SIT TO STAND MOTION ALGORITHM OF NAO ROBOT

Ng Ke Voon

Bachelor of Mechatronics Engineering
June 2012

" I hereby declare that I have read through this report entitle "*Sit to Stand motion algorithm of NAO robot*" and found that it has comply the partial fulfilment for awarding the degree of *Bachelor of Mechatronics Engineering*".

Signature : ....

Supervisor's Name : ENGR. DR. Muhammad Fahmi Bin Miskon

Date : 2/7/2012

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NG KE VOON

A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

YEAR 2012

I declare that this report entitle "*Sit To Stand Motion Algorithm of NAO Robot*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : NG KE VOON

Date : 02/07/2012

To my beloved family

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ABSTRACT

Sit to stand motion is a challenge for any humanoid robot including NAO robot in providing stability and performance. In the project, the stability and the method of sit to stand motion will be studied. The method used is the cubic polynomial trajectory generation by verifying the result of Markerless Computer Vision Technique. The python programming language is used to simulate on the Choregraphe. The percentage of deviation at 2s is 2.9% and drop of the percentage of deviation is 7.4% from 1.5s to 2.0s. By increasing the time of motion. the percentage of deviation decreases but it is not significant so 2.0s is chosen. The significant difference between the left and right part of leg at the graph of RMSE value is because of the zero error at the right and left parts of the leg. The result is proven with the finding of the mechanical defect of 0.9cm difference between the left and right leg. One of those is the left knee where the percentage error is 0.255% and the right knee has a percentage error of 0.573%. From the finding, the velocity of the motion is directly proportional to the root mean square error. At the end, the NAO robot is able to perform the sit to stand motion with the cubic polynomial method base on trajectory generation with stability.

ABSTRAK

Pergerakan Duduk dan berdiri ialah satu cabaran untuk mana-mana robot termasuk robot NAO dalam situasi kestabilan dan prestasi. Dalam projek ini, kestabilan dan kaedah untuk pergerakan duduk dan berdiri akan dikaji. Kaedah yang digunakan ialah trajektori polinomial padu dengan mengesahkan hasil projeck ini dengan hasil Markerless Computer Vision Technique. Bahasa pengaturcaraan yang digunakan untuk mensimulasi di Choregraphe ialah Python. Dalam projek ini, saya mendapati peratusan sisihan di 2s ialah 2.9% dan penurunan peratusan sisihan ialah 7.4% dari 1.5s ke 2.0s. Dengan menambahkan masa pergerakan, peratusan sisihan dapat dikurangkan tetapi ia tidak banyak. Oleh itu, tidak dipentingkan. Sebab itu, pergerakan 2.0s dipilih. Perbezaan kaki kiri dan kanan dalam graf RMSE ialah disebabkan oleh penemuan ralat sifar. Hasil ini dibuktikan dengan penemuan kecacatan mekanikal sebanyak 0.9cm antara kaki kiri dengan kaki kanan. Salah satu daripadanya ialah lutut kiri, di mana peratus ralat ialah 0.255% dan lutut kanan mempunyai peratus ralat sebanyak 0.573%. Selain itu, halaju pergerakanf didapati berkadar langsung dengan RMSE. Kesimpulanya, robot NAO mampu melaksanakan pergerakan berdiri dari duduk dengan menggunakan kaedah polinomial padu berteraskan generasi trajektori dengan stabil.

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LIST OF ABBREVIATION

STS	-	Sit to Stand
UTeM	-	Universiti Teknikal Malaysia Melaka
GF	-	Generalized function
ZMP	-	Zero Moment Point
EEs	-	End-effector
CERIA	-	Centre of Excellent Robotic and Automation
NASA	-	National Aeronautics and Space Administration
DOF	-	Degree of Freedom
PID	-	Proportional-Integral derivative
FK	-	Forward Kinematic
RMSE	-	Root Mean Square Error

Chapter 1

Introduction

Humanoid research is becoming popular day by day. The Figure 1 shows that the timeline of the development of the humanoid robot starting from year of 1972 to present with the most research done toward the Rehabilitation Robots. The motivation of the study come from the benefit of the robot in the our future where it is able to help us human in completing task and help human to overcome our short coming.

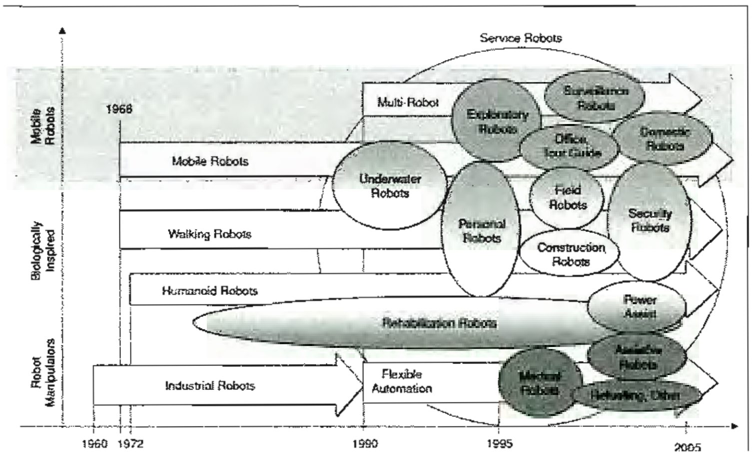

Figure 1:Time evolution of the robotics research towards service robots [21]

The type of robot available on the market include air muscles soft humanoid robot develop by ALife Robotics Corporation Ltd [1], Mahru III develop by Samsung [8], and Carnegie Mellon/Sarcos hydraulic humanoid robot [4], NAO robot develop by Aldebaran [13].

In the modern days, the people are getting older and older where the lifespan of human is getting longer because of the high medical technology. When their children are out to work, they will be alone at home without anybody to accompany them. Therefore, a humanoid robot is created to be with them so that their loneliness can be reduced. As the robot have to perform similar to a human behaviour, therefore we must start teaching the robot the basic motion for them to move around them. In addition, in the field of medical the development of robotic leg is studied so that it can be use as an artificial limb for the disable people. The research will benefit them by giving them hope and the opportunity to live like a normal person again. As a result, the stability of the each movement is very important for the robot to function as expected.

1.1 K-Chart of sit to stand motion using Nao Robot

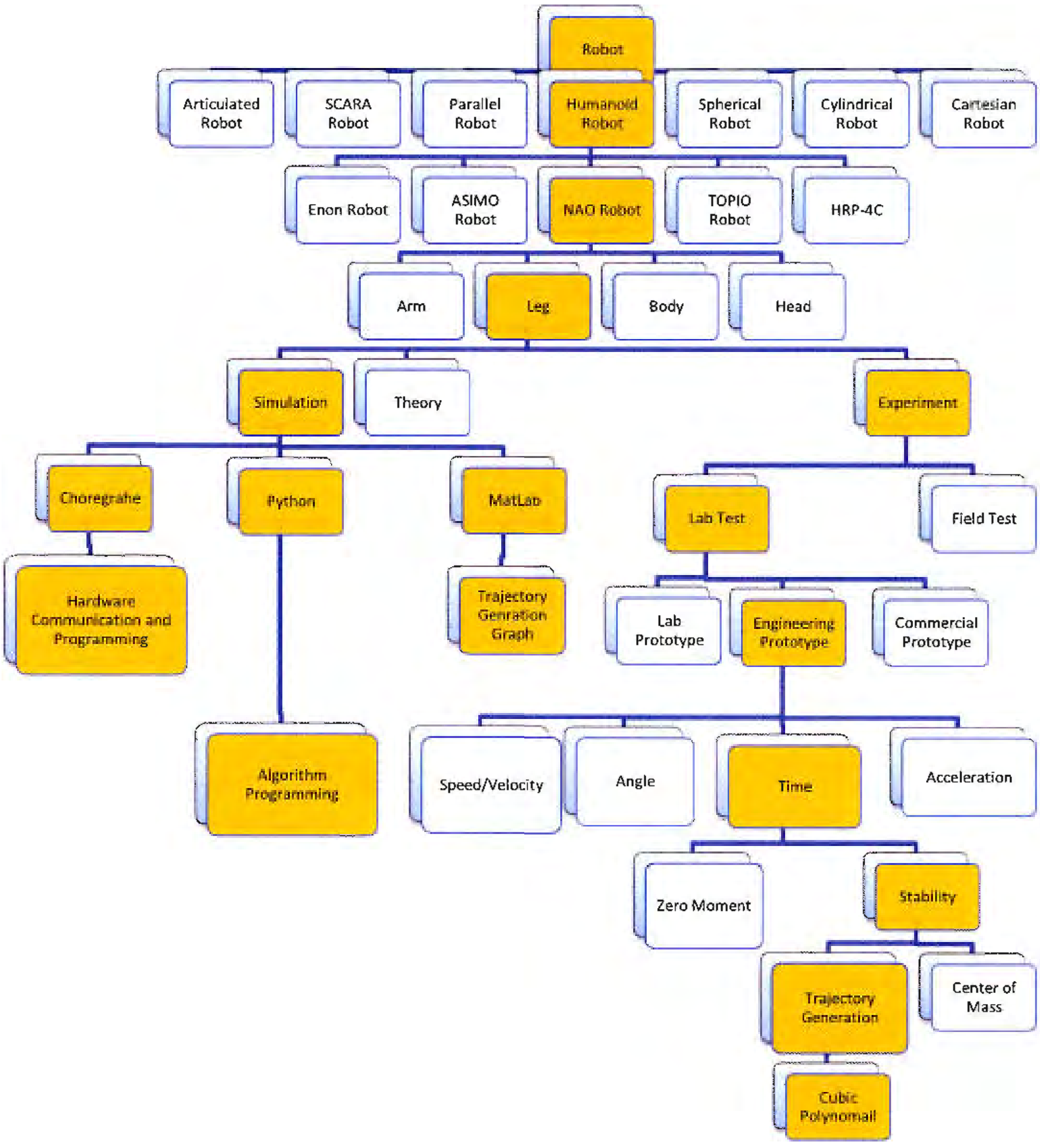

Figure 2 : K-Chart

By using the K-Chart, the scope of my research is being narrow down. Thus, the method that is being use in the my research will be base on the cubic polynomial trajectory to get the best stability where the time are the parameter that needed to be found.

1.2 Problem Statement

In the field of research on the sit to stand(STS) motion, the design of the NAO robot itself is unable to perform the best stability for sit to stand (STS) motion. Where the stability of the robot is based on the joint angle, velocity, acceleration, and rise time of the robot by using method related to trajectory generation. The stability of the robot is closely related to the angle and the raise time of the robot. The use of angle when standing up will affect the centre of gravity and the zero moment point of the robot. Therefore, it is crucial at selecting the right angle for the motion. In making the motion to be natural, the angle of which used in the motion is basically base on human demonstration. Besides that, the rise time is taken into consideration as the velocity and the acceleration of the robot is closely related to the rise time. With the use of high technology such as the "markerless computer vision technique", the human behaviour is studied to gather the required information including the angle and the rise time is set base on ideal curve of cubic polynomial.

The parameters for sit to stand motion is proposed and applied using the theoretical equation of cubic polynomial trajectory below :

Position :

$$\theta(t) = \theta_o + \frac{3}{t_f^2}(\theta_f - \theta_o)\mathrm{t}^2 - \frac{2}{t_f^3}(\theta_f - \theta_o)\mathrm{t}^3 \text{ [20]}$$

Velocity :

$$\dot{\theta}(t) = \frac{6}{t_f^2}(\theta_f - \theta_o)\mathrm{t} - \frac{6}{t_f^3}(\theta_f - \theta_o)\mathrm{t}^2 \text{ [20]}$$

Acceleration :

$$\ddot{\theta}\,(t) = \frac{6}{t_f^2}(\theta_f - \theta_o) - \frac{12}{t_f^3}(\theta_f - \theta_o)\mathrm{t} \text{ [20]}$$

θ_f= final angle of the motion referring to the reference angle.

θ_o= initial angle of the motion referring to the reference angle.

t_f = the rise time of the motion.

t = variable time domain

From the equations :

The controlled parameters are θ_f, θ_o, t_f where the value will greatly affect the stability and performance of the system

1.2 Objective

The main objective is to find the best parameter (time), to develop and to test the movement of sit to stand(STS) motion of the NAO Robot by using the cubic polynomial trajectory.

1.3 Scope

i. Literature review of the project will be related to the control of the robotic leg on STS motion using cubic polynomial trajectory generation.
ii. Setup the connection between programming software and the robot software.
iii. Set the requirement for the initial position of the robot is sitting upright on a chair.
iv. Set the requirement for the final position of the robot is standing upright.
v. The NAO robot used is the version NAO H21.
vi. The programming language that is used is the python programming language.
vii. The Choregraphe software is used to communicate with the hardware.
viii. Naoqi is used as medium between Choregraphe and python.
ix. The experiment will be tested at the CERIA (Centre of excellence in Robotic and Industry Automation) on a flat surface
x. The joint/motors involved are the hip, knee, and ankle. (total 6 motor)
xi. The virtual Nao robot in Choregraphe is used for basic simulation..
xii. Matlab is used to get the theoretical data of the trajectory equation and to compare with the experiment data.

xiii. The angle fixed with hip -75degree, knee 90 degree, and ankle -14.3 degree.

xiv. The final position of the angle fixed at 0 degree for all the joint.

xv. The height of the chair(stacks of books) is set at 11.5cm

xvi. Zero Moment Point is not study in detail due to the lack of equipment.

1.4 Contribution of the thesis

The research of the robot shows the controlling the robot leg to perform sit to stand motion using cubic polynomial trajectory generation. Therefore, the method is possible to be implement on the other part of the robot to perform motion in future on the robot. It is also proven that it is possible to apply the advance method of trajectory generation base on the advance theory of cubic trajectory generation. The result can be use to help in the future research that is related to the study of robot legs to obtain higher stability.

1.4.1 Outline of thesis

i. Chapter 1

It provide a brief introduction to the research of Nao sit to stand motion. It shows the goal and limitation of the research.

ii. Chapter 2

It provide a clear picture on the research and the direction of the project. It also show the relevant method to be use in the research and varies type of motion can be performed by a robot.

iii. Chapter 3

The theory part of the project is discussed in this section.

iv. Chapter 4

The flow of the research and the experiment setup

v. Chapter 5

The result of the experiment is tabled. These comprises the extensive analysis and discussion of the result base on the theoretical data and experimental data.

vi. Chapter 6

The main finding of the research and possible future work that can be done or avoid.

Chapter 2

Literature Review

Many motion of robot to imitate human being has been researched so in the literature review, the type of motion researched is discussed. One of the motion is involving leg motion. In my case, the research is related to sit to stand motion. However, there are many types of method to perform the motion. A suitable method will be use to developed and tested in my project. In taking consideration of the dynamic of the motion, the Zero moment point or centre of pressure is taken into account. The literature review is to find out the advantage, disadvantage, type of research, and suitability of the method to be use in my research. So that, result of a method can be chosen to be referred but the methodology will be redesign to suit my research.

2.1 Introduction

There few basic movement that a humanoid robot must perform daily. One of the motion will be the sit to stand motion where it is a basic motion carry out by human in everyday life. Even though currently there are a lot of humanoid robot around and many research has been done to imitate human behaviour but it still cannot compare with the stability human possess. Human being able to automatically adjust so that we always in the best position in term of stability. However, humanoid robot cannot posses such function without considering the aspect in the change of centre of mass and zero moment point. Therefore, research on the suitable trajectory is necessary to overcome the problem.

The current world is already developing high intelligent humanoid robot for company such as the Honda, Hitachi, Aldebaran, NASA, and etc. All those company are doing their own research and development to help in the development of the humanoid robot. The use of humanoid robot can be vast and it is able to replace human to perform some dangerous action where it may be impossible for a human being to execute. For example, the NASA research on humanoid robot so that someday it may replace human being to accomplish task that is for more dangerous. In addition, humanoid robot can perform task with higher accuracy compare to human if work under long period of time but provided it has enough energy.

When dealing with the research of humanoid robot, it can be categorize into a few parts. One of it will be the lower body parts of humanoid robot. It basically deal with the stability of the motion as robot perform any kind of movement. The lower parts include the hip, knee, and feet. Therefore, a suitable algorithm needed to be developed using suitable programming language to create a reliable and intelligent humanoid robot. The Nao robot is chosen a subject of the research because the robot is consider new to the world and it is more affordable to posses.

2.2 Research on the type of Motion related to Robot

In the field of robotic, many research has been carry out. However, the research carry are basically focus on 1 part of the robot. Therefore, the motion related to leg, hand and different type of movement require different type of research.

How to walk is an important element of research where lots of research already found many methods. One of those method is the control strategy based on the inverse kinematics using Jacobian Matrix and determine position by using trajectory generation [6]. Other method include the joint space trajectory planning strategy for the legs of 4-DOF parallelogram bipedal robot and the use of two sets of pulley-based parallelogram mechanisms [14].

Other kind of motion is the sit to stand motion. The method used for the generation of motion is base on Denavit-Hartenberg notation for joint angle and derive the joint moment N, by setting up Newton-Euler equations for each link base on human model[15].

In addition, the omnidirectional walking is generated by using method like for example foot positioning compensator with foot positioning policy learned through a policy gradient reinforcement learning approach [7].

2.3 Methods of Sit to Stand motion

Generalized function (GF) set and gets the interested end-effectors (EEs) to move the robot is one of the method used by others researches. [9] Besides that, the use of Neural Network also have be successfully used in the field to develop the inverse model while the PID (Proportional-Integral derivative) controller has been used in Matlab/Simulink to simulate the movement [2][3].

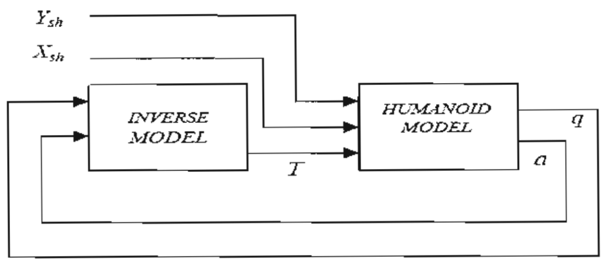

Figure 2 : Control strategy applied to humanoid model[2]

Other methods include the use of the vision system, where the human act as a model to perform the sit to stand motion in front of the robot with vision system so that the robot is able to emulate the motion [4][8]. By using proper controller the record motion was used to analyze how human controlling the Centre of Mass [4].The controller that has be use for the research includes the decoupled optimal controller design for the control of biomechanical sit-to-stand.[5]

Another method is the control strategy based on the Inverse Kinematic (IK). All of the body coordination position (X,Y,Z) – Joints and links - was adapted from the oscillation plan using Forward Kinematic (FK), after determination positions , every joint angle has been calculated using inverse kinematic.[6]

Furthermore, the method of trajectory generation also been used and research in the sit to stand motion. The starting point, ending point, and the time is designed by the user for the system. It will be able to generate a specific trajectory. The method shape the trajectory just by tuning 2 parameters which are the angle and time.[24]

Other kind of method is the simple foot positioning compensator by modify the foot positioning online based on the estimated robot state using onboard sensors . By making the compensator coincident with the dynamics of a full body humanoid robot.[7]

2.4 Dynamic System

The (STS) motion is one of dynamic motion. When discussing about the dynamic motion, it is nonlinear and in phase space, it was coexists of stable and unstable regions [10]. In solving the complicated dynamic system, effort such as human motion capture has been made. Then, the similarity evaluation and dynamic stability based on ZMP (Zero Moment Point) of the humanoid motion are discussed. [11] Another way to solve the dynamic analysis is reinforcement learning, in particular, a continuous time and state temporal difference (TO) learning method [12]. Appendix 1 is the summary of research that used (Sit to Stand) as an objective or method to test the developed controller.