Non-obstructive authentication in AAL environments

António Almeida[a], Ricardo Costa[a,b,1], Luis Lima[a] and Paulo Novais[c]
[a] *CIICESI, Escola Superior de Tecnologia e Gestão de Felgueiras do Instituto Politécnico do Porto, Felgueiras, Portugal*
[b] *USIG, INESC Porto, Portugal*
[c] *CCTC, Departamento de Informática, Universidade do Minho, Braga, Portugal*

Abstract. Ambient Assisted Living environments projects arise as technological responses of the scientific community to problems associated with the population-ageing phenomenon. In theory, these environments should allow de-localization of healthcare services delivery and management to the home, thus containing the economic and social costs associated with old age. The VirtualECare project is one of those environments, enhanced with proactive techniques for a better user experience, focused on elderly chronic patients, through the ability of constant learning and adaption based in user interaction and its contexts. This learning and, consequently, adaption needs, however, unequivocally user identification, especially in multi-user environments. Traditional identification techniques and methodologies are not suitable for these scenario since, usually, require user interaction and wireless identification technique (e.g. RFID, Bluetooth) are very exposed to personification. In order to obtain the expected results we needed a more advanced technology. One possible, appropriate and already fairly developed technique is Facial Recognition. In this paper we present the VirtualECare project approach to Facial Recognition authentication techniques its advantages, disadvantages and possible implementations paths.

Keywords. Ambient Assisted Living, e-Health, Facial Recognition

Introduction

The increased use of Information and Communication Technologies in all aspects and sectors of our day-to-day life opens an unprecedented set of scenarios. Some of these scenarios represent a new and different technique of non-invasive and automatic recognition of individuals. These techniques, already used in various areas of our society (e.g., airports, industry, legal systems), can also be applied to AmI (Ambient Intelligence) and consequently in AAL environments (Ambient Assisted Living). They can be used not only to control access to these environments, but also to automatically make necessary adjustments to them, according to the specific needs of that person (according to his pre-configured profile). This is as an outcome of the possibility of identifying an individual. Today there are already several developments in the domestic sector. Personal computers, such as laptops already have fingerprint sensors and face recognition, although they are quite primitive in terms of operation and detection, mainly because of poor quality of hardware. Face Recognition is now the area of biometrics with more development effort. It is practical because it requires no physical interaction, and applying high-performance cameras many faces can be processed

[1] Corresponding Author: Escola Superior de Tecnologia e Gestão de Felgueiras, Instituto Politécnico do Porto, Casa do Curral, Rua do Curral, Margaride, 4610-157 Felgueiras; E-mail: rcosta@estgf.ipp.pt

simultaneously in seconds. **Figure 1** shows the percentage use of different methods of biometric identification. Facial recognition is the non-invasive method with the highest percentage of use [1].

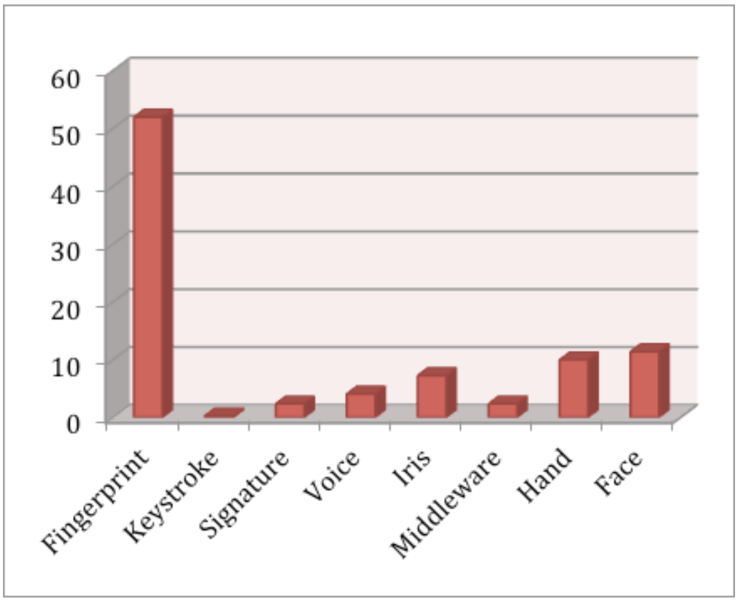

Figure 1. Percentage use of different biometric features.

Biometric

Biometric systems use our physiological characteristics (such as fingerprints, face, retina, iris) and behavioral (e.g., gait, signature) to perform an automatic recognition. These physiological and behavioral characteristics cannot be stolen easily, altered and / or shared. They are even considered more reliable for the recognition of individuals than any other system based on traditional knowledge, making biometrics well suited for environments AmI / AAL. This is even truer for a physiological characteristic, the face, which is one of the most common methods of recognition that humans use in their visual interactions. It allows the user to be recognized in a non-invasive manner, without any physical contact with the sensor. Using multi-point recognition system, we can build a profile of a valid user, registering it in a centralized information system and exchange this profile with the rest of the system, providing the ability to identify him to all parts of the system all at once. **Figure 2** represents the figures obtained for false rejection rate and false acceptance rate of detection of facial recognition in different years.

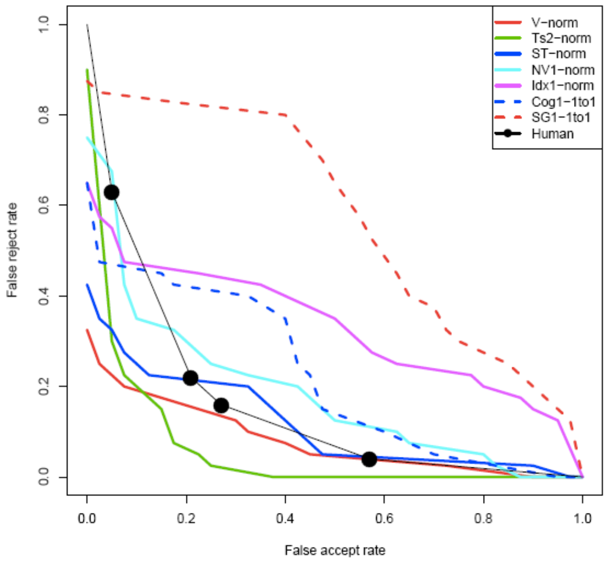

Figure 2. Evolution of False rejection rate (FRR) and False Acceptance Rate (FAR).

Facial Recognition

Facial recognition, as mentioned above, is one of the possible physiological characteristics that can be used to identify a person. Typically, this type of system uses three-dimensional characteristics of the face to verify the identity of individuals accessing the AmI environment in order to personalize the services contracted. In other words, lets you add a social dimension to human-machine communication, which can help make these environments more attractive to the user. The facial signature can be captured today by a single camera or good quality webcam if fast enough to process the data. The representation consists of using facial points and features of the face of the user, usually nodal points are used. For 3D facial recognition several facial captures are held at different angles and facial expressions, using the mapping approach in order to obtain a more realistic representation of the face of the user. This is done so that the user can be quickly detected and identified, and in more advanced cases the system can recognize the silhouette of the head, with the help of infrared cameras in low light conditions. With the abstraction of color and natural light conditions, it is safe to say that this type of recognition may operate in any normal environment within a residence, not to mention the security that this type of recognition system can provide for its accuracy. After the initial capture and their processing, any modern camera can enable to log into the system. It is recommended to use infrared lights to stabilize the brightness of the environment in order to obtain the desired conditions of light exposure. The collection of different captures and 3D scanning allows you to make a perfect model represented by millions of points. These points are taken as markers and if the face is placed in a wrong position, then, as there are several points of reference, the system analyzing the image can reconstruct the missing face parts, comparing to standard models and applying the model texture analysis.

1. Facial Recognition Technologies

Research on facial recognition technology has been a booming area in recent years in areas as diverse as security, protection, health and entertainment. Has had the support of public and private entities, with the aim of obtaining reliable systems of automatic recognition and treatment of any individual's face, and this in any condition, the same way man can do. The advancement of this technology has been achieved mainly due to three fundamental aspects:

- The modeling of the face in 2D or 3D, which aims to extract a set of data representative of each individual in order to get a model that can be processed in a timely manner and obtain the consequent identification;
- Technological advances in tools used to process these models - machines for filming and photographing with higher quality, computers with higher processing capacity, data transmission networks faster and more reliable - make it possible to obtain quality facial recognition systems;
- The continuous evaluation of the different FRT systems available and implemented in different periods of time, helped to create more demanding standards, prefiguring the objectives pursued in the next evaluation.

Following we present a survey of modeling techniques available and used in current systems, focusing on some of the functional systems available in the business market and / or university, to be able to confirm from a practical point of view the current state of the FRT.

1.1. Methods used in Facial Recognition

2D Methods

The 2D methods are among the oldest. It was in 1960 that the first algorithm was developed for face recognition [5]. It used the geometry of some key points (nose, eyes, mouth) and the relationship between them (distance, angle). It integrates the group of local methods. In 1991, Turk and Pentland applied the Principal Component Analysis (PCA) to identify a face in an image, getting to be known as the eigenface algorithm, integrated in the group of holistic (global) methods. Many facial recognition algorithms derived from the eigenface algorithm. Some of the most widely used methods are: Independent Component Analysis ICA [4], Linear Discriminant Analysis LDA [11]. Other methods, nonlinear, have been implemented, such as neural networks, widely used in pattern recognition, however to be viable it is necessary to reduce the amount of information at the input of the algorithm, which was done by applying a method of PCA (Meng et al. 2002). The Elastic Bunch Graph Matching EBGM is based on the fact that the human face is not linear, and features such as lighting and posture are not taken into account. The use of wavelet Gabort allows you to create architecture of dynamic connections projecting the face into an elastic grid. More recently other methods have appeared, such as Fractals and Iterated Function Systems (IFSs), which requires less computational effort than the previous ones or the Thermal and hyper spectral which takes advantage of other biometric characteristics of the human body to identify the face [14].

3D Methods

3D-based methods use local features as well as global. They are more complicated to put into practice given the difficulty that exists to collect the image. The 3D images can be collected using a 3D scanner, or by applying a model of morphological images.

The first approach [14] uses the model of a generic 3D face, to it is applied a single image from a 2D face model and then is automatically extrapolated to build the 3D model taking into account the shape, texture, posture, Lighting, etc. Systems for 3D face recognition are difficult to put into practice given the difficulty of alignment between the image to identify and the available images in the database. Several methods were implemented to align the images with more or less success [14].
The multimodal systems use information coming from 2D images and 3D models, obtaining higher success rates than when each type is used separately.

The different methods presented here have success rates above 90% [13] when conducted in a controlled environment, however the rate drops very significantly when tests are performed in an uncontrolled way, i.e. with different brightness (inside the buildings, on the street), with different expressions (laughter, sadness), with occlusions (glasses, beard), with the face position (front, slightly to one side), or with aging [14].

1.2. Facial Recognition and AmI/ALL

Above all, AmI is a concept focused on the needs of people in everyday situations, wherever they are. To achieve this, ISTAG[2] refers some important technologies and components like smart material, micro electromechanical systems, sensor technologies, and embedded systems, but also refer to some intelligent components like natural interaction, emotional computing, and computational intelligence [15]. Some years ago it was impossible to implement this concept, now made possible by the advances in technologies on differences fields, like nanotechnologies, distributed software, AI (Artificial Intelligence), among others. Terms already used in some research fields and even commercial proposals, like Smart Homes or Pervasive Computing, are all under the umbrella of AmI, but they are not quite the same. They usually refer to some kind of partial implementation of the AmI concept, with a strong emphasis on technology [3], although with some improvements towards AmI.

Basically, we can say that an AmI system need to get information about the state of affairs of the world that surrounds it, process all the data it gets, achieve one or more goals, and act accordingly with the decision made by the system. AmI Process are illustrated in **Figure 3** [3].

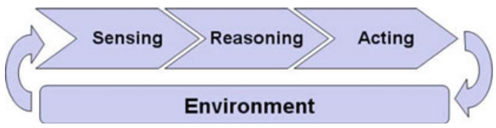

Figure 3. Process of AmI systems [3].

The first stage of the AmI process is to know the state about the user/people and the environment; this is made using sensors which are the first link between them and the system. Sensors can be divided in two mains functional areas: monitoring the user, and monitoring the environment. For example, in health care systems [8] we find sensors inside some clothes to check vital human signals. Or, to control the motion or the identity of the user, many systems use RFID cards. RFID cards are one solution to control motion in defined areas, usually small areas. For long distances we can use GPS, but it is not a good solution to identify the user, the system only can identify a

[2] URL: http://cordis.europa.eu/fp7/ict/istag/home_en.html

number, not a user. Others sensors are used to get information about the environment, like temperature, gas, luminosity, noise, etc.

The Reasoning stage give intelligence to the AmI system, according to the type of data the system receive and to make the system responsive, adaptive, and beneficial for the user. Different kind of Reasoning implementations may be used, including user modeling, decision making, activity prediction and recognition [7].

Acting stage responds to the Reasoning stage: after a decision is made, the system may apply this decision using some device/actuator. Some systems respond with quite trivial tasks like raising the temperature in a room when it detects that the temperature is under the needs of the user, other systems can make a call to medical assistance if it detect a fail of one vital human signal of the user.

As we can see, AmI is a multidisciplinary area which embraces a variety of pre-existing fields of computer science as well as engineering [2]. A lot of improvements have be done since ISTAG refer it like a concept, but some challenges remain, and one of them is the facial and pose recognition, which can turn any AmI system more secure, adaptive and responsive.

2. VirtualECare

The VirtualECare project (**Figure 3**) provides an effective new way to bring well being, where treatment is no longer centered on the institution, but instead will be focused on the user, resulting in better and cheaper service for both the user and the supplier. Although at first glance this might seem a contradiction, cost reduction is possible through the use of new and cheaper technology devices that allow monitoring and assessment of vital patient data and their location in real time. These same data, after suitable treatment, can lead to alarms, recommendations or actions to assist the patient in their needs, while it maintains the normal day-to-day life. This new form of services for health care has great benefits not only for the patient but also for their friends and relatives who may be informed in real time about his condition, allowing them to intervene if necessary. As a result of this new form of health care, we need to enrich the patient's home with Ambient Intelligence (AmI) and more specifically with Ambient Assisted Living (AAL) technology. This approach allowed us to better respond to specific patient needs, managing his home environment to better meet their expectations. In an initial phase of system development, and because of the initial objective of design and target audience, the system was designed only for activation and use by one person per household or implementation. However, in further developments of the project, the upcoming of new developments and the community feedback and also the implementation at health centers and hospitals showed that it was necessary to create a profile for each user in order to associate his preferences and needs to the stored profile. We recognize the importance of implementing the techniques that allow our system, automatically and without user/patient intervention, recognize the presence of different individuals, but also to identify them. This individual recognition, crucial for a multi-user environment, contributed to the creation of subsets of specific environments for each user, through their respective profile obtaining better results [8; 9].

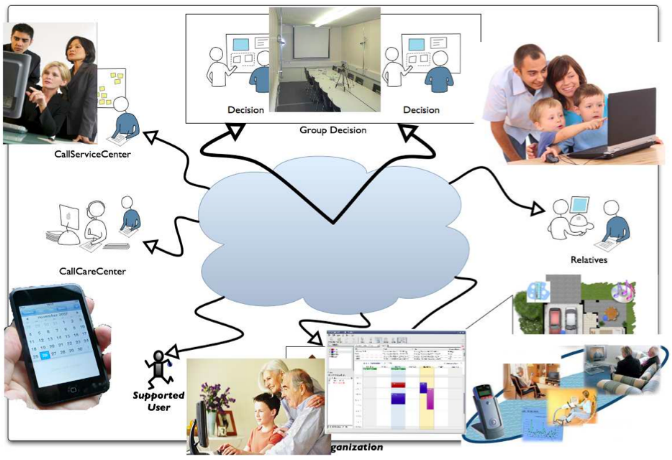

Figure 4. The VirtualECare Project.

2.1. Identification and authentication

When, during the project development, we came across the need for user identification and associated authentication we, almost, automatically decided to use some kind of wireless technologies. After some debate we focuses in two major possibilities: RFID tags or Bluetooth phones. In theory this will allow us to identify someone inside our environment simply by being there (actually, simply by being in range of the respective antennas). We have implemented both this solutions, but during the testing phase we realized that we weren't identifying someone but something (RFID tag or Bluetooth enabled phone) that could be easily changed, or forgotten (the last one is specially worrying since we could have a user in the environment without detecting him and without making the necessary adaptations). After this initial developments we them decided we should focus our attention in a more adequate identification technique. After some digging we came across Facial Recognition, which, apparently, would solve our problems.

2.2. Security

The added security value associated with the use of Facial Recognition is of the most interesting factor. As previously mentioned the face is one the most hard characteristic to forge or manipulate, making this identification techniques one of the most secure around. Additionally, being a characteristic intrinsic to the human been it cannot be lost or forgotten. The combination of these factors assures us that user logged to the system, by simply being in the present of it (or actually in the range of a video camera) is in fact the user registered in the system. The use of the cameras can also be exploited for other purposes like, for instance, monitoring every person that approaches the front door of the house (in case our environment is one) and register them in the database for further analysis and processing (e.g. posterior registration of that person in the system, if the user find it useful) or to monitor and report to the right service/person of possible cases of urgency or emergency happening to the user.

2.3. Implementation

Our main objective was to develop an Open Source Facial Recognition module for the VirtualECare project able to interact with the remaining system maintaining the adopted Web Service philosophy. During our research we found several commercial Facial Recognition applications [1; 12], which use several own, non-public available, C/C++ algorithms. Additional information about these algorithms is hard to obtain. Cognitec, for instance, one of the major companies in this area, is referred in a Intel commercial document as one of the first companies to integrate the Intel Integrated Performance Primitives (Intel IPP) [16] with a major boost in performance. In academic terms, several projects were also found [1; 12], usually, with a common particularity: the use of the Open Source library OpenCV (Open Source Computer Vision) [6] a multi-platform Library with 500+ image and videos process algorithms developed by Intel to demonstrate their processors capabilities, and freely available for academic or commercial use. OpenCV was also our choice for developing the Facial Recognition VirtualECare module.

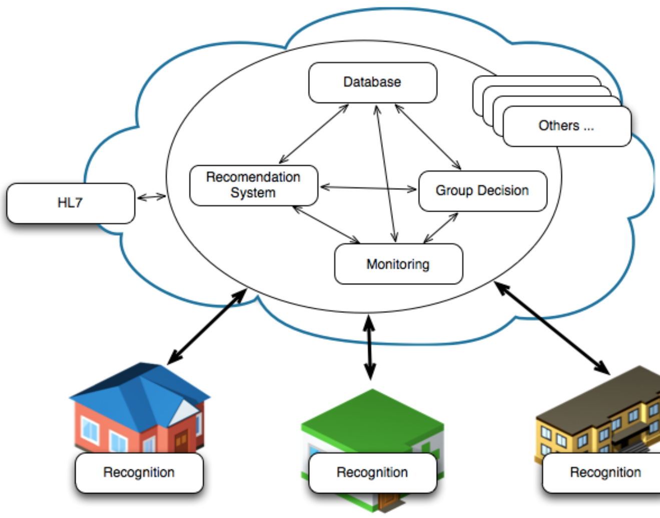

Figure 5. VirtualECare Modular Architecture with the Recognition Module

The natural solution would be to develop our Facial Recognition module recurring to the C/C++ computer language however, once one of the requisites was to maintain the Web Service philosophy, it would be easier to develop in C# or Java. We opted for C# on top of a wrapper (emgu CV[3]) to interact with the OpenCV Library. Due to the VirtualECare architecture modular characteristic, the change from one module (RFID or Bluetooth) for another (Facial Recognition) should be trivial. However, during the definitions and architecture phase of the recognition module, we realized it should not stand in the "cloud" like all the others due to the needed computational power, rapid responses and the fact that recognition should take place in each different environment, despite the user identification being needed in the entire system. Due to this fact, we opted to deploy the recognition modules inside each user environment (**Figure 4** and **Figure 5**), interconnected with the existing local

[3] URL: http://www.emgu.com

technologies (e.g. OSGi and Agents). This decision also allowed us to be able to keep the base characteristics of the environment working (including recognition) even if, for some reason, the connection to the "cloud" was lost. In terms of the technology point of view there can be a camera in each room or terminal or only one to the entire system, this can be adapted to each environment/user necessity. As there will be agents locally controlling the capture of the information, the preservation of the information will be secured and then relayed to the "cloud" to be conveniently logged and for future processing, if needed. Each user has to be inserted in the system by a technician and all the persons that sporadically come in touch with terminal can request to the support line an authorization or use a predefined "guest" login. The availability of this system can be used to control the operation of the several devices present in the house, activating personalized profiles and change the devices configuration in each room the user enters, open automatically the front door without the need of a key, keep track of where the user enters and exits between other several hypotheses available.

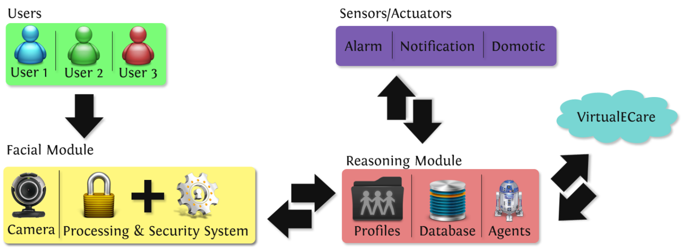

Figure 6. Recognition Module Architecture inside each single Environment.

Currently, our project is still in its initial phase, but we are already able to use a simple web camera to detect one or more faces in the environment, although with some limitations regarding the position (angle) of the face in relation to the camera (**Figure 6**).

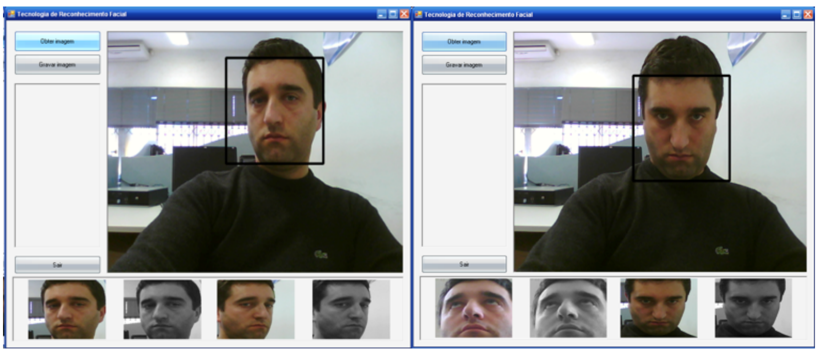

Figure 7. Angle limitation of the face in relation to the camera.

3. Conclusion and Future Work

Facial Recognition technology and techniques are a very promising area, especially in scenarios where non-invasive authentication is needed. As presented, several developments have been achieved in recent years in order to make the technology wide reliable available. We believe this can be a major addition to efficiency and acceptance of AmI/AAL environments, even if for now we cannot still retrieve enough factual data to support it. The presented client/server architecture makes necessary to have some kind of device in the "client" side for image capturing and processing. Although this could be eliminated, it was a conscious choice, not only for the already presented reasons, but also for possible future new developments where we can use this device to monitor facial expressions in order to deduce the user state of mind [6]. We are also analyzing the possibility of adding voice recognition techniques in order to accelerate and obtain a more accurate user recognition phase [10].

These technologies, however, relaunch the debate about all the privacy constrains associated with them. We are also trying to achieve some conclusions about this thematic, although it is very difficult to discuss our privacy against the benefices that we can obtain from systems that are using cameras, even figures cameras, to monitor users for his, and his health, convenience.

References

[1] A.F. Abate, M. Nappi, D. Riccio, and G. Sabatino, 2D and 3D face recognition: A survey, *Pattern Recognition Letters* **28** (2007), 1885-1906.

[2] J.C. Augusto, H. Nakashima, and H. Aghajan, Ambient Intelligence and Smart Environments: A State of the Art, in: *Handbook of Ambient Intelligence and Smart Environments,* H. Nakashima, H. Aghajan, and J.C. Augusto, eds., Springer US, Boston, MA, 2010, pp. 3-31.

[3] A. Aztiria, A. Izaguirre, and J.C. Augusto, Learning patterns in ambient intelligence environments: a survey, *Artif. Intell. Rev.* **34** (2010), 35-51.

[4] M.S. Bartlett, J.R. Movellan, and T.J. Sejnowski, Face recognition by independent component analysis, *Ieee Transactions on Neural Networks* **13** (2002), 1450-1464.

[5] W.W. Bledsoe, The model method in facial recognition, *Panoramic Research Inc., Palo Alto, CA, Rep. PR1* **15** (1966).

[6] G. Bradski and A. Kaehler, *Learning OpenCV: Computer vision with the OpenCV library*, O'Reilly Media, 2008.

[7] D.J. Cook, J.C. Augusto, and V.R. Jakkula, Ambient intelligence: Technologies, applications, and opportunities, *Pervasive and Mobile Computing* **5** (2009), 277-298.

[8] R. Costa, P. Novais, L. Lima, D. Carneiro, D. Samico, J. Oliveira, J. Machado, and J. Neves, VirtualECare: Intelligent Assisted Living, in: *Electronic Healthcare*, Springer Berlin Heidelberg, London, 2009, pp. 138-144.

[9] R. Costa, P. Novais, L. Lima, J.B. Cruz, and J. Neves, VirtualECare: Group Support in Collaborative Networks Organizations for Digital Homecare, in, 2009, pp. 151-178.

[10] F. Joassin, M. Pesenti, P. Maurage, E. Verreckt, R. Bruyer, and S. Campanella, Cross-modal interactions between human faces and voices involved in person recognition, *Cortex; a journal devoted to the study of the nervous system and behavior* **47** (2011), 367-376.

[11] J.W. Lu, K.N. Plataniotis, and A.N. Venetsanopoulos, Face recognition using LDA-based algorithms, *Ieee Transactions on Neural Networks* **14** (2003), 195-200.

[12] J.G. Patrick, W.Q. George, and P.J. Phillips, Report on the Evaluation of 2D Still-Image Face Recognition Algorithms, in, National Institute of Standards and Technology, 2010, p. 58.

[13] P.J. Phillips, P. Grother, R.J. Micheals, D.M. Blackburn, E. Tabassi, and M. Bone, FRVT 2002, *Evaluation Report, March* (2003).

[14] P.J. Phillips, W.T. Scruggs, A.J. O'Toole, P.J. Flynn, K.W. Bowyer, C.L. Schott, and M. Sharpe, FRVT 2006 and ICE 2006 Large-Scale Experimental Results, *IEEE transactions on pattern analysis and machine intelligence* **32** (2010), 831-846.

[15] C. Ramos, J.C. Augusto, and D. Shapiro, Ambient Intelligence - The Next Step for Artificial Intelligence, *Intelligent Systems, IEEE* **23** (2008), 15-18.

[16] S. Taylor, *Intel integrated performance primitives: How to optimize software applications using Intel IPP*, Intel Press, 2004.