

Real-Time Robot Positioning based on Measurement Feedback Control

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ABSTRACT

Industrial robots are well introduced into automated production processes. Their mechanical design is dominated by some major key factors like required flexibility, different payload demands, working range, working speed, combination with different working tools and robot costs. The final achieved position accuracy of the robot tool centre point (TCP) is based on the combination of these key factors. In general, the smallest movement steps and the repeatability of robots are much lower than the absolute achievable accuracy. The positioning results and especially the programmed paths of the TCP show relatively large differences between the programmed nominal paths related to the final achieved movements in reality. These differences can be detected using the Absolute Tracker with its very high dynamic performance, especially if the 6DoF capability is included.

Each set of tracker measurements (X, Y, Z, i, j, k and the timestamp t) are describing the true position and orientation of the measured object in space. The data rate of 1000 measurement per second allowed always a very accurate observation of relatively fast movements. For all inspection tasks and for static positioning processes a short time delay until the measured data are shown on the screen and stored in the computer doesn't have any impact on the results. To correct and improve robot positions during the movement, measurement data have to be available in real-time that it is possible to use these measurements as an input for a feedback control loop. Since last year the Absolute Tracker provides such a real-time interface with a maximum data rate of 1000 Hz via an EtherCAT fieldbus.

Meanwhile several implementations are realized, mainly within research projects to gain first experiences and proof which improvements are achievable. It was immediately recognized that now the robot controller becomes the bottleneck because its capability to react on control commands is the limit now. In addition each robot supplier has its own interface and specific commands available. The best and ultimate solution to reposition the robot TCP in real-time would be develop a robot independent device like a specific end-effector which allows a fast feedback control based on the measurement results with a relatively small working range of about 100 mm. We started now to develop a first model of such a real-time controlled end-effector and want to introduce this idea and hopefully show first results.

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INTRODUCTION

Correction of dynamic movements of industrial robots is strongly dependent on the used robot model, type and manufacturer. Each robot control of different manufacturers varies in interface customisation and algorithm philosophy. Angle representation formats are only one part of this. From an external correction view on the system, with a given task to manipulate the robot movements in terms of tool center point correction, it creates a difficult problem to cover multiple robot types.

The sticky wicket in this is how to communicate to the robot in real-time application and how to set or read needed parameters of the robot control. Resulting, most correction systems are focussing on one

robot manufacturer and most of the times even to one certain group of robot models. A further step in the way of creating intelligent and flexible correction systems for online robot guidance is to find a robot-independent solution to generate corrections and apply them to the system with minimum or no interaction to the robot at all.

ACTIVE TOOL

Given a standard industrial robot for dynamic applications with high path accuracy and a lot of feedback forces like milling, grinding or drilling, the robot will not be able to move its tool centre point along its offline generated path. CAD-programs, used to create these theoretical paths are working and thinking in a theoretical world with

perfect circumstances and conditions, assuming the robot will perform the given movement with perfect path accuracy. Practical experiences in the

Last years mirror us the reality: Dynamic movements along a given trajectory are never performed perfectly, caused by robot flexibility, gear losses and a bunch of additional errors, which are defining the robot dynamic path accuracy, defined by special identification methods like {1 : ISO9283}. Also the object itself causes for additional positional deviation due to varying material hardness of changing feedback forces due to process parameters, e.g. cutting depth or drilling speed. In general, the occurring effects for changing feedback forces can be divided into two different categories: Low frequent force changes and high- frequent force changes.

Taking the example of milling a metallic object, the fact of shrink holes causes step functions in the feedback force profile applied on the robot tool and therefore high- frequent force changes. These changes are not possible to compensate fast enough by the robot, which will cause in additional positional deviations. Another case is low-frequent force changes, which are given by processes like starting a milling process and the combined dive of the miller into the material. Given this scenario, one can imagine an increasing feedback force on the robot tool, linear depending on the depth into the material.

The basic question at this stage is: “How to compensate these low-frequent feedback forces on the robot tool, with minimum interaction to the robot?”

One possible approach to this question is a complete external strategy. Assuming a positional and rotational deflection of the robot tool centre points during its dynamic processes, which are within a given range of some centimetres, an external, robot- independent position compensation of the robot tool would solve the problem. Lets stick to this idea: Moving the robots TCP along a given trajectory, we can compensate the path inaccuracy, if we are able to change the shape of tool. This means, changing the tool centre point coordinates in respect to the robot flange system, with keeping the once integrated transformation data for the TCP constant in the robot control.

By this, the deviation between robot tool transformation data and real geometrical shape of the robot TCP can be used to compensate the positional deflection in the application. More clearly: A physical robot tool deformation in the correct direction will put the real TCP on the desired path, while the robot does stay on its originally programmed path. It is a double minus effect: the robot THINKS he is on the right path, but the reality is cheating on him due to the physical effects. Our answer on this is changing the physical condition of the TCP to bring the real world back to the robot, so he also MOVES on the right path.

This physical deformation can be created by an “active tool”, which is capable to move and rotate the TCP in a certain range based on given correction values. It has to fulfil two major conditions: Cover the range of possible deviations and react on given correction values fast enough to avoid low-frequent positional errors.

Mechanical Design of the Active Tool

Like already discussed, this active tool has just to provide relatively small movements of a few centimetres, but it must be able to act very fast, based on external measurement results. This tool will be mounted to the robot flange and combine several fast moving axis with a short working range. The working device of the robot, for example a rotating spindle to polish an object surface is finally fixed at the TCP of the active tool (central moving point of the tool).

The basic movements of that active tool are three translations in X, Y and Z-direction. For the X and Y axis a small very light and fast two axis cross table device can be used. There are of the shelf units available, with magnetic or optical position detection sensors to measure movements very fast and better than $\pm 2 \mu\text{m}$.



Figure 1. X/Y Cross table from Jenny Science with $< \pm 2 \mu\text{m}$ position accuracy

In addition these axis are directly connected to a controller unit which is capable to act as EtherCAT master to provide and control data in real-time. The third axis in Z-direction will be perpendicular to the robot flange. An easy and very robust version could be realized with a hydraulic or pneumatic cylinder. To measure the movement and position of this cylinder a linear device could be used which could be controlled by the same controller unit like the other both axis.

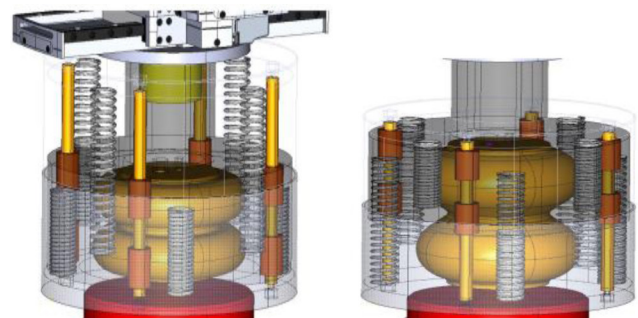


Figure 2. Z-axis device at maximum positions (left side Z = in, right side Z = out)