Communication between Two Humans during Cooperative Motion in a Task of Carrying an Object

Doctoral Dissertation

MARCH 2010

Submitted in partial fulfillment of the requirement for

Doctor of Philosophy Degree

In Mechanical Engineering

By

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ACKNOWLEDGMENT

In name of Allah the most compassionate and the most merciful. The completion of this study is only made possible by the assistance from many individuals and institutions.

I want to express my special and profound gratitude to my direct academic advisor, Professor Ryojun Ikeura, who has always been an excellent supervisor. Through his wise counsel, continuing support, assistance and guidance have encouraged me to complete this study. Just because of him, I made progress in different stages of this research work, which finally enabled me to complete my PhD courses. I would like to give my sincere gratefulness and honor to him.

And also, a special appreciation is owned to Professor Hayakawa Soichiro and Mr. Hideki Sawai for advice, assistance and constructive comments in setting up the experiment setting and other tips.

Secondly, I am especially grateful to my sponsors, the Japanese Government, the Ministry of Education, Culture, Sports, Science and Technology (MONBUKAGAKUSHO), and my employer, University Malaysia Perlis (UNIMAP), which have permitted my post-graduate study at Mie University, Japan.

Especially, thanks to my best friend Mr. Zunaidi Ibrahim, from Mechatronics Laboratory, Faculty of Engineering, Mie University for his helping and advises about graduate study in Japan. Special thanks to Mr. Kazunori Ito and Yuichiro Handa, Takemi Yano and Ahmad Faizal Salleh for their direct support of the experiments. And also, special thanks go to all the members in the Mechatronics Laboratory, Faculty of Engineering, Mie University for their help and co-operation during the whole tenure.

Finally, I am largely indebted to my family for their perseverance support, patience, and understanding, especially my dear wife; Norsikah Aziz, my children; Muhammad Aliff Irfan, Nur Adriana Husna, and Muhammad Imran Danial, who gave understanding, compassion, loyalty and love among others. My wife made major contribution by her encouragement and supports during this study. I express my deepest sense of gratitude to my mother Mrs. Sofiah Ahmad and my father Mr. Abu Bakar Yassin for their continuous encouragement and blessings during my study and all my time in Japan.

Above all, I thank to Allah Subhannahu wa taala for giving me a blessed life.

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CONTENTS

CHAPTER 1 INTRODUCTION

1.1 Background

1.1.1 The origin of robot term

The term robot was initially bring to the world by Czech writer Karel Čapek when he wrote a play named *R.U.R. (Rossum's Universal Robots)* in 1920[1] . The Play tells about a story of a factory that made android or humanoid robot where this humanoid can think for themselves and serve humans.

But Karel Čapek did not come to the name robot himself. Karel Čapek credited his brother, who is a painter and writer Josef Čapek as the person who originally coined the word robot. Josef Čapek suggested the word "roboti". Roboti or robota literately means work or labor in Czech language. There are many interpretation as what kind of machine qualify as a robot but the general agreements are that robot will respond to human input and request to move and operates the robot mechanical limb, sensing their environment and working to mimic the human behavior. The International Organization for Standardization gives a definition of robot in ISO 8373: "an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications." [2].

1.1.2 The history of robot

Men throughout the start of known and recorded history always had a fascination with robot that they can invent and mimic human or animals. The oldest known record is in the 4th century BC, where the Greek mathematician Archytas of Tarentum designed a mechanical steam-operated bird. In 10 AD Heron of Alexandria created machines powered by air pressure, steam and water [3]. In 1088, Su Song from China built clock towers that have mechanical figurines informing the hours by chiming [4]. Al-Jazari (1136–1206), a Muslim inventor during the Artuqid dynasty, designed the first programmable humanoid robots. These humanoid robot robots appeared as four musicians that operated percussion instruments. The robotic mechanism was design so that programmable cam of the robot would tap into levers that plays percussion instruments which is quite similar in idea on today’s music box where the robot could be made to play different rhythm and patterns [5].

Fig.1.1Tea-serving karakuri, 19th century. Tokyo National Science Museum.

In 1738 and 1739, Jacques de Vaucanson exhibited several life-sized automatons: a flute player, a pipe player and a duck [6] .Complex mechanical toys and animals built in Japan in the 1700s were described in the *Karakuri zui* (*Illustrated Machinery*, 1796). The Japanese craftsman Hisashige Tanaka (1799–1881), known as "Japan's Edison" or "Karakuri Giemon", created an array of extremely complex mechanical toys, some of which served tea, fired arrows drawn from a quiver, and even painted a Japanese *kanji* character [7]. In 1926, Westinghouse Electric Corporation created Televox, the first robot put to useful work. In the 1930s, they created a humanoid robot known as Elektro for exhibition purposes, including the 1939 and 1940 World's Fairs [8-9]. In 1928, Japan's first robot, Gakutensoku, was designed and constructed by biologist Makoto Nishimura.

The first electronic autonomous robots were created by William Grey Walter of the Burden Neurological Institute at Bristol, England in 1948 and 1949. They were named *Elmer* and *Elsie*. These robots could sense light and contact with external objects, and use these stimuli to navigate [10].

The first fully autonomous robot which is digitally operated and programmable robot is known as the Unimate. This robot was designed in 1961 to lift hot pieces of metal from a die casting machine and stack them [11].

Today, commercial and industrial robots are in widespread use performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs which are too dirty, dangerous or dull to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, transport, earth and space exploration, surgery, weaponry, laboratory research, and mass production of consumer and industrial goods [12] .

1.1.3 Characteristic of robot

The are many interpretation of robot characteristic [13] most agree that typical robot will have several, or possibly all, of the following characteristics; a modern robot is an electric operated entity that when programmed by a number of programming languages possess a capability to interpret the requested input, think what to do, interact with a physical object or respond to various stimuli such as light and sound and do a specific task. This is different with pure mechanical machine such as car engine, electric saw that have no feedback capability to think, analyze, respond and adapt to the working environment. To guide the robot working rules with human the famous science-fiction author Isaac Asimov suggested in his short stories [14] in 1940s the three principles to guide the behavior of robots which mentioned that;

1. Robots must never harm human beings or, through inaction, allow a human being to come to harm.
2. Robots must follow instructions from humans without violating rule 1.
3. Robots must protect themselves without violating the other rules.

1.2 The motivation of our research-The need for a human helper

Since time immemorial the younger generation of any community ideally is supposed to take care of the aging generation where both are supposed to live in harmony in each other company. Unfortunately the current economic trend among others are causing the shifting equilibrium where the percentage in young generation is reducing steadily where in 2006 the birth rate was 8.7 percent which is lowest in 56years. On the other hand healthy lifestyles coupled with new breakthrough in science and medicines has increases the average life expectancy where in 2007 life expectancy at birth was 85.99 years for women and 79.19 years for men. As a result the ratio of dependent population (the sum of the elderly and younger age population divided by the working-age population) compared to working population is 53.9 percent [15]. This phenomenon, the possible reduction of health care workforce, will affect the life style quality of the aged and those who required constant observation in order to carry on with their lives. To lessen this impact, more and more robotic based helper is introduced to the health industries. A study forecasting robotic demand shows that 400 percent increase from 2005 where the industries spent 292 million USD to forecast value 1.2 billion USD in 2010 for robots that have relation in health and welfare sectors making it's the largest demand in non-manufacturing industry field [16]. To address this issue, we see a need to design robots that have the humanlike capability to interact with humans in order to gain the human trust and comfort with its smooth movement.

This development for robotic system will be concentrating on tending disable or bedridden for their everyday chores as shown in fig.1.2 and fig 1.3, assisting human welfare workers and others. In this human-robotic interaction, a human will take initial step of leading the task and the robot are required to assist the human movement. In this field, the robots are required to work with human operators to handle human patient therefore this robotic system should be designed with consideration of human operator and the intended human patient together with control accuracy of the robotic system to achieve optimum natural cooperative task with all human participants.

Fig.1.2 Welfare robot

Fig.1.3 Robot in assisting human in everyday chores

1.3 Human cooperative robot

Human cooperative robot is a robot designed with a sole purpose to help human to complete a task as an example shown in fig.1.5. In order to meet this requirement, impedance control robot was used to construct human machine systems [17]. The robot and human impedance was designed to ensure system stability and maneuverability. Ikeura et al. proposed a variable impedance control method that switches the robot's impedance properties during task. They studied the human impedance by measuring the cooperative task by two humans and proposed to improve the system by installing the human impedance into the impedance controlled robot [18]. Rahman et al. had conducted studies regarding the impedance characteristic of human arm for developing robots that cooperate with human Single Degree Of Freedom environment [19-20]. These designs concentrate toward robot impedance value but more studies are needed to know how human behaves or react during a cooperative task especially the relationship between operational feeling and human manipulability during task. Kidd pointed out that as human skill is always required in robotic system and the robotic technology should be used to support and enhance the skill of human. Furthermore Kidd mentioned that human centered design was not being actively pursued and suggested that human centered design of human-robot interaction need to consider issues such as cooperative task between human and robots [21]. There are several papers that deal with human robot cooperative task such as [22] where hand shaped force interface that enable communication between human and robot via intentional force for human cooperative mobile robot. Hayashibara et al worked on assist system where they studied the human cooperative behavior in vertical direction. In the experiment, the leader and follower are required to move the object horizontally to target area as quickly as possible but keep the object posture horizontal. In this experiment the slaves were required to close their eyes. One of the interesting results of this experiment is that when the object is fixed with rotational handle they could not complete the task because the subject cannot keep the object's posture horizontal. They concluded that to complete the task the follower needs the information of the object's posture. We also noticed that Takubo et al. successfully manage to move a long object in vertical human- robot cooperative task to intended position using only using only translational force [23].

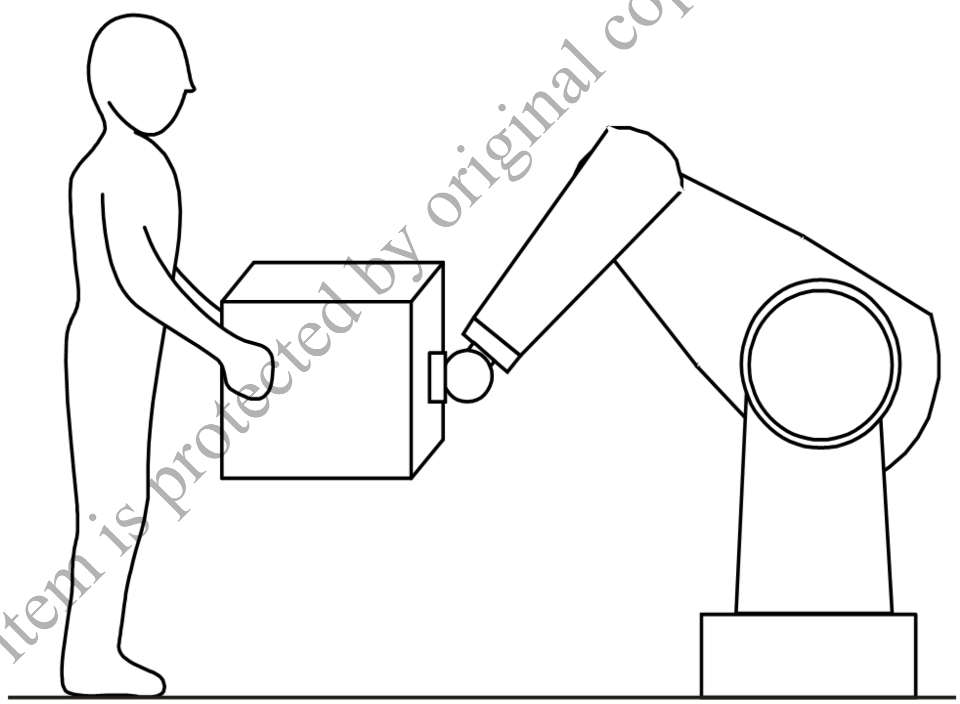

Fig.1.5 Human Cooperative robot

1.4 Research purpose-The need to understand how two human communicate to do cooperative task.

To enable robots to perform in such capacity, there is a need to have a control system that enable robot to behave in human like manner in term of movement smoothness to instill trust and enable human to accept the robot task sharing as natural as possible.

Therefore in the first place understanding human-to-human communication is important in designing robots for interaction with humans. When two people share cooperative task they presumably communicates through their human senses, the scientifically includes vision, somatic (touch), and hearing sense. In order to analyze human characteristic in cooperative task, we need to understand how humans interpret information and relayed during cooperative task between human.

Since our intended target for human cooperative robot is fragile and less than average human strength, it is very important to find out how to design robots that will work with human with optimum smooth characteristic. When two humans interact with each other for cooperative task such as lifting an object as shown in fig.1.6, there will always be a first person (leader) who starts to lift the object and the second person (follower) who will support and follow the initiator to lift up the object. If the follower lift the object too slow or too fast or if the follower did not even know the object is being lifted, than the cooperative task will not be good and even the object can fall on the ground.   We found out in order to design cooperative robot with humanlike movement capability, we need to determine first how human cooperate with another human during that cooperative task. We want to know during this cooperative process how the follower can manage to move the object smoothly, moreover how leader and follower react to each other and synergized both of their trajectory paths for optimum cooperative task. Then we can apply that characteristic for algorithm design and system control to design a robot that cooperates with human.

The purpose of this paper is to analyze the characteristic of cooperative task between two humans and to the next phase of the research is to implement the characteristic into a working robot. We propose a method to study how two humans communicate and use this communication method, either explicit or implicit, in order to achieve maximum smoothness with each other during cooperative task.

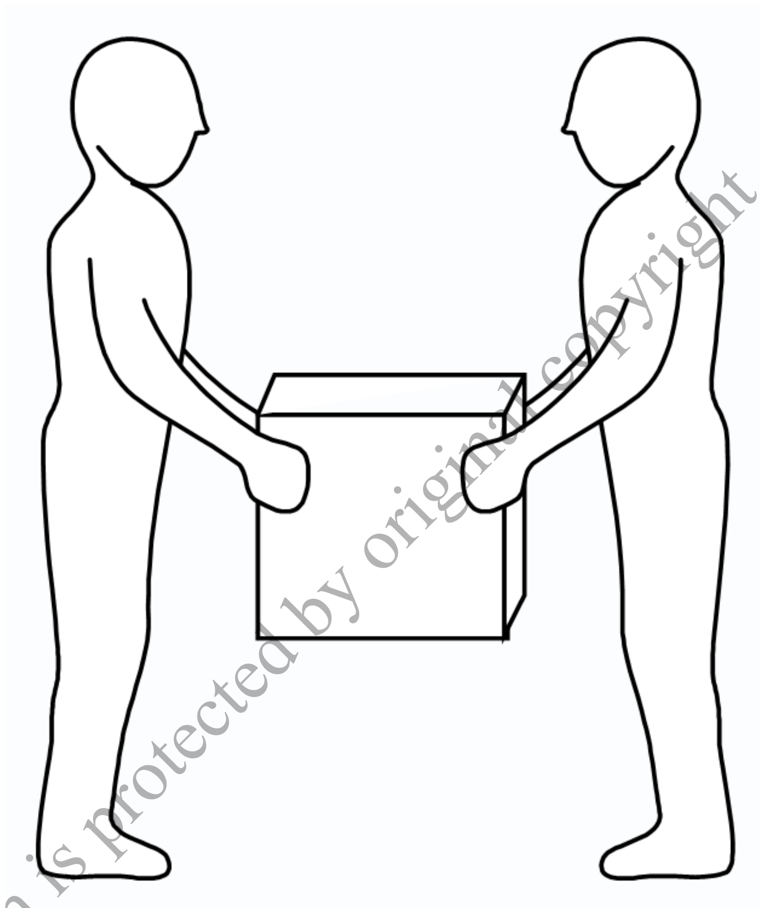

Fig.1.6 Human-human cooperative task

CHAPTER 2 HUMAN CHARACTERISTIC

2.1 Understanding human working system: Human and senses

In order to analyze human characteristic in cooperative task, we need to understand how humans interpret information and relayed during cooperative task between human. Understanding human-human cooperation is important in designing robot that interacts with human. Kyle reed [24] explored the experiment where humans use a significant channel of dyads communication through forces and motion to cooperate between each other. He utilized Fitts Law which observes the performance time; $t=a+b\ \log_2(D/S)$, for a person to move a distance of D, to a target of size S. (where a, b are constant). This performance time varies linearly with index of difficulty, which means that it takes longer time to move a large distance and small target size. The experiment subjects both open their eyes and can see a common target .The above experiments showed that cooperative task obeyed Fitts law but did not specifically mention how the information are conveyed through physical movement.

Hayashibara [25] worked on assist system where they studied the human cooperative behavior in vertical direction. In the experiment, the leader and follower are required to move the object (which is almost similar to our object) horizontally to target area as quickly as possible but keep the object posture horizontal. In this experiment the followers were required to close their eyes. One of the interesting results of this experiment is that when the object is fixed with rotational handle they could not complete the task because the subject cannot keep the object's posture horizontal. They concluded that to complete the task the follower needs the information of the object's posture.

Laming [26] concluded that simple reaction times averaged 220msec. Miller and Low [27] determined that the time for motor preparation (e.g., tensing forearm muscle) and motor response (in our experiment, lifting the object) was the same in all three types of reaction time which is simple reaction time, recognition reaction time and choice reaction time .

We can apply this into our experiment where the followers are blinded and will require recognition time to decided in which direction to follow the leader direction.

The original question is how the information is utilized for cooperative task. From above research we can suggest that for cooperative task process, we can safely say that human utilizes sense of vision and touch.

In our case however, the blinded follower will start to move based only on stimuli exerted from master and the follower's mechanoreceptor [28] will transmit the massage through brain's cerebellum-somatic nervous system. Mechanoreceptor is a human sensory receptor that's responds to mechanical pressure or distortion. In the human hand there is different kind of cutatenous sensors where the most sensitive is located in the index finger while the less sensitive is located at the palm.

Then the follower cerebellum will send information to motor cortex, which makes his hand, moved in response. Also the follower cerebellum will send signal to spinocerebellar tract that will provides feedback on the position of the body in space. This process is call proprioception. Proprioception is a sense that provides feedback solely on the status of the body internally. It's like kicking a ball where we just look at the ball without needing to look at our feet that are kicking the ball. In our case, it is like moving the object up and down without looking at that object.

2.2 Human muscle system

In human anatomy, the upper limb (also upper extremity) is the region of the shoulder to the fingertips. The upper limb includes the shoulder, arm (upper arm, elbow and forearm), wrist and hand. Among the above structures of the upper limb, in this section, the author only introduces the human arm shown in Fig.2.1. Fig.2.2 is the simplified image of the human arm.

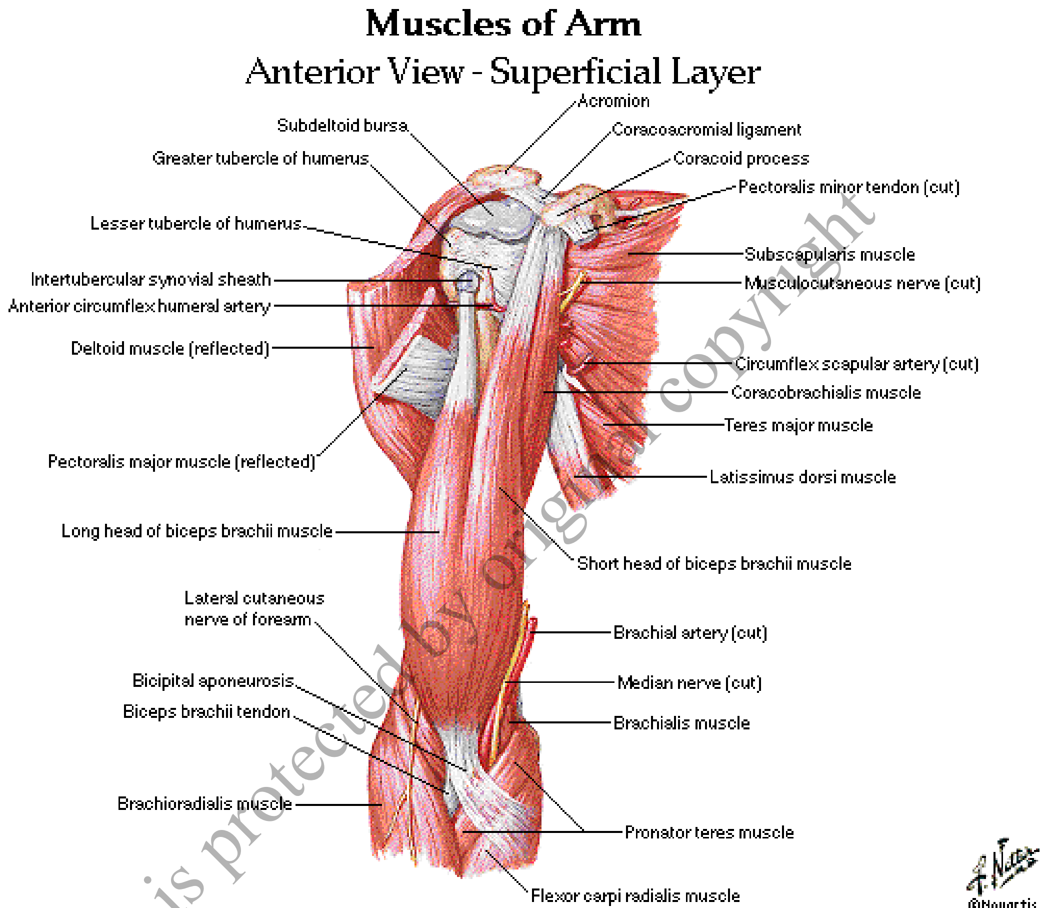

Fig. 2.1 Human arm musculoskeletal system.