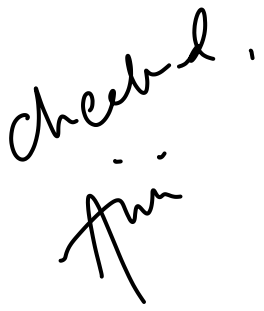
INTERACTIVE VIRTUAL REALITY GAME-BASED REHABILITATION FOR CEREBRAL PALSY CHILDREN USING KINECT

LAU TUCK SHENG



UNIVERSITI TEKNOLOGI MALAYSIA

INTERACTIVE VIRTUAL REALITY GAME-BASED REHABILITATION FOR CEREBRAL PALSY CHILDREN USING KINECT

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A project report submitted in fulfilment of the
requirements for the award of the degree of
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DEDICATION

This thesis is dedicated to my parents, who taught me that the education that we have gone through will help us face the difficulties in life and the lesson through that difficulty will always provide us a lesson to overcome future obstacles

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ABSTRACT

Cerebral Palsy (CP) is a disorder that impairs a person's ability to control their muscles due to damage to the growing brain. Rehabilitation may help reduce issues such as joint contractures and enhance limb range of motion and coordination if begun at a young age. Despite its well-established effectiveness, traditional motor training for children with cerebral palsy encounters several administrative challenges, such as a lack of therapists, lengthy waiting periods, geographic isolation, and difficulty in progress tracking. Furthermore, repeated forms of treatment for children with cerebral palsy without any active engagement from the children may make the therapy less successful owing to boredom experienced by the CP children. The objective of this research is to provide an interactive game-based virtual reality therapy for children with unilateral cerebral palsy (CP) to promote upper limb development in CP children. In this research, a relationship was formed with the Persatuan Cerebral Palsy Johor therapist committee to oversee the research. The therapist assisted in the selection of appropriate children with Cerebral Palsy (CP) and the age of 7 to 12 years old were chosen as the age of research. As for reference, a similar age group of children were chosen to provide understanding between the cerebral palsy children and a normal children. The children's both undergone similar one hour of VR rehabilitation to further understand the effect of the VR rehabilitation on their muscle's signals and their x, and z axis acceleration and angular velocity movement by attaching a surface electromyography and inertial momentum unit on their wrist. The result from the research shows that the game by VR rehabilitation for the cerebral palsy was able provide quantitively show data from the acceleration, angular velocity, and the muscle signals from the surface electromyography sensor. From this research, it shows that while using rehabilitation through virtual reality game, the muscles signals amplitude from the children suffering from upper body spastic was higher as compared to the normal children and the result from the two-sample t-test (Mean = 679.009, SD = 516.595, n = 1035) was lower than the normal children's movement (Mean = 684.578, SD=1.596, n =1035). This shows that the children undergoing the virtual rehabilitation has potential of improving their muscles signals through long terms effort while rehabilitating through VR. As for locomotion, the descriptive analysis shows the t one tail test shows that the greatest difference in the z-axis acceleration while the motion for the other x and y axis has a p value less than z-axis. This shows that the CP and normal children shares similar features acceleration at x and y axis and angular velocity similar for x, y and z axis, which shows that through long term rehabilitation, the locomotion movement may help to improve their movement similar with a normal children.

ABSTRAK

Cerebral Palsy (CP) adalah gangguan yang menjejaskan keupayaan seseorang mengawal otot akibat kerosakan pada otak yang sedang membesar. Pemulihan boleh membantu mengurangkan masalah seperti kontraktur sendi dan meningkatkan julat pergerakan dan koordinasi anggota jika dimulakan pada usia muda. Walaupun keberkesanannya yang mantap, latihan motor tradisional untuk kanak-kanak dengan cerebral palsy menghadapi beberapa cabaran pentadbiran, seperti kekurangan ahli terapi, tempoh menunggu yang panjang, pengasingan geografi dan kesukaran dalam pengesanan kemajuan. Tambahan pula, bentuk rawatan berulang untuk kanak-kanak dengan cerebral palsy tanpa penglibatan aktif daripada kanak-kanak mungkin menyebabkan terapi kurang berjaya kerana kebosanan yang dialami oleh kanak kanak CP. Objektif penyelidikan ini adalah untuk menyediakan terapi realiti maya berasaskan permainan interaktif untuk kanak-kanak dengan cerebral palsy (CP) unilateral untuk menggalakkan perkembangan anggota atas pada kanak-kanak CP. Dalam penyelidikan ini, hubungan telah dibentuk dengan jawatankuasa terapi Persatuan Cerebral Palsy Johor untuk menyelia penyelidikan. Pakar terapi membantu dalam pemilihan kanak-kanak yang sesuai dengan cerebral palsy (CP) dan umur 7 hingga 12 tahun dipilih sebagai umur penyelidikan. Sebagai rujukan, kumpulan umur kanak-kanak yang sama telah dipilih untuk memberi persefahaman antara kanak kanak cerebral palsy dan kanak-kanak normal. Kedua-dua kanak-kanak itu menjalani pemulihan VR selama satu jam yang sama untuk memahami lebih lanjut kesan pemulihan VR pada isyarat otot mereka dan pecutan paksi x, y, dan z serta pergerakan halaju sudut dengan memasang elektromiografi permukaan dan unit momentum inersia pada pergelangan tangan mereka. Hasil daripada penyelidikan menunjukkan bahawa permainan melalui pemulihan VR untuk cerebral palsy mampu memberikan data menunjukkan secara kuantitif daripada pecutan, halaju sudut dan isyarat otot daripada penderia elektromiografi permukaan. Daripada kajian ini, ia menunjukkan bahawa semasa menggunakan pemulihan melalui permainan realiti maya, amplitud isyarat otot daripada kanak-kanak yang mengalami spastik bahagian atas badan adalah lebih tinggi berbanding kanak-kanak normal dan hasil daripada ujian-t dua sampel (Min = 679.009, SD = 516.595, n = 1035) adalah lebih rendah daripada pergerakan kanak-kanak normal (Min = 684.578, SD=1.596, n =1035). Ini menunjukkan bahawa kanak-kanak yang menjalani pemulihan maya mempunyai potensi untuk meningkatkan isyarat otot mereka melalui usaha jangka panjang sambil memulihkan melalui VR. Bagi pergerakan, analisis deskriptif menunjukkan ujian t satu ekor menunjukkan perbezaan terbesar dalam pecutan paksi-z manakala gerakan untuk paksi x dan y yang lain mempunyai nilai p kurang daripada paksi-z. Ini menunjukkan bahawa CP dan kanak-kanak normal berkongsi pecutan ciri yang serupa pada paksi x dan y dan halaju sudut yang serupa untuk paksi x, y dan z, yang menunjukkan bahawa melalui pemulihan jangka panjang, pergerakan lokomotif boleh membantu meningkatkan pergerakan mereka sama dengan normal kanak-kanak

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LIST OF ABBREVIATIONS

CP	-	Cerebral Palsy
GMFCS	-	Gross Motor Function Categorization System
GMFM	-	The Gross Motor Function Measure
IMU	-	Inertial Momentum Unit
EMG-ACC	-	Electromyography Accuracy
ADL	-	Active Daily Life
VR	-	Virtual Reality
EMG	-	Electromyography
GBVR	-	Game Based Virtual Rehabilitation
SEMG	-	Surface Mount Electromyography
LMC	-	Leap Motion Controller
IR	-	Infrared
TD	-	Time Domain
RMS	-	Root Mean Squre
MAV	-	Mean Of Absolute Value
SDK	-	Software Development Kit
I2C	-	Inter-Integrated Circuit
SD	-	Standard Deviation

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Cerebral palsy (CP) is described as a developmental impairment characterized by restrictions in mobility, posture, and activities caused by non-developmental physical alterations followed by illnesses that arise in the brains of physically developing children (Kim *et al.,* 2012). Cerebral palsy is characterized by sluggish reflexes, floppiness or limb and trunk rigidity, aberrant posture, repetitive movement, erratic gait, or any combination of these symptoms. This circumstance provides the clinician with several diagnostic and therapy issues, ranging from mild with modest impairment to severe with many co-morbid illnesses. This condition makes everyday tasks harder, requiring the use of more physical power for any activity than normal persons.

As indicated in the Figure 1.1, The topographic categorization of CP is monoplegia, hemiplegia, diplegia and quadriplegia; monoplegia and triplegia are quite rare. There is a large overlap in the impacted locations. In a research study from India (Singhi *et al.,* 2002), diplegia is the commonest kind (30 percent - 40 percent), hemiplegia is 20 percent - 30 percent , and quadriplegia accounting for 10 percent - 15 percent . Patients experiencing cerebral palsy from hemiplegia or quadriplegia exhibit abnormalities of the upper limb, and face challenges in using their upper limbs frequently comparing with utilizing their lower limb.

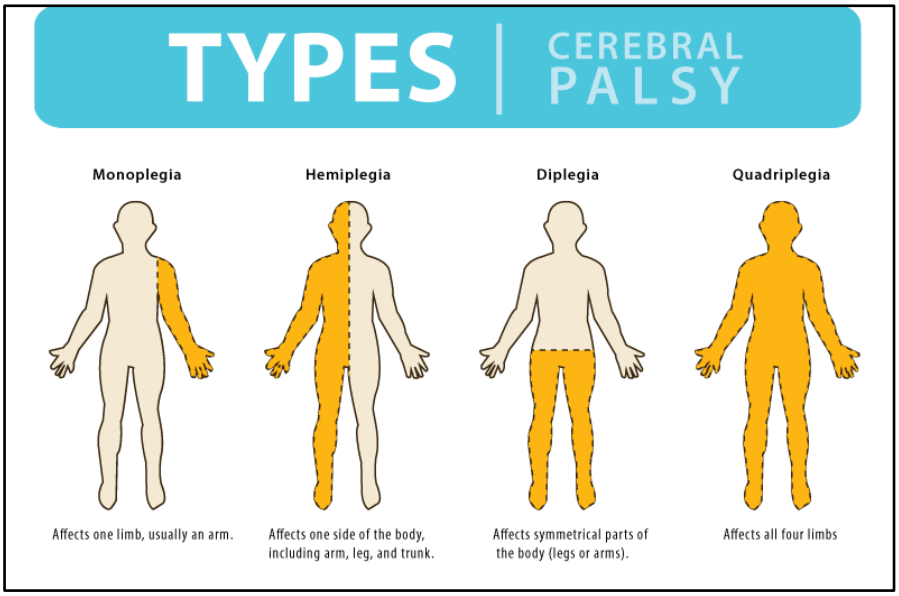

Figure 1.1 Types of Cerebral Palsy(ForkNeedlePen, 2013)

Failure to achieve motor system and other physiological changes in young children with CP-related spasticity begins around the age of one to two years and becomes more severe by the age of three. One notable study found that 66 percent of individuals with spastic diplegia and 50 percent of patients with any type of CP "outgrew" their symptoms by the age of 7. Older people suffering from different types of spastic illness will have normal muscle tightness, cramping, pain in the affected extremities, and general as well as fatigue. Older people suffering from different types of spastic illness will have normal muscle tightness, cramping, pain in the affected extremities, and general as well as fatigue.

In Malaysia, it is estimated that 5% of the 9.3 million population of Malaysia which is around 460,000 children are with disabilities from records of the Department of Social Welfare Malaysia(Department of Statistics Malaysia. Children Statistics, 2019). Within the 5% of the population there are 2766 children's are with special needs and only a mere 216 children's are registered are with CP. Judging from the estimated value of around 2 to 2.5 out of 1000 births in developed country, it is safe to assume that the actual value could be significantly higher(Ying *et al.*, 2021).The burden on family with CP proves that besides the economic burden of financing for the needs of a child with cerebral palsy which is around RM29, 710.76 per year, the primary caregivers are also negatively impact by causing sadness, feeling of overwhelming,

anxiety, depression, worry, low physical health, bad family functioning which in turn cause them to have low quality of life (QOL)(Whittingham *et al.*, 2013). cerebral palsy is a lifelong disease, therefore ongoing motor training is important to rectify incorrect posture and patterns to enhance functional performance, by undergoing effective rehabilitation.

This study will concentrate on the upper limb of CP, which is the most important place for a person to do basic daily functions. They will have difficulty holding or carrying goods, as well as learning how to do tasks that require fine motor coordination, such as writing or athletics. Thus, rehabilitation training for children with cerebral palsy must be prioritised since it has the greatest potential for resolving movement problems.

1.2 Problem Statement

Rehabilitation is an important element of the treatment of CP, and nearly all children with CP receive Rehabilitation therapy. The goals of rehabilitation include assisting the kid with CP in participating in activities and reducing the physical restrictions of the symptoms. Rehabilitation enables children with CP to reach their full potential for physical independence and fitness levels, so improving the children's and their families' quality of life by lessening the impact of their physical impairments. Movement disability in people with cerebral palsy (CP) is one of them, and it is often assessed using the gross motor function categorization system (GMFCS) and the gross motor function measure (GMFM).

Though rehabilitation is used widely and recommended by all members of health-care team, the effectiveness of rehabilitation is inconsistent(NICE Clinical Guidelines, 2012). The CP assessment is perform using visual analysis of abnormal patient movements or questionnaires such as the Ashworth Scale, Modified Ashworth Scale, and Tardieu Scale to quantify patient spasticity by assessing passive movement resistance levels. These clinical practise produce qualitative results that take a very long time to complete for someone knowledgeable with the measures(Sewell *et al.*, 2014). Besides, observation approach utilised to evaluate CP children's performance

and improvement yield qualitative data that is subjective and varies between therapists. Thus, it is critical to evaluate CP children's performance using quantitative analysis, which is more exact and accurate.

Rehabilitation technology can provide quantitative analysis because it is related with enhancing the volume and quality of training available to patients, with clear economic and health advantages. Strengthening exercises and motor learning involve intensive, long-term repetitive routines(Verschuren *et al.*, 2011), which in turn require motivation and dedication (Deci and Ryan, 2008). Additionally, younger children may find it challenging to follow direct instructions required for the therapy. Studies suggest motivation as one of the most influential personal characteristics that determine motor and functional outcomes in children with CP(Bartlett and Palisano, 2002).

Previously, rehabilitation technologies were mainly centred on robotic technology. Several robotic hand rehabilitation systems with multi-degree exoskeletons of freedom have been created, the majority of which require organic joints to be aligned with exoskeletons.

However, since they are not portable, most of these devices are often pricey and meant for in-clinic usage. Furthermore, since the actuators used in these robotic systems are less compliant than the joints themselves, they need specialist for each patient to ensure safety monitoring.

As a result, a virtual rehabilitation program was developed that may be used without the need of clinical settings. Researchers demonstrate that virtual therapy is as least as effective as conventional rehabilitation in restoring upper limb mobility and capacity to conduct everyday activities [17]. Therefore, virtual rehabilitation is more stimulating than standard therapy. Furthermore, it allows people to view objectively while still providing interactive elements in real time. Commercial video games have rapidly developed to the point where computer quality and play experience provide new prospects for healing. Gaming devices such as the Nintendo Wii and Microsoft Kinect have shifted from a passive to an active experience, requiring the user to move

in order to engage with the game [18, 19]. Vision-based rehabilitation is often carried out via optical and visual monitoring based on reflecting markers or cameras connected to the monitored devices.

The technique is thought to be very dependable and might be employed outside of clinical settings. However, due to incorrect camera setup or other moving objects in the acquiring region, the device is expensive, non-portable, susceptible to camera backdrop congestion, and is dependent on equipment located far from the target. In order to overcome the constraints of a vision-based system, a wireless sensor network has been devised. The sensors aroused the researcher's curiosity in using wearable technology to miniaturise rehabilitation equipment. As device downsizing has progressed, sensor and body area network technologies have prompted interest in wearable rehabilitation solutions. Upper limb training approaches and commercial goods have been developed for patients with stroke, spinal cord damage, multiple sclerosis, and cerebral palsy. Wireless sensing networks have recently emerged as an important research subject [20]. Various sensors, such as optical fibre sensors, resistance sensors, and inertial measurement units (IMUs), are used to extract quantitative information from motion signals.

The EMG-ACC upper limb rehabilitation training system was developed to gather quantitative measurements because they are inexpensive in cost, portable, and pleasant to wear. However, the rehabilitative training activity used does not correspond to ADL. Furthermore, the device can only detect muscular contraction and acceleration data. The system was unable to capture the degree of rotation of the upper limb, which is a crucial parameter in the execution of rehabilitation exercise. As a result, it is critical to present a system capable of collecting muscular contraction, acceleration, and angular velocity information from ADL-based rehabilitation training assignments. The signals will be statistically analysed in order to assess the training's effectiveness.

1.3 Project Goal

1.3.1 Project Objectives

The objectives of the project are:

(a) To develop a VR game development based on Unity using Kinect Controller that helps to engage sensory stimulation

(b) To design a locomotion sensor system that incorporated Electromyographic together along with approved rehabilitation procedure

(c) To analyse evidence on the effectiveness of virtual motor training by evaluating the VR rehabilitation EMG signal along with the IMU acceleration and angular velocity.

1.4 Scope

The scope of the project are:

(a) Only CP children aged seven to twelve years old with GMCS levels I and II will be chosen from Persatuan Cerebral Palsy Johor.

(b) CP children suffering from upper body spastic

(c) All childrens are required to perform the VR based rehabilitation tasks based on from Modified Barthel Index, which are squeeze ball, feeding and reaching an object for upper limb under the therapies consent

(d) Kinect Controller as a virtual reality controller to interact with game created with Unity, Myoware sEMG sensor for reading the electromyographic sensor, IMU for detecting the joints rotation.

1.5 Significant of the Project

In obtain a more precise assessment and quantitative measurements to assessment the CP children's progress and make the rehabilitation more interactive and fun, this project will designing a Game-Based Virtual Reality (GBVR) rehabilitation incorporating 3 technology namely Kinect sensor for Game-Based virtual movement, Inertial measuring units (IMU) for tracking joint movement and MyoWare for electromyographic. In order to align the project to the current state of the art the rehabilitation data, the tasks with the based on a Modified Barthel Index that is commonly used for activity for daily life. The data provide could provide a better insight on the effect of using virtual reality as a rehabilitation to replace traditional rehabilitation.

1.6 Organization of the Thesis

Chapter 1 provides an overview of CP and its categorization in Children's. This chapter also clearly states the project's background topic and the under-investigation problem. It also contains background information, issue statements, research aims and goals, and the scope of inquiry to be investigated.

Chapter 2 presents an overview of cerebral palsy, including the main forms of categorization used in prior studies. It also describes the theoretical underpinnings of the case study, which is the major focus of the research. As a critical information exchange in the context of the literature review activity, this provides a description of its specific goal as well as a large portion of the ideas or opinions on previous treatments relevant to the study topic. It also makes the option mandatory as part of the experimental design process.

Chapter 3 contribute to the main research methodological components. The section covers device configuration information such as hardware and illustrations of how the game-based virtual reality will work. This chapter will show the milestones that will be archived during each state.

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1. S. T. Ng, C. S. Lyn, L. T. Sheng, M. S. Bin Mohd Salman and K. X. Hong, "Remote Probing Solution with Augmented Reality," *2021 IEEE Industrial Electronics and Applications Conference (IEACon)*, 2021, pp. 31-34, doi: 10.1109/IEACon51066.2021.9654509.