Kinematic Uncertainty Estimation of Laser Tracker Measurements using Control Information of an Industrial Robot

Dipl.-Ing. Thomas Ulrich

Motivation

Within the field of industrial metrology, laser trackers have long been used to measure kinematic tasks, such as tracking the movement of an industrial robot. This has been done without a particular focus on kinematic uncertainty. However, in order to develop a real-time correction method, or for process monitoring, it is important to have a clear understanding of the kinematic uncertainty of any laser tracker measurement. As this uncertainty is dependent on the actual process, e.g. via the velocity or acceleration, the information from that process has to be included, in order to make a sound assessment of spatiotemporal deviations.

Definition

The term ‘kinematic measurement’ can be interpreted in many ways. Here it is taken to mean the spatiotemporal measurement of a moving object and the results can be related to other measurements through a common time axis.

Objective

To develop an approach for the uncertainty estimation of kinematic measurements, which calculates the probability density function (pdf), regarding:
- the robot control information, as the uncertainty is reliant on the process
- the laser tracker model used
- the geometrical transformation between the robot and measurement space
- the synchronization between the robot time axis and the laser tracker time axis

Analysis method

A robot moving a reflector can be seen as a stochastic dynamic system, which can be analyzed using Bayesian filters to calculate a posterior probability distribution. This requires:
- A robot model that describes the evolution of the system over time.
- A measurement model relating the noisy measurements to the state.

Measurement model

Static influences
- Offset parameters
- Tilt deviations
- Encoder parameters
- Meteorological Corrections

Kinematic influences
- Deviation of the PSD zero point
- Delay time

Time variable model based on the state space vector which describes the process.

System model

The system model of the robot is used within the robot control to calculate the inverse and forward kinematic which is between the axis angles \( \theta \) and the Cartesian values \( X \) of the end effector. This means the output is used as the expected value and the standard deviation is estimated to be 300µm.

Example data

The experiment was conducted using a 6 axis industrial robot KUKA KR 5 arc and a laser tracker AT901 triggered every 16ms by the robot. Throughout the experiment the robot moves the reflector along the trajectory, defined as 28 key points, and trying to reach each key point as precise and fast as possible.

Interpretation

The deviations between laser tracker and robot show outliers at the beginning of each new motion segment, caused by slight jerks due to the rudimentary path planning approach.

Results

Manufacturer’s specification 15 µm + 6 ppm
Bayesian filter + control information + laser tracker model
Speed and Moving Direction

Deviation between laser tracker and industrial robot

Conclusion

A Bayesian filter together with the information gathered from the robot can greatly improve the estimation of the path’s uncertainty. This is because the new approach takes into account the kinematic behaviour, with an improved description of the measurement process itself and by incorporating the robot’s information. Therefore the estimated variance can be reduced when compared to the approximate specification. It provides an invaluable real-time distinguishing point as to whether the correction of the laser tracker is worthwhile or not.