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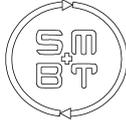
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Real-time seam tracking for robotic laser welding

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1 Introduction

Laser welding puts high demands on the robot or manipulator used, as it requires a high tracking accuracy (down to 0.1 mm) at high velocities (up to 250 mm/s). Sensors measuring the position of the laser focal point relative to the seam to be welded are therefore required to make robotic laser welding successful in a production environment. To use sensor information for real-time seam-tracking a special control architecture called trajectory based control has been developed. It uses a trajectory generator based on cubic interpolation, where Cartesian locations (position and orientation) can be added on-the-fly during the robot motion. This way sensor information obtained during the robot motion is used to generate the robot trajectory in real-time.

2 Trajectory based control

In the top half of figure 1 the robot trajectory is generated from a list of desired Cartesian Tool Locations (position and orientation) in the Motion Location Buffer. The real-time Setpoint Generator calculates smooth location setpoints ${}^B_S T_d(k)$ for the robot every 4 ms using the bounds for acceleration, velocity and deceleration in the Motion descriptor. It only calculates the next setpoint at the moment it is required. During the robot motion it is possible to add new locations to the Motion Location Buffer. From the Cartesian location setpoints ${}^B_S T_d(k)$, robot joint angle setpoints $\mathbf{j}_d(k)$ are calculated using the Inverse Kinematic model of the robot. These robot joint setpoints are the reference input for the joint motion controller. This controller, proprietary to

Stäubli, includes a setpoint interpolator and feedback control to assure that the actual joint angles $\mathbf{j}_m(k)$ track the reference $\mathbf{j}_d(k)$ as good as possible.

If properly synchronized [1], the measurements from the seam-tracking sensor ${}^S_C T(i)$ can be combined with the measurements of the robot joints $\mathbf{j}_m(k)$ into a seam location ${}^B_C T(i)$. After this synchronization, the measurement time is not relevant anymore, only the order in which the seam locations are obtained is important. By moving the sensor tool frame along the seam and storing the obtained seam locations in the Seam Location Buffer, a complete geometric seam description is obtained.

3 Real-time seam-tracking

For real-time tracking of a nominal (approximately known) seam trajectory, the sensor measures some distance (50 mm) in front of the laser spot. The measured seam locations ${}^B_C T(i)$ are filtered by the Predict Seam Trajectory block and added to the Motion Location Buffer. Simultaneously, it makes sure that the laser spot is kept on the just recorded seam trajectory and the sensor field-of-view is kept on the seam trajectory. As long as the Motion Location Buffer is not empty, the robot will track the recorded seam.

References

- [1] M.W. De Graaf, R.G.K.M. Aarts, J. Meijer, and J.B. Jonker. Robot-sensor synchronization for real-time seam-tracking in robotic laser welding. In *Proceedings of the Third International WLT-Conference on Lasers in Manufacturing*, Munich, 2005.

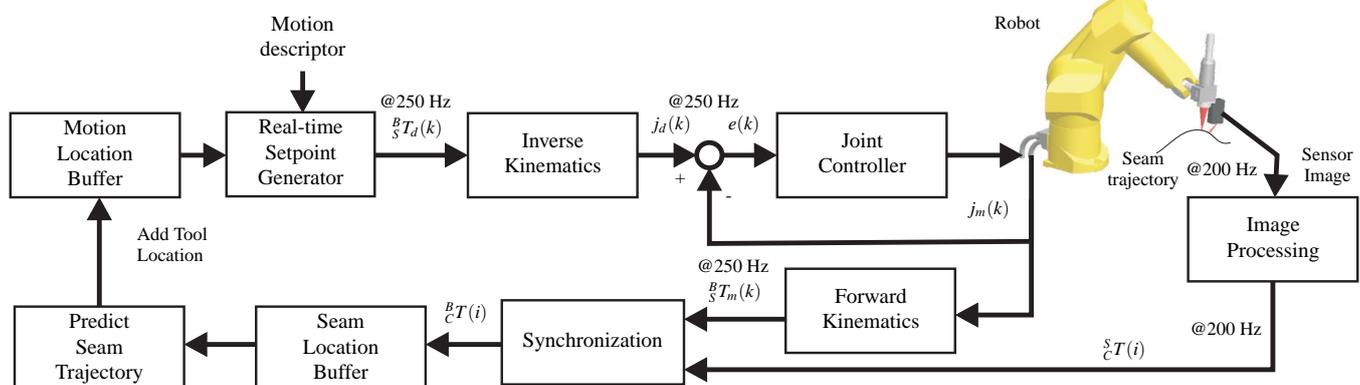


Figure 1: Trajectory-based control architecture