Faculty of Engineering
Mechatronics Engineering Department

Visual Sensory System for 3D Position and Orientation of a Movable Platform

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

MECHANICAL ENGINEERING
(MECHATRONICS)

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Statement

This thesis is submitted in the partial fulfillment of master degree in Mechanical Engineering to Ain Shams University.

The author carried out the work included in this thesis, and no part of this thesis has been submitted for a degree or qualification at any other university.

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Abstract

There are a number of challenging factors that influence the performance of the industrial robotics systems. One of these factors is the error accumulation in robots joints' coordinates due to the imperfect response of the conventional sensory systems. For a robot to do any task, its controller has to give its motors control actions complete with the coordinates of the destination point. When the robot completes its task, it saves the point it reached – the destination point – as its current position but actually due to environmental errors and the mechanical constrains, both are not equivalent. The next control action would give a new destination point based on the current position; this leads to error accumulation and results in wrong control actions.

To find an error compromising methodology; researchers followed many techniques that were either analytical or iterative. The main highlights of these techniques implemented are the Scale Invariant Feature Transform (SIFT) and landmarks.

This thesis applies a self sensing; Digital Image Processing (DIP) based methodology to be further used as a smart sensor in the closed loop control system of any movable platform. Mainly the concept of 3D/2D perspective projection was implemented with three attached landmarks to find the full orientation in space through Matlab 2011a. Neither of any learning methodologies was applied.

The results show that the maximum absolute coordinate error was 59.321e-2 mm, exerted in Y-direction. The maximum rotational error was 2.44e-3 radians exerted while rotating around Z-axis. The maximum translational error was 26.67e-3 mm along X-axis. The obtained results were better than the results obtained in two of the most recent researches. Processing time was calculated per phase and extracting the landmarks was found to be the most time consuming process with an average time of 7.0243 seconds.

Summary of the M.Sc. Thesis

“Visual Sensory System for 3D Position and Orientation of a Movable Platform”

It is not easy for robots to do their assigned tasks precisely while suffering the fetal problems in conventional sensory systems. That was the main objective of the thesis; to find a smarter methodology a robot can use to deal with the dynamic environments without any predefined information of the environment and compensating the conventional sensory systems’ errors.

Chapter 1 provides an introduction to the topic in addition to a survey for researches in the field of the conventional sensory systems and the accumulation of errors due to the problems in such systems. Researchers agree that the compensation of errors can be achieved either analytically or through iterations. Landmarks and SIFT features are the most widely used techniques as control points in digital image processing and computer vision applications.

Chapter 2 introduces the design phase of the complete Mechatronic system for the visual sensory system introduced. The proposed algorithm is also discussed.

In Chapter 3 the experimental setup is illustrated to measure the efficiency of the proposed methodology in addition to a complete definition for each of the subsystems and system's components.

In Chapter 4 the experiments conducted are presented which proved the efficiency of the proposed methodology and algorithm.

Based on the above mentioned work, some recommendations and future research are introduced in Chapter 5.

The contribution of this thesis is a new easily implemented methodology to find the 3D position and orientation of any movable platform that the robot can use without any inference from a programmer or a user where even the

environment can be totally undefined for the robot using only a single camera and three attached landmarks to the platform. Taking into consideration that there is a unique position in space for any movable platform; this position is achieved when all its limit switches are fired. The latest position was denoted "Rest position". This thesis provides a smarter sensory system to compensate the conventional sensory system errors using vision systems in addition to compensating some of the proposed vision systems' errors.

Nomenclature

List of Greek Symbols

α	The rotational angle around X-axis
β	The rotational angle around Y-axis
γ	The rotational angle around Z-axis

List of Alphabetic Symbols

CF	Correction factor
f	Image acquiring device focal length
T_x	Translation along X-axis
T_y	Translation along Y-axis
T_z	Translation along Z-axis
X_{res}	The resolution of the camera in X-direction
Y_{res}	The resolution of the camera in Y-direction

List of Acronyms

AR	Augmented Reality
BMP	Bit Map Picture
DAS	Data Acquision system
DIP	Digital Image Processing
DOF	Degrees of Freedom
DOG	Difference of Gaussian
DSC	Digital Still Cameras
EKF	Extended Kalman Filter
EXIF	Exchangeable Image File Format For Digital Still Cameras
FPGA	Field Programmable Gate Array

GIF	Graphic Interchange Format
HPR	Hybrid Parallel Robot
IPT	Matlab's Image Processing Toolbox
JPEG	Joint Photographic Experts Group
LVDT	Linear Variable Differential Transformer
LZW	Lempel Ziv Welch
MVTP	Machine Vision Toolbox
P	Prismatic Joint
PNG	Portable Network Graphics
R	Revolute Joint
RIA	Robotics Industries Association
RIF	Raster Image Format
RPY	Roll, Pitch and Yaw Motion Configuration
RT	Robot Technology
RVDT	Linear Variable Differential Transformer
S	Spherical Joint
SCARA	Selective Compliant Articulated Robot for Assembly
SFM	Structure From Motion
SIFT	Scale Invariant Feature Transform/ Tracking
SLAM	Simultaneous Localization and Mapping
SSD	Sum of Squared Differences
TIFF	Tagged Image File Format
TUI	Tangible User Interface
VDI 2206	The German design methodology for Mechatronics systems

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