Interactive Rehabilitation Game Development Using Natural User Interface Devices

Billy Andika[1], Johandy Tantra[2], Aung Aung Phyo Wai[3]
Hwa Chong Institution[1], ACS (Independent)[2], Institute for Infocomm Research[3]

Abstract

Upon release from hospitals after recovering from serious injuries affecting limb motion, such as stroke or accidents, patients are expected to follow their physiotherapy routine regularly under the care of physiotherapists. However, as time progresses they find the monotony of the exercise regimen stifling and reduce the amount of time they spend doing the exercise, hence setting back their recovery. To address this problem, we have come up with an interactive game through a Natural User Interface (NUI) Device, the Xbox Kinect which engages patients long enough through visual and audio stimulation to ensure that they fulfil the required quantity as well as quality of exercises in order to cater their rehabilitation needs. It also provides automated or embedded assessment which can then be used by physiotherapists to accelerate the recovery progress.

Introduction

According to the World Health Organization, 15 million people suffer stroke worldwide each year. It is Singapore's third leading cause of death. The number of patients suffering from stroke has been rising and thus physiotherapy is needed to restore and maintain the normal functional ability.

In today's physiotherapy, patients are required to do the exercises regularly. The therapists are required to monitor and track the patients' exercise regimen. This is usually done in the treatment centre where the assessment can be done while the exercise is performed.

One problem for the patient is that visiting the treatment centre can be a hassle due to being costly and time consuming. Moreover, the therapist is only able to monitor the patients' progress during the exercise period. Therapist may also not know the detailed progress of the patient resulting in ineffective treatments. Due to the repetitiveness and monotony of the exercises, patients may lose motivation to perform exercises, thus hindering their recovery.

Objectives and Engineering Goals

Objective: Create a home-based rehabilitation solution that can sustain the patients' interests in regular exercising, evaluate their performance and manage proper exercise regimen remotely.
Engineering Goal: Design and develop an interactive game interfacing with NUI Devices and assess physiotherapy exercises intelligently through recognized movement information.

Materials and Method

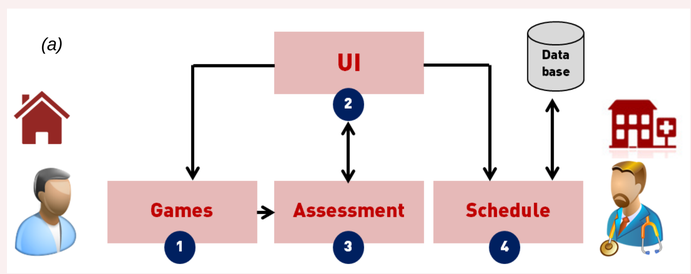
OpenNI Framework
- Interfacing with Kinect sensors
- Provides RGB, Depth and Joint Coordinates

Game design and animation
- OpenSpace 3D Game Library
- User Interface Design & Interaction

Kinect-based Human Motion Recognition
- Track and recognise movements of patients
- Skeletal tracking and Joint Angle calculations

OpenNI logo taken from OpenNI.org, OpenSpace logo taken from OpenSpace3d.com, Kinect picture taken from Microsoft.com

Proposed Solution: RehabMe



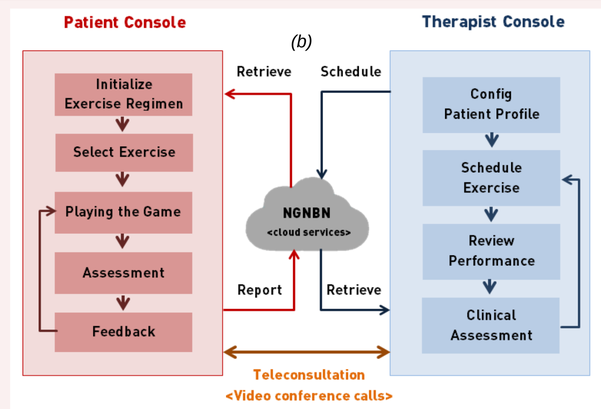


Fig 1: RehabMe: a) System Overview & Components. b) System Flow & Operation. [All diagrams are self drawn]

Our RehabMe solution contains 4 major sub-systems:
- ***Games:*** Provides a virtual environment and interaction with patients according to the game corresponding to the patient's personalized rehabilitation routine at home.
- ***User Interface(UI):*** Enables patients to view their exercise routine and reminders, and allow therapists to review, assign and manage individual patients' profiles.
- ***Assessment:*** Provides automated and objective assessments on movements performed in the game. The assessment report is sent to the therapist for final clinical evaluations.
- ***Schedule/Manage:*** Allows therapist to manage the progress of multiple patients, schedule exercise programs for individual, and track and evaluate rehabiltation progress.

With the support of Next Generation National Broadband Network (NGNBN) and Cloud services, real-time remote connections between patients and therapist center empowering RehabMe, it will be a feasible and effective way to adhere to the exercise regimen.

Game Design & Operation

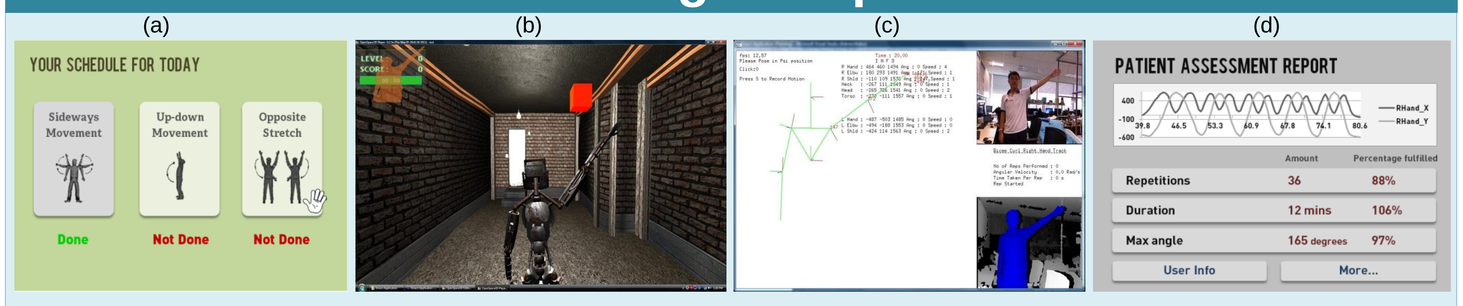
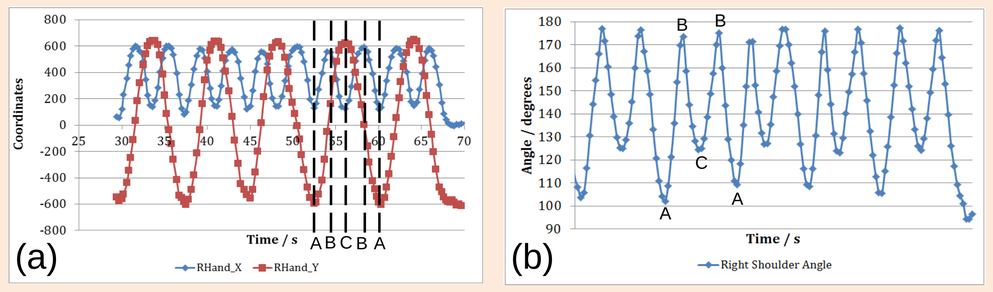


Fig. 2: Game Design and Interfaces: (a) Exercise Schedule UI (b) Game play UI (c) Kinect Outputs and Joint Angles Recording UI (d) Exercise Assessment Report UI [(a) and (d) are self-designed UI illustrations (b) and (c) are self-taken screenshots]

In *RehabMe*, the user interacts with game UI and completes the game flow while the automated intelligence assesses the exercise performance and delivers assessment reports to the therapist.

How the Game Works
- User stands in front of the screen and Kinect and calibrates with the Kinect to start RehabMe.
- User selects the desired exercise that needs to be completed at specified quantities (Fig 2-a).
- In the game play, the user needs to touch the jewels displayed at specific positions according to the exercise regimen which will guide the user to perform exercise immersively (Fig 2-b).
- Simultaneously, the assessment intelligence detects movement patterns and evaluate quantity and quality of exercises performed from recognized coordinates and joint angles (Fig 2-c).
- Such automated assessment will be sent to the treatment centre, where therapists can review and evaluate the progress (Fig 2-d), and further adjust the schedule and intensity of exercise.

Experimentation & Results



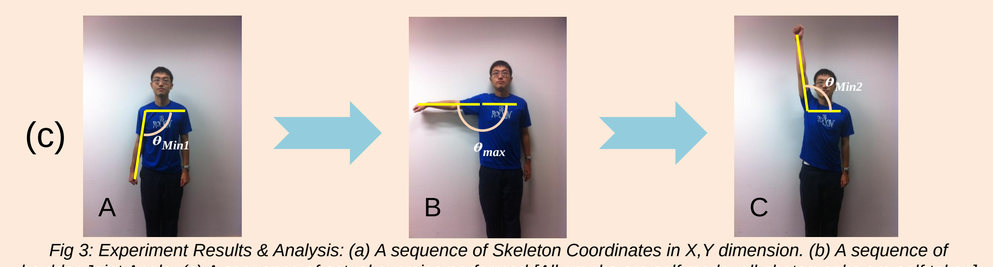


Fig 3: Experiment Results & Analysis: (a) A sequence of Skeleton Coordinates in X,Y dimension. (b) A sequence of houlder Joint Angle (c) A sequence of actual exercise performed [All graphs are self made, all photographs are self taken]

In the experiment, the user's sequence of motion (Fig 3-c) is acquired in the form of coordinates in the 3 axes (Fig 3-a) and shoulder joint angles (Fig 3-b) of the upper body.
- Each hand position gives unique X,Y coordinates and shoulder joint angles to detect which exercise the user is performing.
- Both repetitions and range of motion can be easily recognized

Discussion

Using this solution, users can enjoy performing exercises via interactions with the virtual game environment. Through the embedded assessment, therapists can identify the frequency of exercise performed, and determine if the patient is struggling with the exercise through abnormalities in the results. The assessment report which contains the frequency and range of motion of a particular exercise serves as an important resource for therapists to monitor the recovery progress of users.

Meanwhile, the current game only supports single user interaction and exercise assessment is not fully integrated into the game. Moreover, exercise evaluation was only conducted by ourselves and requires testing with different subjects to prove its effectiveness.

Future Works

- Integration of the game, tracking and assessment into single program.
- Develop and evaluate algorithm for automated exercises assessment .
- Develop game using a more powerful, extensible and advanced game engine.
- Harness advanced functionalities of Kinect's microphone to naturally interact users with multimodal inputs
- Evaluate effectiveness with mockup or real subjects by conducting clinical trials.

Conclusion

By leveraging on NUI technologies, Internet connectivity and interactive gaming, RehabMe:
- enables rehabilitation routines to be shifted from treatment centres to the patient's home.
- provides unique stimulus into the physiotherapy exercises, therefore maintaining the interest.
- makes therapists' work easier as it allows them to analyse the patients' exercises at their own convenience and adjust the exercises accordingly.

References

1.Venketasubramanian, N. (1999). *Stroke in Singapore - an overview.* Singapore Medical Journal, 40((01)), Retrieved from http://www.sma.org.sg/smj/4001/articles/4001ra1.html
2.A. Rizzo and G. J. Kim, "A SWOT Analysis of the Field of Virtual Reality Rehabilitation and Therapy, *"Presence: Teleoperators and Virtual Environments,* vol. 14, pp. 119-146, 2005.
3.Lövquist, E, & Dreifaldt, U. (2006). *The design of a haptic exercise for post-stroke arm rehabilitation*. Informally published manuscript, Interaction Design Centre (IDC), Computer Science and Information Systems, University of Limerick, Limerick, Ireland.

Acknowledgments

*We would like to acknowledge A*STAR Graduate Academy (AGA) and Institude for Infocom Research (I²R) for giving us this opportunity to conduct our research work under the A*STAR Student Research Attachment Program 2011. We would like to thank NTU IAP student, Brendan Ke for his help in providing the C++ program for recording of exercises and capturing 3D coordinates as well as shoulder joint angles. We would like to extend our acknowledgment to our schools for their support for our participation in SSEF 2012.*