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Enhanced absolute accuracy of an industrial milling robot using stereo camera system

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Abstract

In this publication an approach for increasing the absolute positioning accuracy of an industrial milling robot with help of a stereo camera system is presented. To measure the position and orientation of the robot tool center point, a specific adapter with retro reflective markers is mounted on the spindle. The calculation of the transformation of this target holder to the robot tool is part of this paper along with the calibration from the robot to the camera system. These datasets serve as the basis of a static pose control, where the robot absolute accuracy errors will be greatly reduced.

Keywords: Automation; Photogrammetry; Robot accuracy; Hand-eye-calibration; 6D-pose-measurement; Static robot control

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1. Introduction and scope of the work

The high demand of efficient large scale machining operations by concurrently decreasing operating time and costs has led to a new strategy to use simultaneously machining industrial robots in contrast to specially designed large scaled portal machining centers since they are less expensive and more flexible (see Figure 1). The main disadvantage of calibrated industrial robots used for machining processes is their poor absolute accuracy, caused by the serial construction, low structural stiffness and gear backlash [1]. One option for an external feedback to increase the robot absolute accuracy can be found in the recent advancements in the field of photogrammetry combined with faster, low cost cameras and high computation power, delivering fast, highly accurate position measurements in a relatively large volume.

This paper introduces the concept of a stereo camera system using the principles of stereo photogrammetry to determine the position and orientation (pose) of the robot tool center point (TCP) externally. In the experimental setup an industrial robot with a milling spindle is used. The camera system measures the position of retro-reflective targets which have been applied to a target holder specially designed for highly accurate pose measurements and high orientational accuracy. This target holder is mounted on the milling spindle next to the robot TCP and hence is observable during machining processes by the camera (see Figure 5).

Additionally, a lasertracker system is used to calibrate pose relationships between the workpiece, the robot and the camera system as well as the pose relationship between the TCP and the milling tool. The calibrations and algorithms developed in this work demonstrate a precise way to calculate the absolute pose of the robot TCP with respect to the workpiece with help of the stereo camera system. A “Look Then Action” type iterative control strategy will be presented using repeated measurements of the robot end-effector in steady state. The camera system provides the actual position along with the intended target position from the robot control system, a target-actual comparison directly shows the positioning error. The iterative control strategy implemented in this work is helpful to analyse the behaviour of the realized controller.

Advanced validation algorithms allow the monitoring of the accuracy during the process, with both the stereo camera system and the lasertracker to detect absolute positioning errors of the robot. The goal is to show that the robot position accuracy can be brought down to the magnitude of the total camera measurement inaccuracy.

2. State of the art and motivation

2.1. Machining of large CFRP components

The transportation industry is opting more and more for lightweight materials such as composite materials which provide significant weight reduction without reducing the strength and stiffness [2]. In many industries like aerospace, construction works, railway transportation, automotive and military large scaled components made of CFRP are often preferred over conventional sheet metal due to their superior properties. Currently, machining processes are executed mostly by large gantry machining centers that show some specific inadequacies [3]. The construction of typical special machinery needs heavy duty foundation to absorb the high loads of the steel-made portals. Additionally the productivity of these machines is low, owing to the impracticalities involved in setting up a parallel machining process as only one machine can work on one part at a time.

Flexible robotic systems would be able to overcome disadvantages of gantry machines as stated above. There are first attempts to develop mobile platforms, which can move entirely free in the production plant like in the project ProsihP II[†]. These mobile platforms are equipped with robotic systems which will perform the machining process once brought into position.

[†] ProsihP II: “Prozesssichere hochproduktive Präzisionsbearbeitung von CFK Großstrukturen”, Niedersachsenförderung: ZW 3-80140004