3DSSC (3D Smart Sense and Control)

Deliverable D1.3

Experimental System and Algoritm Description

3D Smart Sensing and Flexible Task Programming for On-Line Trajectory Adaptation in Fast Surface Treatment

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1 Experimental System

As mentioned in Deliverable D1.2, we designed a tool specifically for the application and integrated it in the setup, as shown in Figure 2. The tool prototype was tested on wooden blocks (mock-ups for the cheese blocks), which allowed us to find the appropriate process parameters. The tool also contains an outlet port connected to an industrial vacuum cleaner to evacuate the removed material (Figure 1).

The experimental system consists of a wooden block (resembling cheese blocks), the robot tool which is simply a box with three point laser sensors and an electrical motor which is driving a rotating wheel with two cutting blades (knives), and a light-weight KUKA robot (LWR).

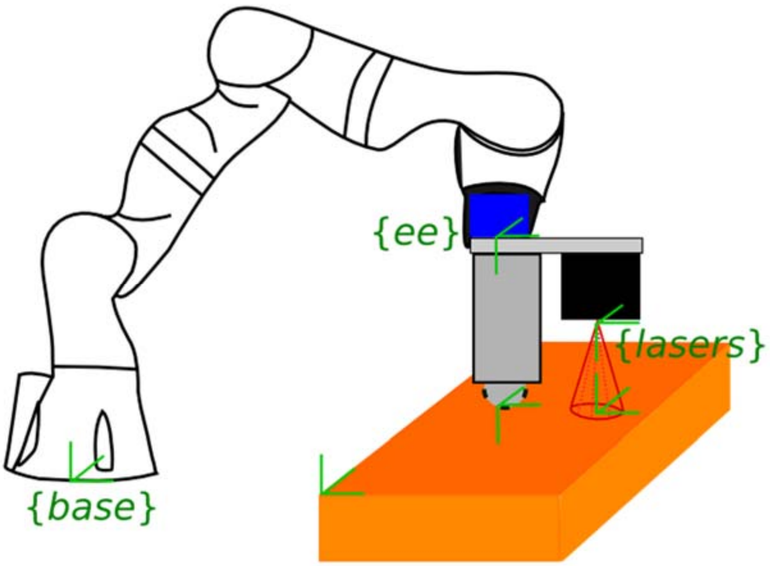

Figure 1. experimental setup: {lasers} indicates the pose of one of the three lasers used to measure the surface. The frame connected to the point on the tool where the knife touches the cheese block is also indicated.

The robot moves above the unknown surface and based on the data of the laser sensors, the surface is modeled in real-time. The available visualization of the whole setup in rviz [http://wiki.ros.org/rviz], also shows the measured laser points in real-time.

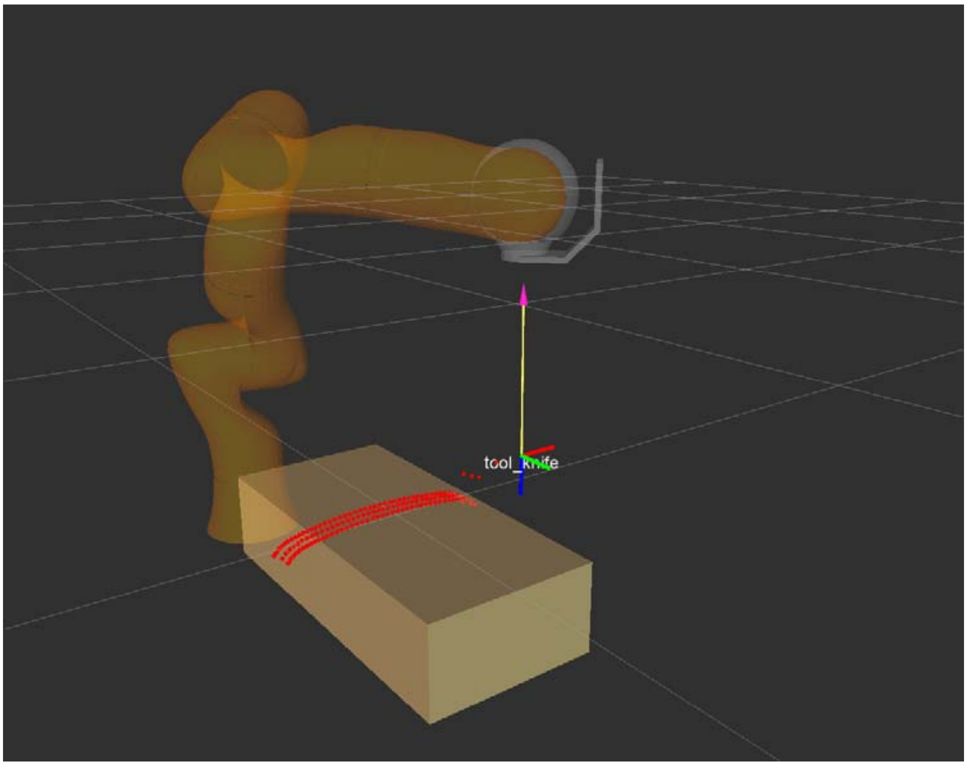

Figure 2: Rviz with real-time data of three laser sensors from surface measurement

The laser data enables us to follow the surface with the help of the higher-level task specification language (eTaSL) [1]. Initial tests were presented at the Hannover-messe industrial exhibition.

2 Algoritm Description

The algorithm contains two steps: surface modeling and control. The former constructs a 3D model of the surface of workpiece while the latter allows the robot to trace said surface.

Surface modeling

In order to model the surface, a small local patch of the surface is selected and modeled as a doubly curved quadratic surface defined with respect to a reference frame fixed to the cheese block. The local patch moves along with the knife. At the edges of the block (start and end of the motion strip) the local surface model extends beyond the edges, hence offering a virtual surface that can be used to define the approach and run-out motion for the cutting tool, i.e. the tool can already align itself with the 'surface' before it reaches the workpiece.

The graphical demonstration of laser data depicted in Figure 2, results in a model of the surface which is demonstrated in Figure 3. In this figure, the height of the cheese block with respect to a reference frame is represented as a function of the knife position along the direction of motion.

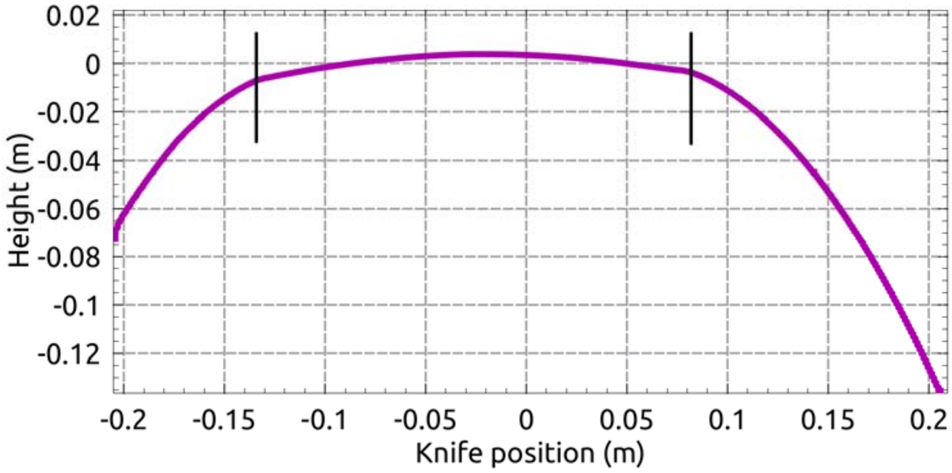

Figure 3: The estimation of the surface of a test-wooden block as a function of the knife position, both in [m]. The black bar show the start and end of the actual workpiece.

The extrapolated parts of the surface are visible in Figure 3 as parts with constant curvature, between vertical dark bars. Figures 4 and 5 show the calculated pitch and roll angles respectively.

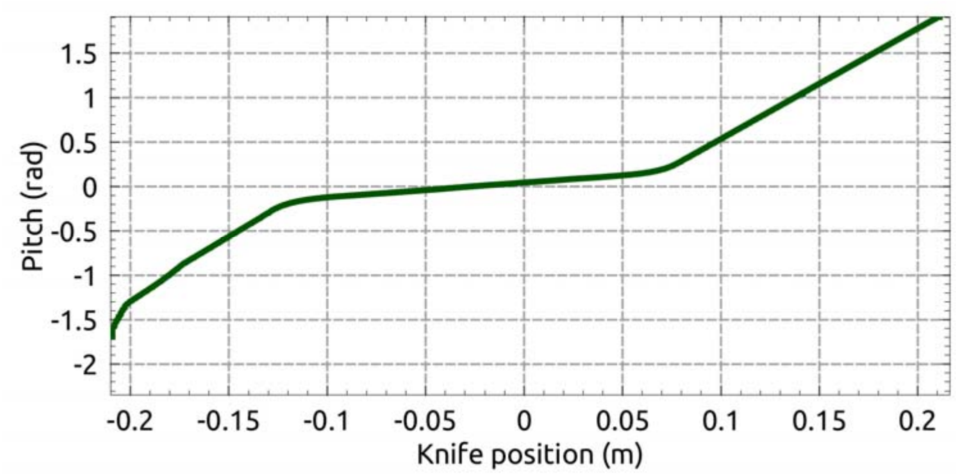

Figure 4: The estimation of the pitch angle, i.e. the angle along the trajectory.

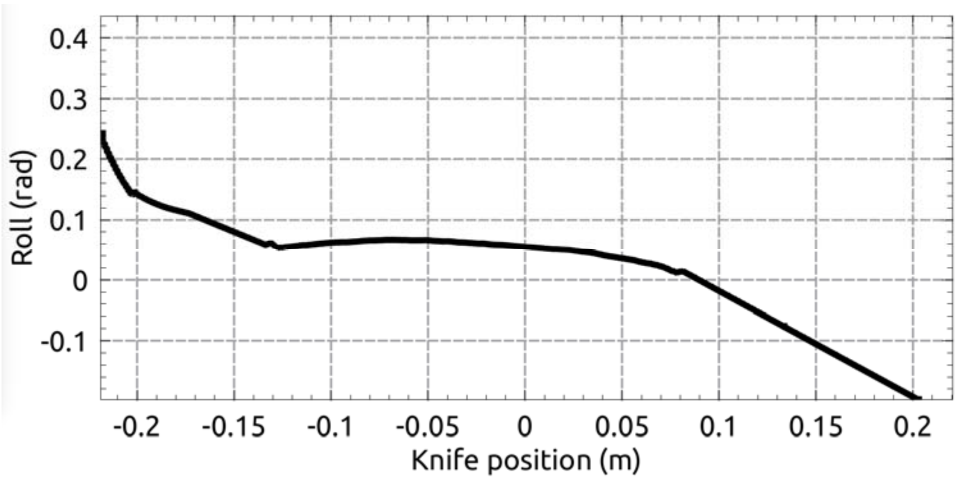

Figure 5: The estimation of the roll angle, i.e. the angle perpendicular to the trajectory or, alternatively, the rotation around the direction of motion.

Control

Once the knife has reached this patch on the surface, these local characteristics are used to modify the pose of the end-effector of the robot. The velocity in the direction of motion is kept as constant as possible, while the height and roll angle of the tool are adapted to the measured local surface.

Since the tool is rotational, one redundant degree of freedom (the pitch of the robot end effector with respect to the surface) can be chosen freely within a certain range without influencing the quality of the cut. This allows for additional constraints to be applied to this degree of freedom. To ensure the lasers at the front side of the tool are constantly receiving data, the pitch is adapted to keep the surface within the measurement range of the sensors.

Based on our iterations on the specification of the application in eTaSL, we defined the necessary extensions of eTaSL and the underlying software tools to make it possible to instantiate the application from this higher-level task description.

Status

The algorithm (surface modeling and control) is fully functional and has been tested in surface tracking experiments (i.e without actual cutting). The algorithm was demonstrated at the Hannover Messe (April 25-29 2016) on a KUKA LWR robot and performed well and robustly during the entire week. A demo video can be seen at https://goo.gl/tF7vI8.

Next steps

Currently, we are in the process of fine-tuning the control parameters and the applied constraints. Additional constraints, such as collision avoidance and solving the kinematic redundancy of the robot, are still begin tested and evaluated: it is paramount that these constraints do not influence the cutting trajectory and therefore the surface quality. At the time of writing, variable weighting functions are being tested to change the level of control based on the confidence the system has in the received measurements.

The quality of the local model will be validated using extensive testing. Possible improvements, such as higher order approximation of the surface in the cutting direction, are still being considered. We are also looking into variable trajectory generation based on prior estimates of the shape of the workpiece to boost the precision of the robotic system.