Autonomous Intelligent Assembly Systems

LABORATORY DIRECTED RESEARCH & DEVELOPMENT

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Problem

Ground-based military and emergency-response robots currently require direct human operator control, i.e., tele-operation, to conduct operations. This leaves the operator at risk, requires a high-level of bandwidth to maintain, and limits the system's effectiveness. GPS-based waypoint navigation can guide the vehicle platform autonomously, but can do nothing once the robot has reached its destination. New algorithms are needed to enable a remote robot arm to perform automatic grasping and other assembly tasks in unstructured, outdoor environments.

Approach

Our goal is to implement advanced perception and command and control algorithms onboard our existing squad of mobile manipulator systems and develop a series of demonstrations that illustrate key functionality. Rather then working in a completely unstructured world, we utilize robot-friendly visual features and grasp points, but otherwise must cope with real-world lighting variations, communication issues, and vehicle platform uncertainty.

We are developing technology in four key areas. Vision algorithms are being developed to segment, identify and track known features. Communication algorithms are being developed to allow multiple agents to communicate efficiently. Command and control algorithms are being developed to simplify the orchestration of advanced behaviors. Finally, a six Degree-of-Freedom (DOF) Bayesian Filter framework takes sensor based estimates of objects, landmarks and robots, and computes measurements of positions and uncertainties.

Perception Results

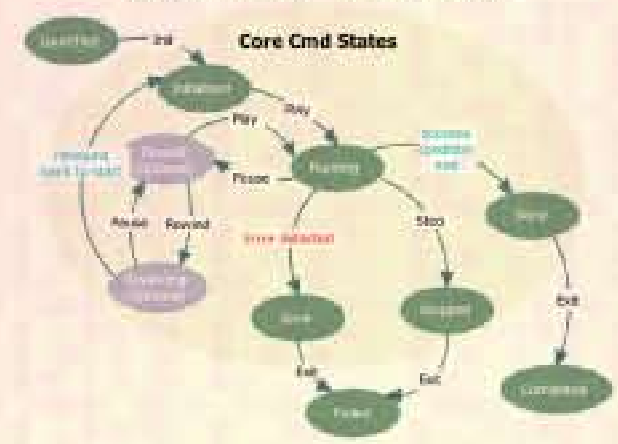
- Initially developed algorithms for segmentation and part fitting data from a compact commercial LIDAR sensor.
  - Obtained fitting accuracies of 5 cm.
  - Decided that inherent sensor features such as surface warping would make precision assembly difficult.

- Developed a unique "Polygon Snake" algorithm for tracking painted polygon features on the sides of objects.
  - Algorithm performs high-speed tracking of colored areas with minimal computation.
  - For a priori known features, pose fitting can be performed.
  - Using a dual camera system, obtained fitting accuracies of <1 cm at 1 meter distance.

Command & Control Results

- A new object-oriented Command & Control framework has been developed for multiple robot control.
  - Contains methods for Init, Play, Pause, Stop, Rewind, Abort, and Monitor.
  - XML based implementation for saving/retrieving commands.
  - Single graphical interface enables activation and control for every command.
  - Commands can be combined in sequence and in parallel, and can be executed in a distributed network.
  - Command objects have been developed for visual servo-ing, waypoint following, arm motion, gripper control, etc.

Abstract "Cmd" State Machine



Preliminary Demonstration

- An automated visual site survey, with precise digital photogrammetry was recently conducted.
- Using an operator generated script, the mobile robot automatically proceeded to a series of locations and took a series of overlapping images to create a panoramic visual map of the site.
- The demonstration combined distributed broadcast communications, automated command scripts, and Bayesian estimations.
- Using LDRD-developed tools, the script generation took only minutes to generate.

Future Demonstrations

- Sensor deployment demonstration will emulate the deployment of a sensor grid.
  - A navigation/mule robot will retrieve sensors from base station.
  - A robot arm will dock to sensors, and then deploy at defined locations.
  - Demonstration illustrates coordination, precise docking, advanced scripting, and large area operations.

- Brick wall building demonstration will illustrate a sample construction task.
  - Navigation/mule robot will retrieve and carry a few "bricks" at a time.
  - The mobile manipulator will track and follow the mule, and retrieve and place bricks to form a small wall.
  - Demonstration illustrates precision (sub-centimeter) assembly, advanced multiple object tracking, and advanced scripting.

Significance

This technology will have impact for multiple potential customers. The Army would like to automatically set up infrastructure in Green Zones, without risking the lives of engineers. NASA needs to automate docking and cable assembly for satellites and future moon missions. The Navy hopes to assemble underwater based sensor arrays. DOE requires better, more-efficient technologies for decommissioning activities in high-radiation environments. By establishing a core competency and a series of demonstrations illustrating this competency, we should be able to attract customers in multiple industries, and ultimately, reduce costs and save lives.

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