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A new Software Driven external Sensor System for Industrial Robots

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Abstract

For decades, laser tracker and working station have been the state of the art to measure externally the position disturbances in robotic systems. High system costs limit their usage for control systems in common production machines. We present details for an alternative software-driven approach. Hereby, we combine a new self-referencing, high-precision photogrammetry sensor system with a software system for camera placement layout and trajectory optimization. Furthermore, we outline the integration in a closed loop control system and corresponding strategies.

Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

1.1. Scope of this Paper

2. Process Perception

2.1. Optimized Perception

2.2. Metrological Error Estimate

3. Process Perception

3.1. Optimized Perception

3.2. Metrological Error Estimate

4. Process Strategies

4.1. Path Planning

There are severall error sources impeding the accuracy of a robotic manufacturing system. An overview of these sources can be seen in Fig. **??**. Most of these errors can be compensated using our external measurment system. This leaves the finite precision of the robot itself, whose contribution can not be compoensated but only mitigated. Previous works such as

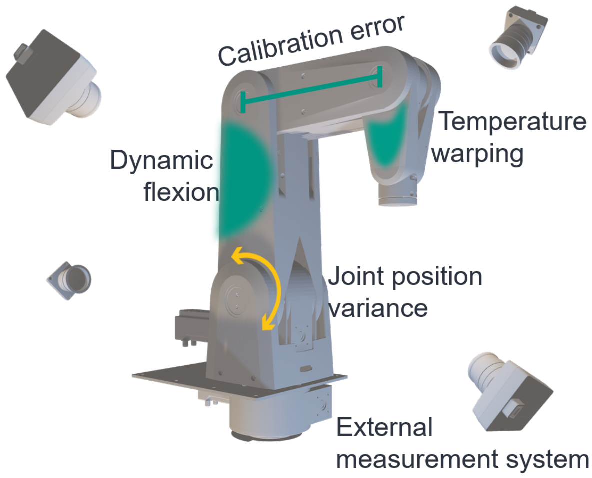

Fig. 1. Error sources in a robotic manufacturing system. Errorsources which can be compensated using external sensors are marked in green.

[**?**] have shown that the optimal repeatability of a path is dependent on the workpiece placement. This means that we can use the workpiece holding robot to reposition the workpiece in such a way that the optimal repeatability is achieved. It might be tempting to try to find a continous trajectory of this second robot to minimize the error. However the second robot also suffers under finite joint precision, while moving these will introduce additional errors. It is therefore better if the workpiece holding robot moves to a fixed position before the second robot starts moving. This leads to a two step process similar to the one described in [?]. Here the authors propose a 4 step process to path planning:

1. Cut path into multiple segments
2. Downsample each segment
3. Optimize the pose of each subpath and compute the joint path
4. Apply the new pose to the original segments

The division of the path into multiple segments was performed by identifying turning points using path simplification algorithms [?]. However instead of using the pose optimization algorithm described in [?] we use the problem formulation of [?] since it allows us to integrate more constraints which are later used for the joint trajectory optimization.

4.2. Camera Placement

After planning the path the two robots are bound to perform complex movements that might obscure some makers from the camera. It might even be the case that all markers are visible but that they are in regions where the camera system has a low measurement accuracy. To mitigate both problems we propose a software system that can optimize the placement of the cameras as needed. This system is largely based on the work of [?] and follows a two step optimization approach. However instead of only considering the condition of the triangulation equation as well as visibility we use the full error model described in section **??**. This allows use to way the benefits of repositioning against the aditional effort needed to do reposition and recalibrate the system. It also has practical advantages. Replicating the results of [?] where the smallest singular value was used as a measure of the quality of the camera placement we can additionally plot the largest angle to the optical axis. Here we see that the system always tries to find a tradeoff between minimizing the field of view angle while trying to maximize the smallest singular value. This is shown in Fig. **??**. In a unified error description this problem does not exist and the system can be optimized for the best possible accuracy.

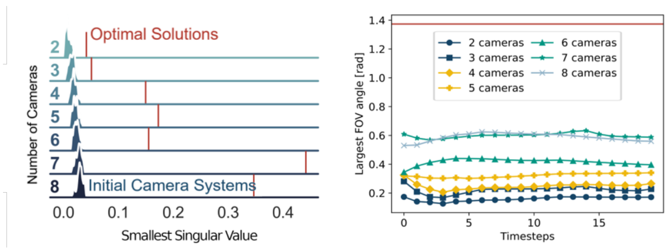

Fig. 2. The conflict between the field of view angle and the smallest singular value. Left: The smallest singular values of the system replicated from [?]. Right: The largest angle of a marker to the optical axis. Comparing both one can see that lower singular values correlate with lower maximum field of view (FOV) angles.

4.3. Trajectory Generation

5. Outlook

6. Online license transfer

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Appendix A. An example appendix

Authors including an appendix section should do so before References section. Multiple appendices should all have headings in the style used above. They will automatically be ordered A, B, C etc.

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