Design of a Hopping Platform using Laminate Construction

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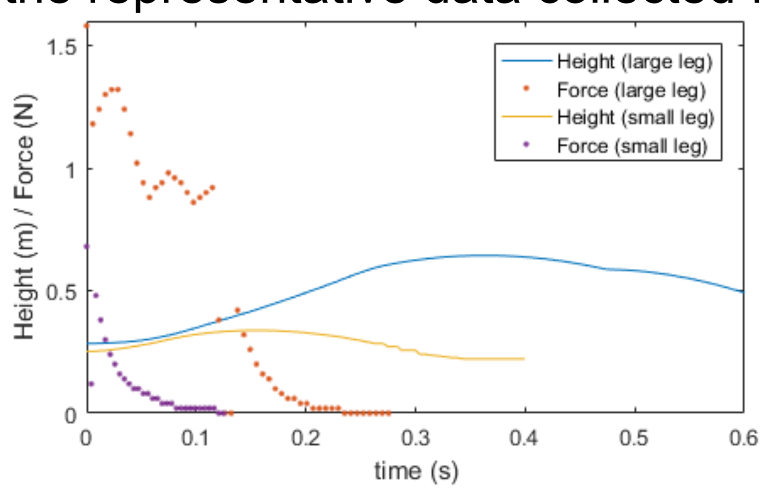
Method

Laminate devices have the potential to lower the cost and complexity of robots. Taking advantage of laminate materials' inherent flexibility, a high-performance jumping platform is developed. The platform is designed by simulating variable leg dimensions: first with a simplified single-mass, variable-force model and then through a full dynamic computer simulation incorporating variable lengths, masses, and flexibilities. The leg design variables are chosen from the simulation to optimize jump height. The platform's jumping ability is then tested and analyzed in comparison with the simulation results with the aim of improving the accuracy of the simulation predictions.

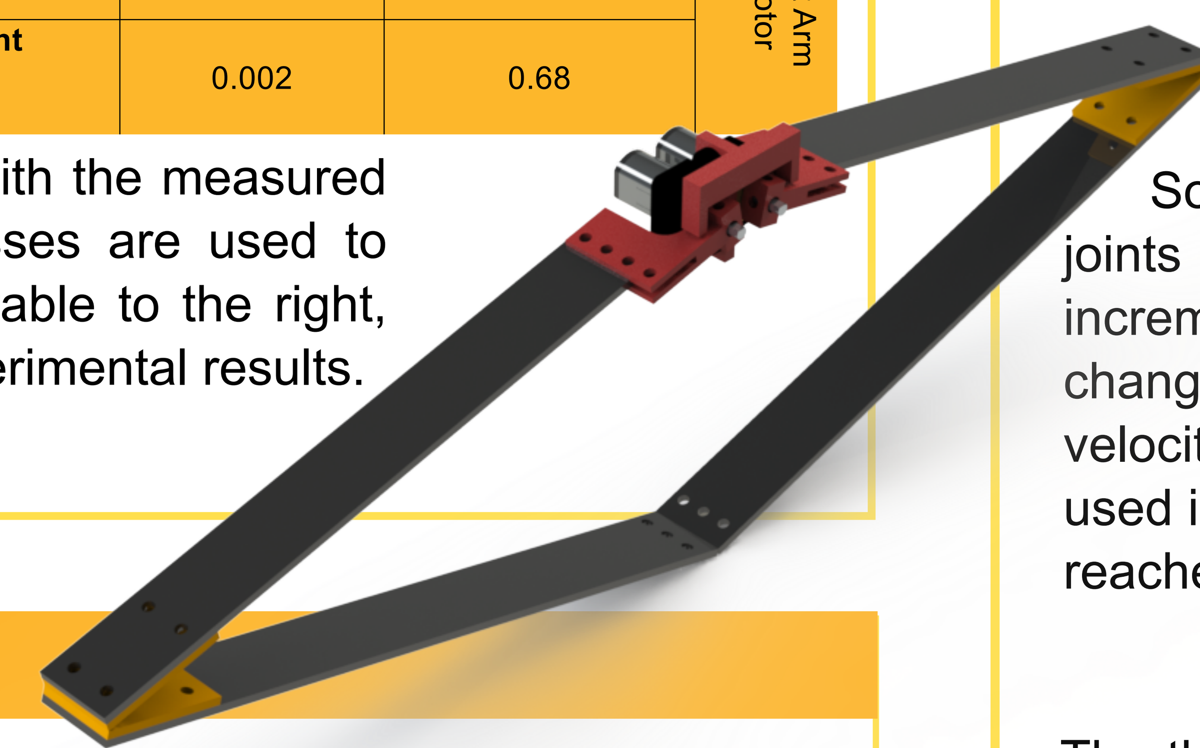
Experiment & Results

Two leg designs are selected and tested. The first uses 18 cm long moment arms and 300 rpm motors, while the second has 5 cm long moment arms and 1000 rpm motors. Both legs utilize laminate fiberglass construction and 3D printed brackets to connect the motors to the laminate device. The test setup includes a platform attached to a load cell allowing the legs' abilities to generate force to be measured. High-speed, motion-tracking cameras are used to measure the position of the leg. The figure below shows the representative data collected for the two leg designs.



The predicted masses used in the optimizations are then updated with the measured masses of the legs. These masses are used to create the results shown in the table to the right, which are compared with the experimental results.

	Jump Height (m)	Maximum Force (N)	
Single Mass Model	0.2055	1.755	18cm Moment Arm 300 RPM Motor
Unity Simulation	0.0157	1.755	
Experiment	0.0314	1.320	
Single Mass Model	0.2009	1.970	5 cm Moment Arm 1000 RPM Motor
Unity Simulation	0.0559	1.970	
Experiment	0.002	0.68	

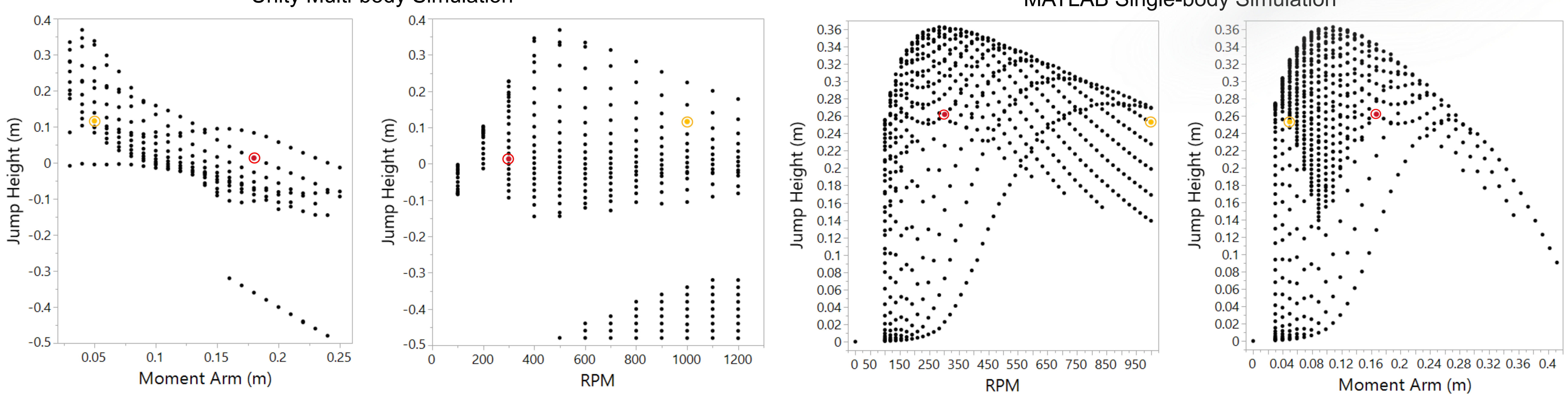


Simulation

Jump Height vs Moment Arm Length vs Gear Ratio

Unity Multi-body Simulation

MATLAB Single-body Simulation



Model

Model I: Single-mass Model

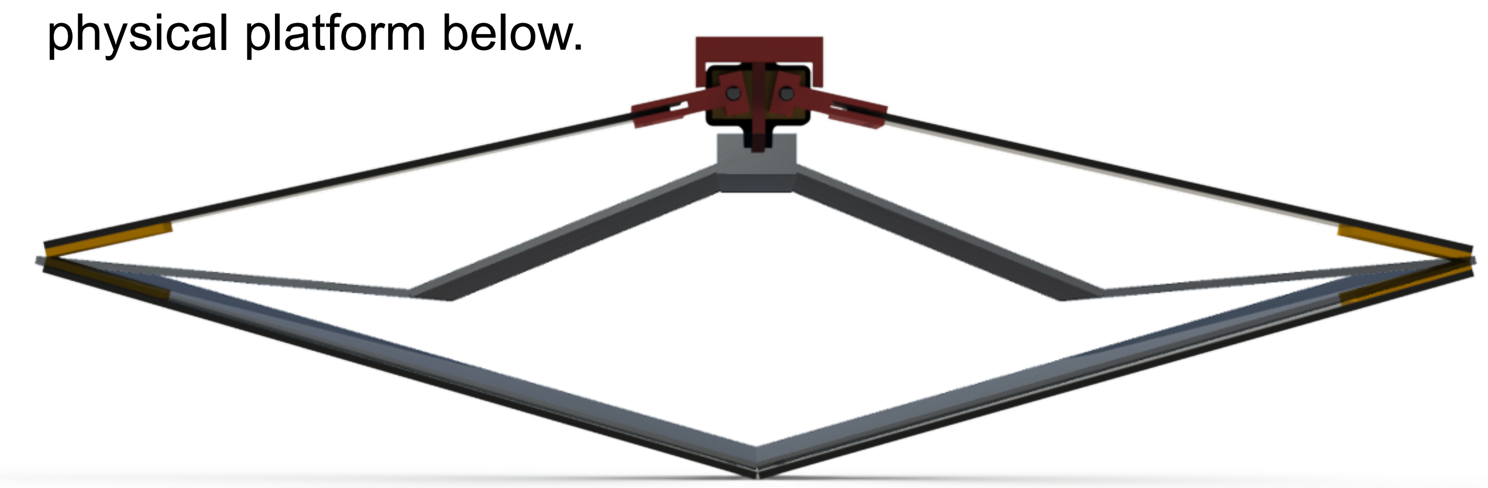
The first model uses a simplified single-mass representation which assumes all of the robot's mass is concentrated in a body at the hip. The force applied to this mass is determined using the linear torque / angular velocity motor model and the instantaneous orientation of the legs. The system of equations is shown below.

```
w = 0.5*v/moment_arm/cos(theta);
T = (Tmax - w * Tmax/wmax);
F = T*cos(theta)/moment_arm - 9.81*mass;
a = F/mass;
```

Solving the system for velocity and the angle of the hip joints allows the instantaneous force to be calculated incrementally as the angular velocity and joint orientation change throughout the extension of the leg. The final velocity resulting from the full extension of the leg is then used in a projectile model to determine the maximum height reached by the body.

Model II: Multi-body Unity Simulation

The the second model is created in the game engine Unity and includes separate rigid bodies for each of the leg members and a body representing the motors and connecting hardware. This simulation includes inertias for the leg members, offering improved accuracy over the single-mass representation. The fidelity of the Unity model is further improved by adding a spring-loaded joint to two of the leg members to simulate the flexibility of the material. The representation in Unity is shown in comparison with the physical platform below.



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