MODELING OF HUMAN MOTION THROUGH MOTION CAPTURED DATA USING NON-LINEAR IDENTIFICATION

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A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

DECEMBER 2007

DEDICATION

Specially dedicated to my beloved father, mother and brothers
for their understanding, caring and support.

ACKNOWLEDGEMENT

First of all, I would like to express my deepest gratitude to our beloved God for giving the opportunity for me to accomplish my project successfully.

A sincere appreciation to Assoc. Prof. Dr. Mohd Shafiek Yaacob and Dr. Robiah Ahmad who graciously guide me throughout this project. Their guidance, encouragement, critic and advice have proved invaluable throughout the period of my project.

Apart from that, I'm grateful with my family, course mates and fellow friends who gave me endless moral support and understanding attitude through the time of my further studies.

Thank also for those who involved and contributed directly or indirectly in this project.

ABSTRACT

The importance of estimating human motion analysis can be illustrated by numerous applications such as performance measurement for human factors engineering, posture and gait analysis for training athletes and physically challenged persons, animation of the human body, hands and face, automatic annotation of human activities in video databases, control in video games and virtual reality or teleoperation of anthropometric robots. Image processing technique from motion captured images is an accurate and cost effective method to give a set of data that defines the location of specified limb at every sequence of human motion. From this set of data, system identification was done to model the human motion. This project is a study on how performance of an identified model is influenced by different types of model representation whether it is a linear model or non-linear model and a single variable model or multi variable model. Two types of parameter estimator was used which were least square and recursive least square. The study also included the effects of different number of lags on the model. The objective is to formulate a predictive model to analyze human motion. Simulation studies were done on this model representation and compared with actual human motion. Several model validation techniques were done to validate the identified models. In this study, multivariable non-linear model is a good human motion representative. The model accuracy increases as the degree of non-linearity and number of lags are increased but it makes the model become more complex.

ABSTRAK

Kepentingan dalam analisis pergerakan manusia boleh dilihat dari pelbagai aplikasi seperti ukuran keberkesanan dan kejuruteraan faktor manusia, analisis postur dan gerakan untuk latihan atlit, animasi tubuh badan manusia, tangan dan wajah, anotasi automatik bagi aktiviti manusia melalui data video, kawalan dalam permainan video atau robot berkebolehan seperti manusia. Teknik pemprosesan imej dari imej pergerakan yang direkod adalah suatu teknik yang mempunyai ketepatan tinggi and efektif dari segi kos. Ia dapat memberi set data yang menghuraikan lokasi setiap anggota badan di setiap urutan pergerakan manusia. Daripada set data ini, pengenalpastian sistem dilakukan untuk memodelkan pergerakan manusia. Projek ini juga merangkumi kajian bagi melihat bagaimana keberkesanan model yang dibangunkan dipengaruhi oleh pelbagai jenis struktur model sama ada ianya linear atau tidak linear mahupun pembolehubah tunggal atau pembolehubah pelbagai. Dua jenis penganggar parameter digunakan iaitu anggaran kuasa dua terkecil dan anggaran kuasa dua terkecil rekursif. Kajian juga meliputi kesan kelambatan atau data terdahulu yang diperlukan terhadap model. Objektif kajian adalah untuk mendapatkan model yang mempunyai ketepatan anggaran yang tinggi untuk analisis pergerakan manusia. Kajian simulasi turut dilakukan terhadap model dan ianya dibandingkan dengan pergerakan sebenar manusia. Beberapa teknik pengesahan model digunakan untuk megukur keberkesanan model tersebut. Model pembolehubah pelbagai tidak linear adalah suatu model yang baik bagi mewakili pergerakan manusia. Dalam kajian ini, apabila tahap ketidak linearan and bilangan keperluan data terdahulu ditambah, ketepatan model turut bertambah tetapi ianya menyebabkan model menjadi semakin komplek.

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
AR	Auto Regressive
ARMA	Auto Regressive Moving Average
ARMAX	Auto Regressive Moving Average with eXogenous input
ARX	Auto Regressive with eXogenous input
BJ	Box-Jenkins
CD	Compact Disc
EI	Error Index
HSV	Hue, Saturation, Value
LSE	Least Square Estimation
MIMO	Multi Input Multi Output
MISO	Multi Input Single Output
MLP	Multi Layer Perceptron
MPO	Model Predicted Output
MSE	Mean Square Error
NAR	Non-linear Auto Regressive
NARMAX	Non-linear Auto Regressive Moving Average with eXogenous input
NARX	Non-linear Auto Regressive with eXogenous input
OSA	One Step Ahead
RGB	Red Green Blue
RLSE	Least Square Estimation
RMSE	Root Mean Square Error
SI	System Identification
SIMO	Single Input Multi Output
SISO	Single Input Single Output
SSE	Sum Square Error

LIST OF SYMBOLS

$u(t)$	system input
$y(t)$	system output
a_i, b_i, c_i	coefficients of polynomial models
n_y, n_u, n_c	output, input and noise lags
θ_i	unknown parameter
d	time delay
$f(\bullet)$	non-linear function
$\phi(t)$	regressor
$f^l(\bullet)$	non-linear function of degree *l*
$\varepsilon(t)$	error of residual sequence
$\hat{y}(t)$	predicted output
e(t)	a random white noise
l	degree of non-linearity
M	maximum number of terms
N	data length
n, m	system order
na	number of outputs
nb	number of inputs
P	covariance matrix
t	time step

CHAPTER 1

INTRODUCTION

1.1 General Introduction

The human body is one of the most sophisticated and complex system where it is highly a non-linear system. It is a challenge to model the human motion. Motion analysis entails measurement, analysis and assessment of the movement features that are associated with the walking or running task. Significant technical and intellectual progress have been made in the area of motion analysis over the past new decades, especially because of the advance in computing speed which in turn has aided the development of more advanced movement recording system that require less data processing time. Improved computing speed has also made feasible and inspired increasingly complex and innovative motion data analysis technique [1]. This field has been studied by many professional from varied discipline such as science, engineering, sports or medicine. Each discipline has its own research interests and motivations of study. Examples of the application for biomechanics biomechanics field include a gait pattern classification and recognition task including categorization of normal and pathological gaits. The field of human motion study can be divided into two sections, kinematics and kinetics as illustrated in Figure 1.1.

Walking and running are the most important and common human movement. Developing a computer model of the motion has been the goal of many researches with good reason. If a computer model can be developed it make an accurate prediction of human gait analysis.

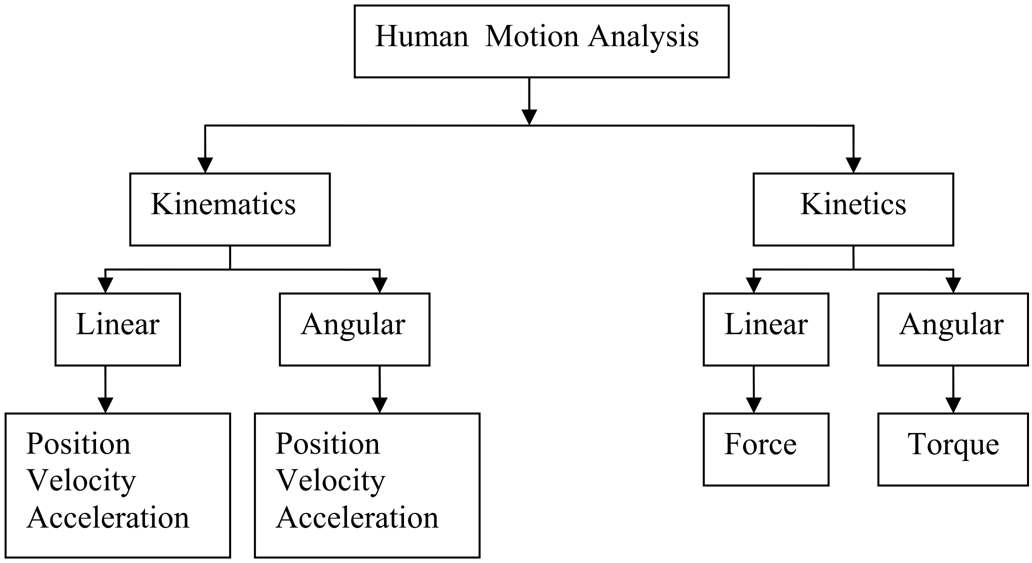

Figure 1.1 : Types of movement analysis [2]

1.2 Objective

The objectives of this project are:

1. To apply the video digitizing and image processing technique with capability to capture images of real human motion (two dimensional) and process the images to give a set of data that defines limbs location at each sequence of the motion.

2. To determine a good mathematical model that gives adequate and high predictive model of human motion.

3. To simulate the human motion based on the identified model.

1.3 Scope

The scope of the study encompasses the following aspects:

- Walking and running motion
- Two dimensional motion
- Lower human body segments
- Kinematics study

1.4 Problem Statement

In this human motion study, the model must be sufficiently realistic to represent the real motion. The analysis of human movement may be greatly enhanced by assigning digital values at specific body segment in a particular time during walking or running. Available techniques include wave signal processing technique or magnetic system technique. Several factors are being considered as the argument to select the best method for this purpose. The factors are:

- The price of the data device
- The accuracy and reliability data given by the device
- The price of high accuracy data acquisition device
- Some device limited to a specific limb only

High accuracy device is good to get a reliable data but it is expensive. However, using a low cost device, it might be lose some important data during the motion data acquisition and decrease the accuracy of the model. A balance between cost and accuracy has to be drawn. The most common technique used is image measurement technique. This technique captures the motion sequence of human movement then analyze and assigning particular values of each body segment at each sequence of the motion. This technique is not too expensive and can give a quite good result if the procedure of data acquisition is done correctly.

From the set of raw data, the identification technique also can be an issue because human motion is a non-linear system. In identification techniques, both statistical and intelligence approaches (i.e., neural network, fuzzy logic or genetic algorithm) can be used for analyzing the movement data. The main advantages of using statistical technique is that they provide insight into the motion model being used and the effects of various independent variables on the dependent variables can be studied directly [1]. However, this technique has significant limitations especially when the problem to be studied is non-linear or complex. Neural network and other intelligence techniques have the potential to offer better alternative to solve this problem and becoming increasingly popular. The main obstacle in designing an intelligent neural network system is the determination of artificial neural network architecture and experimentation in order to establish a robust network [3]. The parametric identification techniques included Non-linear Auto Regressive Moving Average eXogenous (NARMAX) or Auto Regressive Moving Average eXogenous (ARMAX). Parametric models have some advantages in applications such as, easier to understand and interpret, can simplify forecast, and model comparison in a parametric context has been well studied.

1.5 Research Methodology

The project is carried out by referring to the project flow as shown in Figure 1.2.

In this project, types of human movement that was studied include walking and running in kinematics field. The human part to be analyzed is lower part of human body segment. In this project, the analysis procedure has been simplified to two dimensional motion due to the mechanical complexity of the human body, the complexity for movement modeling and capabilities of presented instruments.

A video camera with medium resolution and frame rate was used as an image device to capture the human motion. This is the main input device for data acquisition. This is sufficient for two dimensional analysis. To have an accurate data acquisition for three dimensional human movement, it needs at least two high speed and high resolution cameras with same characteristics.

Calibration was done to determine correlation between device resolution and length of human limbs. Using the medium frame rate video camera, human motion of walking and running was recorded. Then the video was analyzed frame by frame. Each frame represents a particular sequence of human motion. In each frame, location of specified limbs are determined. For this purpose, passive markers are fixed to the specified limbs during the motion recording. The image was processed and analyzed (using MATLAB) to determine the location of every marker at each sequence of motion. Each marker represents a specific part of human body.

The extracted data is the coordinates for specified limbs and are used as basic data. This basic data is transformed into angles and are used as raw data in modeling the motion using non-linear identification. The parametric modeling are used where good model structure and parameter estimation method are to be determined. Then validation of model is done to ensure that the model adequately represents the true system. Finally, animation is conducted to evaluate the performance of the model visually.

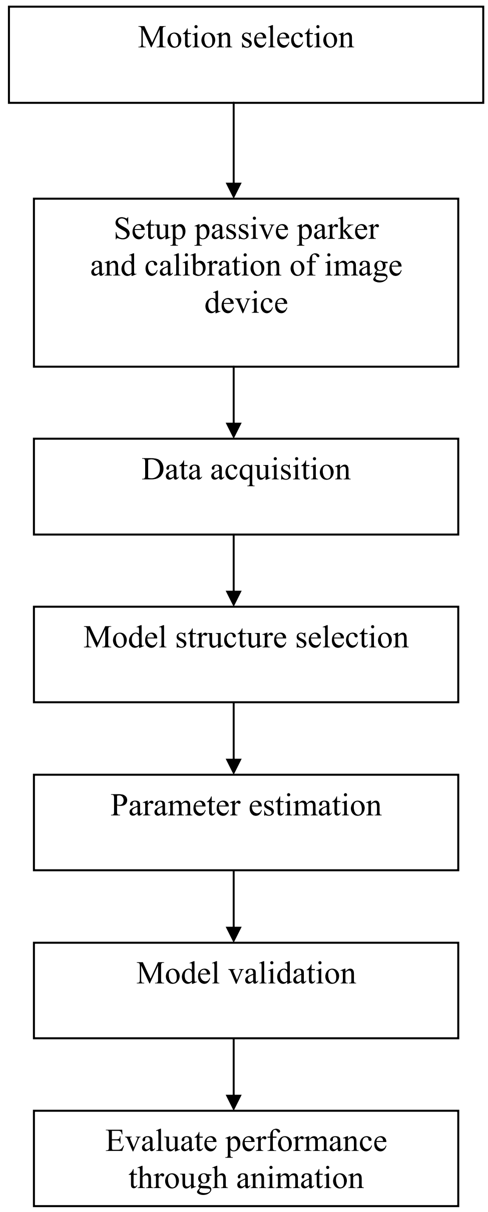

Figure 1.2 : A flow chart of project implementation

1.6 Outline of the Report

The report consists of five chapters. This chapter provides an introduction and background of this project including the objective and scope of project.

Chapter 2 is a literature review and detail discussion about system identification including model structure, single variables model and multivariable model, parameter estimation methods, model validation and performance measurement. Different types of model structure as well as linear and non-linear model are discussed and compared. This chapter also discusses about the human gait cycles including walking and running task. A literature review of study in kinematics is included too. Comparison and information about available technique to acquired human motion data is also discussed in this chapter. Finally is a review of related works have been done in the field of human motion modeling.

Chapter 3 describes the methodology used in this project. The chapter discusses the data acquisition technique which involved image processing. It follows with examples of result by using this technique for three different speeds of walking and three different speeds of running. Next is the discussion about the model structure that going to be used in this project followed by parameter estimation method. Finally is the model validation approach that was used in the simulation study.

Chapter 4 presents the results of the simulation of human motion by the methodology discussed in Chapter 3. A short brief of expected results are discussed in the introduction of this chapter. Simulation is done for a chosen speed of walking through different types of model and parameter estimation. Such a number of variables are changed to see the effect to the developed model. Finally the best model is chosen and modeling for the remaining speeds of motion is done through this selected model.

Chapter 5 consists the conclusion of this study followed by recommendation and discussion about possible extension of the studies for future research work.

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