Ubiquitous Computing and AI Towards an Inclusive Society

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ABSTRACT
Elder citizens are faced with a large number of problems on their everyday lives. Loss of motor, sensorial and cognitive skills results in a growing difficulty to live and interact in today's society. Ubiquitous computing can help alleviate these problems, by allowing elders to have a normal life despite their shortcomings. Medical monitoring, communication and memory aids are already being developed. However, the large amount of data produced by those devices is of little use if not subject to some kind of analysis. Some Artificial Intelligence areas such as Knowledge Representation, Learning and Automated Planning can be used with success to improve what can be learned from the data. This will open the door for a wide range of applications that will adapt to the needs of each user and greatly improve the quality of life of elders.

Categories and Subject Descriptors
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1. INTRODUCTION
It is well know that elder citizens often face serious problems in their everyday life. The gradual loss of motor, sensorial and cognitive skills results in an increasing difficulty to interact with the world around them, sometimes leading to social exclusion.

Furthermore, the rapid succession of technologic novelties contributes to the growing alienation of those not equipped to quickly deal with them.

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One of the latest trends of technologic growth is ubiquitous computing. While this could at first be perceived as another barrier, the possibilities it allows are enormous. In the short term (3-5 years), it is expected that each person will carry with him several computing appliances, communicating between themselves and those of others, resorting to technologies such as the emerging Bluetooth [14]. Today, mobile phones and Personal Digital Assistants (PDAs) are just the beginning. Smart clothes, health monitoring devices and positioning systems will someday be commonplace. Eventually, some of those devices will be implanted in the body and will be carried around at all times.

Not only will this allow for better monitoring and care for the elders, but also, if used correctly, it will give them means of overcoming some of their shortcomings. However, as more and more devices are used, one will soon have to deal with a great number of variables and a large amount of data.

In this paper we'll discuss how some of the applications of ubiquitous computing can be used to solve the problems of elder citizens, and how the help of some Artificial Intelligence techniques can help towards that end.

2. PROBLEMS AND BARRIERS
There are three main classes of problems elder citizens have to face. Sensory problems are due to the loss of sight and hearing. Cognitive problems arise with short-term memory loss and loss of attention. Motor problems translate in the increasing loss of motion capabilities.

These problems, physic in nature, can easily give rise to social problems of abandon and exclusion. Modern society makes it hard for elders taking care of themselves and for others to take care of them. A gap between those who are "technologically-literate" and those who aren't is quickly widening with concerning consequences.

At first sight, it would seem that, in some way, older people are unable or unwilling to learn new technologies. However, some studies [8] reveal that, in fact, the appetence of elders for new technological solutions is as large (if not larger) than that of the rest of society. The barrier resides in the fact that most new applications are developed without the least of concerns towards making them accessible to otherwise excluded potential users.

The interfaces of most applications, be it a word processor, web browser, ticket vending machine or ATM, take for granted a number of things that are true for the majority of the population but not for all. First of all, the mental model a person with cognitive problems can build is clearly different from what is expected by most interface designers. Metaphors are not perceived equally by elders and other people, with different (and shorter) life experiences. Also, short-term memory problems and a short attention span are not taken in account when designing the interaction with most interfaces. Motor problems are also not taken in account. The sizes, spacing and locations, of keys and buttons are not suitable for elders and other excluded users. Pen based interfaces common on most PDAs, require a precision and dexterity that most don't possess. The simple act of holding a mobile phone and dialing a number, or answering a call in time is not that simple for them. Finally, most interfaces waste screen real estate while presenting a density of information ill-suited for most users, let alone elders and others with sensorial problems.

3. TOWARDS A SOLUTION

In order for these problems, among many others, to be solved, special care must be taken by the industry to design products that take into account special needs of special users. For instance, multi-modal interfaces, combining text, speech and voice recognition can help minimize sensorial and motor problems [9] [8]. The use of force-feedback devices could also be a great advantage in this field [7]. Also, the withdrawal from the desktop "click-and-drag" metaphor towards a more expressive and natural interface will undoubtedly make interfaces easier to use. Each user has different needs, so it is hoped that applications will be able to *adapt* to them, unlike the current novice/expert separation where interfaces try to adapt to *classes* of users. Designing *with* the elders rather than *for* the elders is something that has to become a reality.

The advent of ubiquitous computing can help solve some of the problems discussed above. We'll first discuss what can be accomplished in the next 3-5 years, and then what might be possible with the development of technologies that are still walking their first steps.

3.1 Short Term

In the next 3 to 5 years, ubiquitous computing will become a reality. Several benefits for elders are evident. One of the fields where the benefits will be clearer is medical support. Heart rate, blood pressure and other sensors can give an accurate, real-time idea of the state of health of the wearer. Some technology already exists in this field. Devices that allow an ECG to be made from one's home just by dialing the hospitals have been working with success for some years [13]. Diabetics can have a sensor that monitors the bloodstream and decides when is time for another insulin shot (administered automatically). But, when ubiquitous computing becomes a reality these measurements can be made at all times. The sensors can communicate with some kind of mobile communication device (a Bluetooth enabled mobile phone, perhaps) and an emergency call could be automatically dispatched to the nearer hospital if something goes wrong. A portable positioning system (GPS or some evolution of GSM-based triangulation) can help the ambulance by providing accurate information on the position of the patient. While the ambulance is on the way, the medics will be downloading the medical history of the patient, and when they reach him, the sensors can upload the most recent information on his status.

This was just an example of what is to come. Even on less dramatic situations, ubiquitous computing can be of tremendous help. No more fumbling for the house keys (who might have been forgotten inside!) when the door recognizes its owner and opens to let him pass. No need to hunt for change inside a wallet when the registering machine at the supermarket completes the transaction automatically with the e-wallet. Even in the social field, these devices can help minimize exclusion. Communicating with other persons, friends, family or strangers becomes as easy as pushing a button or voicing a command. The anxiety of leaving one's elders at home while somewhere else is reduced because we can monitor their location and contact them at all times [10]. "Smart" appliances can help the elders to get things done, and at the same time protect them from most accidents.

Monitoring of the user will be done ubiquitously, and not only when he uses a computer. Also, the remembrance process is associative in nature. So, having collected a lot of information the user can relate to will be crucial to the design of effective memory aids and alleviate cognitive problems. The system can also use this information to recognize and adapt to the particular needs of its user. In order for this adaptation to be possible, a new architecture for applications must be developed and adhered to. The functional core of the application must be separated from the interface (with an intermediate layer to establish the connection between them). Only with such an architecture can the interface adapt, either inside a given mode of interaction or by using (or stop using) different modes, according to the user's needs and the environment where the system is being used. Different interfaces are, thus, easier to build and will not compromise the functionality of the application.

Studies are taking place for some time now, even in academic, undergraduate domains [5], showing a clear interest in producing solutions in the short term, While some privacy problems might arise, the net result will be undoubtedly good.

3.2 Medium-Long Term

While there are many advantages on using ubiquitous computing, on the short term this will translate into the cumbersome carrying of multiple devices. Some elders already have to carry other things, like canes or wheelchairs, and some devices could be installed into them [5].

However, while there are already attempts to integrate several devices into one (PDAs and mobile phones, for instance), a complete integration will never be possible. This is the case of medical sensors, whose location is critical. Just like there are already implants to automatically administer the correct amount of insulin to a diabetic, so soon other devices (medical or otherwise) can be implanted in the body. Some experiments are already taking place in this field [11].

This would allow a significant reduction of the load one must carry, plus the need to remember all the devices that must be picked up every time we move somewhere (a major disadvantage when dealing with memory problems). Some studies show that elder persons will be more receptive to this than younger ones, since, most likely, they already have had some kind of surgery and some other parts implanted in them, as is the case of bone prosthetics or pacemakers.

Implants open an entirely new range of possibilities. An implant that somehow intercepts the images going from the eye to the brain in the optic nerve, with some image processing capability could help elders identify other people they meet, and, with the help of augmented reality, display this information. It will also be possible to show directions, or, with a connection to an information repository, superimpose information on what is being seen. More sophisticated medical data can be collected directly from some organs. Ultimately, using a computer or other appliance could be as easy as thinking on what to do, and the information, collected by an implant on the brain, will relay the commands to the nearby appliance.

All this will greatly improve the quality of live of elders, since it will solve or minimize motor problems (no need to actually move to use devices), memory problems (with constant reminders and other useful information) and sensorial problems (with augmented reality to produce whatever information is missing).

4. THE CONTRIBUTION OF AI

As we have seen in the preceding sections, the possibilities before us are enormous. A lot of information can be produced and accessed by new devices. While technologically challenging, the development of these devices is within current industry and research standards. The main challenge here seems to be not finding out *how* to build things, but *what* to build and how to use them.

One of the major problems that will arise is excess of information. With several sensors continuously monitoring several aspects of our activities, a lot of information will be generated. How to use it in a proper way? How can applications use it to adapt to their users? Take, for instance, the medical monitoring example given above. Since each person is a unique individual with special behaviors and needs, how will the system decide if an alarm should be given or not, in border situations, that can be normal for one patient but indicate danger to another?

Some areas of AI can give tremendous help in dealing with the information made available by the new devices, and also allow for the construction of new applications using them.

4.1 Knowledge Representation / Learning

Two of the areas whose use is of great importance are, of course, Knowledge Representation and Automated Learning.

The raw data collected by the sensors isn't, by itself, of much use. It can be searched for known patterns, but it's hard to use it in novel ways, and adapt its use to the needs of each user.

A structured way of storing the information will greatly improve the use that can be made of it. By using automated learning techniques, rules and patterns can be inferred from the raw data. Inductive Learning, such as Decision Trees can be used to infer rules and classify sets of data into several categories. Bayesian Networks, Neural Networks and Data Mining techniques can also be used to a similar end.

The rules and patterns inferred will be unique to each user, and the system will become increasingly adapted to it's users traits and needs. The utilization of ontologies on several domains is also a powerful way to reuse information. And, by storing the information in a structured way, perhaps in some modal or temporal logic formalism, inference becomes possible, providing a generic means for deriving new information not anticipated beforehand by the developers of the system. In fact, information is now stored *explicitly* in the system, rather than *implicitly*, making it easier to understand, extend and correct the way it works.

Imagine the following: an elder citizen is preparing a meal in the kitchen when the postman rings the doorbell. When dealing with loss of short-term memory, it is possible and, in fact, somewhat likely that, after answering the door, what was being done before has been forgotten. It has been suggested elsewhere that then the system could remind the user of what he was doing, in order to resume that activity [10]. But, using learning and knowledge representation, it could suggest what should be done *next*.

If the house and appliances have been keeping track of the activities of their owner for some time, some rules of what he was doing and what should be done next have, surely, been found by then. If the recipe being prepared is well known, an ontology on recipes will have the information on how to proceed. And, even if the recipe being prepared is something not originally in the ontology, if it has been prepared often it would have been learned and the ontology updated to contain it.

These techniques can be used in more generic situations. Imagine, for instance, that every morning, after having breakfast, the user watches the morning news and afterwards checks his email. If the postman rings in the middle of the newscast, the system would, following his departure, instruct the user to finish watching the news or, if the newscast has ended, tell him to check the e-mail (and, of course, turn off the TV and open the e-mail application).

4.2 Planning

Learning gives us a way to induce new rules and patterns from the observed data, and Knowledge Representation allows us to store those rules and infer new knowledge from them, as well as using knowledge already found to be useful in general.

While helpful, this isn't, in itself, enough to explore all the advantages of what ubiquitous computing can provide. It should be possible not only to help elders do what they have already done before, but also help them perform new tasks without fear of mistake, or taxing their skills with complex decisions or concerns. To this end, Automatic Planning can be of great assistance.

The most obvious use for a planning system is to produce a plan on request, in order to achieve some goal. For instance, someone could ask the planner what to do in order to get somewhere, or instructions on the best way to shop a number of items. This, in itself, is useful, but it can also be done nowadays. However, with the advent of ubiquitous computing, we can go a step further.

The planner will have access not only to a pre-defined set of operators or actions, but also all the information produced by the learning processes described. Also, it will have to deal not just with a model of the world, as is traditionally the case, but, since the user will be carrying a number of devices that monitor the world itself, the planner can rely on more accurate information. Resorting to this information, the quality of the plans is sure to increase. Instead of a disembodied planner (the most common kind nowadays), we'll be dealing with a situated planning agent [3][4], capable of interacting with the world. Other systems, like OK-BDI strive to integrate inference reasoning and acting [2][12].

So, instead of just planning on demand, the system can now monitor the actions of the user and produce plans on what will be the most likely course of action and provide the information as it becomes necessary. Of course, it is not assured that the users will always do what the planner expected, or that the world reacts exactly as predicted. Conditional planning is traditionally used to solve these problems [3][1] [12], by preparing alternate courses of action according to the actual outcome of an action, between several possibilities. But, since the system is continually monitoring the user's actions, it can deal dynamically and incrementally with inconsistencies on what was planned and what indeed happen, without the need to prepare beforehand. Techniques like action monitoring or execution monitoring [3] can be used to quickly re-plan the parts of the original plan that became unusable.

Imagine, for instance, that the user wants to place a card in the mail, and, to start a new hobby, buy a book and some replacement lamps, which can be done either at a drugstore or the supermarket. He can ask the system for help, and it will produce a plan with the instructions to follow to accomplish all tasks with minimum effort. So, the user will leave its house, go to the bookstore, buy the book and then to the drugstore (since it's closer), where he bought the lamps. But if for some reason the user doesn't follow the instructions the planner gave him (decides to take a look at something at a nearby street), the original plan becomes invalid. The system, however, recognizing the user has detoured (a sensor the user carries constantly gives out his position), can promptly find a way to get from the current location to the drugstore. Or, maybe, the route now points to the supermarket, which just got closer. Furthermore, if the bookshop didn't sell the book the user sought, this would also be recognized (the user would leave it without having completed a transaction, for example), and an alternative shop could be suggested.

Another possibility is *contingence planning*. Imagine that the user indeed goes to the supermarket. The new position is reported to other appliances. Then, the refrigerator, that knows that the milk is running out, can communicate this to the planner. A new step is introduced in the plan instructing the user that, since he's already at the supermarket, he can take advantage of the situation and buy milk, saving himself another trip later.

And, of course, all successful plans can be stored on the knowledge base to be reused in the future, if needed be.

5. CONCLUSIONS

As we have shown, the dawn of ubiquitous computing can have tremendous impact in the lives of not only current users of computers, but also, if employed correctly, be a factor for the integration of elders and other often excluded persons.

New devices can help elders to cope with their problems, by allowing new forms of interaction with other devices and persons. Memory loss and other cognitive problems can be minimized, as well as motor and sensorial loss.

As with any new technology, some effort will be required before it can fulfill its entire potential. Artificial Intelligence fields like Knowledge Representation, Learning and Planning were shown to be of great use towards that goal, making the creation of a gestalt of the devices one will carry easier.

If correctly designed, taking in account the real needs of the prospective users, the capabilities that will be provided and simplicity of use will soon lead to cases of successful use of the new technologies. This will help to reduce feeling of complexity and uselessness that often is associated to state-of-the-art technology, and make elders more likely to try them and take advantage of all the new possibilities ahead of us.

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