Absolute interferometry for a flexible in-process robot calibration

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Abstract

Highly individualized and customized products with dynamic lifecycles increase the need for flexible and reconfigurable assembly systems. Industrial robots are a key technology for future production systems especially for large scale components. The trade off between increasing work piece dimensions on the one hand and increasing tolerance requirements on the other, that are in some cases comparable to micro assembly systems, has to be solved by flexible and precise manufacturing and fixtureless assembly processes.

1. Assembly of large scale parts

The achievable accuracy of a robot based assembly system is influenced by the weight of work pieces and end-effectors, process forces, gravitation and temperature of the surroundings. Manufacturing, handling and assembling processes of large scale parts often take place in production sites with harsh environmental conditions. Temperature changes are influencing the handling kinematics as well as the work piece geometry[1]. The deflections lead to inaccuracies during the handling and assembling process that complicate the compliance with the required tolerances[2].

It is possible to improve the positioning accuracy of the robot kinematics by the use of Global Reference Systems (GRS). The GRS defines a communication network for the exchange of information such as the position of manipulating machinery and non-manipulating devices of a production system. For manipulating machinery, large-volume measurement systems [3,4] such as indoor-GPS (iGPS) and laser trackers are especially suitable [5,6,7]. The integration of the measurement technologies is expensive and the measurement uncertainty is generally >100µm already without the influence of very harsh environmental conditions. The presented approach is supposed to have a reduced measurement uncertainty.

2. Design of a "virtual metrology frame"

In the 1960's BROWN describes the idea of a "virtual metrology frame". GREENLEAF illustrated the principle of a selfcalibrating surface measuring machine in 1983 as shown in figure 2 [7]. The concept bases on the multilateration principle.

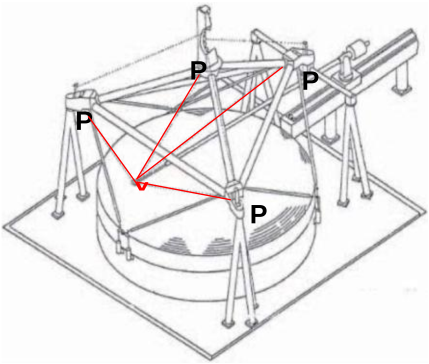

Figure 1: Greenleaf's selfcalibrating surface measuring machine of 1983 [8]

The "virtual metrology frame" of the present approach is based on the "High-Accuracy CMM" presented in 2000 by Hughes from the National Physical Laboratory, UK. The position of the TCP equipped with retro reflecting targets is tracked and measured by fixed measuring stations spaced at appropriate positions around the working zone of the robot kinematics. As Hughes pointed out the virtual metrology frame approach will use eight measuring stations or better eight "line of sights" to achieve a six-degree-of-freedom measurement capability[9].

3. New measurement technologies for maximum precision

A new measurement system (Absolute MultiLine) based on frequency scanning interferometry (FSI) seems to be capable for a reconfigurable, fast and very precise calibration of a number of robot kinematics in the same working space. The measurement system is able to measure 24 absolute lengths with an uncertainty of U=0,5+0,5µm/m. The fundamental elements of the measuring system are the laser-interferometer-based tracking stations, retro reflectors and a mathematical approach to enable the determination of the spatial coordinates of the measured points. The first set up will use four line of sights to enable a accurate evaluation of the 3D position of the robots TCP in the working space. The tracking of the targets bases on the operational control data of the robots.

Figure 2: Actual static set up of a “measuring line”

The tracking kinematic must provide stable, accurate and continuous changes in angle of the beam in the horizontal and vertical direction. The angle changes should be initiated individually by two powertrains. The objective is to produce these kinematics at affordable costs to build up a measuring system, that provides a number of trackable “line of sights”. The later test set up should consist of four robot kinematics working in one working space.

A first test rig was build to investigate the needed accuracy of the kinematic for a sufficient intensity of the reflected signal. The target was mounted into a high precision linear “mover”(Fig 4).

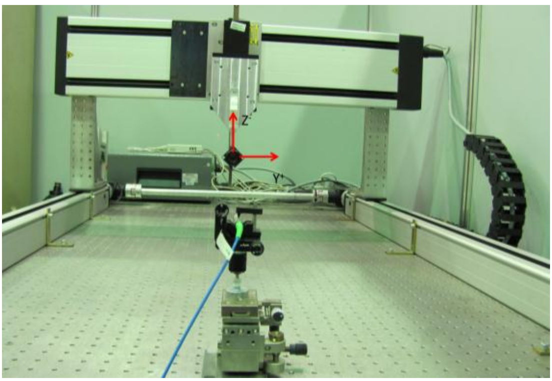

Figure 4: Test rig with a high accuracy linear drive axis and a mounted target

The collector was mounted on the optic table in a defined distance to the target and centered in the position of the highest reflected intensity. The target was then moved in steps of 10µm in Z-direction and Y-direction. The intensity of the reflected signal was measured and combined to the relative position of the target (Fig. 5).

The results show that the tolerance range for the positioning of the laser beam relative to the optical center of the used target can be named as a circle of a diameter of 1mm. This knowledge was used to design and choose the components for the tracking kinematic.

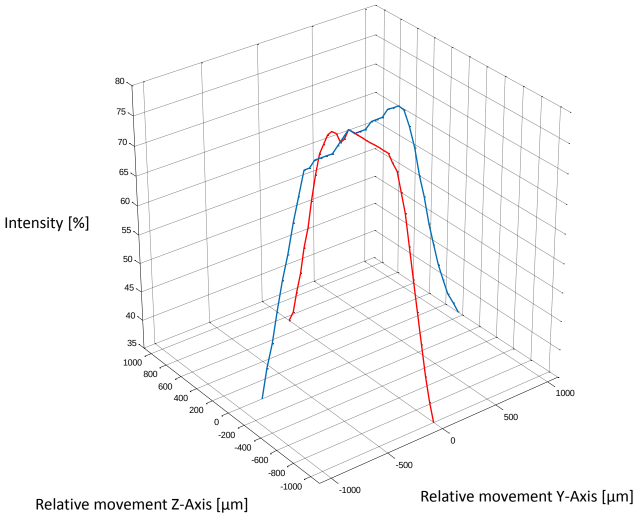

Figure 5: Intensity oft he reflected signal depending on target movement

Beneath the accuracy of the used rotary axis the accuracy of the later kinematic is influenced by the precision of the assembly of all components. The end of the fiber inside the collimator has to be placed in the pivot point of the rotary axes. To assure the correct location a calibration method for the tracking system has to be developed. The possible deviations and resulting errors can be compared to the example of a laser tracker. In 2011 Hughes et al. developed a method for the calibration of laser trackers by using a network to determine the mechanical errors of the kinematic[9].

4. Outlook

The presented concept will allow the compensation of system deviations in absolute positioning by implementing a measurement system based on absolute interferometry into the assembly process. The compensation will improve the positioning accuracy of the robot kinematics and in order the accuracy of the assembling process. The calibration of the designed kinematic has to be investigated as well as the validation of the mathematical approaches for the tracking of the moving target. The simulation of robot paths and line of sights of the measuring system will provide an improved assembling process by an adaptive path planning of the cooperating robots.

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