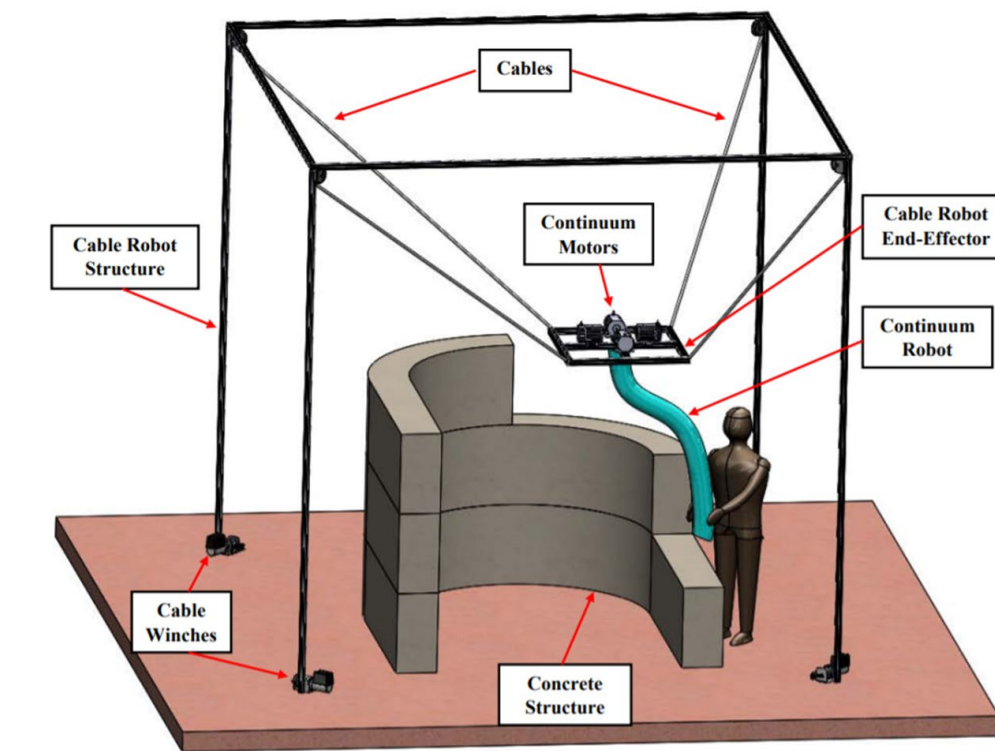
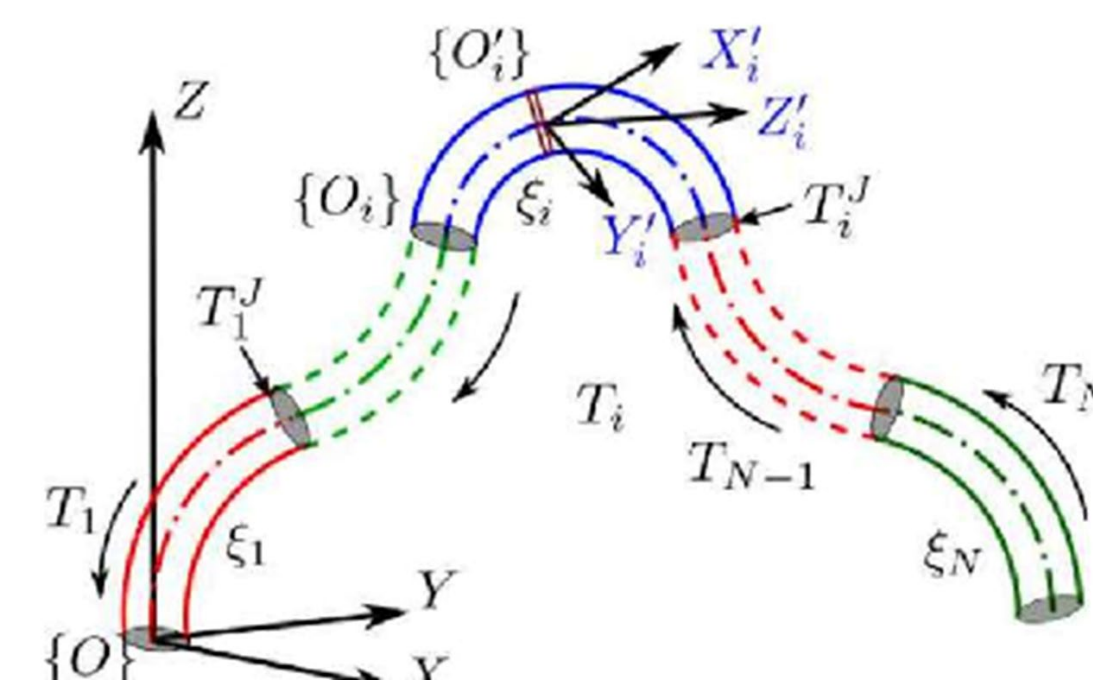
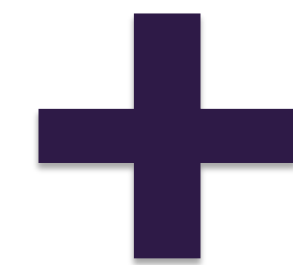
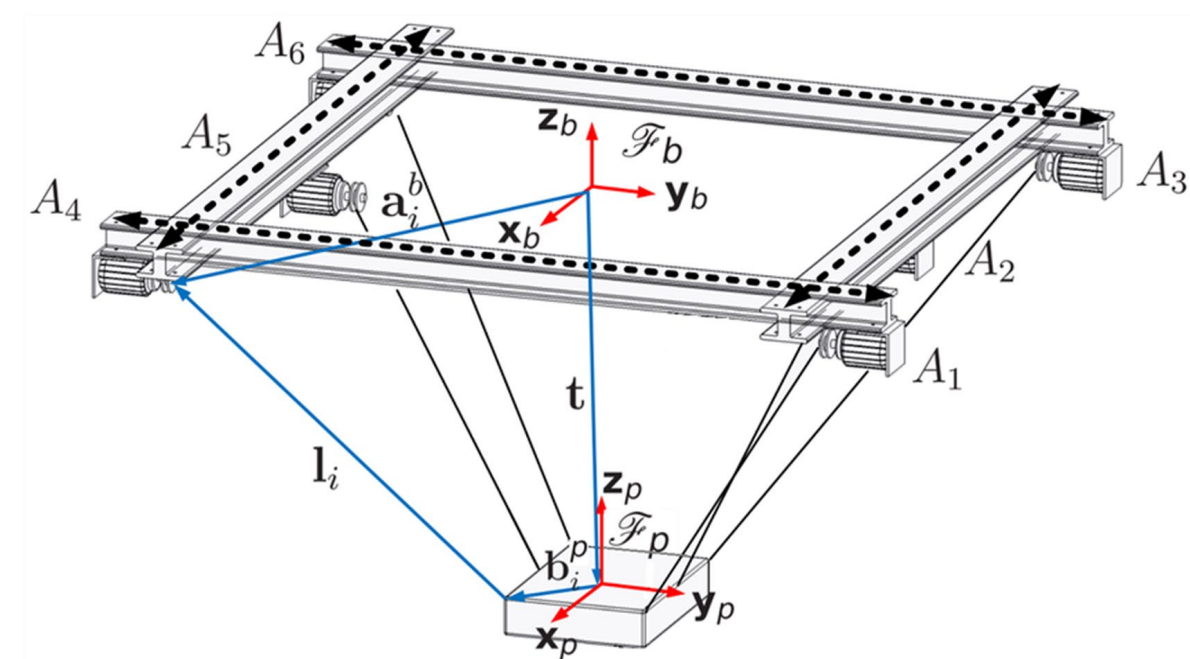


NRI:FND: 3D Concrete Printing with Macro-Micro Robots

Ian D. Walker, Venkat N. Krovi, Prasad Rangaraju, and Matthias J. Schmid, Clemson University

Project URL: https://cecas.clemson.edu/armlab-cuicar/research_1/cavs-in-manufacturing



Challenge

Interactively assist construction workers to dexterously deploy concrete-delivery hoses in congested spaces for 3D printing of concrete

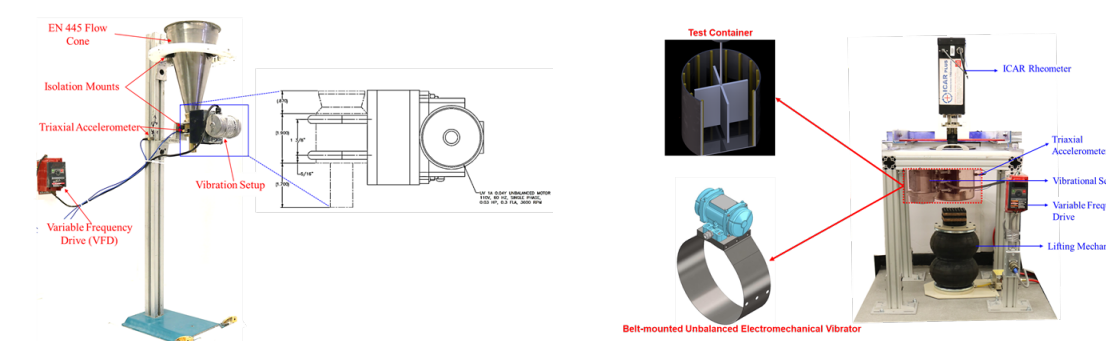
Background

Construction industry vital for national economy:

- 🐾 ~ 5% of US Gross Domestic Product (GDP)
- 🐾 1.463 trillion, 6.7 M workforce (in 2017)
- 🐾 Construction one of least automated industries in the world
- 🐾 Productivity hindered by lack of automation tools
- 🐾 Concrete operations a foundational element in construction

Materials Research Results

- 🐾 Designed/manufactured active-rheology control test setup
- 🐾 Material trials in rheometer and flow rate measurement setup being conducted.



- 🐾 Active-stiffening test setup designed and currently in manufacture.
- 🐾 Draft for impact of chemical accelerators on properties of printable mixes in preparation

Proposed Solution

Intelligent novel cable-driven macro/micro co-robot:

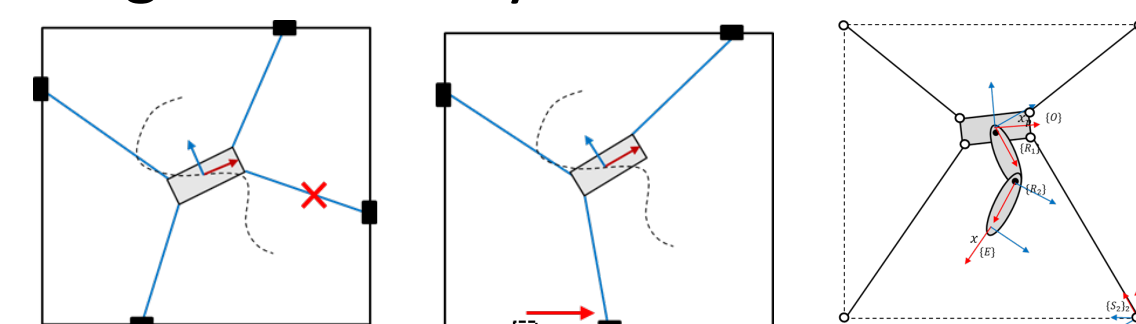
- 🐾 Cable-robot acts as the macro-base
- 🐾 Cable-driven continuum robot (integrated with concrete delivery hose) serves as micro-unit
- 🐾 Field Intelligence: Situational awareness and physical-assist

Impact of Solution

- 🐾 Fundamental research in rheology of 3D-printable concrete
- 🐾 New generalizable modeling of coupled cable-driven macro-micro robot systems
- 🐾 Intelligent assist for concrete delivery in construction industry

Macro Cable Robot Results

- 🐾 Proposed modeling framework for prototyping reconfigurable cable driven parallel robot (CDPR) designs
- 🐾 Performed wrench space analysis of end-effector properties of reconfigurable CDPRs
- 🐾 Developed redundancy resolution schemas to optimize different parameters
- 🐾 Developed a framework for failure mode identification and recovery using redundancy



Broader Impacts

- 🐾 4 Ph.D. Students (2 female) and 1 REU student hired
- 🐾 Paper in Journal of TRB: Transportation Research Record
- 🐾 Industry and conference (IEEE ICRA, CableCon, ACI, TRB) presentations
- 🐾 Plenary and Workshop talks (IEEE RoboSoft, IEEE ICMRE, TRB Meeting on Active Rheology Control for 3D Printing)
- 🐾 Summer outreach seminars to high-schools and industry
- 🐾 External Advisory Board (EAB) to Phinnize J Fisher Middle School (STEAM school)
- 🐾 Developing a University-Industry Collaboration for Design and Construction of Scaled-3D Printed Models for Concept Validation

Continuum Hose Robot Results

- 🐾 Euler curve based variable curvature (VC) kinematic model for multiple continuum robot sections
- 🐾 Significantly improved end effector (EE) control compared to the constant curvature (CC) model
- 🐾 Statics-based model that ensures uniform EE velocity and curvature at all bending planes developed for single section
- 🐾 Improves upon VC kinematics model
- 🐾 Multi-section model under development