited resource subsystems when entering environments with higher richness of services or high complexity. Thus, the system can have a set of available services, and every subsystem can choose the most useful or manageable via semantic interaction. Although users may be active (selecting and configuring the most useful and appropriate services), pre-selection is often desirable to offer adapted assistive services to the right people. Excess or useless contents must be avoided because the users will reject them [6].

Second, interfunctionality can be used to adapt or empower the functionality of existing applications according to new services. The new applications may become available based on the new services. One example is a wheelchair user with an assisted navigation application who enters a building with a positioning and location system. Under user supervision, the navigation system can ask for information about the path to follow to reach the desired destination, and then incorporate the positioning service to follow it. The functionality of navigation assistance has improved greatly due to the new services and involve more than just avoiding bumping into objects and helping when passing doors.

4 Conclusions

In this paper, the design of Ambient Intelligent Systems (*AISs*) is discussed in the context of assistive technologies. AISs include several devices and sub-systems that should provide support for ubiquitous communications, context awareness and natural interactions, and also deal with heterogeneity. As a kind of higher layer, interaction among these sub-systems is identified as a key issue. We identify three levels of interactions, including a higher, semantic interaction that would extend the usefulness of future AISs.

Acknowledgements

This work was supported by the Spanish MCyT project TIC2001-1868-C03.

References

1. ISTAG (Information Society Technologies Advisory Group) report: “Strategic Orientations & Priorities for IST in FP6”. 2002. http://www.cordis.lu/ist/istag.htm.
2. ISTAG Draft Consolidated Report: "Ambient Intelligence: from vision to reality". Sept. 2003. http://www.cordis.lu/ist/istag.htm.

3. M. Lindwer *et al.*, "Ambient Intelligence Visions and Achievements: Linking Abstract Ideas to Real-World Concepts". Proc. DATE'03. pp. 10-15, March 2003.
4. J.L. Sevillano, "Smart Homes: Ambient Intelligence". 1st French-Spanish Workshop Assist. Techs. http://www.ifrath.univ-metz.fr/article.php3?id_article=57
5. A.K. Dey, "Understanding and Using Context". Pers. Ubiquit. Comput. 5(2001)20-24.
6. E. Kaasinen, "User Needs for Location-aware Mobile Services". Pers. Ubiquit. Comput. 7:(2003)70-79.
7. T. Erickson, "Some Problems with the Notion of Context-Aware Computing". Communications of the ACM 45(2002)102-104.
8. A.A. Hopgood, "Artificial Intelligence: Hype or Reality?". Computer 36-5 (2003) 24-28.
9. J. Falcó, "Assistive Technology for old adults and mental disability". 1st French-Spanish Workshop Assist. Techs. http://www.ifrath.univ-metz.fr/article.php3?id_article=57
10. Stephanidis C., Savidis A. "Universal Access in the Information Society: Methods, Tools, and Interaction Technologies". Universal Access in the Information Society. 1(2001)40-55.
11. J. Abascal, "Accessibility to Information and Communication Technology". 1st French-Spanish Workshop Assist. Techs. http://www.ifrath.univ-metz.fr/article.php3?id_article=57.
12. J.H. Jahnke, M. D'Entremont, J. Stier, "Facilitating the Programming of the Smart Home". IEEE Wireless Communications (2002) 70-76.
13. Cho S.Y., "Framework for the Composition and Interoperation of the Home Appliances based on Heterogeneous Middleware in Residential Networks". IEEE Trans. Consumer Electronics 48-3. (2002) 484-489.
14. Carpenter B. E.: "Interoperability among Heterogeneous Communications Networks- an IETF Perspective". Computer Standards & Interfaces 20(1998)147-149
15. Rasheed Y., Edwards J., Tai C., "Home Interoperability Framework for the Digital Home". Intel Technology Journal 6 (2002) 5-16.
16. Mascolo C., Capra L., Emmerich W.: "Mobile Computing Middleware". Tutorial in IEEE MWCN'02. Stockholm, Sweden. Sep. 2002.
17. Wils A. et al.: "Device Discovery via Residential Gateways". IEEE Trans. Consumer Electronics, 48-3(2002)478-483
18. Saif U., Gordon D., Greaves D.: "Internet Access to a Home Area Network". IEEE Internet Computing 5-1(2001) 54-63.
19. Corcoran P.M., Desnonnet J., Biogioi P., Lupu I.: "Home Network Infrastructure for Handheld/Wearable Appliances". IEEE Trans. Consumer Electronics, 48-3(2002) 490-495.
20. Nakajima T. et al.: "A Virtual Overlay Network for Integrating Home Appliances". Proc. 2002 Symp. Applications and the Internet. Nara, Japan. Jan. 2002. Pp. 246-253.
21. Pahlavan K. et al.: "Handoff in Hybrid Mobile Data Networks". IEEE Personal Communications (2000) 34-47.
22. Miller B. A., Nixon T., Tai C., Wood M.D.: "Home Networking with Universal Plug and Play". IEEE Communications Magazine 39 (2001) 104-109.
23. Paolucci, M.; Sycara, K.; "Autonomous Semantic Web services". IEEE Internet Computing, 7-5(2003) 34 -41.
24. Special issue on "Web Services". Computer, vol.36, Oct. 2003.
25. S. Decker, P. Mitra, S. Melnik, "Framework for the Semantic Web: An RDF Tutorial". IEEE Internet Computing 4-3(2000) 68-73.