CPS: Small: Cyber-Physical Communication for Cooperative Human-Robot Mobility

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https://a2sys.engin.umich.edu/current-projects/cooperative-payload-transport/

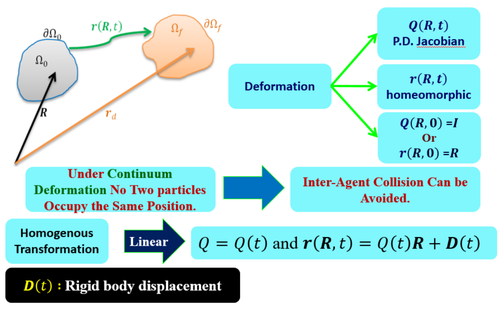
Challenge:

This project studies 1) continuum deformation theory for safe cooperative transport and 2) Experimental UAS to validate the use of multiple vehicles being guided by a haptic feedback through a tethered instrumental payload.

We study the following research problems:
- ✓Safety formal verification
- ✓Cooperative aerial lift and manipulation
- ✓Human cyber-physical heads-up interface
- ✓Experimental evaluation and validation

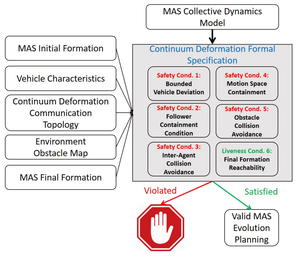
Scientific Impact:

Continuum Deformation Coordination

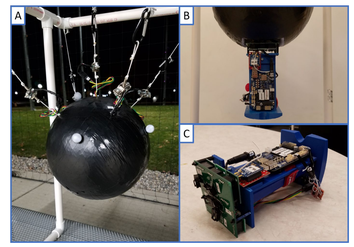


Continuum Deformation Safety Specification

- ✓Developed continuum deformation safety and liveness conditions.
- ✓Constructed Linear Temporal Logic (LTL) formulae to check validity of inter-agent and obstacle collision avoidance as well as agent and motion-space containment.



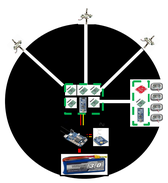
Open-Source Instrumented Payload



A) Instrumented payload on test rig
B) Payload insert partially removed
C) Payload insert with self-contained electronics

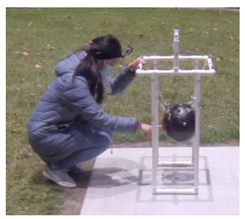
Sensor Specifications:
- 5 Inline Tension Sensors
- 9-axis IMU
- Push Force Load Cell Sensor
- 6DOF Pose (Motion Capture)

Features
- Real-time data collection and streaming
- Ground truth for tension force estimation
- Supports user force input identification

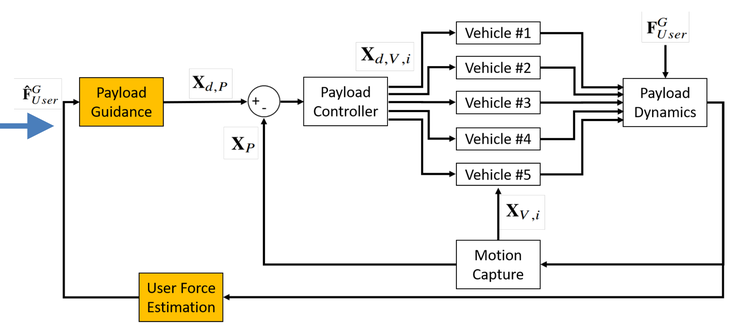


Solution:

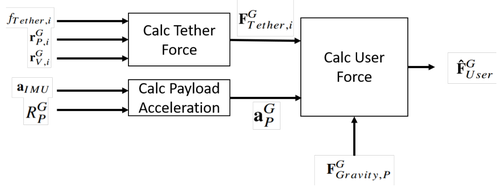
User Force Input



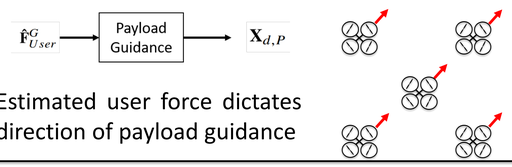
Human Cyber-Physical Heads-Up Interface



User Force Estimation



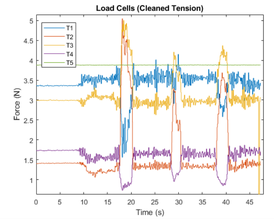
Payload Guidance

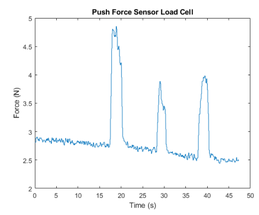


- Estimated user force dictates direction of payload guidance

Experimental Evaluation

- 4 Quadrotors & a Payload
- Formation guidance (to-date)
- Successfully carried payload
- Modelled haptic force inputs
- Benchtop Push Test Data w/ Tether and Estimated User Force (Below)





Broader Impact:

Society

- ✓ A system like this can be used in disaster relief scenarios. Users who have never seen the system could understand the intuitive push-based interface. Using many small vehicles is safer than one larger vehicle (smaller props, smaller vehicles) when a user gets near the system
- ✓ Small-UAS can be used in humanitarian missions
- ✓ Shipyard and warehouse environments – want users to be engaged in environment for safety

Education and Outreach

- ✓ This project has provided education opportunities to high school and undergraduate students, e.g., construction and test of a tensegrity tether
- ✓ Tours Given to K-12 students and prospective Robotics students
- ✓ M330-Quadrotor platform developed for this project has been open-sourced (website with build documentation and clear instructions) and has been used by several other researchers, student project teams, and individuals
- ✓ Experimental UAS class developed by PI based on quadrotor platform developed in this project

Potential Impacts

- ✓ In disaster relief, many smaller vehicles could pose less of a danger to those in need and be cheaper to deploy
- ✓ More lives could be saved if supplies are transported faster
- ✓ Less Energy used compared with manned helicopter
- ✓ Decreased risk because of heads-up interface
- ✓ These metrics could be quantified in the future for their potential impact from this project

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