Robotic Exoskeleton System Controlled by Kinect and Haptic Sensors for Physical Therapy

Daniela ChavezGuevara, *Student Member, IEEE*, Giuseppe Vietri, Mangai Prabakar and Jong-Hoon Kim, *Member, IEEE*

***Abstract*— Exoskeleton systems have been used to provide treatment to people with temporal paralysis. Control strategies to control the exoskeleton's motion for the patients and coordinating their muscle response are effective but cannot retrieve force feedback or the paraplegic limb's position.**

We propose an innovative control system by which therapists can easily operate the exoskeleton based on force feedback and limb's position retrieval. Kinect and Haptic sensors have been implemented in order to retrieve the angle position values of each movement and the applied forces needed to perform each motion.

Although we are still in the prototyping stage, our control system is proven to be successful.

I. Introduction

Robot-assisted therapy has been used to provide physical therapy to people with paralysis since 2010. Current exoskeleton rehabilitative devices have proven to improve treatment outcomes by showing multiple advantages over traditionally manual techniques, including data tracking for performance feedback, the ability to apply controlled forces at each joint as well as magnitude adjustment of such forces based on patient needs. These exoskeleton devices can be adjusted for multiple size limbs to fit different patients and can replicate the majority of the patients' upper and lower limb healthy workspace by using multiple degrees of freedom [4,5]. However, many developed systems lack easy control mechanisms to get accurate and appropriate feedback of the patients' limbs motion and force applied to perform each motion.

II. Sate of Art

Several groups have proposed different types of control strategy to improve the interaction between the patient and the system such as MANUS, RUPERT and EKSOBIONICS [2, 3, 8]. Especially, the most popular exoskeleton devices are currently applying an adaptive robot control strategy to assist in the physiotherapy and rehabilitation of the upper or lower extremities. An adaptive robot control strategy combines Proportional Integral Derivative controller (PID)-based feedback and Iterative Learning Controller (ILC).

Although the adaptive robot control strategy has proven to be successful for a patient's physical therapy, there is a remaining issue: it lacks accurate feedback. It is not possible to determine the position of each limb or the mechanical energy needed by the patient's limbs to perform certain motions. Our project addresses this issue by implementing a more practical and innovative control strategy. Kinect and Haptic sensors are used to control the exoskeleton system by retrieving the limbs position and giving force feedback. The Kinect's 3D retrieval makes possible to obtain the angles of rotation and translation of each limb based on its joint positions and the Haptic Sensor retrieves the mechanical force needed to move a specific limb.

III. System Architecture

In this paper, we propose a simple yet very efficient and innovative Control System.

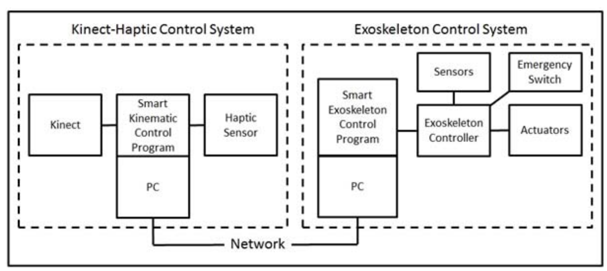

Figure 1. Control System

Our proposed system depicted by Fig.-1, consists of two parts: Kinetic-Haptic Control System (KHCS) and Exo-skeleton Control System (ECS). The KHCS has 4 major components; a Kinect Sensor, a Smart Kinematic Control Program (SKCP), a Haptic Sensor (HS), and PC. The Kinect Sensor is used for retrieving the therapist's motion, which is expected to be reproduced on the patient. The Haptic sensor is used for controlling the force on actuators on ECS. SKCP is the program for processing motion and force values to be sent to the Smart Exoskeleton Control Program (SECP) on ECS. The ECS has 6 major components; a SECP, an Exoskeleton Controller (EC), Sensors, an Emergency Switch (ES), and PC. The SECP is used for processing the motion and force values to control each actuator through the EC. The EC is used for collecting sensing data from various sensors and emergency trigger on the ES. The ES is used to keep the patient safe in case of an ECS failure.

Both KHCS and ECS are connected through the network and are communicating with each other in real time. The HS

*Research partially supported by State Farm.

D. Chavez Guevara is with Discovery Lab, School of Computing and Information Sciences, Florida International University, Miami, FL 33199 USA (e-mail: dchav016@fiu.edu).

G. Vietri is with Discovery Lab, School of Computing and Information Sciences, Florida International University, Miami, FL 33199 USA (e-mail: giusevtr@gmail.com).

M. Prabakar is with Discovery Lab, School of Computing and Information Sciences, Florida International University, Miami, FL 33199 USA (e-mail: mangai123@gmail.com).

J.H. Kim is with Discovery Lab, School of Computing and Information Sciences, Florida International University, Miami, FL 33199 USA (phone: 305-348-3751; fax: 305-348-3549; e-mail: kimj@cis.fiu.edu).

978-0-7695-5032-9/13 $26.00 © 2013 IEEE
DOI 10.1109/SBEC.2013.44

receives force values from the SECP so the therapist will perceive the force applied in each motion. In case of the presence of resistance, the HS will send back the force valued needed to complete the motion to the SECP, and then the process is repeated until the force values are adjusted to the patient's needs. This force feedback mechanism is interactive between response from patient's resistance in the upper limb exoskeleton and the therapist's force reaction on the haptic sensor device.

IV. PROTOTYPING UPPER LIMB THERAPY

In this paper, we have implemented an upper limb therapy exoskeleton system with a simple Kinect-Haptic control system and Exoskeleton Control System.

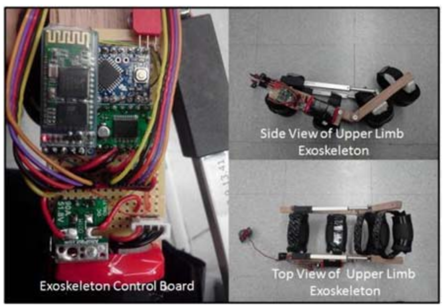

Figure 3. Exoskeleton Limb

The exoskeleton limb is a sleeve-like device that features one pair of linear actuators and a exoskeleton control board. The exoskeleton control board consists of a current sensor controller, a motor controller, an arduino board and a Bluetooth device. (Fig-2)

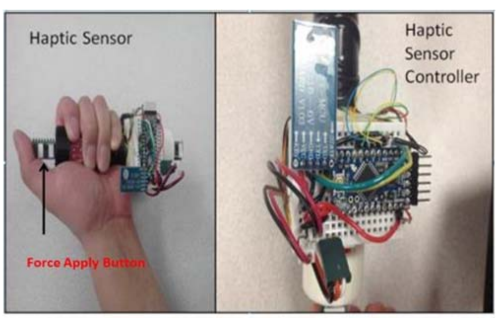

Figure 4. Haptic Sensor

The haptic sensor has a spring inside that shrinks whenever the current is increased so that the force apply button will be hard to be pressed and therapist will sense the resistance of the patient. The current is produced by a motor that is attached to one of the sides of the haptic sensor. An arduino board is attached to the other side of the haptic sensor. The motor controller, the batteries and the Bluetooth are connected to the arduino board. (Fig.-3)

The translation angles retrieved by the Kinect sensor are mapped into a position value that is sent to the linear actuators. If resistance is encountered during the motion, the current sensors send the resistance to the therapist through the haptic sensor.

The Haptic sensor will generate a force onto the button to provide force feedback to the therapist.

The therapist can push the button to complete the patient's therapy if it is needed and acceptable. (Fig-4)

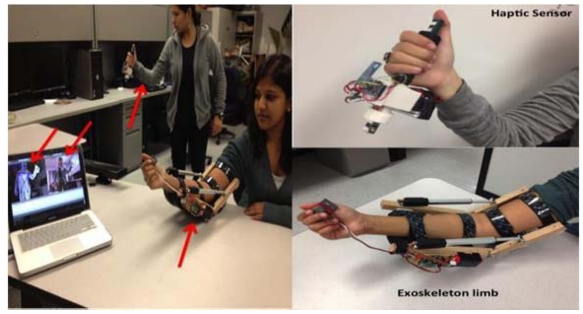

Figure 2. Prototype Testing: Arrows indicate the progress of the arm motion.

V. CONCLUSION AND FUTURE WORK

In this paper, our novel and simple Exoskeleton Control system and Kinect-Haptic Control system provides excellent motion control and successfully retrieves force feedback. However, safety issues need to be investigated, the force values need to be debugged in order to have high quality feedback and avoid injuries to the patient. For future work, and enhanced interface between the two Kinect - Haptic Control System and the Exoskeleton Control System will allow the patient to perform therapy without real time guidance from the therapist.

REFERENCES

[1] Ward, Jeffrey A., Sivakumar Balasubramian, Thomas Sugar, and Jiping He. "Robotic Gait Trainer Reliability and Stroke Patient Case Study.", Proceedings of the 2007 IEEE 10th International Conference on Rehabilitation Robotics.

[2] Hogan, Neville., Krebs, Hermano Igo; Charnnarong, J.; Srikrishna, P.; Sharon, Andre., "MIT-MANUS: a workstation for manual therapy and training.I.", Proceedings of IEEE International Workshop on Robot and Human Communication, 1992.

[3] Wei, Ruihua , Sivakumar Balasubramian, Lihong Xu, and Jiping He. "Adaptive Iterative Learning Control design for RUPERT IV", Proceedings of the 2008 2nd Biennieal IEEE/RAS-EMBS International Conference on Biomedical Robotics and Bioinformatics.

[4] Daniel Garcia, Victor Soto, Yojans Lurbe, Melissa Morris, Sabri Tosunoglu. "Development of a Rehabilitative Exoskeletal Arm", 2012 ASME Early Career Technical Conference.

[5] Butefisch, H. Hummelsheim, P. Denzler, and KH Mauritz. "Repetitive training of isolated movements improves the outcome of motor rehabilitation of the centrally paretic hand", Journal Neuro Sci, 130(1): 59-68, 1995.

[6] T.G Sugar, Jiping He et al, "Design and Control of RUPERT: A Device for Robotic Upper Extremity Repetitive Therapy."IEEE Trans on Neural Systems and Rehabilitation Engineering, Vol.15, No.3, 2007.

[7] Online: "HAL": Hybrid Control System- CYBERDYNE." http://www.cyberdyne.jp/english/robotsuithal/move.htm l\

[8] Online: "Ekso Bionics." http://www.eksobionics.com/

[9] Online: "What's "HAL CYBERDINE" http://www.cyberdyne.jp/english/robotsuithal/index.htm l\