DEVELOPMENT OF A VISION AIDED REACH-TO-GRASP PATH PLANNING AND CONTROLLING METHOD FOR TRANS-HUMERAL ROBOTIC PROSTHESES

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgment any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

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Abstract

This study proposes a reach-to-grasp path planning and controlling method for trans-humeral prostheses. Trans-humeral prostheses are used to replace the missing body part after the loss of upper limb (UL) above elbow. Reach-to-grasp paths refers to the paths taken by the human UL to reach towards an object with the intention of grasping.

A trans-humeral prosthesis has been designed and fabricated with 5DOF. A simulation environment has been proposed using the design. Simulation environment consists of a virtual shoulder joint which can be actuated according to a natural human shoulder using an Inertial Measurement Unit (IMU). Prosthesis and the simulation environment has been used to experimentally evaluate the proposed path planning method.

A reach-to-grasp path planning method combining Electromyography (EMG) signals and vision signals has been proposed. EMG Based Module (EBM) is capable of controlling prosthesis elbow motion effectively with an accuracy of 92%. Visual Servoing Module (VSM) consists of a 2-1/2D visual servoing system to center the object of interest to the hand of the prosthesis and to correct the orientation. An object reaching algorithm has been proposed to reach towards the object. Later, the EBM and the VSM has been fused using an fusion filter.

An improvement to the above method has been proposed to make the paths straight. It consists of a path generation module and a path tracking module. Path generation module is capable of generating a path towards the object. The object position is located and a path is generated from the current position of the prosthetic hand to the object position with the aid of vision. Path tracking module takes the prosthetic hand on the generated path considering shoulder motions. Two path tracking methods has been proposed: spatial path following method and Model Predictive Controller (MPC) based path tracking method. Proposed path planning method has been experimentally evaluated.

Keywords- **Trans-humeral prosthesis, electromyography, visual servoing, reach-to-grasp path planning, path following**

DEDICATION

To my parents,

D.G. Sunil Santha and *Indralatha Udayakanthi Wijesinghe*

Without whom none of my success would be possible

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LIST OF ABBREVIATIONS

AAD	Abduction/Adduction
ADL	Activities of Daily Living
ANN	Artificial Neural Network
API	Application Package Interface
BLDC	Brush Less DC
CCD	Charge Coupled Device
CMOS	Complementary Metal Oxide Semiconductor
DAQ	Data Acquisition
DC	Direct Current
DH	Denavit Hartenberg
DLS	Damped Least Squares
DOF	Degrees of Freedom
EBM	EMG Based Module
ECoG	Electrocorticography
EEG	Electroencephalography
EFPMB	EMG Force Proportional Moment Balance Model
EMG	Electromyography

EPE	End Point Error
FE	Flexion/Extension
FIS	Fuzzy Inference System
FK	Forward Kinematics
IBVS	Image Based Visual Servoing
IER	Internal External Rotation
IK	Inverse Kinematics
IMU	Inertial Measurement Unit
IP	Inertia Point
MAV	Mean Absolute Value
MDA	Multiple Discriminant Analysis
MMG	Mechanomyography
MPC	Model Predictive Controller
MSE	Mean Square Error
MU	Motor Unit
MUAP	Motor Unit Action potential
MUAPT	Motor Unit Action potential Train
PBVS	Position Based Visual Servoing
PC	personal Computer
PCA	Principal Component Analysis
PID	Proportional Integral Derivative

RMS	Root Mean Square
RMSE	RMS Error
ROM	Ranges of Motions
SD	Standard Deviation
SP	Supination/Pronation
SSC	Slope Sign Change
TDANN	Time delayed ANN
TMR	Targeted Muscle Reinnervation
UI	User Interface
UL	Upper limb
URD	Ulnar Radial Deviation
US	Ultrasonic
USA	United states
V-REP	Virtual Robotic Experimentation Platform
VSM	Visual Servoing Module
WL	Waveform Length
ZC	Zero Crossings