“laserspotdetection.png”

Detection of the laser spot using the thresholding method with versus without Kalman filter.

“learningcontrolsetup.png”

Lab-based laser beam steering control. (a) Path following of the laser spot on a projection plane using the soft laser manipulator. The laser spot position can be determined based on the robot tip position and orientation measured with an EM tracking system. (b) Laser spot visual servoing is achieved with an MRI-compatible fiberscope.

“learninglasersteering.png”

Architecture of the proposed learning-based controller. (a) Overview of the learning-based model. The laser spot position in the camera view is varied by the laser manipulator. 2-D displacements of the laser spot, along with the soft actuation states, act as inputs of a multilayer perceptron which map to the actuation changes of each chamber. (b) The feedback control loop. With this learned inverse mapping, the proposed eye-to-hand visual servoing controller allows laser steering along paths prescribed in-situ by the operator.

“learningpathfollowing.png”

(a) Laser spot trajectories tracked with open-loop control (column 1 and 2), EM-tracked closed-loop control (column 3), and laser spot visual servoing control (column 4). (b) Associated tracking errors.

“learningzigzag.png”

Laser spot steering in a zig-zag pattern. (a) Laser spot trajectory tracked when filling the area of a batman shape with a zig-zag pattern. (b) Tracking error distributions in both the left-to-right and right-to-left paths. (c) Associated tracking errors over 10 minutes of tracking.