Using Virtual World Activities for Amputee Rehabilitation

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Abstract. We report on a novel method for engaging an amputee in rehabilitation activities delivered through an advanced telehealth mechanism using virtual worlds. Patients use two instrumented gloves moving their upper extremities in gestures that mimic a rock climbing activity. These actions cause their avatar in the virtual world to climb a virtual rock-climbing wall. Other activities using low cost sensors can be implemented within the virtual world to support therapeutic needs, and data collected form these sensors can populate a data base the therapist can access to assess patient progress.

Keywords: Virtual worlds, human factors, health, telehealth, handicapped persons/special needs rehabilitation, avatars

Introduction

In the past decade, we have seen an explosion in social networks enabled by technology, including networked, persistent, easily accessible Virtual Worlds (VWs) with tens of thousands of participants. These networked 3D virtual spaces need no special equipment to experience, beyond an ordinary computer and Internet connection. In particular, such worlds provide a social aspect that is highly appealing, and their game-like nature makes them popular with young adults who have grown up playing video games. According to a leading United Kingdom research firm, KZERO (2011), the growth of virtual worlds over the last several years has been stunning. Their latest published figures for the fourth Quarter of 2011, show 1.77 billion worldwide users of numerous immersive virtual worlds. A most surprising finding of their extensive research is that just over 1 billion of these participants are children ages 5-15. This indicates that virtual worlds may be a known and comfortable medium for the upcoming generation to use for both information delivery and social networking. The immersive nature of these worlds seems to be especially compelling for this group. Other social networks (such as Facebook) have considerably less users in this demographic, not in the least part due to the age restrictions in many social networking sites (Lenhart, Purcell, Smith and Zickuht, 2010; Evangelista, 2011).

A virtual world is persistent and malleable. The data containing the world and its contents is stored on server-side computers. A user downloads a software client that runs locally on his computer, synchronizing to the data server in a continuous real time process. All interaction within the content of the virtual world is accomplished through a graphical, embodied representation of the user called an avatar. This avatar can be customized or personalized to a range of appearances, from cartoony to fairly realistic (Figure 1). Avatars can even be made to look like animals, fantastic creatures, or robots. The avatar is the basis by which all socialization in the VW is accomplished, as participants interact avatar to avatar, with hundreds who can be logged on at the same time.

Emerging research is beginning to show that activities performed via an avatar in the virtual world can have an effect on our physical minds and bodies (Yee and Bailenson, 2007; Fox and Bailenson, 2009). More research is needed to find out exactly why such effects occur, but one hypothesis is that effects stem from the social interactions VWs afford, and another speculation is that they may be due to the intimate connection formed between a person and their avatar

(Jensen, 2009). Even though with more research is needed to understand the causes, we can still leverage these affordances to help address the many health needs with VW-delivered care.

Figure 1: Typical avatars in virtual worlds

Activities in VWs cover an extensive range, from discos and musical entertainment, to costume contests, fishing competitions, adventure quests, trivia quizzes and interactive games. Shopping for items to customize one's avatar is very popular, and people will add many looks to their inventories over time. There are as many types of things to do in the virtual world as there are in material world, perhaps even more since one is not limited by physical constraints. For example, the most popular way to navigate around the spaces of the VW is by having one's avatar fly.

Virtual Worlds and Potential for Heath Care

We believe VWs can serve as an advanced form of telehealth care delivery. Telehealth experts Bauer and Ringel (1999) define telehealth as ... *the combined use of telecommunications and computer technologies to improve the efficiency and effectiveness of healthcare services by liberating caregivers from traditional constraints of place and time and by empowering consumers to make informed choices in a competitive marketplace*. VWs offer the advantages of traditional telecommunication and computer delivered care, such as accessibility from rural locations, remote patient monitoring, better continuity in disease management, reduced hospitalization. They too, can help foster a positive impact on the provider-client relationship, but they can do much more. VWs contribute to telehealth care uniquely via their highly social nature with thousands of users logged on simultaneously, which allows social networking and even the formation of support groups. VWs also allow people to create and interact via the avatars described above, providing a form of extremely personal embodiment that engages people psychologically in the virtual space.

The need for innovative forms of telehealth is becoming more apparent. Since September 11, 2001, over 2 million United States military personnel have been deployed to conflicts in the Mid-East. As a result, there has been a huge increase in the demand for resources to help these soldiers transition back into the civilian sector when they return (DCoE, 2010). In addition, there is a growing need for continued care when soldiers return to their homes, which is not currently being met by traditional medical and health offerings. Because of this, new methods must be developed to expand the ways in which assistive resources can be made available to these soldiers. Virtual worlds can provide motivation, engagement, and most importantly, because they are easily available to anyone who has a computer and an Internet connection, help address access to care, especially in underserved areas. They also provide means to help support compliance and continuity of care once a person has finished their clinical sessions and returned home.

Patient Interaction and Monitoring

Patient-therapist communication can be improved by having channels that are perceived by all parties to be open and two-way. Typically a patient must travel to a therapist's clinic or office to take advantage of the therapist's observations, advice and insights. Once they return home, they may have little access to that therapist without repeat in-person visits, which may be difficult. With the connectivity afforded by virtual worlds, not only is a therapist able to set up meetings "in-world" that do not require travel for either party, data from a patient's therapeutic VW activities can be accessible to both parties. For the patient, this data might take the form of a motivational "leaderboard" where they can visualize their progress over time, earn new levels of challenge, etc. For the therapist, data gathered from both physical and virtual sensors can be delivered at regular intervals or on demand, and can also undergo analysis and visualization to provide optimal information on what the data indicates. Avatars are typically known in world by a pseudonym, and not their real name. This helps to address privacy concerns to some gree, though more work in making virtual worlds HIPPA-complia nt is needed as VWs ontinue to be explored for their potential health benefits.

The patient-therapist dyad facilitated by the virtual world system has additional benefits: several patients who are further along in their progress might be seen as a group, encouraging peer support and interaction, with the therapist giving general instructions and educational materials once, rather than individually to each person. Patients still perceive this as personal interaction, since they are in-world with the therapist (who is also represented by their own avatar) even though it can require significantly less time on the part of the therapist. In addition the therapist can see when a patient is online and look in on them. This allows for additional impromptu interactions that do not have to be time consuming, but can indicate more of a caring approach by the therapist. This is better than random phone calls that might have occurred in the past, as the therapist could be alerted when the patient is actually performing the therapeutic activity.

Creating Telehealth Value in the Virtual World

The ICT has developed considerable expertise over the past five years creating, maintaining and expanding virtual worlds, including work in ActiveWorlds® (Jan et al., 2009) and in Second Life® (Morie, 2009a; Morie, 2009b). The ICT's Second Life work includes the development of a four-region veterans' healing space for the Army-funded project "Coming Home", which includes a resource center with links to government-sponsored websites and information, social activities and new tools to promote healthful activities within the virtual world, focused primarily on accessible stress relief activities.

One such activity is an innovative jogging path for use in the virtual world whereby a participant practices relaxed, even breathing into a microphone to control the running of their avatar along a running path (Figure 2). In pilot testing, this activity - relating physical breath and virtual running - has shown to promote significant relaxation in participants (Morie, Chance and Buckwalter, 2011).

Figure 2: The breath-activated running path in Second Life®

In collaboration with AnthroTronix, Inc, a company focused on biomechanical solutions for better training and health care, we have created a rehabilitation activity for amputee veterans that can be conducted in the virtual world space of Second Life®. The "Amputee Virtual Environment Support Space" (AVESS), is an initiative funded by the US Army's Telemedicine and Advanced Technology Research Center (TATRC) to support development of a range of technologies to provide beneficial activities for soldiers who have incurred life-changing physical injuries. These activities can include social connections, reintegration to civilian life, ongoing physical therapy and mitigation of psychological repercussions. While the physical needs of America's soldiers are initially well provided for by military hospitals, the virtual world has the potential to facilitate a higher level of continuing care and follow-through once soldiers are back at home. Virtual worlds can also provide an environment for ongoing psychological health and peer support that can be key to a healthy outlook and future quality of life.

Our first effort for AVESS uses AnthroTronix's low cost instrumented AcceleGlove™ technology connected to a rock climbing activity in the virtual world (Figure 3). These gloves contain accelerometers on each finger, thumb and palm, and can be trained to recognize gestures such as those used in sign language spelling. A lower limb amputee wears two gloves – one on each hand, and by performing the gestures of rock climbing we have defined, can raise and lower his arms to cause his avatar to climb the virtual rock wall (Figure 4).

Three technical components work in concert to allow a user's avatar to progress up a virtual climbing wall one rock at a time, via moving their real hands alternately in a climbing motion. First, the AcceleGloves allow the user to define a series of gestures that can trigger the actions of the avatar within the virtual world. These gestures represent a subset of the physical actions that a climber uses to physically grasp and pull rocks on a climbing wall, using two hands. Gestures were defined and implemented for each hand separately. The second component is the keymapper software, which takes those gestures and calls standard keyboard actions in the virtual world.

The final component is an application written in Linden Scripting Language (LSL) that resides inside the Second Life client. This script causes the avatar to move up the climbing wall in an imitation of the actual physical activity. A key press is triggered each time the user closes his hand. The LSL application recognizes the key press and sends a command to the avatar, who then begins to grip the next rock with that hand. When the user opens his hand, the corresponding key is released and the avatar releases the rock. If both hands open, the avatar falls to the ground and has to start over. This LSL application also synchronizes the avatar's vertical movement up the wall with the animations. Because avatars in Second Life have such widely varying heights, the avatar must be of a specific height in order to sync up with the position of the rocks correctly. Other than that, there are no restrictions for the user.

We used the AcceleGlove's Software Developers' Kit (SDK) to establish communication between the glove sensors. A set of climbing gestures was defined through the gesture editor. Once this was done, we specified which animations the Second Life wall climbing activity needed and then created these animations to closely resemble physical world climbing motions. Several different gestures for each movement were recorded to cover the range of variations that a user might perform. Each set of gestures was then keymapped for proper triggering of the animations and movement in Second Life (Figure 5).

Figure 3: AnthroTronix AcceleGlove™ Gloves

Figure 4: Rock-climbing in the Virtual World

The LSL application comprises two objects that communicate to make a seamless climbing activity. A Heads-Up Display (HUD) inside SL detects the keystrokes (triggered by the gloves through the keymapper). It also displays graphical feedback to the user in real time regarding their progress.   A Movement Control object, which is linked to the avatar, controls the avatar's actions and animations. This object also maintains constant communication with the HUD and continuously updates its display.

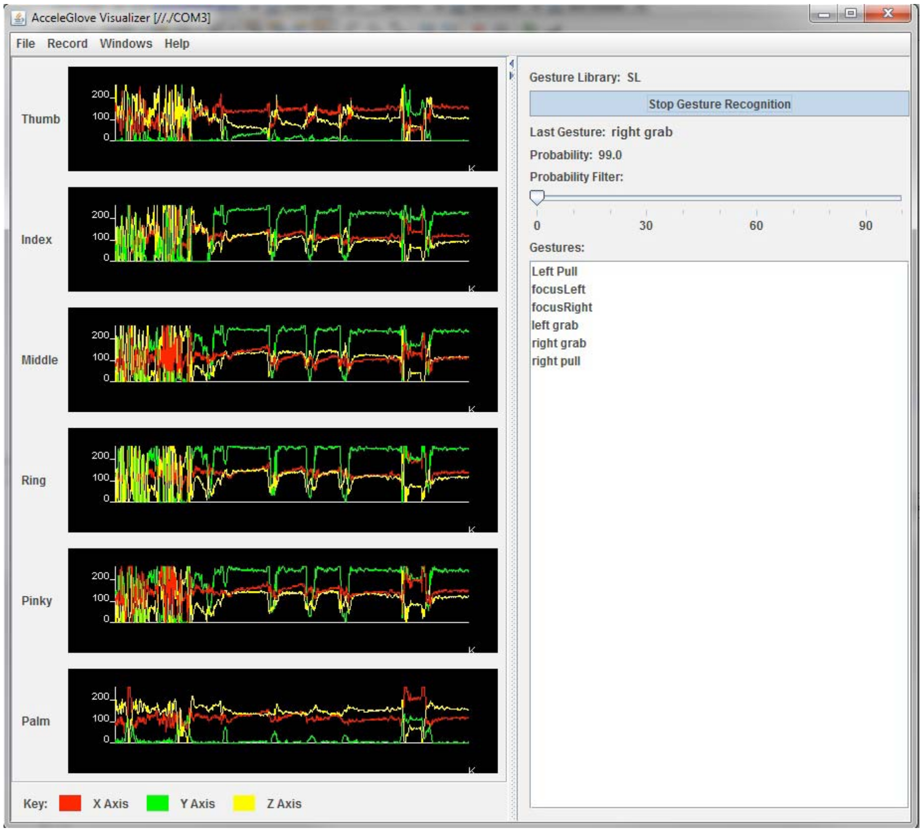

Figure 5: Motion data from gloves

At this early stage, there are two animations being triggered: climbing the wall with the left hand fully extended and grabbing, and climbing the wall the right hand fully extended and grabbing. These two animations are single poses, but Second Life attempts to blend from one to the next utilizing user-defined ease-in and ease-out blend times. This makes it appear that the avatar is moving his limbs to each new position without actually having to implement full animations on our part. There is a limit to how many keys can be intercepted via LSL (limited to the number of keys used to normally move the avatar), so we must carefully consider how many additional animations to use for future improvements. Currently, the user must make the grabbing gesture and hold it for a specified amount of time before the climbing animation is played. This simulates the approximate time that it would take to grab a real rock and pull up to it. However the exercise could be improved by synchronizing the avatar's arm movement toward a rock with each grasping gesture by using real time acceleration data from the sensor.

Sensors in the Virtual World

One of the main benefits of virtual worlds is their persistent nature. Because the virtual space itself is active, it enables us to place virtual sensors where needed to record various forms of data. This data can be used to enhance VW forms of telehealth therapy. ICT has created a system that logs avatar activity over several Second Life simulator regions, for various purposes. This system can be customized to benefit patient-therapist needs.

For example, in the image below (Figure 6), software sensors have been embedded in the virtual land that "read" where avatars are within a region in Second Life. These sensors are placed every 60 meters on the virtual space (which provides full overlap) and report an avatars presence at a temporal granularity of every 10 minutes (though other time ranges can be specified). The data of avatar name, location, and time spent are sent to a database that can be both queried and graphically visualized.

For such a query a therapist can use an interface to choose a date range and then select the avatars of interest from a list of avatar names that have visited that region.

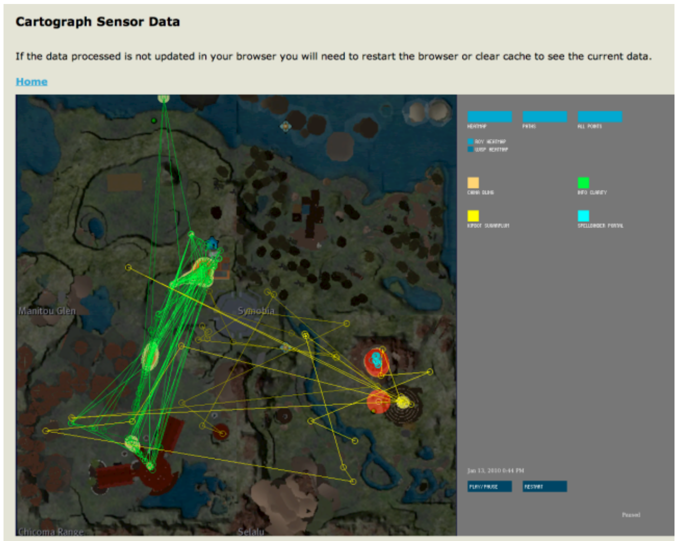

Figure 6: CARTOGRAPH Visualization Tool

Once these filters are chosen (Figure 7), the visualization page loads and allows the therapist to play animations that show the paths an avatar has taken through the area over the days or times selected. In addition, one can visualize length of time an avatar lingers in a specific place via a "heat map" option that creates shapes that correlate in size to amount of time spent. Several avatars, each displayed with a different color, can be tracked and compared on a single visualization screen.

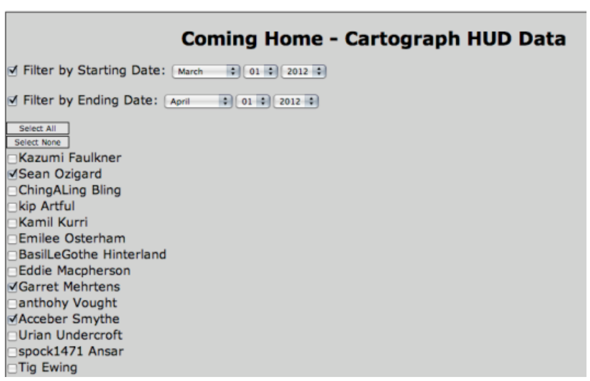

Figure 7: Selecting CARTOGRAPH Filters

Not only location data, but data gathered from other virtual and physical sensors can be recorded to the same database. For example, we can record which exercise a patient is performing, their respiration or heart rate measurements during that act (if those sensors were used), whether or not they were alone or with others, how many repetitions were done, indications of balance issues and a host of other useful data. This information can be made available to the therapist either as raw data, or delivered after processing with appropriate analysis tools to provide a summary or overview of patient progress.

Future Work

AnthroTronix, Inc. is currently developing and testing a wearable balance sensor – a low cost miniature device that can facilitate a wide variety of balance-oriented exercises (Figure 8). The balance sensor is based on the InvenSense MPU-6050 accelerometer and digital gyro, along with the ARM STM32F microcontroller (Figure 9.). In our next phase of AVESS work for TATRC, we plan to integrate this sensor into the virtual world to support a suite of fun and engaging balance exercises.

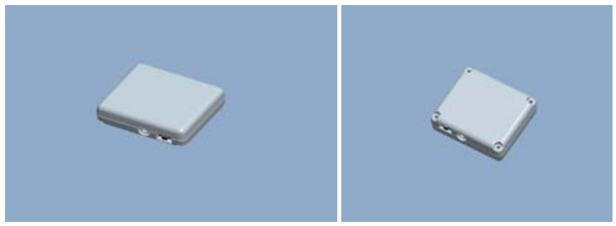

Figure 8: Wearable Balance Sensor

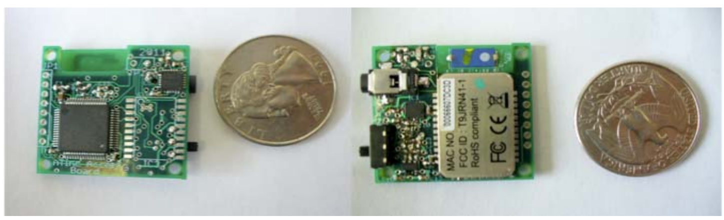

Figure 9: Accellerometer and Gyro for balance sensor.

Conclusion

Although telehealth in virtual worlds is a relatively new area of research, we see important potential for its use in providing rehabilitation care that is not only effective but also enjoyable. When direct face-to-face contact between health care providers and patients is not possible, we believe that the virtual embodiment of the patient (and the therapist) can not only provide a strong sense of engagement and presence in the interaction, but the virtual embodiment can positively effect the outcome of some types of therapy. Additionally, the social nature of virtual worlds can be a catalyst for peer support during a time in the amputee's life where he may be in great need of emotional support and the physical presence of his friends, family and even other amputees. Finally, virtual worlds for telehealth provide new ways for caregivers to interact with patients and monitor their activities. As sensor technology continues to develop (such as recent advances like the Kinect™ and the AcceleGlove™), virtual worlds for telehealth will be an ideal testing ground for those sensors to collect data and enhance both the patient and therapist's experiences. The USC ICT expects to to develop more novel approaches to in-world activities that are beneficial and engaging to the patient and provide useful data to the caregiver. We are currently adding levels of difficulty to the rock-climbing wall and have plans to include a competitive option for additional motivation. The ICT also plans to conduct studies to determine the usefulness of these in-world activities to the amputee population as well as to others needing both motivation to encourage compliance, and access to continuity of care that virtual worlds can provide as a modern form of telehealth care.

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