Network on Privacy-Aware Audio- and Video-Based Applications for Active and Assisted Living: GoodBrother Project

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***Abstract*— Active and Assisted Living (AAL) systems have a purpose to improve the lives of older or impaired people in various aspects. However, the use of equipment for data acquisition in these systems can be considered intrusive in some cases. Although de-identification may provide the needed protection to some extent, it is not always preferred, as it could affect the quality and utility of any obtained data. It is therefore crucial to establish methodologies for protecting the privacy of those monitored and thus affected by AAL systems. The purpose of GoodBrother is to a) analyze any issues arising from the use of monitoring AAL systems, regarding the users' privacy; b) establish proper guidelines for the use of these systems; c) develop privacy-aware methodologies for data handling; d) increase the systems' robustness and reliability; e) create databases to use towards benchmarking. Each one of these objectives are handled by separate interdisciplinary working groups.**

Keywords—GoodBrother, AAL systems, privacy-aware applications, audio data, video data, cybersecurity, cryptography

I. INTRODUCTION

During the last few years, the application of Active and Assisted Living (AAL) systems has spread widely across a variety of situations, such as rehabilitation, support in healthcare, etc. Regarding the aspect of automating tasks at home, these new developments could greatly upgrade the living circumstances of many individuals. Basically, these systems have the capability of allowing remote operations through user-friendly interfaces, with the purpose to fulfill everyday tasks, such as operating home appliances.

As the average life expectancy of people increases throughout the years, there are new requirements that arise regarding the reinforcement of healthy aging [1]. It is well known that the majority of people of older age tend to rely on others for their care and fulfillment of some of their needs. The development of these new aforementioned technologies could aid towards minimizing the assistance that these people need on a daily basis, in tasks including, but not limited to, nutrition and medication schedules, movement tracking, etc. Moreover, AAL related technologies could prove useful for people who do not necessarily suffer from health problems and can simply be used as a preventive measure with the purpose of predicting or indicating possible issues that these people could face in the future.

AAL systems were introduced about 20 years ago, with the purpose of developing technologies for tackling mostly health-related needs. Many researchers have already dealt with describing the characteristics of these systems [2,3]. Some works have related AAL systems to the development of applications that aim to create a better life quality and improve the independence of people who face health challenges [4]. Some important aspects towards achieving the goals of autonomy and independence are the ease of use, the comfort, and the users' safety and security. Throughout the years, the use of AAL systems has expanded, allowing the term to be used not only when referring to activities and applications limited to the area of a home, but also when considering outdoor and work places. This indicates that there is an imminent need for continuous support of people by these systems, regardless of place or time, to ensure the fulfillment of the aforementioned goals. In Fig. 1, the most fundamental points that need to be considered while designing AAL systems are shown, which are related to the target groups, the environment (indoor and outdoor), and the main functionalities of the AAL systems.

The concept of observing and keeping track of health-related parameters is highly connected to research fields such as the Internet of Things (IoT). This is mainly because IoT is an umbrella term for all the applications that are related to the supervision of people's health, with the purpose of preventing situations that would otherwise be difficult to handle. This is achieved through data collection, for example by monitoring either someone's body parameters or medication schedule. Some researchers have underlined the importance of IoT systems towards the analysis of an environment, to promote and provide sufficient healthcare in a variety of situations [5].

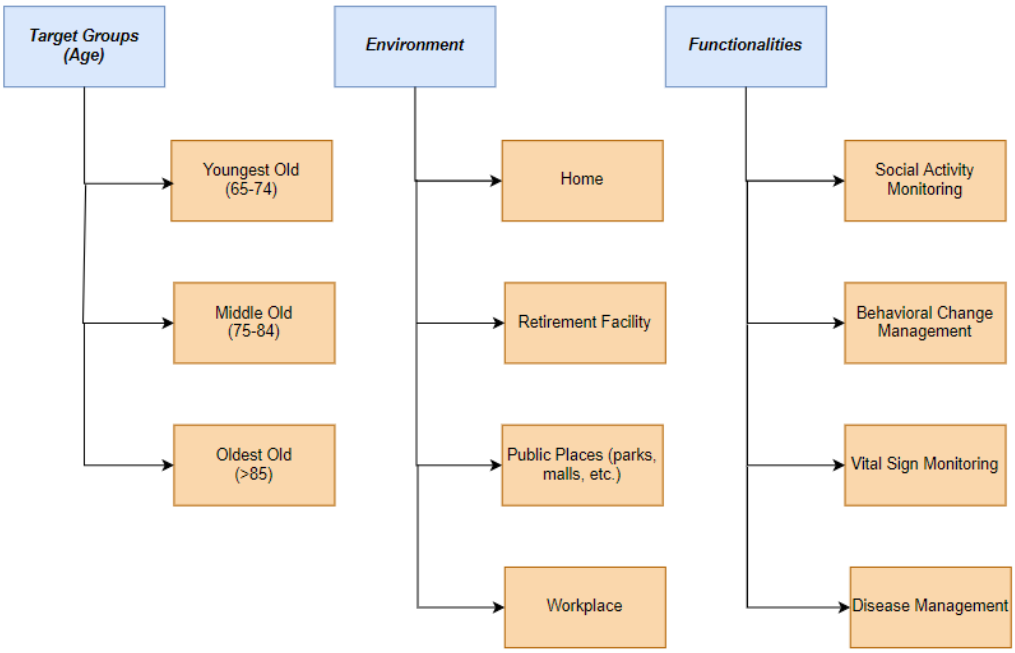

Figure 1: Key points while designing an AAL system

The main purpose of AAL systems is to offer an improved life quality and independence to people, while at the same time ensuring that this is achieved in a user-friendly and inconspicuous way. These systems should contain an embedded intelligence, allowing them to adjust their operation according to the circumstances and the environment. AAL systems are highly related to concepts such as Ambient Intelligence or Assistive Technologies, or even Robotics. Specifically, the latter could be one of the main components of AAL systems to aid towards achieving physical tasks [6].

Because of the importance and necessity of AAL systems in the everyday life of older or impaired people, many researchers and companies are focused on designing and developing such systems which include new features and are user-friendly. Although continuous monitoring of the activities appears to be helpful and sometimes crucial for people's lives, this functionality invades privacy according to some end-users. The GoodBrother project aims to increase the awareness on the ethical, legal, and privacy issues which are associated to audio- and video-based monitoring and to propose privacy-aware working solutions for assisted living.

This paper describes the main objectives and tasks of the GoodBrother project, which are related to the development and design of privacy-aware audio- and video-based applications for Active and Assisted Living. The paper is organized as follows: Section 2 provides a general background in AAL systems regarding their structure. In Section 3, some of most common methods that can be used to preserve the privacy in audio and visual data are presented. In Section 4, the applications of the AAL systems are presented briefly to show the importance of the development of these systems. In Section 5, the main objectives and tasks of the five Working Groups of the GoodBrother project are discussed. Finally, conclusions are highlighted in Section 6.

II. Background In AAL Systems

The structure of an AAL system consists of three basic layers, as it shown in Fig. 2 and each one of which is responsible for a different function. The first layer is the sensing or perception layer of the system, where sensor technologies are used. Sensors are the most important feature of an AAL system and are usually embedded in many "smart" devices. Their main purpose is to acquire useful data regarding the environment in which the assisted person lives and moves in, as well as their everyday activities and health condition. The perception layer can be a complex sensor network, in which many kinds of sensors are embedded, such as environmental sensors, or even video cameras that are used to survey the ambient space.

The second layer is the data-processing or interpretation layer, where specific algorithms are embedded in the living environment or in mobile devices. These algorithms process the information acquired by the sensors that are placed in the first layer. The goal when using these algorithms is to recognize the moments when the individual needs assistance with everyday activities or is in a risky condition by analyzing the incoming information (e.g., gestures, gait, voice, etc.). Finally, there is one more layer which is called the actuator/application or interaction layer. After the processing of the sensor data and the interpretation of the individual's

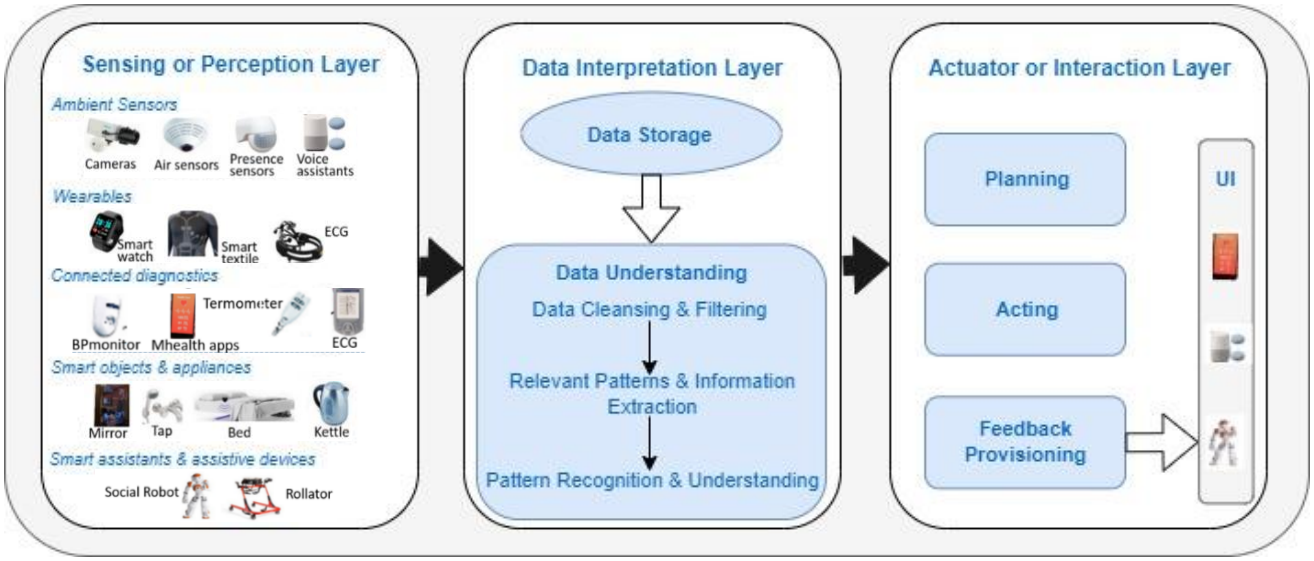

Figure 2: A functional view of the main components of an AAL system. The various sensors networked in the sensing layer need a suitable orchestration to regulate data recording and storage. The algorithms in the data understanding layer can work on data coming from a single sensor or on multiple sensors. The user interface could be embedded in any type of smart appliance (i.e., could be tangible or intangible).

need, the system can provide feedback to the user, regarding the tasks that need to be performed after a specific alarm or when an abnormal situation is detected. Additional computing elements are required for the implementation of this layer, for the user to be able to interact and "communicate" with the system.

Sensors used in AAL systems obtain data from the environment, including but not limited to weather and climate conditions, or information about the device being used. Image or sound recording sensors, such as cameras or microphones, can be easily installed in several places or be embedded in actual devices. They offer the capability to monitor a space from a distance, without directly being attached to an individual. They moreover could be a part of wearable devices, with the purpose of keeping track of someone's vital body functions constantly. Data obtained from these sensors can later be transferred to and processed by other health devices. For example, a camera installed in an indoor space is able to record and monitor the majority of movement and activities taking place in that space. The fact that monitoring equipment such as cameras are being widely used in AAL applications can be attributed to their decreased cost during the last few years [7]. Audio-based sensors, such as microphones have also been broadly used in AAL systems, due to their ability to record a wide range of information from a space, and their presence is very discrete [8].

There are still conflicting opinions as to whether audio and video-based monitoring is more intrusive or not in an individual's everyday life. Although wearable devices could potentially cause discomfort to some people, sensors such as cameras or microphones are considered more invasive against one's privacy, as they record a much wider variety of data, both in outdoor and indoor spaces.

III. Privacy-By-Design In Audio And Video Data

After the analysis of the ethical, legal, data protection and privacy issues associated with the use of cameras and microphones in private spaces, it is of great importance to examine the methods that can be used to preserve the privacy in the acquired data. This specific task is performed by Working Group 2 of the GoodBrother project.

In this paper, focus is given on some of the most fundamental techniques that are used for visual privacy preservation. Padilla-Lopez et al. [9] have proposed a taxonomy, based on which these privacy preservation methods can be categorized into five categories: intervention methods, blind vision, secure processing, data hiding, and visual obfuscation. Intervention methods have a purpose to obstruct any video- based recording of an environment [10-12]. This can be accomplished either with the help of software installed in the recording devices, or with the use of additional devices embedded on the existing ones, which will physically prevent the capture of certain information. Methods belonging to the category of blind vision process visual data anonymously. This is done with the use of specific algorithms, which allow the data to be processed with only some part of the information being disclosed [13,14].

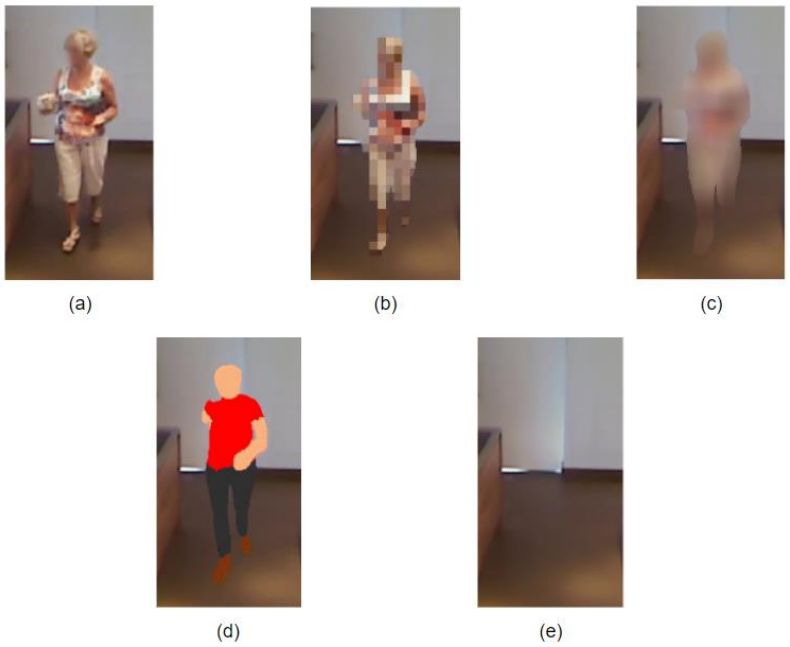

Figure 3: Example frame from the Toyota Smarthome dataset, within the workflow of the method proposed in Climent-Pérez and Florez-Revuelta [2021]. (a) original frame; (b) pixelation; (c) blurring; (d) avatar; (e) invisibility (adapted from [18]).

Secure processing methods are based on stricter rules regarding privacy. For instance, in a case that it is needed to obtain an image from a database, the image can be kept confidential [15]. Methods in the category of data hiding accomplish what was previously mentioned, with the addition of keeping a form of the initial information on the modified visual data. Some of these methods include but are not limited to watermarking and fingerprinting. Fingerprinting allows the owner of an image to identify unauthorized modifications. Watermarking embeds additional information on an original image.

Finally, visual obfuscation methods obscure data and make them impossible to access from individuals without permission. This is accomplished by applying image filtering techniques, such that the initial data are different from the original. Filters can be applied in specific areas or on an entire image. Filters that cause blurring are based on Gaussian kernels, which use neighboring pixels to affect other pixels. Filters that cause pixelation use grids of various sizes to apply on specific areas, changing the original colors. Additionally, some methods based on body abstraction can even replace a person's body with a digitally generated body. Segmentation is used to distinguish the part of an image that corresponds to a human body. Moreover, these methods can replace or modify faces and change or completely omit backgrounds [16,17]. Examples of these methods when applied to an image are shown in Fig. 3 [18].

A combination of the aforementioned techniques with some others related to the processing of audio-based data can be used towards maintaining the privacy of audio and video-based data. Working Group 2 of the GoodBrother project carefully examines and analyzes the capabilities and weaknesses of these methods, with an ultimate goal to develop reliable, private and safe AAL systems.

IV. AAL Applications

As it was mentioned before, the demographic problem that appears to exist in the last few years is caused mainly by the aging population [19]. This is the reason why there is an increasing need for social services, healthcare, and long-term care to support older adults as they age. Diabetes, heart disease, arthritis, and hypertension are only a few of the chronic diseases that adults over 65 suffer from [19-21]. That means that especially people who belong in these age groups have different healthcare needs than children and younger adults. A large majority of older adults have at least one chronic disease that requires specific treatments and medical care [22]. Older adults not only rely on their primary care physician, but also on long-term care services and supports. Teams of physicians, long-term care assistants, nurses, social workers, and family caregivers often work together to provide tailored and coordinated care to older adults. Moreover, the increasing healthcare costs nowadays [23], lead everyone and not only the elderly people to the need to find alternative methods to monitor their health condition.

AAL systems enable the continuous monitoring of human physical activities and behaviors, as well as physiological and biochemical parameters during daily life. The most commonly measured data include vital signs such as heart rate, blood

pressure, and body temperature, as well as blood oxygen saturation, and physical activities through the use of electrocardiogram (ECG), ballistocardiogram (BCG), etc. All these vital signs can be monitored by wearable devices, but there are also many, video- and image-based as well as audio-based methods that enable contactless monitoring of multiple parameters. These methods appear to be beneficial for a long-term, continuous, and comfortable for the user, health monitoring and can also be applied in working and driving settings to prevent accidents [24]. During the last few years, many different methods for health and behavior monitoring have been developed and provide the opportunity for medical diagnosis and prognosis, as well as for chronic diseases management.

Except from vital signs and behavior monitoring, AAL technologies are also used for fall detection and prevention. The risk of an individual suffering a fall increases dramatically with age [25,26]. A division of AAL systems researchers focuses its work on identifying fall scenarios to assist people after an accident [27,28]. It is of great importance to design and develop this kind of systems as falls can even prove fatal when we refer to elderly people. Fall events appear to be a common phenomenon and almost 20-30% of falls lead to mild to severe injuries, and form 10-15% of all emergency department visits [29].

Methods aiming towards fall detection can find application through wearable devices or sensors [30]. Wearable devices are a low-cost solution that fulfills the goal of maintaining one's privacy. These devices mostly use accelerometers, and also gyroscopes or magnetometers. Information obtained from these sensors can be useful in detecting a fall-related accident. However, wearable devices might not be worn 24 hours a day by the users, which can be a major limitation, bearing in mind that a person can suffer a fall when taking a shower or slipping on a wet floor [31]. It seems that monitoring devices such as cameras need less to no effort put in by the user and are able to keep track of many people at once [31-33]. There is a wide range of situations where these systems can be proved useful and help individuals to cope with difficulties in their everyday activities due to their age. Working Group 3 of GoodBrother project is responsible to review all the potential applications of these systems and to develop new AAL solutions compliant with users' requirements and the legal regulation.

V. Working Groups And Objectives Of GoodBrother Project

The ultimate goal of the GoodBrother project is to establish a good understanding of the ethical and legal aspects of audio or video-based monitoring, and to maintain a high level of privacy solutions regarding the use of AAL systems. This can be accomplished by the collaboration of researchers from various fields. This project will aim to improve users' acceptance towards AAL systems, as well as to explore novel solutions and work to achieve developments in this field.

GoodBrother is organized in five different Working Groups (WGs) in order to complete these tasks successfully, as it is shown in Fig. 4. Each one of them has specific objectives and the collaboration between them will finally lead to the goal of the specific project. Working Group 1 is focused on the analysis of issues with regards to the maintenance of privacy when using audio and video devices, and on the management of the data obtained by these devices. A survey is moreover conducted with a purpose to uncover the relationship between an individual's background and their perception of these issues. WG1 is therefore concerned with embedding all these requirements for AAL systems. Their work is being used by WG2, WG3 and WG4.

Working Group 2 encourages collaboration of researchers with the industry. This collaboration aims to achieve the development of methods needed for de-identification of data obtained by audio and video devices. This process needs to protect the user's privacy, while at the same time needs to keep the data in a form that contains useful information [34-35]. Working Group 3 is focused on the more technical aspects of this project, such as fall prevention/identification, lifestyle profiling of an individual, etc. Moreover, WG3 is responsible for embedding these tasks into robotic or other systems through processing of big data [36]. These are achieved under the guidelines imposed by WG1 and methods developed by WG2.

Working Group 4 develops the necessary software to improve the methods and ideas developed by WG2 and WG3. Additional benchmarking is also required to validate any proposed methods. Any obtained data are stored in a repository. The last group, WG5, has the purpose to increase the impact of any produced applications to the market. People should become aware of AAL systems and applications and develop trust towards these solutions.

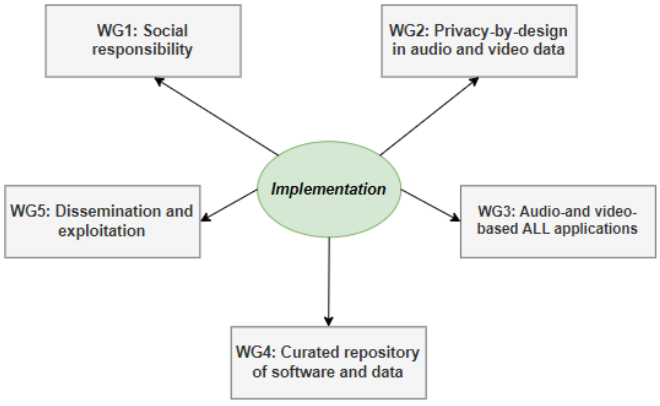

Figure 4: Working Groups' tasks.

VI. Conclusions

Due to the increment in the average life expectancy during the last few years, the development of Active and Assisted Living (AAL) systems is of great importance and a possible solution to this demographic problem. These systems improve the life quality of older or impaired people and help them cope with difficulties in their everyday activities. In order to monitor and be aware of people's moves and health

condition, the use of microphones and cameras in AAL systems is unavoidable. This is the reason why many end users are concerned that their privacy is invaded. GoodBrother project aims to analyze the ethical and privacy issues related to the use of cameras and microphones in private spaces to monitor individuals' lives and the final objective is to develop methods that preserve privacy in audiovisual data.

ACKNOWLEDGMENT

This publication is based upon work from COST Action 19121 "Network on Privacy-Aware Audio-and Video-Based Applications for Active and Assisted Living, (GoodBrother)", 2020-2024, supported by COST (European Cooperation in Science and Technology).

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