Abstract

Magnetic levitation is a recent technology which nowadays is used in high-tech systems. It is developed due to the inherent benefits of these type of setups such as lack of wear, friction and problems due to mechanical phenomenon as play and backlash. Achieving higher accelerations and ultra-precise position control while reducing maintenance.

At Owl Tech the goal is to develop a magnetic levitation system capable of six-degrees-of-freedom motion to be employed in positioning systems, such as a 3D-printer, for the consumer market. The system consists of an array of electromagnets with an iron core which by controlling the current through each can shape a magnetic field. The magnetic field is manipulated to levitate and position a platform with permanent magnets in six-DoF.

In previous research, the equations of motions for the platform have been derived. The equations of motion are a linearized version of the rigid body dynamics, allowing for translations and tiny rotations, subjected to external forces such as gravity, actuation and attraction forces. The actuation and attraction forces are non-linear with respect to the location of each permanent magnet. Finite element modeling was used to derive models for these forces with respect to the magnet location.

To measure the location of the moving platform an array of 36 Hall-effect sensors is employed. The output of each sensor is combined and through sensor fusion with an extended Kalman filter using an experimental measurement model the platform location is determined. The proposed extended Kalman filter of previous research is compared with an approach based on real-time optimization and a linear Kalman filter. With as argument that the EKF has no theoretical guarantee to converge and might give biased results whereas the optimization algorithm has guaranteed convergence towards to magnet location.

The localization algorithm is tested on the real system employing a positioning system. The positioning system performs a stroke while the algorithm is tracking the position. Resulting in an estimation accuracy error of $/pm1$ mm while the precision error is $/pm0.1$ mm.

The proposed control architecture of previous research consists of a feedback control loop based on a non-linear output mapping. The non-linear output mapping decouples the coupled input currents after which each degree of freedom can be controlled separately by single-input-single-output state feedback controllers.

In this research, a model predictive controller is proposed instead. A model predictive controller can deal with constraints inherently. Therefore it is capable of dealing with actuator saturation which would destabilize the system in the control architecture of previous research. Additionally, the MPC architecture is extended to the so-called tube-based model predictive control to achieve a robust model predictive controller.

Both control architectures are implemented in simulations and the real-system limited in two degrees-of-freedom and three degrees-of-freedom to test performance in regard of achievable bandwidth. In this analysis, the output uncertainty of the localization algorithm is taken into account. The results show that the system can be controlled and that the output uncertainty can be dealt with. The model predictive controller performs better achieving higher bandwidth due to the ability to perform at the saturation limits.