NRI: FND: Human-Guided Robot Teams for Manipulating Large Flexible Sheets in Manufacturing Applications

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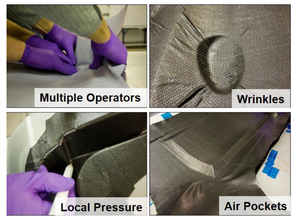
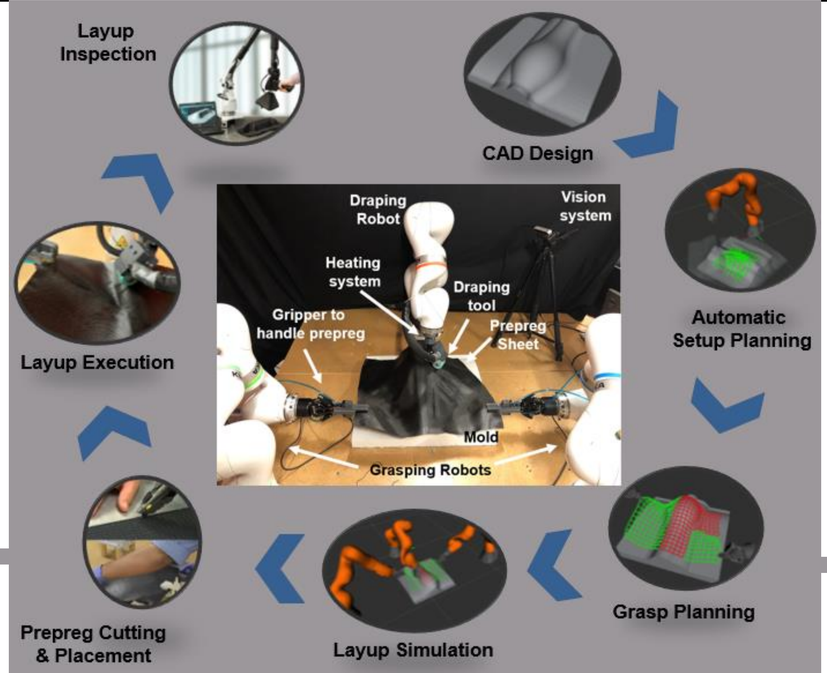
Motivation

- Composite materials provide high strength to weight ratio
- Layup of prepreg sheets is one of the main processes for realizing composite parts with complex geometries
- Sheet layup process requires significant manual labor
- Sheet layup automation can reduce ergonomic challenges and increase process throughput

Ongoing Layup
(Source: Modernmachineshop 2018)



Characteristics and Defects



Goals

- Develop deliberative planning algorithms for collaborative manipulation by proactively accounting for interventions by controllers and humans during execution to handle contingencies
- Develop algorithms for monitoring of the task progress during the execution and initiating interventions to ensure that part is manufactured in a safe and efficient manner
- Demonstrate approaches developed to meet the first two objectives on the composite layup application
- Integrate research results with graduate and undergraduate manufacturing and robotics courses

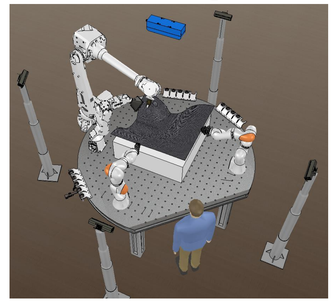


Illustration of a hybrid cell that can be used for composite sheet layup

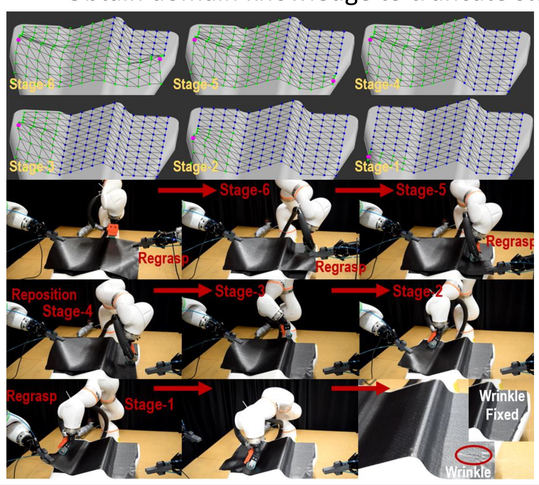
Deliberative Planning For Collaborative Manipulation

Formulation for Coordinated State Space Search

- Develop an energy-based method for simulating the sheet
- Develop cost function to evaluate quality of sheet states
- Efficiently solve grasp sequence search
- Use gradient descent-based ordering heuristics to expand nodes in graph

Human Guidance During Search

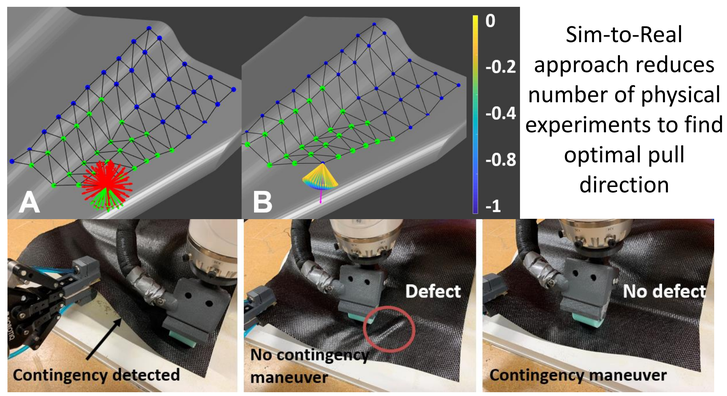
- Develop GUI for human input
- Obtain domain knowledge to truncate state space



Grasp locations planned for a discrete set of stages for an industry inspired mold. The grasp locations are then used during execution by the grasping robots under impedance control. A small defect appears under impedance control which is eliminated by using intervention controller

Execution Monitoring and Intervention Planning

- Fast and accurate automated cell calibration
- Preventing defects through contingency maneuvers
- Planning for rework and recovery from errors
- Seeking help from humans
- Safe and efficient human intervention during execution

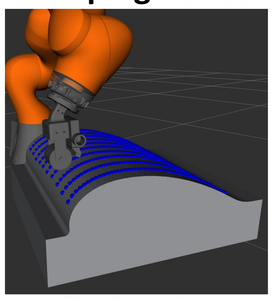


Sim-to-Real approach reduces number of physical experiments to find optimal pull direction

Contingency maneuver as an optimal pull direction prevents defects from occurring

Path Constrained Trajectory Planning For Draping Robot

- Use multiple TCPs and tolerances to find low-cost trajectories and improve success rate
- Use graph-based planning by approximating constraint manifold in configuration space
- Sequentially progress using a workspace heuristic to bidirectionally generate sub-graphs in configuration space
- Develop a cost map for all nodes in source and sink to bias future samples
- Machine learn the exploration and exploitation profile for biasing



Draping robot executing paths under motion constraints in simulation

Broader Impacts

- Introduce robotics in small volume operations and make manufacturing cost competitive in the US
- Enhance robotics and manufacturing curricula by incorporating research results into graduate and undergraduate courses
- Engage students from underrepresented minority groups and undergraduate students in research
- Outreach activities for K-12 students to educate and inform them about career opportunities in robotics and manufacturing

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