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Development of Imitation Learning Through Physical Therapy Using a Humanoid Robot

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Abstract

Humanoids have increasingly become the focus of attention in robotic research, especially in rehabilitation robotics. In the past few years, the prevalence of Cerebral Palsy (CP) in the world population has remained unchanged. CP is one of the most common disorders affecting muscle control and coordination in children, resulting in movement disorders. There are assistive technologies that are used for increasing, maintaining or improving the functional abilities of CP children. However, there is still a lack of interventional; therapy which involves Social Assistive Robotics (SAR). Socially assistive technologies have great potential in education & learning for children, especially for children with disabilities. Problems faced by children with CP may not be confined to physical impairment but may in addition have impairments of cognition, visual, language and communication. Therefore, combining physical, speech and language and occupational therapy with cognitive and social development is very important. This paper aims to describe the architecture of using humanoid robot NAO as a tool to augment physical learning for CP children. This work is mainly based on qualitative study, which is aimed to analyze how the HRI impacts the motor gross function and attention. This paper will describe the aim, objectives, methodology, and experiment layout. Experiment with CP children will be done in the near future after obtaining ethical approval from UiTM Ethics Committee. The outcome of the study may exhibit positive utilization of the humanoid robot NAO as a new intervention tool to augment therapy for children with CP.

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Keywords: Human - robot interaction;cerebral palsy; humanoid robot; rehabilitation robotics

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1. Introduction

Cerebral palsy (CP) is a group of permanent disorders involving the development of movement and posture causing activity limitation that are attributed to non-progressive disturbance that occurred in the developing fetal or infant brain[1,2]. Types of CP can be classified into spastic, dyskinetic and mixed [3]. In the mid-1800s, Dr. William John Little Osler[4] and Dr. Sigmund Freud[5], a neurologists, pioneered the study of CP and knowledge regarding CP has been increasing since then. CP is the most common physical disabilities in childhood[6]. Over the last decade, an unchanged of the prevalence of CP in the world population has been noted. Generally, worldwide statistics show that approximately 2-4 in every 1000 children born today has CP[3,7].

Physical therapy addresses gross motor function and skills. Considered one of the mainstay therapies of CP, it is used to decrease spasticity, strengthen underlying muscles, and teach proper or functional motor patterns. Physiotherapist will also teach the family or caregivers how to help the child with CP to help themselves. Since most children are attracted to technology, robots can be used to elicit cooperation in physical rehabilitation. In this paper, it will describe the use of a humanoid robot as an augmented tool in the physical therapy of CP children. For this study, 4 modules will be programmed to generate the robot behavior in the interaction session.

1.1. Human Robot Interaction(HRI) for CP children

Human robot interaction (HRI) has widened their wing to be applied in rehabilitation. Interest in social robots is growing as one of the upcoming field of next generation robots especially as assistive tools in rehabilitation[2]. It is believed that HRI promises better experience for CP children to learn motor skills[8].

Previous studies involving CP children investigated robotic exoskeletons and electrically powered wheelchair [9] to replace function. In previous years, there is still lacking of intervention therapy which involves Social Assistive Robotics (SAR). SAR is one of the robotic technologies that assist user primarily through social rather than physical interaction [10]. For example, previous study from [11] has introducing Kindergarten Assistive Robotics (KAR) as a tool for learning development for normal children in preschool education. SAR has increase children's motivation and communication during the interaction.

Play has been successfully introduced into physical therapy and rehabilitation of children with disabilities [12,13]. Thus, SAR is suggested to move to be applied for CP children. One of the study involve SAR is Robotics Agent Coacher for CP motor Function (RAC CP FUN)[14] which is designed to improve their motor function and activities of daily living. Besides that, study from [15]which using a mobile robot named "Neptune" and [12] using a toy robot named "Cosmobot" results that robot can become a social mediator for learning. While study from [16] and [17] used Lego Mindstorms robots [18] for CP children's play activities and resulted that the children reacted positively toward the robots where some children increased their attention span, and keep engaged while they used the robots. However, most explored robotic systems before are mainly in the form of toys, not in humanoid form. Thus, this study proposed to use a humanoid robot as adjunct in physical therapy session with CP children. It has good potentials to be used as a therapeutic tool because the movement of the robot can be controlled and reprogrammed to suite the children's ability. The robot may have the potential to influence the physical therapy imitation learning, helping the child to be more responsive and kept engagement during the therapy session.

1.2. Motivation

Conventional physical therapy conducted by humans will have some issues especially in imitation learning. Therapists have the tendency to get tired, hence resulting with less accuracy. From a study done by [10], they had observed that the children responded positively towards the robot. Some children showed increased attention duration, spontaneity and frequency of their smiles vocalizations and verbalization while using robots[11] .With the potential to increase children's motivation, robots will be able to help the children to be more active and motivated during the learning sessions. Two objectives of the study are to develop a physical therapy algorithm for physical therapy imitation learning between a robot and CP children, through interactive motor exercise and to develop and implement the modules for human robot interaction.

1.3. Humanoid robot

Humanoid robot that is physically shaped like an actual human can produce controlled and repeatable exercise. This is more precise compared to conventional therapy involving therapist. Thus, imitation learning quality can be improved. Therapy for CP have general goals, which are to help the children to grow up and develop to their maximum capabilities so that they may succeed as contributing members of society. The robot NAO, an autonomous and programmable humanoid robot developed by a French company, Aldebaran Robotic will be used in this study. Humanoid robot NAO has potential to be used as a tool in rehabilitation therapy for CP children. Moreover, humanoid robot NAO size is like a 2 year old toddler and naturally can attract children's attention. For this study, NAO will execute modules which will focus on repetitive motion training to improve lower motor gross function of CP children.

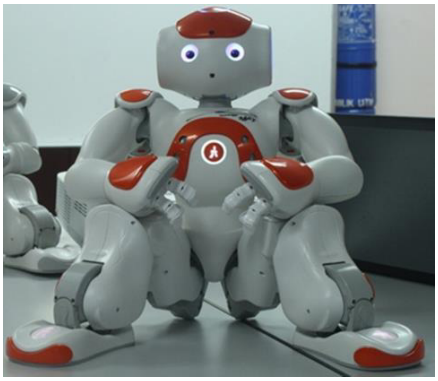

Fig. 1. Humanoid robot NAO

2. Methodology

2.1. Subject population

The intended target group is children diagnosed with CP GMFCS level I –IV, with age range between 5-14 years old. Other inclusion criteria included no hearing and vision deficit, and able to follow simple command in English. Parent or caregivers of the selected child will be well informed and consent their child to participate get. They will perform a 20 minutes session once a week for 8 weeks involving interaction with humanoid robot. The experiment protocol is waiting to be approved by UiTM Ethics Committee.

2.2. Initial assessment

Figure 2 below shows the experimental flowchart which acts as a guideline in this study. For the initial assessment, each CP child who has been selected will undergo Gross Motor Functional Classification System (GMFCS), Intelligent Quotient (IQ) Test, and Time Up and Go (TUG) test and Trial Making Test as well. All of the test will be conducted by therapist and/or clinician. Gross Motor Functional Measurement (GMFM) is a clinical tool designed to assess change in gross motor function in children with CP. Researchers will also refer to GMFM while developing modules for the HRI stage.

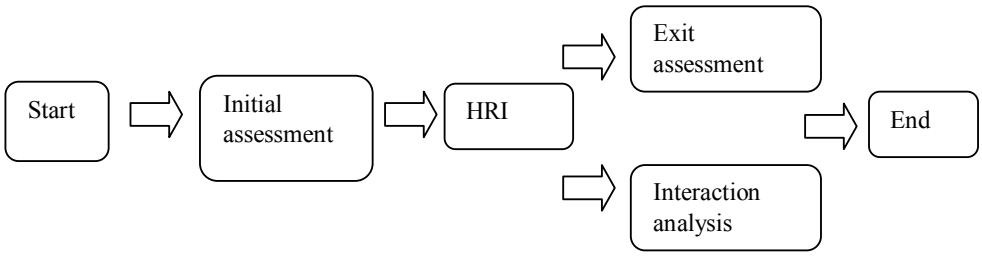

Fig. 2. Experimental flowchart

2.3. HRI stage

At this stage, the interaction between a child and humanoid robot NAO will be supervised by a Physiotherapist (PT) and/or clinician. They will observe type of interaction shown by the children. They will also be in charge of the flow of modules as shown in the protocol flow. Each Robotic session lasts for 20 minutes per week. The session will be repeated once a week for 8 weeks.

2.4. Exit assessment

After HRI phase has been completed, the children will undergo an exit assessment. Again, the children need to complete GMFM, TUG and Trial Making Test conducted by physiotherapy and/or clinician. Results of the final evaluation will be used as a comparison between pre-and post-program interaction between robots and CP children.

2.5. Exit assessment Interaction analysis

The recorded video will be analyzed after all the study phase completes. Comparison between Initial assessment and Exit assessment will be done to evaluate on the effectiveness of module, the capability of the children to complete the module and the effectiveness of the goal and outcome to the child after therapy module with presence of humanoid robot NAO.

2.6. Experimental layout

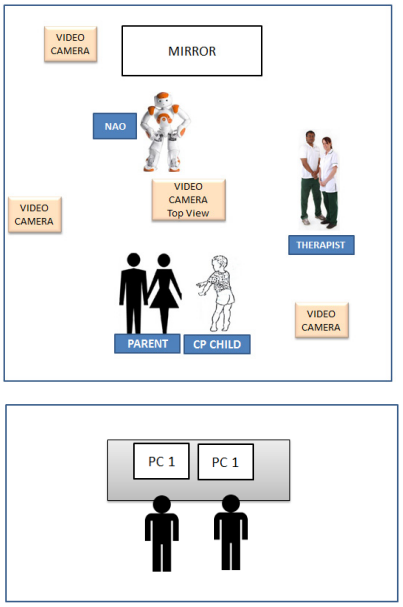

Fig. 3. Experiment layout

2.7. Modules

Four CP learning modules will be executed by humanoid robot NAO in this study. GMFM will be referred while developing modules for this study which are designed to focus on lower extremity function. Learning modules for CP children are approached through play imitation with focus on improving physical and cognitive function.

The four modules are:

- Module 1: Static Interaction
- Module 2: Sitting and Standing
- Module 3: Balancing
- Module 4: Ball Kicking

2.7.1. Module 1

In this module, the robot is in a static sitting position and will be placed on the table facing towards the child. This module aims to observe the child's reaction to the presence of a robot.

In this module, humanoid robot NAO will do two way communications. The content of the module 1 as per below:

- NAO greeting the child
- NAO self-introduction

The aim of this module is for NAO robot to introduce itself and to encourage the children to continue to the next module. This module lasts for 2 minutes where humanoid robot NAO will indicate the end of session.

2.7.2. Module 2

The aim of this module 2 is to improve lower extremity function, truncal balance and coordination (stand-up and sit-down).Initially, humanoid robot NAO is facing the child, both in sitting position. The humanoid robot NAO asks the child to imitate next movement. NAO shall start to stand up from sitting position and maintain for 10sec. After that, NAO will return to sitting position. Then, humanoid robot NAO ask the child to mimic the motions that NAO makes. This movement will repeat for 5 minutes. NAO will keep motivate the child to complete the module. Humanoid robot NAO will indicate the end of session.

2.7.3. Module 3

The aim of module 3 is to improve balancing ability .This module involves humanoid robot NAO initially at sitting position. NAO shall greeting the child and ready to stand up. in at standing position for 30 seconds, humanoid robot NAO will start to do movement as follow: Lift Left foot for 10 second, Stand for 10 second, Lift Right foot for 10 second. The CP children need to imitate the movement simultaneously with the humanoid robot NAO. NAO will keep motivate the child to complete the module. This module lasts for 5 minutes and the robot will indicate the end of session.

2.7.4. Module 4

The aim of module 4 is to improve lower extremity function through ball-kicking movement. In the fourth module, the humanoid robot NAO is initially at sitting position. NAO will ask the child to stand up together with him. At the same time, physiotherapist (PT) and/or clinician will put a ball in front of the child. Then, humanoid robot NAO will kick a ball with right feet and ask CP children to imitate the robot. After that the step repeated with left leg. NAO will keep motivate the child to complete the module. Physiotherapist (PT) and/or clinician will help to conduct this module. This module lasts for 5 minutes. The Physiotherapist (PT) and/or clinician will indicate the end of session.

3. Discussion

Each stage in the flow of protocols are important to act as guidance for researcher to make Each stage in the flow of protocols are important to act as guidance for researcher to make preparation, especially regarding the timeline or program duration, the intensity of the HRI and also the proper setting involved to carry out the program. Setting up involves decision regarding where the robot and children will be placed, the involvement of parents and clinician and researchers during the HRI. Some of the benefits of the HRI are the; it is non-threatening and playful, motivating children to do exercise imitation learning. In order to keep CP children keep engaged during the interaction, modules will be design and tailored to the abilities of the children. The main expected outcome from this HRI approach is to improve the quality of life of CP children.

4. Conclusion

As for conclusion, robot based intervention based on human robot interaction approach has great potential to optimize and improve therapy program for CP children. It can combine all criteria of conventional therapy program in one customize therapeutic tool of humanoid robot system. Furthermore, robot is suitable as social partner for children and it always creates interest to them. Research on HRI and humanoid robot in therapy of children with CP is still new in Malaysia. It is anticipated that the outcome of this research will contribute to future development of robotic training tools based on HRI platform tailored with individual needs of CP community, and for further exploration on rehabilitation and therapy robotics that will benefit many people not only in Malaysia, but also abroad.

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