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3D visual rapid robot programming system

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3D VISUAL RAPID ROBOT PROGRAMMING SYSTEM

A thesis submitted in fulfilment of the requirements for the award of the degree

Doctor of Philosophy (PhD)

From

UNIVERSITY OF WOLLONGONG

By

DIEGO ADOLFO RODRIGUEZ CANTOR

Master of Engineering Practice in Mechatronics

Electronics Engineer

FACULTY OF ENGINEERING

2008

CERTIFICATION

I, Diego Adolfo Rodríguez Cantor, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

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Diego Adolfo Rodríguez Cantor
27 January 2008

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ABBREVIATIONS AND NOTATION

mm	millimetres
m	metres
mW	milliWatts
O_c	Projection focal point
x_f, y_f, z_f	Focal plane coordinate frame axes
x_i, y_i, z_i	Image plane coordinate frame axes
x_w, y_w, z_w	World frame axes
x_c, y_c	2 dimensional image camera frame axes
f	Focal distance
fx	Focal distance in pixels (using the scale in x)
fy	Focal distance in pixels (using the scale in y)
α_x	Image scale in x (pixels/mm)
α_y	Image scale in y (pixels/mm)
$\mathbf{R}$	Rotation matrix
$\mathbf{T}$	Translation matrix
•	Dot product
$\otimes$	Cross product
$\|\ \|$	Norm

ABSTRACT

Robotic welding may be used to enhance quality and improve operating conditions in manufacturing and repair situations. However, it may be difficult to implement robot automation for some applications which involve non-repetitive tasks such as in repair and reclamation work. The present work was aimed to address some of the robotic automation difficulties that arise in such situations where it is necessary to rapidly generate a robot program for every different task, in particular for weld repair.

A technique for rapidly generating off-line robot programs for weld repair was developed in this work. The system proposed uses a single camera in order to obtain information about the object to be welded. To perform the task, it is not necessary to know the geometry of the system "*a priori*" although smoothness of the overall shape of the object is assumed. Artificial feature points are used with the aim of being able to obtain the characteristics of the shape of the object in 3 dimensions.

A software application was developed which provides the system with an easy to use interface, sequence control and data processing which in combination with a vision system and a tactile technique allows weld repair jobs to be performed on complex curved surfaces.

A review of two camera calibration techniques was carried out as well as a review of commercial devices and techniques used to map 3D surfaces. A modification to the

planes camera calibration method was suggested and tested. Two methods to estimate 3D coordinates were review and tested, additionally a combination of these two methods was also tested. Results showing the errors obtained with the various combinations of camera calibration methods and 3D estimation methods were obtained. A technique to “unfold” a three dimensional surface (i.e. to create a two dimensional representation of a three dimensional surface) was proposed and used as an essential part of the image data processing. Tests were performed to evaluate the system and encouraging results were obtained.