Embedded, Accurate and Safe Control System for a Commercializable 5-Axis Microsurgery Robot

Subject: Surgical Robotics
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A robotic manipulator for minimally invasive cochlea access for implantation of cochlea electrodes has been developed at the ARTORG center for Biomedical Engineering. The system has been successfully tested on cadaver heads, however, a design review for improved system safety and accuracy is required for the production of a commercial version of the system.

Materials and Methods

The main output of the risk analysis of the current robotic prototype and the resulting new safety concept is that absolute rotary position data at the axis level is required. It is additionally hypothesized that the use of absolute position data for motion control could enhance the positioning accuracy and repeatability of the robot. A single axis test bench, which emulates the mechanical structure of the first axis of the current robotic system, but with the proposed position sensor, was designed in order to perform. The axis can be controlled by both the current and proposed motion controllers to compare the positioning performance, which is measured with the high resolution position sensor RESA at the output of the axis.

Results

The comparison of the positioning showed clearly that the steady-state position error could be reduced by more than 99 % with the new control concept. The measured steady-state error, with the axis perpendicular to gravity (worst case) was found to be:
Epos: $\mu \pm \sigma$ (increments RESA) = 3.58E+2 ± 5.15
DCGB: $\mu \pm \sigma$ (increments RESA) = 8.07E-2 ± 1.12E-1

The new control structure was also shown to improve the distortion behavior of the system, since the axis could return to its start position after a heavy mechanical shock by a 1 kg metal hammer falling on the axis. Generally, the measurements showed that the new motion controller can position the axis within the resolution of the absolute rotary sensor, since $\mu < 1$ inc.

Discussion

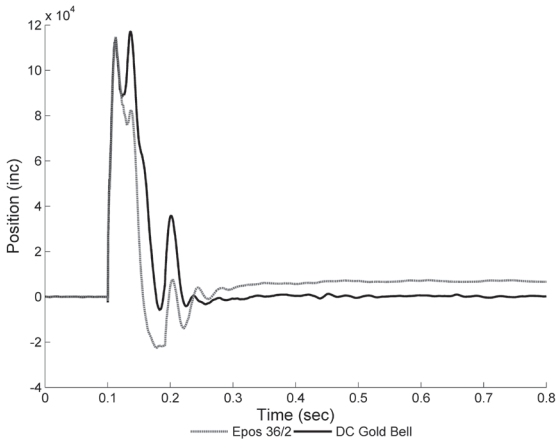
The dual feedback control structure, with an incremental encoder at the motor, to measure the velocity, and a high resolution absolute rotary position sensor at the output of the gear, promises a significant improvement of the positioning performance. A calibration procedure has to be developed in the future. The sensor can achieve an accuracy of 2.78E-4 degrees if the axis is calibrated with a laser measurement system and a corresponding error mapping, implemented directly on the motion controller. [1]

References

[1]Renishaw, ''White paper – The accuracy of angle encoders''. New Mills, United Kingdom, 2014.

Marco Matulic

Single Axis Test Bench



Stepresponse of the hammer test