Identifying Ethical Issues during the Development of a Computer Vision Based AmI System: A Case Study

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Abstract. AmI applications are normally embedded in a user's environment and everyday objects. As much, as such applications might add value to our everyday life, there are also ethical concerns that need to be considered particularly in the early stages of AmI application's design and development. Considering ethical issues at such an early stage of development may help to avoid and perhaps even eliminate potential problems once an application is ready for its target audience. This paper examines a case study of the development of an AmI application. The application under development is computer vision based system for person tracking and occupancy and fall detection with a long term goal of building a system with an automated mobility assessment capability. This application is used as a basis to discuss potential ethical concerns within the technical development process.

Keywords: ethics, ambient intelligence, older users, systems development

1 Introduction

Healthcare for the elderly is of massive societal and economic importance. The World Health Organisation points to a "Demographic Revolution" with a 223% growth in the elderly population expected between 1970 and 2025. The developed world is expected to have an elderly population of some 2 billion individuals by 2050 [14]. The EU's population is projected to reach 520.7 million in 2035 from 495.4 million in 2008 [6]. This will have a huge global impact, requiring significant changes in economic, social, welfare, familiar and psychological structures and services [10]. Any methods, technologies or techniques that can help the elderly manage their lives have the potential to help individuals, families and society. To this end, the EU for instance is supporting ICTs for the elderly population via a number of plans and programmes such as the 'Ageing well in the in the Information Society', an Action Plan on ICTs and Ageing, adopted in June 2007 and aimed at improving older people's accessibility to ICTs [5]. The Commission also supports the Ambient Assisted Living (AAL)[1] programme whose objective

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is to enhance the quality of life of older people and strengthen the industrial base in Europe through the use of and research and development of ICTs targeted at the elderly. These initiatives show that technology has a substantial role to play in meeting the challenging demographic shift where the older population is growing and expected to increase from its present levels of 25.4% to 53.5% in 2060 compared to the younger population whose growth ratio is projected at 25.0% [6] Therefore, technologies that will be of benefit especially to the elderly will have to be people-focused, helping individuals to lead more independent, active lifestyles with a reduced dependence on social care [13]. To this end researchers at De Montfort University are developing an integrated monitoring system to capture data from elderly individuals in a variety of situations and environments. This data can then be used to learn about the behaviour of these individuals thereby informing the design and development of further assistive technologies which will be introduced in the next section.

2 The Case: Tracking at Home

One of the technological developments being undertaken at De Montfort University is vision based tracking of individuals in their home environment. Currently the work is at the feasibility study stage, so we are currently considering different methods for capturing the images such as RGB cameras, infra-red cameras, stereoscopic cameras and different approaches to processing this data. Work to date has focused on the use of RGB and stereoscopic cameras for tracking individuals in an environment, in this paper we only discuss the RGB approach. Tracking an individual in an environment is a highly challenging task. Most approaches use a similar methodology:

1. Create an adaptive background model of the environment. This may be done with variety of models including histograms, textures or statistical models.
2. Anything in the scene that does not fit with this background model must be dynamic object.
3. A classification system of some kind is used to decide whether this dynamic object is a person or not.

2.1 The RGB Camera Approach to Person Tracking

We create a relatively simple background model where each RGB pixel has an interval range representing normal background colour which is computed over a number of frames. More formally let an image I at frame t be I_t and the number frames used to calculate the background model be n. Let the calculated background model contain two matrices b_u and b_l which respectively hold the upper and lower bounds of the background model:

$$b_u = \bigvee_{n}^{j=1} I_j \tag{1}$$

$$b_l = \bigwedge_{n}^{j=1} I_j \tag{2}$$

Each new frame captured by the camera is compared to the background model on pixel-by-pixel basis. Any pixels in the new frame which fall outside the background model are preserved and all others set to black. Let I_n be a new image captured from the camera and I_e be the final image extracted by system then:

$$I_e = \begin{cases} 0 \quad if\ b_l < l_n < b_u \\ I_n\ otherwise \end{cases} \tag{3}$$

Figure 1 depicts an example of our RGB extraction technique. Figure 1 (a) depicts an example scene, 1(b) an example where a person has entered that scene and (c) the image extracted from the figure 1(b) using a background model constructed over 20 frames with the system running at 8 frames per second.

Fig. 1. (a) An example scene. (b) A person in the scene. (c) The extracted image.

The next step in the algorithm is to find the number of artefacts in the extracted image and then to classify these artefacts as a person or not a person. This is the focus of our current research. The current system, in its prototype state uses standard of the shelf RGB camera connected to standard PC running software which implements our approach and displays the results as a real-time video feed. Teaming up with the Ethical Issues of Emerging ICT Applications (ETICA) project also at De Montfort University, the developers of the system sought to identify potential ethical concerns in the development process. This was mainly to understand how such identification can help develop a technology that is best able to meet user's needs as well as avoid as much as possible potential future ethical problems when it is complete.

3 Ethical Perspective

Ethics can be understood to be about morality and values. Quinn [12] states that ethics is "a rational examination into people's moral beliefs and behaviour (p. 55). Extrapolating this to ICTs, ethics will be about the moral issues emanating

from the development as well as use of ICTs. This will include how the ethical issues may affect user's lives. The expectation therefore, is that morals and values will be reflected in technological development process and eventual technologies that are intended to add value and improve user's lives, particularly the elderly. This means that the technologies should be developed and used for the good of the intended user. It is important to point out that all technical development is based on value considerations. New technologies are meant to fulfil a useful purpose or function and therefore by definition are based on particular views of values and ethics. The purpose of explicit ethical consideration of technology is to broaden the understanding of technology and its consequences to ensure that the technology actually fulfil its (moral) purpose and does not imply foreseeable side effects. It can also question the very vision underlying the development of the technology. As such, any technological development needs to take into account any potential difficulties that may arise during the course of the development of a technology as well as be able to identify potential ethical issues that are likely to arise when a technology is fully developed. Identifying such issues at an earlier stage in the development process is advantageous because improvements can be made to the development process. Ethical considerations will matter even more when a technology is targeted at a population that is for all intents and purposes more vulnerable than a younger population in its physicality, healthcare needs, technology skills and know-how. Bearing this in mind, some of the concerns that need to be addressed in the computer vision system are

- the impact the technology will possibly have on the elderly,
- its relevance to the elderly and their carer's where involved,
- how the technology will work and how the users expect it to work including how it will work for them, their carer's and families,
- its benefits as well as the implications for the user's environment and their surroundings.

3.1 Application Benefits

With the above, the system offers potential benefits not only for the elderly, but for their healthcare practitioners, for those under care as well as their families. The system offers:

i. **Safety:** For the intended users, especially the elderly who may live on their own, the systems tracking capability offers carers and families the opportunity to have their client and/or relation monitored. Knowing that someone is able to attend to them because of the system's ability to track movement and potentially detect unusual changes such as a fall, may contribute to an elderly person's sense of safety and well being.
ii. **Security:** Having the knowledge that the system is able to transmit and identify human and non-human objectives gives a sense of security, particularly in alerting monitors of unwanted intruders. This can be a liberating application which can offer a sense of protection for the elderly because help

may easily be at hand. Blythe et al [3] have alluded to the potential reduction of old people's fear of crime in their assessment of wearable computing technologies.

iii. **Cost benefits:** The adoption of such a system may potentially cut healthcare costs associated with the elderly such as home visits, employment of carers and care home costs in the long term. However, this cannot be seen to be a substitute for care but should instead be seen to supplement existing care practices.

The outlined benefits help to meet some of the aims of e-inclusion for the elderly as envisioned in the "Ageing Well in the Information Society Action plan" and contributes to the bridging of the digital divide between the elderly and the rest of the population, a concern highlighted in the Riga Declaration [4]. A digital divide between the elderly and the rest of the population has been a source of concern and technology applications like the computer vision system contribute to bridging this divide. As Mordini et al observe [11], a digital divide biased towards the elderly may have implications for older senior citizens because they are in most need of assistive technologies. Therefore, bridging the elderly digital divide reflects positively on the morals and values that the EU aims to adhere to and as reflected in declarations such as the Riga Ministerial Declaration and in the Ageing Well in the Information Society Action Plan.

3.2 Ethical Concerns

Although the system has a number of advantages there are also potential ethical concerns which need highlighting and thinking through in terms of how they may be dealt with if necessary. The ethos of the system is centred on person tracking and occupancy and fall detection with a long term goal of developing a system with an automated mobility assessment capability. Although the tracking capability of the system is advantageous for many reasons including those outlined above, it also raises ethical issues and questions. As such, the potential benefits must be weighed against the costs and opportunities weighed against the challenges of the technology to the intended user and/or its intended use. The importance of considering ethical issues, particularly for the elderly is also underpinned in the EU's Communication on Ageing well in the Information Society [5] in the following statement:

> Solutions can only bring benefits if users have access to basic ICT facilities, have the appropriate education and motivation, and ethical and psychological issues are properly addressed. There is no specific reference point for ethics in ICT for ageing, for example, in safeguarding human dignity and autonomy where solutions require a degree of monitoring and intervention.

Considering the above, what are the moral issues, indeed ethical concerns associated with the system under discussion, how are these justified and how can they be reconciled with the overall purpose of the system and the subsequent needs of the intended users?

Data Collection and Management One of the aims of the system is the capturing of data from elderly individuals in a variety of situations and environments. The concern at hand is what will happen to the data once captured and how will the captured data be stored. Additionally, how much of this aspect of the system would end-users be privy to and how much control will they have over their data. This concern leads to the issue of informed consent.

Informed consent Bearing in mind that the elderly are a diverse group who require different levels of care or assistant and who also have different levels of capabilities, the issue of informed consent in as far as the data that will be captured and how it will be used also merits concern. This is in addition to taking into account elderly people's different levels of understanding. The issue to further consider is what mechanisms will be included to factor informed consent and to what extent such consent might be sought for the target audience. Furthermore, where an elderly person's mental capabilities are diminishing for instance due to dementia, the question of who is liable for their consent may also become an issue. As Friedman et al [8] state in their work on value sensitive design, which is an approach concerned with human values in technology design, "informed consent provides a critical protection for privacy, and supports other human values such as autonomy and trust" (p. 74). As such, as an assistive technology targeted at the elderly, the computer vision based system would have to build in mechanisms, be it guidelines or other measures that allow and take into consideration aspects of privacy, autonomy and trust among others. Like everyone, the elderly have a right to give consent to and know how the data being collected by the system will be used.

Privacy Having a sense of control of one's environment and surroundings gives one a sense of empowerment. However, the introduction of a system that is able to track ones mobility may lead to feelings of loss of privacy. For Fried [7], privacy is about one's control over information about oneself. If that control were to be lost due to a violation of one's privacy, this may run counter to the intended objectives of the system, which is to improve the well being of the user. In addition, there exists the possibility of the data being used for purposes it was not intended for, particularly when it lands into wrong hands. As a result, a threat to loss of privacy may also lead to a loss of dignity, particularly if data collected is of a very personal nature. With this, privacy is an issue which needs to be addressed together with the extent to which users will be able to control and protect access to their environment and to the data being collected.

Surveillance The constant presence of AmI applications such as the computer vision based system in a users environment may make the intended user feel as if they were under surveillance. This will also be against the backdrop of privacy concerns due to a technology that they may feel is intrusive and therefore infringes on their independence. Giraldez and Casal [9] note that AmI applications

have implications for continued family nurturing and socialisation, particularly if the elderly were to start being concerned about surveillance and a loss of control of their environment.

User Involvement in system development For the system to work well, the developers have to have a good understanding of the end-user environment as well as an understanding of what the end-user would potentially like to achieve from the system. This is likely to call for end-user involvement in the development process of the technology so that a better understanding can be cultivated from the target audience. Blythe et al [2] argue that technology end-users should be actively involved in the design of technologies targeted at them "in order that we might identify concrete recommendations for design. Accordingly, we make the methodological election to let people speak for themselves, to document their experiences, and to tell their stories. (p.2). By so doing, even the intrusive nature of the system into an end-user environment is less likely to seem daunting because the user becomes a willing participant and is more likely to be understanding, accepting and willing to engage with the system. This may help alleviate some of the concerns raised above because by having user involvement, designers may also learn and understand more, the needs of the user and as a result have a basis to incorporate measures acceptable to the user.

4 Conclusion

The paper has given an account of a computer vision based AmI system being developed for person tracking and fall detection, particularly for the elderly. The paper has outlined some of the benefits of the system which include safety, security as well as cost benefits. However, with the benefits also come potential ethical problems, some of which this paper has discussed. The aim of highlighting the potential ethical issues was to show that ICT developers need not only look at the benefits of ICT applications but should also be able to identify potential problems that may have an effect and possibly override the benefits. By tackling the ethical issues at an earlier stage, measures are likely to put in place to either alleviate the problems or eliminate them all together. In so doing, the elderly are likely to enjoy the full potential that assistive technologies like the one discussed are likely to offer.

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