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Melynda Eden

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CSE MS Project Report

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ABSTRACT

Cerebral palsy is a group of neurological disorders that impair body movement, muscle coordination, hearing, vision, and cognitive function. Symptoms vary but can include muscle weakness, muscle and joint tightness, abnormal or unsteady gait, seizures, learning disabilities, speech problems, as well as hearing or vision problems [1]. Although cerebral palsy cannot be cured, treatments such as physical and occupational therapy can greatly help affected children develop motor skills needed to increase mobility and foster independence [2]. Computer based therapy games have shown promise in helping stroke survivors recover from stroke [3]. Initially, stroke therapy games developed in Looking Glass utilized Nintendo Wii remotes (informally known as Wiimotes) to sense user's movements. Challenges unfolded with stroke patients who were unable to grasp Wiimotes, thereby limiting and inhibiting game development and the user experience [3]. In this paper, I describe my efforts to integrate the Microsoft Kinect with Looking Glass and build therapy games that utilize the Kinect to track user movements. I detail the Kinect integration and discuss its advantages of seated skeletal tracking with no hand held devices required by the user.

INTRODUCTION

Individuals with motor impairments often require years of rehabilitation therapy, however these individuals often struggle with motivation to perform repetitious therapy exercises [8]. Persons with cerebral palsy need this ongoing therapy to prevent muscle atrophy and increase self care skills [1,7]. In a study of over 300 stroke survivors with motor impairments, only 31% reported performing their recommended rehabilitation exercises [4]. The benefits of traditional rehabilitation exercises are not immediate, and finding lasting motivation to perform numerous and monotonous therapy exercises can be difficult. The level of motivation varies from person to person, and this can have a direct impact on the results of rehabilitation [9].

Video games are seen as a possible solution to the motivation problem for some individuals. By their very nature, video games are fun and therefore intrinsically motivating [28]. They provide instant feedback and gratification, are typically developed with themes that pique user's interests [23]. Video games have been enjoyed extensively for decades primarily for entertainment purposes. Additional benefits of mainstream video games are sometimes overlooked. Some commercial video games promote strategic thinking, cooperation, communication, and multitasking [29]. The latest gaming systems have evolved to include player movements as part of the gaming experience, and these games can have physical benefits as well.

In recent years, researchers have explored using video games and systems for therapeutic purposes [8, 14]. As game controllers have evolved from handheld joysticks and buttons to sensors and cameras that detect body position and movement, there is an abundant potential of employing video games to rehabilitate persons with motor impairments [8]. That said, commercially available video games involving full or partial body movement such as Kinect Adventures and Nintendo Wii Sports can be too challenging for some disabled individuals, requiring levels of speed and accuracy not possessed by those with motor impairments [8].

Computer based therapy games show promise in motivating users to perform more rehabilitation exercises resulting in increased strength and functionality. Video games that utilize body motion sensors instead of joysticks can incorporate repetitive therapy exercises into an intriguing and stimulating gaming environment. Therapy games can adapt to users of differing abilities and allow for slower reaction times, limited range of motion, reduced muscle strength and coordination as compared with mainstream games developed for individuals with full muscle functionality. Multiplayer games can be developed to increase users' motivations to perform therapy exercises [6, 13]. Users perform therapy movements in order to achieve the goals of the game, thereby motivating individuals to perform more therapy exercises than they otherwise would.

The results for using customizable video games for therapy exercises are promising. Research suggests that individuals can improve motor control using computer based therapy games. One study profiled a woman seventeen years post-stroke. The study cited both quantitative and qualitative improvements in the woman in six weeks time including increased range of motion and improvements in her ability to perform daily tasks [12]. Another study focusing on an adolescent with cerebral palsy cited improvements in visual-perceptual processing, postural control, and functional mobility were measured after using the Wii for rehabilitation purposes [10]. Another study focusing on young adults with cerebral palsy showed an increase in motivation to participate in rehabilitation exercises when using a Kinect based rehabilitation system [5]. Yet another study focusing on adults with cerebral palsy who had previously abandoned their rehabilitation plans found that they did not abandon a therapy program based on video games, and even expressed interest in continuing this therapy after the study [11].

Looking Glass, a programming interface that does not require previous programming experience, can be used to build customizable therapy games. In the past, this had been accomplished using the Nintendo Wiimote with some success. With the introduction of the Microsoft Kinect, the possibilities for developing Looking Glass games for motor-impaired individuals significantly increased. This paper discusses the implementation of the Kinect in Looking Glass to provide an avenue for Looking Glass users to develop computer based therapy games that do not require any hand held input device.

BACKGROUND ON CEREBRAL PALSY

Cerebral palsy is non-progressive and non-contagious, and is caused by damage to the developing brain during pregnancy, infancy, or early childhood [7]. Although in most cases of cerebral palsy the exact causes are unknown, cerebral palsy results from injuries or abnormalities of the brain, which usually occur during pregnancy but may result from brain injuries in infancy or early childhood. Symptoms vary, and may be prominent in one or both sides of the body, can be more severe in either the arms or legs, or may involve all limbs [1]. Cerebral palsy is one of the most common congenital disorders. Cerebral palsy affects balance, muscle coordination and control, and may lead to involuntary movements [20]. The focus of physical therapy for individuals with cerebral palsy is often range of motion exercises designed to stretch muscles and prevent contractures, and repetitive exercises designed to build muscle strength [8]. Both types of exercises help patients maintain or improve coordination, mobility, and independence.

PROJECT GOALS

The goal of this project is to enable Looking Glass users to develop therapeutic games. As a step towards this I integrated the Microsoft Kinect with hand tracking support and then created two example games to showcase hand tracking. Using the Kinect to track user body positions and movements is advantageous over Wiimotes because users need not grasp a controller and therefore will not be limited by fine motor skill requirements. These Kinect based sample computer therapy games will serve as a proof of concept for continued research and therapy game development.

Attaining this goal proved to be challenging because Looking Glass was built using Java, while the Kinect for Windows SDK enables developers to create applications in any .NET language such as C#, VB or C++. This project involved researching ways to integrate the Kinect with Looking Glass, building needed events and listeners for the Kinect, and developing therapy games which gather user data with the Kinect and move objects in Looking Glass in direct response to user movements and body position.

XBOX 360 KINECT TECHNOLOGY

Microsoft's Xbox Kinect has forever changed gaming, creating an environment where no controller or remote is needed and the player becomes the controller [15, 16]. The Kinect is an input sensor that was developed for the Xbox gaming system and for Windows PC. In June of 2011, Microsoft released the Kinect for Windows SDK 1.0, allowing developers to create applications in any .NET language for the Kinect.

In May of 2012, Microsoft released the Kinect for Windows SKD 1.5 which includes joint tracking for seated mode as well as standing (default) mode [18, 22]. Seated mode tracking is potentially very useful in a therapy setting where patients may be wheelchair bound. Kinect seated tracking features a ten joint tracking system. Seated tracking gathers data for the ten upper body joints: right wrist, right hand, right elbow, right shoulder, center shoulder, left shoulder, left elbow, left hand, left wrist, and head, and does not collect data from any lower body joints that might be out of the Kinect camera's views or too difficult to distinguish because of the user's seated position. Standing mode tracks the ten upper body joints as well as the following torso and lower body joints: right foot, right ankle, right knee, right hip, center hip, left hip, left knee, left ankle, left foot and spine [21].

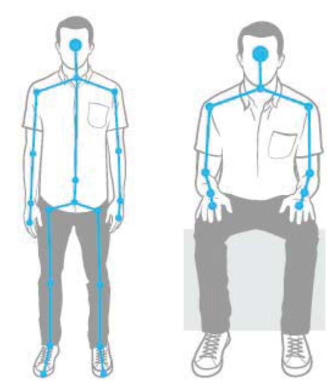

FIGURE 1:
Kinect Joint Tracking
Standing Mode and
Seated Mode [21]

FINDING JNECT

Looking Glass is written in Java while the Kinect for Windows SDK allows developers to use C++, C# or VB to write Kinect applications. This posed an integration problem between the two. I first explored open source solutions, including OpenKinect and OpenNI/NITE. OpenKinect's libfreenet, which began as a reverse-engineered hack for the kinect that was available months before Microsoft released the Kinect SDK [27]. OpenNI framework provides an interface to sensors including the Kinect, and NITE middleware can be used to work with Kinect sensor data [17, 27]. Although these open source solutions could provide a more direct pathway to coding applications for the Kinect in Java, none of these solutions can currently compete with the functionality offered by the Kinect for Windows SKD 1.5, which includes seated skeletal tracking. For the purpose of this project, which is to use the Kinect sensor in a therapy gaming environment to track movements of an individual with cerebral palsy, it was determined that seated tracking capabilities are desired since some individuals with cerebral palsy are wheelchair bound.

Jnect is an Eclipse plugin that bridges Java and the Microsoft Kinect SDK. Jnect provides a JNI wrapper that accesses the Kinect for Windows SDK 1.5 [19]. Using Jnect, applications can be built in Java that can take full advantage of functionality of the Windows SDK including both standing and seated skeletal tracking. The issue presented with using Jnect is that Jnect was originally developed to be an Eclipse plugin and to only run within Eclipse as an Eclipse Application.

Before Jnect could be integrated with Looking Glass, Jnect had to be modified so that it could run as a standalone Java Application rather than requiring the Eclipse runtime environment. This was accomplished by altering Jnect so that it could run without any dependencies on the Eclipse runtime platform. Since Jnect was designed as a plugin, when it launches within Eclipse it is designed to make calls within the Eclipse runtime to determine plugin information. I modified these calls to retrieve plugin information directly from the plugin from its location within the Looking Glass workspace rather than looking for bundle information in the Eclipse runtime environment. Also, Jnect retrieved plugin extension information in the Eclipse runtime. This code had to be modified to retrieve this plugin registry information directly from the plugin from its current location rather than through the Eclipse runtime system.

Once these dependencies to Eclipse were resolved, I was able to run Jnect as a Java Application within Eclipse. I was also able to export Jnect and run it as a standalone jar file to show that all Eclipse runtime dependencies had been alleviated. The next step was to determine how to best integrate Jnect and Looking Glass.

INTEGRATING JNECT WITH LOOKING GLASS

Looking Glass is a freeware, educational software programming environment aimed at helping middle school aged children learn how to program [24, 25, 26]. Looking Glass is written in Java, and provides users with a fun programming interface that allows them to quickly create short animated videos [26]. Looking Glass can also serve as a development environment for persons without any programming experience, such as physical and occupational therapists. Looking Glass has been used to create therapy games for stroke survivors, using Wiimotes as input sensors [3, 12, 26]. Wiimotes proved to be difficult for some stroke survivors to use, as some individuals were unable to grasp and hold the Wiimote. A solution was to strap one or more Wiimotes to the user's upper extremities [3]. A proposed better solution is to use the Kinect sensor as the input device for therapy games because the Kinect sensor captures the user's position and movements without a remote or controller thereby eliminating any requirements of the user to grasp or hold a sensor.

Jnect's code base allows full use of the Kinect for Windows SDK 1.5 using Java. In order to integrate Jnect into Looking Glass, a Kinect Listener needed to be added to Looking Glass in order to recognize Kinect events. The Kinect Motion Listener resides in Looking Glass to detect Kinect events, and is tied in with the existing event listener system in Looking Glass. When creating a Kinect enabled therapy game in Looking Glass, the Kinect Motion Listener must be added to the game's world's procedure that initializes event listeners. A Kinect enabled method should then be added, such as playerRightHand or playerLeftHand. The method should be mapped to an object in Looking Glass (for example, choosing the UFO object to move with the player's left hand movements), and the sensitivity factor (discussed later in this paper) should be set from 1 to 10. The Kinect Motion Listener recognizes any Kinect motion, and as it fires the Kinect Event creates a body model. Creating a body model allows Jnect to gather skeleton tracking data (via the Kinect for Windows SDK 1.5). Using the body model, Looking Glass can then retrieve and use joint data for any or all joints, such as the right or left hand.

The best way to seamlessly integrate Jnect with Looking Glass was to build an abstraction layer. In the Looking Glass code base for this project, Jnect sits outside of Looking Glass and the two are bridged by the abstraction layer. When a game in Looking Glass is played, the program startup classes in Looking Glass call the Kinect Controller in the abstraction layer to start the Kinect and start skeletal tracking. If a game in Looking Glass has added the Kinect Motion Listener to be initialized, the Kinect Handler in Looking Glass will be called to add the listener as the game starts. As soon as the game begins, the Kinect event creates a body model by calling Jnect, and the Kinect methods are implemented (for example, the user's left hand movements are immediately reflected by the UFO in the Looking Glass game). The Kinect Controller also adds a Gesture Detector Listener (a listener that resides in the abstraction layer), which listens for any motion. As this listener detects movements, the body model that was created continuously retrieves new joint data from Jnect. The body model is used according to the methods in Looking Glass to move an object or objects according to the user's movements.

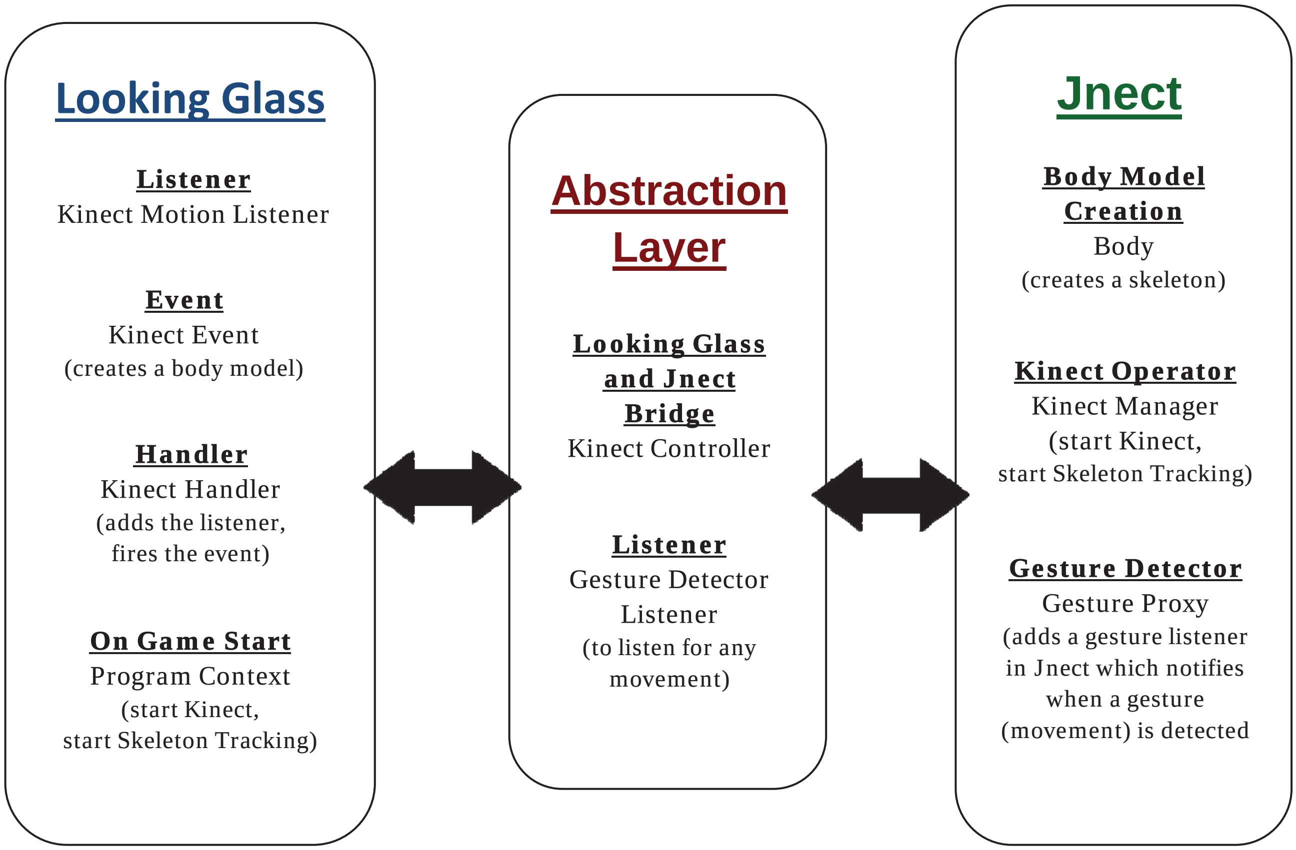

FIGURE 2:
Looking Glass, Jnect, and the Abstraction Layer
Overview of Jnect's integration with Looking Glass

GAMES DEVELOPED

To demonstrate the possibilities of therapeutic games that can be developed utilizing Kinect joint tracking, I created two example games that exhibit hand tracking. Therapy exercises for individuals with cerebral palsy often focus on maintaining or increasing range of motion, muscle strength, and coordination [8]. Both sample games present ways to employ hand joint data to assist persons with motor disabilities in working towards these common therapy goals.

The game Alien Robot versus UFOs utilizes the left hand joint data from the Kinect. The purpose of the game is to help the user increase the range of motion in their left shoulder. In this game, the user's left hand movements are immediately reflected in the movements of an alien robot. There are several UFOs on the screen, and the goal of the game is to hit each UFO one time. The UFOs are placed in strategic locations on the screen to encourage the user to perform left arm movements with their full range of motion. As they hit each UFO, the UFO disappears and the score increments by one. The user wins the game by touching every UFO once.

The game Painting the Roses Red utilizes both right hand and left hand joint data from the Kinect. The primary purpose of the game is to help the user increase coordination skills. This game will also aid in building muscle strength as well as range of motion for both shoulders. The user controls two playing card characters, one with their right hand and one with their left. As the white roses appear on the screen, the user touches them to paint them red. To build coordination skills and to encourage use of both hands, the roses on the left half of the screen require the user to touch with their left hand while the roses on the right half of the screen require the user's right hand. Touching each white rose scores one point, and touching all roses allows the user to win the game.

Looking Glass users can use the right and left hand tracking methods to create their own therapy games. These sample games can serve as starting points and can be expanded into more extensive or customized games. The example games can also be used to help Looking Glass users conceptualize new games and develop them for their own specific purposes.

GAME CALIBRATION FEATURES

Both games can be adjusted for persons of differing abilities. Before launching the game, a value called the sensitivity factor can be changed from 1 to 10. A sensitivity factor of 1 is appropriate for users with a full range of motion, while a value of 10 is suitable for users with a very limited range of motion. Values 2 through 9 can accommodate individuals with motor skills between these two extremes. As the sensitivity factor increases, the joint data gathered by the Kinect is magnified so that a small movement by the user produces a larger movement on screen. Therefore, as the sensitivity factor is increased, less mobility is required to complete the goals of the game.

Both games automatically adjust the range of motion for different sized users. At the beginning of each game, data is gathered to determine the user's arm length using their shoulder joint and hand joint. Using the arm length data and the screen dimensions, the user's on screen range of motion is adjusted. The game can automatically adapt for children, small adults and tall adults. The games take into account the approximate size of the user and magnify movements for smaller users, and minimize movements for very tall users.

Both games automatically center the user based on the position of their center shoulder joint (the point directly between the right and left shoulder joints). This allows the user's hand motions to be at the correct position according to the game even if they are standing or sitting off center according to the Kinect camera's view.

Finally, both games minimize on screen jitter and smooth movements as much as possible without noticeably increasing latency. The disadvantage of mapping from a single joint data point to a Looking Glass object is some noticeable on screen jitter. This has been reduced by taking the exponential weighted average of a few data points at a time for the relevant joint to determine the resulting position of the object in Looking Glass. This helps reduce the effects of extraneous data points that would otherwise cause the object in Looking Glass to move suddenly or unexpectedly, and results in smooth, predictable movements.

PRELIMINARY EXPLORATIONS OF BODY TRACKING

Hand tracking is a good utilization of Kinect joint data to create games that target upper body range of motion and coordination. The next step beyond mapping the Kinect data from a single joint to a Looking Glass object is to translate the Kinect data from all body joints to the joints of a Looking Glass biped (two-legged) character, resulting in full body animation. I have begun this work by animating the right and left arms of Looking Glass biped characters. This proved to be a challenging feat because the data collected by Jnect from the Kinect is absolute for each joint, while Looking Glass animates characters using relative joint data. The Kinect gathers x, y, and z values in Kinect camera coordinates for each body joint independent of any other joint. When Looking Glass animates a biped character, each new joint position of the character is based on the joint position relative to the position of nearby joints.

In order to animate the arms of a Looking Glass biped character, Kinect joint data must be collected and translated into values usable by Looking Glass. For example, the Kinect reports independent absolute joint data for the left shoulder, left elbow, left hand, and left wrist. Looking Glass uses the relative position of each joint to draw the moving character. To draw the left shoulder, Looking Glass uses the Kinect data for the left shoulder and the left elbow because it animates the left shoulder relative to the elbow. To draw the left elbow, Looking Glass uses the Kinect data for the left elbow and left hand, and so on for each joint in each arm. Continued work is needed to correctly animate the torso and lower limbs, and to correctly rotate all joints through full body movements.

DISCUSSION AND FUTURE WORK

Complete utilization of Kinect joint data in Looking Glass will result in fully animating a Looking Glass biped character. A fully animated character can then be used to reflect user movements and body position. Finally, therapy games can be developed in Looking Glass that use fully animated character as the player. Future work by the Looking Glass research group may include building on the work that has been done to animate the upper limbs of the Looking Glass biped characters with Kinect data into fully animated characters. This may result in a more complete user experience, and increased possibilities for therapy game development.

Future work by the Looking Glass team may also include accessing Kinect data for more than one skeleton so that the joint data from more than one user at a time can be tracked and used. Once the data from more than one skeleton can be tracked and utilized in Looking Glass, the possibilities for multiplayer games can be explored. Developing two player therapy games for collaborative play can provide individuals with motor impairments a means for social interaction [3]. Multiplayer games developed for two therapy patients to participate together can lessen social isolation [12]. Multiplayer games can provide an avenue for those with motor impairments to play alongside typically-abled friends or family members [3].

The potential for building entertaining and purposeful therapy games in Looking Glass is great, and the two sample games discussed in the paper will provide a launching pad for Kinect integration and therapy game creation.

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