An Integrated Design and Simulation Environment for Rapid Prototyping of Laminate Robotic Mechanisms

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IDEAB

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Problem

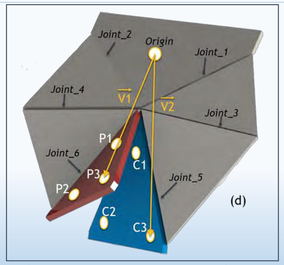
Laminate mechanisms are a reliable concept in producing low-cost robots. However, iterating through the design space to come up with the best design for a robot is still a time consuming and rather expensive task and therefore, there is still a need for model-based analysis before manufacturing. Until now, there has been no integrated design and analysis software for designing laminate robots.

Approach

We have introduced Pynamics, a companion to popupCAD, which is an existing laminate design tool. Pynamics is capable of generating dynamic equations and produces simulation results via rendered plots and videos. We have validated the accuracy of the software by comparing the position, velocity and acceleration of the simulated mechanisms with the measurements taken from physical laminate prototypes using a motion capture system.

Material/CAD data

popupCAD



A laminate mechanism consists of several joints made from a flexible material. In many cases, it is a closed loop mechanism. popupCAD facilitates the design of such mechanisms.

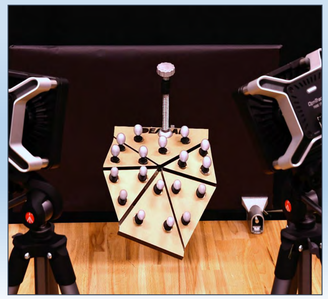
Damping Coefficient and stiffness of the hinge based on its geometry

YAML file

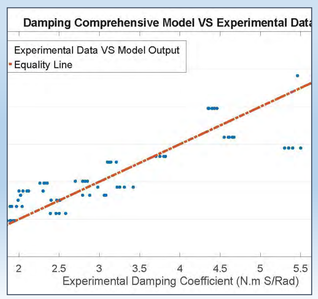
Hinge Geometry Data

Hinge Model

System Identification



The dynamics of a laminate mechanism is recorded using OptiTrack cameras.



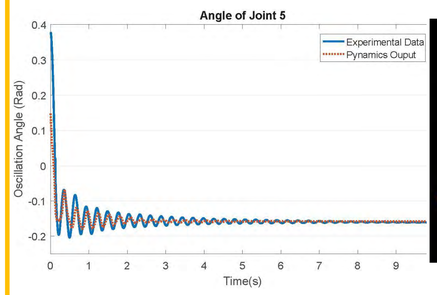
Damping coefficient and stiffness models are extracted using the data from motion capture.

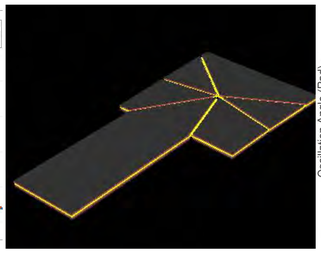
Pynamics

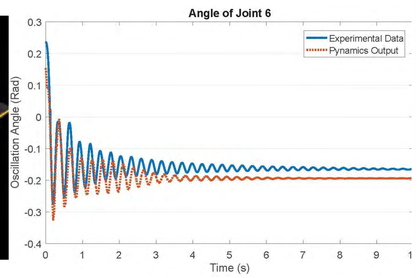
Rigid bodies, hierarchical interconnections of bodies via rotational joints, Newtonian bodies and material properties are stored in this file as Python-based classes after the YAML file is read by Pynamics. A hierarchical tree represents the network of connected mechanisms in which rigid bodies are the nodes and the joints connecting them are branches of the tree. However trees do not adequately capture the topology of parallel mechanisms. Next steps which are done automatically in Pynamics are:

- Obtaining the Dynamic Model using Kane's method
- Adding kinematic constraints and initial conditions
- Using Baumgarte's method to eliminate initial value errors
- Integration and solving

Results







The output of Pynamics is in the form of graphs of position, velocity and acceleration of the bodies as well as animation of the moving mechanism

Future Work

Include mechanisms with more than one closed loop
Automating the selection of and terms
Considering contact between mechanisms and the ground

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