UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MAXIMUM TORQUE ESTIMATION TECHNIQUE OF THREE LINK SYSTEM FOR SIT TO STAND MOTION

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MAXIMUM TORQUE ESTIMATION TECHNIQUE OF THREE LINK SYSTEM FOR SIT TO STAND MOTION

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DECLARATION

I declare that this thesis entitled “Maximum Torque Estimation Technique of Three Link System for Sit to Stand Motion” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion, this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

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Supervisor Name	:	Assoc. Prof Dr Muhammad Fahmi bin Miskon
Date	:	………………………………………………...

DEDICATION

To my beloved wife and my family

ABSTRACT

In Humanoid robotics field, capability to perform any task that imitates human movement has been the major research focus. Sit to stand (STS) is a very challenging motion for any humanoid robotic system. In the field of rehabilitation, it is difficult for the physiotherapist technician to readjust prosthetic leg to fit all the patient without proper knowledge and not all of them has the basic knowledge involving robotic system. Thus from several model of STS including telescopic inverted pendulum, single-link, two-link and three-link (3L), we choose to emphasize more on 3L since it is having a similar segment with human body and it fit most of the current prosthetic leg in rehabilitation centre. Current studies involving torque analysis was using a dynamic model, which is complicated and requires high computational resource to compute. Hence, the purpose of this thesis is to study the effect of mass and length's link changes to each joint torque and much simpler equation to estimate the torque needed in short time is proposed. Simulation model were run and torque information were collected. In order to validate the equation, experiments were carried out with three-link model. Having an error with ± 0.1% proof that the results shows that there is a possibility to estimate maximum torque needed by each link with equation derive from both simulation and experiment .

ABSTRAK

Dalam bidang kajian robotik humanoid, keupayaan untuk melaksanakan pelbagai tugas yang dijalankan oleh manusia merupakan satu fokus utama. Duduk-berdiri (STS) adalah satu pergerakan yang mencabar bagi sistem robot humanoid. Dalam proses pemulihan pesakit yang kehilangan upaya,seorang fisioterapis yang tidak mempunyai asas ilmu robotik agak sukar untuk melaras keupayaan motor pada kaki palsu dan hampir kesemuanya tidak mempunyai asas tersebut dan menyukarkan lagi proses pemulihan. Maka daripada beberapa model pergerakan duduk berdiri (STS) termasuk teleskopik bandul terbalik (TIP), satu-sambungan, dua-sambungan dan tiga sambungan (3L) kami memutuskan untuk menumpukan kepada 3L kerana ciri-ciri persamaan yang hampir dengan tubuh badan manusia dan kebanyakan kaki palsu hanya tertumpu kepada bahagian bawah abdomen pesakit. Kajian masa kini menggunakan 3L, melibatkan pergerakan dinamik dan perkiraan yang kompleks. Maka, tujuan thesis ini adalah untuk mengkaji kesan berat dan panjang keatas kuasa motor yang terlibat dan di penghujung kajian, persamaan matematik yang lebih mudah untuk menggangarkan daya kuasa maksima yang diperlukan motor dapat dicadangkan. Simulasi dijalankan terlebih dahulu dan data yang terbabit dikumpul. Untuk mengesahkan model ini, eksperimen menggunakan 3L model di laksanakan. Dengan ralat ± 0.1% *keputusan menunjukkan, kita boleh menganggarkan nilai maksima daya yang diperlukan oleh setiap sambungan melalui persamaan yang terhasil di akhir eksperimen dan simulasi.*

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LIST OF ABBREVIATIONS

3L	-	Three Link
TIP	-	Telescopic Inverted pendulum
STS	-	Sit to stand
HAT	-	Head arm torso
CoM	-	Centre of Mass
WB	-	Whole body
COP	-	Centre of pressure
θ_f	-	Theta final
τ_{hp1sim}	-	Torque hip phase 1 simulation
τ_{hp2sim}	-	Torque hip phase 2 simulation
τ_{kp2sim}	-	Torque knee phase 2 simulation
τ_{ap2sim}	-	Torque ankle phase 2 simulation
τ_{hp1exp}	-	Torque hip phase 1 experiment
τ_{ap2exp}	-	Torque ankle phase 2 experiment
τ_{kp2exp}	-	Torque knee phase 2 experiment
τ_{hp2exp}	-	Torque hip phase 2 experiment
τ_{hp1ls}	-	Torque hip phase 1 length simulation
τ_{ap2ls}	-	Torque ankle phase 2 length simulation
τ_{kp2ls}	-	Torque knee phase 2 length simulation

τ_{hp2ls} - Torque hip phase 2 length simulation

τ_{hp1ms} - Torque hip phase 1 mass simulation

τ_{ap2ms} - Torque ankle phase 2 mass simulation

τ_{kp2ms} - Torque knee phase 2 mass simulation

τ_{hp2ms} - Torque hip phase 2 mass simulation

$\tau_{hp1mexp}$ - Torque hip phase 1 mass experiment

$\tau_{ap2mexp}$ - Torque ankle phase 2 mass experiment

$\tau_{kp2mexp}$ - Torque knee phase 2 mass experiment

$\tau_{hp2mexp}$ - Torque hip phase 2 mass experiment

$\tau_{hp2mexp}$ - Torque hip phase 1 length experiment

$\tau_{ap2lexp}$ - Torque ankle phase 2 length experiment

$\tau_{kp2lexp}$ - Torque knee phase 2 length experiment

$\tau_{hp2lexp}$ - Torque hip phase 2 length experiment

τ_{km} - Torque knee mass

τ_{kl} - Torque knee length

LIST OF PUBLICATIONS

Conference Paper

M. Z. bin Ghazali, M. F. Miskon, F. bin Ali and M. B. bin Bahar, "Investigating the relationship between TIP and three-link models when the mass are varied," *2015 IEEE International Symposium on Robotics and Intelligent Sensors (IRIS)*, Langkawi, 2015, pp. 196-201

M. Z. bin Ghazali, M. F. Miskon, F. bin Ali and M. B. bin Bahar, "Investigating the relationship between TIP and 3-link models when the links' length are varied," *2015 IEEE International Symposium on Robotics and Intelligent Sensors (IRIS)*, Langkawi, 2015, pp. 202-207

Journal

Mohd Zaki Ghazali, Muhammad Fahmi Miskon, Fariz Ali, D. Mohd Bazli Baha, 2016. Analysis of three-link position control during Sit to Stand motion. *Journal of Telecomunication, Electronic and Computer Engineering* ,8(7), pg 77 – 82

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The purpose of this thesis is to analyse the torque involved during Sit to stand (STS) motion using a three link (3L) model. STS is defined as the movement of human or humanoid robot to standing up from the chair. (Banerjee et al., n.d.; Mughal and Iqbal, 2008; Shen et al., 2008). Some researchers also called this as chair rise motion (Marcello et al., 1994). The study of this motion particularly in humanoid robotics gives high impact in the robotic field especially in the rehabilitation process. (Jr et al., 2006; Xiong et al., 2007; Saint-Bauzel et al., 2009).

Some researchers have been known to study STS using humanoids. M. Mistry used human volunteer to perform STS motion and recorded it before mapping it to humanoid robotic system (Mistry et al., 2010), motion planning and generation for humanoid robots based on the concept of virtual holonomic constraints (Mettin et al., 2007). S.Pchelkin analysed a constructive procedure for planning human-like motions of humanoid robots on finite-time intervals (Pchelkin et al., 2010) and X.Gu et al. had proposed how to compose complex movements in 33 DOF humanoid using three different ways of motor synergies over multiple motor routines (Gu and Ballard, 2006).

In the field of rehabilitation (Jr. et al., 2006), exoskeleton (Strausser and Kazerooni, 2011) as well as humanoid robotics (Ali et al., 2013; Shaari et al., 2013) STS motion were most popular area where most researches run their study and experiment. The characteristic of STS motion itself has not been given emphasis until recently.

In robotics field, several works on STS were done using model of three link (3L) (Hemami and Jaswa, 1978; Music´ et al., 2008), two-link elastic inverted pendulum (Aissaoui et al., 2011) as well as single rigid pendulum (Pai et al., 1997) and telescopic inverted pendulum (TIP) (Papa and Cappozzo, 1999). The main purpose of the study includes the structural stability, balance and energy transfer during STS task. From all the model mentioned, 3L model was found to be the most similar structure as human body segment and it is easy for planning and analysing humanoid or exoskeleton robot since it directly represents the whole body motion or the CENTER OF MASS (CoM) of the robot in Cartesian space (Bahar et al., 2014; Robotics, 2014; Miskon et al., 2015)

Mainly in rehabilitation facility there were some issues with prosthetic leg (Legro et al., 1999). Some patient loss their leg due to accident, war or even become paralyzed. Being different in body mass and height, it is hard for single prosthetic leg to be used by many patients. With this analysis, perhaps, it is plausible to make a simple calculation to estimate the maximum torque needed for each motor for each link involved. Thus, it can be used for all patients of varied mass and height.

However, the characteristic of STS motion using 3L robotic system has never been investigated with different mass and length before thus; it is not clear whether simple calculation can be used to estimate the torque needed by the joint motor. For 3L model, it consist of 3 link segments represent each humanoid body, leg, thigh and upper-body (Wada and Matsui, 2013). For this particular reason, this thesis presents a study to see the detailed analysis of torque for each segment joints via simulation and experimental setup.

1.2 Problem Statement

The problem of torque estimation of a three link system (3L) for STS Motion is in how to estimate the appropriate torque required to perform STS motion particularly in the case of the rehabilitation and assistive technology application. By far, no researcher has come out with a simple way to estimate the torque. The cost for the leg itself is high and some patient in the rehabilitation cannot afford to have it even with donation and sponsor. It would be helpful if the rehabilitation centre have a single prosthetic leg can be used for every patient. Since each patient has different measurements of mass and height, it is complicated for physician or technician to adjust the walking suit to fit all the patient. The therapist involved also do not have any knowledge in robotic, dynamic, motor or even they do not have a proper set of computer to perform complicated computational just to get the required amount of torque needed by patient. Most of the calculation involved either complicated dynamic or need a highly computational method which take a long time to complete. Thus a simple method of estimation is needed.

User of this assistive device varies in terms of height and weight. Thus, the robot designer needs a simple approach to estimate the required maximum torque in the motor joint to prevent any error to the motor or injuries to the user. A 3L system is the closest approach that mimics human joint. The current model system is too complex and involves a lot of dynamic parameters including inertia, gravity, angular velocity, Coriolis and Centrifugal Vector and many more (Wada and Matsui, 2013). With this approach, it is hoped that the parameter is being reduce to mass and length of link only. Most of the user affected below the waist. So this study focused on joint ankle, knee and hip. Of all this three joint, highest torque are found in knee joint (Bakar and Abdullah, 2011). Dynamic equation may get the precise torque needed by the user but it will take longer time to compute and analyse.