NuSense: A Sensor-Based Framework for Ambient Awareness applied in Game Therapy Monitoring

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***Abstract* — the usage of technologies for the treatment of patients is constantly emerging. A recent trend is the usage of games for healthcare, mainly in motor rehabilitation. The entertainment facet of the game attracts the attention of patients making them more engaged in the treatment. A difficult in the usage of commercial games is that they require full attention of the healthcare professionals, since they were not created to this purpose. To contour this kind of situation, decreasing the attention demanded by healthcare professionals, tailor-made games with monitoring capabilities have been developed. The problem with this approach is that these games falls short of entertainment, compromising their playfulness. Given this scenario, we believe that by adding monitoring capabilities to environments in which commercial games are used for health treatment is the best approach for game therapy. Therefore, it is necessary to create a mechanism that helps developers on building applications to monitoring patients' pre-determined characteristics during a gameplay. In this paper, we propose the NuSense, a sensor-based framework to support the development of applications to automatically monitoring people while they are playing electronic games as a health therapy.**

***Index Terms*—Ambient Intelligence; games for health; monitoring capabilities; framework.**

I. INTRODUCTION

The rise of new technologies has promoted the use of new approaches in healthcare, making changes in the traditional models of treatments. Some of these models, especially regard the patient motor rehabilitation, consists in the repetition of specific movements. This treatment is effective, but in the long run it tends to become unattractive to the patient, reducing the adhesion and efficacy of treatment [1]. In this case, the usage of electronic games has obtained good results, making this a good alternative due to the motivational and playfulness aspects [2].

The main aspects that contribute to these good results can be associated with the fact that this methodology can promote entertainment and consequently be used as a motivational tool - even if it is not the primary purpose, as in the case of Serious Games [3]. At this point, is important to highlight that usage of games goes beyond provide rehabilitation exercises [4], since they can be used for disease's prevention [5], and stimulate mental development [6].

The game engine improvements has allowed the use of increasingly realistic graphics. In addition, the enhancement of hardware has helped in the process of immersion and improvement of user's experience by using image recognition, movement and sound techniques, such as the Microsoft Kinect Sensor (KS) [7]. This has allowed the use of commercial games, which focuses exclusively for entertainment, in the treatment of several diseases such as Parkinson's disease, Stroke, Huntington's disease, and Cerebral Palsy [8].

Many of the new technologies allows the monitoring of users by collecting information while they are playing electronic games [9]. Hence, health professionals can have a reduction in workload and devote their attention to important aspects of patient care. The automatic monitoring of people could help on identifying irregularities in therapies and optimize the work time of health professionals, which have his attention divided by several patients [10].

We cannot use commercial games to assess automatically the medical conditions of patients' treatment, because mostly of games do not approach health issues. Besides, the adaptation of such games is not always possible due to copyrights, interest of game companies and high costs involved. In the other hand, tailor-made games for health with monitoring capabilities has being developed, but they have a lack of playfulness, presenting a low quality and affecting the user's experience. The costs to produce a tailor-made game do not always worth [8].

To overcome this problem, we believe that the best solution is to add monitoring capabilities to environments in which commercial games are applied for game therapies. In this way, it is necessary to create a mechanism that helps developers on building applications to obtain and evaluate specific data and monitoring of patients during a gameplay. Also, the developers must be concerned mainly about the aspects of business logic - which are health issues.

In this sense, we propose a sensor-based framework to provide applications to monitoring of people in environments of game therapy and motor rehabilitation, aiming to reduce the overload of healthcare professionals. The framework will allow that the developers do not have to worry about non-trivial aspects of the technologies to build such applications, like the integration of different sensors, the data collection, treatment and transmission according with different sensors and techniques. At the same time, we intend to reduce the difficult to develop monitoring applications and accelerating the developing process.

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II. Related Works

The emerging of new technologies has enabled the creation of games even more realistic. Due to its playful feature, games have been successfully applied in healthcare, mainly as a supplementary therapy for motor rehabilitation. Games are providing several benefits, including improvements in physical, sensory and cognitive functions, diagnosis, targeted treatments and remote monitoring.

A. Game Therapy

There are many works offering game therapies and having good results in the treatment of illnesses. In the case of the Brain Injury, it is the leading cause of death and disability worldwide [11]. That's why most part of game methodologies is focused on it [8].

For children with cognitive impairment, the use of games has been very restricted. However, we can highlight the JECRIPE game, designed for children with Down syndrome, focusing on the cognitive development of children of preschool age. With this game, the authors promoted activities such as imitation, perception, motor skills and verbal language [12].

As for people with advanced age, Kayama et al. [13] shows the Dual Task Tai Chi, a game focusing on dual activities, which showed an improvement in executive cognitive functions of patients. This kind of activity helps to reduce the fall risk in older people, who statistically have a higher probability of incidence [14].

The sedentary lifestyle and overweight have also been widely explored in the games for health area, especially with commercial games. With the convenience of playing in home, is being common for that public the use of technologies like KS, Wii balance board, Sony Eye Toy, mat of dance, and many others motion sensors.

To promote physical activity and reduce sedentary behavior in children, we can highlight O'Donovan et al. [15], which makes use of jogging and boxing games with the Nintendo Wii, and Maddison et al. [16] who used dance games for EyeToy. Both had positive effects on body composition of children.

However, games have been developed to utilize the same technologies of commercial ones. The competitiveness is currently explored as a motivating factor to overweight and sedentary persons. Zhang et al. [17] developed a game in a virtual network that simulates a bike marathon. They used sensors to catch some parameters of the users, thus, with help of adaptivity, the game was able to determine the user's performance based on their effort.

B. Monitoring Capabilities

For the monitoring of patients, there are games focusing on the treatment of overweight and sedentary people [18], as well as for the treatment of diabetes [19], in which therapists can monitor the performance of patients remotely and make recommendations. To monitoring of children while they're doing eye exam, the game PlayWithEyes [20] was made to do a pre-test and detect the children's visual acuity, so the ophthalmologist can monitor them while they're playing a ludic game which retains their attention.

Konstantinidis et al. [21] developed an application for monitoring older people with the integration of several sensors, like KS, Wii Balance Board and Android smartwatch. They used standard web technologies to encapsulate the data in the cloud, so the applications are able to work in a single data format with different sensors.

Apiletti et al. [22] developed a framework for monitoring of patients that allow a real-time analysis of their physiological data. With a detailed analysis, a risk function is calculated, and the current state of the patient is provided. In the field of Body Sensor Networks (BSN), Iyengar et al. [23] proposed a framework to assist in the development of applications for monitoring of patients. This framework was intended to be used in postural recognition applications and physiotherapy.

Pirovano et al. [24] created a game engine called IGAR, which focus on the motor rehabilitation of patients at home. The IGAR engine provides a real-time correction of user's mistakes made at therapies. One of the features of the IGAR engine is a middleware layer that allows the use of several sensors into the game to be developed. However, this approach is focused on building tailor-made games, which brings us back to the initial question – tailor-made games may affect the user experience.

Yet, the complexity of the development of monitoring applications still large. Besides, few solutions allow the integration of different sensors, the flexibility on generating outputs to other devices or technologies, and the information storage about the monitored environment. Lastly, still the developers' assignment to abstract the complexity of the sensor, when they could be focused on the application domain, such as the variables to be monitored.

III. NuSense Framework

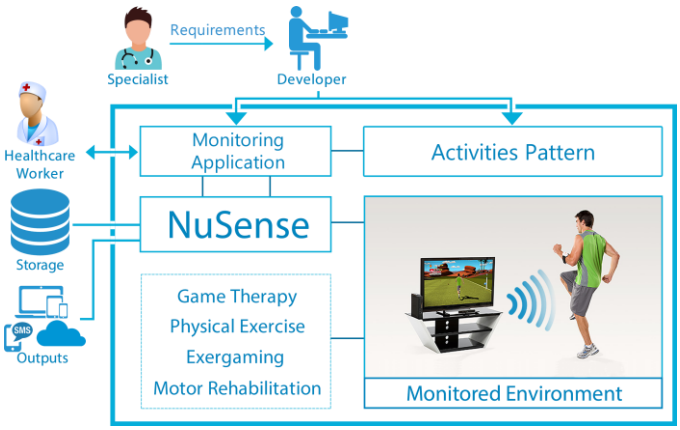

Figure 1. NuSense's Usage Scenario

We developed the NuSense, a sensor-based framework that allows building applications for the monitoring of environments focused on game therapies and motor rehabilitation. In Figure 1, we show the usage scenario of the NuSense Framework. To develop a solution to monitoring users, the specialist defines the activities that he want to be tracked during a therapy. According with the requirements, the developer will implement an integrated solution to NuSense, which will assist in the creation of the monitoring application. Finally, the healthcare worker will use the application to the

monitoring of users during activities like physical exercises, exergames, motor rehabilitation, or game therapies.

The framework should help to generate outputs to other devices, to storage the knowledge, and to make recommendations about the monitored activities. The application is created according with the sensors, which can be the KS, Sony EyeToy, mobile devices, webcams, body sensors and others. The framework provides a sensor interface allowing this flexibility. For every sensor, there is an associated plugin, which will perform the bridge between sensor and application. Initially we developed a plugin for the KS, and we are currently working on a plugin for Android devices.

Following, we show the NuSense's architecture, and explain the modules functionality, according to Figure 2.

A. *Communication Module*

This module will be responsible for enable the interaction between sensor and application. Every sensor will need a predetermined plugin. The communication protocols used in the interaction between application and sensors are defined here. The collected data should be organized in a single format and sent to the Output Module.

B. *Output Module*

This module receives the encapsulated data from the Communication Module, and makes the data conversion according with the respective output, which could be image, text, bluetooth connection, cloud storage or another sensor.

C. *Notification Module*

While the activities are monitored and processed, if any anomaly is found, this module will create a register log. If the anomaly is related to the activity analysis, a recommendation should be sent to the Output Module, hence we can create an entry to another sensor or device such as smartphone. As example, if there are patients doing motor skill rehabilitation exercises at home, the doctor is able to receive the progress status on their smartphone, so he can give assistance to critical patients.

D. *Storage Module*

This module will store all the useful knowledge about the monitored activity. By default, the information is stored through a text log. A storage interface is provided to the developer, so he can store specific data, or use a specific DBMS.

E. *Interfaces*

In order to add a different sensor, the developer needs to implement the interface ISensor, according to Figure 2. The methods that must be implemented to create an extension point of the NuSense are described on Table I

The IActivity is the key-factor of the application, which is an interface to implement the features that need to be monitored. The Table II show the methods that should be implemented.

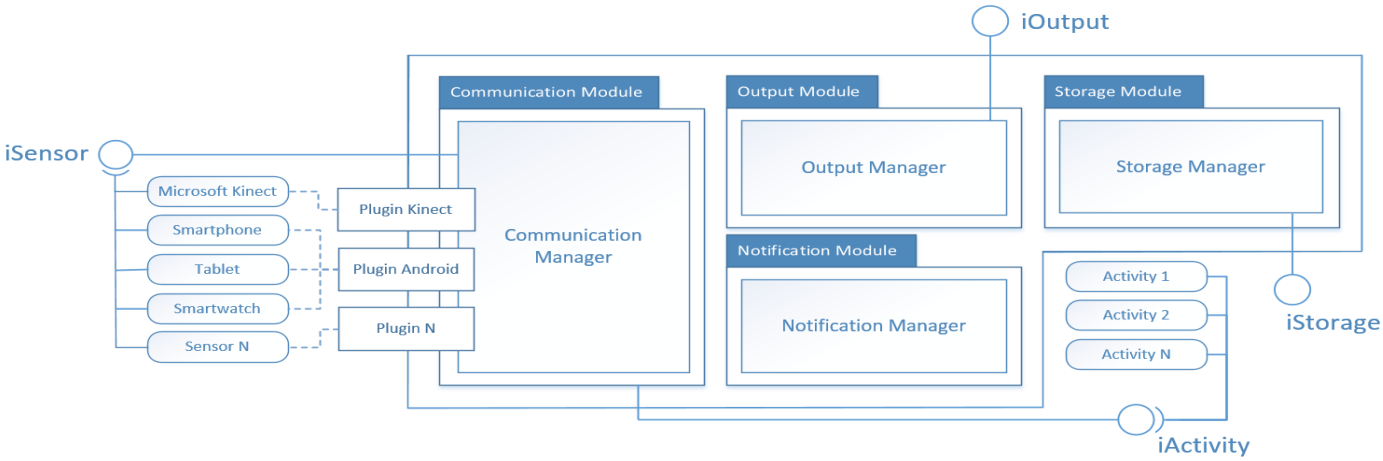

Figure 2. NuSense's Architecture

TABLE I. DESCRIPTION OF THE ISENSOR INTERFACE

Method	Description
initComponents	Initialize the main entities of the component.
finishTransmission	Stops the data transmission.
newDataAvailable	Transmit the data available in the sensor.
initActivity (IActivity)	Initializes the activity analysis. *IActivity: Interface that defines the user behavior to be analyzed when he is doing an activity.*
finishActivity	Stops the activity analysis.
getActivity	Gets the activity properties.

TABLE II. DESCRIPTION OF THE IACTIVITY INTERFACE

Method	Description
initComponents	Initializes the main entities of the component.
checkParameters (Object)	Analyzes the user's parameters and compare this with the activity pattern. *Object: Data provided by the sensor (e.g. user body coordinates)*
sendAlertMessage	Sends an alert to the notification module.

TABLE III. DESCRIPTION OF THE IOUTPUT INTERFACE

Method	Description
getData(Object, type)	Get the single format data from Communication Module. *Object: Encapsulated data.* *type: Object Enum.*
dataConverter	Converts data to a local output.
dataConnection	Sends data to a remote output.

To generate the data output, the interface IOutput was defined, which the Table III shows the required methods. Finally, for the storage of the analyzed information activity, the IStorage interface was provided, and the methods for their implementation can be found in Table IV.

TABLE IV. DESCRIPTION OF THE ISTORAGE INTERFACE

Method	Description
writeData (IActivity)	Saves the parameters according with the application. *IActivity: Interface that defines the user behavior to be analyzed when he is doing an activity.*
readData (id)	Performs data reading. *Id: record identifier.*

IV. CASE STUDY: FLEXIBILITY ANALYSIS

For this case study we aim to create an application to benefit people with upper extremity dysfunction. The upper extremity dysfunction is common in people who have Brain Injury, Cerebral Palsy, Diabetes and Parkinson's disease. This problem can affect the educational outcomes, the participations in activities of daily living, vocational options, etc. [25].

The specialists commonly use the flexibility test of body members to determine the presence of changes in the mobility of limbs, predict the natural history of the disease, evaluate changes in the range of motion (the range through which a joint can be moved) and check the treatment and disease progressions [26]. The purpose of evaluation is to determine the member's angular displacement. Currently this rate is measured by devices like the Fleximeter and Goniometer, but it is required that a qualified professional perform the measurement to ensure the accuracy of the test.

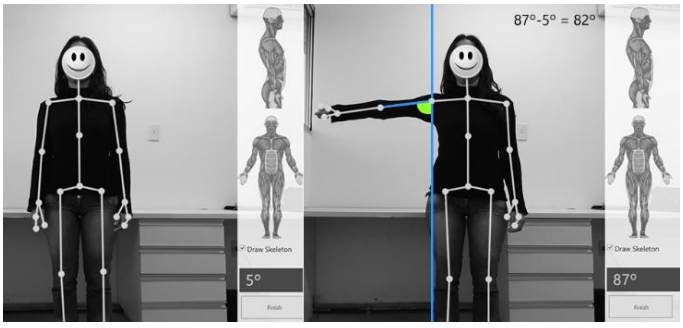

Figure 3. Shoulder's Flexibility Application

The NuSense makes easier the process of building such application, because the developer can focus on the application purpose. The benefits of the NuSense are related to the communication between application and KS. Using the KS, we do not care about the data gathering and the encapsulating of the information. Since the data are encapsulated, they are sent to the Output Module to be processed in the application with a *System.Drawing.Image* property from Microsoft .NET. In this case study, we developed the shoulder flexibility analysis, with the adduction and abduction of the shoulder, as illustrated in Figure 3.

To build this application, the framework was enhanced with a KS plugin, so the framework supports the KS 2.0, which use the Microsoft Kinect SDK 2.0.

The implementation of the adduction/abduction analysis aims to discover the angle below the shoulder, and uses the X and Y coordinates of the elbow and shoulder as described in the Equation I. The Listing 1 show the C# code of this analysis. After that, the angle is compared with the Leighton flexibility measure [27], and then the diagnosis is revealed.

$$\theta = \sin^{-1}\left(\frac{|Ex-Sx|}{\sqrt{((Ex-Sx)^2+(Sy-Ey)^2)}}\right) \qquad \text{(I)}$$

Ex: elbow coordinate X; **Ey**: elbow coordinate Y;
Sx: shoulder coordinate X; **Sy**: shoulder coordinate Y.

In the game context, the NuSense allows, during a gameplay, that the features defined by the specialist be mapped into the system. When the player performs an activity mapped at the application, an alert should be sent to the output module, which can generate a recommendation, such as adjustments of the therapy.

Another output was developed to send the monitored data to a mobile device. It is an Android version of the flexibility analysis application, which uses the KS as data gatherer and a desktop as data processor. Furthermore, we are developing another application with this structure focused on the posture of cyclists and bike fit. To develop such applications, it was needed only the development of the iOutput and iActivity interfaces, once the KS is still being the data gatherer.

V. CONCLUSIONS

In this paper, we presented the NuSense, a framework for support the development of applications for the automatic monitoring of people in environments applied to game-based therapies, motor rehabilitation and physical exercises.

This framework can help the developers to build such applications without concern about non-trivial concepts of technologies and techniques, such as different sensor integration, the data transmission and communication of the sensor with the solution.

We have detailed the modules functionalities and the interfaces that can be used according to the activity which will be monitored and the sensor type. It is expected that, with this framework, healthcare professionals be able to define features to create solutions to monitoring and assess users during a game therapy, solving problems such as divided attention.

As we demonstrated on our case study, the developers will have less work to create applications by using this approach. They should only implement the activities to be monitored,

leaving the data gathering of the sensor and the generation of outputs with the framework. Also, we notice that the NuSense is scalable, because every time a sensor or an output is added into the framework, the developers will be even more focused on the application domain, which is the main contribution of this work.

We are currently developing an extension of the NuSense, which supports Android device sensors as data gatherer, so it will be an Android plugin. As future work, we intend to focus on the synchronism of multiple sensors and the treatment of conflicting information between different sensors.

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