An Autonomous Robotic Nurse for Patients and the Elderly: Care, Monitoring, Diagnostics and Supply Delivery[†]

Ajay Jain
Monta Vista High School
Cupertino, California

March 2014

Abstract

I built a $1000 autonomous robot to replace day-to-day tasks performed by nurses and intelligently improve patient care.

PROBLEMS: Nurses spend 30% of their time away from patients fetching medications, supplies and reports, and hospital staff suffer strain and fatigue from transporting heavy items and excessive walking. At the same time, hospital error can be prevented with automation. Finally, nursing homes cost on average $90,000 per year in California for constant health and safety monitoring for the elderly.

APPROACH: The robot, called "RoboNurse," autonomously navigates changing environments to safely deliver items. 2D depth scans allow the robot to perform Simultaneous Localization and Mapping (SLAM). The robot verifies medications visually with my object recognition algorithm, RFID tags and precise localization. With an RGBD depth camera, patient poses are recognized to detect injury and falls. Computer vision algorithms are implemented to follow moving objects including people and carts and to recognize faces.

RESULTS: The primary mobile robot base is suitable for homes, and the Hercules 3 base allows 250 lbs of payload for three hours for hospitals. The robot interfaces with an electronic pharmacy–a medication dispenser is controlled over the network for full automation after a nurse or doctor orders a delivery for a patient. Extended to homes, RoboNurse has a voice interface and integrated long-term health tracking, with the ability to alert emergency services.

CONCLUSION & IMPACTS: My robot autonomously delivers cargo, freeing nurses to spend more time with patients. By monitoring the environment, unsafe conditions are detected. The robot catches several errors and emergencies soon after they happen by monitoring patients and medication deliveries, possibly preventing hundreds of hospital deaths every year in the US. Monitoring increases medication compliance. RoboNurse delays the need for expensive extended living facilities, saving tens of thousands of dollars per year and allowing for independence.

Figure 1: Front view of robot.

Figure 2: Rear view during delivery.

[†]Research poster board available online at `http://ajayjain.net/robonurse/`.

Time-Optimal Robotic Path Planning in Dynamic Ocean Flows: Efficiency and Sensitivity Studies†

Ajay Jain
Research Science Institute
Ocean and Science Engineering
Massachusetts Institute of Technology

July 28, 2015

Summary and Impact

Self-driven Autonomous Underwater Vehicles (AUVs) need to take advantage of surrounding ocean currents to navigate between ocean locations to reach objectives quickly. These underwater vehicles often move only slightly faster than the surrounding currents, and risk being swept out to sea with naive navigation approaches. Our autonomy methods allow naval, scientific or rescue robots to stay at sea for weeks or months with minimal power use. In our approach, we accurately model ocean currents and find the path of least time to reach a goal for an underwater robot with computational techniques called "Level Set Methods". Improvements to the method are presented along with error analyses and studies of tidal patterns.

Abstract

Path planning approaches for Autonomous Underwater Vehicles (AUVs) must handle the presence of a time and space variable background fluid flow field that may significantly hinder or propel a robot. Here, we find the runtime scaling of the level set method in dynamic ocean flows and discuss implementation of extensions that substantially reduce theoretical algorithmic complexity—namely restricted domain evaluation and narrow band approaches. Our narrow band approach reduces the level set evaluation from quadratic to linear complexity per timestep. We also analyze the development of path error with the full-field level set scheme. We study waypoint accuracy for paths generated with coarser current data and level set evaluation grids, numeric error between forward heading tracking and backtracked waypoints, and path variance that emerges from tide phase shifts in the underlying ocean current model. The sensitivity of a realistic AUV to currents is explored in conjunction to the error analyses.

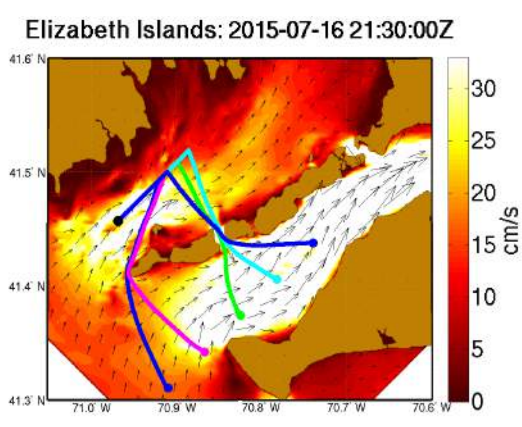

Figure 3: Underwater robot path plans in dynamic ocean currents off of the Elizabeth Islands of Massachusetts for intercepting a moving ship.

†Full paper and references available online at `http://ajayjain.net/files/rsi/path_planning.pdf`.

Autonomous Robotic Pursuit-Evasion: A Framework for Distributed Behaviors†

Ajay Jain and Dr. Timothy H. Chung
Department of Systems Engineering
Naval Postgraduate School
Monterey, California

March 2015

Abstract

Formulations of the problem of chasing a target and escaping from a pursuer have played an important role in aerial military strategy, game artificial intelligence, and recently in robotics. In military or aerial acrobatic applications, tactics for following a target and escaping have been crucial, and will grow in importance for Unmanned Aerial and Ground Vehicles. The ability for a ground robot to follow a target is important in autonomous delivery, swarm tasks, or security. We present our implementations of autonomous robotic pursuit and evasion algorithms, analyze their efficacy in simulation based on robot constraints, and present a functional hardware and software system for chase on wheeled robots. Our approach focuses on geometric adversarial and defensive behaviors for target chase and tagging that have limited information requirements, and composition of behaviors with a Behavior Tree to enable two-target pursuit and evasion. Finally, we present a general distributed robotic behavior framework, DRBL.

Impacts

The project directly helps with the implementation of autonomous scout, combat or patrol robots, collaborative robot behaviors, convoys of self-driving shipping vehicles or trucks, and emergency obstacle avoidance for autonomous cars. Automatic breaking and debris detection can prevent highway pileups and accidents. Adversarial and defensive robotic algorithms of this research directly translate to autonomous swarm vs. swarm UAV competition and surface boat competition. In addition, the presented DRBL framework speeds robotic swarm research.

Figure 4: The Clearpath Husky A200 robot platform.

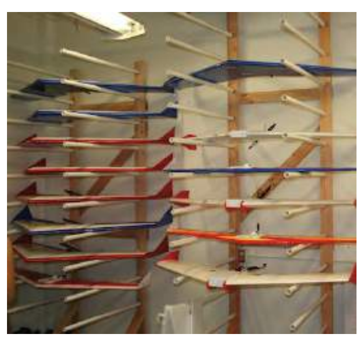

Figure 5: ARSENL's flock of autonomous UAVs.

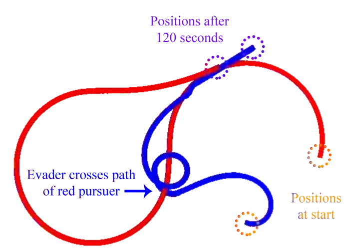

Figure 6: Pursuit-evasion by a fast pursuer with a low turning velocity (a Homicidal Chauffeur).

†Full paper and references available online at `http://ajayjain.net/files/nps/autonomous_pursuit_evasion.pdf`

Post-Disaster Recovery by Rapid, High Resolution Aerial Imaging and Indoor 3D Mapping with Autonomous Quadrotors†

Ajay Jain and Paras Jain
Monta Vista High School
Cupertino, California

October 2013

Summary

We created an autonomous quadrotor UAV system to: 1) quickly map outdoor disaster zones to prioritize rescue efforts and 2) create 3D maps of building interiors for remote diagnosis of trapped victims. Fresh aerial imagery allows first responders to target high-damage areas. However, satellites can take 8-10 days to reach the disaster area, and post-storm clouds obstruct clear view.

The UAV produces aerial maps that are 10 times higher resolution than commercial satellite maps on the market, allowing disaster responders to prioritize search and rescue efforts and assess the extent of damage after a disaster. Victims are automatically recognized by the drones and are tagged for rescue. Each drone collaborates with other drones in its network to map a city rapidly. A version of the drone can navigate around the inside of a building, producing a 3D map of the interior of a building that may be too dangerous to enter. A victim inside a collapsing building can be located, potentially saving the life of an EMT or firefighter.

Our sub-$500 platform can help save thousands of victims of floods, earthquakes, hurricanes and other disasters by automatically searching for victims, both indoors and outdoors. This technology is extensively applicable to post-disaster response, such as in Hurricane Sandy or the Fukushima Nuclear Disaster by automatically searching for victims and entering a radioactive hazard zone to assess damage.

Figure 7: Panoramic image from above rooftops

Figure 8: Generated 3D indoor model

Figure 9: Full panorama from a low-altitude sweep

†Full paper, references and demonstrations available online at `http://ajayjain.net/uav/`.