Experimental Demonstration of Eddy-Current Technology for Relative Positioning

Katherine Wilson and Mason Peck

Cornell University

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Conclusion

Rotating permanent magnets actuate relative position from a conductive client. Experiments demonstrate capabilities for lateral and normal force components in one degree of freedom. Analytical modeling confirms applications at centimeter-scale separations along the surface normal of the client. Future work will further geometrically isolate individual force components to improve understanding of system dynamics.

Background

Eddy-current actuation is an approach to propellantless, non-contact relative positioning. Time-varying magnetic field sources induce currents in a conductor and corresponding force components. Aluminum Micrometeoroid and Orbital Debris shielding provides the required conductive surface, which motivates applications for manipulation in microgravity. This work builds on applications for mobility and detumbling tasks [1-4].

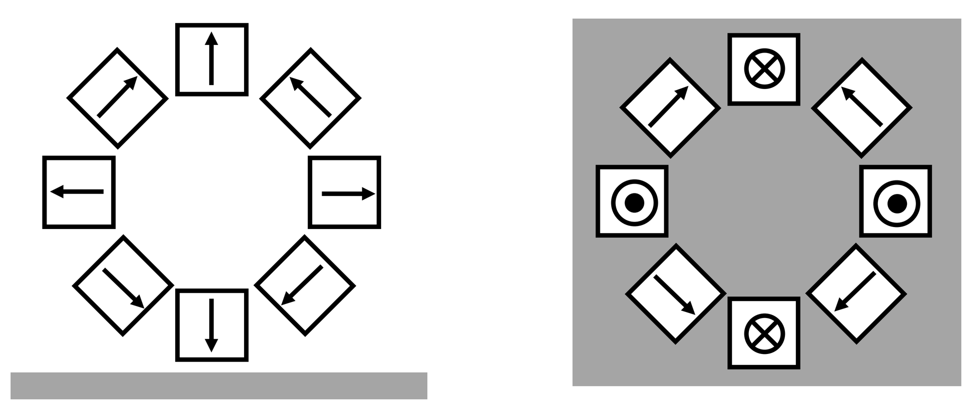

Figure 1. Tangential (left) and normal (right) permanent magnet Halbach arrays.

Methods

Table 1. Actuator Dimensions

Parameter	Value
Repulsion (R) Actuator	
Magnet dimensions	12.7 mm x 12.7 mm x 12.7 mm
Inner radius	18.2 mm
Mass of array	157 g
Stepper* power (900 rpm, 12.0 mm separation)	6.1 W
Tangential (T) Actuator	
Magnet dimensions	6.4 mm x 6.4 mm x 25.4 mm
Inner radius	9.7 mm
Mass of array	88 g
Stepper* power (600 rpm, 10.7 mm separation)	6.3 W
6061-T6 Aluminum Targets	
Dimensions of each target	152 mm x 152 mm x 2 mm
Mass of repulsion target	368 g
Mass of tangential target	406 g

*Other motor selections may improve performance

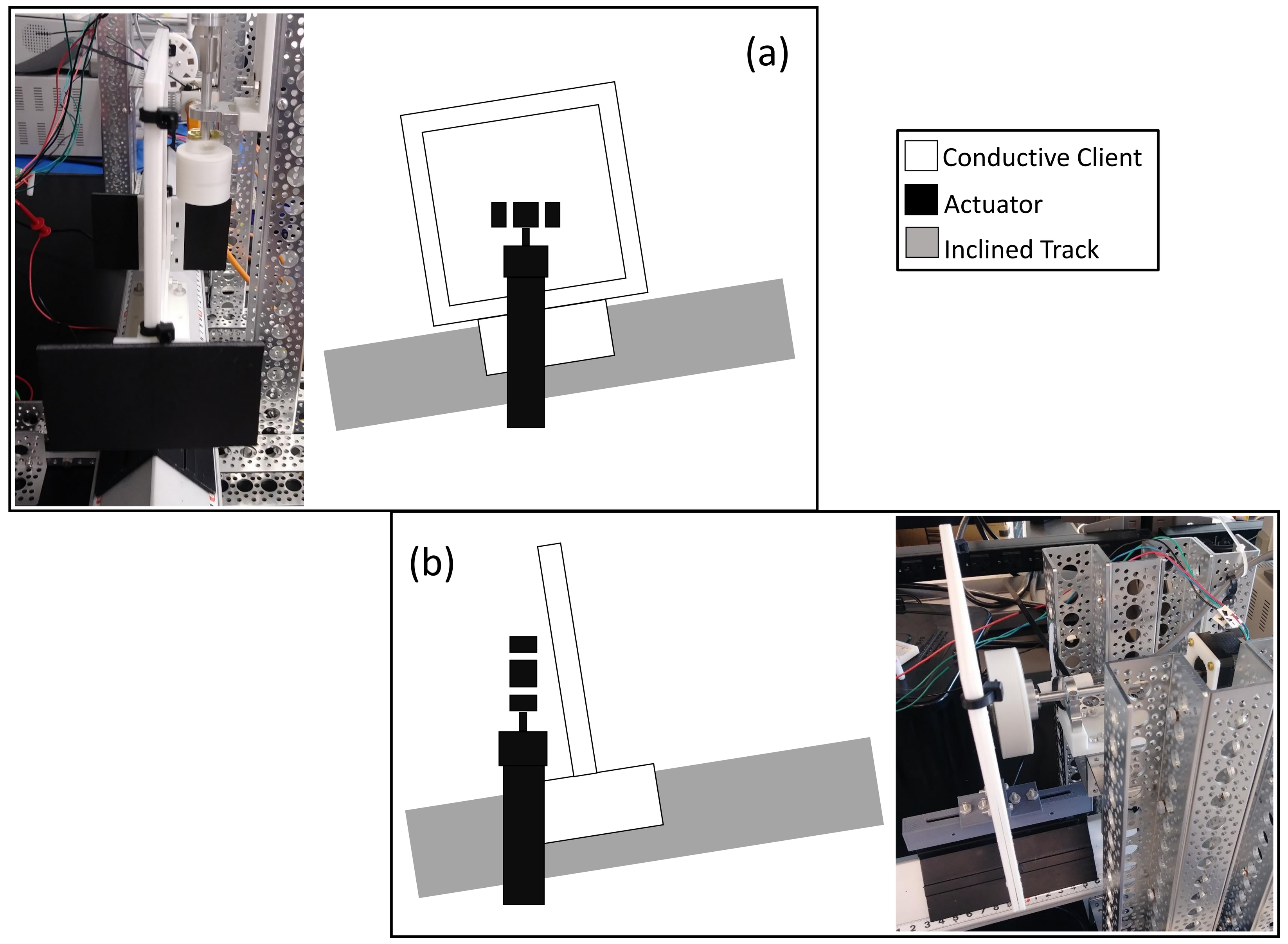

Figure 2. Tangential (a) and normal (b) air track test setups.

Actuator Models

Superposition of magnetic fields from individual magnets [5] provides the source field for an array. A charge sheet model [2] describes the force components due to the spatial Fourier transform of an arbitrary magnetic field source projected into two dimensions (B_s) with a reflection coefficient (R) for a given separation (d) from the conductive surface

$$F_R + jF_T = \int_{-\infty}^{\infty} R(\lambda, d)|B_s(\lambda, d)|d\lambda .$$

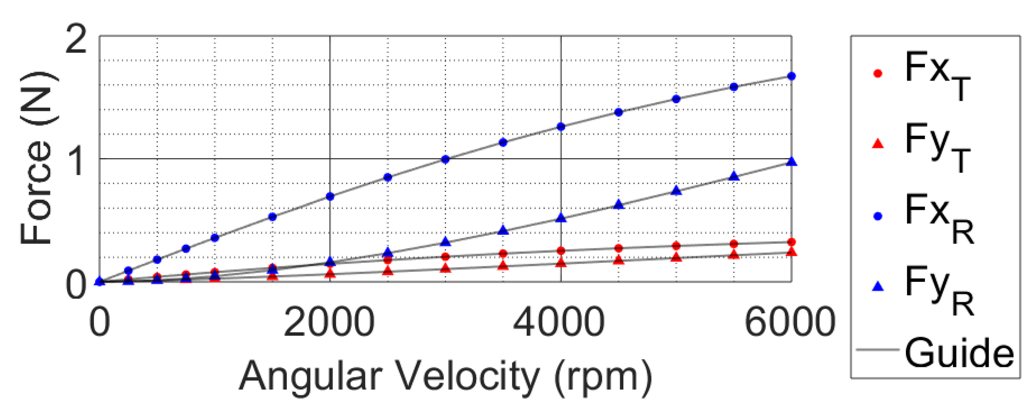

Figure 3. Tangential and normal force components over angular velocity with a separation of one centimeter and negligible relative velocity.

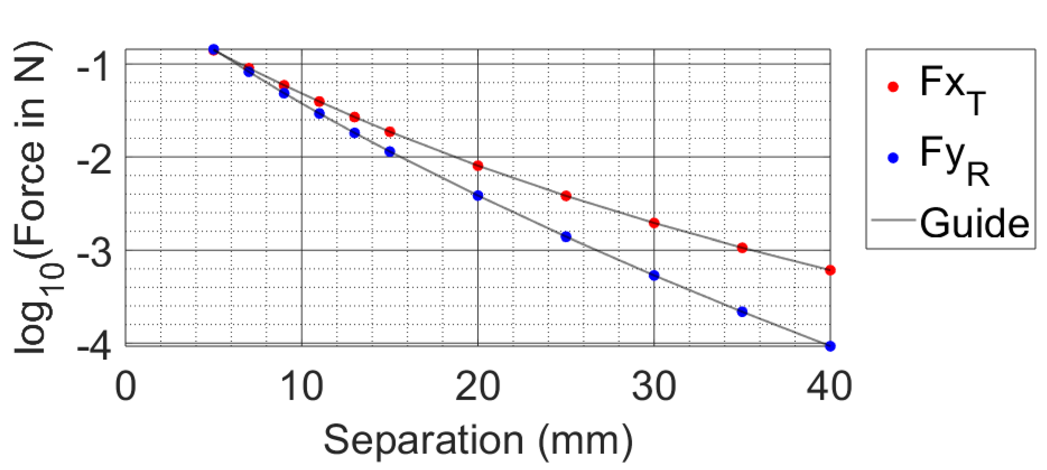

Figure 4. Tangential (600 rpm) and normal (900 rpm) force components over separation with negligible relative velocity.

Results

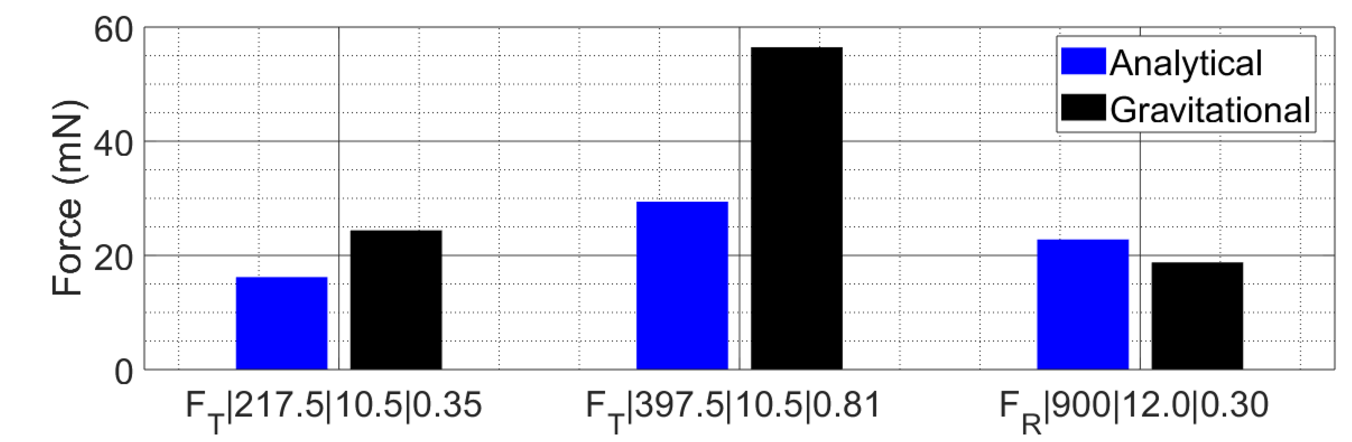

Figure 5. Comparison of the gravitational force due to the incline and the corresponding steady-state force components for each actuator. Labels give the actuator type|angular velocity (rpm)|separation (mm)|incline (°).

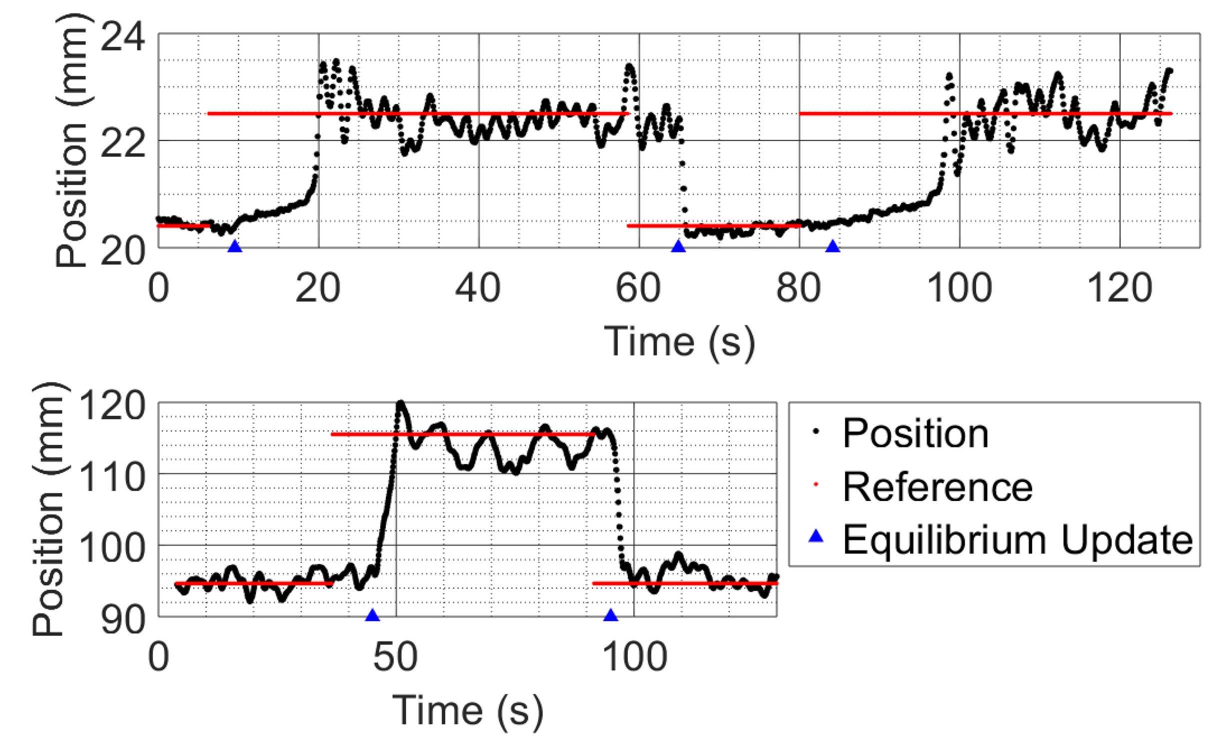

Figure 6. Normal (upper) and tangential (lower) position tracking at a 0.35° incline using proportional-derivative control for the linearized systems.

References

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Acknowledgements

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