Mobile@Old: A Smart Home Platform for Enhancing the Elderly Mobility

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***Abstract*—Regular physical exercises are widely considered to be a key factor for living a healthy life. In this paper we present Mobile@Old, an integrated platform for assisting elderly people to maintain a healthy lifestyle in their homes. Our aim is to highlight the main concepts, technologies, and findings this system rests on. To this end we integrate Mobile@Old in the general conceptual framework of serious games. We provide details about the designing and implementation of Vital Signs Monitoring (VSM) and Physical Activity Trainer (PAT) components of Mobile@Old. Relevant exercises and utilization scenarios are also presented in order to emphases the practical applicability of our approach. We evaluate the usability of platform using the System Usability Scale (SUS). Experimental data regarding the accuracy of whole body movements are also presented.**

***Index Terms*—smart homes, gesture recognition, health information management, knowledge engineering, affective computing.**

I. Introduction

Regular physical exercises seem to be one of most important habit for living a healthy and joyful life. Despite significant differences every age brings to someone's life, the physical activity remains a general framework for dealing with all levels of human needs as they were formulated by the Abraham Maslow [1]: basic physiological reactions (e.g. feed, sleep, homeostasis) [2,3], personal safety [4], social relationship [5], self-confidence [6], problem solving [7], aesthetic needs, and self-accomplishment [8]. In its reports, World Health Organisation presents physical inactivity as "the fourth leading risk factor for global mortality" [9]. It also emphases the causality relation between physical inactivity and "cancer, cardiorespiratory, metabolic, musculoskeletal, and functional health" [9]. All these findings make the World Health Organisation to state that "regular physical activity reduces the risk of coronary heart disease and stroke, diabetes, hypertension, colon cancer, breast cancer and depression. Additionally, physical activity is a key determinant of energy expenditure, and thus is fundamental to energy balance and weight control" [9]. These considerations lead to the conclusion that maintaining a satisfactory level of physical activity becomes critical even for elderly people. However, due to health problems, general lack of energy or social conformism, the increasing of age often comes hand in hand with the decreasing of availability for making physical activity [10]. A negative feed-back mechanism emerges since the less physical activity someone performs, the bigger the causing factors become. It requires specific and specialized intervention in order to determine inactive elderly to regularly perform physical exercises.

The development of an informatics system that support (i.e. guide, monitors, and encourage) elderly to perform individual and/or group physical exercises seems to be an accessible and robust solution for all the problems stated above [11, 12]. The health issues can be integrated in the therapeutic process by real-time adapting the exercises' type, amplitude and speed to the person's age, physical capabilities, and emotional state. Moreover, the difficulty of exercises can be gradually increased in agreement with previous attempts. Appropriated audio-visual stimuli (e.g. virtual animated models) and a challenging but rewarding environment can enhance the availability for performing exercises. Finally, the social conformism can become a great ally especially in the case of group activities.

In this article, we present the demonstration model of Mobile@Old as a solution for encouraging the physical activity and for improving the mobility of elderly people. Our contributions are as follows: (1) the design and implementation of Vital Signs Monitoring (VSM) and Physical Activity Trainer (PAT) as the core components of Mobile@Old platform (2) the development of exercises and utilisation scenarios that are adapted to the age, health condition, and emotional state of elderly (3) an usability evaluation of Mobile@Old by applying questionnaires based on the System Usability Scale (SUS), (4) an experimental evaluation of accuracy of body movements during the exercises.

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II. Related Work

A. Serious Games for Elderly

Based on recent studies, playing games can improve the eye-hand coordination, slow down memory loss or increase physical mobility. Serious Games are considered a new non-medical measure for elderly, allowing them maintaining good health conditions by playing cognitive and physical exercises. Serious games can be described as ”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” [13].

Also, in these cases, user’s motivation is a main common problem that must be addressed. There are proposed games for stimulating user’s cognitive function or training their physical condition. Also, several games were proposed for rehabilitation in case of different disease (Parkinson, Alzheimer or post stroke rehabilitation). A study performed in the AAL Project Join-In [14] concluded that although it is not perfect, the Microsoft Kinect is the most suitable device for exergames for elderly. This is also the best tool to capture the movements properly and thus ensuring that exercises are performed correctly.

Paper [15] describes a system that can initiate elderly people into serious games. The proposed system interacts with the user through an interface with an animated avatar, accompanying the user into a therapeutic game. The system was evaluated with 19 participants that are recruited during their memory consultation. Three of them were mobility impaired and one of them has understanding disorders of understanding for 2 others, did not manage to interact with the system. It was evaluated the influence of the interface on the user interaction with the system through a questionnaire with different characteristics: avatar appearance, its gestures, its voice as well as the content of its communication. The results shown that the avatar established a collaboration relation with the user throughout the interaction.

There are approaches that develop games for improving elderly conditions (mental or physical) that addressed different disease (for example Alzheimer or Parkinson diseases). X-Torp, presented in [16], allows the patients suffering from the Alzheimer’s disease to train their cognitive capacities by realizing the exercises in the form of missions integrated into the game.

Online-Gym [17] is a platform that allows users make on-line physical exercises, interacting with each other during the on-line session. The exercises are captured using a Microsoft Kinect. The interaction through users is made in OpenSimulator or Second Life virtual worlds.

In [18] is presented a home-based rehabilitation system based on Kinect sensor that assists patients in conducting safe and effective home-based rehabilitation without the immediate supervision of a physician. There are different exercises recorded by a physician that must be reproduced by the user at his home. The user movements are compared and aligned using a Dynamic Time Warping (DTW) algorithm and fuzzy logic. Also the system evaluates the patient’s performance based on his trajectory and speed using fuzzy inference.

In GameUp project [19] there were developed seven mini exergames for training mobility (for the trunk), strength (abductor, calf and quadriceps muscles), and balance of elderly people using a Kinect sensor. The project uses a Fitbit sensor associated with the user that is capable to track the number of steps, stairs climbed, distance traveled and calories burned every day. The aim of this tracker is to encourage the patient, through a real-time feedback to be more active.

Gerling et al., [20] investigated the differences between motion-based (i.e. whole body gestures) and sedentary interfaces. They used regular devices such as mouse and Xbox 360 gamepad for static interaction and Sony PlayStation Move and Kinect as dynamic interfaces. The users’ performance was assessed during three basic tasks: pointing, steering, and tracking. The experiment involved 33 participants, 17 being between 62 and 86 years old. The results shown that although the elderly obtained significantly lower results than young people, they were able to efficiently use their body in order to interact with a computer. Moreover, they liked to use motion-based interfaces in spite of the fact that they feel significantly more tired after using this type of interaction compared to the classic one.

Another attempt to monitor the physical activity of elderly people is the Step-Kinnection system [21]. In addition with the gait assessment, the risk of falling was also evaluated through the Choice Stepping Reaction Time (CSRT) test. The movements were collected using the Kinect sensor and only the feet representation was displayed. The participants were asked to step over some regions that changed the colour on the screen. Parallel cognitive exercises such as reading or answering a question can increase the overall difficulty of the task.

Rice et al [22] investigated the people abilities to cooperate through whole-body movements interfaces. The participants (60 people of 15-20 and 55-75 years old) were divided in three groups: young-young, young-elderly, and elderly-elderly. The results shown that the first group (i.e. young-young) performed significantly better than the third one. However, the fact that the elderly from the mixt group performed significantly better than those from the third group emphases the importance of supportive attitude.

B. Vital Signs Monitoring

The rapid growth in technology enhanced the remote health monitoring systems. These systems are based especially on the advanced wireless and wearable sensor technologies. Such systems are useful due to the possibility of offering cost efficient healthcare services. Also, wearable technology has an important role in healthcare monitoring systems, due to their low cost. For example in cardiovascular diseases and heart failure, the weight is important to follow. A sudden increase in weight can indicate fluid accumulation in the body, which should be reduced. Blood pressure is another important parameter to monitor, as well as pulse rate and arrhythmias. Arrhythmias increases the risk of stroke. ECG will give information both on the heart rhythm and the status of the myocardium of the heart (the accuracy depends on the number of leads). Also oxygen saturation can be an essential parameter to monitor for this group. In diabetes, blood glucose level is of major importance to monitor, buy also weight and blood pressure are important to follow. Diabetes is also a major risk factor for coronary heart disease and stroke.

There are different Ambient Assisted Living (AAL) or European Unit projects that developed systems for health monitoring at home. All these systems will improve the quality of life for elderly people by increasing their freedom and safety.

For example, AAL project CAALYX [23] offers health monitoring at home for elderly people with multiple chronic conditions by promptly detecting and controlling any decompensation episodes. Thus people can have an independent life in their homes, decreasing periods of hospitalisation. Another AAL project Health@Home [24] uses wearable sensors for monitoring patients' cardiovascular and respiratory functions. The gathered data is continuously monitored by an automatic processing system and accessible by the medical staff, who can take action in case of necessity or caregivers.

The REACTION [25] solution was developed based on integrated ICT with personal integrated care to support diabetes management in both short-term risk and long-term management not only in the hospital but also at patients home. The platform supports physiology measurement as: Blood glucose, Blood pressure, Oximetry and weight.

LinkWatch [26] is an intelligent platform for medical data collection as well as monitoring of patients at their home. The platform enables monitoring of vital signs as well as weight and physical activities. The data can be collected via touch PC, tablet or hidden data receiver based on individual interest of technologies and needs. The platform enables data acquisition equipment through an engine that consists of LinkWatch TeleMonitoring for using of long-term user-driven design process. The physical measurements of patients and activities will be transmitted automatically into the platform, completely. The patient can allow measurements or reject them, as confirmations. LinkWatch also supports monitoring of peak flow meter, blood glucose meter, blood pressure, Pedometer, Heart Rare, ECG.

A system for monitoring heart rate using a wearable sensor together with mobile technology by developing a remote monitoring system for heart patients is given in paper [27]. The wearable sensor collects data and generates patient's diagnostic information which is then transferred to a smartphone wirelessly via Bluetooth. The system can generate emergency alerts informing the doctor if there is something wrong.

Based on the existing solution described in this section, the Mobile@Old platform will combine health monitoring with a game for stimulating physical exercises adapted to elderly people. The health monitoring component gathers medical data from different sensors, process all collected data and generates reminders in case of an emergency. The reminder component is implemented as a multimodal interface adapted to elderly needs using gesture or voice commands. The type of the physical exercises recommended to the elderly people is selected according to the medical user profile. The type of the exercise is adapted based on the user's emotion recognized during the exergame session.

III. Technical Description of Mobile@Old Platform

A. *Platform Architecture*

The Mobile@Old platform proposed an integrated system offering to elderly people – it offers a game adapted for elderly people, in order to maintain a healthy lifestyle, tracking the level of their physical activity. Also the platform will take care of their medical parameters, providing them reminders about their medical status. As described in [28], the system is composed of two main components: *Vital Signs Monitoring* - VSM and *Physical Activity Trainer* - PAT (Figure 1).

Vital Signs Monitoring is responsible with medical parameters monitoring. A user profile will be set up by a physician. Also, different medical parameters can be automatically measured (for example, heart rate, pulse rate will be automatically measured through different sensors, pulse oximeter).

Physical Activity Trainer is responsible for recommendation of physical exercises using medical expertise and observed behavior. The module will recognize the performed exercises. The level and type of the exercise is adapted based both on the delay detected in exercise performed by the user (as given in [29]) and on the emotion recognized from the face expressions of the user (as described in [30]). The physical exercises will be created using a personal avatar with Kinect sensor.

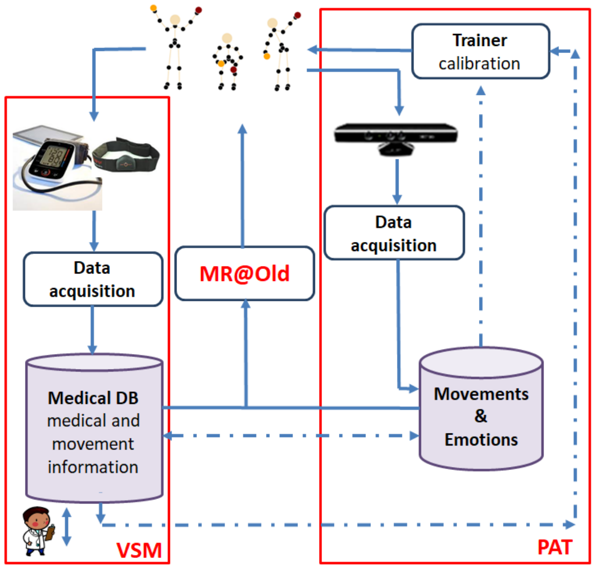

Figure 1. Mobile@Old architecture

Both components are connected through a reminder tool (MR@Old) - related to the health condition of the elderly user [31]. It is developed as a user interface focused on memory related factors. The interface has elderly as the main targeted users and will play a critical role in the acceptance of the system by them. It should be adapted both to the preferences of the elderly people and to the environment, supporting multiple types of interactions. In our case, the multimodal interface respects these special requirements and allows users' to command the system through speech or gesture in addition to traditional input methods. The system will generate visual or phonetical outputs to communicate with the user.

B. Physical Activity Trainer

The aim of the Physical Activity Trainer (PAT) is to monitor the elderly people during the physical exercises [32, 33]. It computes the joints relative positioning errors between the real whole body movements of participant and the movements proposed by an impersonal silhouette. The visual data are collected from a Kinect sensor (Figure 2) by extracting relevant information from the depth and skeleton streams. These data streams are precisely enough to find the location of joints but, in the same time, they hide personal details such as face, clothes, and environment.

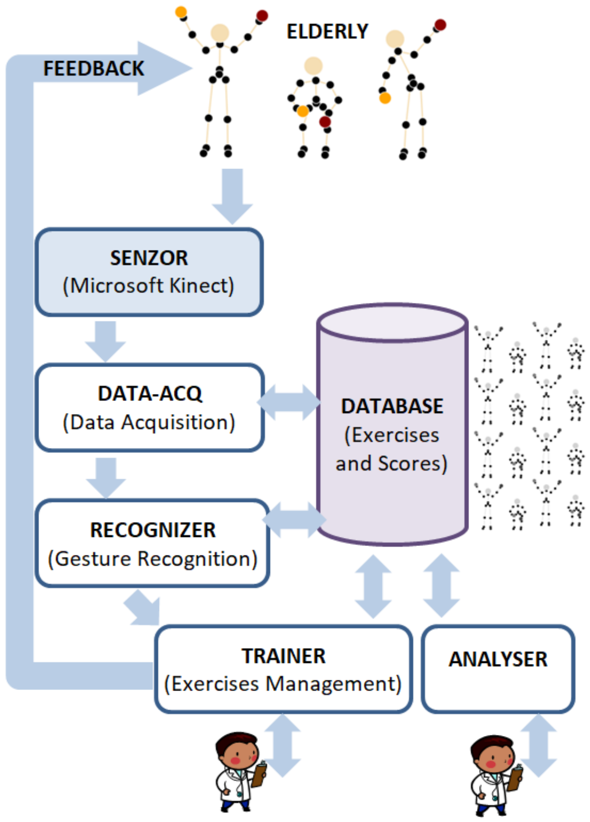

Figure 2. Physical Activity Trainer Architecture

The DATA-ACQ module receives information from the Kinect sensor and translates them in an internal format. Afterwards, the gestures (training and testing sets), the exercises, and the participants' scores are stored into the DATABASE. This information is further used by the RECOGNIZER module in order to classify the participants gestures. The recording and management of exercises are implemented by the TRAINER component of PAT. The assessment of participants' performance during the physical activity is performed by the ANALYSER module.

The similarity between the real and the referential gestures was computed using the Dynamic Time Warping (DTW) algorithm. The DTW virtually aligns the two gestures in order to find out the geometrical distance between similar joints in the postures. Moreover, a new methodology for measuring the agreement on gesture performance [34, 35] was used to obtain a better understanding of similarity across multiple participants. We designed the modules of PAT component so that to be compatible with the Spatially-Indexed Media concept [36] and easily integrated in the architecture of a smart environment.

C. Vital Signs Monitoring

VSM module as a part of Mobile@Old platform has 3 actors involved in elderly monitoring and treatment: doctor, kinetotherapist and caregiver (Figure 3). Doctor is core of VSM make elder's examination (step 1) and fill the table Daily_Habit, Elder_Disease, Disease_Type, Generic_Drug, Drug, Normal_Analysis, Schedule for LAB Analyse from Data Repository of Mobile@Old platform (step 2). He/she can indicate or change medication, can add, modify or delete the elder's records and/or fields from several tables, according to personalized medicine and elderly health parameters and doctors decide the time management for the medication (morning/ lunch /evening, weekdays, before the meal / how long before lunch / afternoon / after the meal), indications and contraindications for exercise and daily activities at home, and follow and decide prescriptions based on Analysis, Medication Administration and History table. This table is core of MR@Old mobile application as a source for message reminders for medication, analysis and reminder.

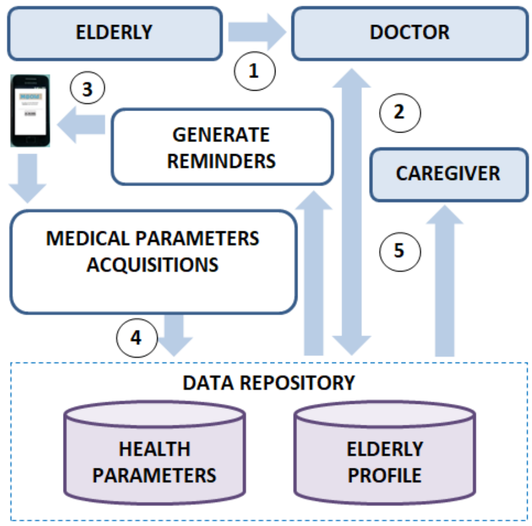

Figure 3. Vital Signs Monitoring Architecture

Based on Elder profile several messages are sent daily to the elderly, to take a medication at the correct time, according to Daily_Habit, Elder_Disease (step 3). Medication management is a core functionality of MR@Old application and use elders personal data from Analysis, Medication Administration and History table.

Based on information from Normal_Analysis and Schedule for LAB Analyze, MR@Old offers warning message for appointment (step 3). In addition elders can use location button for GPS localization and SOS button for Personal Emergency Response System (PERS). These functions feet to elders with Age-Associated Memory Impairment (AAMI) and Mild Cognitive Impairment (MCI). AAMI is a normal ageing-related decline in cognitive functions, resulting in mild forgetfulness. Mild Cognitive Impairment (MCI) can be considered as a more-than-average cognitive decline of an elderly person, and it has a chance of developing into Alzheimer's disease (AD) [37].

Another message is related to daily health parameters (body temperature, blood pressure, pulse rate, bless, blood sugar). Senior sends via mobile application MR@Old these values (step 4) which is compared Normal_Analysis table.

This table has personalized values for each senior (minimum and maximum) depending on sex, age, chronically diseases and other factors [38]. If superior or inferior limit of one of these analyses is exceeded, Mobile@Old web application will send an automatic Alarm message to doctor and caregiver (step 5). If senior cannot use MR@Old application, communication between Mobile@Old platform can MR@Old mobile application can done by caregiver associated with senior, based on configuration settings of Mobile@Old platform. We mention that between doctor and senior and between caregiver and senior has 1-n association. In normal situation, trustee rights for Caregiver is read only for Daily_Habit, Elder_Disease, Disease_Type and Normal_Analysis tables and update fields in Analysis, Medication Administration and History table.

Any abnormal cases of daily self-evaluation are sending to doctor and kinetotherapist or caregiver, depending on internal classification in tables from Data Repository. If these abnormal health states appeared after exergame program kinetotherapist must decide subsequent conduct, according to doctor decision. We pointed several of them: feel tiredness, get tired after exercise, feel bad, muscle hurt, head ach, losing balance, throat hurt, joint hurt [39,40].

Other elders health pain or frequent inconvenience can be: feel fever, losing thinking capability, losing concentration, could not sleep well, cannot recover after sleep, cannot think deeply, sleep for too long time, unconfident about health, feel depression, do not want to work, limper hurt, cannot remember something. In this case only doctor can decide treatment or supplementary heath evaluations [38, 39].

Kinetotherapist indicates medical exercise for recovery or maintenance and supervises their implementation, monitoring the patient's progress and recovery scheme adapted to their needs and progress via VSM. The main role is to follow doctors' recommendations from elders database tables and access several table as: Exercise_Type, and Exercise_details for add, modify or delete elders' personalized exercises records and/or fields from.

Before and after seniors finished exergame program, they send health parameters (step 4) and other symptoms from MR@Old. Kinetotherapist received elderly health parameters (step 4) and other symptoms from MR@Old and PAT and decided to continue ore stop exercises program.

Unfortunately out of the elderly that participated in our study, only 8 out of 69 (12%) accepted to monitor their health parameters using the mobile application made available to them and only 4 out of 69 (6%) accepted monitoring via Kinect. In this case is difficult to assume usability of PAT from elders point of view. By the other side a significant number of the participants have intense daily outdoor activity (more than 5 hours a day), e.g. gardening, especially in the case of those from rural areas (12 out of 19 seniors from rural areas). These activities qualify as ADLs, and are equivalent to the 7 exergames designed by the GameUp project, for mobility, strength and balance.

We consider the following medical parameters: blood pressure – systolic and diastolic, blood glucose level, oxygen saturation, ear temperature. We use the following sensors:

- Blood pressure and glucometer – Foracare sensor (model D40b);
- Oximeter sensor – Nonin (model Onyx II 9560);
- Thermometer sensor Omron.

All sensors transfer data using Bluetooth through the databases that collecting medical parameters.

D. Exercises

In order to implement the Mobile@Old platform we consider the following scenario: An elderly people contact doctor for medical evaluation and prescription. Doctor recommended all investigations and analysis necessary, than fill report in Mobile@Old forms, related to *Elder_Disease, Disease_Type, Generic_Drug, Drug, Daily_Habit* and make some restrictions if elder has one or more chronically diseases. Also he/she recommended *Normal_Analysis* and Schedule for LAB Analyse which became source of messages in MR@Old mobile application. Daily elder receive a message for daily health parameters (body temperature, blood pressure, pulse rate, bless, blood sugar). If senior has others symptoms like headache, feel bad, muscle hurt, he/she can choose easy from drop down menu associated to Reminder function (step 3 and step 4 – from Figure 3). Kinetotherapist read doctors recommendations and make an exergame program according to existing chronically diseases. The elderly people makes daily exercises based on personalized program, and sends daily health parameters before and after finished the exergame program. He/she will send these values via MR@Old. Mobile@Old platform will compare actual values with *Normal_Analysis* table and if exceeds the age and sex values a trigger action and MR@Old send Alarm message to doctor and kinetotherapist (step 5, from Figure 3). In this case kinetotherapist will ended elder exergame program.

The exercise performed by the user is designed as a game using two avatars: a user avatar and a trainer avatar (a screenshot of the game is given in Figure 4). The user must reproduce the movements of the trainer avatar. The trainer movements are recorded based on the recommendations of a kinetotherapist. The user movements are captured using a Kinect sensor and mapped on his avatar. Then the user and the trainer movements are compared using Dynamic Time Wrapping providing a score that will be displayed to the user in a friendly manner. After that, all data will be saved in logs for each user in order to track their evolution.

Figure 4. Screenshot from the game

After the user's movements are captured by the physical Kinect sensor, the raw data is transferred to the Unity 3D [41] game engine via Kinect's API, at a rate of 30 frames per second. To interpret it, a library [42] that provides a wrapper over the default SDK was used. The library is aggregating a large number of methods for computing various vital information, such as user's position relative to the camera, joint orientation, testing whether the user is tracked or left the scene, and, generally, maintaining consistency in the environment. It collects key-data (such as joint coordinates or orientations and user's distance) which is then filtered and transferred to the avatar. Apart from the actual code that does specific computations, the Unity game engine alone resolves issues of collision detection and physics compliance regarding the 3D model.

One very important aspect of the script that performs the actual calculations in order to animate the avatar is the loose coupling relative to the avatar's joint hierarchy. The script requires the Animator type (in Unity), facilitating the mapping between the standard Kinect skeleton's joints and the 3D model's joints.

User' emotions are analyzed from the features extracted from the user face. RGB images obtained from the Kinect sensor. Emotions are recognized using features extracted from the user's face: reference points from face and intensities of the action units. Data acquisition is realized using Microsoft.Kinect.Face and Microsoft.Kinect [43]. Image acquired from Kinect. Microsoft.Kinect.Face detects 1000 reference points from the user 's face. Only 51 points are selected in order to recognize user's emotions: 5 points for each eye brow, 6 points for each eye, 11 points for nose and 20 points for mouth. These 51 points are mapped to action units (AU) associated to the basic emotions. Emotion recognition is performed using FACS [44] – there are 7 basic emotions and each emotion is described using different action units. As described in [30] we use 19 action units in order to perform emotion recognition. Thus 19 support vector regression networks (SVR) are used for computing intensities of the action units.

IV. RESULTS AND DISCUSSIONS

A. VSM Evaluation

Measured health data are presented along with predefined threshold values stored in the profile of each user. The threshold values can be default values indicated by the manufacturer of the medical device used to acquire the measurements. Alternatively, the values can be defined by a medical practitioner for a given user. For example, users without pulmonary pathologies should have oxygen saturation levels in the range 95-99%. However, for users with various pathologies (e.g. asthma) lower values might be acceptable. Normal threshold values for the integrated devices are:

- Blood pressure ranges: systolic < 140 mmHg; diastolic < 90 mmHg;
- Blood glucose levels: normal between 70-119 mg/dl (3.9-6.6 mmol/l). Values lower than 26-69 mg/dl (1.1-3.8 mmol/l) indicate hypoglycemia while higher than 120 mg/dl (6.6 mmol/l) indicate hyperglycemia;
- Normal values for oxygen saturation levels are between 95 – 99 %;
- Normal ear temperature < 37.6 C;
- Typical resting heart rate in adults is 60–80 beats per minute.

While there are no threshold values for body weight, this can be in some cases a relevant parameter signaling a critical condition. For example, a sudden increase in body weight can indicate water retention due to kidney or heart failure. It is also important to note that although hyperglycemic episodes are producing long term damaging effects in the body, the more critical ones are hypoglycemic episodes. Symptoms of hypoglycemia include shakiness, nervousness, palpitations, sweating, nausea, etc. While, these are rarely fatal, ignoring them for too long can lead to loss of consciousness and fatal accidents.

We made a usability study for Mobile@Old platform using a user questionnaire. Our usability study focused on 9 seniors as computer literate users (CLU), from urban and rural areas, which accepted to monitor their health parameters using the mobile application made available to them and only 4 out of accepted monitoring via Kinect. For them we apply SUS questionnaire regarding MR@Old application, which cover several important features: reminder (REM) for medication management, health tracking and monitoring daily parameters (VSM), safety application for seniors who live alone and thus can get help from loved ones.

SUS questionnaire provide 10 standard statements (Q1-Q10) with 5 response options (5-point Likert scale with anchors for Strongly agree and Strongly disagree) and recommended range is: Non Acceptable for score 0-64, Acceptable for 65-84 and Excellent for 85-100 [40]. Our responders obtained scores between 57 and 89, average 77 situated MR@Old in Acceptable category. At Q10 "I needed to learn a lot of things before I could get going with this system" most answer was 5 and 4, and Q4 "I think that I would need the support of a technical person to be able to use this system" only half seniors answer was 5 and 4. By opposite at Q7 "I would imagine that most people would learn to use this system very quickly" most answer was 1 and 2.

In similar manner we applied same questionnaire to 6 doctors, 4 kinetotherapist and 12 caregivers regarding MR@Old mobile application and Mobile@Old platform. At same questions (Q4, Q7) last group answers was most 2 and 3 and at Q10 average was 4. In this case obtained scores between 64 and 91, average 83 situated MR@Old in Acceptable category. For Mobile@Old platform obtained scores between 60 and 92, average 82 which classified also in Acceptable category.

B. PAT Evaluation

We test our system in laboratory with 20 users (not elderly people) with 6 types of exercises: hip extension, squats, lateral lunge, quadriceps stretch, lateral stretch, arm stretches. For each exercise we compare the reference exercise with an ideal user, an average user and a bad user (based on performed exercises). The comparative results are given in Figure 5.

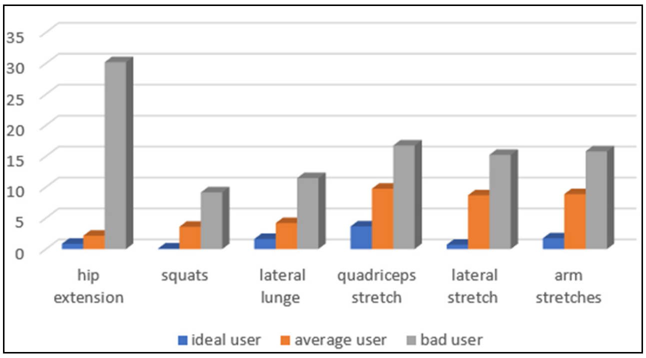

Figure 5. Score of the exercises

The average errors for each joint expressed in millimeters are illustrated in Figure 6. More than half of joints performed in a less than 5 mm error range and 14 out of 20 in a less than 10 mm error range.

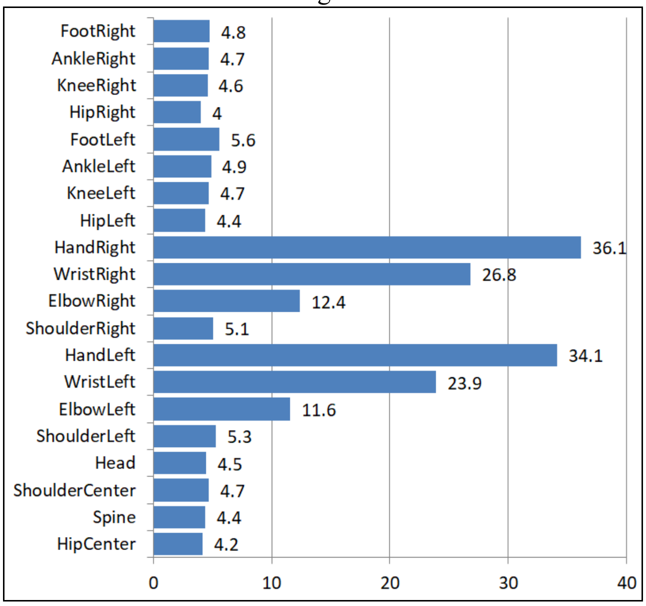

Figure 6. Error from the template expressed in physical units (cm)

Based on the results from [30], we performed tests without adaptation and with adaptation based on user's emotional state. We performed emotion recognition based on the extracted reference points. Each network has part of the extracted reference points. One SVR is used for obtaining the user's emotion. This SVR has as inputs the emotion intensities previously obtained. We consider 7 basic emotions: happiness, sadness, surprise, fear, anger, disgust and contempt. We create two groups of emotions: group 1 (happiness, surprise) and group 2 (sadness, fear, anger, disgust and contempt). We also formulate two rules for adaptation of the exercise based on user' emotions:

- If the current detected emotion is part of the group 1, we will maintain the exercise;
- If the current detected emotion is part of the group 2, the user is not happy and the system we'll change the type of the exercise in order to keep the user making physical activity.

Results given in Figure 7, shows that the user will make exercises for long time if we use game adaptation based on users' emotions - the execution time for performing physical exercises is increased with approximately 46% in case of the adaptation of the type of the exercise based on user's emotions.

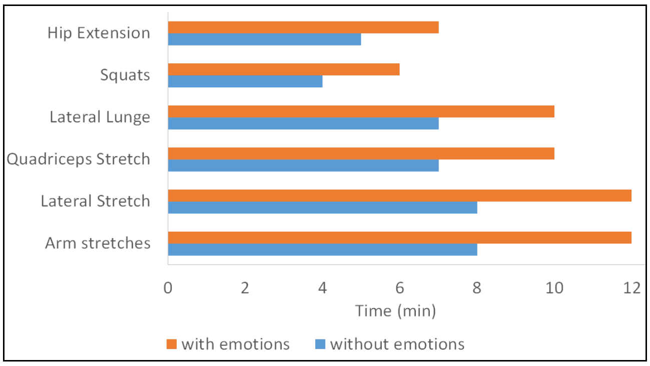

Figure 7 – Time evaluation of game after emotional state adaptation

V. Conclusion

We presented in this work Mobile@Old, an integrated platform for assisting elderly people to maintain a healthy lifestyle in their homes. We detailed the blueprint of the core components of our system, Vital Signs Monitoring (VSM) and Physical Activity Trainer (PAT). Exercises and utilisation scenarios were adapted to the age, health condition, and emotional state of elderly people. The results of a usability evaluation of Mobile@Old indicated that the participants rated our platform with an average score of 77 (acceptable for utilisation). A slightly higher average score (82) was obtained when the same usability questionnaire was applied to kinetotherapists and caregivers. We also found the experimental profile of three types of users (i.e. ideal, average, and bad) in relation with six types of exercises. Moreover, we found that adaptation of exercises in accordance with the emotional state of the subjects lead to a longer time participants were available to perform physical activity. However, future work is needed in order to refine our results with respect to the age, gender, and educational level of participants. Additional experiments could reveal the key factors that influence the availability of elderly to include regular physical exercises in their life style.

The originality of Mobile@Old platform rests on two characteristics: flexibility of exercises and interaction techniques and the adaptation of therapeutic approach to the user's profile, medical condition, acquired progress and emotional state. Both features increase the motivation of elderly people to use this system and to enhance their mobility. In addition, we intend to extend Mobile@Old for remote users interaction so that to replace the sharing of the same physical space with the sharing of the same digital environment.

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