Adaptive Mobile Sensor Network

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Introduction

CENSAM's primary goal is to develop a representation of the natural and built environment that can seamlessly transition from micro-scale processes, to the meso-scale of the city-state of Singapore and the macro-system of the coupled biosphere-atmosphere-ocean. Multiple resolution environmental models will assimilate remote sensing data from satellite and airborne platforms with ground observations from diverse sensor networks and mobile robotic sensor platforms.

Water and Air Vehicles for Environmental Sensing or in short WAVES Lab is part of CENSAM which facilitates CENSAM with such platforms. Our key research interest is to develop platforms and sensors that enable us to acquire atmospheric data autonomously and adaptively. Our main research thrust is to develop robotic sensor networks, control algorithms, novel propulsion, and navigation and sensing tools to safely and efficiently monitor and survey the Singapore harbor and coasts. Our main research areas includes
• Robotics and autonomous systems, • Adaptive path planning and inspection and • Bio-mimetic locomotion

Robotics and Autonomous Systems

Using autonomous surface, underwater, and air vehicles our team is developing a system capable of individual and coordinated actions relative to feature maps, and adaptive sampling. Part of our work is to incorporate new acoustic communication, novel sensing techniques, and adaptive navigation systems to improve the performance and safety of our autonomous operations capable of individual and coordinated actions using feature maps and adaptive sampling.

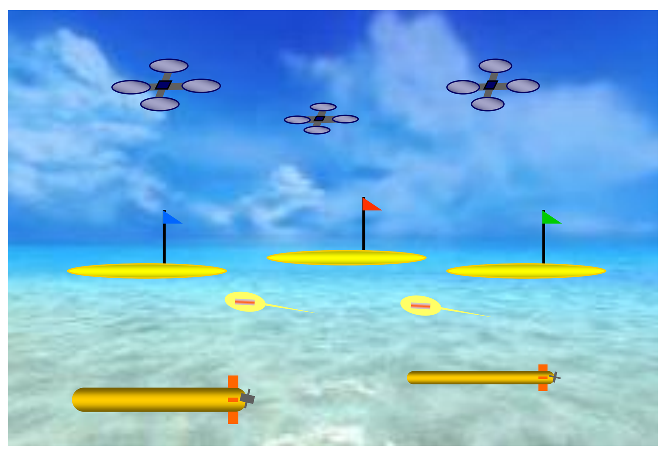

Figure 1: Illustration of a Mobile Sensor Network

Figure 2: Deployment of a Kayak in Singapore coast.

The Surface Craft for Oceanographic and Undersea Testing (SCOUT) were developed by engineers at MIT's Department of Ocean Engineering in order to facilitate surface and undersea oceanographic monitoring. The SCOUTs use ocean kayaks equipped with computers, electronics and mechanical propulsion mechanisms. In addition, the vehicles can be equipped with various third-party and custom oceanographic, vision, navigational, and acoustic sensors. The kayaks are largely used as a test bed for robotic algorithms including but not limited to cooperative multi-vehicle operation and intelligent obstacle avoidance.

The Iver2 family of vehicles from Oceanserver are a modern workhorse AUV designed for coastal data collection. The system is designed to give a single operator the ability to run several vehicles, including launch and retrieval. The vehicles are modified at CENSAM to be equipped with oceanographic chemical sensors, acoustic transducers for communication and localization and ADCP. The vehicles use their built in sensors such as pressure sensors, altitude meters, surface GPS and DVL for navigation.

Figure 3: AUV in operation.

Figure 4: Quad rotor during flight

The pelican quad-rotors from Asctec are currently being used in our autonomous air operations. The quad-rotors are small (less than one meter diameter), battery powered, and equipped with four independent rotors. The total weight of the vehicle does not exceed 2 kg (including sensor payloads). All vehicle controls are handled on board, while wireless communications with a ship allow the operator to view color video feed and send commands. The quad-rotors have a maximum flight time of approximately 20 minutes and are capable of maximum speeds of approximately 40 km/hr. The vehicles are modified to allow for water landings in case of emergencies due to inclement weather. We have also added Gumstix embedded CPU, long range 900 MHz Xbee module for reliable communication.

Adaptive Path Planning and Inspection

Adaptive path planning and inspection is motivated by the various incidents such as collapsed bridges, oil spills, and marine structure failures which cause human loss and damage the natural ecosystem. The basic idea is to prevent failures thorough structural inspection. In order to do that fundamental algorithms and robotic technology for autonomous surface reconstruction of marine structures has been developed. In particular, we are developing algorithms for robust robot motion planning, robotics technology for autonomous navigation and scanning of marine structures and software technology to construct 3D models of marine structures.

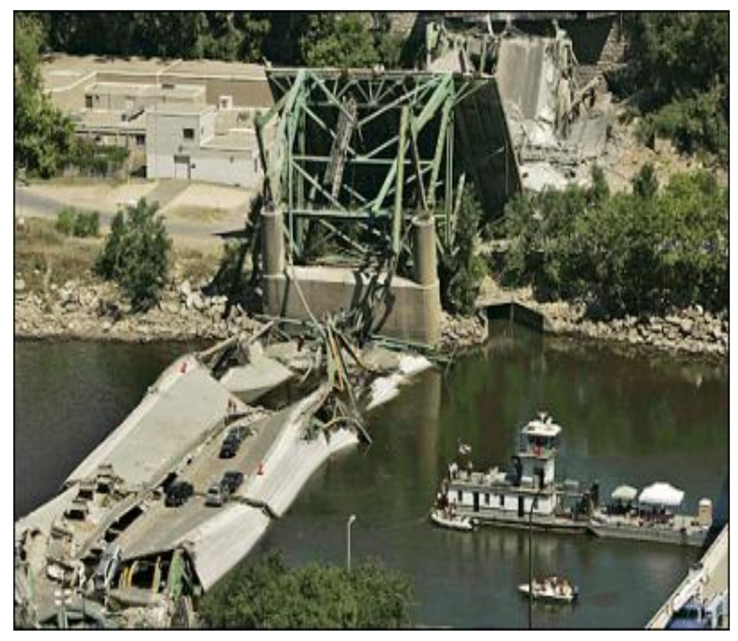

Figure 5 : Collapsed I-35 bridge over the Mississippi river in Minnesota (http://www.thefunctionality.com/blog/2009/1/28/infrastructure-now-3-under-the-bridge.html)

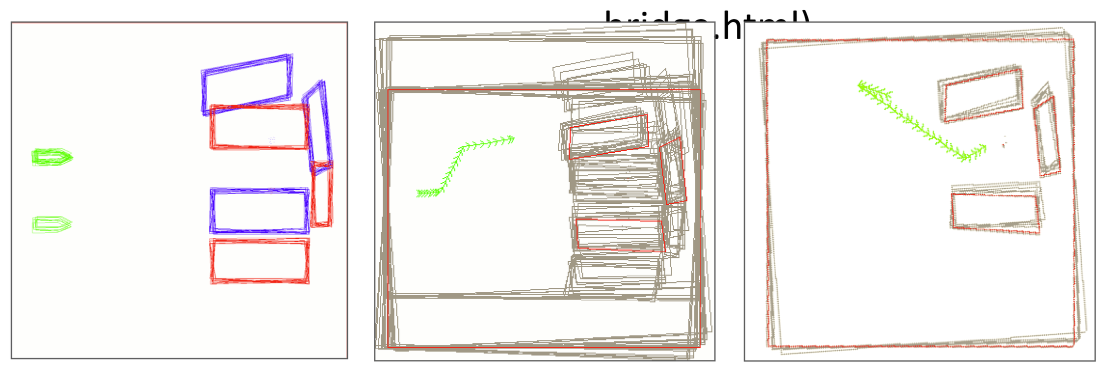

Figure 6: *On left:* 3D model reconstruction of a jetty above water surface in Pandan Reservoir. *On Top:* Simulation results of our POMDP based Global motion planning algorithm

Biomimetic Locomotion

•Pervasive sensing in harsh environments requires mobile vehicles with high maneuverability, mechanical robustness, high propulsive efficiency, and stealth.
•Biological locomotion techniques have the potential of enabling all these features.
•Understanding the governing physics that enable biological propulsive performance can help us adapt such techniques to man-made vehicles and improve their performance.

Mission oriented prototypes:
• Larger scale
• Communication & control: Wifi modem, GPS, compass, IMU
• Sensors: Scanning sonar, temperature, salinity.
• Power supply: Li-ion cells.

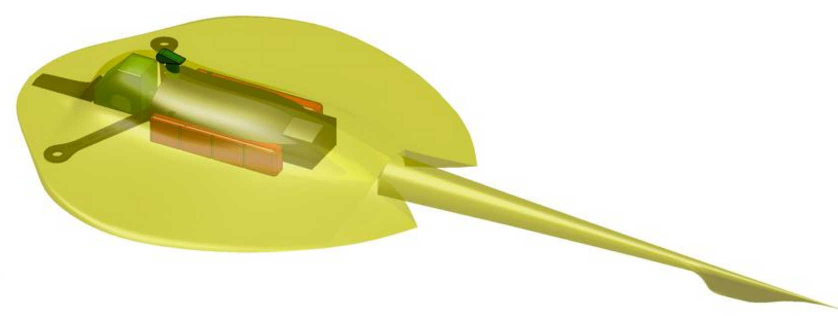

Figure 7: 3D sketch of a biomimetic AUV.

Environmental Model

Environmental models are linked to tidal, hydrodynamic, chemical and biological factors of the atmosphere. We try to gather these information using our robotic fleet. Data acquired by this system enable us to study the environmental parameters of the Singapore coastal area. Our group uses a mixed physics-based and learning-based approach to model various oceanographic phenomenon such as harmful algae blooms.

Figure 8: Thermal image captured from a Quadrotor

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