A Re-Engineering of the PID Controller Using a Novel 10-MF Fuzzy Logic Module for Regulating the Electromagnetic Force in Magnetic Levitation (Maglev) Vehicles

Kim, Ian (School: Wiregrass Ranch High School)

Since 2018, over 3000 trains have derailed in the US, causing nearly $650 million in damages. Maglev vehicles could be the solution, being able to be continuously regulated under a controller, but there is a lack of agreement on optimal controller structure. This study aimed to engineer a linear compound controller that had small error (<10^-3) in tracking an input signal by i) deriving a transfer function representation of a maglev vehicle and defining that as the plant on which controllers in this study will run, ii) constructing and comparing the performances of three variations of the linear Proportional-Integral-Derivative (PID) controller, one with the novel 10 membership-function Fuzzy Logic Controller (FLC) module, iii) constructing an LQR and comparing its performance to the most accurate PID controller, and iv) adding the FLC module onto the LQR and comparing its performance to PID-FLC. Using the transfer function in i), the PID controllers were tasked with following a reference signal (N=50) as accurately as possible, with PID-FLC being 11x more accurate ($p < 0.01$). PID-FLC was then compared to LQR tracking the same signals, where it was 13x more accurate than LQR ($p < 0.01$). LQR was then given the FLC module and tested against PID-FLC, where PID-FLC was 8.5x more accurate ($p < 0.01$). Thus, the gap has been narrowed by creating PID-FLC, as it was the most accurate controller in this study. Future efforts to close the gap may be in comparing the performance of PID-FLC against nonlinear controllers, or experimentally verifying simulation results from this study.