# E-Inclusion: From Assistive Technology to Smart Environments


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**Abstract.** With main reference to research activities carried out in Europe, the paper describes the impact of Information and Communication Technology (ICT) in supporting the integration of people in the society. It starts from its immediate use in assistive technology for granting communication and access to information to people with limitations of activities (e.g., blind, and deaf people). Then it describes the change of attitudes due to the technical developments in the field and the approach of international organizations (UN and WHO), leading to the proposal of Design for All (DfA) and to the concept that technology must be used to guarantee the well-being of all people. This is made possible by the developments of technology leading to the emergence of intelligent environments, where technology can be interconnected to support all people in any activity. Some prototypes developed to show the present feasibility of interesting support applications are shortly described, pointing out the possibility of improvement due to Artificial Intelligence.


### E-Inklusion: Von Assistiven Technologien zu smarten Umgebungen


**Zusammenfassung.** Mit Hauptbezug auf die in Europa durchgeführten Forschungsaktivitäten beschreibt dieses Kapitel die Auswirkungen der Informations- und Kommunikationstechnologie (IKT) bei der Unterstützung der Integration von Menschen in die Gesellschaft. Er beginnt mit dem unmittelbaren Einsatz der IKT als Hilfsmittel, um Menschen mit eingeschränkten Aktivitäten (z. B. Blinde und Gehörlose) Kommunikation und Zugang zu Informationen zu ermöglichen. Anschließend wird der Wandel der Einstellungen beschrieben, der durch die technischen Entwicklungen in diesem Bereich und den Ansatz internationaler Organisationen (UN und WHO) ausgelöst wurde und zum Vorschlag des Design for All (DfA) und zum Konzept führte, dass die Technologie genutzt werden muss, um das Wohlbefinden aller Menschen zu gewährleisten. Ermöglicht wird dies durch die technologischen Entwicklungen, die zur Entstehung intelligenter Umgebungen führen, in denen Technologien miteinander verbunden werden können, um alle Menschen bei jeder Tätigkeit zu unterstützen. Einige Prototypen, die entwickelt wurden, um die Machbarkeit interessanter Unterstützungsanwendungen zu demonstrieren, werden kurz beschrieben, wobei auf die Möglichkeit von Verbesserungen durch künstliche Intelligenz hingewiesen wird.

# 1 Introduction

This paper aims to discuss the activities carried out to encourage the use of ICTs to promote integration into society, starting from people with limitations of activity (WHO 2018b).

According to the WHO International Classification of Functioning, Disability and Health (ICF), the term 'people with limitations of abilities' replaces the terms 'people with disabilities' or 'disabled people'. In such a perspective, people are characterized by their abilities and by the lack of some of them. Disability is a complex situation determined by people's abilities and interactions with the environment and the society. The important contribution of WHO ICF (WHO 2018b) at a conceptual level is the model of disability that is used. Two main models have been proposed in the past:

- The *medical model*: disability is a feature of the person, caused by a disease, a trauma or other health condition.
- The *social model:* disability is a socially created problem and not at all an attribute of an individual.

According to WHO disability is a complex problem at the level of a person's body and a complex and primarily social phenomenon. Disability is always an interaction between features of the person and features of the overall living environment. In other words, both medical and social responses are appropriate to the problems associated with disability. This more useful model of disability is called the **biopsychosocial** model.

ICF definition of activities and the classification of health and health-related domains allows the identification of what people with a well-defined health condition can do in a standard environment (their level of capacity), as well as what they actually do in their usual environment (their level of performance). These domains are classified from body, individual and societal perspectives by means of two lists: a list of body functions and structures, and a list of domains of activity and participation. ICF also lists environmental factors that interact with all these components. Therefore, it is very important for a correct analysis of the impact of technology on independent living of people and for reasoning about its usefulness.

When communication and information technologies emerged, ideas for developing products able to support people in some of their activities were immediately conceived, as the telephone for interpersonal communication, the television for information distribution and the computer for collecting, processing, and accessing information. At the same time, it was immediately clear that they could create problems for some user groups. For example, the radio is not useful for deaf people, the television for blind people and the computer for people not able to use the keyboard, the mouse, or the computer screen. The main problem was the access to the systems and to the information made available by them. The solution was essentially the following: a person has a disability (for example she is blind) and technical solutions (AT – Assistive Technology) are produced to address this specific problem.

Then, it was understood that many problems are not produced only by a lack of ability, but they are created or made worse by the way the environments and social contacts are organized. As a consequence, for example, architects began to produce designs in which obstacles for people in wheelchairs were eliminated with spaces designed to be accessible to all (DfA - Design for All). The concept was accepted also in the ICT,

taking advantage of the fact that ICT technologies are programmable and therefore modifiable.
In 2001, two circumstances changed the approaches to previous problems. The first is the publication of the already cited International Classification of Functioning, Disability and Health (WHO 2018b). Then in the same year the European Commission published the document of a group of experts, set up to imagine the development of intelligent environments, based on the distribution of computer-based equipment in living spaces and the development of artificial intelligence (Zerdick et al. 2004).
In this paper, European research activity, about AT and the transition to DfA are summarized, with reference to projects carried out under the responsibility of the authors. Then proposals for structuring future research activity are presented, based essentially on the following points:

1. The development of the information society is foreseen as the emergence of an intelligent environment;
2. The impact of this development will be not only on the access to information and communication but in all activities;
3. Users will not be only information technology experts, but all people;
4. Not only accessibility and usability will be important, but mainly usefulness.

## 2 From Assistive Technology to Design for All

### 2.1 Assistive Technology – The Reactive Approach

In ICT, Assistive Technology (AT), whose official definition can be found in WHO (2018a) was essentially interpreted as the implementation of hardware and/or software adaptations of interfaces and interaction modalities, considering groups of people with a single limitation and solving their problem of accessibility through a specific solution. The solution was to guarantee accessibility through transduction among different modalities and the modification of interfaces to make them usable by exploiting the remaining abilities of the user.
A fundamental change in the possibility of access to information and communication was possible when computers, mainly personal computers, were made available. It was immediately clear that the new technology had the possibility of transducing different forms of information (e.g., from text to voice and from voice to text). Many input, output and interaction peripherals were designed. For example, as soon as speech synthesizers were made available, screen readers, i.e., software to allow people to explore the screen using speech, were implemented.
Although AT may be the only viable solution in some cases, the reactive approach to accessibility (i.e., developing specific solutions when a problem is found) suffers from some serious shortcomings (Vanderheiden 1998). One of the most important is that by the time a particular access problem has been addressed, technology has advanced to a point where the same or a similar problem re-occurs. A typical example is the case of blind people's access to computers. Each generation of technology (e.g., DOS environment, Windowing systems, and multimedia) caused a new wave of accessibility problems for them.
As an exploratory activity aimed to point out foreseeable problems and possible solutions, the IPSNI project (Integration of People with Special Needs in the Broadband

Communication Network) (1989-1991) (IPSNI 1991) investigated the possibilities offered by the multimedia communication network environment, and in particular B-ISDN (Broadband Integrated Services Digital Network), for the benefit of people with activity limitations. Several barriers were identified which prevented people from having access to information available through the network. The identified barriers were related to accessibility of the terminal, accessibility of the anticipated services, and the perception of the service information.
To cope with these difficulties, different types of solutions were proposed, which address the specific user abilities and requirements, at three different levels:

1. Adaptations within the user-to-terminal and the user-to-service interface, through the integration of additional input/output devices and appropriate interaction techniques;
2. Service adaptations through the augmentation of them with additional components capable of providing redundant or transduced information;
3. Introduction of special services.

The IPSNI-II (1992-1995) (IPSNI 1994) project built on the results of the IPSNI project and demonstrated the technical feasibility of providing access to people with activity limitations to multimedia services running over a broadband network. Adaptations of terminals and services were implemented and evaluated. In particular, two multimedia terminals (one UNIX/X-Windows based and one PC/MS-Windows based) were adapted.

## 2.2 The Information Society and Design for All

Due to the shortcomings of the reactive approach to accessibility, there have been proposals and claims for proactive strategies, resulting in generic solutions to the problem of accessibility. Proactive strategies entail a purposeful effort to build access features into a product, as early as possible.
The used definition of Design for All is equivalent to the one that has been integrated in the European Institute for Design and Disability (EIDD) Stockholm declaration, available online at (European Institute for Design and Disability 2004), here summarized as “the design for human diversity, social inclusion and equality so that all people have equal opportunities to participate in every aspect of society, including the built environment, everyday objects, services, culture and information.
It is interesting to point out that the Design for All approach has been accepted also at the political level in Europe. The document “Implementation of the Council of Europe Action Plan to promote the rights and full participation of people with disabilities in society: Improving the quality of life of people with disabilities in Europe 2006-2015” (Council of Europe 2015) is a list of 15 Action Lines, many of which were supposed to be tackled with methodologies of Design for All.

## 2.3 Design for All Implementation

Two approaches have been used to implement Design for All. The first is based on the development of guidelines to be satisfied in the implementation of products to be usable by all. The second is based on adaptability and adaptivity (Stephanidis 2001), i.e., on the assumption that any system and service can be designed to be intelligent enough to be able to automatically adapt its functionalities and interface to each single user.

### 2.3.1 Web Accessibility Guidelines

As an example of guidelines, the Web Accessibility Guidelines (WCAG), published by the W3C WAI in 1999 and in continuous revisions up to 2023 (World Wide Web Consortium 2023), are cited. Reference is made to the W3C WAI guidelines because they have been discussed for more than 20 years and agreed upon by an international working group under the responsibility of W3C.
The WCAG 2.0 guidelines were published in 2008. Their emphasis is not on technical-centered checkpoints, but on guidelines and success criteria rooted in four core principles, stating that the Web must be: perceivable, operable, understandable, robust. Each principle is supported by specific guidelines (12 in total). The 12 guidelines provide the basic goals that authors should work toward. For each guideline, testable success criteria are provided. WCAG 2.1, the current sub-version of WCAG 2, was adopted in 2018. It adds new success criteria, especially in the area of mobile devices. All success criteria from 2.0 remain unchanged, as do the four core principles. The development was initiated with the goal to improve accessibility guidance for three major groups: users with cognitive or learning ability limitations, users with low vision, and users with ability limitations on mobile devices.
The guideline approach is in principle very interesting, being based on an educational approach through which producers of Web sites are supposed to understand the usability problems of users, including people with limitations of activities, and learn how it is possible to solve them. Unfortunately, they are not yet part of standard education and as a result, most of the available Web sites are not really accessible.

### 2.3.2 Proactive Technical Approaches

Proactive approaches to the problem of accessibility were based on the proposal of adaptive and adaptable interfaces. The concept of Dual User Interfaces was proposed in the TIDE-GUIB (Graphical User Interface for Blind People) (GUIB 1991) and TIDE-GUIB2 (1992-1995) (GUIB 1994). For the access of blind people to computers, a User Interface Management System (UIMS) was developed to facilitate the design and implementation of dual interfaces, leading to the concept of User Interfaces for all (Savidis and Stephanidis 1998).
The ACCESS project (Development Platform for Unified ACCESS to Enabling Platforms) (1994-1996) (ACCESS 1996) aimed to develop new technological solutions for supporting the concept of User Interfaces for all. It proposed the concept of Unified User Interface development (Akoumianakis, Savidis, and Stephanidis 2000). The unified user interface development method was validated in two application domains, namely in the development of a hypermedia application accessible by blind people (Petrie et al. 1997) and two communication aid applications for speech-motor and language-cognitive impaired users (Kouroupetroglou et al. 1997).
The technical feasibility of the Design for All approach was shown in two European projects. The EC ACTS AVANTI project (Adaptive and Adaptable Interactions for Multimedia Telecommunications Applications (1996-1998) (AVANTI 1998) developed a new approach to the implementation of Web-based information systems, by putting forward a conceptual framework for the construction of systems that support adaptability and adaptivity at both the content and the user interface levels (Emiliani 2001). The AVANTI framework comprises four main components:

1. A collection of multimedia databases;
2. The User Modelling Server (UMS) (Kobsa and Pohl 1995)
3. The Content Model (CM)
4. The Hyper-Structure Adaptor (HSA) (Fink, Kobsa, and Nill 1997), which adapts the information content (Vanderheiden 1998)
5. The User Interface (UI) component, which is also capable of adapting itself to the users' abilities, skills, and preferences, as well as to the current context of use (Stephanidis 2001).

The above framework was applied in the development of three information systems: (Italy) the Siena system, offering tourist and mobility information; (Finland) the Kuusamo information system, providing information on travelling and accommodation; (Italy) the Rome information system, aimed at providing cultural and administrative information.

PALIO (Personalised Access to Local Information and Services for Tourists) (2000-2003) (PALIO 2021; Savidis and Stephanidis 2004) was funded by the EC's IST Programme. Its main challenge was the creation of an open system for accessing and retrieving information without constraints and limitations. Mobile communication systems played an essential role. Moreover, it envisaged the adaptation of both the information content and its presentation to the user, as a function of user characteristics (e. g., abilities, needs, requirements, interests); user location; context of use; current status of interaction (and previous history); and, lastly, available technology.

## 3 The new Century – Change of Paradigm

In 2001, from the technological perspective, a document published by the European Commission suggested probable developments of the Information Society opening interesting new possibilities for people. It was starting to be accepted that society was undergoing a fundamental transition, from an industrial society towards an information society, with one possible embodiment as an Ambient Intelligence (AmI) environment in which

> "people are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognizing and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way" (Zerdick et al. 2004)

From the user perspective, as outlined in the introduction, the World Health Organization (WHO) published the International Classification of Functioning, Disability and Health. ICF is the WHO framework for measuring health and disability of both individuals and entire populations. ICF was officially endorsed by all 191 WHO Member States in the Fifty-fourth World Health Assembly on 22 May 2001 (Savidis and Stephanidis 2004) as the international standard to describe and measure health and disability.

In order to produce a structured way for obtaining a forecast of how an information society could emerge, a scenario planning exercise was conducted in Europe in 2000, leading to the publication of the report "Scenarios for Ambient Intelligence in 2010" (Zerdick et al. 2004).

The following is a list of some of the features supposedly possible in Ambient Intelligence (AmI). It is possible to navigate in unknown environments (airport, city), to live and work in hotel rooms, to be supported in business activities, and to be in contact with the family and home environment. A personal communicator is continuously in connection with the AmI environment. It can offer a connection with the surrounding environment, but also with any place in the world. A communication agent, which learns from the individual user the way of dealing in different situations, can conduct most communications autonomously, taking decisions and speaking with the voice of the owner. The intelligence in the environment can capture, process and share information about human beings, expanding human relationships. Interconnected agents can create networks. Houses are intelligent and interconnected with the network, with access to e-commerce systems. The city system takes care of following the cars during travel and gives advice regarding traffic. Learning environments can adapt to the needs of different learning groups and individuals with different ages, knowledge, and interests. It can restructure itself also physically, offering, when necessary, interaction "islands" for different groups and very advanced presentation facilities (e. g., 3D holographic rendering). Contents, presentation speed, and complexity are controlled by AmI.

Therefore, the AmI environment is not considered as a space full of computer/based equipment, but as a new environment where activities and contacts are favored by the intelligence in it, which "knows" people and is able to support them in any situation. A variety of new services are supposed be made available, including home networking and automation, mobile health management, interpersonal communication, and personalized information services. These applications are characterized by increasing ubiquity, nomadism, and personalization (Antona, Burzgali, and Emiliani 2012; Emiliani and Stephanidis 2005). In the AmI environment, the starting points are the goals of the user. They are inferred by the system and decomposed into tasks that are adapted to the preferences of the individual, in order to help people in their activities and to be adaptive to their needs and preferences.

## 4 The new Century – Research Activities and Social Integration

In the period 1998-2002 the FP5-IST program for research, technological development, and demonstration on a "User-friendly Information Society," was active. No explicit reference is made in its description (FP5-IST 1999) to disability and design for all. However, a second implementation of an application for tourism based on DfA was developed and tested in the IST PALIO project.

In the eEurope 2005 (i2010 2005) and i2010 Action Plans (eEurope 2005) reference is made to "einclusion" in all action lines. In 2003, as a commitment to the European Year of People with Disabilities, the European Commission presented an action plan to promote equal opportunities to be run from 2004-2010, aiming to improve economic and social integration. One of the objectives of the i2010 is the creation of "*an Information Society that is inclusive, provides high quality public services and promotes quality of life*". It is also claimed that in order to reach this goal a Design for All approach should be used.

In 2006, the Implementation of the Council of Europe Action Plan (2006-2015) to promote the rights and full participation of people with disabilities in society was published (Council 2006).
In this period, activities aimed to support the European Design for All e-Accessibility Network (EdeAN) were supported (EDeAN 2002). EDeAN (2002-2009) was a European Network of more than 160 organizations in European Union Member States, with National Contact Centres (NCCs) selected in 24 countries throughout Europe. According to its Charter, EDeAN was a non-profit, self-financing network, coordinated by the Secretariat that rotated yearly. EDeAN was supposed to be supported by other EC-funded projects (Bühler and Emiliani 2013).
One of the supporting projects was the (D4ALLnet) Design for All Network of Excellence (2003-2005) (D4ALLnet 2005). D4ALLnet aimed to set-up a thematic network of centers of excellence in Design for All (DfA) in Europe, in order to promote and advance DfA practices in the Information Society, and in particular to contribute to the efforts of EDeAN and of the EC eAccessibility Expert Group towards the implementation of the eEurope 2005 Action Plan. D4ALLnet built an infrastructure to enable systematic cooperation among members and with other networks, stakeholders, and actors in the field, to advance common objectives. A second project was the (Dfa@eInclusion) Design for all for eInclusion Coordination Action (CA) (2007-2009) (DfA@eInclusion 2007). From a technological perspective, the main aim of DfA@eInclusion was to contribute to the support and enhancement of the networking and cooperation activities of the European Design for All (DfA) community, emphasizing the overall target of eInclusion, which is to ensure that technological developments are user-based and, therefore, take into account the needs and requirements of all citizens, including people with disabilities and elderly people.
The document "European Disability Strategy 2010-2020" (Disability 2010) confirmed the interest of the EU in dealing with the problems of integration of people in the society, even if only when they have health problems. The main emphasis is on the fundamental efforts on guaranteeing the rights to accessibility to the information. Moreover, Design for All or Universal Design completely disappeared from the documents.
In the HORIZON 2020 program (European Commission 2014) the pillar "Societal Challenges" and especially the topic "Health, demographic change and well-being" are of main interest for the eInclusion problems. From an analysis of the Working Plans 2014-2015, 2016-2017, 2018-2020 and the related calls, the following observations can be made. There are not many calls concerned with people in general, but only with patients and medicine. Elderly people are normally only considered if they are ill. There is an interest in technology, as tactile interfaces and virtual reality, but no interest in the positive or negative impact of technology on everyday life.
With reference to ambient intelligence, a specific AAL Program has been active in Europe in the last 10 years, first with the title Ambient Assistive Living and then changed in Aging Well in the Digital World. According to the document (AAL 2020), the main achievements can be described as addressing three goals:

(I) Improve the well-being of older adults through the use of adapted digital technology"
(II) Stimulate the development of an age-tech sector in Europe

(III) Contribute towards more sustainable health and care systems. Even if interesting results have been obtained, they are mainly connected with the use of technology for improving security at home, health care, and communication. The analysis of the possible positive or negative impact of available AmI technology on the general well-being of the entire population is not explicitly addressed.

# 5 Foreseeable Future Research Activities

The experience of the past decades has shown that, although accessibility has nowadays been established as a right in national legislations and is employed by international standardization organizations, it is a fact that industry has only partially embraced Design for All. However, it is true that most of the technology used for making available information and communication to all, as for example voice synthesis and recognition, gesture analysis, multimedia interfaces, is now built in the operating systems of all equipment, smart telephones included. However, this is mainly because this technology has become fashionable for the public at large. Moreover, a change of attitude is necessary with respect to the support of people who are old or/and have activity limitations. The main question is no more how technology can be made accessible, but how it can be used to be useful for (all) people.

More recently, there has been an increasing interest about people well-being, which, in accordance with the principles in WHO-ICF, is here defined as the possibility of conducting an independent, active, and fulfilling life (Antona, Burzgali, and Emiliani 2012), being able to carry out the necessary activities. Most of the real opportunities will be based on (artificial) intelligence in health care and support to well-being in general. AI should make available necessary knowledge (e.g., expert systems), in understanding problems (machine learning, deep learning), and in using suitable technology as robotics.

## 5.1 The Emerging World – From Accessibility to Enabling Technology

From a technological perspective, the dimension to take into account is the evolution towards intelligent environments, which will not be simply the smart home or workplace, but entire smart or hybrid cities (Streitz 2011), as foreseen in the ISTAG document. Considering that technology will be a vital component of any daily activity and it will cater for humans' needs, prosperity, and well-being, the stake for universal integration in the technological society is now much higher than in the past. Strategies followed in the past for the development of Assistive Technologies will no longer be appropriate in the context of new technological environments (Treviranus et al. 2014).

However, the most important changes have been from the user perspective. Today, ICT is widely distributed and useful, sometimes fundamental, for all people. The active members of the information society are all citizens, with the emerging need to make it not only usable by but useful to all. It should not create obstacles for any one and, instead, it should help all to reach their well-being.

The rapid aging of population is an important influential factor in this respect, resulting in a considerable proportion of the future technological environments users being old, who may perceive technology differently, due to functional limitations and age-related changes in cognitive processes (Charness and Boot 2009; Czaja and Lee

2007). At the same time ambient assisted working can foster adaptations of the workplace, thus ensuring that the population aging and/or with limitations are active and participate for the longest possible in the workforce (Bühler 2009). In addition to living and working environments, it is necessary that public environments, for example transportation systems, are revisited and redesigned in order to be age-friendly and age-ready (Coughlin and Brady 2019).

One of the main concerns is the acceptability of technological environments, from the perspective of the respect of ethics, the generation of positive emotions and the production of the prove to be worthy of trust. A trade-off is necessary between the creation of smartness and the balance of smartness and offered services under control of the person to maintain transparency. Intelligent agents create problems about where moral, societal, and legal responsibility lies, that is about accountability.

### 5.2 Interactions and Universal Access

The foreseen abundance of interactive and distributed devices can result in a relaxed and enjoyable interaction, employing multimodal interfaces, thus providing for each user those interaction modes that are more natural and suitable (Coughlin and Brady 2019). Other benefits ensured by these new environments include the possibility of task delegation to the environment and its agents, which can reduce physical and cognitive strain.

Considering past knowledge and experience, as well as the opportunities and difficulties inherent in technologically enriched environments, it is evident that several research directions need to be explored. Understanding the evolving human needs and context of use, developing appropriate user models (Burzagli, Emiliani, and Gabbanini 2007), as well as advancing knowledge of user requirements and of the appropriateness of the various solutions for the different combinations of user and environment characteristics (Casas et al. 2008) constitutes elements that should be explored.

The development of appropriate architectures, ready-to-use accessibility solutions, and appropriate tools are also essential elements of pursuing universal access in technologically enriched environments (Margetis et al. 2012; Smirek, Zimmermann, and Ziegler 2014). Automatic generation of accessible user interfaces is another research direction worth exploring for its potential to create accessible personalized interfaces (Jordan and Vanderheiden 2017).

### 5.3 Independent Life – The Role of Artificial Intelligence

Finally, it is necessary to emphasize the role of artificial intelligence towards providing useful means to support people in their daily life activities and thus improve well-being for everybody, including older people and people with limitations of activities (Burzagli et al. 2022). In this context, accessibility, and usability, although necessary, are not sufficient. In order to achieve the above objective, it is necessary that:

1. The design of intelligent environments is centered around the well-being of people, thus emphasizing usefulness in addition to usability;
2. The environment is orchestrated around activities and contains knowledge about the abilities necessary to perform them and how people need to be supported to perform them with functionalities in the environment, when some abilities are limited;

3. The environment uses monitoring and reasoning capabilities in order to adapt, fine-tune and evolve over time the type and level of support provided, and this process takes place considering ethical values;
4. The applications also support the possibility of contact with other people, who in many cases may be the only effective help. The above perspective moves on from the concept of Design for All and advocates an extension of its definition by not only addressing the accessibility and usability of technologies, but also placing emphasis on its usefulness, with reference to the entire population.

Research has identified several factors that have an impact on digital inequality, including race and ethnicity, gender, and socioeconomic status (Robinson 2015). Other influential factors include age, education, occupational status, health, social connectedness, and availability of infrastructures (e.g., people in rural areas have lower levels of access to high-quality internet connections) (Robinson et al. 2015). Whatever the reasons for which individuals may be at risk of exclusion, the challenge is that universal access becomes a matter of paramount importance in the forthcoming future, when access to technology will not only mean access to information and communication but also to well-being. This is possible if an approach is used that starts from the needs of users, in relation to everyday activities and well-being, and not from available technology.
This can be obtained by introducing Artificial Intelligence in the system, with the evolution of the control component to include two main blocks: a knowledge base and a reasoning system, as shown in Figure 1 (Burzagli and Emiliani 2014).

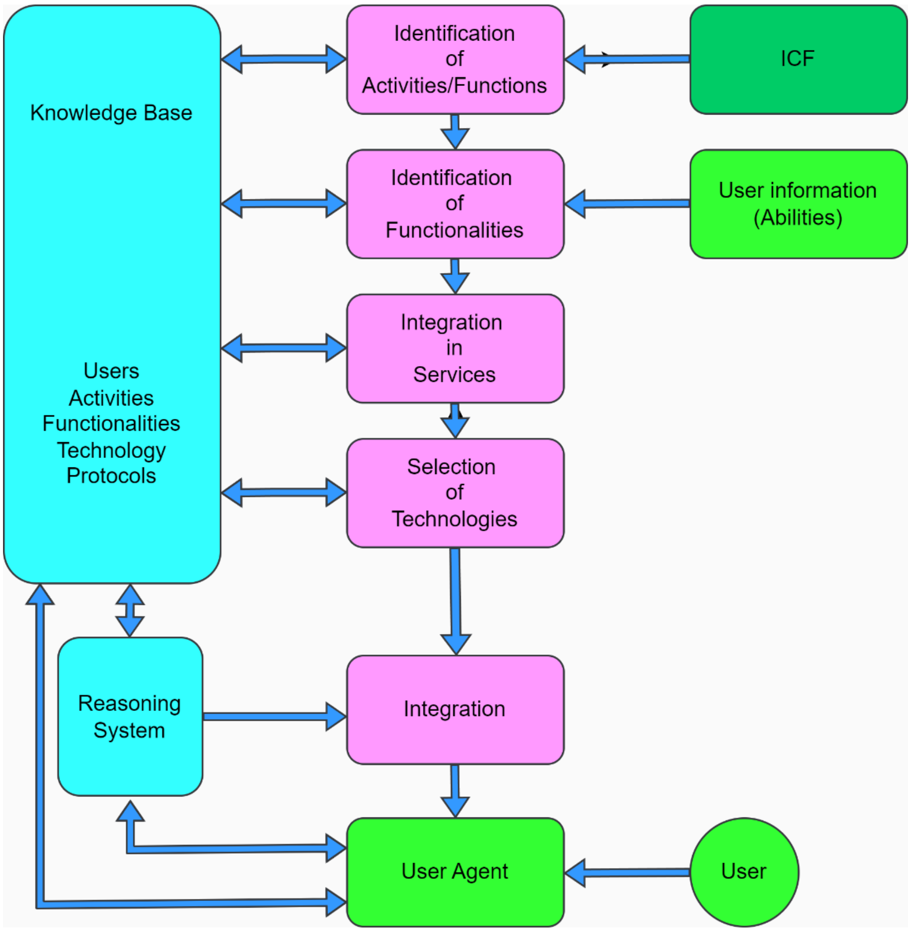


Figure 1 Block diagram of a support application using Artificial Intelligence (own figure)

### 5.4 Some Implemented Applications

The proposed design approach required a verification, through the development of a series of prototypes applications to support people. The implementations were funded by international projects, such as the AAL FOOD project (AAL Food Project 2012) and by national ones, such as D4All of the Cluster Technological Living Environments program (Burzagli et al. 2014).
The implementation of the applications started from a study of their specifications and those of the component services, of the needed functionalities, and of the possibility of management by people. They were chosen in order of increasing complexity:

1. Application addressing a single user in a limited and controlled environment (e. g., nutrition);
2. Application implying the interaction of different users (support to solitude);
3. Application needing interactions with people and information in an open environment (mobility in the city).

A fundamental type (1) application is the support of nutrition of persons living alone with different expertise in cooking and varying sensorial and/or physical abilities (Burzagli et al. 2014). This involves the choice of recipes, their preparation, the storage and management of food and the use of appliances, in an integrated manner. Therefore, it is necessary to collect and structure information related to the user, the environment (physical appliances in the kitchen and their position), the tasks necessary for nutrition (e.g., management of the pantry, use of appliances, and realization of a recipe or several recipes at the same time) and to integrate all the above information components. For the interaction in this case is convenient to create an App on a tablet (as in the project D4all) for the kitchen and food management, with an interface adaptable to the different visual, cognitive, and physical abilities. The realization of such an application at its basic level does not require particular processing complexity, but only a careful structuring of the input/output information. The situation is different if the application needs to be personalized, for example, to adapt the suggestions of food considering the dietary needs of the person. In this case, before suggesting possible food, it is necessary to “reason” about the health situation of the person, the food eaten the previous days and so on.
The situation becomes more complex in applications of type (2), when the support application requires the interaction of several people, such as, for example, to alleviate loneliness through social interaction (Burzagli and Naldini 2020). It is necessary to take into account the characteristics of different people and to have information about their availability and activities in real time. A prototype developed in our laboratory considered a person living alone in condominium, where people are available to support her. They obviously have different user profiles, both from a physical, sensory, and motor perspective, personal preferences, and activities in progress. In this case, the system must reason on the profiles and activities of all potentially involved people. In the prototype algorithms were introduced that allow to reason in uncertain environments, inserting, for example, a machine learning level for the optimization of weights related to the choice of possible suggestions based on the user’s reaction to the previously offered proposals. This suggested the adoption of the Dempter Schafer’s algorithm (Wikipedia 2024) for the selection of the most appropriate suggestion since this algorithm is adopted for reasoning with uncertainty.

The system is characterized by an additional degree of complexity (applications of type 3) when the support must not be offered in defined environments but outdoors, as it is necessary for guiding people through pedestrian paths in a city (Burzagli and Emiliani 2021). In this case, a new element, i.e., the management of geographical environmental data, is inserted. In this case information is seldom available in the quantity and form necessary to define the characteristics of the environment, for example to walk around. Besides, an extreme variety of possible results exists, when paths are optimized not only to the physical, sensory, and cognitive characteristics of the user, but also to her preferences. For example, a person may prefer not to follow the shortest route but to pass near shops and other services or walk through a garden. The implemented application aims to optimize the suggestion, adopting a concept of physical accessibility that, in addition to the lack of architectural barriers, also considers the use of public transport services and the proximity of services. The processing system required the adoption of reinforcement learning algorithms to find the optimal path.

## 6 Conclusion

The main purpose of the paper is to outline the importance that ICT and AI may have in supporting people in the society. The living places (house, school, working places, cities) are developing toward complex intelligent environments. The technology in them can be used to develop applications able to support the well-being of all people irrespective of their abilities. It can also to be observed that even if AI may offer important improvements, the currently available technology can be used to produce useful applications, as, for example, the one dealing with nutrition.

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