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Advancing Ambient Intelligence with Caution

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Abstract As technology advances, systems involving artificial components provide more and more support for people. The potential consequences of this phenomena are examined in the specific circumstances of 'ambient assisted living' as an instantiation of the concept of 'intelligent environment'. This chapter describes the idea of 'ambient assisted living' and looks at some of the possible ways humans may be affected by the prevalence of technology. The general example of assisted healthcare, and the specific example of medication support are used to show that systems are advancing. Moreover, these advancements can lead to problems with both the artificial systems, and the larger systems with which they are involved. In many cases there is a trade-off around having people in the loop, but inevitably they will need to be included for many decision making processes. The chapter concludes with reflections on how these considerations can help us to retain the positive aspects whilst avoiding the negative side effects of the hypothetical technological singularity.

Keywords Ambient Intelligence · Ambient Assisted Living · Human in the Loop

1 Introduction

Artificial systems will become more sophisticated and will assist humans in more ways. While technology becomes more prevalent, it is important to guard against damages that this technology can cause [Tenner, 1997], but instead of

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blindly using more and more technology, it is important to consider problems that may arise from new technology

Artificial Intelligence is one set of technologies that is being used to support people. It is ill-defined, but generally refers to computer based systems that have a certain degree of intelligence. The systems can be used to help people in a wide range of tasks including robotics, Internet search, and language translation. The state of the art in Artificial Intelligence is that domain specific systems can be built, but the systems are brittle and do not extend beyond the specific domain for which they were designed [Smolensky, 1987, Shi, 2011]. That does not mean the systems cannot learn, indeed learning is perhaps the major recent advancement in the area. Instead the systems fail altogether when they go beyond their intended purpose.

Ambient Intelligence foresees information systems in a way in which the user is the central entity [Cook et al., 2009]. In consequence, the technology is oriented towards (1) natural implicit interaction between the system and humans, (2) ubiquitous and smaller hardware disguised within the environment and (3) intelligent and autonomous behavior. This general concept becomes more specific when directed through application domains. One of the application domains of Ambient Intelligence is AAL (Ambient Assisted Living)[1]. AAL pursues the development of Information and Communication Technology (ICT) systems supporting independent daily living for people that may have a limited capacity to take care of themselves autonomously. Those AAL systems (AALSs), with an assistive orientation, are designed to ease daily tasks such as cooking, cleaning the house, having medication and social relationships. Moreover, such assistive focus is not only directed by the attended subject but also to family, caregivers and any other stakeholders within the global information system in which the AALS is subsumed (e.g. a care organization's health information system (HIS)). An example of assistive tasks for the family is making them aware of up to date information about the subject's health condition through continuously monitoring the subject at home. Similarly, with respect to caregivers, they benefit from an AALS thanks to ubiquitous access to the subject's state at any time and anywhere. This considerably improves efficiency in their daily working routines. Thus AALS works for different user roles and all these roles get some benefit in this relation.

The development of more and more intelligent and autonomous AALSs will, arguably, raise problems of a different nature. If they can be foreseen, solutions to these problems may be found.

This paper will focus on one particular AALS task: taking medicine. The scenario will be discussed in section 2, and systems that currently support medicine taking will be addressed in section 3. The paper then engages in analysing, in a speculative manner, the different paths that advances in this technology might follow in the near future, exploring how the technology might advance, section 4, and the more distant future, section 5; these sections ex-

[1] http://www.aal-europe.eu/

plore the technology, possible problems, and possible solutions to these problems. A brief section 6 concludes.

2 Scenario

AAL is a vast field ranging from automatic setting of household temperature levels to cutting edge smart-rooms [Dooley et al., 2011] that support education (see section 3.1). A particularly active area within AAL is assisted healthcare (see section 3.2.) The scenario explored below, from the area of assisted healthcare, is for technology to support people in taking medication. Taking medication is often important for people and in many cases crucial for them to live a normal life.

There are also a range of factors involved in taking medication. These include, but are by no means limited to, frequency of dose, regularity of that dose, dosage, combination with other medications, and if the medication is taken with or without food. Furthermore, a patient's adherence to the prescribed therapy is important as a high percentage of the population does not stick to the prescribed therapy. An important part of the group simply do not care about taking the medication, others may not even fill the prescription.

People have, of course, been taking medication from time immemorial. While they typically take the medication correctly, every person can make mistakes. People with learning disabilities, or short-term memory impairments can have particular difficulties. Technology already supports medication taking; for example, an alarm on a person's phone or watch can remind them to take their pill. Furthermore, other social factors, including cost of medication, can lead to a failure to take medication. There is scope to improve this further with systems actually monitoring whether tablets are taken, and potentially determining whether medication is needed at all.

3 State of the Art in Ambient Assisted Living

Currently, the AAL field is experiencing important advances, both in academia and industry, towards commercially available and dependable AALS products. There are particular applications in the health domain, and specific applications to support medicine taking. These systems are not perfect, but there are potentially solutions for some of their current problems.

3.1 Ambient Assisted Living

Nowadays, the main AAL target group of users is elderly people [Augusto et al., 2012]. This is a natural consequence of the number of elderly people that keeps growing year by year worldwide. To cope with this scenario, governments focus an important part of their research programs on this broad community of users.

A clear example of this is the AAL JP[2], an initiative of the European Commission devoted to funding research projects on using ICT to develop elder oriented AALS[3]. For the same reason, companies see an interesting business possibility when focused on the elderly. However, AAL is oriented also to user groups with other kinds of impairments (e.g. mobility, visual, mental, and social).

An AAL ICT system is composed of a set of hardware and software elements. Hardware does not refer exclusively to personal computers, laptops, smartphones or tablets. It also includes any kind of sensor and actuator. Examples of sensors include room temperature, humidity, flood, and gas sensors; and wearable sensors such as body temperature, blood pressure or any sensor that might be relevant to perceiving part of the user context. Actuators are any device or appliance intended to modify the user's state. Examples of actuators range from simple automatic light switches to all the engines required to put an automated bed in the required position. Companion robots, as an assistive technology, are also used in AAL. Finally, with the advent of the IoT (Internet of Things), any physical object at home connected to the Internet (e.g. a light bulb, or a refrigerator) can be considered part of the AAL ICT system's hardware.

With respect to software elements, all AAL systems have basic components for communication and coordination of all the software modules (i.e. sensor and actuator handlers, services, and applications) taking part within the system. This is called middleware. On top of the middleware, basic services are built, for example, a chat service to connect the elderly user, caregivers and family; an alarm service to start emergency processes when required; or monitoring services to continuously gather and track the evolution of variables of interest. Depending on the capabilities of the AALS, it is possible to find pattern recognition services in charge of modeling the user and detecting any anomalous behaviour from the generated patterns (e.g. the user has suffered a fall or has fainted, and, as a consequence, their behavior is not as expected). Also, the AALS may exhibit autonomous behavior, i.e. it might be designed to take the initiative in, hopefully, some perfectly controlled situations. The higher the system level of autonomy, the lower the workload for the caregivers. A sufficiently high level of AAL autonomy can replace the need for the elderly user to have complex interactions with the AALS, something specially important for users that are unfamiliar with technology or who are suffering cognitive deficits. The ICT technology involved in AAL systems must be designed to monitor and assist the human subject 24x7. Thus, an important part of the overall development effort must be oriented to creating friendly systems that are easy to interact with.

[2] www.aal-europe.eu

[3] Thus, it can be said that the term AAL has a European context; it is hardly found in research programs outside Europe, but this is only an issue of terminology.

3.2 Assisted Healthcare

While more is being done to improve in-patient care in the medical sectors by taking advantage of technology, attention should also be paid to out-patients. In-patient care should make the future hospital 'permissive', i.e., the technology should support the widest possible range of clinical practice, patient access to records, and general well-being. Out-patient care involves people who are living at home with medical conditions, in particular the elderly who are in frequent need of taking medications to maintain health. As stated in a recent article [Whelan, 2010], new technology like smart pills, a wireless heart monitor and a robotic surgical assistant could radically reshape patient care.

At the beginning of the century the term ubiquitous healthcare was coined. There is increasing support for the idea that healthcare is accessible, not only from the hospital, but at home, in the office, and even in one's automobile. Tiny sensors gather data on almost any physiological characteristic that can be used to diagnose health problems. While much of the literature focuses on ethical challenges ranging from small-scale individual issues of trust and efficacy (privacy, security, accuracy, etc.) [Brown and Adoms, 2010], to the societal issues of health and longevity gaps related to economic status, technological issues still remain in order to make the living environment more intelligent, more user friendly, and more reliable.

In the UK, there are over 1.4 million people aged 85 or over and 10.8 million aged 65 or over among a total population of 60 million [ONS, 2013]. Elsewhere, for example, in Japan, 22% of the population is aged 65 or over [Yamamoto et al., 2010], which presents a clear picture of an aging society. Not only does an aging population require more medical care, out-patients who return from hospitals also need medication. While living at home helps maintain a sense of independence, comfort and a near normal life for most of the people, it also poses challenges for them to take sufficient care of themselves in order to maintain that freedom.

For example, one system, HealthPAL using tiny sensors to gather data, remains one of the simplest devices to operate. It automatically collects data from compatible, off-the-shelf, medical monitors using a smart cable, or wirelessly via Bluetooth, which is currently available in the market.

HealthPAL is currently approved for use in conjunction with glucose meters, blood pressure monitors, weight scales, pulse oximeters and pedometers. As a dedicated device for transmitting health data, HealthPAL eliminates the need for a smart phone or computer to transmit and upload health readings. This promotes higher adoptability and compliance for the patient, and removes the opportunity for the misuse or abuse of data plans and equipment that is commonly associated with cell phone and computer health monitoring. However, because of its singular core function of transmitting biometric data, other ambient systems have to be in place to complement and support the intended user's medication taking monitoring task.

3.3 Medication Support

There are a range of systems to support people taking medication. Medication is typically prescribed for a patient by a physician; this prescription is part of a system that is largely human, though the system is often supported by simple electronic databases. The physician, in concert with their records and the patient, makes sure that the patient is not prescribed separate medications that are incompatible.

The basic prescription system has evolved over several centuries. Undoubtedly errors have been found and the system has evolved to cope with most of these.

If, for instance, the medication is prescribed to be taken twice daily for a week, the patient may merely remember to have it at breakfast and dinner from Saturday to the next Friday. They may also make a paper list, or they may set an alarm on their mobile phone to remind them twice a day.

In hospitals and care homes, staff may administer medication, typically keeping a record. Out-patients should adhere to an appropriate medicine taking regime. Specifically, the people in consideration should remember to take necessary medicines at the right time and the right doses. Some people might have different prescriptions from very different clinicians (e.g., dentists and cardiologists); a drug taking support system should be able to discern conflicting medicines and be in the position to inform users the time intervals for taking them or not to take some of them at all. With the proliferation of advanced technologies, the task of taking prescribed medicine can be made easier and safer.

With the advent of an array of ICT technology, many medicine management systems are in place to assist this task and to monitor the progress. In most cases, those systems use a radio-frequency identification (RFID) tag that is usually attached to the medicine product to identify and track the objects based on radio waves [Jeong et al., 2005]. Such tags can be detected and read within the range of several meters. For example, in Addenbrooke's hospital in Cambridge in the UK, by the application of an RFID system to track tagged items via fixed portals and handheld readers, the labour cost has been reduced by half, and drug misuse has been effectively prevented [Swedberg, 2013]. The only remaining pitfall is that tags are only attached to medicine cases, which does not guarantee that the medicine is taken. For example, a tagged item has been opened. Then the user might proceed to prepare water and then be interrupted by a phone call, resulting in them forgetting to take the medicine. In this case, a video camera based monitoring system might detect the problem.

On the other hand, with regard to assisting drug taking, a drug management system has been proposed to allow users to follow drug schedules as illustrated in Figure 1. The system features a touch screen interface, bar code scanning facility, and voice and vibration feedback mechanisms to prompt users to take medicine. In addition to communication mechanisms with clinicians about medical treatment and with HIS to refresh needed information, there are mechanisms to provide a memory aid and medicine safety to en-

Fig. 1 A drug management system proposed at a MedGudget show [MedGudget, 2013].

sure the effectiveness of self-care at home. Although still in its prototype, the system has shown potential in circumventing a number of issues that are encountered while staying at home alone, especially for elderly or ill people. For example, losing memory, less mobility, and reduced hearing ability all contribute to problems in the solitary home. In parallel, however, people living alone have the advantages of knowing their homes better, familiarity with their living space, and above all being optimistic knowing they are independent and that they can do whatever they like at their own home.

The above system has its pitfalls. For example, communication with hospital HIS systems poses more challenges than the development of such system itself mainly due to technical compatibilities with any HIS systems. In a typical hospital, the HIS systems in each department are usually installed from different vendors and therefore have their own compatibility issues. A more realistic, simpler system is proposed based on RFID and wireless sensors technique [Yamamoto et al., 2010]. It employs a fuzzy logic approach to define rules for decision making, sending warning messages at a predicted time of taking medicine. Those predictions are deduced from users' everyday living habits, in particular, the time range when they take their daily meals.

Again, this system cannot assure the intended medicine is taken because a disruption may occur between medicine being taken from an RFID tagged case to the user's month. As a result, for example, a relatively simple solution would be a video camera based monitoring system to ensure that the right medicine is indeed taken at the right time with the right dose, which will subsequently lead to the safe taking of prescribed drugs; in some cases, the sequence of drugs plays a crucial role in maintaining a user's health. This system is shown in Figure 2.

In addition, the system should be able to figure out any conflicts between the medicine a user is going to take, and calculate the safest interval to take

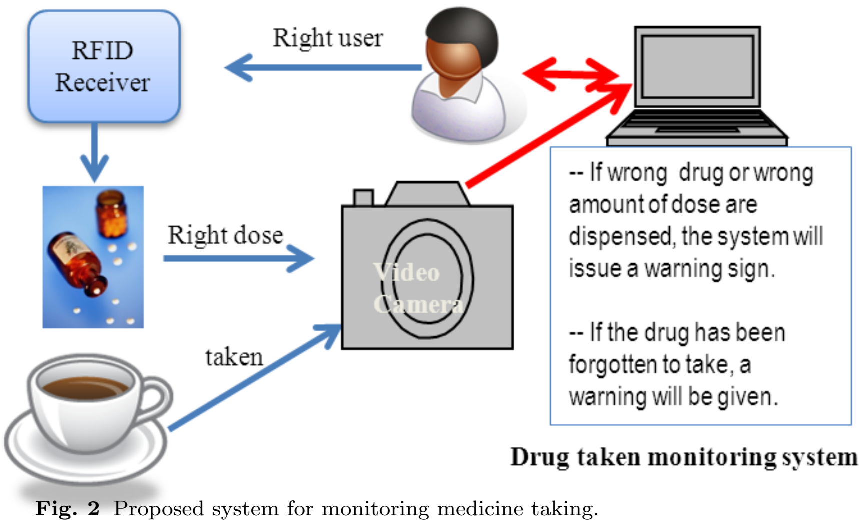

Fig. 2 Proposed system for monitoring medicine taking.

them, or to issue a recommendation to see consultants in regard to taking those conflicting medicines.

4 On the Horizon

Whilst it is difficult to predict with certainty how popular AAL systems will be in the future and in particular how much of a role they will have in helping with medication intake, the recent uptake of technology at various levels and the interest and investment in the areas here discussed seem to suggest it makes sense to indulge ourselves in a 'what if' exercise. Previous sections have described how automated systems can be deployed at home to provide assistance at various levels and how some of that gadgetry is related to medicine reminders. These medicine reminders have so far been mostly applied to well-structured intake regimes and with medicines which pose less risk to the patient.

If Ambient Intelligence systems driving an AAL application become so powerful that they can work at levels comparable with humans, will they be trusted for the monitoring of more powerful medicines? Will they be able to supervise a patient and advise on medicine intakes which are not rigidly regimented, that is, situations where the decision-making behind taking or not taking medicine is not a certain day and hour but is based on symptoms?

4.1 Potential Problems

An Ambient Intelligence system that is capable to working at the level of humans may be trusted with the task of monitoring the intake of drugs, e.g. pain killers for a person suffering chronic pain. Assessing a patient is often a difficult task even for a fully trained GP, because humans present a rich combination of physical and emotional manifestations. There is also an increased access to information and more people self-medicate. Self-medication by non-medically trained people can sometimes have severe consequences. A GP, based on the account of the patient and other observations and tests, has to navigate their way through a maze of partially overlapping cases discarding some and sometimes considering a number of possible options of equally feasible causes for a condition. Hence a first obstacle for an automated system will be to have access to the same, or at least equally effective, means to gather the data that supports a differential diagnosis. The consequences of getting a diagnosis wrong is that inappropriate medicine or medicine that is taken more often than necessary can have serious untoward consequences. There may also be harmful scenarios that are induced by the patient, for example a hypochondriac may learn how to cheat the system to take more medicine, as they sometimes manage to fool the health system run by humans.

One additional complication here is that humans tend to trust systems that work reasonably well for a while and tend to enjoy the 'peace of mind' reliable automated systems provide [Augusto et al., 2011]. For example, when we turn on our car in the morning we assume it will work, probably because it has been working for the last three years without a problem; experience has led to positive inertial thinking.

4.2 Potential Solutions

Fortunately for us humans, we have the skills of hypothesising possible futures and to weigh their pros and cons, a skill which probably developed out of necessity for survival in a hostile planet. Because we can forecast these potential problems, we can also think of ways of avoiding undesirable situations as well as ways of coping with undesirable situations, which have happened anyway. Probably one of the most reassuring elements of our social life is that there are other humans around us who care about what may happen to us and we are always contacted by someone if we have not been in touch for a while. Getting humans in the loop, involving people as part of the process, can be a way to rule out or to ameliorate harmful situations. For example, it can be embedded in the safety of the system that medicine intake systems will need to consult with a number of qualified individuals as external consultants ratifying the decision.

We also suggest a way of progressively getting the human out of the loop. We envisage an ecosystem in which the AAL system starts working with the rest of the elements (i.e. patient, caregivers, family and doctors) silently, just observing, building internal models of behavior and continuously assessing their correctness by comparing their responses with those of the ecosystem's actors. Once the AAL system's internal behavior models deserve enough confidence, it starts suggesting to the actors how to proceed given an event of interest until one day, there is enough evidence for each actor that actions can be delegated to the AAL system.

4.3 Tradeoffs

In a way, the need to consult with external humans (i.e. maintaining the human in the loop) defeats the purpose of such systems. The advantages remaining will be that the patient is still allowed to take the medicine at home without the need to go to the hospital and the system of AAL will be 'watered down' to one of telemedicine. However, the benefits of having assistive technology at home should not be ignored because costs are reduced and service quality improved by the patient from the hospital to home.

On the other hand, maintaining facilities with centralised assistive technology has obvious advantages: affordable maintenance costs, easy management of services and controlled decisions when dealing with the patient. Another important issue to consider here that goes against keeping the patient at home is that in such cases the other actors (i.e. humans) may withdraw contact and visits to the vulnerable person under care. This withdrawal can lead to debilitation, and undetected problems developing.

4.4 Legal aspects to consider

Besides the pros and cons of adopting AAL technology in the future, we have to consider also how a possible adoption influences the legal dimension. At the moment, any mention of legal aspects have been intentionally omitted as AAL systems were analysed from a perspective grounded on the present time. At the present moment, discussion about the impact of intelligent systems in medicine and healthcare is emerging

However, in the near future, artificial intelligence based systems in general, and those of the ambient intelligence kind in particular, should be subject to legal treatment as a natural consequence of their ever increasing autonomy.

A clear example of a real intelligent system whose autonomy makes itself capable of violating the law is the Google self-driven car, as an example although other manufacturers are also creating their own models. This car is legal on streets in three US states now. It seems obvious that these autonomous vehicles will be seen on our streets in the coming years. But for this to occur, a good balance must be found about who has legal responsibility at the face of an accident: the car (i.e. the manufacturer) or the driver.

The same will occur with autonomous AAL systems with enough responsibility on their decisions to affect people's lives. A suitable trade-off is needed. If most of the legal responsibility is put on the AALS, then companies will be less interested in bringing such potentially problematic products to market. On the other hand, if caregivers, relatives or even the subject under monitoring are responsible for all actions taken by the AALS, they probably will prefer a not so autonomous AAL technology. The right point of equilibrium should be found in the near future. And such a point of equilibrium should be found as a result of a common agreement from experts on many different areas: law, ethics, medicine, philosophy and computer science [Collste et al., 2006].

5 One Possible Future

There are an infinite number of possible future scenarios, and this section will discuss two scenarios. The first is systems that recommend when to take medication that is taken at irregular intervals, such as pain medication. The second are conversational systems that interact with the user via natural language conversation.

There are a range of medications that are taken irregularly, including at least some times pain medication, weight loss medication, and insulin. Future systems will now be able know to when this irregular medication is needed. This might make use of sophisticated monitoring systems that measure specific physiological properties of the patient, his cognitive state, his diet, and his exercise levels.

In these cases, medicine intake depends on subjective judgment. If the person is in pain, the system may suggest to take medicine, but at a higher dosage than needed. This may lead to unneeded negative side effects.

The future monitoring systems will also be able to make recommendations about information to read about the medicine, and provide links to medical professionals when necessary. The system will of course ensure that ad hoc occasional medicine use does not compromise the existing routine medication, and more importantly, does not cause additional unnecessary unwanted medical conditions.

People have the right to make informed decisions about their own medical treatment. It is crucial that in a wide range of circumstances the person is involved in their own care. They need to be informed about options and risks. The system can point the user to information, and even explain some things. To some extent this can support a physician in this task.

Like other Artificial Intelligence systems, conversational systems are domain specific. These 'chatbots' interact with a person via text or even speech. One simple example are automated phone operators that give the user options to choose from. More sophisticated systems (e.g. TRAINS [Allen et al., 1995] or tutorial agents [VanLehn et al., 2007]) perform complex domain specific tasks, like scheduling trains, in collaboration with users.

A dialogue system will be able interact with the future user to decide when and which medication to take. It could even be part of a larger AAL conversational system that interacted with the user.

These systems will probably be connected to the Internet, and will be able to learn things from the Internet. They will use sophisticated mechanisms to learn about the user. Current technology such as rule-based systems, Bayesian systems, and neural networks will probably improve. None the less, like now, these systems will be imperfect. Some types of systems are better at some tasks, and other types at others. For example, Bayesian systems are good for learning from a large amount of data, while rule-based systems are good for encoding an expert's knowledge. In recent years, researchers aware of this complementarity have started to use a mix of them, sometimes simultaneously. A solution based in one tool alone will be easier to fix but limited in effectiveness, and one with different parallel tools working at once may be able to cover more situations effectively but more difficult to engineer and fix if something does not go well.

It is unlikely that the medical support system will be able to do a better job than a physician at managing medication and informing the user, but unlike a physician they will be machines. They will be available without fatigue, unlike a physician or even a nurse. Even if they are more effective than a physician, the person will still need to make some decisions.

When people are unable to make their own decisions, for example infants or people with advanced dementia, a human will continue to have the final authority. The system may try to convince the person, via conversation, but as now, the person with power of attorney will have the final word.

6 Conclusion

AAL is still in its infancy, but is becoming progressively more sophisticated. It will continue to become more complex and will help people in an ever-growing range of tasks. While these systems are useful, like any system, they can have problems. This chapter has used the example domain of systems that assist in medicine taking. It has shown that these systems are in use; that these existing systems have problems; and that these problems can potentially be solved.

Creating an Artificial Intelligence system with an aggregation of methods to make decisions will not be trivial. Possibly more effective solutions lie outside the technical sphere and involve humans.

It is important to find problems before they happen. These problem may have technical solutions, but they may also require a solution from a larger system that involves people. The example of who is legally responsible for an assistant is one issue that must be considered.

Moreover, people will always need to be involved in a range of roles. The example of people having control over their own decisions is one particularly pertinent one. However, people will need to be involved both to empower them, and to make the overall system more effective.

AAL systems will aid people more and more in the future. It is important that they are not treated as a panacea, but more as a useful technology that may have flaws. These flaws need to be carefully considered and corrected to give people the most effective assistance.

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