國立高雄科技大學

機械工程系 博士班

博士論文

操縱機器人所需物件分類和量測機械視覺系統之開發

Development of machine vision systems on object classification and measurement for robot manipulation

研究生：吳玉武　　**Graduate student: Ngo Ngoc Vu**

指導教授：許光城 教授　　**Advisor: Prof. Quang-Cherng Hsu**

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中文摘要

本研究介紹了機器視覺系統在物體分類和機器人操縱測量方面的研究。首先，在不同的照明條件下開發了一套可用於金屬零件的自動分類和量測的機械視覺系統，並將其應用於具 6 個自由度（DOF）的機器手臂。為了獲得準確的定位資訊，整個圖像藉由工作平台上方的 CMOS 攝影機來進行取像。本研究中亦探討不同照明條件下對本系統的影響，在正向打光的條件中有四種不同的打光狀態，且在每種條件，皆使用全域和局部閾值來獲得較佳的圖像品質。研究中主要利用張氏方法、線性轉換函式與二階轉換函式來取得影像座標與世界座標的關係。

實驗結果顯示，在背向打光相較於前向打光其所獲得的物體中心更為準確，而在校正結果的部分，二階轉換函式比其他校正方法更準確。透過使用二階轉換函式的校正偏差，在 X 和 Y 軸其最大正偏差分別為 0.48 mm 和 0.38 mm 而最大負偏差分別為-0.34 mm 和-0.43 mm。

本研究亦開發了一套機械視覺系統於六自由度(DOF)的機械手臂用以進行物件顏色的分類和座標的量測。整個圖像藉由工作平台上方的兩個相機以藉此獲得準確的定位資訊，並在二維(2-D)和三維(3-D)的校正過程中採用二階轉換函式與透視投影法來建立影像坐標和世界坐標間的關係。在二維校正的部分，於 X 和 Y 軸上的最大正偏差分別為 1.29 mm 和 1.12 mm；而最大負偏差分別為-1.48 mm 和-0.97 mm。在三維校正的部分，X，Y 和 Z 方向的偏差分別為 0.07、-0.418 和-0.063 mm。本研究所提出的視覺識別系統可以對物件進行分類並取得該物件之三維坐標。

關鍵字：機械視覺、機械手、相機校正、影像分析、物件分類、光源

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Department of Mechanical Engineering

National Kaohsiung University of Science and Technology

ABSTRACT

This research presents development of machine vision systems on object classification and measurement for robot manipulation. Firstly, a machine vision system for the automatic metal part classification and measurement process is developed under different lighting conditions, and has been applied to the operation of a robot arm with 6 degrees of freedom (DOF). In order to obtain accurate positioning information, the overall image is captured by a CMOS camera which is mounted above the working platform. The effects of back-lighting and front-lighting conditions to the proposed system were investigated. With the front-lighting condition, four different conditions were performed. For each condition, global and local threshold operations were used to obtain good image quality. The relationship between the image coordinates and the world coordinates was determined through Zhang's method, the linear transformation and the quadratic transformation during the calibration process. Experimental results show that in a back-lighting environment, the image quality is improved, such that the positions of the centers of objects are more accurate than in a front-lighting environment. According to the calibration results, the quadratic transformation is more accurate

than other methods. By calculating the calibration deviation using the quadratic transformation, the maximum positive deviation is 0.48 mm and 0.38 mm in the X and Y directions, respectively. The maximum negative deviation is -0.34 mm and -0.43 mm in X and Y directions, respectively. The proposed system is effective, robust, and can be valuable to industry.

The second, a machine vision system for color object classification and measurement process for robot arm with six degree of freedom (DOF) is developed. In order to obtain accurate positioning information, the overall image is captured by a double camera C615 and a camera C525 which are mounted above the working platform. The relationship between the image coordinate and the world coordinate is performed through calibration procedure. The quadratic transformation and generalized perspective transformation algorithms were used to transform coordinates in 2-D and 3-D calibration process, respectively. According to calibration results, with 2-D calibration, the positive maximum deviation is 1.29 mm and 1.12 mm in X and Y directions, respectively. The negative maximum deviation is -1.48 mm and -0.97 mm in X and Y directions, respectively. With 3-D calibration, the deviation is 0.07 mm, -0.418 mm, and -0.063 mm in X, Y and Z directions, respectively. The proposed system can catch the three dimensional coordinates of the object and perform classification and assembly automatic operations by the data from visual recognition system.

Keywords: machine vision, robot arm, camera calibration, image analysis, object recognition, lighting source.

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