Enter the ROBiGAME

eNTERFACE'15 Project Proposal

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Project Objectives

The objective of the project is to develop an intelligent serious game for rehabilitation of the upper limbs for stroke patients using an interactive rehabilitation robot. The robot screenplay adapts to the patient's functional abilities and the robot mechanical assistance evolves according to patient's motivational, motor and cognitive performances.
ROBiGAME will be developed on the REAPlan robot providing a distal effector which can mobilize the patient upper limb(s) in a horizontal plane (http://www.ncbi.nlm.nih.gov/pubmed/22367455) but could also be transferred to other robots or even simpler rehabilitation setups. This project is related to the ROBiGAME project, funded by the Region wallonne, which officially began in October 2014.

The eNTERFACE project will be divided into 4 Worpackages:

- WP1: Motivation-related features extraction using the Kinect V2 sensor.
- WP2: Motivation-related features processing.
- WP3: Integration of the Kinect V2-based Motivation module to the REAPlan robot.
- WP4: System testing

Background information

Thanks to advances in basic and clinical research, neurological rehabilitation knowledge has greatly developed in recent years [ref1] [ref2]. During the rehabilitation, to learn a task, the exercises in brain-injured patients are improved by the use of rehabilitation robotics that achieves intensity (number of movements / time) higher than the conventional rehabilitation [ref3] [ref12]. One of the possible optimization of this technique is the implementation of serious games with robots that would combine the benefits of rehabilitation robotics and those from the serious games mainly in terms of patient motivation. Indeed, they have already proved their specific interest in the adult brain-injured patient [ref4]. The "Enter the ROBIGAME" project can be broken down into four components, medical, robot, video games and analysis of motivation.

Medical
For the deficiencies of hemiplegia, the most popular and most effective method of rehabilitation is to restore function rather than offsetting the deficit [ref6]. Different restoration protocols have been developed to relearn both a specific skill (eg walking) than the general activities of daily living [ref7]. Research in neuroscience show that relearning protocols result in positive changes in the structure and activity of the brain [ref8] [ref9]. However, because of the cost they generate, the alternative which is preferred is the use of the imagery. It has been shown that the use of mental imagery

has beneficial effects [ref10], but these are not as important as the benefits obtained from the actual physical exercise [ref11]

Robot

Rehabilitation robots are divided into two families after they support or not the entire joint chain located between the patient's trunk and hand. In the first case we speak of exoskeletons, while in the second we speak of manipulators distal effector. The most famous robot belonging to this second family is the Manus robot developed at the Massachusetts Institute of Technology (MIT) and marketed by Interactive Motion Technologies (IMT) based in the United States. Robots REAplan and REA²plan developed at Mechatronics Research Centre (CEREM) UCL also belong to this category. The latter two robots are those used in this project.

Video games

While the video game is sometimes seen by the wider public as an entirely fun activity, it has rather great potential serious and socializing. Indeed, it can be used as an aid or psychological engine allowing the player to carry out meaningful tasks. This potential motivation for carrying out serious tasks is increasingly taken into account (First IEEE International Conference in Games and Virtual Worlds for Serious Applications). The medical world, particularly rehabilitation is an area where serious games are developed [ref13][ref14].

Analysis of motivation

When performing an exercise, ROBiGAME must be able to capture information related to motivation performance of the patient. The patient's motivation will be assessed from two features extracted from patient's behavior. The first one concerns the direction of the head [ref15]. This will be extracted using a 3D camera (type Microsoft Kinect sensor). The second one concerns the analysis of the patient's emotional state. From the patient's face that can be automatically detected, it is possible to extract emotional parameters such as "FACS" which are basic units related to the emotions. This would make it possible to know the valence of the emotions of the patient (positive or negative emotions) and also the degree of energy spent by the patient during the task (neutral, very involved, etc.).

Detailed technical description

Technical description

The development will follow two steps. Firstly, each sensor (Kinect and robot to estimate motivation, motor and cognitive performance) will be developed independently. A test interface will be created for each sensor to perform tests with healthy individuals and then brain-damaged patients. These tests will determine the objective parameters that the sensor must assess ROBiGAME. Secondly, a work of integration of these sensors the robot will be realized. An interface integrating and managing all this information will be created and tested.

Computer vision

When performing an exercise, ROBiGAME must be able to capture information related to motivation, cognitive and motor performance of the patient. The patient's motivation will be assessed from two features extracted from the patient's behavior.

- The direction of the head. This will be extracted using a 3D camera (Microsoft Kinect sensor). Figure 1 shows a person sitting at 1 meter in front of the 3D camera. Thanks to the 3D point cloud, it is possible to calculate the direction of the head, especially if there are tasks, is close to the viewing direction. UMONS team also has a tracking commercial equipment of the head and eyes (FaceLab 5: http://www.seeingmachines.com/product/facelab/) that will validate the results of the system developed.

- The second point concerns the analysis of the patient's emotional state. From the patient's face that can be automatically detected, it is possible to extract emotional parameters such as "FACS" which are basic units related to the emotions. It would be possible to know the valence of the emotions of the patient (positive or negative emotions) and also the degree of energy spent by the patient during the task (neutral, very involved, etc.)

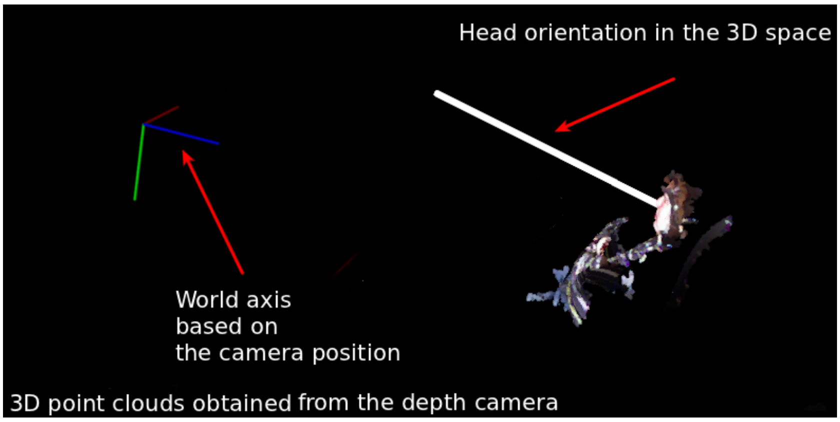

Figure 1 :Head pose estimation with a user.

Analysis the data from robot

Motor deficiencies (strength, joint mobility, dexterity) will be evaluated clinically according to the validated protocols. An evaluation protocol of these deficiencies by the robot will be developed to provide ROBiGAME quantitative and objective data. Force and position sensors will be used to assess:

- Patient force;
- Comprehensive passive and active range of motion by measuring the largest perimeter the subject can perform with or without assistance;
- Kinematics and kinetics of the arm in standardized movements.

The patient's motor performance will be quantified during rehabilitation exercises using the robot's sensors. Their data will calculate kinematic and kinetic parameters, as well as to quantify the assistance provided by the robot. During development, these measures can be validated by comparing them with those obtained using a system of analysis of the independent movement of the robot (Figure 2).

Figure 2: illustration of the robotic system REAPlan1 and REAPlan 2

Ressource needed

For this project, we need to access to Numediart Room with the Qualisys system to perform recordings. This will be for validation part of the project because we need to measure the different error in tracking method using the final setup (Kinect + robot REAPlan). We also need to use the REAPlan robot from Robigame project. As the robot is noisy, the ideal would be to be the only team in this room (not far from Numediart lab to move easily the robot).

Project management

The project will be split into 4 work packages focusing on the Motivation module (using a Kinect V2 sensor), its integration into the system and its testing.

- <u>WP1: Motivation-related features extraction using the Kinect V2 sensor.</u>

The output of the Motivation tool will be in a first step a set features concerning patient head direction (towards the screen, towards the working area, or any other direction), patient body position (arms/upper body), and patient basic emotions (using features extracted from his/her face). A feature selection need to be made depending their robustness to the setup of the REAPlan robot (Kinect sensor position, distance between the patient and the sensor, etc. A confidence level for each final feature is also setup. The output of WP1 will be a list of features which are robust enough in the setup context with their related confidence levels.

- <u>WP2: Motivation-related features processing.</u>
  Once all features extracted, they need to be processed using rule-based or learning-based techniques to infer a level of interest from the patient to the ongoing rehabilitation task. A simpler rule-based approach will be taken into account first to provide first results. More complex learning algorithms will be than used to learn motivation based on a database with a scenario containing sequences where people are motivated or not.

- <u>WP3: Integration of the Kinect V2-based Motivation module to the REAPlan robot.</u>
  The Motivation module output will be directly sent to the robot using a network protocol. This output will be used by the robot to change the difficulty of an already existing serious game used to motivate the patient for his rehabilitation task. The network protocol will be selected and implemented and the data transmission will be sent between the different robot modules. The Motivation level is used to select between several game difficulty levels.

- <u>WP4: System testing</u>
  The system will be tested on control people and patients to figure out:
  1) If the motivation module fits the real people motivation
  2) How the motivation module can be used at best to enhance the patient rehabilitation experience

All participants will be assigned working on each of the different development work packages. The WP1 and WP2 team will work the whole months to get a good motivation-related features extraction module. The people assigned to the task 3 will establish the tools to connect information from WP1 and WP2. This part of the work will take about 2 week. The testing work package will test compound during the month with clinic patients to validate the design steps, and also at the end to validate the whole system by WP1, wp2 and wp3.

Work plan and implementation schedule

<table>
<tr><th></th><th>WP1</th><th>WP2</th><th>WP3</th><th>WP4</th></tr>
<tr><td>1st week</td><td>Set features concerning patient head direction</td><td></td><td></td><td>Make survey with patients about interface design</td></tr>
<tr><td>2nd week</td><td>Set patient body position</td><td rowspan="2">rule-based or learning-based techniques to infer a level of interest from the patient to the ongoing rehabilitation task</td><td>Establish communication protocol</td><td>Perform test with user and validate WP1</td></tr>
<tr><td>3rd week</td><td>Set patient basic emotions</td><td>Communication between motivation part and Robot</td><td>Perform test with user and validate WP1 and 2</td></tr>
<tr><td>4th week</td><td></td><td></td><td></td><td>Validation of WP1, 2 and 3</td></tr>
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Benefits of the research

The objective of the main project is to develop an intelligent serious game for rehabilitation of the upper limbs for stroke patients using an interactive rehabilitation robot which screenplay adapts to the patient's functional abilities, and which assistance evolves according to patient’s motivational, motor and cognitive performances. ROBiGAME will be developed on the REAPlan robot providing a distal effector which can mobilize the patient upper limb(s) in a horizontal plane but could also be transferred to other robots or even simpler rehabilitation setups.

Besides being able to gather around the table partners to work together as part of a workshop, the benefits across the four work packages are manifold. The first and most important of these is the integration between Kinect for Windows v2 and REAPlan robot. An application will extract features on the motivation of the user from the data provided by the Kinect and will react the robot. In the best case, this application will be associated with a complete mini-game created especially during enterface.
Achieving real-time tests in collaboration with hemiplegic patients will be performed during the enterface. These tests will be carried out through various applications that will work on the robot. These do not have to use the Kinect initially. Thereafter it will be the application referred to in the previous paragraph will be tested. This is the second benefit.

Analysis of the results of previous tests will be conducted by all project participants. The third benefit is the sharing of knowledge in various fields on the same results. This

is a very important point because, for example, a physician will not have the same view that an electrician engineer and vice versa. By listening to each other analysis will be even better.
The fourth benefit that will be discussed is the involvement of people outside the ROBiGAME project. These may therefore participate in the development of various sensors motor, cognitive or motivational and bring a critical and constructive review of these.
The four benefits listed above are not exhaustive. Others may be generated from this project during the Workshop.

Profile Team

Leaders

- Rocca François (UMONS/FPMs), Phd Student - Researcher: François Rocca holds an Electrical Engineering degree from the Faculty of Engineering of Mons (University of Mons, Belgium) since June 2011. He did his master's thesis in the field of emotional speech analysis, and more especially on laughter frequencies estimation. He is currently pursuing a PhD thesis on head pose estimation and facial expression analysis by markerless motion capture.
  He is part of the « creactifs » courses teaching team from the Numediart Institute (University of Mons). These extra scholar courses are given to bachelor students to learn about digital arts technologies through electronics, image and signal processing.

- Pierre-Henri De Deken(UMONS/FPMs), researcher : Pierre-Henri De Deken holds a Master's Degree of Electrical Engineering, specialized in Biosystems Engineering, at the University of Mons (since 2014) and a Bachelor's Degree of Computing Technology at HELHa (since 2009). His master thesis was performed at Fishing Cactus (Belgian video game development studio) and dealt with Video Real Time Analysis of the hand's position on the face. He is currently working on a serious game to help in the rehabilitation of hemiplegic patients

- Matei Mancas(UMONS/FPMs), PhD - researcher: Matei MANCAS holds a PhD in applied sciences from the FPMs on computational attention since 2007. His research deals with signal saliency and understanding.

Staff

- LEJEUNE Thierry, Louvain la neuve / IONS (Belgique)
- Daniel Galinski, Louvain la neuve / CEREM (Belgique)
- Julien Sapin, Louvain la neuve / CEREM (Belgique)
- Stéphanie Dehem, Louvain la neuve / IONS (Belgique)
- Bruno Dehez, Louvain la neuve / CEREM (Belgique)
- Martin Edwards, Louvain la neuve / IPSY (Belgique)
- Vincenza Montedoro, Louvain la neuve / IPSY (Belgique)
- Alessa Brandabur, University ”Politehnica” of Bucharest (Romania)

The staff need to be confirmed and completed.

Researcher needed

- Computer scientists with good programing skills (C/C++) with optional interest to social signal processing. He/she would work on system integration and help on social signal processing

- Of course any interested people are welcome both from engineering and humanities.

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