Toward Automated Parachute Packing: A Multi-Arm Robotic Approach to Vision-Guided Line Stowing

Students: Chenhan Guan (RBE), Zheren Li (RBE), Fiona Prendergast (RBE/CS), Gunnar Rorapaugh (ME), Oliver Van Campen (RBE)

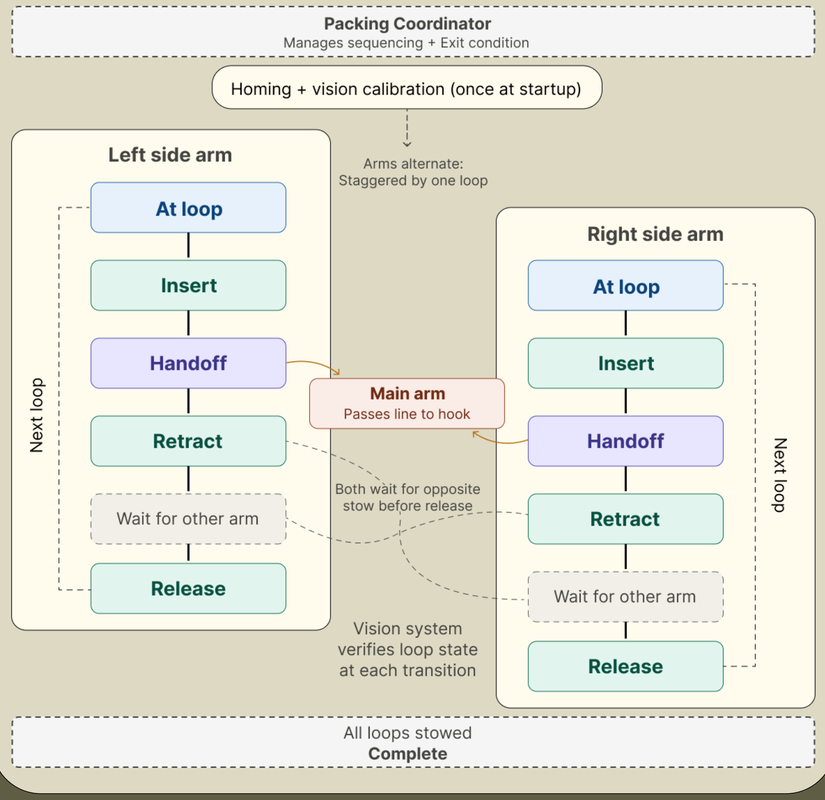
Advisors: Professor Constantinos Chamzas (RBE/CS), Professor Connor McCann (RBE/MME), Professor Mohammad Mahdi Agheli Hajiabadi (RBE/ME), Professor Jing Xiao (RBE/CS/ECE)

Abstract

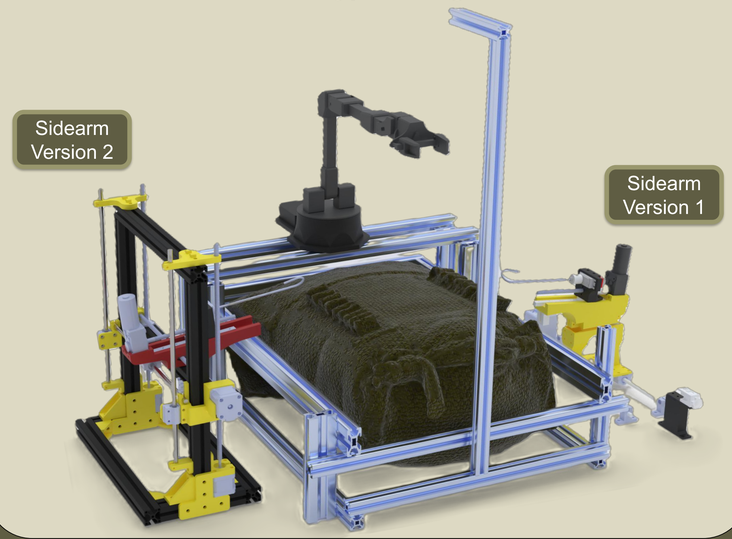
Parachute packing is a largely manual process due to the complexity of working with the canopy and suspension lines, which are made of flexible and deformable materials. The specific task of stowing suspension lines into loops on the back of the parachute bag requires consistency and controlled tension, which makes it difficult to automate with a traditional robotic manipulator. To address this challenge, we developed a robotic system with a primary manipulator and two secondary tensioning arms that can manipulate flexible lines and guide them through two arrays of constrained elastic loops. The results suggest that the robotic handling of these deformable materials can be performed reliably and contributes to the advancement of robotic textile manipulation.

Line Stowing State Machine

- State Machine coordinates three arms through staggered, alternating stow cycles with wait-based synchronization
- Built on ROS2 with custom packages, state transitions defined in YAML configuration, and coordinated through decentralized action servers



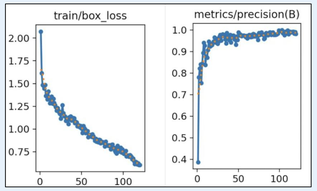
Prototype Design

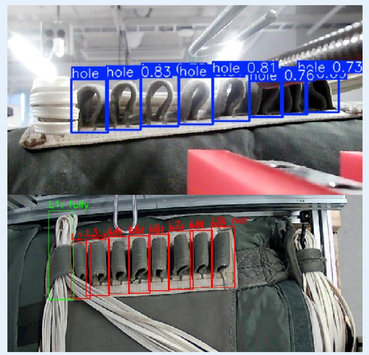


At Loop: Loop Perception

YOLO-based object segmentation detects the state of stowed lines.

- Side cameras track stowing loop positions.
- Overhead camera verifies stow placement.



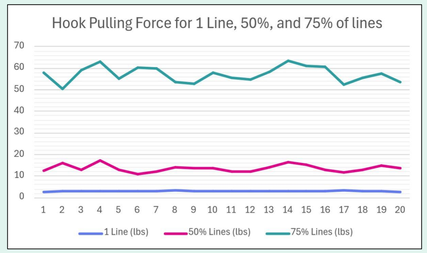


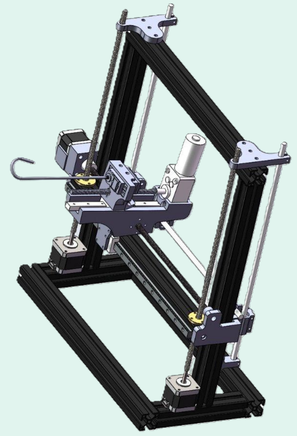
Handoff: Top arm

- 5 Degrees of Freedom robotic arm performs initial grasp of suspension lines
- Transfers lines to sidearms between stows

Insert–Retract–Release

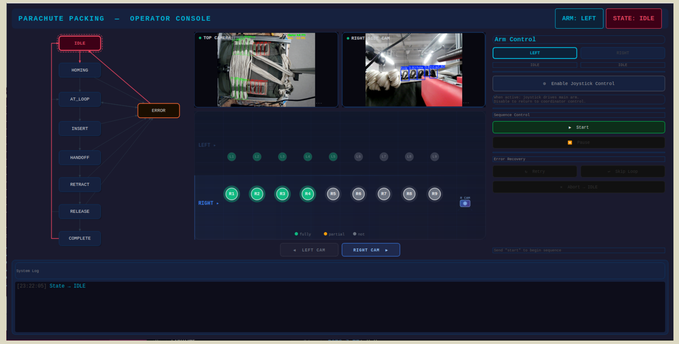
- Performs pulling of lines through parachute bag loops
- 4 Degrees of Freedom
- Servo-driven hook rotation
- 150–200 mm vertical travel
- ESP32 communication bridge





Operator GUI

- Provides operator with starting and stopping the stowing process, control of the state machine, and views of each camera



Results

- Sidearms generate sufficient torque to pull line bundles through loops
- Gripper reliably handles bundles during handoff
- Vision pipeline accurately localizes loops
- State machine coordinates subsystems with supervised recovery
- Completes full stowing with ~3 interventions per side

Acknowledgements

We would like to thank the U.S. Army Natick Soldier Systems Center for presenting the problem and lending the parachute bag and packing tools.