ABSTRACT

ADAPTABLE VIDEOGAME PLATFORM FOR INTERACTIVE UPPER EXTREMITY REHABILITATION

By Sally Jensen

The primary objective of this work is to design a recreational rehabilitation videogame platform for customizing motivating games that interactively encourage purposeful upper extremity gross motor movements. Virtual reality (VR) technology is a popular application for rehabilitation therapies but there is a constant need for more accessible and affordable systems. We have developed a recreational VR game platform can be used as an independent therapy supplement without laboratory equipment and is inexpensive, motivating, and adaptable. The behaviors and interactive features can be easily modified and customized based on players' limitations or progress.

A real-time method of capturing hand movements using programmed color detection mechanisms to create the simulated virtual environments (VEs) is implemented. Color markers are tracked and simultaneously given coordinates in the VE where the player sees representations of their hands and other interacting objects whose behaviors can be customized and adapted to fit therapeutic objectives and players' interests. After gross motor task repetition and involvement in the adaptable games, mobility of the upper extremities may improve. The videogame platform is expanded and optimized to allow modifications to base inputs and algorithms for object interactions through graphical user interfaces, thus providing the adaptable need in VR rehabilitation.

ADAPTABLE VIDEOGAME PLATFORM FOR INTERACTIVE UPPER EXTREMITY REHABILITATION

by
Sally M. Jensen

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APPROVAL PAGE

ADAPTIVE VIDEOGAME PLATFORM FOR INTERACTIVE UPPER EXTREMITY REHABILITATION

Sally M. Jensen

Dr. Richard Foulds, Thesis Advisor Date
Associate Professor of Biomedical Engineering, NJIT

Dr. Sergei Adamovich, Committee Member Date
Assistant Professor of Biomedical Engineering, NJIT

Dr. Lisa Simone, Committee Member Date
Assistant Research Professor of Biomedical Engineering, NJIT

BIOGRAPHICAL SKETCH

Author: Sally M. Jensen

Degree: Master of Science

Date: May 2007

Undergraduate Education:

- Master of Science, Biomedical Engineering
  New Jersey Institute of Technology, Newark, NJ 2007

- Bachelor of Science in Biomedical Engineering,
  University of Rochester, Rochester, NY 2006

Major: Biomedical Engineering

Presentations and Publications:

- S. Jensen. Adaptable Videogame Platform for Interactive Upper Extremity Rehabilitation. Proceedings: Northeastern BMES, 2007, New York.

- S. Jensen. Adaptable Videogame Platform for Interactive Upper Extremity Rehabilitation. Proceedings: New Jersey 4th Annual BME Showcase, 2007, New Jersey.

- S. Jensen and R. Foulds. Hands-Up Game Platform. Proceedings: RESNA 2007 Annual Conference Student Design Competition, 2007, Phoenix.

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CHAPTER 1

INTRODUCTION

1.1 Objectives

The primary objective of this work is to design a recreational rehabilitation videogame platform for customizing motivating games that interactively encourage purposeful upper extremity gross motor movements. The videogame platform for rehabilitation is independent of bulky laboratory equipment and is inexpensive, motivating, and adaptable. The platform is also capable of continuous game modification to fit changing therapy goals, to match the needs of the players, and to provide continued motivation while allowing capturing and interactive repetition.

The system will be accessible in that it will be inexpensive, made for at-home, recreational use, straightforward in its application, and available in the public domain. Therapists, parents, users, or guardians of the user will be capable of easily adjusting game parameters through simple graphical user interface interactions. The creation of novel games with specific therapeutic objectives and various user input options will be achieved. The system will incorporate the most beneficial rehabilitation techniques and adjustable parameters, as requested and suggested by gross motor therapists.

1.2 Motivation

With an adaptable videogame platform that is easily customized for players who may have possible limitations in mobility, interactive play will be encouraged and motor tasks practiced. Over 13 billion dollars are spent annually on videogame systems and nearly two game systems per household are distributed (usatoday.com, 2007). These statistics are evidence that videogames are popular and captivating. A game system that is affordable and less constraining, which children and their families enjoy, and that therapists can use to successfully meet the therapeutic objectives of a child's rehabilitation program will be ideal and fitting. Independent living and quality of life for children with any upper extremity or gross motor disorder may be improved after the interactive therapy game play and motor practice.

Current technology for gross motor rehabilitation and improvements in the upper extremity therapy processes are developed and enhanced to provide more accessible and user friendly videogame platform capabilities. System improvements will prevent encouragement of non-functional motor tasks or frustrations and concentrate on the most appropriate trajectories of movement and functional orientations. The continuously adaptable, recreational, gross motor therapeutic intervention is designed as specifically detailed and illustrated by the Rehabilitation Engineering Research Center (RERC) on Technology for Children with Orthopedic Disabilities and by the needs of the Children's Specialized Hospital (CSH) and the Biomedical Engineering Department at NJIT.

The proposed use for the recreational videogame platform is to supplement and motivate therapy for children with deficiencies in gross motor movements, such as those children at the CSH. The game platform incorporates customized rehabilitation techniques and appropriately provides therapists with the necessary tools to initialize and setup a game based on the motor deficiency, range of motion (ROM), and pattern of movement. The final public domain recreational videogame rehabilitation system will be:

> "a video-based VR system for rehabilitation in CP that will be motivating for kids, easy to use for clinicians and parents, and will provide two key elements necessary for any CP therapy to be successful: intensity of training and shaping. The intensity of training will be achieved through exciting and modifiable game interfaces that will motivate the participants to use their affected limbs, and through adaptable algorithms of target setting that will provide the subject with challenging interactive environments but without excessive frustrations" (RERC, 2006).

In current rehabilitation programs, it is thought that initiating movements in the extremities that would otherwise not be used creates new patterns of neuronal activation and hence, neural reorganization or shaping begins. This neuroplasticity, or changing neuronal activation and reorganization of the brain, is what drives the idea of rehabilitation for improving the quality of life (Trojan, 1997). After repetition and involvement in a VR program, such as this videogame platform, mobility has been shown to improve due to the concept of neuroplasticity (Whitall, 2004). Recent research and experimentation has concluded that intensive motor repetition and game interaction may be required in order to initiate neural reorganization and recovery of functional motor skills (Naylor, 2005; Foulds, 2007). To encourage this repetition and motivation in a graphical manner, with simple options and user inputs, and to meet the changing therapeutic goals, is another objective of this design.

Virtual reality (VR) technology has successfully been used as an application for physical rehabilitation aimed at improving the activities of daily living (ADL) of children with physical impairments and motor deficiencies (Whitall, 2004). Through movement encouraging VR games, motor tasks can be learned as the user views themselves completing the tasks. However, there is a constant need for more accessible and affordable systems that can be easily modified to the users' varied abilities and therapy goals. Current systems are expensive and available with only a limited number of games and simulations involving specific built-in tasks like playing the piano, stacking blocks, or catching birds (Foulds, 2007). A system that can be continuously modified to the users' abilities and therapy goals is most beneficial. The system designed here meets these needs as it is easy to interface with and requires only straightforward inputs to change gaming parameters.

Cerebral palsy and cerebrovascular disorders, such as stroke, result in partial or complete limitations in motor abilities in upper or lower limbs with arm function being the most disabling and most affected. These conditions require attention from physicians and therapists during the physical rehabilitation process to reduce muscle contracture and enhance sensory-motor skills. Rehabilitation often requires labor-intensive, one-on-one manual interaction or it necessitates the use of expensive laboratory equipment (Colombo, 2005). An accessible computerized rehabilitation system, not requiring continuous therapist attention, and encouraging customized mobility of the affected extremities is necessitated and designed.

The accessible computerized VR game platform developed here utilizes a public domain Matlab toolbox equipped with the ability to assign behaviors to autonomous mobile robots which can detect and respond to their environments based on numerical collision feedback and individualized algorithmic patterns of mobility. Robots that are hand representations are given the behaviors of the real hands and are represented in the recreational, motivating, goal-oriented VR interface. The mobile robots can be any desired shape selected, and they can autonomously interact with users' hands based on the mathematical sensors for collision detection. When behaviors are changeable, the possibilities of adapting the therapy and maintaining the motivation are more extensive.

Evaluation by occupational therapists (OTs) at the Children's Specialized Hospital determined many of the platform characteristics and specified the desired game activities like drawing, hitting balls, completing tasks, or following paths that would maintain motivation and levels of excitement, as well as aid in platform accessibility and ease of use.

Rewards for using an affected extremity are displayed through scores or sound and color feedback. There are features available to decrease the rewards as range of motion increases, and the difficulty of the task can then be increased. As improvement is seen, the behaviors of interacting objects can be altered using the platform's graphical user interfaces (GUIs). These novel and adaptable interfaces, simulation capabilities, and object behaviors can be altered as needed to provide simulations that encourage continued motivation and gross motor advancement.

CHAPTER 2

BACKGROUND

2.1 Physical Rehabilitation

Physical rehabilitation is the restoration of lost or never used motor functions gained through the development of current or remaining motor capacities. Passive rehabilitation, where a person is manually moved through motor tasks, is commonly implemented but is less effective in the therapeutic process (Foulds, 2007; Gordon, 2005). The more involvement and interaction the person has, along with how voluntary the attempt to control their motor function is, the more effective the therapy will be (Whitall, 2004).

Virtual systems incorporating movement tracking that encourage voluntary motor tasks and interactions can be applied to rehabilitation. When used in conjunction with virtual interfaces and motor practice, computerized, virtual systems provide a simple way of encouraging people to interact with their environment in order to improve their motor capacities. Even in very simple, recreational, task-oriented virtual environments, motor improvements may result in the same manner as physical rehabilitation in *real* settings. This manner of encouraging active mobility for fine or gross motor skills is the basis for the process of physical recreational rehabilitation (Crosbie, 2006).

2.2 Neuroplasticity

To truly understand the success of physical rehabilitation both the motor functional gains and the underlying neural plasticity are examined (Whitall, 2004). Throughout rehabilitation programs, visualizing actions and feedback as encouragement to move farther, without just passive movements, is necessary. This challenge forces unused motor neurons, or excitable cells in the central nervous system, to aid the new movements and it causes neuronal activation and reorganization, discussed below, and even enhancement of visual, sensory-motor, and proprioception areas (Bly, 2003).

Rehabilitation programs involving combinations of different arm movements, reaching stretches, and new learning skills have been shown to more actively stimulate the user's brain (Whitall, 2004). After repetition from combination therapies with additional involvement in a VR program encouraging goal oriented movements, mobility has been shown to improve due to the motor control reorganization of the neuronal activations usually in the cortical region (Trojan, 1997).

Constant motor reorganization, both structurally and functionally, in response to stimuli or to injury occurs by means of neuroplasticity (ucpresearch.org, 2007). There are varying numbers and patterns of neurological connections throughout the brain, which make reorganization somewhat unpredictable. However, with accurate and directed motor rehabilitation training, changes in brain structure and function may begin whether they are subtle, dramatic, or beneficial (Pullela, 2006).

The most dramatic neuroplasticity exists during the first two years of life when most nerve circuits have not yet been activated and normalized. Physical therapies that are directed at children may result in the most successful motor rehabilitation. As children age, their brains become more organized in response to the environment (Pullela, 2006). The mechanisms of plasticity are still under question and until a more definite understanding is achieved, the manner of motor reorganization will be based on the trial and practice of such recreational rehabilitation programs.

2.3 Rehabilitation Techniques

Rehabilitation techniques that are aimed at both fine motor and gross motor tasks are important in the ideal rehabilitation program. Therapy sessions in which the patient is manually moved and stretched and therapies that require machine interactions such as rehabilitative apparatus' and robots may be beneficial. However, it has been shown that more active or goal-oriented movements with mobility requirements are more beneficial to the rehabilitation process as more neurons are excited when the individual initiates the movement. It is helpful to combine the active rehabilitation systems with sessions involving possible drug therapies, gait training, electromyography (EMG) triggered functional electrical stimulation, or strength training, and have supplements to particular therapies (Bly, 2003; DeLuca, 2003).

It has also been found that more concentrated sessions with more diverse repetition are better than longer and unvaried therapy sessions (Whitall, 2004). Time-course for rehabilitation is very important to consider as permanent motor restitution is desired and unlikely if the rehabilitation therapy was performed or repeated only once. Knowing what the person's range of motion and muscle contracture patterns are before rehabilitation begins is also essential in designing the rehabilitation program and how it may be repeated. Physical conditioning and repeated motor learning principles along with retention in some form of maintenance of functional recovery may more likely result in permanent motor learning (Bly, 2003).

As stated in Huang's 2006 studies at the Rehabilitation Engineering Center in Arizona, one of the major goals of rehabilitation is for people with motor deficits to "reacquire the ability to perform functional tasks". The main understanding behind this goal is that by reacquiring functional motor skills for ADL, independent living might be facilitated. To improve this reacquisition of task-oriented skills Huang suggests that "improvement in functional activities would benefit from biofeedback therapy" (Huang, 2006).

Proof that receiving feedback, in the form of scoring and visual and audible game encouragement, on the rehabilitation procedures and concentrating on the movement task is beneficial is shown in Huang's study on game feedback. With feedback in the form of scoring as an added motivation and personal competition, EMG signals, or muscle activations, increased with the time of therapy. The increased muscle activation upon receiving feedback indicated that continued neuronal activation was occurring and possibly more neural reorganization than without the concentration and competition. Without biofeedback the activation decreased over time as the movement was made. The decrease in activation translates to less concentration and motivation and a smaller likelihood that the rehabilitation process would be beneficial (Huang, 2006).

Giving scoring or improvement feedback and evaluations of the training session to the user is also known as Knowledge of Result (KR) and Knowledge of Performance (KP). It has been shown that KR and KP feedback are important rehabilitation exercise aspects for the patient and for additional evaluation. Rehabilitation feedback is a key characteristic of rehabilitation programs that increases the potential for functional improvement due to the added motivation and attentional factors (Newby, 1993). When the user knows how well they are doing at the functional motor tasks they may be encouraged to advance, and the added feedback may stimulate their brain even more. Whether the patient is in a traditional physical therapy program, a robotic therapy session, or a game-based and goal-oriented task program, feedback on how they are doing can be encouraging and beneficial to the quantification of their progress.

Another important rehabilitation technique is the recreational aspect of the programs. Recreational at-home training is considered to be one of the most effective supplementary methods of rehabilitation because repetition is a key point of motor functioning maintenance (Byl, 2004). One of the only disadvantages to this supplementary therapy is that it may lack rigorous training. At-home rehabilitation therapies are completed under less pressure and there may be less concentration and challenge, but this has not been proven. On the other hand, the recreational aspect could be drastically more successful, as the videogame system can be played in the users' own time, with their own rigor and motivation.

2.4 Virtual Reality

Virtual reality (VR) is a general area that implies a computer simulation of a real or an imaginary environment. A virtual environment provides the user with a means to interact and operate within the simulated or virtual environment in real-time. The tools of VR can be applied to rehabilitation in a number of ways. For all VR technologies the first and most important task to master is the real-time movement capturing or tracking method. As discussed in the 2007 review of video capturing for rehabilitation, virtual environment (VE) generation is based on the real-time movements that can be captured using data of all body positions in real-time (Weiss, 2004). This manner of data collection allows for rapid acquisition and display on a scene in 3D or even 2D.

Figure 2.1 One of the twelve IREX® game samples with whole body representation and very extreme, immersive VEs.
(gesturetek.com, 2007)

For user interaction with the VE development systems, different types of tracking mechanisms are implemented to collect the body positions. The systems may have different space requirements, from large media center setups like the one seen in figure 2.3 to smaller setups that do not require hardware other than a PC and webcam as in the simple optical system used in the design and seen in figure 3.1. The tracking devices can be based on a number of different data types including mechanical information, visual or optical information, or they can even be magnetically or acoustically based (Winter, 2005). Regardless of the tracking mechanism, application to recreational rehabilitation aspects requires movements to be visualized successfully and interactions to be manipulated interactively.

2.5 Virtual Tracking Mechanisms

Different varieties of motion capturing mechanisms exist in VR systems, but remotely located video cameras for optical tracking are chosen to display upper extremity position data in this recreational videogame system.

Mechanical capturing methods for collecting positions of gross motor movements to be depicted in the virtual environment are thought to be the most realistic methods, but there are limitations based on the setup required to implement the tracking system. These limitations include the need for bulky equipment, intensive accompanying software and hardware, and even helmets or other constraining devices or sensors. Mechanical VR tracking systems may utilize force feedback components that convey the users' movement to a haptic interface. This mechanical tracking mechanism requires any type of joystick, mouse, robot, or mechanical arm or object to which the user must be attached. In this manner, every movement that the user makes will be haptically conveyed to the VR system (McCarthy, 2005).

Acoustically based systems, like the optical system chosen for the platform design, require line-of-sight between transmitter and user or else the data is not conveyed to the base system. For the acoustical method, precise placement of microphones is required in order to capture the sounds needed and avoid acoustically reflective surfaces (www.cybertherapy, 2007).

Magnetic tracking is one of the most popular methods. Unlike the optical or acoustical techniques though, magnetic tracking can be used for any movements and no positions will be lost because of blocked sensor readings as extremities overlap. The system is based on small sensors that radiate a magnetic field created by a transmitter (ascension-tech.com, 2003). A popular example of a magnetic tracking system is from Ascension Technologies®.

Each sensor in the Flock of Birds (FOB) Ascension system tracks up to 144 measurements per second and as low as 30 measurements per second. The system captures positions and orientations within four feet of the transmitter. The FOB works by transmitting a pulsed direct current magnetic field from a transmitter that is simultaneously measured by all sensors, or birds, in the Flock (ascension-tech.com, 2003).

Figure 2.2 'A' is the magnetic tracking system electronics unit. Two of them used together for two sensors is called a flock. 'B' is the sensor or bird and two are required to track to hand positions. 'C' is the transmitter and one is used for the complete tracking system.
(ascension-tech.com, 2003)

The transmitter can be placed behind the user who holds each bird with minimal cable interference. From the measured magnetic field characteristics in each sensor, a position and orientation can be computed and transferred to the computer resulting in the position and rotation coordinate of the users' hands. One of the downfalls of this tracking method is that there has to be a connection between the user and the transmitter and electronics unit.

Some optical tracking mechanisms may be similarly constraining as the user may have active or passive markers placed on their body and they have to be in a laboratory under the view of multiple camera systems (McCarthy, 2005). Intensive evaluation may also be required in order to correlate all the camera viewpoints and avoid sensor obstruction.

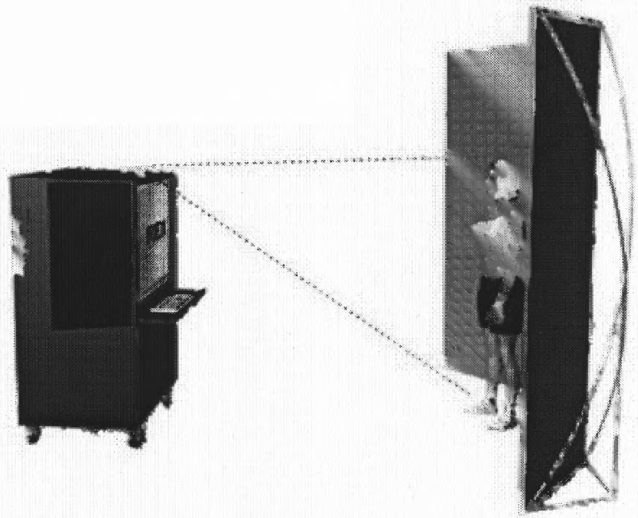

Figure 2.3 IREX® Gesturetek VR rehabilitation game system with back drop requirement and costly hardware.
(gesturetek.com, 2007)

Less expensive optical tracking systems are more applicable for VR. Video cameras, or smaller webcams, that instantaneously process images are more useful. With a simple camera based system application as in this design, the user can be removed from the constraining laboratory equipment and may only need one or two color markers for tracking the chosen extremity. A large backdrop is not required and the marker choice can vary if the tracking mechanism is color. This method of position tracking is more favorable for children, especially those with motor disorders, and more appealing markers that act as rackets, paddles, tools, toys, or pointers can be chosen. Children with hemiparetic CP may have difficulty even holding a marker, therefore the small webcam can detect a color dot that can be attached with Velcro or worn by the player.

2.6 Video-Based Virtual Tracking System Users

One group of potential users who may benefit from the webcam based system designed here are the children at the CSH. The children are age five to eight and may have varying motor control disorders, cerebral palsy, arthrogryposis, contracture due to burns, congenital and traumatic amputations, polio, and bone diseases. Adding a videogame system that can individualize training sessions is beneficial when combined with the daily therapies that are given at the hospital (Foulds, 2007). With one arm less functional than the other, the system may encourage the use of the impaired limb and reduce the amount of accommodation that is otherwise developed. Usually the good arm is used for everything and the impaired limb is neglected, thus reducing its function even farther. The videogame adaptability would be useful for the therapists and employees who could easily change the simulations and then let the children play.

Cerebral Palsy (CP) is one example of a neurological disorder, causing a wide variety of physical and mental impairments, in which functional gross motor skills can be learned after performing specified therapeutic tasks interactively and repetitively in a gaming environment (Foulds, 2007). Cerebral refers to the region of the brain that has been damaged and palsy means shaky or uncontrolled motion (Colledge, 1999). The majority of children with CP are diagnosed as infants or toddlers due to the fact that the cause is usually trauma during the birthing process. CP occurs more commonly in children who are born prematurely or with complications. In some cases, a child will have delayed onset of CP symptoms, and in most cases there is a pseudoprogression of symptoms involving increased muscle stiffness and functionality, stunted growth, or deformity in the extremity. Deformity may be a result of the *never learned to use,* or compensation and neglect, causation in which bones and muscles remain inactive and subsequently deteriorate. A recreational rehabilitation program that appeals to this population of children can lessen the degree of stiffness, increase functional use, and discourage dependence on one limb to reduce additional *never learned to use* impairment.

It is also important to note that CP is a common problem worldwide and each year about 10,000 babies born in the United States develop CP. Mental retardation and impaired vision may also accompany the motor disorder symptoms making mobility and gross or fine motor function even more impaired (Ashwal, 2004; Green 2003).

A rehabilitation system that can be adapted for varying ranges of mental capacities is desired. A few examples that have been implemented in the proposed videogame platform include memory games which are made available along with spelling or counting activities. Games with goals or for following instructions and completing tasks are also possible and adaptable within the platform. The limitation in vision can also be accounted for with choices in colors, scales, and magnifications of screen movements. By encouraging the use of the affected limbs or different thinking processes and approaches, function can be gained and the quality of life can be improved (Foulds, 2007; Sung, 2005).

2.7 System User Motor Conditions

There are a number of different types of motor control disorders that affect the functional motilities of children and adults. Recreational rehabilitation programs, like the videogame platform discussed and designed here, can target different motor tasks and movement patterns of these people.

Spastic CP infers damage to the motor cortex which prevents muscles from working together and therefore children are incapable of completing effective gross or fine motor movements (Sung, 2005). Videogame object behaviors that encourage complete movements of the upper extremities and are task–oriented, such as reaching for a corner of the screen where another object interaction occurs, might be directed at motor improvement for this type of CP. The game tasks may also be customized for the particular limb that is more affected.

Choreo-athetoid CP involves damage to the basal ganglia or cerebellum and results in difficulty controlling and coordinating movements. Accuracy and control tasks within the game environment, like tracing or following objects, would be a functional motor task for this CP type. Ataxia, which induces unsteady or clumsy walking and balance problems, and results from damage to the cerebellum, the brain's major center of balance, may occur in choreo-athetoid CP. Athetosis, chorea, and dystonia may also occur with choreo-athetoid CP inducing slow movements, jerky movements, and twisting movements of the extremities respectively (Sung, 2005). Motor tasks encouraged by the game system to limit the features of unsteadiness would be bi-manual tasks and movement task completions. Corralling objects in a certain direction, doing figure eights, or making the infinity symbol with rewards or color and sound feedback at the end might work towards improving this motor deficiency.

Mixed-Type CP affects the areas of the brain that control both muscle tone and voluntary movement (Sung, 2005). All variations of game tasks and customized, interactive movements will be encouraged here, and neural motor area reorganization will occur to replace or renew lost or weakened stimuli.

An additional classification of the users to be targeted is through the number of limbs, upper or lower, that are affected. An example of this is hemiparetic CP which is unilateral or affecting one side or brain hemisphere only. The game system can be used with anywhere from one to three hand markers modeling the extremity position information. The behaviors and interactions with each hand marker can be customized allowing for the different virtual representations to be challenged accordingly.

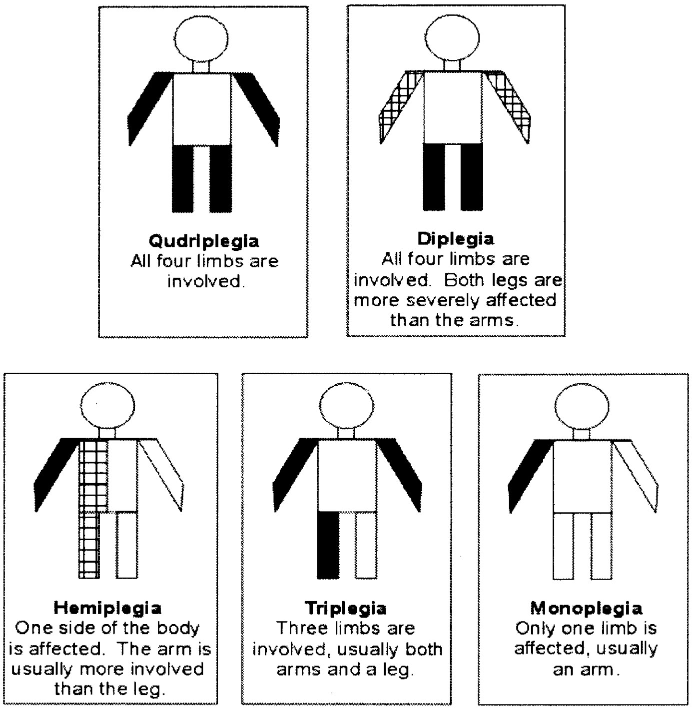

Figure 2.4 Different sided CP conditions effect different limbs and have varying patterns of severity that are considered when developing a therapy.
(Colledge, 1999)

It must be noted that none of these conditions have universal symptoms and a system design for customized rehabilitating exercises and individualized programs is necessitated. There may be varying ratios of fine and gross motor control, the extent and ranges of motion may fluctuate, or the arm or hand equilibrium rest position may be deformed. There is a need for an adaptable platform to create the rehabilitation simulations in which object interactions can be constantly changed.

An example of posture deformities can be found in hemiparetic CP children who have impaired voluntary movements and may have affected “pincer grasp” of the thumb, extension of the wrist and supination of the forearm. Increased flexor tone, cranial nerve abnormalities, and even the childs’ visual field may even be defective (Sankar, 2005). These tendencies can be relieved or reduced with therapy to return the normal patterns of flexion or extension. Supination and wrist position can be tracked and discouraged or encouraged through game rewards along with grasping and fist angle motivations. The markers that can be used with the videogame system can be changed depending on the variation of grip strengths or deformities.

Users may have certain muscles continuously contracting and their muscle tone might be increased if spasticity is a symptom of the disorder (Gelber, 2002; Goetz, 2003). Reductions in spasticity, a common symptom of CP, might also be possible with recreational rehabilitation programs that encourage the repetition of functional motor tasks requiring control and even more accuracy. Spastic contractions can be caused by over-active stretch reflex responses that cause muscle fibers to lengthen or shorten. Other motor disorder symptoms that may benefit from repetitive motor control may include hypertonicity (increased muscle tone), clonus (rapid muscle contractions), or "exaggerated deep tendon reflexes". (Katz, 2001; NINDS, 2006) The degree of spasticity can vary from mild muscle stiffness to severe, painful, and uncontrollable muscle spasms. Spasticity can interfere with the child's' rehabilitation programs or even their ADLs (Thompson, 2001). The adaptability of the rehabilitation videogame platform can account for these differences in abilities and degrees of spasticity and motor disorders.

The most commonly seen and more detailed definition of spasticity that is accepted by the majority of researchers, scientists and doctors is "a motor disorder characterized by a velocity dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyper-excitability of the stretch reflexes, as one component of the upper motor neuron syndrome" (O'Dwyer, 1996; Fee, 2004). This definition originates from Lance's research in the 1980s when interest in spasticity first arose and he published a paper on disordered motor control (Pisano, 2000; Mayer, 2006). The definition is based on changes that occur within the stretch reflex arc which is the most basic neural circuit contributing to spasticity (Mayer, 2006). Unfortunately, no perfect rehabilitation programs for spastic patients exist. Nevertheless, virtual reality (VR) rehabilitation has potential and it is what Hallett, the chief of the Human Motor Control Section of the National Institute of Neurological Disorders and Stroke, is calling "a new, neurorehabilitation intervention aimed at enhancing motor performance in children with hemiparetic CP" (Sung, 2005).

2.8 Recreational Video Gaming

The techniques and game situations for rehabilitation that are mentioned as benefits to therapy programs, are all designed based on typical video gaming strategies. As noted, video gaming can actually fit with the recreational rehabilitation aspects and videogame development is an important concept for this project.

Recently the recreational video gaming community has placed increasing emphasis on movie-like production values as opposed to classical games like Pac-man® or Tetris®. The movie-like production is, however not essential for game attraction. Simple games have been shown to maintain their popularity through the decades, yet the more action packed and graphically oriented games still appeal to today's generation.

The whole process of designing a computer videogame involves countless steps and phases that all require time and money. Each production requires huge teams of artists for texture, background and animation along with sound artists, level designers, game testers, software engineers, graphics, artificial intelligence, tools, engine, lead programmers and even more support teams for advertising and distribution (McCarthy, 2005). Nevertheless, simple videogames for rehabilitation may be more beneficial and they need only the adaptable features and appealing interactions, such as color changing, noises, speed alterations, or scale magnifications.

Game development also depends a lot on the level of play that might be induced. The characteristics of play, according to Denise Reid in a pilot study overview on VR systems, include intrinsic motivation, focus on a means rather than ends, organism-centered rather than object-centered behavior, relation to the instrumental behaviors, freedom from external imposed rules, and active engagement (Reid, 2004).

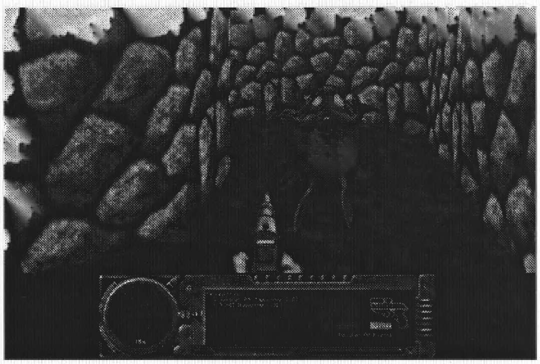

Figure 2.5 A typical game scenario with a user controlling a virtual weapon. With the users' coordination and computer interaction, movement in the world is permitted.
(marathon.bungie.org, 2007)

Allowing for spontaneous actions within the game, and having limited rules may increase the level of game interaction and recreation. For recreation videogame writers, a product can result from an idea that merely sparks their interest not one that is laid out and detailed right away. The benefit of making a game platform that is less structured, more intriguing, and interactive is that it will attract the players, lure them in, involve them, and sell very well.

Figure 2.6 This is one example of a world in Second Life®. Second Life® is an online VR system that can be played over the internet network. Players control their own Avatar in the virtual world through keyboard or joystick inputs. This type of videogame is less structured as there is no goal and just about any action can be made. There are recent developments to this game that allow for more gross motor control of the avatars. In this manner, people with less limb function may also be able to play in the virtual world.
(secondlife.com, 2007)

Another one of the more profitable gaming plans, not related to rehabilitation, is a prototype that provides people with all the tools that they might need to create their own games. These prototyping platforms usually include the editors, actor converters, terrain generators, and the possibility of changing interfacing devices. An example of one system that acts as a platform is *Reality Factory*®. These platforms may be helpful and fun for non-commercial or commercial videogame developers, but they are still expensive and they are not necessarily compatible with alternative computer interfacing devices, like un-cabled position tracking mechanisms. There are also videogame engines that supply libraries of designs or behaviors for objects. These videogame libraries are said to make programming simpler and of higher quality (McCarthy, 2005).

From the success of recreational video gaming shown using these products, it is obvious that individualizing a game is a worthwhile and fulfilling objective that many people have whether or not they are in rehabilitation engineering. Limited game rules, individualized and adjustable features for simulations, directories of object shapes, and customized interactions of characters and objects within the platform environments are all techniques and parameters that should be available in this recreational videogame system.

2.9 Virtual Reality Videogame Systems

VR technology can be applied to physical rehabilitation and research through interventions such as VR rehabilitation videogames and game platforms. Virtual reality is more motivating than typical game systems with keyboard or joystick inputs because there is more proprioceptive information being conveyed as you watch and feel yourself move realistically in the virtual environment (Reid, 2004). Rewards for new movements or movements that encourage use of the affected extremity can further increase this motivation. VR rehabilitation is most commonly implemented with children or young adults. VR videogames are also thought to be more successful with children because of their increased motivation and excitement with video gaming when compared to adults.

VR technology for rehabilitation is also beneficial in that it can provide a more quantitative analysis of motor improvements. Passive therapies rely on qualitative functional motor task analysis (Gordon, 2005). Qualitative motor analysis such as timing for functional tasks includes those tasks outlined in Bruininks-Oseretsky or Jebsen's Hand Function Tests (Sung, 2005; Bruininks, 1978). Challenging, game-like tasks such as standing on one leg, bouncing a ball, or cutting out shapes may be monitored, visually judged, and given a score. Hand function tasks may include flipping cards or stacking checkers. If the patient is using a VR system the improvement is computed, stored mathematically, and not assumed or perceived as they are in these qualitative examinations of mobility.

An additional benefit of VR rehabilitation and robotic therapies, is that they allow for multiplexing which reduces the number therapists needed. If everything is working with the rehabilitation systems, the therapist can manage more than one therapy session. The therapists would mainly be responsible for monitoring the play to make sure that no excessive fatigue results and that the modifications are made as mobility or task changes (Honeycutt, 2003).

Yet another one of the key features of VR rehabilitation is virtual equivalence to motor performance within the actual and physical environment. This includes, not only making sure that the movements represented in the VE are real-time, but also utilizing knowledge of essential movement properties and those motor activities that will be most effective for obtaining changes in the motor system.

VR videogame therapy programs that involve movements to coordinate the user's gross motor functioning may be even more beneficial. These coordinated therapy plans are outlined by the therapists from their past experiences, the diagnosis, available therapy tools, and the recommendation of prescription from the physicians. What therapists suggest in regards to therapy goals (unilateral or bilateral) are all options that are incorporated into the system. A child's abilities should be analyzed before the system is coordinated so that their motor performance is consistent with the need and goal along with the physical environment.

2.10 Downfalls of Current Virtual Reality Systems

Currently, rehabilitation programs are lacking simulation variability and repetition is found to be boring once the specified tasks and simulations are mastered (Deutsch, 2001). A VR system that can be modified and made more difficult prevents this boredom as the task and level is changing. These expensive and intensive therapies are also limited by accessibility and resource allocation including costs, therapists' time, and availability of space and equipment.

The main downfalls of VR videogame platforms that are currently used for recreational gaming are that they are expensive and limited in their movement sensitivities and game variability. For instance, in four of the ten V-Tree® games displayed below, the positioning of the interacting objects (instruments, balls, or birds) is permanent and the abilities of the players' extremities are not considered.

Figure 2.7 Example of four V-Tree® VR games with permanently placed objects and set behaviors for the interacting objects.
(vtreeinc.com, 2006)

VR systems like Gesturtek® or V-Tree®'s special needs software may be visually appealing, but they are expensive and have limited options for adapting to different ranges of motion or speeds. Of all the VR systems, V-Tree® has the greatest number of set game options. They include games entitled I-C-Me soccer, drums, orbosity, snowboarding, volleyball, letter matching, word matching, hand painting, car racing, and breakout.

Many systems also provide limited settings or input types for only fine movements that are sometimes difficult for people without complete mobility in their hands and upper extremities, such as hemiplegic CP patients. These systems are also difficult if the resting hand position is deformed. Joysticks or cyber gloves with sensors that detect finger movements with respect to the hand might work, but driving the game with gross movements is not always possible.

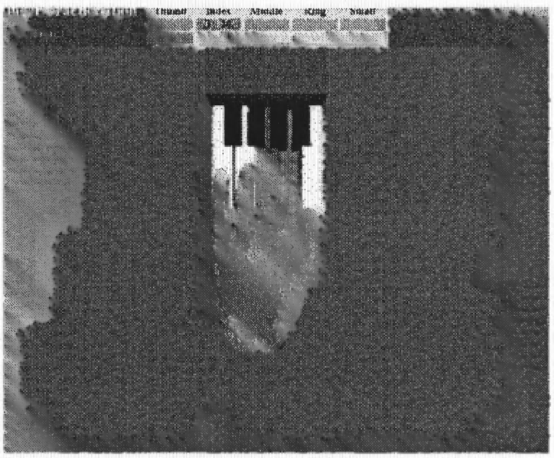

Figure 2.8 Cyberglove VR game for fine motor tasks and is only set up for a few specified settings.
(Adamovich, 2003)

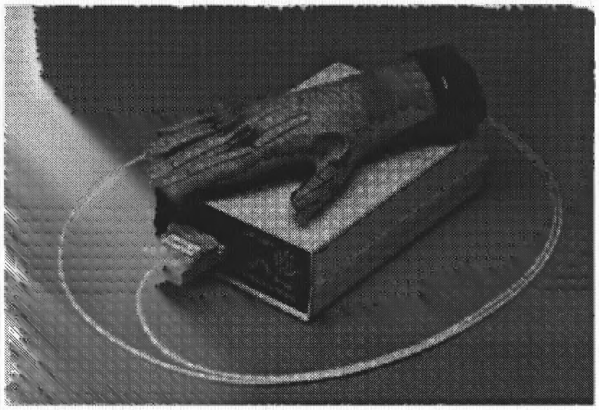

Figure 2.9 Immersion Inc® Cyber Glove constrained with sensor cables and an expensive hardware unit.
(vresources.org, 2007)

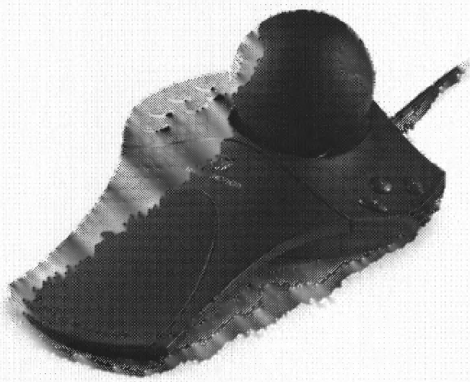

Figure 2.10 3D Connection® Spaceball for manipulating fine motor movements. Like the common joystick, this controller can have up to 6 degrees of freedom including the added buttons which also necessitate fine motor control.
(Murdock, 2007)

In the proposed VR rehabilitation system the user can be safely immersed in the simple 2D or 3D games and will unlikely get cyber-sickness or virtual fear that may result from VR systems such as head-mounted displays (HMD) or other more limiting games that prevent the player from sensing anything outside of the virtual world. HMD involves goggles or helmets that are worn to permit the user to see only what is in their VE.

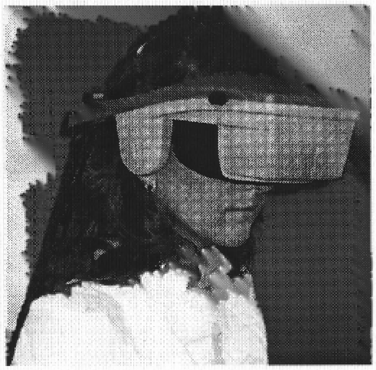

Figure 2.11 HMDs are restrictive, they can be heavy, and in some circumstances they can be dangerous as they are highly immersive and the viewer can not see anything in their actual environment.
(Lynch, 2007)

This VR technique is thought to increase the participant's sense of presence or immersion in the VE, but has been found to increase the incidence of other side effects if the game coding is incorrect or the speed is shifty (Newby, 1993).

CHAPTER 3

PURPOSE AND SCOPE

3.1 Development of the Videogame System

This design and development project has several important aspects that include; incorporation of adaptable videogame making features; and collaboration and input from OTs. Through the manipulation of software for virtual and autonomous simulation, adaptable features are created. Incorporation of the most cutting edge rehabilitation technologies and therapy goals learned from first hand experience, is then required for manipulation of the adaptable game system.

The two main system specifications for the development are;

1) The motor control actions encouraged in the games, made on the new videogame platform for upper extremity rehabilitation, are purposeful. Encouraged game activities and actions meet the customized therapeutic objectives of the particular rehabilitation session.

2) The games are developed rapidly and appropriately upon the request of a new therapy objective or concept. The translation of therapeutic goals into games is the key aspect in the development process.

In order to succeed at these development plans, a working groundwork for a videogame platform is chosen based on a pre-existing manner of controlling and giving behaviors to virtual mobile robots.

The compilation of functions, callbacks, initial simulation window set-up, and collision detection mechanisms are compiled into a software toolbox that is utilized. Collision detection mechanisms can track and report what virtual robots in a computer generated bitmap environment may see through a series of Matlab function and structure updates. The public domain Simrobot toolbox includes these functions, callbacks, methods, and GUI set-ups which are modified for application in the Videogame toolbox.

The Videogame toolbox is capable of running through game simulations in which robots can be inserted and given behaviors in the bitmap world. In addition, robots that behave as the users' hands, or extremities, are inserted. These mobile robots representing the hands respond to position data that is calculated and processed in real time. Just as the objects in the game can *see* the world, they can *see* the users' hand representations and likewise the users' hands can sense the other robots and the environment. Objects in the simulation can respond and interact based on the programmed patterns of movement and behavior.

The game tasks can be set up in a functional manner and the suggested game ideas can be applied. When the task or exercise is completed or certain actions are performed feedback on what the hand representations did can be displayed and tracked objects can be triggered, contacted, or just *seen* and rewards and scores can be given. The videogame system can be constantly adapted to maintain competition, involvement, attention, and motivation.

Through observation by the treating therapist, or parent or guardian, and analysis of data by the therapist to assess success, changes in the game system can be made and improvements in such scores can be seen. After repetition and involvement in the games, mobility of the upper extremities may improve.

3.2 Videogame System Benefits

Some virtual rehabilitation game environments may incorporate real-life experiences with visual, auditory and physical interactions between the objects in the environment. These interactions have been shown to be more effective than the conventional one-on-one passive physical therapies. Passive physical therapies may incorporate simple manual task-oriented movements, but the movements are initiated by a therapist or machine and do not provide the necessary degree of sensory motor stimuli that can be found in a VR game system where the user is moving in a completely voluntary and involved manner.

An example of a slightly more effective therapy technique involves the use of a virtual room or kitchen environment. The "room" scenario encourages motor activities of daily living like pouring drinks or reaching and putting objects (Huang, 2006). In this situation, the user may be able to interact, but there may not be behaviors or patterns of interaction given to the objects. No feedback of response may be provided to the user. In the Videogame toolbox, objects, such as those in the "room" scenario, can be given customized behaviors causing them to interact with the user at varying levels and respond to movements.

An added frustration that may result occurs when systems have interference from constraining devices required to play some of these games. This frustration is removed in the Videogame system. There are no added constraints or discomfort and the benefits of the rehabilitation program may increase (Eliasson, 2005). HMDs are often used for increasing immersion in some game systems, but there could be potential negative side affects. This explains the benefit of lower immersion systems like the Videogame system where novel interactions and appealing, but un-distracting graphics, are used to capture attention and provide continued challenge. The Videogame toolbox is low immersion with more concentration on the motivational game aspects and the functional tasks and movements. These are two key factors in the success of therapies to induce neuroplasticity (Huang, 2006).

As mentioned previously, for people with CP, fine motor tasks may be difficult and in hemiplegic people the movements might be impossible. A game system that incorporates wireless sensors or color detecting mechanisms to input the position coordinates is preferred over systems that are constrained with cables or that require manual operations. The on screen character representations can be simple yet still be incredibly interactive because of their adaptations to the player's movements. With unconstrained therapy that encourages varying gross motor movements, VR games can be played more successfully with more repetition and less interference, distraction, and negative side-effects.

Figure 3.1 Set-up of system hardware without background or movement constraints.

As a summary of the beneficial features implemented in game platform, the next seven topics are outlined.

1) Adaptable – The system can be altered for any type of game simulation. Options for speeds, colors, sizes, scales, accelerations, or area of mobility and accuracy can be chosen based on what the robots are *seeing* and where they are located. Differences between the mobility of each extremity are incorporated based on the individuality of the robots and the manner in which the objects interact with extremity representations. Unilateral or bilateral tasks are possible when one or two robot representations of the hands are used to complete tasks.

2) Editable - by GUI inputs,; sliders, drop downs, and check boxes to:

a. change the speeds and sensor ranges of interacting objects

b. alter the manner in which objects accelerate to your hands or your hand(s) accelerate to the objects

c. change patterns of accelerations and velocities of objects

d. define the range of motion of objects based on where they are located and where they are controlled

e. amplify movements, sizes, or colors of the objects in response to the hand(s)

f. change the overall directional actions, appearances, or colors of objects

3) Safety -- In practicing a virtual task, which is potentially dangerous (such as hitting an object), there are no negative consequences to failure.

4) Time -- The games or game features can be quickly altered to become easier or more difficult. This allows more time on the motor control activities or repetitions of therapy

5) Space and Equipment – Space requirements are minimal. System tracks chosen color markers on or in the hands with a webcam. Color detection implemented is precise and a back drop or a special outfit is not required.

6) Cost Efficiency -- Can be an individual, at-home activity, without one-on-one therapist supervision. It is public domain and can work on a PC, in any environment, while still maintaining a similar outcome level following training or treatment.

7) Documentation -- Automatic scoring and report systems are displayed to monitor subjects' progress, based on number of crashes or area covered. Documentation choices

can be altered as desired or turned on or off depending on whether the user becomes too reliant on the score and the competition becomes a distraction (Holden, 2005).

These seven categories of importance and scope are implemented based on the platform characteristics and development process.

CHAPTER 4

IMPLEMENTATION

4.1 Software Implementation Overview

The videogame platform runs on Matlab 7.0 with the newly designed and implemented Videogame software toolbox. The Videogame toolbox is a functionally modified and manipulated version of the Autonomous Mobile Robot Toolbox, Simrobot (uamt.feec.vutbr.cz/robotics, 2003).

Simrobot was built as a graduate thesis at the Brno University of Technology Department of Control Measurement and Instrumentation (Petrinic, 2005). It is a public domain Matlab toolbox package for autonomous robot simulation. Its base function as a software toolbox is very useful as it allows for mathematical control of one or more autonomous robots, which can assume the shape of any solid object. Control algorithms for each robot can be written individually by the user and then applied to the object or shapes in the editor window. These variable and editable algorithms can be selected and customized through straightforward GUI inputs and applied to objects that take on *real* movements and represent the players' hands.

Simrobot also allows for objects including hand representations to *see* other objects including themselves and the background environment. The sensing mechanisms are altered by parameters contained in another GUI window named the Sensorial System Editor (uamt.feec.vutbr.cz/robotics, 2003). Each simulated robots' sensor system, either laser based or ultrasonic based can be edited in distance, range, direction, and number (Petrinic, 2005). Ultrasonic based sensor systems, that measure the shortest distance in the selected and individualized sector surrounding a robot, report the identification number of the objects in contact or nearby. Robots can interact with the hand representations that move as the users' extremity. They can *see* each other and respond in varying manners after novel applications using the provided toolbox functions and methods.

4.2 Simrobot Structure Parameters

The programming object, simrobot, has many parameters that are necessary for implementation of the game simulations. The parameters of each robot that can be altered are the name, number, algorithm (af), color, scale, patch, position, heading, velocity, acceleration (accel), sensors, history, user data (userdata), power, crashes, xdata, ydata, and zdata. In the Videogame toolbox these fields are directly edited with callbacks from the GUI, making direct code manipulation straightforward and in many cases, unnecessary for the therapists.

An overview of the simrobot parameters begins with the name, which is a string that can be given to each robot that is created in the GUI.

Simrobot labels every robot with an ID number parameter. The number one goes to the background and for every robot added after, the numbers count up.

The string, af, is the robot's algorithm. Interfaces in the Videogame toolbox can assign algorithms based on the parameter values that are chosen in the GUI or written into a Matlab m file. An example of a videogame character algorithm is shown in figure 4.1. The parameters that are editable in this particular algorithm, v and d, are called through the GUI control options in the simulation editor window. The script shown below in figure 4.1 is algone.

```
function new = algone(simrobot,matrix,step,vid)

global d v

[dist,num] = readusonic(simrobot,'sensor_1',matrix);
[dist1,num1] = readusonic(simrobot,'sensor_2',matrix);
[dist2,num2] = readusonic(simrobot,'sensor_3',matrix);
[dist3,num3] = readusonic(simrobot,'sensor_4',matrix);

%NEEDS--v  2x1 input from a v from somewhere else v has to be [v1 v2]
%NEEDS--d  1x1 input for distance--d=10, 20, 30, 40, 50, 60, 70, 80, 90,
%100, 120,130, 140, 150

%v1 is for the right side v2 is for the left side
%robot will turn when with this speed when it touches either hand
%d is the distance (difficulty) an object needs to be from a hand to recognize it

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%if that far awayitself or wall(4 or 1)
if dist<d
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%itself or wall(4 or 1)
    if num==1 || num==4
        simrobot = setvel(simrobot,[-1 -7]);
    end
    if num1==1 || num1==4
        simrobot = setvel(simrobot,[7 -1]);
    end
    if num2==1 || num2==4
        simrobot = setvel(simrobot,[-1 7]);
    end
    if num3==1 || num3==4
        simrobot = setvel(simrobot,[7 1]);
    end
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%the hands (2 and 3)
    if num==2 || num==3
        beep;
        simrobot = setvel(simrobot,[-v(1) -v(2)]);
    end
    if num1==2 || num1==3
        beep;
        simrobot = setvel(simrobot,[v(1) -v(2)]);
    end
    if num2==2 || num2==3
        beep;
        simrobot = setvel(simrobot,[-v(1) v(2)]);
    end
    if num3==2 || num3==3
        beep;
        simrobot = setvel(simrobot,[-v(1) -v(2)]);
    end
    simrobot = setvel(simrobot,[.2*v(1) v(2)]);  % turn left
    beep;

else
    simrobot = setvel(simrobot,[v(1) v(2)]); % go straight on

end

simrobot=clearcf(simrobot);
simrobot = delhist(simrobot);
new = simrobot;
```

Figure 4.1 M file algorithm indicating the parameters that are chosen in the GUI.

Algorithms can define each robot's attributes (color, shape, or sensor characteristics) and behavior (response to sensor data and locomotion) allowing players to interact virtually. The algorithms are adapted by simple loop inputs or color specifications to change the simulation characteristics as necessary or as desired.

Color is based on the background color of the robots that are a 1-by-3 red, green, blue (RGB) array with each value normalized on a scale of 0 to 1.

The scale is the size of the robot. An initial scale can be set and in each algorithm the scale can be altered sequentially upon game interactions.

The patch is the actual robot shape. It consists of the xdata, ydata, zdata for the coordinates of the shape that can increase or decrease in relation to the scale of the robot shape. Robot shapes and coordinate systems are user defined based on the coordinate system outlined below.

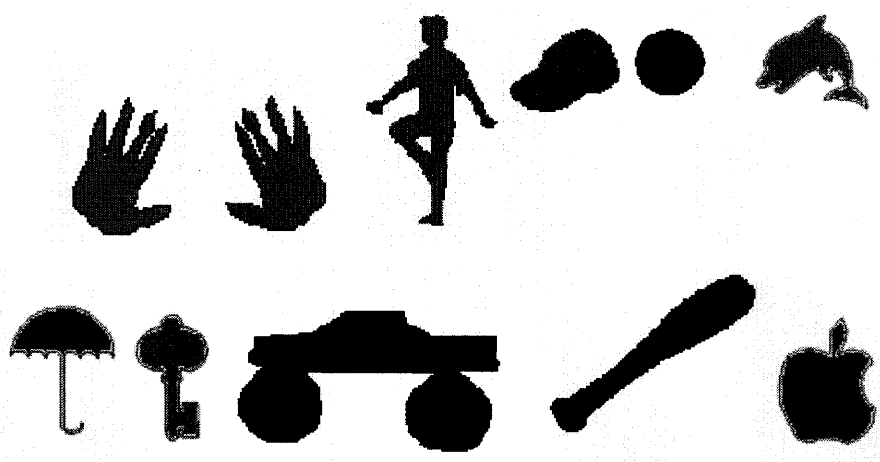

Figure 4.2 Examples of patches from the robot directory of coordinates that is created and included in the platform. The patches can be interacting robots or hand representations. A script for getting coordinates from a chosen jpeg image is written. The program orients the selected points about the origin so that sensor alignment and heading will be correlated about the same origin.

For the hand robots in the Videogame toolbox, coordinates are pre-determined based around the original robot shape.

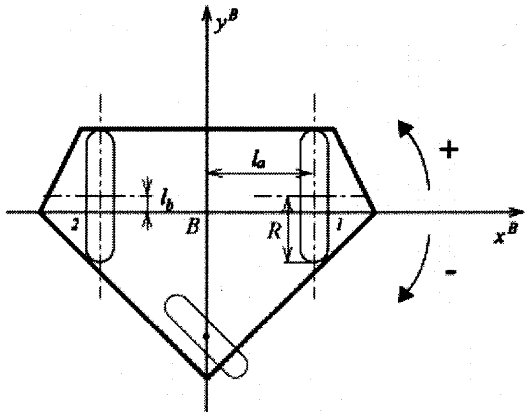

Figure 4.3 The initial shape and coordinate system of the autonomous robots is shown here. Coordinates can be altered as desired to provide new object shapes. Velocities and accelerations are based on the velocities of each of the robots' wheels and the geometric specifications that are potentially editable as well.

The position field is the starting position based on the coordinates and size of the bitmap. In the videogame platform the position is based on the 320 by 240 sized bitmap. The position can also be manipulated if the options for range of motion are limited in the simulation setup GUI. Interactions may be magnified within the chosen quadrant or side of the game screen. The position can also be limited to the top or the bottom to provide yet another option to fit the needs of the therapy goals. These parameters are also an option in the setup GUI.

The heading is the direction that the robots are facing. For the hand representations in the Videogame toolbox the heading is not altered as the image remains right-side up to prevent frustration of the player.

The velocity field is an initial set value, individualized for each robot in a simulation, based on the assigned control algorithms. In the Videogame toolbox the velocity ranges from 3 to 15. This range was chosen based on trial and error for program crashes related to update speeds that are too slow or too fast. When the velocity is above a value of 15 the update on crash flags is overlapped. The robot is more likely to move out of the boundaries because of the increased robot velocity with respect to the sensor crash updates.

The velocity is an important parameter for adaptation in the Videogame toolbox as it alters the game difficulty level. The velocity of each robot is designated by the velocity of the two wheels that point in the negative y direction as seen in figure 4.3.

The acceleration is a parameter that can be utilized to change the way in which objects collide. Because the simulations do not have to obey the laws of physics, the accelerations can be manipulated as wanted with no concern for realistic responses.

Sensors are a field that includes many other options that are outlined by a separate GUI as shown below.

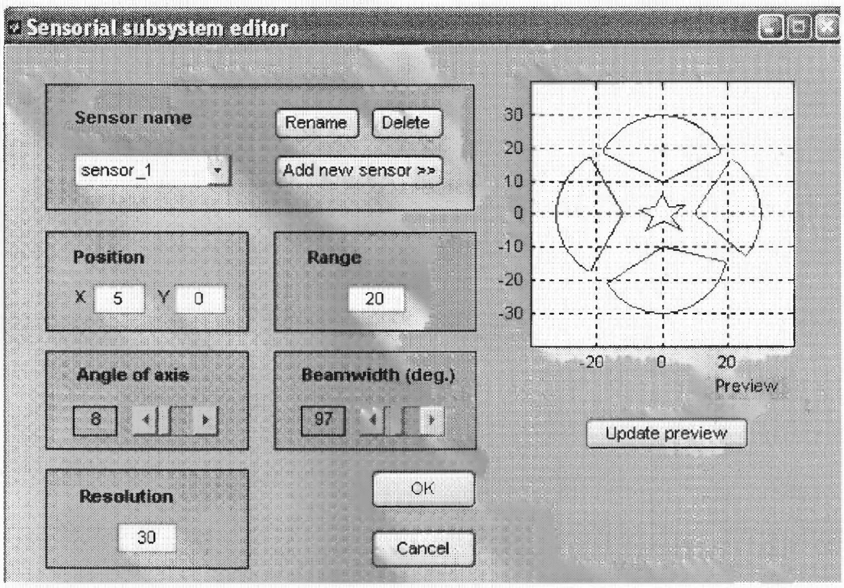

Figure 4.4 Sensorial subsystem editor showing the parameter options for the sensors. For interacting objects there are four sensors. Having four sensors allows the behaviors in every direction to be unlimited.

Sensor arrangement in the Videogame toolbox is manipulated to alter the manner in which objects interact with the robots for hand representations. The sensor initialization reports the distance that an object is from the robot (dist, dist1, dist2, dist3) and the number of that robot (num, num1, num2, num3) which can be any number between one and the total number of robots that are used in the simulation.

```
% sensor reading
[dist,num] = readusonic(simrobot,'sensor_1',matrix);
[dist1,num1] = readusonic(simrobot,'sensor_2',matrix);
[dist2,num2] = readusonic(simrobot,'sensor_3',matrix);
[dist3,num3] = readusonic(simrobot,'sensor_4',matrix);
```

Figure 4.5 Sensor initialization in the algorithms.

There are four sensors indicated in the sensorial subsystem editor in figure 4.4, and they all report different number and distance values, as seen in figure 4.5. Each side of the robot can report the readings from the sensor. Varying numbers of sensors can be inserted, allowing manipulation of crash responses. The sensors can also be manipulated in the robot control algorithm, where they are initiated and utilized in conditional loops driven by the distance values that they output at each simulation step and the ID number of the robot they are *seeing*.

History and userdata are implemented in the scoring sessions of the Videogame toolbox. History is a parameter that can store the position of the robots. It is utilized in the drawing or tracing applications. Userdata is a field parameter that can be used to store any desired type of information as a simulation is run.

Power can turn off a robots algorithm so that it is no longer mobile within the simulation.

Crash is a binary value that is set as 1 when the robot has crashed or touched another robot or 0 when it is not interacting with any other objects. It is possible to stop the execution of an algorithm once a crash has occurred. For the purposes of the Videogame toolbox, the crash flags are cleared and all robots can continue to simulate.

4.3 Toolbox Modifications

The original Simrobot toolbox is expanded and manipulated even more to create a viable platform for videogames. Modifications made to the function of Simrobot include:

- modifications to set-up and callback functions for editor window options
- initialization inputs and algorithms that allow camera initiation, color detection, and even position sensor data and analysis
- drawing or tracing options implemented using the history field of simrobot
- interfaces for selecting algorithms created based on globalized variables for initial velocities and sensor ranges
- options for inserting varying numbers of hand representations with the chosen color detection control algorithm
- application of more unique and customized bitmaps for various, customized simulation scenarios
- scoring boxes and methods of saving lists of scores after multiple simulations or sessions

The initial set-up screen for the games is altered and more accessible options for starting and stopping the simulation are provided, along with options to edit the game once the simulation is initiated.

When the Videogame toolbox is first initiated the editor window appears. At this point, simulations can be imported or set-up based on the parameters and necessary objectives of the therapy session.

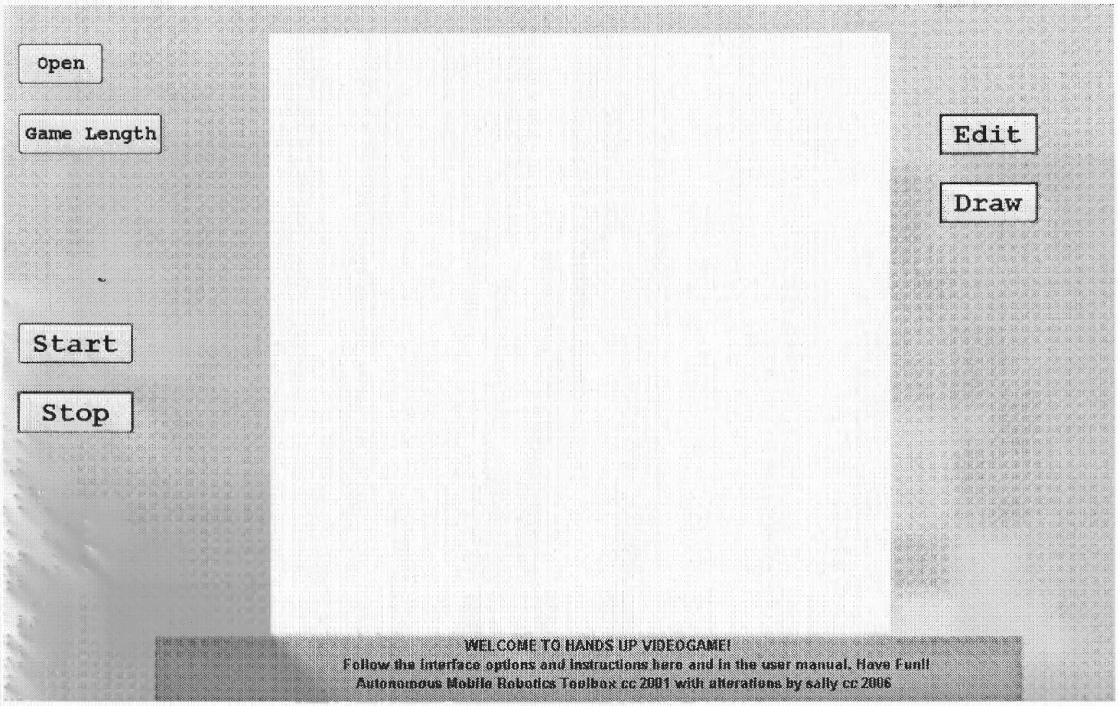

Figure 4.6 Initial editor window where simulation set-up GUI is also initialized. Accessible buttons are inserted into the GUI based on input from OTs.

Added GUIs and question dialog boxes make the set-up of any game straightforward and quick. These pushbutton features are inserted as Matlab uicontrols, using callbacks in the set-up functions that are completed.

An option to draw, based on the history data that is stored during the simulation, is an additional button feature for tracing and drawing objects or visualizing tracks.

Additional new interfaces are created to allow for direct algorithm manipulation, so that the user or therapists will not have to edit script files or command lines.

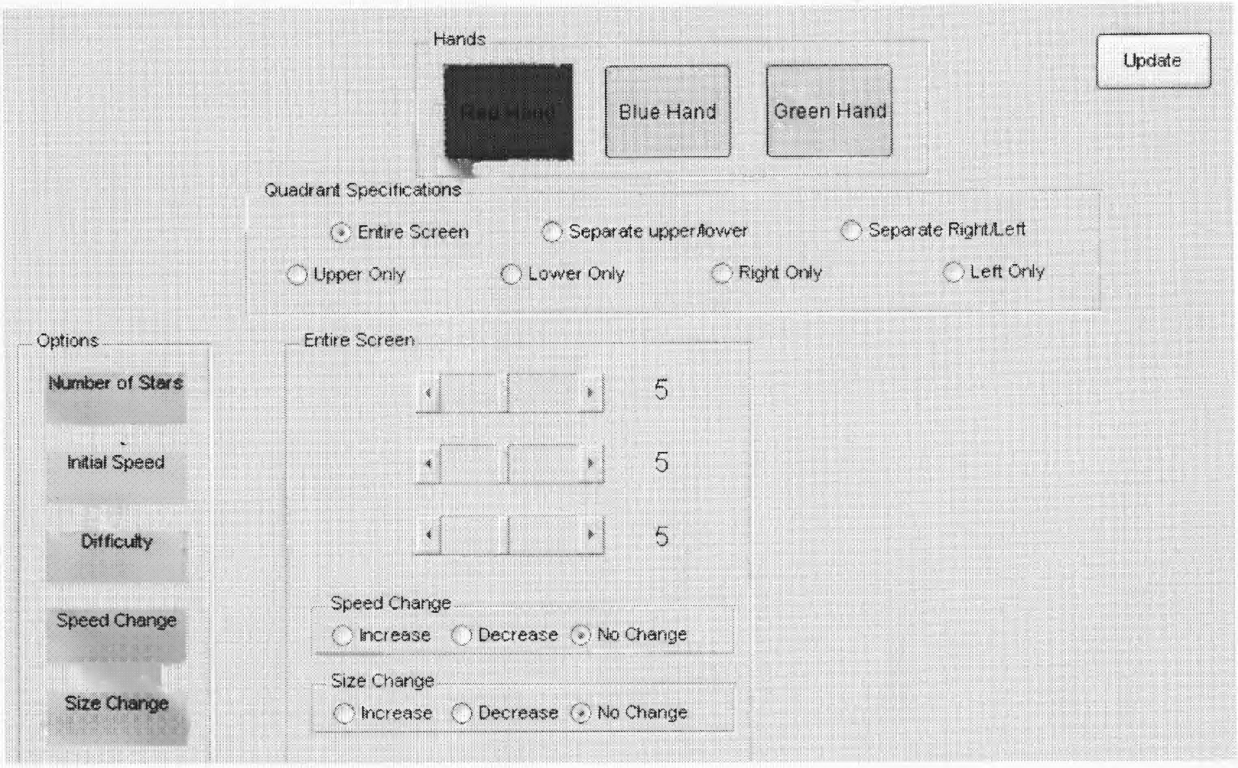

Figure 4.7 Screen shot of the GUI used to select parameters for the simulation. One red hand is selected to initiate a unilateral game. When separate upper/lower or separate right/left is chosen there are sections for the behaviors in the respective section. This allows parameters to be unified

Any number of hands can be inserted into a videogame simulation. For example, by clicking blue and green in the Videogame toolbox set-up GUI, three robots are inserted:

1) border ID 1 (bitmap that will also be imported if different boundaries or environment are desired)

2) handgt ID 2 (green hand)

3) handbt ID 3 (blue hand)

Furthermore, the games have options for altering the parameters for each robot representing a hand. Two players may be involved, each with a hand towards which objects react differently or equally. This option gives the user with unequal and compromised mobility the chance to play competitively with their friend or sibling to provide a normal and healthy interaction that might otherwise be limited when one child has a motor dysfunction such as CP (Abramovitch, 1986).

Bitmaps for backgrounds are pre-made and basic, set-up, VR worlds permit simple modifications based on the user's individual interests, color or shape preferences, along with their capabilities and range of motion (ROM).

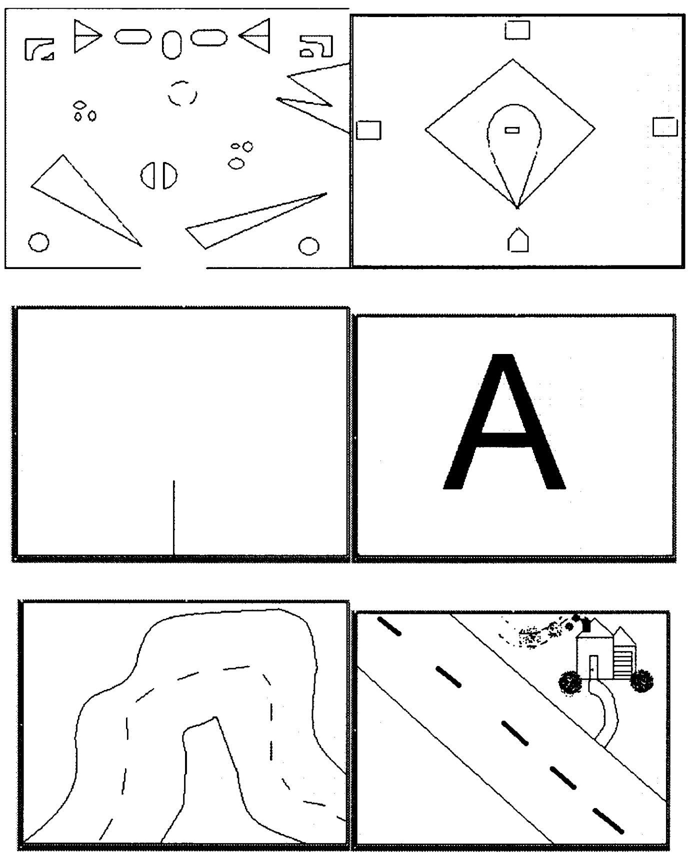

Figure 4.8 Example choices of virtual worlds, or background bitmap environments, for varied simulations.

Scoring or grading mechanisms are added based on the number of crashes or on the area of the simulation screen that was covered. As a player increases their mobility they may begin to reach other corners of the simulation window which can translate to a quantitative analysis of their improvement. Having different scoring mechanisms is a beneficial characteristic that was implemented based on the idea that diversity among outcome measurements promotes more customization and interaction for the user (Glanz, 1995; Huang, 2006).

Players' crashes are printed to the scoring box on the screen and reports are saved as a mat file in the command window workspace. The scoring box in the simulation window can be turned off in case the player is basing their entire therapy session on increasing their score, thus interfering with their play and positive motivation.

The OTs at the CSH have determined that all of these modifications are useful parameters for manipulation of a videogame session to meet the therapeutic objectives given.

4.4 Control Algorithm Implementation

It is important that the control algorithms for all robots in game simulations have efficient syntax. Matlab loops are required for making the autonomous behaviors for all robots. Whether the loops are efficient or not, is determined by the step speed. The control algorithms for the hand representation are lengthy, due to the image data analysis that is required, but the code is optimized to maintain the real time step completions.

Every control algorithm uses the Simrobot initialization line with a function input. Functions are faster than running m file scripts. Functions include parameter lists with inputs left of the equal sign, and outputs in the parentheses (web.cecs.pdx.edu, 1995). An example is given in the green marker algorithm below. The variables that are passed include the structure, simrobot, the matrix which includes all the robots and their user data, the step number of the simulation, and vid which is the device name that is initialized in the simview callback.

function new = handgt2(simrobot, matrix, step, vid)

The variables that are collected for the color detection mechanisms are globalized next, so that the acquisition does not consume two robot update periods. In this manner coordinates for hands are found, and one set is passed along, instead of repeating the calculation and search. This globalizing speeds up the overall step completion.

global rows1 columns1

This same code consolidation is used if the single hands are used to play the games or if any combination of red, green, and blue markers is chosen.

The camera is initialized in the game set-up but in the algorithm for the green marker representation, the frames of the camera are checked using the device structure name, vid, and the fields that are applied in the imaq toolbox. FramesAcquired, an imaq toolbox structure for function input, is checked so that at the start of the step, if an image does not exist or is not acquired, (the camera is off or no image appears) then the next frame will be used as it will stay in the loop until a frame is available. This coding also prevents the need for conditional operations, which, in turns, allow for faster operation.

```
while(vid.FramesAcquired==0) %setting at 100 makes the video shorter
end
```

Next, the initial matrices are set up and ready to be filled with the position data based on the x and y position which directly correlate to the row and column value in the camera data and the VE. Setting up empty matrices will save time later in the algorithm when the data is collected and inserted in the Matlab while loop.

```
i=0;
rows1=[];
columns1=[];
rows2=[];
columns2=[];
```

Now, the data from a single frame is captured as the loop initiates. There is a double check based on the i value that limits the loop to one iteration. The double check is required so that no more than one frame is analyzed. This assures smooth image transition and real-time capturing.

```
while i<1
i=i+1;
while vid.FramesAvailable<1
end
```

After a frame is available, the image data from that one frame is read using the getdata function from the imaq toolbox. The string vid is the name of the device that is given in the initialization code of the platform and one is the device number. Rather than using a conditional statement to check the frames available, the field is called and the algorithm runs faster.

```
data = getdata(vid,1); % grab images on the fly as they come in
```

The camera data is 320 by 240 by 3 and the information comes in as the reverse image, not the mirror image. To correct for the dimensional translation, the data is transposed with respect to the columns and then with respect to the rows. This creates a mirror image of the data that is beneficial to the rehabilitation process as extremity motions are viewed in the same manner as they were made.

```
data=flipdim(data, 2);%flips with respect to the columns (2nd dim)
data=flipdim(data, 1);%flips again with respect to the rows (1st dim)
```

From this camera data a value for the color of the hand markers needs to be found. This is completed by determining the specific combination of red, green, blue (RGB) pixel values that are on the color scale 1-255. With a neutral background the determined value for green, blue, and red were determined based on a trial and error approach.

It was found that green includes a value for red less than 110, green greater than 220, and blue less than 210. With this range, the bright green color will be depicted. If the scale was on the normalized 0 to 1 standard then the green value would be 0 in the red page, 1 in the green page and 0 in the blue page. It works out so that the values, from the RGB data that defines green, are not normalized, but are tracked by brightness, with 255 being the brightest.

```
%%%%%%%%%%%%%%now here is the green hand:
[r2,c2]=find(data(:,:,2)>=220 & data(:,:,1)<110 & data(:,:,3)<210);
```

The blue marker is defined by the combination of values between the ranges of less than 155 in the red page, less than 155 in the green page and greater than or equal to 235 in the blue page.

```
%%%%%%%%%%%%%%%now here is the blue hand
[r1,c1]=find(data(:,:,3)>=235 & data(:,:,1)<155 & data(:,:,2)<155);
end
```

With the vectorized Matlab function, find, the column and row index number for the location of the pixel value that is found in the specified ranges of each RGB page of data are located and stored to the matrices r1, r2, c1, c2. Because more than one value might be located within the specified range an average value is calculated.

```
r1=sum(r1)/(length(r1)+.000001);
c1=sum(c1)/(length(c1)+.000001);
r2=sum(r2)/(length(r2)+.000001);
c2=sum(c2)/(length(c2)+.000001);
```

The 0.000001 value is added to prevent a divisor of zero. The locations are then stored in the empty matrices that are set up in the beginning.

```
rows2=[rows2;r2];
columns2=[columns2;c2];
rows1=[rows1;r1];
columns1=[columns1;c1];
  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
nx = columns2;
ny = rows2;
new=[nx ny];
```

Now, with the coordinate values located, the positions of the hands are known and the actual position that simrobot calculates based on the hand is calculated with a built in function called getpos. This is completed inside a Matlab for loop that prevents the robot from being plotted at the zero-zero position if no pixel value is found. Instead, the loop runs the length of the loop variable which in this case is anything greater than one.

```
for nx>=1 && ny>=1
old=getpos(simrobot);
```

Now with two positions, a unit velocity can be calculated based on the difference between the position the hands should be at and the position that they are actually at. The velocity is set to this difference which is equivalent to the real time movement speed.

```
vell=new-old;
simrobot=setvel(simrobot, vell);
```

The acceleration of the hands is also set using another simrobot function, setaccel, and the for loop is ended so that the desired values are sent.

```
simrobot=setaccel(simrobot, [0 0]);
end
```

Finally, the crash flags are cleared, the history is deleted, and the information is written over the old data in the simrobot structure.

```
simrobot=clearcf(simrobot);
simrobot = delhist(simrobot);
% end of your algorithm
new = simrobot;
```

By setting the data as the same simrobot object, but labeled as the local variable new, the algorithms are completed more rapidly. Another indication of the algorithm speed that can be adjusted is the delhist command. By deleting the history the simulations do not have the potential to slow down over time.

4.5 Hardware Implementation

A popular and inexpensive USB-based, 30 frames per second, webcam is utilized in the color detection mechanisms for sending position data to Simrobot. The webcam is designed to take snapshots at up to 640 by 480 pixel resolution and video at 352 by 288 depending on processor speed. The frame rate that results from application in the toolbox is approximately 28 frames per second. As code improvements are made and code compilation is completed the rate may be brought up to the fixed 30 frames per second. According to accepted rates of human motion capture, not including fast action sports, 25 to 30 frames per second is sufficient (Winter, 2005).

The camera is accompanied by three lines of Matlab initialization code that is incorporated into the toolbox set-up functions. The game initialization and play requires a USB port and the Image Acquisition toolbox for the initialization code and for the initial device recognition As the camera streams the video frames in, once initialized in the videogames, the color image data dimensions are 320 by 240 by 3. The standard camera analog signal consists of 640 rows and 480 lines (640 x 480) but for the smaller webcam the dimensions are smaller and the frame rate is reduced upon implementation with Matlab.

4.6 Color Detection Implementation

Green, blue, or red markers, chosen after evaluation of the environment, accessibility, and availability are held or attached to the players' upper extremities. Once the player is in range of the camera (up to 10 meters away from the lens) the individualized game is initialized with the start button. A video preview is available upon selection to aid in the viewing set-up of the game.

Once the game is started the camera is initiated in the software platform and color detection begins. First, the image data is captured by the webcam and then processed in Matlab. For each frame of the video, the data of the image is saved in a variable called 'data' that has the size 240 rows by 320 columns by 3 pages.

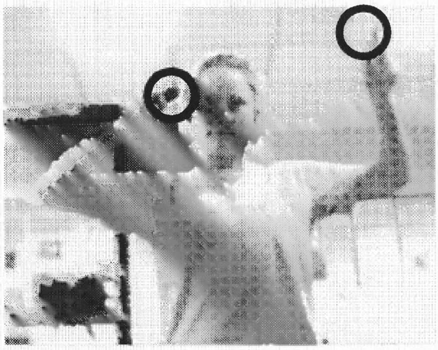

Figure 4.9 Webcam view of play standing anywhere from 1/4 meter to 10 meters away. Color markers are depicted.

With the data that is sent to Matlab, general Matlab functions are implemented to locate the determined pixel values from the three page image data that streams into algorithms assigned to the players' hands. The code for this pixel search is shown below, and it is discussed in more detail in the hand algorithm optimization section.

```
%%%%%%%%now here is the blue hand:
[r1,c1]=find(data(:,:,3)>=235 & data(:,:,1)<155 & data(:,:,2)<155);

%%%%%%%%now here is the green hand:
[r2,c2]=find(data(:,:,2)>=220 & data(:,:,1)<110 & data(:,:,3)<210);
```

The group of pixel coordinates, r2, r1 and c2, and c1, are averaged to get a singular location, which is sent to the position field of the robot's structure. The robots representing the hands of the player are simultaneously given coordinates calibrated to the simulated virtual environment (VE).

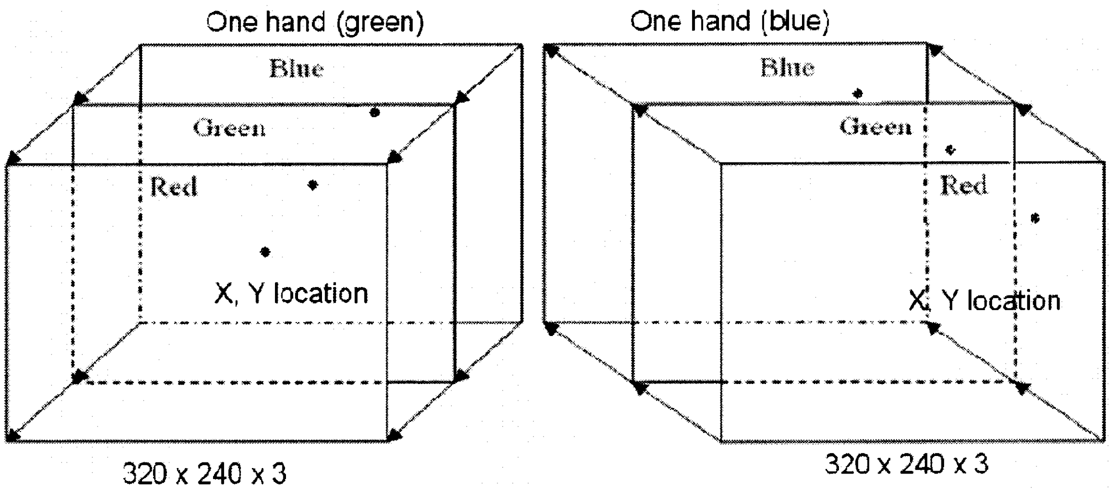

Figure 4.10 Depiction of the camera data dimensions and the pixel location. Red is page one, green is page two, and the blue is page three. At the marked location for green (at the left) the pixel value in the red, green, and blue page are within ranges of less than 110, greater than 220, and less than 210 respectively.

The position field of the robot's structure is then used to manipulate the new position of the robot based on the update for the patch, or shape of the robot, and the previous location.

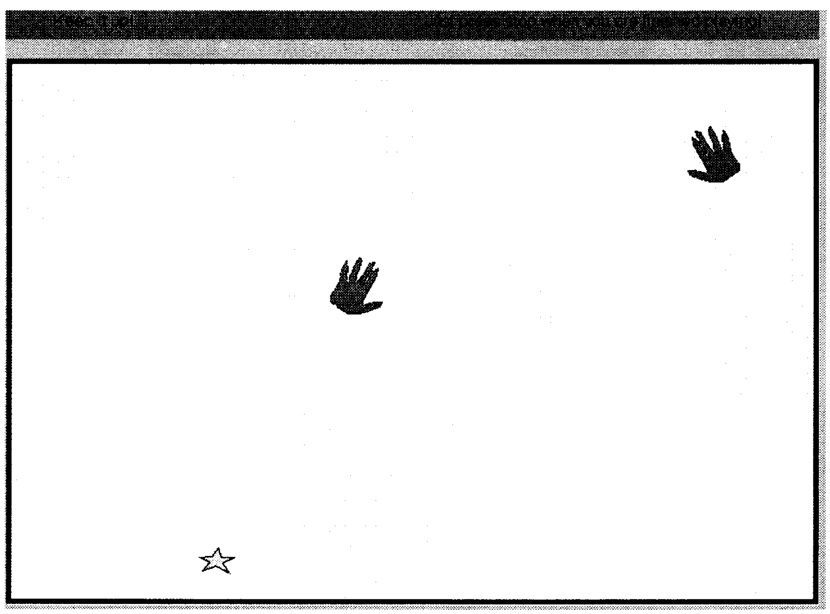

Figure 4.11 The pixel value coordinates' and translation to the VE coordinate system.

Color detection is precise enough that the game can be played in any environment providing that the walls do not include the colors bright red, green and blue all together. Even if there are variations of pale red, green, or blue in the background the markers are still detected.

One minimal constraint includes the fact that florescent and bright lights are required. A dimly lit room with warm lighting from a lamp may not be enough for pixel detection to be accurate as the wave lengths may report different pixel values for the same colored surfaces.

Figure 4.12 Webcam view of user and the color markers. Background color does not interfere with the color detection Mechanism that is designed.

Even though there are background colors that may share similar pixel values as the markers, the markers are still followed because of the precise detection code.

4.6.1 Color Marker Hardware Options and Considerations

The color markers for extremity tracking can be any combination of green, blue, or red as chosen in the set-up GUI or selected simulation. The markers can be mittens or hand socks, Velcro® markers or bands, small pointers, or colored 3D or 2D objects. The variety is important to consider because the user may have different deficiencies or preferences. The therapist can also chose the marker based on the aim of the therapy and the materials available.

Flat, 2D markers maybe held in a way that when the hands are supine they disappear and signal the user to correct their wrist contortion to a more pronate position. Spherical markers, like colored toy balls, can be held in a manner that assures the camera will always be able to track the 3D color despite the users grip position. Even weighted markers or larger balls held in both hands can be used to increase the fatigue limits and grasp development.

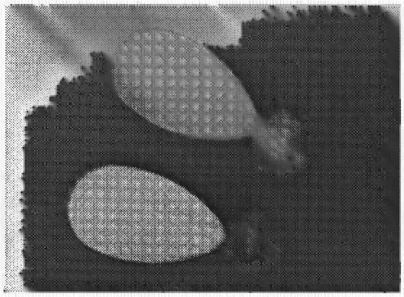

Figure 4.13 One example of everyday colored markers used for grip tracking. They include a 2D and 3D option for grasp.

In some game situations it is more interactive to have the user hold the objects. Holding the markers adds another degree of sensory motor input and motor control. However, for patients that may have deformities, such as twisted wrists or bent in elbows, a fixated marker would be more effective.

Wrist bands or colored hand socks may be appropriate when finger positions are considerably compromised. There are also universal cuffs, used at the CSH, that provide a pocket in which any type of color marker may be placed and made visible. These cuffs are usually used for holding a tooth brush or an eating utensil. In addition, fixated markers that are worn may allow for more confident color detection abilities as fingers or hand position will not obstruct color from the webcam lens' view.

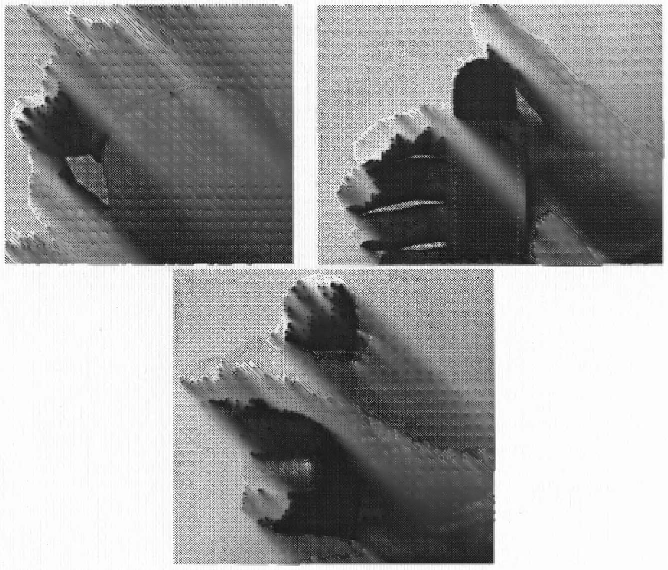

Figure 4.14 Universal cuff used at the CSH and fitted with a pocket for color marker insertion.

Conventional household options are preferred over tools that are more difficult or costly to attain. Game controllers for some VR systems are large and may also involve additional buttons.

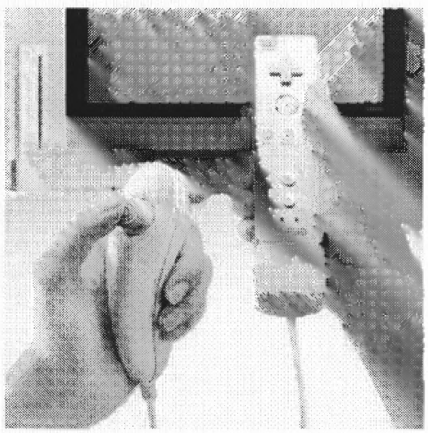

Figure 4.15 Game controllers with gross and fine motor requirements along with interference cables. For children with CP thumb function may be limited and wrist extension may be compromised to varying degrees. These alterations in motor function may make these controllers hard to use.
(http://www.gadgetspy.co.uk/)

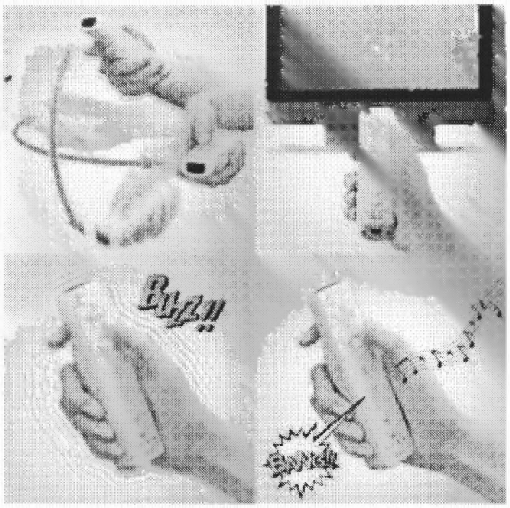

Figure 4.16 The wireless Nintendo Wii® remotes that have 3 axis of freedom require extensive wrist mobility. They are unconstrained as long as they can fit in the user's hands, and they provide one type of feedback shown above. Younger children may not be capable of handling such a remote.
(http://www.rsi-relief.com/blog/img/WiiController.jpg)

Figure 4.17 A game controller that requires some degree of fine motor function and wrist pronation that some CP children do not have is shown here. The controller does, however, demonstrate how holding a remote or tracking sensor may increase the sensing aspect of the system and make the user feel like they are involved in the game as their marker is somewhat realistic.
(http://assembler.roarvgm.com/Jaguar/Jaguar_VR/controller2a.jpg)

With video based game systems, such as the IREX Gesturetek® system, the full body is replicated in the VE through a complicated image removal process. In order to create a one-handed game, the user must wrap one of their limbs in a fabric so that the video screen image removal will not display the covered limb (gesturetek.com, 2006).

With color detection, game play can be limited to the specified therapeutic motor tasks. Color detection also allows modifications in sidedness, or encouragement of unilateral interaction, without the hassle of added physical constraints.

Another benefit of the webcam based tracking mechanism is that it prevents the user from attempting to reach with other body parts in order to achieve the same goal. If a motor task such as reaching an object in an upper corner of the screen is encouraged the user has to reach with their hand to which the color marker is placed or attached. In the IREX®, and other similar systems, the player could just stand up a little taller and their head could interact with the object instead. Accommodation is common if the user is frustrated. Color markers are placed at the extremity location and only at that point can interaction with the simulation occur. With a system that only encourages the correct extremity movements the benefit to motor improvement will be greater.

4.7 Model Simulation Implementation

In order to create a customized game that challenges the user and maintains the interaction and attention, therapists ask certain questions. The following outline explains the process and reasons for setting up a number of successful, customized therapies to improve motor control and encourage more functional motor task completion.

Regular activities: Are they usually active and directed in their movements; or spastic and uncontrolled? Do their activities involve the whole body? Are they limited in a particular way that affects their regular activities?

An example response includes details about the child's' manner of asking for help when eating and scratching their head. They also display difficulties when they move from room to room therefore they normally stay in one location and are not mobile. This indicates that all encouraged movements may be beneficial, but a slow speed and lower difficulty level may be a motivational start.

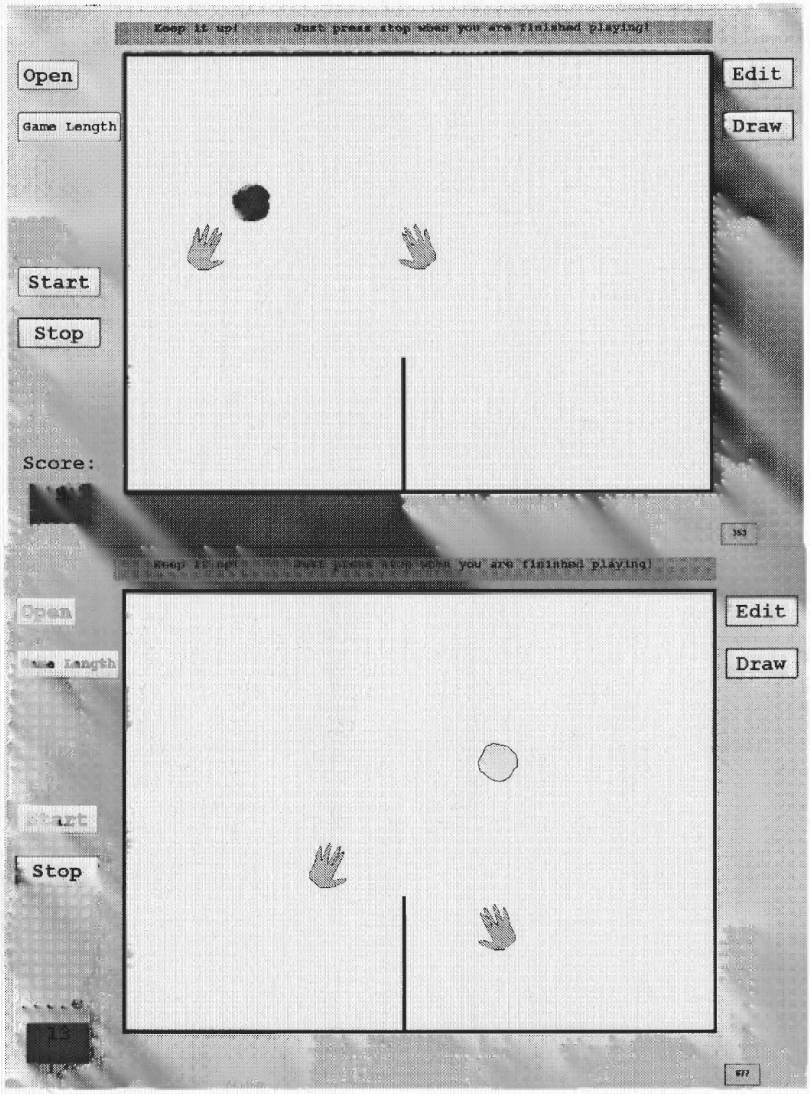

Figure 4.18 A level one volleyball game with slow speed, simple, color changing feedback, and larger scale ball is shown above. Ten levels are available with the platform, but more variations in types of game parameters can be made through the user interface. The level is based on the speed of the traveling ball and the distance from the user's hands at which it recognizes, or *sees*, the ball or object.

<u>Favorite activities:</u> What types of functions do they enjoy using? Do they successfully complete these activities or motor tasks? Is their favorite activity completed efficiently or awkwardly?

They enjoy getting their head rubbed by others and they like communicating and holding toys in their lap, especially stuffed stars. This may indicate that using star shapes may encourage mobility in a slightly more motivating fashion. More real-life tasks may also be appreciated.

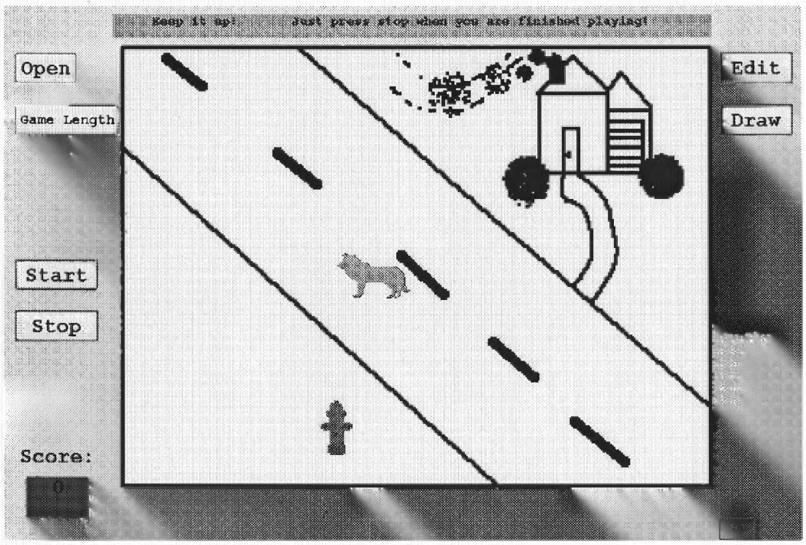

Figure 4.19 Dog walking simulation where the player's hand is represented by the dog and there are specific interactions or tasks to be completed. These tasks can be described in writing on the screen, or they can be given verbally, or by demonstration. In this simulation the fire hydrant can be turned yellow, the dog may have to stay in the road, otherwise it changes color, or the door step of the house must be visited and a new robot appears. These interactions are provided by the use of specific functions in the customized algorithms and manipulation of the simulation matrix.

<u>Normal patterns of movements</u>: When they are completing tasks do they succeed? How do they succeed? Are there particular motions they use to help themselves? Do they accommodate for their limb function?

They move in a linear fashion, reaching out straight with both arms. They do not use arcing movements very frequently. This may indicate that objects, such as stars, that run away from their limbs in a swirling fashion may be beneficial. A game with tracing and drawing options might also be motivating.

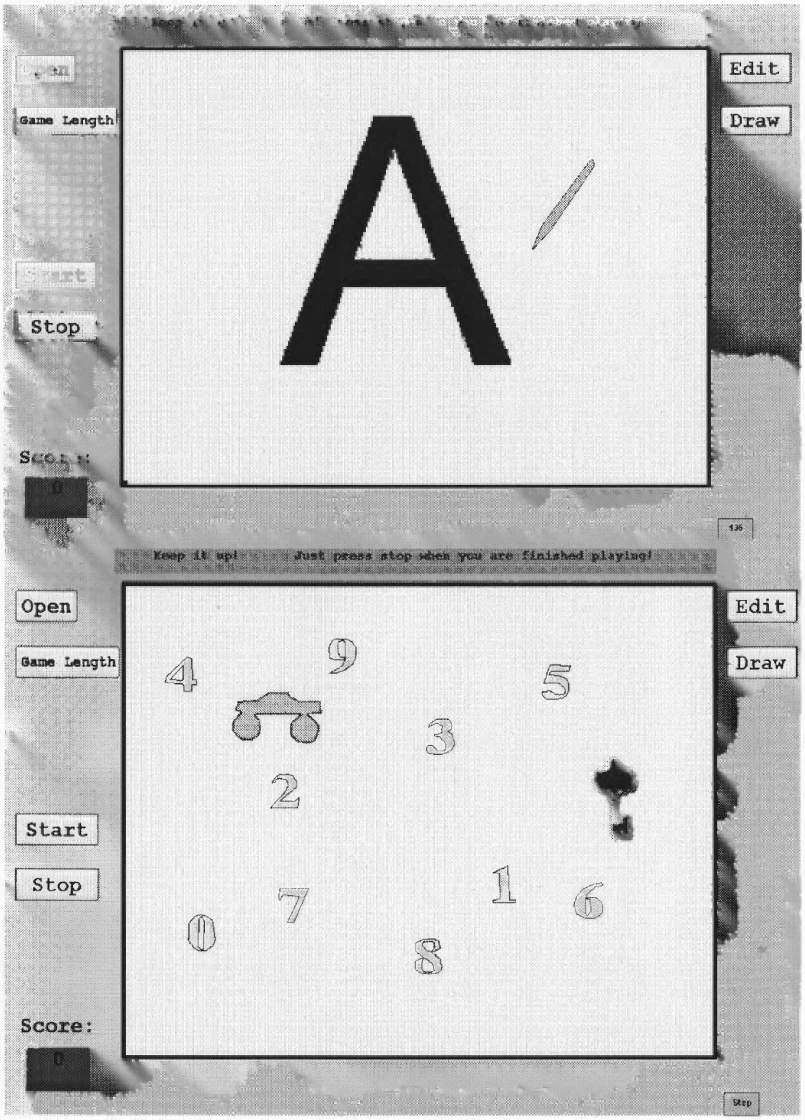

Figure 4.20 Simulation options with tracing and drawing capabilities. Numbers, letters, or simple objects like figure eights, as suggested upon OT input, can be chosen for the tracing tracks. Patterns to follow can be given through instructions either verbally or visually. Visual tracing tasks can be implemented by copying the pattern of a therapist, sibling, parent, or friend who also may have a hand representation in the simulation. Control is required by the player to maintain a position following the arcing track between the objects.

Variability of their abilities and extent of mobility: Do they maintain a certain motor pattern? Can they sustain a given motor task? What is their range of motion? Is their range of motion consistent over time?

More game details may be deduced based also on the child's own opinion of his or her mobility. The following questions are discussed to determine the next steps in the customized game development.

Frustrations: What movements do they struggle to achieve? Is reaching high, reaching low, reaching to the left, reaching to the right avoided? Is maintaining small high movements or low repetitive motions difficult? What do they state as their frustrations? What are their interests?

A game in which the child bounces a star from one hand to the other may be appealing. Games are not required to obey the laws of physics; therefore a user with very severe physical disability can participate with immediate success. Speed of the star and accuracy with which it must be hit are entirely adjustable. In the case of a child with hemiplegia, the star can behave differently with each limb. The game can be edited when a child achieves success to provide an ongoing therapeutic challenge.

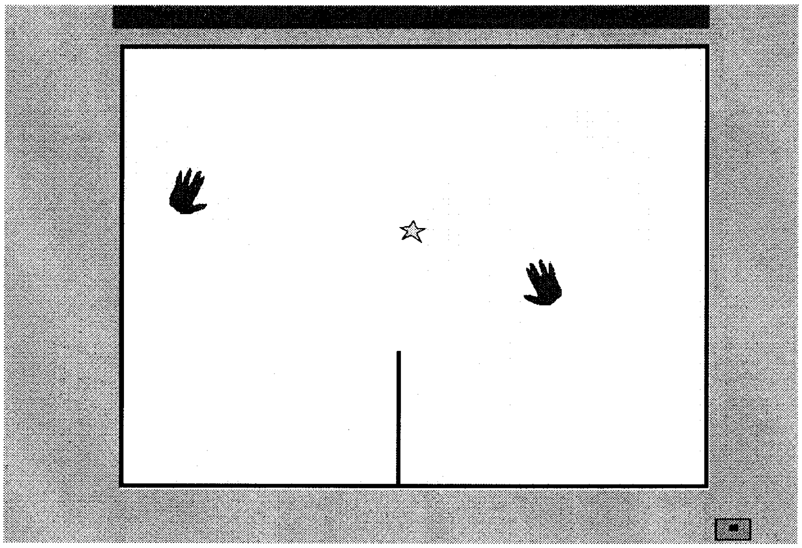

Figure 4.21 Bouncing star simulation with bilateral coordination necessitated. Star or ball interactions with each hand may be customized separately.

A summary of the design options includes features of the virtual environment or bitmap, the sensorial subsystem editor, the options for adding new robots, the simulator and game play screens, the control algorithms, and the chosen collision detection mechanisms. All the different options for changing the videogame aspects, including speeds, directions, movement patterns, and shapes and colors, are outlined in the set-up interface and in the Videogame toolbox API and instruction manual package that can be used by somebody with no programming skills to modify and adapt the gaming activities. A table of contents is also provided with the software game platform.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Platform Results Overview

The basic function of the platform is successfully carried out by the Videogame toolbox software operations and the robust color detection mechanism; and the toolbox provides all the necessary tools for rapidly creating games for customized therapy. The processes and considerations for creating and initiating a therapy session using the platform are summarized in the outline below. Each step has been carefully detailed for the platform users and implemented by the novel software that is used.

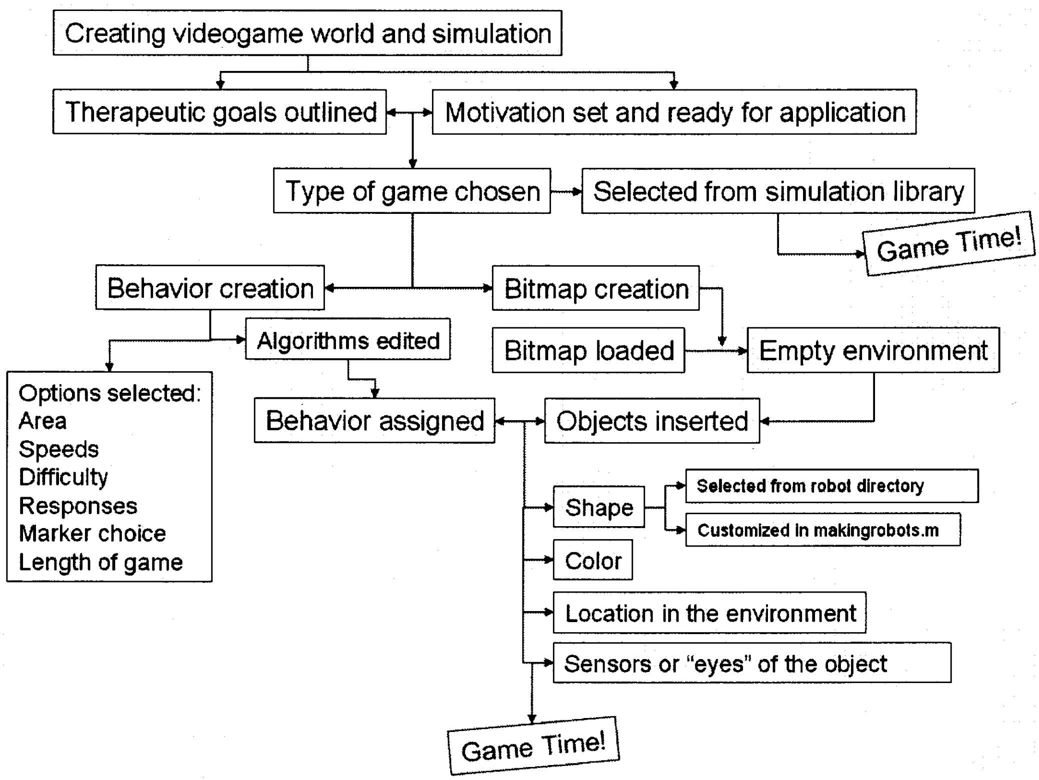

Figure 5.1 Flow chart of the platform usage.

To begin videogame development the goals of the therapy session are recognized. The player's interests are considered and the therapist's objectives are incorporated into the individualized game. Based on the therapy objectives, a game simulation can be opened, and played, or edited.

The process of creating customized interactions within a simulation and implementing new game ideas or situations is successful, as shown by the speed at which new games are completed. Undergraduate level students with minimal programming skills can take the platform toolbox files, listen to a 15 minute overview of the system, and give back a playable game within the half hour.

Students apply their creativity to the game making process based on the necessary, straightforward steps. A given task involving a pin ball game simulation with extremity representations as paddles is implemented as an example. The individual makes their own bitmap, compatible with the simulation environment size and format attributes in Windows Paint®. The bitmap is then imported into the Videogame toolbox initialization window with the menu option commands. New robots are then added by left click options and GUI selections for color, shape, and heading. Sensor assignment and alignment is also manipulated in the interface options, and in the algorithms that are written to fit the characteristics of the game environment.

The algorithms for the objects in the simulation are written rapidly by the student using the m file outline shown below and in figure 4.1.

```
function new = jouds(simrobot,matrix,step,vid)

%sensor reading, more entries added per sensor chosen in editor window
[dist,num] = readusonic(simrobot,'sensor_1',matrix);

%Behavior is inserted here:
%  -with loop operations based on the number of the robot that the sensor
%   is seeing or the distance the robot is from a particular robot (the
%   background is also a robot).
%  -makes use of the toolbox funtions, methods, and stored structure
%   information.

%inserted to prevent robots from stopping when they encounter other robots.
simrobot=clearcf(simrobot);
%delete history to keep from slowing down RAF
simrobot = delhist(simrobot);
%inserted in order to attach the algto the robots
new = simrobot;
```

Figure 5.2 Basic component outline for robot algorithmic behavior.

A basic understanding of Matlab loop operations is found to be necessary. In order to make a bouncing ball in the pin ball simulation, an algorithm is assigned which instructs quick changes in velocity if a hand representation is detected (crashed). When the wall is detected, a less drastic change in velocity results, in order to simulate a ball sliding down the obstacles, rather than bouncing off, as it would the hands. The need for rapid game development, including the time required to train a person with minimal programming knowledge on how to build a game, is achieved.

The creative new ideas regarding potential interactions of the robots in games and increased tasks and challenges are found to be unlimited upon further exploration of the platform and continued manipulation of the toolbox functions. These new game possibilities also require and implement an analysis of the success of the previous therapy session or game simulation. The following flow chart marks the important observations that need to be made upon session completion.

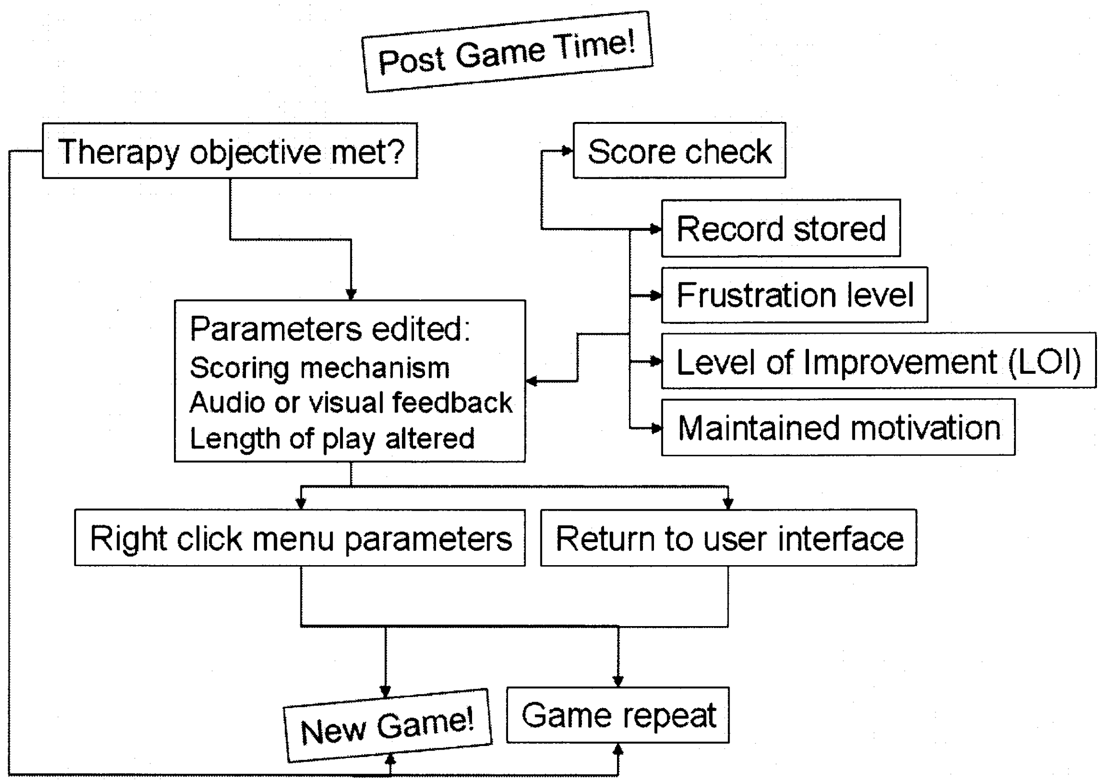

Figure 5.3 After a game has been completed there are considerations made regarding the next steps of the therapy program. The concepts for understanding how a game is adapted are shown.

The therapy analysis and documentation process was suggested by therapists and implemented. Games were successfully made based on the questions therapists ask and the most appealing therapeutic objectives they have. This implementation is required in order to further increase the benefits of the therapy session.

5.2 Specific and Individualized Benefit

Developing a customized therapy session has recognized challenges, and the following outline explains the process and reasons for customizing a particular therapy to improve motor control of a specific child.

First, the child's overall motor function is considered, along with their age, and interests:

A particular five year old girl, wearing her favorite color, red, is hemiplegic with cerebral palsy and extensive hypertonia. Her muscles are often stiff and her bimanual tasks are impaired. She has not lost the infantile tendency to extend both arms in what looks like an embrace, at any offset in motion. She loves computers and wants to write her own version of a car racing game. She does not have typical, CP induced hand preferences but has very limited fine motor control. Past therapies have been forceful and un-pleasurable for her.

The motor function analysis then leads to a game choice with customized parameters:

A bimanual task with two color markers, other than red are selected. These selections call algorithms for green and blue hand representations to two different robots in the bitmap. The shape of these hand representations can be found in the directory of robot coordinates. The color is initially assigned by a right click menu for appearance. In the button grouping for hands, shown in figure 5.4, the blue and green hand buttons are selected.

Both of her arms are in need of equal mobility training, so the entire screen is selected in the quadrant selection group. Having the entire screen active makes all the robots move with the same behavior and have the same response to her hand representations.

Five stars are inserted and the speed is set at a slow, five units per frame. The difficulty level is set at five also. This means that the distance at which the stars begin turning away from her hands is 50 units as opposed to a very easy 100 units or a very small reaction distance of five units. The speeds will not change when she approaches the stars and the size of the stars will not change either. These are parameters that can be changed after the initial simulation.

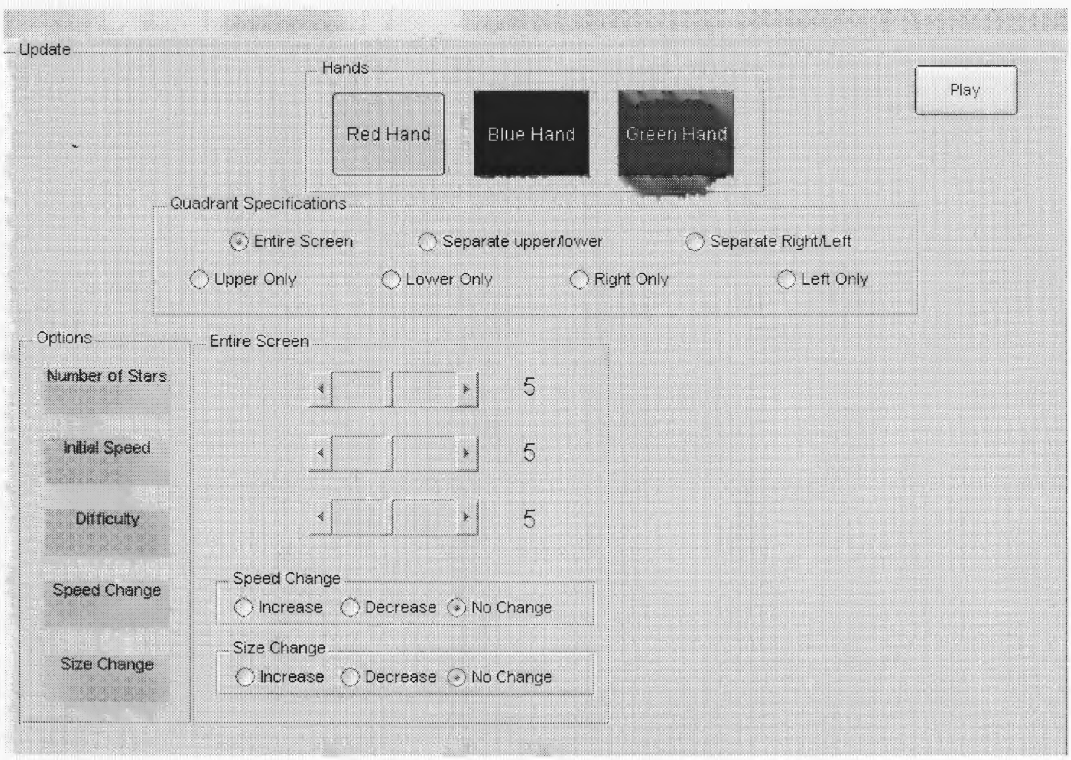

Figure 5.4 Here is the information selected that plays the mat file created upon selection of the options.

Upon application of these selections, the correct algorithms are chosen from the case functions, and the specific values for velocity and difficulty are globalized for use in the star algorithms.

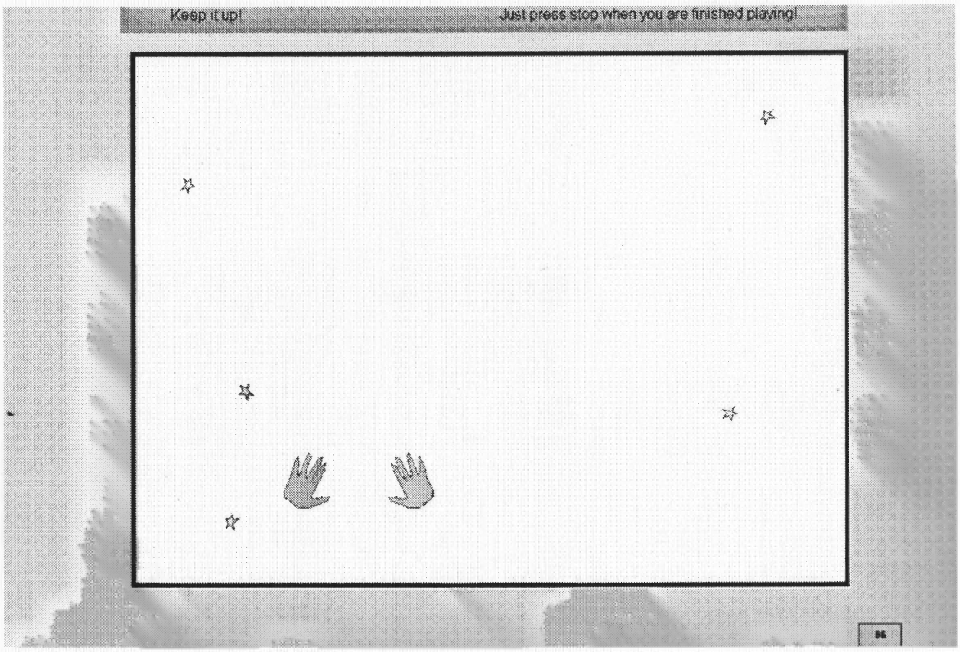

Figure 5.5 Here is the game initialized and at step 86. Each star is programmed to avoid the hands, while her objective is to catch as many stars as possible. The game encourages active and accurate reaching, as well as eye-hand coordination. Her therapeutic goals have defined the ease or difficulty with which the stars can be captured.

5.3 Overall Benefits

With the interactive and adaptable features of this VR videogame platform, repetition is easily achieved and temporary improvement in mobility may be translated to permanent motor learning that is the aim of many rehabilitation programs. Another major benefit over current VR systems is that this is a videogame platform that can always be altered to make more interactive games. The games made on this platform successfully encourage different arm movements, reaching stretches, and new learning skills. The system also discourages inappropriate motor tasks as only the targeted extremity can interact, not the whole body.

It is known that variable practice in rehabilitation is more effective. When the games are easily changeable and personalized and the system is essentially free, rehabilitation is more advantageous.

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