Sensors and Algorithms for Safe Navigation in Singapore Harbor

SMART Singapore-MIT Alliance for Research and Technology

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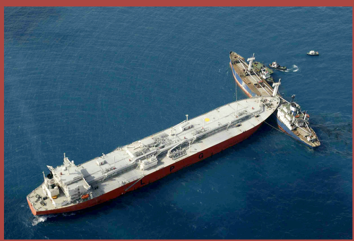
I. Motivation



Collision off Singapore Harbour

M/T Gas Roman collided bow-on 90 degrees into the port side of the No. 4 cargo hold of **M/V Springbok**

http://www.cargolaw.com/2003nightmare_t-bone.html

OBJECTIVE:

Safe Navigation for Autonomous Surface Craft robots (ASC's) in Singapore Harbor.

Unknown obstacles and moving traffic pose a major concern in autonomous operations. Due to the large number of ships and numerous small kelongs, fishing boats present, it is not possible to plan a collision-free motion trajectory *a priori*.

We propose a safe navigation scheme for ASC's, that uses information from onboard sensors to plan a collision-free path in real-time.

II. ASC Platform and Sensors

SCOUT ASC

- Payload capacity up to 100 kg
- Localization module with a GPS + IMU unit
- Dual CPU boards for higher computational loads

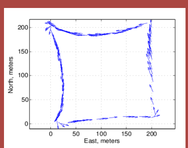
COMAR Class B AIS Transponder

- Long range detection of ships
- Uses the existing maritime framework for passing information about vessels and their heading and speed

SICK LD 1000 Laser Rangefinder

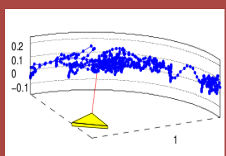
- Omnidirectional sensing
- Very high fidelity range sensor to 150m in calm waters; degraded performance in rough conditions

III. Operational Challenges



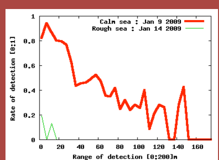
Water currents can create undesirable drift of the ASC.

A nominally square trajectory is shown distorted due to strong surface currents. The maximum velocity of the ASC is insufficient to counter them.



Rolling and pitching cause errors in detecting obstacles.

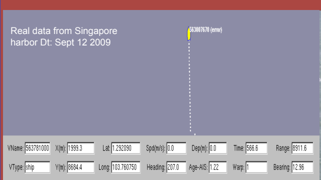
The figure shows a single laser ray's motion, after applying the roll and pitch from the ASC in water.



Laser detection rate falls when the sea is rough.

The plot shows the detection rate for a fixed obstacle under different sea conditions. Reliable detection of an obstacle drops from 100m to under 20m in rough seas.

Obstacle Detection by Different Sensors



Snapshot of a ship whose information is received by the AIS transponder.

CENSAM ASC deployed in choppy waters at Selat Pauh.

Ships picked up by the laser sensor, viewed as clusters

AIS information has an uncertainty bounded by the error of its GPS module

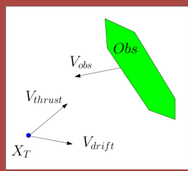
Data for each vehicle comes sporadically. The rate cannot be changed when critical.

The laser cluster detection is done at a high rate of about 10Hz.

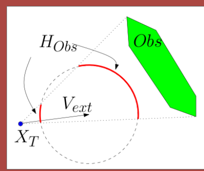
The laser cannot differentiate a stationary obstacle from a moving one, as it gets only partial scans at one time.

IV. Avoidance Algorithm

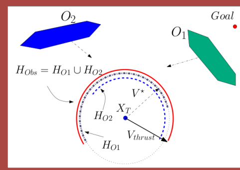
The ASC computes its relative drift velocity towards an obstacle $V_{ext} = V_{drift} - V_{obs}$ and chooses a control V_{thrust} that gives a collision-free heading in the projected position space.



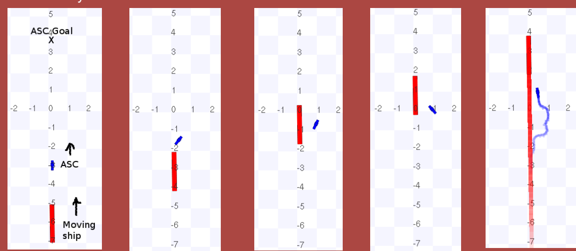
The ASC has to avoid obstacles in spite of its own uncontrollable drift and any obstacle velocity.



The projection of the obstacle on V_{thrust} limits the choice of the safe direction of motion.

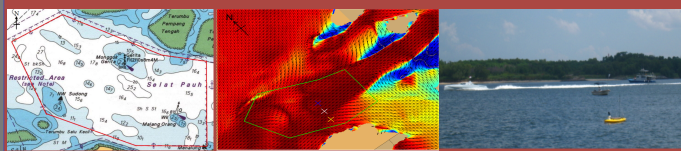


If the desired direction to move is unsafe, a closest safe velocity is chosen.

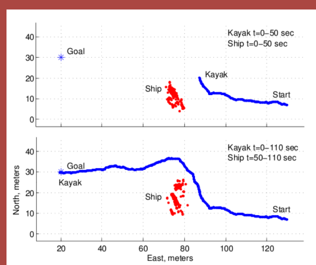


A series of snapshots showing the blue ASC stepping out of the way of an incoming ship and returning to its original trajectory once the ship passes on.

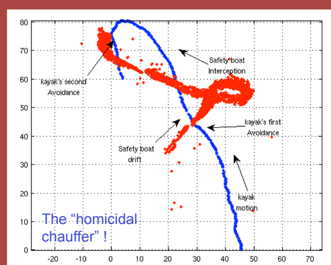
IV. Deployment in Singapore Waters



Experimental evaluation was done in Selat-Pauh and at Pulau Ubin Channel (not shown). A currents forecast is shown for Selat Pauh. A number of unannounced vehicles were operating in the trial area.



Avoidance results for a stationary ship detected by the laser.



A small safety boat posed as an obstacle and actively tried to disrupt the ASC's intended path.

V. Conclusions

- Strong currents and heavy traffic are serious concerns for a large-scale autonomous deployment. Planning for such scenarios cannot be made *a priori*.
- We propose an online distributed planning approach for collision-free navigation in such scenarios.
- Deployment in Selat Pauh and Pulau Ubin channel has shown that the system works in practice in rough waters.

Acknowledgements

The research described in this project was funded in whole or in part by the Singapore National Research Foundation (NRF) through the Singapore-MIT Alliance for Research and Technology (SMART) Center for Environmental Sensing and Monitoring (CENSAM).

References

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