Videogame Technology to Support Seniors

Dario Maggiorini Laura Ripamonti Andrea Scambia

University of Milano
Via Comelico 39
20135 Milano, Italy

{firstname.lastname}@unimi.it

ABSTRACT

The current demographic ageing in Europe is the result of a relevant economic, social, and medical development. This is also leading to an increase in the demand for Long Term Care (LTC) by seniors. One viable way to offer qualified cares at home, while at the same time containing costs, is to exploit digital technologies as enablers of a constant interaction with assisting personnel. In this paper we tackle this problem proposing a solution based on technology commonly used for videogames: we aim to provide remote at-home support to seniors exploiting intuitive and non-invasive off-the-shelf technology. We first describe a design methodology for the system, then the feasibility of current technology is evaluated and a prototype application is shown. The proposed system, thanks to its user-friendly interfaces and smooth learning curve, will contribute in minimizing the interference in the elder's private life.

Categories and Subject Descriptors

J.3 [Health]

General Terms

Design, Human Factors.

Keywords

Ambient Intelligence (AmI); context awareness; videogames; healthcare.

1. INTRODUCTION: LTC IN AN AGEING WORLD

According to estimate, by 2025, people over 60 worldwide will be 1.2 billions, and by 2050 they will reach 2 billions (in 2000 they were "only" 600 millions). In the same year, in Europe, the number of over 60 will equal the 40% of the total population, and the 60% of the population in working age (see e.g., [2], [11], [20]). In the following decades the so-called "baby-boomers" will start to retire, further exacerbating the situation. Italy is among the oldest Country in Europe, with a ratio of 143 elder to 100 people under 65 [10]. This progressive increase in population age impacts deeply on a number of areas, such as: healthcare, pensions, housing, community care, etc., among which one of the most afflicted is the long-term socio-medical assistance. The OECD (Organisation for Economic Co-Operation and Development) defines the Long-Term Care (LTC) as *any kind of cure supplied for a long period of time, without any pre-defined end date* [14]. The LTC encompasses a heterogeneous set of cares, both highly specialized and not: medical and paramedical assistance, domestic help, personal care, and social assistance. At the moment, the supply of services addressed to elders is largely insufficient in all the EU Countries (e.g., in 2006 the 12% of elder received home cares in the northern EU countries, while in Japan this ratio was 73,4% already in 2003. The situation is even worst in the southern EU Countries, with a ratio of 3% in Italy and of 1% in Greece [10]). As a consequence, hospitals are often forced to prolong patients staying, because of the shortage of services able to support LTC at home. In spite of this, domiciliary cares would be an effective alternative to long-term hospitalization: the psychological and affective benefit for the patient would be huge, and shorter hospitalizations would mean shorter queues to access public health services and a shrinkage in costs.

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One viable way to offer qualified cares at home to elders is to exploit digital technologies as enablers of a constant interaction between seniors and the people in charge of their assistance. For this purpose, we are developing a medium-term joint project with a non profit Italian organization (Assoaqua - www.assoaqua.it) focused on home LTCs for elders. The main goal of the project is to put the basis for deploying, step by step, a "virtual hospital at home", basing on the exploitation of Natural User Interfaces as a mean to interact with Serious Games in an environment "augmented" through Ambient Intelligence techniques.

2. SERIOUS GAMES, NATURAL USER INTERFACES, AND AMBIENT INTELLIGENCE

Learning patterns have changed radically in the last decades [21], [16], and the idea of exploiting (video)games as a teaching/training media has been "formalized" in 2002: in that year, the Woodrow Wilson Center for International Scholar in Washington, D.C. founded the Serious Games Initiative. Nonetheless, this idea was already in place long before computers and electronic devices became a way to convey entertainment [1]. In spite of their old story, no generally accepted and shared definition of what a Serious Game (SG) should be exists yet; anyway, the one provided by Zyda seems good enough for our goals: *Serious Game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives* [6, p.26]. It is important to enlighten that SGs are not only a way to instruct people about something, but also a way to convey knowledge within a context that is motivationally rich. To this extent, it is of paramount importance to provide tools for designing effective user interfaces. This necessity couples with the simplification of the interaction modalities ongoing in the HCI field, which drives research – and business – towards the development of new AmI (Ambient Intelligence) solutions and the exploitation of the NUI (Natural User Interface) paradigm.

AmI is a relatively new concept: it was born in the late 90s, and has been defined in 2001 by the ISTAG (Information Society Technologies Advisory Group) as an ambient sensitive to the presence of people, able to remember and to anticipate their behaviour, with the scope of supporting their activities [7]. This approach implies the deployment of NUIs – able to guarantee at least interaction through voice and gestures –, together with the ubiquitous and/or pervasive computing paradigms.

NUIs aim at adopting the same communication patterns used among humans as a mean for interacting with machines, as underlined by the NUI User Group [12]. At the moment, this declaration idea has been concretely and successfully embodied in quite few cases. From a business perspective, this trend is exemplified by the huge success obtained by the videogame industry with the pioneering introduction of Nintendo Wii in 2006, followed by Sony Playstation Move and Microsoft Kinect for Xbox in 2010. Among the retail solutions the motion gaming proposed by Microsoft Kinect is by far the most innovative. In this case the controller has been replaced by a technologically advanced webcam and the system will react to gestures and voice commands [13], [19], thus, implementing a "real" example of Natural User Interface. Kinect has also been the first device whose drivers are freely available for development of software – also not strictly related with games (e.g., to support physiotherapy [9] and/or post-operative rehabilitation protocols). PrimeSense (the company in charge to design the Kinect hardware and to develop its real-time body tracking software) founded the OpenNI organization, intended to standardize software APIs and methodologies for any kind of devices providing a NUI. OpenNI drivers have been freely released for many operating systems [15]. In the same vein, Microsoft released its own official SDK (KinectSDK) under a non-for-profit license during spring 2011 [3]. When compared with the OpenNI framework, KinectSDK is a single platform product, but offers a better voice recognition and is able to start tracking the users without requiring a pre-determined setup position.

3. THE PROPOSED SOLUTION

Assoaqua needed an AmI solution able to support their multiple activities (among which physiotherapy) by allowing remote interaction, on a daily basis, with elders (especially those living alone) to assign exercises, to verify progresses in mobility, to monitor health/environmental parameters, etc. Providing all these functions implies the adoption, and the consequent integration, of a number of different devices and technologies, namely: domotics, support to social interaction, remote monitoring, audio-visual monitoring, movement and presence detection, humidity and temperature measurement. One of the main constraints of the project is to minimize the number of devices to be put in the elder's environment, in order to reduce to a minimum the interference in her private life.

In Fig. 1 we have sketched the general structure of the system that emerged from the design phase (see §3.1). For minimizing the intrusion in the elder's private life/home, we will install only one personal computer, in charge of providing the interface between her home and the caretakers (dashed lines represent wireless connections). Through this channel, data (environmental, medical, physiotherapy exercises, alerts, etc.) will be exchanged and the possibility to interact remotely with the caretakers supplied. More than one Kinect could be connected to the PC, e.g. in order to monitor elders status (if the elder falls and cannot get up, does not wake up in the morning, etc. an alert is issued) in a more fine-grained way than with usual movement sensors. The design and deployment of such a system calls for careful consideration of multiple aspects, not only related to the design of the overall hardware/software infrastructure, but also – and perhaps mainly – dealing with issues typical of the HCI discipline, like: usability, acceptability, affordance, etc.

In the present work we will first give an overall idea of the approach we have followed in the design of the prototype of the system, and then focus on the aspects specifically related to its general hardware/software infrastructure. More details on the HCI-related issues are described in [4].

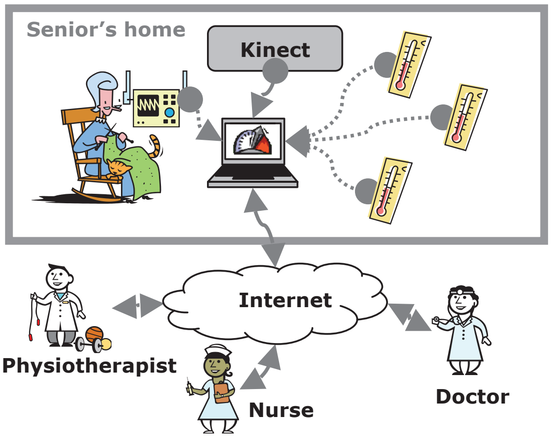
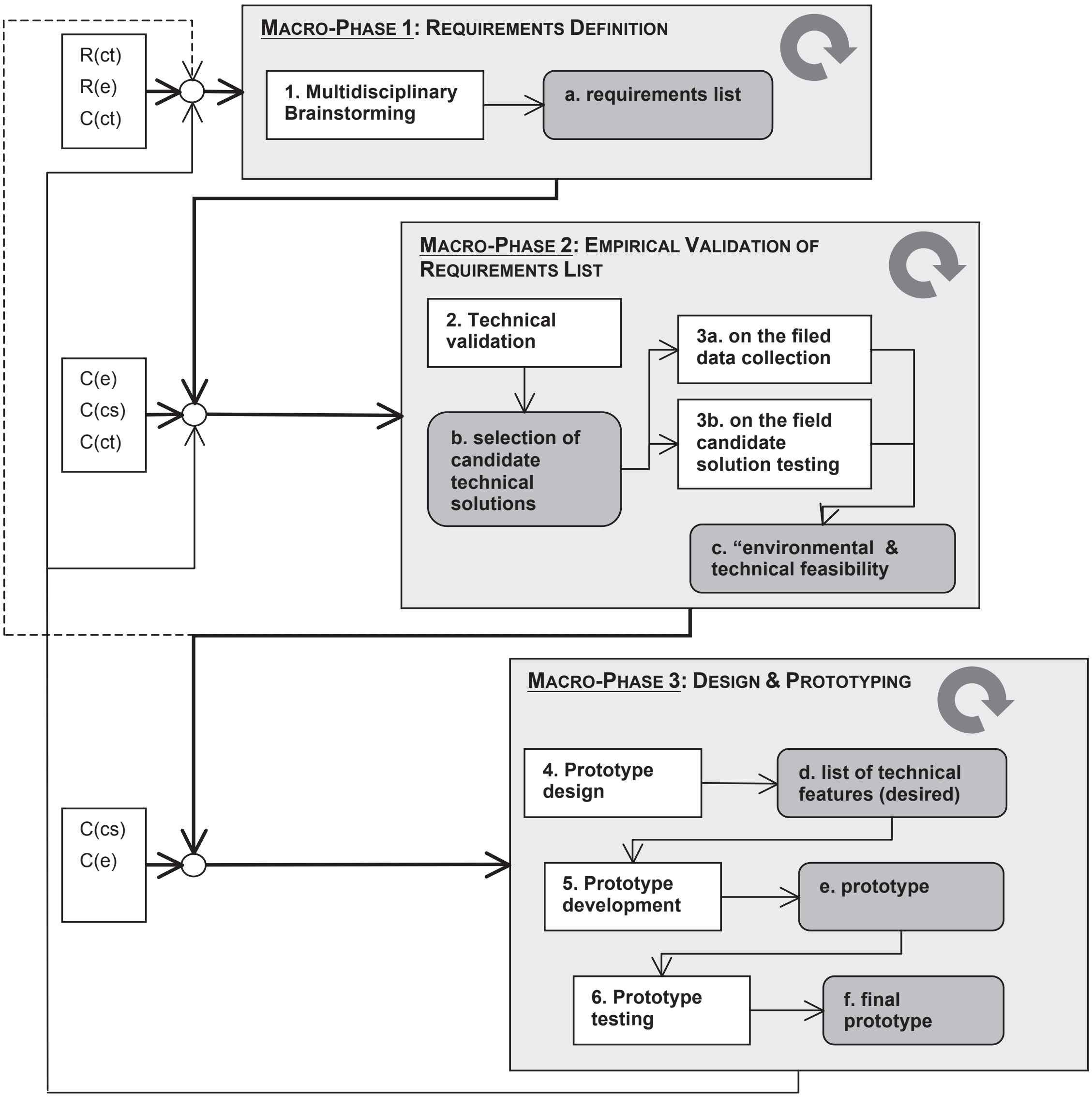


Figure 1: General structure of the system [4]

3.1 Methodological Approach to Design: the Dyad Elder-Caretaker

In the project framework, we have defined and tested an approach for supporting effectively the design phase of the AmI system [4]. Actually, one among the main critical points is to provide an interface (in the broader sense of the term) to the system that respects several mandatory constraints, such as being: enough friendly with elders, not obtrusive, resilient to unforeseeable behaviours, context aware, etc.

In our vision, and according to Dey approaches (see e.g. [5], [6]), these goals can be achieved only if the intended "user" (the *dyad elder-caretaker*, who can be – in different moments – a senior plus a doctor, a nurse or a physiotherapist), embedded in her environment, is put "at the centre" of the design process, especially during the definition of the *problem space* [18]. This implies analyzing also which the more diffused issues deriving from elders homes – at large – are (e.g. size of the rooms, presence of pets, habits and technological proficiency of domestic workers, etc.). For these reasons, it has been mandatory to explore requirements and constraints through an *immersive* approach. Hence we have deployed a methodological approach to the design (summarized in Fig.2, were *R* represents requirements, *C* constraints, *ct* the caretaker, *e* the elder, *cs* the computer scientist) that aims at intermingling tightly the different competencies present in the project (see table in Fig.2): those of the computer science with those of the caretakers-senior dyad. In particular, we have organized mixed teams (typically: a physiotherapist or a nurse and a computer scientist, or a physiotherapist, a nurse and a computer scientist) that conducted an on-the-field research to collect qualitative data about needs and constraints encountered by the dyad.



INVOLVEMENT OF DIFFERENT ACTORS IN THE MAIN PHASES OF THE PROCESS			
	COMPUTER SCIENTIST	ELDER	CARETAKER
1. Multidisciplinary Brainstorming	+	+	+++
2. Technical Validation	+++	+	+
3a. On the field data collection	++	+	+++
3b. On the field candidate solution testing	+++	++	++
4. Prototype design	+++	++	+
5. Prototype development	+++	+	+
6. Prototype testing	++	+++	+++

Figure 2: Methodological approach to the design phase [4]

This lead to the collection of information that could hardly have been figured out without immersing in the dyad environment [4], and that bud multiple multidisciplinary brainstorming, in order to define the most suitable interaction model and, subsequently, the candidate technological architecture. One among the main outcomes of this preliminary phase has been the selection of Ms Kinect as the primary device to support the NUI interaction model (and the subsequent exclusion of other alternatives, such as Sony Move and Nintendo Wii).

4. TECHNICAL ISSUES IN TRACKING SENIORS' MOVEMENTS

While collecting data on the field, several technical issues have come forward. A particularly relevant one regards the actual feasibility to use MS Kinect as a tool to support physiotherapy. As a matter of fact, quite often, physiotherapy exercises imply the necessity for a strict control on the angles formed while moving specific limbs (other way, the patient could hurt herself). To match this requirement, we have tested Kinect tracking precision using software applications, developed on the purpose, using both OpenNI and the official KinectSDK.

4.1 Evaluation of Tracking Error

As said before, the most critical issue is about measuring angles in the three dimensions. To verify Kinect precision on this matter we measure the error produced while tracking a 3D angle among shoulder, elbow and left hand. To guarantee consistence among data we have blocked the elbow joint with a wooden constraint (Fig. 3). The evaluation procedure is the same for all limbs; we selected an arm in order to minimize errors introduced by involuntary movements.

Figure 3: A 90° angle in the elbow

Data representing the position of the points (shoulder, elbow, and hand) are vectors [x,y,z], were *x* is the distance from the vertical plane that passes through the Kinect sensor, *y* the distance from the horizontal plane that passes through the Kinect sensor and *z* is the distance from the sensor. Through simple mathematical manipulation it is possible to verify that the following expression:

$$\arccos\left(\frac{V_1 \cdot V_2}{|V_1||V_2|}\right)\left(\frac{180}{\pi}\right)$$

can be used to calculate the angle between two 3D vectors, V_1 and V_2, sharing the same origin. The measurements have been collected in the following different conditions:

1 Limb is kept still and
 a there is natural light in the environment;
 b there is no light in the environment.
2 Limb is in movement and
 a there is overlapping among body parts;
 b there is no overlapping among body parts.

For all combinations we scanned the user using 30 frames per second and taking 10 samples per second over 10 seconds. We then evaluated the error from the supposed angle of 90 degrees.

Results from condition 1.a are reported in Fig. 4. From this figure we can observe that data from Kinect SDK are in general more stable and subject to a lower error. In particular, as it can be seen from the OpenNI measurements we found a considerable error to be sometimes a consequence of the wrist alignment (first half).

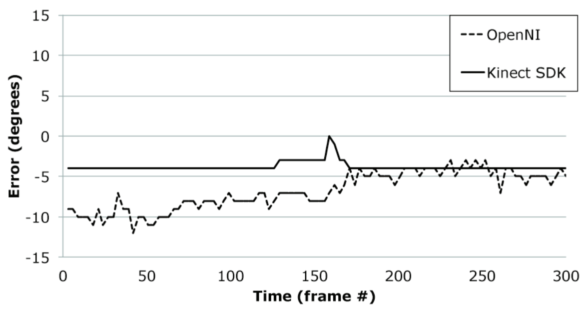


Figure 4: Kinect measurement error with still limb and normal light conditions

Experiments in condition 2.a are similar: error does not seem to be connected with light availability and may be still caused by wrist alignment.

With regard to measurement while moving a limb, results from experiments 1.b can be seen in Fig. 5. As it can be observed, error has increase considerably and we have two spikes (around frames 100 and 240) due to overlapping joints (elbow and shoulder).

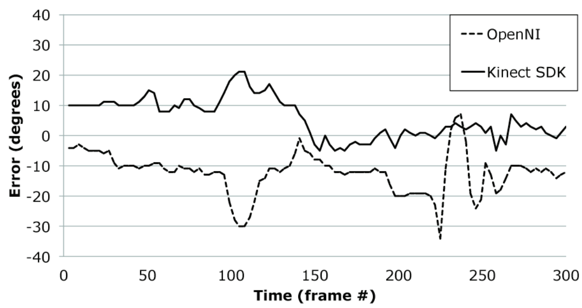


Figure 5: Kinect measurement error with limb in movement overlapped with the body

Other extensive tests have been performed getting closer to the sensor and scanning only the upper half of the body; results hinted that this will also reduce the relative error. Unfortunately, this option is only available with OpenNI. Nevertheless, all test results have underlined the major precision that can be achieved through applications developed using the official Kinect SDK. This SDK has therefore been elected as development environment for our prototype implementation.

5. A PROTOTYPE IMPLEMENTATION

We developed a prototypal application for supporting remote interaction between patient and physiotherapist while executing exercises related to a therapy. This development requires taking into account issues ranging from technical constraints to those related to psychological aspects (e.g., acceptance). In this section we will focus on the technical issues. In particular, during the first phases of the design process, a number of problems emerged, among which the major ones are:

1 Kinect-related problems:
   - a Latency while generating the skeleton: movements produced by the generated skeleton have quite always a little delay
   - b Computation is CPU-intensive: from time to time added delay is introduced by intensive calculation
   - c Intense sun rays reflection on the floor may interfere with infrared used by the sensor to create the deepness map

2 Room/patient-related problems:
   - a Not enough space in the room to allow a correct long-length recognition
   - b Garments (e.g. skirts) interfering with a correct skeleton recognition
   - c 60% of exercises require the patient being in horizontal position, thus excluding the possibility to trace their skeleton.

5.1 Choosing the Rehabilitative Path to Support

Once the range of possible problems and constraints to deal with has been defined, our attention focused on choosing, together with the physiotherapists, the most appropriate rehabilitative path to support. Given the constraints described above, the most viable solution seemed to be to support patients in need for a maintenance therapy aimed to reacquiring muscular resistance after the recovery from fracture of the femur, total knee arthroplasty, or managing exacerbation of arthritis. Moreover, since the rehabilitative path is not standardized, but tailored around the specific needs of every patient, we have decided to develop a software application which is able to manage exercises described by the doctor and provided as input. The prototype application includes a bunch of sample exercises which are meaningful for the rehabilitative paths mentioned above. We are currently implementing: abduction, hip extension, and triple flexion (and return) of the ankle, knee and hip.

5.2 On the Senior Side

The software on the senior side has been planned focusing on simplicity: the interface will react to vocal commands, the number of possible directives has been kept to a minimum, and for each recognized command there is an immediate visual feedback. Moreover, when the tracking system is active, the image coming from the camera and the skeleton tracking are shown (see Fig. 6).

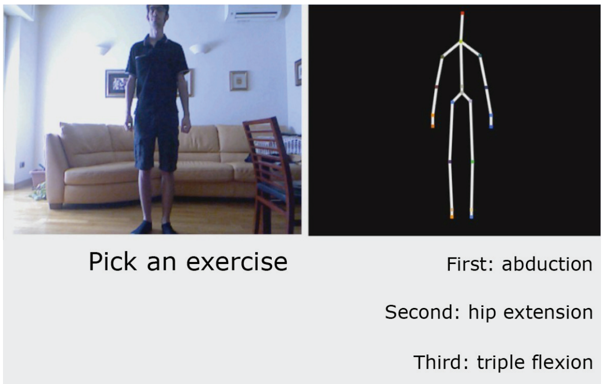


Figure 6: Initial interface with tracking active

The program has been implemented using Windows Presentation Foundation (WPF) and C#. With WPF the interface is defined by means of a particular XML file taking, by convention, the extension *xaml*. The core or our system is a class called *MainWindow* taking care to manage the interface (as described by the XAML file) and the Kinect hardware. From this class, two secondary classes are instantiated and run in separate threads. The first class, called *Recognizer*, takes care to identify vocal commands, while the second one, called *ExerciseData*, is managing exercise data. Figure 7 shows a simple block diagram for the application.

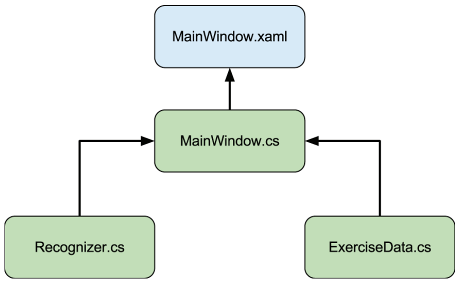


Figure 7: Application classes' dependence

The recognizer thread hooks to the device microphone and keeps on recognizing audio input. When an audio burst different from background noise is received, it is checked against an internal dictionary. If a positive match is found in the dictionary, an asynchronous signal is sent to the main thread, reporting the matching sequence and a confidence index about the recognition.

The last class is a container for exercise data: sequences of skeleton positions detected from the main thread are checked against a reference description, to validate the exercise correctness.

When an exercise is selected, a specific subclass of *ExerciseData* is instantiated and the sequence of skeleton position starts to get checked (see Fig. 8) using it. This kind of approach makes the software easily extendible to new exercises: all we need to do is to create a new specific subclass for every exercise to be added. Moreover, any class can implement its own checking policy and focus on monitoring specific postures, which may be critical for the current exercise.

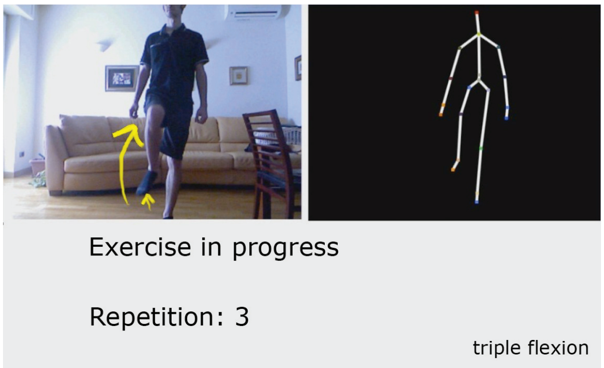


Figure 8: Real-time skeleton tracking

If, while performing an exercise, the skeleton is too off the required asset, the wireframe is drawn in red and an alarm is immediately raised on the screen; see Fig. 9 for an example. Of course, sometimes it may happen that the senior is not able to recover from a wrong posture and will loose balance. In such cases we implemented a fall detector, which will raise an alarm and call for assistance (see Fig. 10). In particular, the fall detector has been implemented in the main class and will work with any kind of exercise.

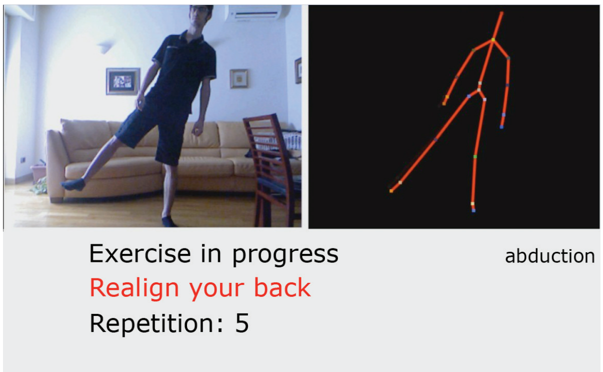


Figure 9: A wrong position is detected while performing an exercise

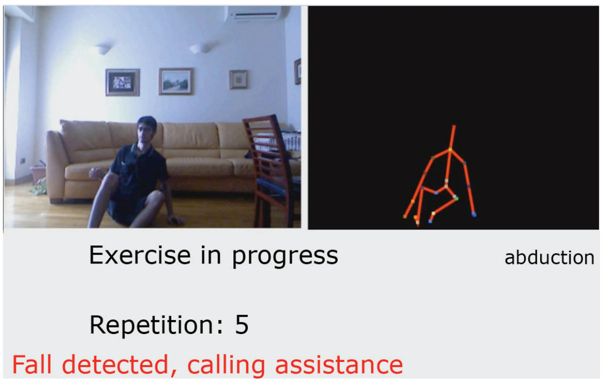


Figure 10: Fall detection triggers an alarm

One last feature of the system is about a log facility: exercises can be recorded and then reproduced at a later time by the doctor, in the case a deeper evaluation is required.

5.3 Communication with the Caretaker

The system described so far may be a valid stand-alone solution but, in order to become truly effective, it must become part of a larger, distributed, architecture. With this goal in mind, during our research we devised also a network infrastructure, which will be able to connect multiple homes to a centralized control center. The general architecture for this network infrastructure is described in Fig. 11. As we can see, there are many more elements participating to the process.

In the house of the patient (right hand of the picture) there is a Kinect as well as other sensors, which may be monitoring health parameters of the users (e.g., heart rhythm, blood pressure, and skin hydration) or the surrounding environment (e.g., temperature and humidity). All these sensors can be radio equipped for wireless communication with a local management point. This local manager has been called *DeviceProxy* because its purpose is to work as a hub between the local instrumentation and the remote control center.

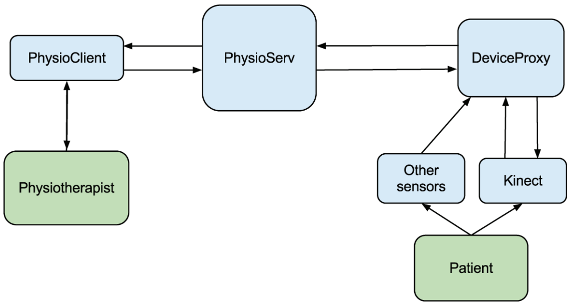


Figure 11: Network architecture to connect the home with a centralized control center

The DeviceProxy will connect to a remote server (*PhysioServ* in the picture) by means of DSL or other residential access technology. The PhysioServ, which is located in the service-provider datacenter, will periodically connect to each DeviceProxy to collect statistics and check equipment status. On the other hand, the DeviceProxy can also connect to the PhysioServ to raise an alarm (such as a fall event or a health/environmental parameter going out of the security range) or to request remote monitoring during an exercise. The PhysioServ is in charge to coordinate all the information regarding patients and store them in a secure way. The last element on the left side of Fig. 11 is the *PhysioClient*: the software used by the caretaker to connect to the PhysioServ and interact with each single DeviceProxy. The PhysioClient prototypal interface is shown in Fig. 12 and Fig. 13.

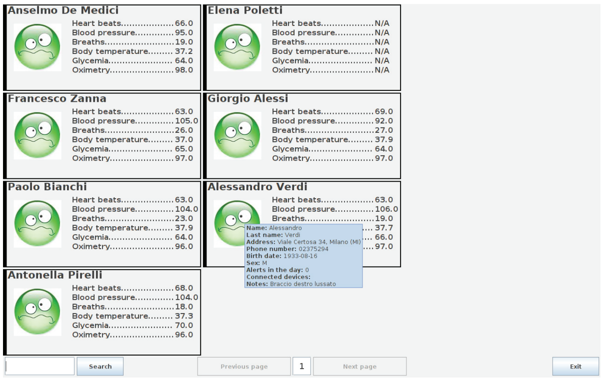


Figure 12: The PhysioClient prototypal interface while monitoring users' health parameters

Figure 12 shows a number of patients under monitoring: in each box health parameters are reported for the patient, and a green indicator means that none of them are out of scale.

In Fig. 13 the operator selected a number of users to observe while performing exercises. Each column is divided into three sections: at the top there is the image capture by the Kinect device (when available), in the center we can see a log of recent activity and, in the lower part, we can have buttons to interact with the patient. An emergency condition is immediately notified to the operator by putting a red frame (such as the second column) and with an audio signal.

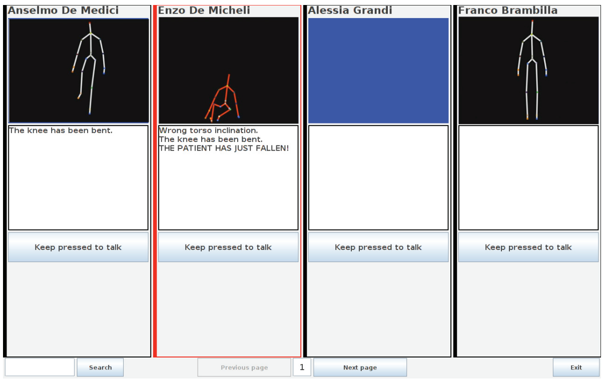


Figure 13: The PhysioClient interface while observing users during exercises

Both DeviceProxy and PhysioClient are required to authenticate top the PhysioServ. While the PhysioClient is somewhat secured at the service provider premises and we can ask physiotherapists to use a password to log in the system, the same does not hold on the patient side. To manage security we implemented a password mechanism on the PhysioClient side and we are planning to build a public-key authentication system bound to the hardware device on the DeviceProxy.

The communication protocol is one of the most important parts in the system. While we can assume PhysioClient and PhysioServ well connected through a LAN, the DeviceProxy may be poorly connected, and will almost certainly suffer from frequent disconnections due to its DSL (or worst) access network. Moreover, no assumptions can be made on which kind of traffic the ISP will let the user send and receive.

To overcome some of the aforementioned limitations we devised our protocol as an extension of HTTP [8]. This way, our communication can be firewall-friendly, secure transmission can be easily managed using HTTPS [17], and provide asynchronous messaging via a string oriented protocol relying on the JSON format for data exchange.

Apparently, the last open issue is about the frequent disconnections. This has been solved by managing sessions at application level using cookies and sending keep-alive messages. The state diagram for connection management at DeviceProxy is reported in Fig. 14.

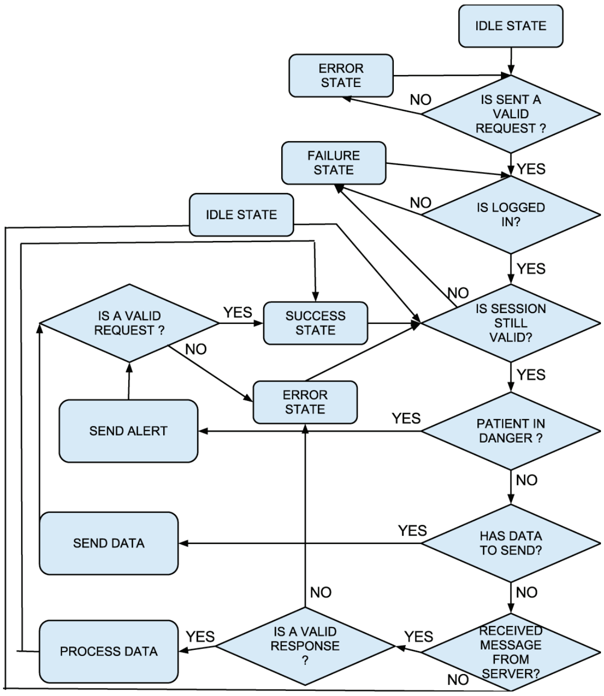


Figure 14: State diagram for connection management at DeviceProxy

6. CONCLUSION AND ONGOING WORK

In the present work we have presented the intermediate outcomes of an ongoing project aimed at supporting remote LTC for seniors. In particular we have summarized the innovative approach to the design of the system we have adopted, the major technical issues arising from the necessity to track seniors' movements in their homes, and the overall distributed infrastructure of the system.

We are now confronting with new issues. On the senior side, we have to design and prototype a sufficiently compelling serious game (that should guarantee a certain degree of motivation while performing exercises). In the same vein, we have to integrate physical and environmental sensors into the envisaged system deployed at the seniors' home. On the caretakers' side, we have to design and prototype an effective interface for monitoring remotely patients (legal issues should be taken into account too, such as privacy, responsibility, etc.). On the server side, we have to deal with the problem of disconnections. And, last but not least, once the whole prototype, we intend to undergo a testing phase with real patients under the supervision of Assoaqua medical personnel.

7. ACKNOWLEDGMENTS

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