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Position Control and Force Allocation Algorithms for Hybrid Pneumatic-Electric Linear Actuators

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Abstract **–** It has been shown that hybrid pneumatic electric actuators (HPEAs) can provide both accurate position control and high inherent safety, due to their low mechanical impedance; making them a suitable choice to be used in applications such as collaborative robots. HPEAs are redundant actuators that combine the large force, low bandwidth characteristics of pneumatic actuators with the large bandwidth, small force characteristics of electric actuators. If these characteristics are mathematically modelled, input allocation techniques can improve the HPEA performance by intelligently distributing the required input (force or torque) between the redundant actuators. In this study, after developing a model for a HPEA-driven system, a model-predictive control (MPC) approach is designed that employ this model and solve the position tracking and input allocation problem using convex optimization. Another approach based on conventional linear controllers is included and compared. Although the linear controller was more computationally-efficient, it was inferior to the MPC-based controller in position tracking and force allocation performance. The MPC-based controller with a two-layer structure reduced the position RMSE by 59%, the mean absolute electric actuator force by 36%, and the mean absolute pneumatic actuator force by 24% relative to the linear controller. It can also be computed fast enough for real-time operation.

Keywords**:** redundant actuators, hybrid pneumatic-electric actuators, force allocation, model predictive control, collaborative robots