Editorial
Home Automation as a Means of Independent Living

I. INTRODUCTION

THROUGH automation a person's home can potentially become a place where they can interact more seamlessly with the immediate environment. In addition, some forms of automation can enable persons to gain access to, and interact with, the outside world. This allows access to services which historically have been beyond the reach of the home environment. Hospitals, shops, libraries, and museums are just some of the places that provide services that, at one time, could only be obtained locally. Although the potential is there to make the home a service rich environment, we still face many challenges and hurdles in both the development, roll out and acceptance of these services.

Fundamentally, "home automation" can be thought of as the combination of sensors and actuators. This combination of technology is then built upon to render systems for the control and automation of lighting, heating and ventilation, power (windmills , solar energy, etc.), and entertainment (video, digital cable, DVD, etc.) to name but a few. Perhaps more recently, systems and services which record and act upon data from the individual or individuals in the home providing medical or care related services are also being categorized as forms of home automation.

It is also possible to consider the various forms of home automation in terms of the application area or user needs which they address. One particular area, which is the focus of this paper, is the use of home automation to aid those who require assistance to live independently. Examples of services within this category are the provision of basic security functionality, to reassure the individual who lives alone and the provision of complex medical interventions to treat health related problems outside of the hospital or clinic. Although uptake within this domain has been slow, if a similar level of change, as witnessed through the application of automation in industry and commerce for example, is observed in the home environment, we should expect far reaching changes for which we should be prepared.

In the remainder of this paper, we investigate the various approaches to home automation which can be used to facilitate independent living. Within our work, we consider that the solutions provided to support home automation for independent living form a small, yet important component within the broad range of home automation systems and services. Within this grouping, we have identified a number of specific areas within which home automation services are being delivered. In the first instance, there are the range of technologies which can be used to automate the needs and processes of health related issues within the home. These are complimented through the usage of robotic technology to support mobility and transport with a further grouping of robotic systems offering assistance with the completion of a number of day-to-day home-based activities. We consider the notion of an intelligent home to support independent living as a further niche area. In this scenario, all of the data which is collected can be centrally processed and managed in an intelligent manner and subsequently used to control the home environment to improve the user's living experience. As a final area for consideration, we have identified the need to provide a means of integrating the heterogeneous home automation-based solutions that have been discussed. By presenting the material in this manner, we aim to provide a general overview of the area which should be of interest to those wishing to have an introduction to home automation and independent living.

The remainder of this paper is arranged as follows. Section II provides a general overview of user needs within the realms of independent living. Section III provides details of the various types of home automation systems which can be used to support independent living and Section IV concludes this paper discussing the challenges and the way ahead.

II. USER NEEDS

At present, we are witnessing demographic changes that will have an impact upon all aspects of society. Although we are just starting to see the effects caused by these changes, the most dramatic changes are not likely to emerge until several more decades have passed. A particular change that is likely to have significant impact is the ageing population. Estimates suggest that by 2050 the global median age will be 36.8. This has risen from a global median age of 23.6 in 1950 and 26.4 in the year 2000 [1]. According to the World Health Organization, we are expected to see an increase in the elderly proportion of the population rising from around 600 million in the year 2000 to close to 2 billion in 2050. Additionally, as the size of the population continues to grow coupled with the growth in the number of individuals suffering chronic diseases, the prevalence of those suffering from a form of disability is also increasing. According to the World Health Organization, approximately 10% of the population experience some form of disability.

As a result of these demographic changes, huge demands are being placed on health and social care services. For example, in North America, 2.2% of the annual healthcare expenditure can be attributed to those under 25 with 15% of expenditure being attributed to those in the older category of the population [1]. This is accompanied by the fact that older persons themselves demonstrate a higher spend on healthcare than any other proportion of the population. It is, therefore, possible to identify a relationship between age and expenditure in addition to a relationship between age and prevalence of disease.

The combination of all of these factors realizes a rationale for the role of home automation as a means to facilitate independent living. To maximize the impact of the technology, it is necessary to have some degree of the appreciation of the needs of the end users. This is a complex topic and is further complicated by the fact that user requirements will vary on a person-per-person basis. This is mainly due to the degree of support which may be required along with the user's personal preferences and their previous experiences with technologies. From

the user's point-of-view, home automation can be used to address a number of key areas which include the following:

— a means to augment cognitive impairments;
— the ability to provide a level of independence for those suffering from a form of disability;
— a means to offer support in the management and delivery of health care related services;
— the ability to offer support in the completion of general activities of daily living.

Although we devote our discussion to those in the ageing population and those who experience a form of disability who can avail of augmentation to counteract physical or cognitive limitations and decline, there are those who may not benefit from such aggressive intervention. Such persons rely on monitoring more so than on automation. Indeed, due to the complex nature of the problem, there are instances were automation may be seen as detrimental. For example, smart environments can help keep people functionally capable by detecting health problems early, thus preventing serious physical and cognitive decline, this is typically achieved through monitoring. The danger here is that if this monitoring is accompanied with automation support relatively healthy subjects may be discouraged from undertaking the physical and mental activities required for preservation of current state. This reflects some of the more complex issues that relate to the consideration of user needs. Although this paper does not extend to the discussion of these more complex scenarios, it is important that they are acknowledged.

III. EXISTING SOLUTIONS TO HOME AUTOMATION

As previously discussed, home automation can be delivered in a number of ways and currently exists at both research and commercial levels. In the following sections, we attempt to categorize the different ways in which home automation may exist and subsequently provide some examples of each type of solution.

A. Intelligent Homes

Automation for the household has developed at a rapid rate on a global scale. The huge developments of both microprocessors and networks have stimulated not only progress of automation on an individual level but also development of integrated systems based on networked devices. Furthermore, evolution of sensors have derived new aspects of home automation such as behavior estimation and behavior prediction through motion analysis. Considering all of these elements together has led to the establishment of "Intelligent Homes" or "Smart Homes." The goal of an intelligent home is to monitor the activities of the person within their own living environment along with how they interact with domotic devices and based upon these interactions and their current sequence of activities the ambient environment can be controlled and adapted to provide an improved living experience for the person. This improvement in living may be achieved by providing a higher level of personal autonomy and independent living, increased quality-of-life or increased feelings of security and safety. Embedded sensing technology of various forms is used to record the activities within the home and actuators and control devices are subsequently used to adapt the living environment. Research in the area of intelligent homes has been prolific in the past two decades. The following paragraphs provide a summary of some of the activities within this area.

The TRON Intelligent House established in 1989 [2] has 380 CPUs connected to each other via the TRON (The Real-time Operation system Nucleus) architecture. Within the house, windows may be controlled along with other services such as light control, recipe/menu display, and automatic toilet room, all of which have been verified through real experiments.

In 1996, Sato proposed the "Robotic Room," which was based on the concept of a ubiquitous robotic system [3]. This concept aimed to build robotic systems which served human beings anytime, anywhere within a specific environment. Recent results from this work have demonstrated a refinement of the initial concept, showing that both behavior estimation and behavior prediction can be achieved by using only invisible sensors within the environment [4]. Hashimoto proposed a similar concept of "Intelligent Space" [5]. This work shares a similar concept to that of the Robotic Room, but it focuses on network functions. The "Ubiquitous Home" [6] environment is equipped with multiple sensors, e.g., cameras, pressure sensors, etc., and two kinds of robots. One robot communicates with users using dialogue, the other is a movable robot. The developments within this work have supported services such as finding missing objects by behavior history and a checking service for forgotten or lost devices. In Japan, the Zojirushi Corporation provides a service called "Mimamori-hotline" for the monitoring of elderly people [7]. The service utilizes a special electric pot named i-pot which reports the status of use to remote family members by e-mail. The electric pot should be used to make tea several times in a day. From the analysis of the daily pattern, it can detect unusual conditions. The system does not use camera systems which invade privacy, but it can detect abnormality by a very simple system and analysis of the data collected. Matsushita Electric Works, Ltd., developed an EMIT Suimin System which creates a room environment leading to the promotion of quality sleeping and wake-up patterns [8]. The system has the ability to control lighting, the angle of the bed, the height of the pillow, the air-conditioning, and electric curtains.

In the U.S., a number of research groups are actively addressing the area of Intelligent Homes. Within the MavHome [9] project, research is directed towards the development of a home which is viewed as an intelligent agent. Within such an environment sensors are deployed to perceive the environment upon which decisions to use actuators are made. Within the Gator-Tech Smart House [10] project, efforts are currently being made to develop solutions to maximize the independence and improve the quality-of-life for the elderly and disabled mainly through pervasive computing technology. Research within the Aware Home Research Initiative [11] aims to develop environments which can be aware of the activities and whereabouts of the persons within the home in addition to providing services which can offer independence during the ageing process. The method presented in [12] has used neural network reinforcement to control the smart environment. This adaptive system has the ability to infer modes of operation based on the user's profiles and energy conservation goals. The MIT House_n group are developing solutions which are investigating the ability of the technology within the home to offer support to the person at the time and place they need it subsequently helping them to make decisions and avoiding any sense of the perceived lack of control over an automated environment [13].

As with all of the efforts within this domain it is evident that the correct application of technology and its resultant service

can provide benefit to its end users. This specific area of research is gathering much attention and has the potential to deliver tangible solutions which will improve the levels of independence for the end user. The main thrust of the work can be considered to be the efficient processing of the information recorded and its subsequent analysis in terms of the person's behavior.

B. Intelligent Healthcare Devices Within the Home

Intelligent healthcare devices are proliferating in the home environment hence introducing the potential benefit to improve certain aspects of independent living. These devices are particularly beneficial to those who require assistance and intervention with healthcare within their home environment. In the following paragraphs, we look at some of the trends in home-based automated services and intelligent healthcare devices. We have presented this section by focusing on a number of specific and potential applications ranging from services that assist in the provision of medical interventions to those that offer a form of therapeutic support.

An initial category of intelligent devices/systems can be identified as those which are designed to support people who are dependant on medical intervention. These devices operate by administering some form of treatment based on either predetermined or ongoing assessment or the patient's own requirements. This can range from delivering scheduled oral medication to the administration of intravenous medication, which could be injected based on a change in a patient's vital signs. In either case, the deployment of such systems within the home environment assists in the promotion of independent living. As an exemplar, we have chosen to elaborate on the former of these systems, namely, automated medication dispensers. Medication dispensers can be subdivided into several categories, these include simple pill holders, alarmed reminder containers, and most relevant to this article automated dispensers [14]. Several automated medication dispensing devices are currently commercially available, for example, CompuMed [15] and MD2 [16]. The latter of these devices, MD2, possibly offers the broadest functionality as this particular device can store, organize, dispense, monitor, and remind patients about their medication regimes. In the event of the patient not taking their medication after multiple reminders, the system can be configured to automatically alert a family member or carer by telephone [17]. A similar system, which has recently been developed, is the MEDICATE system [18], [19]. This system offers similar functionality to the MD2, however, also includes a portable unit which detaches from the home-based unit. The benefit of the additional portable component is the ability to provide a continuum of service delivery once the person leaves their home environment.

Further devices and systems which come under this umbrella of intelligent healthcare devices are those which physically interact with the user to provide preventative and therapeutic support. Examples of these are calf stimulators combating deep vein thrombosis [20], or devices providing therapeutic support for patients recovering from some ailment, trauma, or post operative situation. As an example of the therapeutic oriented device, we highlight a current study that entails the development of a motor function management system for the rehabilitation of stroke patients [21]. This system uses accelerometer-based technology to track patient's limb movements. This information is then processed remotely and feedback is provided to the patient in order to maximize recovery.

An area which is also gathering much interest in this domain is that of wearable computing and smart textiles. The area of smart textiles encompasses elements of research and technological advances from the domains of polymers, advanced material processing, sensor technology, nanotechnologies, and microelectronics. In addition to these core technological components there is also a significant role for Information and Communication Technologies and Health Informatics. The consolidation of technology under the single umbrella of one recording device in the form of clothing provides the opportunity to record a series of clinical parameters and integrate this information with other ambient information [22]. Although this area of work has been largely research-based, current efforts are being focused towards improving reliability of the recording systems and hence moving one step closer towards commercial products.

C. Transport and Mobility in the Home

Mobility is one of the key characteristics of independence. Usually, mobility is not an issue for young and healthy people, and therefore all home automation solutions addressing mobility refer to the needs of elderly and disabled people. There are basically two approaches to support mobility in the home. The first consists of installing fixed transportation systems in and around the home, whereas the second relies on more advanced technologies to provide flexible motion capabilities.

Fixed transportation systems rely on classical mechanical concepts and designs which can be customized to the specific needs of the users and are usually standalone systems, i.e., not integrated within a global home automation system. Normally, they consist of fixed and mobile systems. Fixed systems are open frame elevators, with a vertical run, people movers, with a sloped run, or chair lifts that can be installed on staircases. They are very reliable and economical, but require complex installation within the home and cannot be moved to a different location. On the other hand, mobile systems are devices that connect to wheelchairs which lift them to enable them to negotiate stairs, curbs, and other obstacles. These systems are not autonomous and require the presence of a person to guide the motion.

Advanced automation for flexible mobility is represented by the large body of research on intelligent wheelchairs. Navigational aids for powered wheelchairs, as preliminary research results, appeared in the 1980s. Although there have been quite a large number of projects and contributions since then, advanced automation has reached very few commercial products. The main focus has been on the development of navigation algorithms, to assist people to negotiate a path, or move in a crowd, or simply learn how to move.

The concept of an intelligent wheelchair that can assist the wheelchair driver has existed since the 1980s [23]. In the late 1980s, the Swedish Permobil Company developed a "track follower" module to enable their wheelchairs to follow taped floor tracks and ultrasonic sensors to detect obstacles [24]. In the past few years, researchers have developed wheelchairs with systems for obstacle detection and avoidance [25], autonomous wall-following, and negotiating doorways [27], [28].

In the U.K., the CALL Centre has been developing infrared track followers, collision, and ultrasonic sensors since 1987 [29], while the Challey Heritage Engineering Department in

Sussex has developed inductive track-following and ultrasonic obstacle detection systems [30]. The European TIDE Initiative [26] has also supported two projects developing sensor-aided systems for power wheelchairs: SENARIO [27] and OMNI [31], [32]. The main objective of the SENARIO project was to develop a prototype of a sensor-aided intelligent wheelchair navigation system, applied on a commercial powered wheelchair for use in indoor environments. The OMNI project addressed the development of an omnidirectional mobility aid to powered wheelchairs, based on Meccanum-wheels. A further development in the area of wheelchair autonomy is presented in [33], which describes the experiments of autonomous navigation of a wheelchair in the crowed hall of a train station.

Similar research has also been conducted in the U.S., Japan, and Korea, addressing mobility and sensing systems for wheelchairs. Sensor integration was addressed by NavChair [34] to navigate an indoor environment with some autonomous function and hybrid mobility is addressed in RHOMBUS [35], which is a powered wheelchair with an omnidirectional drive.

Current European research on intelligent wheelchairs focuses on more complex activities, such as planning and modularity of functions. The MOVEMENT project proposes "Modular Mobility" to allow flexibility, operational stability, and cost reduction by using functional modules. The MAPPED project [36] is dedicated to providing users with the ability to plan point to point motions, using public transport, their own vehicle, walking, or wheelchairs.

Although systems are being designed for the elderly and disabled this may not be the best approach, since it cannot take advantage of addressing the much larger market of normally able people. Perhaps mobility aids should be developed first for normally able people, and then adapted to elderly or people with disabilities. It is interesting to note that no research has taken this point-of-view, except perhaps the work on human augmentation, e.g., exoskeleton. Clearly, elevators were not designed as mobility aids, and perhaps also normal people would not mind some automatic mobility system at home.

D. The Role of Robotics in Home Automation

Although heralded as the solution of most domestic problems, domestic robots are still in their infancy with few commercial applications on the market and several systems under development and testing in research laboratories. Furthermore, none of the commercial systems are integrated into a home automation system, but rather exist as standalone devices at best connected to a home personal computer. To date, the main applications of robotics at home to support independent living have been found in the areas of automatic cleaning, entertainment, and supporting persons with physical disabilities.

Automatic cleaning may be considered as the area with the most potential. Home cleaning robots are mobile robots, with a small footprint and limited navigational capability. The latest count shows at least 11 different products on the market, manufactured by large appliance companies, and by small startups as well. This is complemented by a number of earlier attempts to introduce robotic domestic cleaning appliances [37]. Two exemplars among the commercial home robotic cleaners are *Trilobite* [38] developed by the European manufacturer Electrolux and *Roomba* [39], by the U.S. manufacturer iRobot.

In 2001, AB Electrolux in Sweden launched the home cleaning robot Trilobite 1.0. It was the first home cleaning

robot that became commercially available as a "mass" product. Trilobite uses a very sophisticated sonar system for its navigation. It has the ability to explore its workspace and subsequently create a map hence offering better coverage performance than can be achieved by a pure random motion. Roomba may be considered as the most popular cleaning robot with more than two million units sold since the product was released in 2002. The robotic technology of Roomba is very simple. It has a differential drive with two rubber wheels and a caster wheel in the front, which provides good manoeuvrability. Four infrared cliff sensors protect it from moving down stairs, and an infrared sensor allows it to measure the distance from obstacles and walls.

Although robotic cleaning is now considered an established area of home automation the same cannot be said for the other applications of robotics at home. Other areas of home robotics which have also received some attention have been diverse in terms of their application. Kakikura developed a robotic system which supported the handling of clothes following a laundry service [40]. The system was capable of selecting and folding the clothes through the use of robotic hands. Another area which can be seen as a valuable aid in supporting independent living is the use of anthropomorphic manipulators. Such systems are usually part of larger automation systems customized for a specific user's needs. The Assistive Robot service Manipulator (ARM) [41], also known as "Manus," is a 6+2 DOF robot which represents this type of application. It can be mounted on an electric wheelchair (or mobile base) and, under human control allows numerous daily living tasks to be carried out at home, at work, and outdoors. Nevertheless, the device is more like a medical/rehabilitation system as opposed to a true home robot. A more versatile robotic manipulator for home use is Asibot [42]. Asibot has five DOF, and weights around 10 kg. The feature that makes the robot unique is the fact that all the control systems are on-board and it only requires a 24 V external power supply.

Finally, an application of home robots which is showing interesting potential in supporting independent living, which combines some of the characteristics of the two aforementioned applications, is that of Entertainment robots. These are devices which are mainly developed for companionship and amusement and, in addition, can also perform some helpful tasks within the home environment. One of the best known examples of this technology is AIBO (Artificial Intelligence roBOt) [43]. This is a robotic pet, introduced by Sony in 1999. (Unfortunately, even though it had commercial success, this product will be discontinued.) Another robotic device that is finding some very interesting use is PARO, a robotic seal developed at AIST Laboratories in Japan. PARO has been designed to provide entertainment and stimulation to persons within retirement homes and has been shown to provide improved brain function for those suffering from a cognitive disorder [44]. It is interesting to note that although entertainment robots have been designed to be sophisticated toys, their interactive features have made them suitable also for more demanding tasks, such as companionship or substitutes for real animals.

E. Living Automation Projects

At the other end of the spectrum from the aforementioned devices and systems are those which extend beyond the realms of healthcare and robotic-based solutions into the broader home environment. There is much interest and scope in developing

systems that integrate all aspects of everyday life into the home. This involves the centralization of the control of all aspects of everyday life. The "holy grail" of such systems would be one control unit (remote controller) with the ability to control all devices in the home. This would include not just consumer electronic devices such as televisions and stereos but would extend to all domestic appliances such as kitchen washing equipment and could also include door and window latches. Such a system may seem to be relatively uncomplex, nevertheless, the integration of such diverse systems and devices in terms of device genre and vendor variation make this the most difficult system to realize of all. Such a system poses less problems when a new set of services are being developed, for example, development of a new smart home, however, implementation of such a system in a preexisting scenario where all fixtures and appliances are preexisting poses more of a problem.

In addition, systems must not only be able to interact with various hardware and software from various vendors but must also accommodate the user and their environment. For example, if the home is sold to another owner, it and any devices need to be "reset" to their original settings and the devices and other fixtures (sensors, for example) that are to move with its previous owner need to "remember" their personalized settings. This is a challenging problem and one which is expected to receive further attention in the future.

F. Standards and Interoperability

One of the main issues that manufacturers are addressing at present are related to interoperability of devices from various manufacturers, and the development of simple and efficient command languages to monitor and control all the various devices. However, as pointed out in [45], the many standards currently being developed must be evaluated in order to assess their suitability to the home environment and their efficiency. For example, in [46], the authors discuss the various characteristics of wireless networks, as applied to a domestic environment. There may rise the necessity of modifying some aspects of the current standards, for example, the data layer of the ISO-OSI standard, to avoid interferences among networks established in adjacent apartments. These situations may also be addressed by mobile agent technology, as discussed in [47], which can prevent interference and support more homogeneous home network configurations.

The effective implementation of large scale multimodal automated environments obviously relies on the seamless integration of numerous peripheral devices and services. The necessity to integrate devices and systems that are often not of the same genre and not produced by the same vendor, as previously stated in the previous section, raises compatibility issues. An important direction, therefore, concerns the introduction of protocols and standards to this arena [48]. Numerous consortiums have set about defining such protocols and standards and a review of these have been presented in [49]. Two of the more prominent standards which have emerged, are the open standards gateway initiative (OSGi) and Konnex [50], [51]. In general, the aim in developing these standards is to make all aspects of home automation simpler. This includes, but is not limited to, the connection of systems, the transfer of data, and the management and provisioning of network devices. A common methodology used to realize this is the "gateway" approach, and this forms the basis of the approach adopted by OSGi.

The OSGi, now referred to as the OSGI alliance [50], was established in May 1999 with the aim of creating an open specification to allow the delivery of a wide array of services to end users [52]. In particular, the specification was designed to accommodate the provision of broadband services to networks in homes, cars, and other environments [53]. In the home environment, the vision was that every home should contain a home area network to which most household devices would connect. This was to be realized through a "home services gateway," which would effectively act as a gateway between the end users and service providers [54]. The OSGi specifications are made up of a number of components. Core to this is the OSGI framework, which defines the actual service's gateway [55], and provides a standardized environment to applications also known as "bundles." On top of this framework, a number of services have been specified, these include standard services, framework services, and protocol services [50]. The application of the OSGi model has been reported in several automation and smart home scenarios, these include the implementation of generic smart home platforms [55], [56], "location aware" applications for monitoring the elderly in their homes [57], and "context aware" applications [58].

The Konnex standard, abbreviated to KNX, is a further standard which has been studied. This standard came about with the merger of three existing standards, European Installation Bus (EIB), Batibus (BCI), and European Home Systems (EHS) [59], [60]. The EIB standard, whose communication stack forms the basis of KNX [51], was developed under the auspices of the European Union. EIB was designed to link sensors and actuators to building systems that control parameters such as heating, ventilation, security, entertainment, and access [61]. In the specification of KNX, the previous EIB standard is supported with the configuration modes, physical layers and application experience of BatiBUS and EHS [51]. The current KNX standard provides three configuration modes referred to as system mode (S), easy mode (E), and automatic mode (A) [62]. These modes are designed to facilitate different types of users, ranging from well trained installers to end users in the configuration of system components.

IV. CONCLUSION

Home automation systems are one of the less studied areas of automation, and have been mainly left to the development of simple applications. In fact, most of the home automation systems available today can be considered to be simplistic and are and mostly deployed as a means of security devices. These systems have the capability to perform a variety of functions, often integrating room entry and light management, with recording of access and motion in the rooms. Since the early days of home automation, some of the main problems, and main solution trends, were already well known. In fact, a short review of early papers on home automation [63]–[67] shows most of the ideas, and the solutions are now commercially available. The main needs that were identified, and that are still relevant today, refer to communication support and standards [63], system architecture and components [65], power management and utility participation [66], and security in remote access [67]. Interestingly, [64] mentions issues that are still considered unsolved today and key challenges within real living environments, namely,

the inclusion of knowledge-based systems and artificial intelligence-based engines to endow the home automation system with some awareness of the home situation and of its inhabitant's conditions, and with the capability of learning useful living patterns. These aspects are still at the core of the research efforts in Intelligent Ambient systems and Smart Home research.

Fortunately, the lack of interest towards this field shown by researchers and manufacturers alike is due to change in a short time frame, due to the combined appearance of increased needs to support independent living and of new technical resources. New and emerging services will have the main objective of preserving self-sufficiency, either by keeping people more physically and socially active, or by providing automation aids that will permit independent living and safe living.

In this paper, we have presented this evolving social and technological landscape by summarizing some of the main applications of home automation available today. In Section II, to motivate the research and development in this area, we discuss the needs in the context of changing demographics. In Section III, we identify and provide an overview of the main areas of home automation, describing products available on the market along with more research-based developments.

Based on this general introduction to the role of home automation to support independent living, it is useful to briefly summarize the main research challenges facing the field and what can be achieved within some reasonable time frame. It is important to note that home automation, unlike domestic appliances, will unlikely consist of a single, standalone device. The end solution is more likely to consist of an integrated ensemble of functional units. The basic hardware elements can be considered to be currently available, however, what is currently lacking is the development of robust and nonintrusive and personalizable ambient intelligence and situation awareness solutions [68]. Furthermore, this technology should also be compliant with privacy protection laws. These two goals are quite challenging from the technical and ethical points of view. Even for humans it is hard to understand certain situations, and hence it is even more difficult to try and detect the onset of a possible dangerous event. Nevertheless, we expect that the development of home automation systems will be developed further within this direction. To reach such a goal, a number of key factors should be addressed. First, the system should be easily reconfigurable and adaptable to different user needs and where possible support the needs of more than one person living in the same environment. Second, a step moving towards an improved level of awareness should be the capability of recognizing unusual behavior patterns in conjunction with subtle trends in changes in behavior. Although machine and robotic learning will be key elements in future home automation systems, these technologies cannot cope with the large amount of data produced by real sensors, and therefore, other important data mining techniques will be required to manage the information. This is an area of active research, also funded by several research projects worldwide, and hopefully in the short term will be able to produce results applicable to home automation systems.

Clearly, the path to a more efficient, intelligent, and, if necessary, pervasive use of automation at home is still very long and many challenges are still ahead of us. A number of scientific and technological problems must still be solved. It is important to note that, in this specific area, theoretical and practical aspects are tightly coupled by the need of achieving a product cost which is accessible to a large segment of the target population. Safety is also another major concern of home automation. Can new devices be equipped with an acceptable level of awareness and responsiveness that can react and even prevent, dangerous situations? For these reasons, we think that home automation will be the arena in which automation science will be forced to meet even more stringent constraints than those of the shop floor.

The Special Section dedicated to Home Automation consists of three technical contributions addressing specific aspects of home automation. The paper by Liau *et al.* presents a solution to one of the key challenges of home automation, namely, situation awareness. The authors narrow the problem to location tracking, and present a nonintrusive solution to detect the motions of people in the environment, filter out noise, and discriminate among different people. The solution proposed relies on pressure sensors embedded into a wooden floor and on probabilistic data association techniques. This is an innovative approach, which can probably be extended even further, by making the floor, and not only the house, more intelligent. The paper by Park *et al.* addresses the issue of interfacing with an intelligent home. The solution proposed consists of a mediator, i.e., a device that can communicate better (in comparison to the automation system) with the home users. The mediator is capable of showing emotions, making facial expressions, and especially of learning its user's behavioral patterns to respond in an improved manner to requests and commands. Finally, the paper by Wang *et al.* addresses another aspect of human-system communication, namely, vocal communication. It presents a robust method to detect intentions in human speech, to facilitate interaction with a home automation system.

CHRIS D. NUGENT, *Guest Editor*
School of Computing and Mathematics
University of Ulster
Jordanstown BT37 0QB, U.K.

DEWAR D. FINLAY
School of Computing and Mathematics
University of Ulster
Jordanstown BT37 0QB, U.K.

PAOLO FIORINI, *Guest Editor*
University of Verona
Faculty of Sciences
Verona 37134, Italy

YUICHI TSUMAKI, *Guest Editor*
Hirosaki University
Faculty of Science and Technology
Bunkyo-cho, Hirosaki 036-8561, Japan

ERWIN PRASSLER, *Guest Editor*
Department of Computer Science
University of Applied Science Bonn-Rhein-Sieg
Sankt, Augustin 53757, Germany

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Chris D. Nugent (S'96–A'99–M'03) was born in 1973. He received the B.Eng. degree in electronic systems and the D.Phil. degree in biomedical engineering from the University of Ulster, Jordanstown, U.K., in 1995 and 1998, respectively.

In 1998, he took the post of Research Fellow at the University of Ulster and is now currently a Reader. His research interests include computerized electrocardiology, Internet-based healthcare models, smart homes, and the evaluation of medical decision support systems.

Dewar D. Finlay was born in Northern Ireland in 1977. He received the B.Eng. degree in electronic systems and the Ph.D. degree in computer science from the University of Ulster, Jordanstown, U.K., in 1999 and 2006, respectively.

He is currently a Lecturer of Computer Science at the University of Ulster. In particular, his research interests include medical devices, healthcare technology, and computerized electrocardiology.

Paolo Fiorini was born in Verona, Italy, in 1953. He received the Laurea degree in electronic engineering from the University of Padova, Padova, Italy, the M.S.E.E. degree from the University of California at Irvine, and the Ph.D. degree in mechanical engineering from the University of California at Los Angeles (UCLA).

From 1985 to 2000, he was with the NASA Jet Propulsion Laboratory, California Institute of Technology, where he worked on telerobotic and teleoperated systems, small hopping robots for planetary exploration, and service robotics for demining and assistance to the elderly and disabled. Since 2000, he has been an Associate Professor of Control Systems at the School of Sciences, University of Verona, Verona, where he has built a research group in robotics. Current activities include teleoperation and mobile autonomous robots, for applications ranging from surgery to logistics. He has published more than 100 papers in scientific conferences and journals.

Dr. Fiorini has served two consecutive terms as AdCom member of the IEEE Robotics and Automation Society (RAS). He is the Co-Chair of RAS Educational Committee and has been the Co-Chair of Service Robotics, and Search, Safety and Rescue Robot TCs. He was the Italian coordinator of the European Project MEDICATE, and is now the Italian Coordinator of the EU projects XPERO, ACCUROBAS, and ROSTA.

Yuichi Tsumaki was born in Miyazaki, Japan, in 1965. He received the B.Eng. and M.Eng. degrees in precision engineering and the Ph.D. degree in engineering from Tohoku University, Sendai, Japan, in 1990, 1992, and 1998, respectively.

From 1992 to 1994, he was with Kamakura Works of Mitsubishi Electric Company, Ltd. He was a Research Associate with the Department of Aeronautics and Space Engineering, Tohoku University, from 1994 to 2001. In 1999, he was visiting the NASA Jet Propulsion Laboratory, California Institute of Technology, as a Visiting Researcher. Since 2001, he has been an Associate Professor with the Department of Intelligent Machines and System Engineering, Hirosaki University, Japan. His research interests include telerobotics, virtual reality, wearable robot, haptic interface, space robot, humanoid, and medical robot.

Erwin Prassler received the M.S. degree in computer science from the Technical University of Munich, Munich, Germany, in 1985 and the Ph.D. degree in computer science from the University of Ulm, Ulm, Germany, in March 1996.

From 1986 to 1989, he held positions as a member of the scientific staff at the Technical University of Munich and as a Guest Researcher with the Computer Science Department, University of Toronto. In Fall 1989, he joined the Research Institute for Applied Knowledge Processing (FAW), Ulm, where he headed a research group working in the field of mobile robots and service robotics between 1994 and 2003. In 1999, he joined Gesellschaft fur Produktionssysteme (GPS) in Stuttgart as Director of the Department of Project Management and Technology Transfer. In this function, he coordinated the MORPHA Project (Interaction and Communication between Humans and Intelligent Robot Assistants, www.morpha.de) one of six national research projects in the field of Human Machine Interaction funded by the German Ministry for Education and Research. In February 2004, he accepted a joint affiliation as Associate Professor at B-IT Bonn-Aachen Int. Center for Information Technology and Fraunhofer AIS.