A Proposed Serious Game Architecture to Self-Management HealthCare for Older Adults

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***Abstract*—As people age, older adults' health begins to slow down. Moreover, the elderly population number will grow in upcoming years, according to statistics. This fact can lead to clinics and the hospitals becoming overloaded, and the demand for supervision becomes a challenge for the healthcare area. Because the majority of health issues are in the kinesiology domain, using new technologies like Kinect Sensor, this paper proposes a home system that implies the serious games for older adults, machine learning models for exercises recognition and remote activity supervision. The aim is to minimize the physical effort by offering a believable and motivating virtual world where the patient simulates kinesiology exercises, responds to quizzes and sends feedback. In the same time, the system recovers the exercise data and interprets it in order to model personalized care solutions, to create user profiles, to calibrate the difficulty level of the game using a language of powerful questions, to analyze the exercises progress and the performance feedback, to detect symptoms or falls and to learn the users' behavior. The approach described in this paper is based on analyses of the existing similar systems and on the statistics regarding the acceptability of the lifestyle in self-management physical level for elders.**

Keywords- serious games for health; kinect; eldergames; remote patient health monitoring; well-being

I. INTRODUCTION

This article proposes a serious game architecture for older adults that incorporate motor training and feedback in a virtual simulation. The idea is to recreate a believable artificial environment that stimulates physical responses similar to those in real environments. Older adults are interested in playing digital games because is creating a physical exercise routine [1] and improve the motor skills.

The different characteristics between the related work in the field and the approach presented in this paper are:

- In the beginning of the game the user will choose a virtual friend (e.g., male, female, dog, cat, etc.) who will participate during the exercises.
- The game will ask the user a few psychological questions meant to measure the mood factor of the user, which determines the difficulty level of the game (easy, medium and hard).
- The systems entail the surveillance of a kinesiologist.
- The "Learning" Module adapts the next set of exercises according to the user profile, preferences, feedback and activity history.
- The benefit that the user can visualize the successful execution of each movement in a given exercise. This will strengthen the brain pathways that will coordinate the muscles for the visualized activity.

The structure of this paper is: Section 2 presents several similar existing systems and the description of their facilities, Section 3 describes a scenario of the game and Section 4 details the associated architecture. Conclusion and future work are given in the final section.

II. RELATED WORK

There are many researches that describe integrated social and health care services to face the growing need of care in ageing societies. The average age of the general population may significantly rise in the upcoming years [2], by default the elderly population will grow in age and size [3]. In the last decade the aged cohort increased from 11.1% to 13.5% [4]. Moreover, older adults observe changes in their motor skills, slower response times, disruptions in coordination and balance, difficulty to maintain continuous movements etc. [5]. They are among the least physically active groups in society, and lack of physical activity, even when the reason for it seems justified, can only be detrimental to health. This is why it is particularly important for them to stay active. Apart from this, elderly people may suffer from social isolation and may be less motivated to exercise [6]. For this reason, existing exercise and motor training interventions ameliorate balance and gait deficits, coordination deficits, and movement slowing in older adults.

Firstly, over the past few years, there has been an increase in motion-controlled video games, which offer the opportunity of motivating seniors in physical activity. The studies show that 93% of the retired people spent less than an hour playing at the time [9].

Secondly, a growing number of video games designed to address exercise for seniors, offer a wide range of activities, each with its own set of benefits: muscle strengthening, aerobic, dancing, stretching games, bowling, and so on.

As example, an online social exercise game, named "Join-in" [2], promotes social interaction by featuring competitive and cooperative game modes.

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Another aspect that may motivate elderly people to play exercise games is for their health and exercising benefits, which make them, feel strong and energized, decreases stress and depression, gives a better night's sleep and can help prevent certain chronic diseases or ease their symptoms. Also, the lack of thrills, entertainment, challenges or pleasure may become a discouragement for them to exercise and improve their confidence [7]. So it is important to create stimulating methods for maintaining active lifestyle tailored to the specific psychological requirements of the elderly while providing the benefits of physical exercise routines [8].

Furthermore, aerobic fitness and exercises are effective at preventing cortical decay or cognitive impairment in older adults and epidemiological studies suggest that physical activity can reduce the risk for developing dementia [10].

"Jewel Mine" [11] is a rehabilitation therapy tool customized to overcome health issues. This video game-based application targets balance training, upper limb reaching exercises and is designed to motivate people with orthopedic and neurological injury like stroke issues.

"GameUP" [20] sustain mobility of seniors over 65 years to prolong the time they can live autonomously in their home environment and consequently enhance quality of life. Older adults use Kinect sensor for detecting movement, pedometer for outdoor walking, TV and Small PC connected to internet.

"Flowie" [12] has a virtual coach that encourages seniors to walk more. In order to incorporate the user values and needs in the design concept, a user panel of elderly people is actively involved in the design process. The game use a pedometer with wireless and a touch-screen photo frame.

"iDance" [13] is a music video game four-panel dance game. Dance games can increase physical activity and can be vital to reducing the time seniors spend being sedentary.

"Evergreen Fitness System" [14] is a game-based prototype developed to train older adult's balance, especially lower limb strength by exercises (knee marching, side hip raise, partial squats and standing knee flexion). The system software use Microsoft Kinect SDK 1.6 [21] that allows the sensor to recognize body gestures and body motions.

"SimBODY" [15] is an interactive simulator that educates people on how to mitigate the risk of cardiovascular diseases offering contextualized lifestyle advices and depicts the progression of atherosclerosis.

"The Red Ball Game" [16] is an exergame where the user has to move a blue ball with the movement of the hand. There are a number of red balls attacking the blue ball from different angles. Also, there are some black holes and yellow balls on the screens. The user has to push the yellow ball through the blue ball and make it fall into the black holes.

"FishCatcher" [17] is a senior game controlled by arm movements, that are tracked by a 3D sensor (e.g., Microsoft Kinect) using the OpenNI library. One game lasts 30 seconds, and the player try to catch fish by waving the hands.

"Out in nature" [18] is a game designed for balance training and muscle strength, based on the senior's feedback. The design approach is user-centered and uses the user testing, prototypes and user group, focusing on exercising muscle groups with difficulty levels and number of players. "Voracy Fish" [19] offer patients an offset and ludic universe where to perform movements that are worked at a session of classical functional rehabilitation: lateral movements, proximal and distal. This game is the most similar with the approach presented in this article.

In summary, all these serious games use the recommendations of different medical experts (psychologists, therapists, doctors, fitness trainers, etc.) to recreate a believable artificial environment that stimulates cognitive and physical responses similar to those in real environments. The purpose is the same: to motivate elder society to maintain a healthy life and wellbeing condition by improving their overall level of agility, fitness or balance.

From the therapeutic point of view, health experts recommend physical activity that improves balance and coordination at least twice a week to reduce the risk of falls and at least two and a half hours of moderate intensity aerobic activity for seniors who don't suffer from any health conditions, as well as muscle strengthening exercise at least twice a week [22]. Still, having one kinesiologist per patient, in daily practice, make games logistically impractical and quite expensive. Concerning the field of elderly care fall detection, fall risk reduction and stroke rehabilitation, research presents the possibility to reduce this aspect through guided interactive solutions and virtualized therapists [23].

More recently, researches find methods containing Kinect sensor [24] for sending real-time fall alerts in home, even to detect naturally occurring falls in the main living area of each home. Another study in the field, shows that physical activity was not related to life-space area (home bound, within neighborhood, and outside neighborhood), implying that older people could be physically active within smaller life-space areas or they could be sedentary even when reaching areas further away from home [25].

III. GAME DESCRIPTION

The system is designed to use the Microsoft Kinect SDK 1.6 [21]. The system concept is based on medical care for older adults (patient/non-patient) focused on health and wellness by physical exercises with real-time interaction between the kinesiologist and patient, including eldergame therapy, progress monitoring, performance feedback, adaptability and symptoms detection.

For the purpose of better explaining the concept presented in this paper, the following scenario will be considered: changes in an older adults motor skills, slower response times, disruptions in coordination and balance, difficulty to maintain continuous movements etc. [26] will generate worry about health issues, thus the need to consult a health expert – a kinesiologist.

The kinesiologist investigates the patient situation and the symptoms displayed. Therefore, the kinesiologist provides and manages the information that concerns the patients' health and medical records, after which he will assigning the psychical exercises program to be performed at patients' home. Each exercise is associated with a game proposed by the system. At launch, the kinesiologist creates a user profile with the medical data gathered from the patient (age, weight, initial mood, symptoms, etc.) and the settings for the exercises (execution speed, difficulty level, target

zone for pulse and heart rate, time, number of exercises, etc.). This serves as a context vocabulary which can verify the completeness for each period of time during the exercises. The planning of the exercises can be made by a pattern-based development. Extracted patterns are stored in a knowledge base and not compiled each time they are needed, which is structured to minimize database operations for pattern retrieval at runtime. Some examples of physical exercises are: Quadriceps Stretch, Chest and Arm Stretch, Upper Back, and Shoulder Stretch, presented in [27].

A set of exercises can be divided into several types. These standard types of exercises are stored in a database that the kinesiologist may access remotely, via an interface, and prepare the exercise plan for a period of time. The implication of a music therapist is possible, in order to find the appropriate music for each plan of exercises [18].

Once the exercise plan has been created, the system will notify the patient via the smartphone application through a push notification, 15 minutes prior to the exercise session. The patient connects in the application installed on the Kinect and signs in using the credentials provided by the therapist. After that, the user will answer at few questions before starting the game. At this point, he/she can also modify and configure game elements according to condition.

Before launching the exercise session, the patient watches a tutorial with the exercise that he/she will engage. The game challenges the user depending on the difficulty level through sound cues (E.g.: "You can do better than that") and by offering rewards.

As stated before, upon starting a session the game will ask the user a few psychological questions meant to determine a "mood temperature factor" which will be considered when proposing the specific exercise to be performed and its level of difficulty. This factor will represent a composed state formed by combining two out of three essential states: fatigued, rested or energetic.

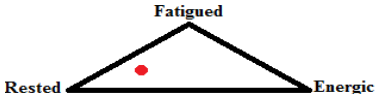

Figure 1. Representation of the "mood temperature factor".

An example of this kind of questions may be to choose a "Luscher" color, by the method called "Color Diagnostics of Emotional States". Every color is the symbol of a different mood (green is calmness, red is excitement, orange is joy, blue is sadness, purple is anxiety, black is decay). [28]

The kinesiologist defines an exercise plan for the specific needs of the patient and adjusts the maximum values for movement, duration and speed of each exercise. After that, based on the "mood temperature factor", the system will adjust itself within these limits. Once the session is finished, the game will store the records in a database. The recognition module will compare the skeleton joints positions provided during the session with the ideal positions set by the kinesiologist.

The system will measure the evolution and the progress of the patient through the amplitude and duration of the movement reaction time, the number of peak velocity, precision of the trajectory and the potential level of negligence. Also, it will choose the bonus and next exercises.

Patients' performance will be analyzed, so that real-time feedback can be provided, thus granting online access to the records and tracking the activity.

Each patient's gesture is recorded. The system provides different graphs with the evolution of the patients' condition by analyzing the records, which the kinesiologist can access.

By tracking a patients' range of motion and other clinical data, therapists can engage with patients and provide them with real-time feedback as they perform their exercises at home. Through on-screen motion-analysis capabilities, therapists can measure the patients' progress and customize their treatment to optimize therapy benefits.

Data provided by the Kinect is collected and analyzed using data mining or machine learning algorithms to build motion based models and perform exercise recognition.

The game leverages the data stored in a typical personal health record, augmenting it with environmental and sensor data and enabling the monitoring and analysis of an individuals' habits. Through the analysis of game sessions and graphic reproduction of the results, the game allows the kinesiologist to have a visualization of the patient's progress over several sessions, facilitating monitoring of the patient.

The scoring in a game gives immediate feedback, but usually reflects a small portion of the user performance. Also, it is critical to make users feel in control and help them understand what's happening in the game. While it is useful to keep the patient engaged and help him to achieve a better score, the scoring systems needs enough information on what was done correctly and incorrectly. This is accomplished by feedback, selection states, progress indicators, performance, activity history, rhythm, speed of exercise and visuals. Patient's performance will be analyzed and calculated, so that real-time feedback can be provided, according to the individual total score of a session. According to the results obtained, the system will propose personalized set of exercises and provide constructive feedback for the user.

IV. PROPOSED GAME ARCHITECTURE

The proposed architecture is composed of the following components stated in Figure 2. Architecture of the system:

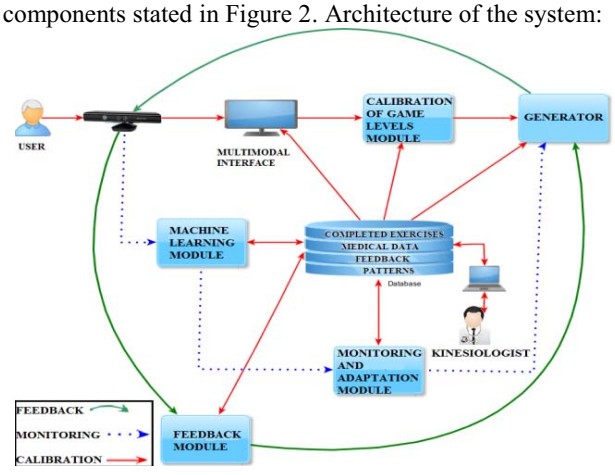

Figure 2. Architecture of the system

From the image above and from what has been stated in the scenario in the previous section the architecture would be based on the primary modules described further.

Calibration of Game Levels Module: this is the module in which the application settings are configured by the kinesiologist and by the application, based on the "mood temperature factor".

Generator Module: this module contains the backstory, the story line, the game mechanics, the rules, the immersive graphical environment, the interactivity, the challenges, the risks and the consequences. The ambient effects that fit the game environment, sound effects that give users feedback on actions and the music suitable for the intensity in the game, are retrieved from the Database. The Generator defines a scoring system that gives immediate feedback to the user. Furthermore, the Generator will send the tutorial specific to the difficulty level game received and send the game specific to the exercises received by the Calibration Module.

Monitoring and Adaptation Module: this module captures the exercise data generated within a session and communicates with the calibration module for the purpose of adjusting the game level settings and the future exercises. Thus, this module receives each frame from Kinect and delegates each frame to the appropriate model component that has the right medical logic to parse and detect which motion is taking place in which joint. Then compares the data received with the exercise pattern from the Generator.

Feedback Module: this is where the patient can view the direct output of the interpreted data captured in the monitoring module. The user will be able to view various graphs, as mentioned before.

Machine Learning Module: after the feedback process ends the data recovered is archived and stored in the database. At this point a series of patterns are generated specifically for the patient and are stored in the knowledge base. These will be useful in future sessions with the same patient. Therefore the Machine Learning Module analyzes the preferences of the user for proposing new tasks, maintaining the motivation high, and studies the behavior of each user to create applied methods for other users.

V. CONCLUSIONS AND FUTURE WORK

In conclusion, one kinesiologist may guide, manage and monitor many patients, using this serious game approach. The proposed architecture associated to the system aim to minimize the physical effort by offering a believable virtual world that stimulates physical exercises witch motivates the elderly society to maintain a healthy life and wellbeing condition. This architecture utilizes adaptation, user profile, calibration of level game by language of powerful questions, progress monitoring, performance feedback, adaptability and symptoms detection and behavior learning.

In the future work, is possible to mix the Kinect with wearable devices/ sensors like: pedometers, accelerometers, wearable complex gloves, rHEALTH Sensor [29], Smart T-Shirt with Heart Rate Monitor [30], etc., in order to obtain a better precision of balance, healthcare and adaptability.

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