Using Mixed Reality to Map Human Exercise Demonstrations to a Robot Exercise Coach

Ayanna M. Howard[1*], Luke Roberts[1], Sergio Garcia[1], Rakale Quarells[2]

[1]School of Electrical and Computer Engineering, Georgia Institute of Technology

[2]Social Epidemiology Research Center, Morehouse School of Medicine

Abstract

Obesity is a growing health problem in the United States, especially among children. Indicators show that the rate of obesity for children age 12-19 years old has risen from 5% percent to 18% over the last ten years. To deal with the obesity epidemic, a number of technology interventions, including the use of robotics and virtual reality games, have arisen to motivate youth to become physically active. The difficulty though lies in providing a tool for health professionals to embed established clinical health protocols into these technologies. As such, in this paper we present a mixed reality system that translates physical demonstrations of various exercise protocols into movements for a robotic agent. This is accomplished by mapping real-time data from an RGB-D sensor to a robotic exercise coach. Details of the system are discussed and results from evaluation with 20 human subjects are provided.

Index Terms: 1.2.9: Artificial Intelligence—Robotics

1 Introduction

The burden of childhood obesity has reached epidemic proportions in the US. The National Health and Nutrition Examination Survey [1] concludes that 34.1% of children aged 12-19 years are either overweight or obese, which represents a tripling of the prevalence of obesity in childhood since the early 1970's. To deal with the obesity epidemic, a number of technology interventions, including the use of mobile apps and virtual reality games [2], have arisen to motivate youth to start and continue improving their health and become physically active. In the robotics domain, there is even a small class of social robots that use verbal engagement to engage their human users in complying with healthy behaviours, such as Clara [3], a rehabilitation exercise coach, and Autom [4], a weight loss coach.

Although state-of-the-art health-based intervention technologies have been utilized in various pilot studies, there are still a number of limitations prevalent in current designs. Namely, the ability for healthcare professional to embed proven clinical interventions for addressing individual exercise goals utilizing robotic technologies are still limited in scope. Typically, the aforementioned systems do not provide the personalization tools necessary to individualize the exercise intervention. This personalization is especially important when trying to address the diverse needs of all children, regardless of socioeconomic status, gender, or ethnicity. What is needed therefore is to provide supporting technology that enables health professionals the ability to *program* new exercise protocols into systems that not only work to engage the child, but also simulate natural human interaction. Our goal in this project is therefore to design a technique that enables this natural interaction.

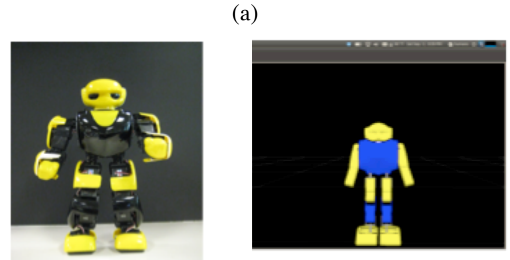
* ayanna.howard@ece.gatech.edu

IEEE International Symposium on Mixed and Augmented Reality 2012
Science and Technology Proceedings
5 - 8 November 2012, Atlanta, Georgia
978-1-4673-4662-7/12/$31.00 ©2012 IEEE

2 System Platform

The Center for Disease Control (CDC) Youth Media Campaign Longitudinal Survey found that 61.5% children do not participate in any organized physical activity outside of school hours, and 22.6% do not engage in any physical activity at all during their free time [6]. One way to change this trend is to design a personal health coach that correlates with exercise protocols but is also engaging for the child. To examine this hypothesis, we built a Manoi AT01 humanoid robot to function as our robot exercise coach (Figure 1). The Manoi-AT01 is a humanoid robot with 17 DOF (degrees of freedom) geared for athletic robot competitions. The 5 DOF in each leg and the 3 in each arm allows it to adequately mimic both upper and lower-body exercise motions. The Robot Operating System (ROS) architecture is used to control the robot through use of groups of code called nodes that subscribe and publish to data topics, and take action based on data published to topics they are subscribed to (http://www.ros.org/). The nodes are written in C++ and Python for use with ROS. An RGB-D sensor is also employed in sensing the human's exercise movements. For our application, the RGB-D used is the Kinect, a motion sensing device by Microsoft for the Xbox 360 video game console. The NUI Skeleton API provided for the Kinect provides information about users standing in front of the RGB-D sensor array, with detailed position information. About 20 points of body position are provided by this API, which we utilize to track human motions for our application.

(a)



(b)

Figure 1: (a) System showing the RGB-D sensor and Interface used for mimicking exercise, (b) Physical and Virtual Renditions of the Robot Exercise Coach

3 Mimicking Human Motions

The first step in building our robotic exercise coach is to provide a simple and natural method for the exercise physiologist to teach the robot desired exercise patterns. To implement this, we use the RGB-D sensor to capture human exercise movements, which can then be translated to the robot's joint configuration space. This initial work focuses on motion translation where the human 'end effectors' (i.e. hands and feet) are tracked and then applied to the robot. In order to limit the focus of this paper, we discuss the mapping of exercise movements that are dependent on arm joint angles concentrating on upper body movements. Basic leg mimickery for control of the leg joints was done on the hip and knee joints and explored in the same manner.

The human arm is considered to have 7 DOF, which includes the shoulder, elbow, and wrist. Through shoulder pitch, yaw and roll (3 DOF), elbow pitch (1 DOF), and wrist pitch, yaw and roll (3 DOF), a human has the ability to move the hand to any point in space and grasp items from different angles and directions. Although our humanoid robot only has 3 DOF in the arm, it can rotate its arm up to 260 degrees and has the equivalent of a shoulder, an elbow and a wrist. However, in order to correctly mimic human movement, a matching algorithm between these two structures is needed.

Inverse kinematics refers to the use of a robot's kinematics equations to find the joint actuator trajectories necessary for achieving a desired end-effector position. Since the human arm has redundancy in its configuration space, it has multiple inverse kinematics solutions for a given end-effector (i.e. wrist) position. As such, in order to map the motion of the human arm, which has 7 DOF, to a 3DOF robot arm, we need to identify similar configuration among all possible solutions. In order to obtain joint angles, the joint coordinates of the human arm, which are provided by the NUI Skeleton driver, are converted to 3-D vectors. Angles between these vectors are then published as joint states to ROS (Figure 2).

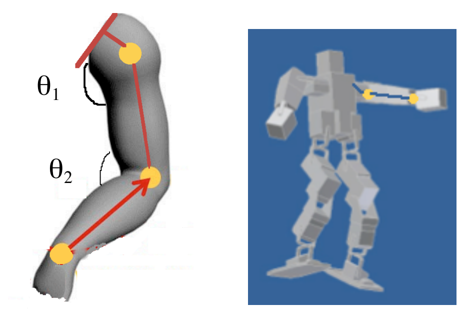


Figure 2: Mapping angle information from human arm to robot

4 Human-Interaction through Mixed Reality

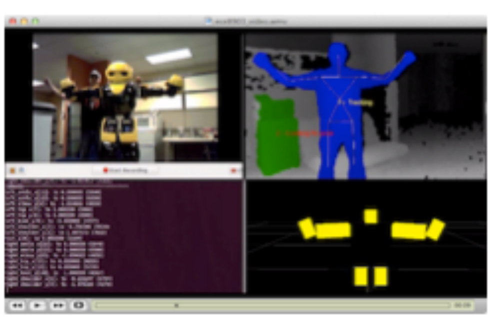


Figure 3: Human Interaction through Mixed Reality

Based on prior studies [7], individuals typically perform better when their movements are reinforced by a virtual version of themselves. Thus, to provide a system that provides sufficient feedback to the user, we designed an interface that enables a user to view three versions of their actions – a virtual version of self, a virtual version of the robotic coach, and the physical version of the robot (Figure 3). When showing the robot an exercise movement, all viewpoints were thus provided to the user.

5 User Study and Results

To evaluate system performance, 20 human subjects tested the system using the RGB-D sensor to map exercise movements to the robot. All subjects signed IRB approved consent forms. 9 subjects were female and 11 subjects were male. The subjects' ages ranged from 18 to 32 years old with an average age of 23. The users were allowed to show the robot any exercise movement they preferred, lasting any duration up to 3 minutes. While exercising, the robot would mimic the subject's movement. The average response time between human and the first initiation of robot movement was recorded at 0.70 seconds. Following the testing, using a 5-point Likert scale ranging from very satisfied to not satisfied, each subject answered the following question "How well did the recorded motions match what you intended?" - 65% were either very satisfied or satisfied (4.2/5) with the recorded motions whereas 35% were not completely satisfied (2.6/5). The subjects also answered: "How much did you enjoy playing with this system overall?" - 75% were either very satisfied or satisfied confirming the interest of the subjects in such system.

Since a typical pattern of interaction between an exercise coach and a child involves switching between child-led versus robot-led behaviors, the next step required for pilot development of the robot coach with younger subjects (Figure 4) is to enable scenarios where either the robot or the human can initiate movement.

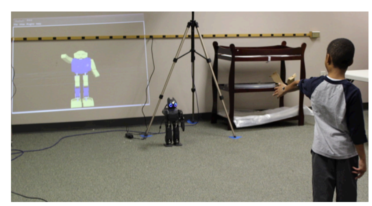


Figure 4: Exercise interaction in case study with a child

References

[1] C. Ogden, et. al., "Prevalence of overweight and obesity in the United States, 1999–2004," *J. American Medical Assoc.*, Vol. 295 (13):1549-5, 2006.

[2] S.M. Arteaga, M. Kudeki, A. Woodworth, "Combating obesity trends in teenagers through persuasive mobile technology," *ACM SIGACCESS Accessibility and Computing, 2009*.

[3] J. Fasola, M. Matarić, "Using Socially Assistive Human-Robot Interaction to Motivate Physical Exercise for Older Adults". Proceedings of the IEEE, T. Kanade, ed., 2012.

[4] C. Kidd, C. Breazeal, "Robots at Home: Understanding Long-Term Human-Robot Interaction," *IEEE/RSJ International Conference on Intelligent Robots and Systems*, Nice, France, 2008.

[5] C. Lathan, A. Brisben, C. Safos, "Cosmobot levels the playing field for disabled children," *Interactions*, 12(2): 14–16, 2005.

[6] Centers for Disease Control and Prevention, "Physical activity levels among children aged 9-13 years United States, 2002," *Mortality and Morbidity Weekly Report*, 52(33);785-788, 2003.

[7] D. Brooks, Y-P. Chen, A. Howard, "Simulation versus Embodied Agents: Does either induce better human adherence to physical therapy exercise?" *IEEE Int. Conf. on Biomedical Robotics and Biomechatronics (BioRob)*, Rome, Italy, June 2012.