PhD Dissertation Defense

Development of a Position Sensitive Device and Multi-position Alignment Control System for Automated Industrial Robot Calibration

By

Erick Nieves

Advisor: Dr. Ning Xi

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Abstract

In our modern era, the complexity of industrialization has played an important role on developing a strong economy, typically related to technological innovation in manufacturing. Manufacturing in general, involves the development of large-scale productions utilizing industrial robots to create assembly lines. Generally industrial robots reach high repeatability levels and for repetitive applications, they are able to perform such tasks successfully. Certainly repeatability demonstrates the quality of a modern robot and their precise positioning capabilities. However, it is also well known in the robot industry that industrial robots have high repeatability but low accuracy. Nevertheless, the recent demand of high accuracy applications such as welding tasks, micro assembly operations, surgery, etc. have increased the importance and interests of robot calibration among researchers over the last decades. Although there have been significant improvements in terms of accuracy on the newly designed industrial robot models, for such high accuracy applications, the accuracy of the robot alone is not enough. While there are several sources of inaccuracies, the main source of inaccuracy lays in kinematic model
parameter errors. According to researchers, around 90% of the inaccuracy in robot positioning is mostly due to errors on assumed initial joint values of the robot. Without an appropriate robot calibration, any robotic system will experience accuracy degradation over time. Due to this fact, robot calibration has been used to improve position and orientation accuracy of industrial robots by identifying inaccuracies in the kinematic model parameters in order to create a more accurate model that better fit to the real robot. This dissertation proposes a novel calibration system approach capable of automatically calibrating industrial robots. Often, wrong assumptions on real links parameters or even small offsets exist in the individual robot joints that lead to errors in the internal kinematic model equation and as consequence, affecting the accuracy of a robotic system. To solve this problem, the proposed approach introduces a completely new technique for industrial robot calibration. The proposed system consists of an industrial robot manipulator, a camera, a laser fixture attached to the robot tool center point (TCP), a PC-based interface, and a new position sensitive calibration device (PSCD). This wireless calibration device comprised of 2 fixed position sensitive detectors (PSD’s) tilted with an angle between them to reflect the laser line from one PSD to another. Such device is capable of feeding back the movement information needed to localize the TCP frame relative to the device frame. The new calibration approach is not only able to compute the joint offset parameters of the robot, but is also capable of simultaneously calibrating the robot's workpiece relationship. It was also designed to be faster, simpler and cheaper than any other state of the art calibration systems. Throughout this dissertation our newly developed calibration device, the principle of our calibration system and the control approach needed to achieve automation of the entire system is presented and discussed. Finally, experimental results demonstrated the feasibility of the overall calibration system including device hardware, software and calibration algorithms.
International Conference Presentations:

- Development of an omni-directional 3D camera for robot navigation. Zhang, Chi; Xu, Jing; Xi, Ning; Jia, Yunyi; Li, Weixian; Advanced Intelligent Mechatronics (AIM), 2012 IEEE/ASME International Conference on 11-14 July 2012.

Publications:

- Industrial Robot Calibration Using a Virtual Linear Constraint. Du, Biqiang; Xi, Ning; **Nieves, Erick;** International Journal on Smart Sensing and Intelligent Systems (s2is.org). December 2012, Vol. 5, No. 4, Page(s): 987 - 1001.
Professional Poster Presentations:

- *A reflected laser line approach for industrial robot calibration.* Nieves, Erick; Xi, Ning; Engineering Graduate Research Symposium on 09 Nov. 2012, MSU Breslin Center, East Lansing MI.

- *Design and development of a wireless device for automatic robot calibration.* Nieves, Erick; Xi, Ning; Michigan State University Graduate Academic Conference on 15 Feb. 2013, The Kellogg Hotel and Conference Center, East Lansing MI.

Patents:

- *Calibration System and Method for Calibrating Industrial Robot. (U.S. Patent Pending).*