UNIVERSAL DYNAMIC SIMULATOR FOR ROBOTIC MANIPULATORS: KINEMATIC MODELING

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by

LASANTHA KURUKULARACHCHI

Supervised by: Dr. Rohan Munasinghe

Department of Electrical Engineering
University of Moratuwa, Sri Lanka

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DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

UOM Verified Signature

Lasantha Kurukularachchi

Date- 19/2/2008

I endorse the declaration by the candidate.

UOM Verified Signature

Dr. Rohan Munasinghe

Table of Contents

Abstract

This project highly focuses on a total simulating solution to the robotic manipulator users. The existing simulators are narrow with limited applications. Therefore the simulator users do not have an adequate solution for the universal manipulators. The simulating solution developed through this project is the combination of kinematic, dynamic, trajectory planning and frictional model on a one interface. This project has been divided into four different research components because of the vast extent of the research areas.

This thesis is based on the kinematic behavior of this robotic simulator. Under the kinematic behavior, the forward kinematic and the reverse kinematic have been focus on. In the forward kinematic bases, the systematic analytic approaches are used to develop the algorithm. This algorithm describes the spatial relationship between links & link parameters of the manipulator and it supports to find the end-effector position and orientation with respect to the joint space parameters in a graphical way. On the other hand the forward kinematic supports to visualize the manipulator in the 3D environment.

The reverse kinematic is required to find a set of joint variables that would bring the end-effector in the specified position and orientation. In general this solution is non-unique for the universal model, but solving the inverse kinematic is most important to design the practical manipulators. Therefore the inverse kinematic algorithm is the combination of Jacobian transformation and the Taylor series expansion. This combination is ideal to solve the inverse kinematic in this simulator.

The software tool is the final output of this project. The kinematics module supports to find the manipulator geometry and the joint angles. But the software tool is the combination of kinematics, dynamics and the trajectory planning.

The object-oriented program is well adapted to this application since OOP can describe each part of the robot as one object with its own properties and behavior. Even if C++ is not a perfect OO language, a lot of very useful libraries are available, and maintains very good efficiency for

intensive computations. The robotic applications will be highly popular in the future. Therefore this software tool may be most important to develop the manipulator application because it provides a total solution for designing the application. Still nobody has developed this type of an application tool to manipulator designers. This software application operates with out any hindrance and the major advantage is that this simulator can be used for universal serial link manipulator for N-degree of freedom.

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List of Figures

Figure **Page**

List of Tables

Table **Page**

List of Principal Symbols

q_i	Joint Variable
θ	Joint Angle
a_i	Link Length
α_i	Link Twist
d_i	Link Offset
${}^{i-1}A_i$	Homogeneous Transformation Matrix.
R_i	Rotation Matrix
P_i	Translation Vector
T	Forward Kinematics Equation
J	Jacobian Matrix
$\dot{x}$	6x1 Cartesian Velocity Vector
$\dot{q}$	nx1 Vector of n Joint Velocity
ω_i	Angular Velocity of i^{th} Link
δq	Small Displacement of Joint Variable
δx	Small Displacement of Cartesian Variable
I	Identity Matrix

List of Acronyms

IK	Inverse kinematic
RP	Revolute & prismatic
DOF	Degree of freedom
OOP	Object oriented programming
D-H	Denavit-Hartenberg parameters
TP	Trajectory planning
TPA	Trajectory planning algorithm