Escape and evade control policies for ensuring the physical security of nonholonomic, ground-based unattended mobile sensor nodes

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Hazards faced by unattended mobile sensor nodes

Spray underwater glider

Spray stats (2003-2010)
-171 mission
-2368 days
-16620 dives (500 m typ.)

www.spray.ucsd.edu

4 unintentional recoveries by fisherman

10 recorded fish attacks

Photos Courtesy of Russ Davis, Scripps Institute of Oceanography

Hazards faced by unattended mobile sensor nodes

"**The key technologies that enable UGVs include** complex world modeling, ground based hazard detection (e.g., mines, explosives), lane detection/road following, **anti-tamper/self protection,** highly dexterous manipulation, collaborative teaming in urban environments, etc. **Of particular note among ground systems is the requirement for anti-tampering. In no other environment is an unmanned system more vulnerable to human tampering than when on the ground. It is imperative for the success of UGV operation that it be invested with the ability to deter humans from interfering with its activities, as well as from tampering with or damaging it via close physical contact**."

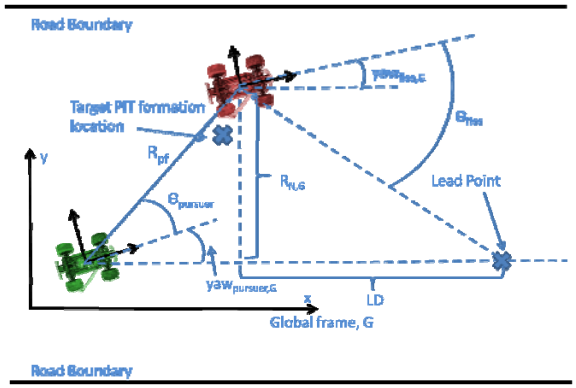
2009 Unmanned Systems Integrated Roadmap (pg 49)

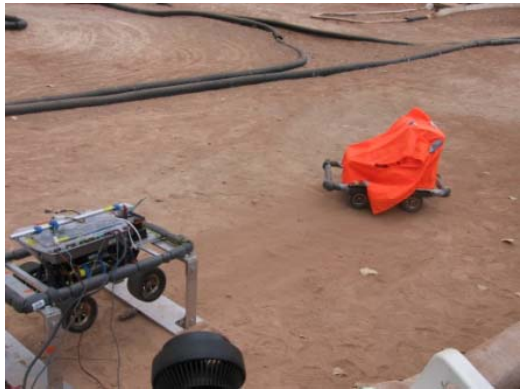
http://www.acq.osd.mil/psa/docs/UMSIntegratedRoadmap2009.pdf

Outline

Summarize PIT maneuver problem and background

Proposed control policies to implement PIT maneuver-related actions.





Experimental platform and initial field testing results.

Summary of the Precision Immobilization Technique (PIT Maneuver)

Textbook PIT maneuver

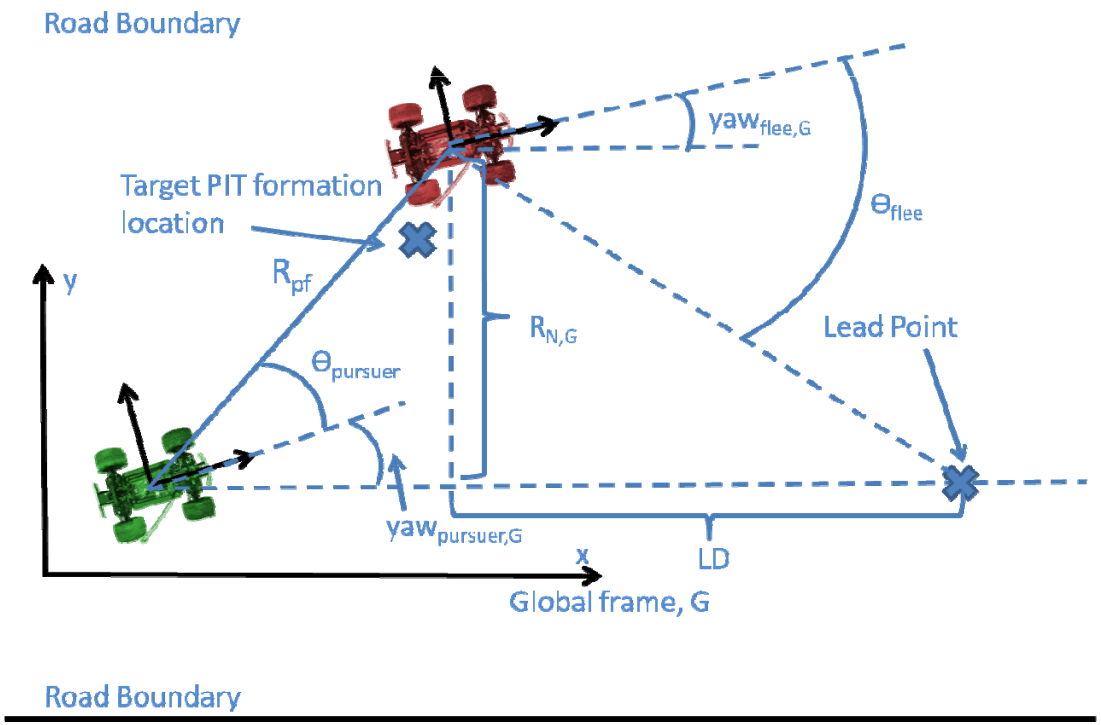
It is easy to imagine that such a technique could be used by thieves to steal and tamper-with car-like mobile sensor nodes as they gain popularity,

Resisting and Recovering From the PIT Maneuver

Fleeing and recovering from the PIT maneuver

Improperly executed PIT maneuver

PIT Resistance Control Law Overview



$$LD = \Delta x = x_{flee} - x_{pursue}$$

$$\Delta y = y_{flee} - y_{pursue}$$

$$A_T = G_{R_{pf},flee} * \frac{(R_{threat} - R_{pf})}{R_{threat}} + G_{V_c,flee} * V_c$$

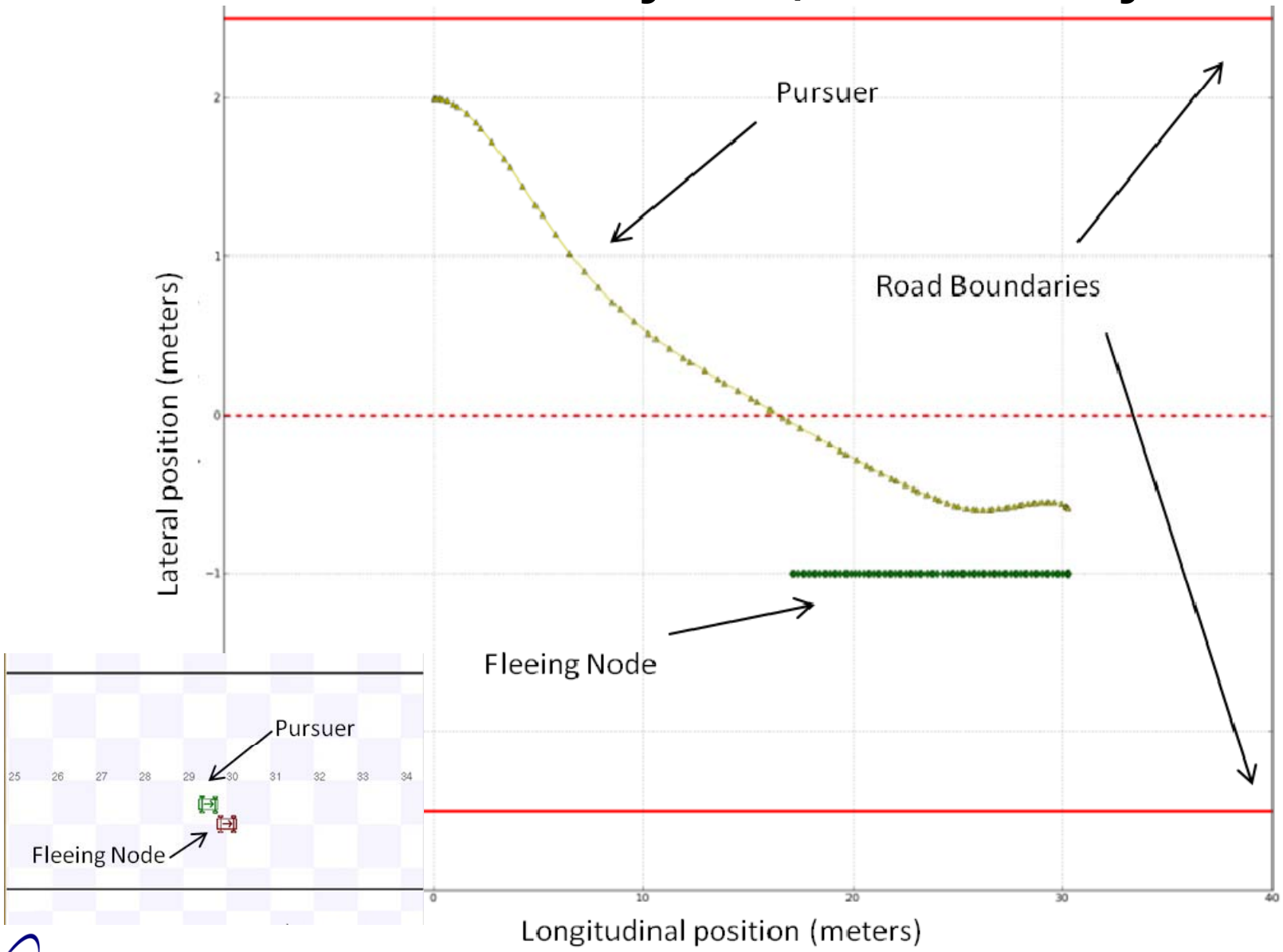
$$\alpha_{yaw} = G_{Heading,flee} * \theta_{flee} + G_{\dot{Heading},flee} * \dot{\theta}_{flee}$$

And for small |Δy|

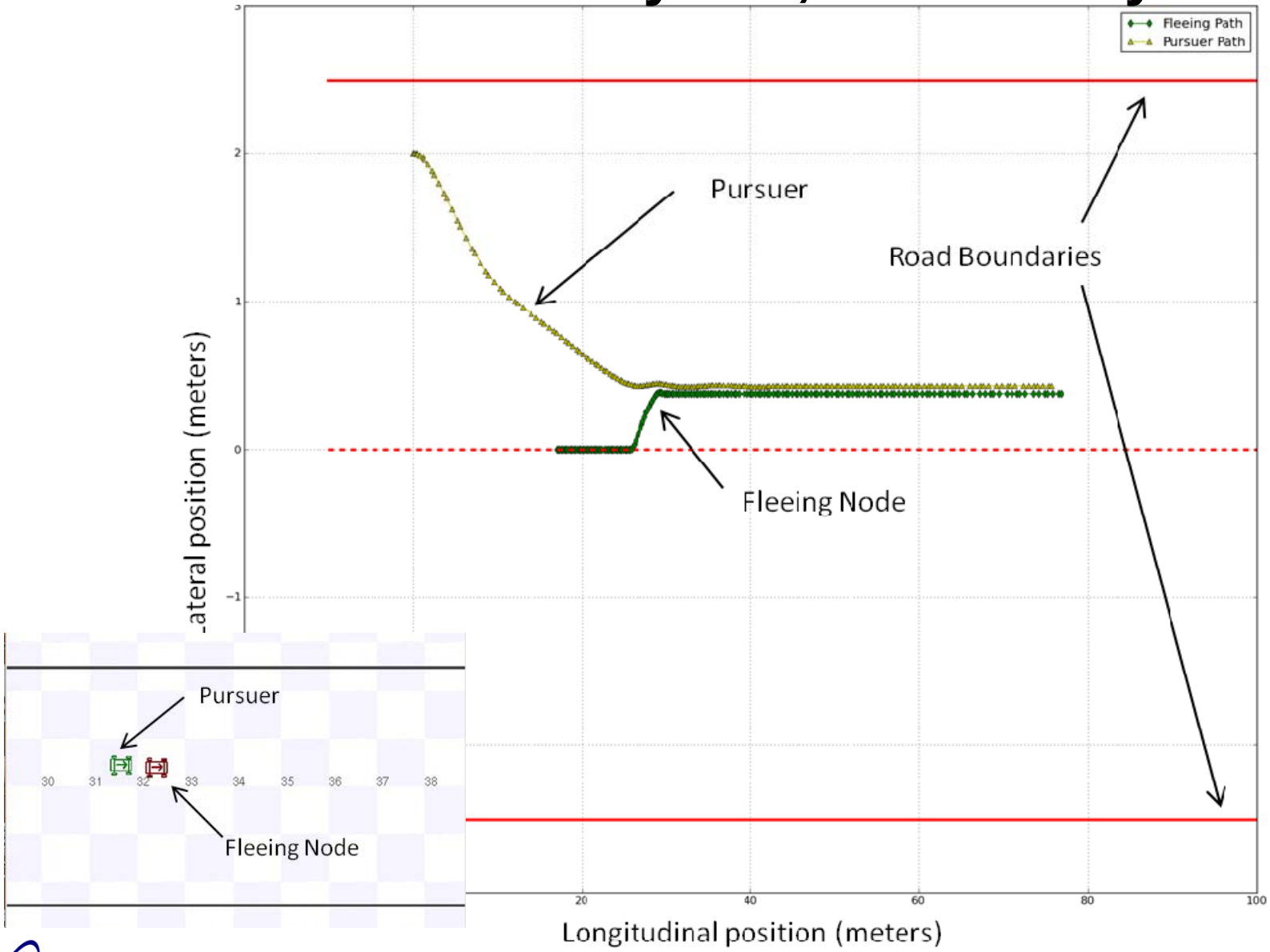
$$yaw_{error} = yaw_{desired,G} - yaw_{flee,G}$$

$$\alpha_{yaw} = G_{Heading,small,pursue} * yaw_{error} + G_{\dot{Heading},small,pursue} * \dot{yaw}_{error}$$

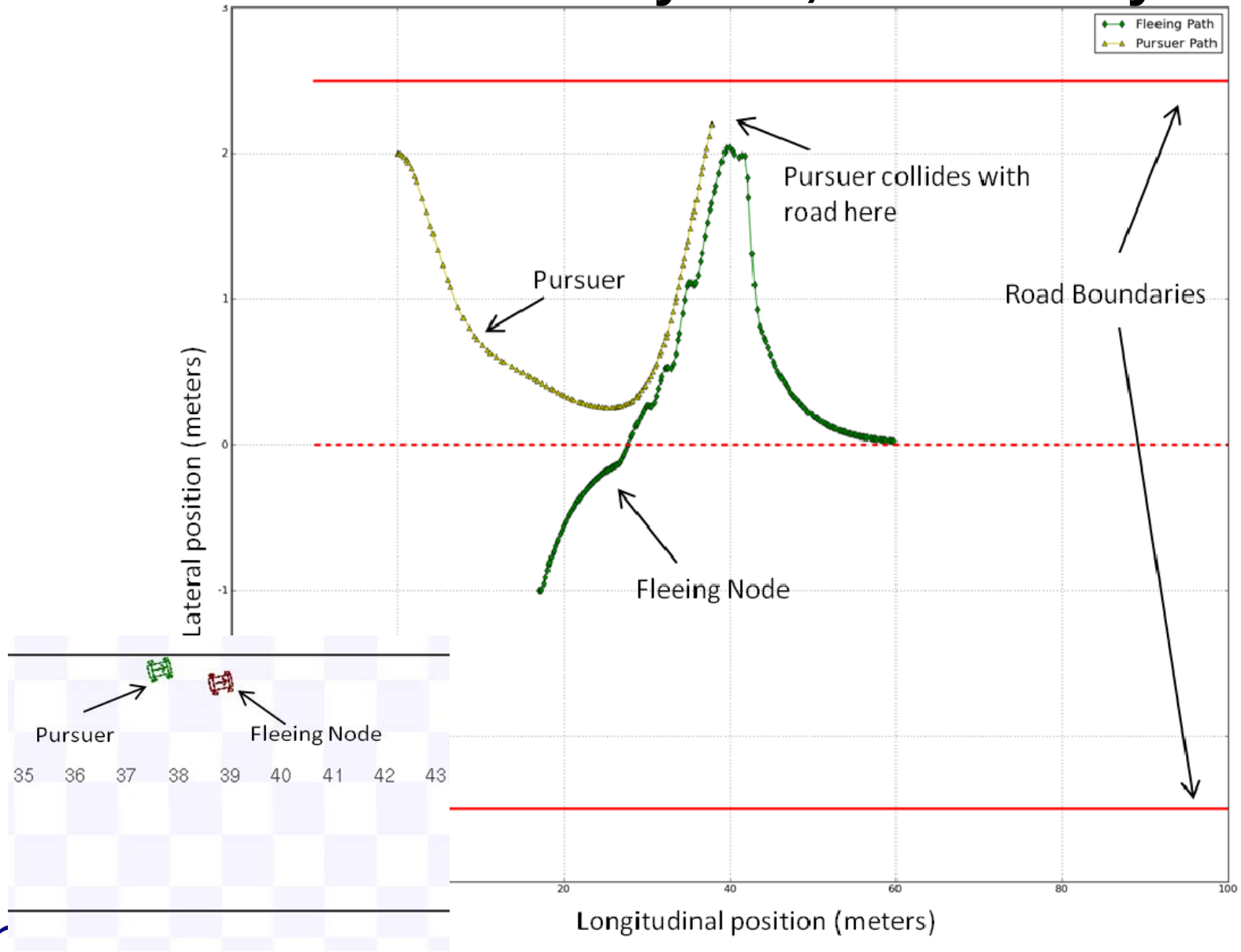
PIT/Pursuit Policy: On, Flee Policy: Off



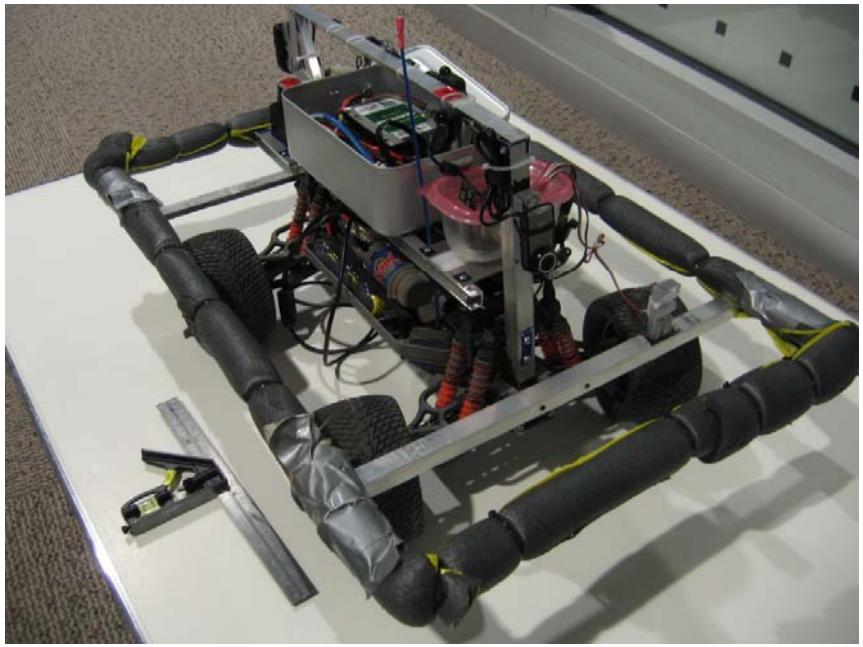
PIT/Pursuit Policy: On, Flee Policy: On

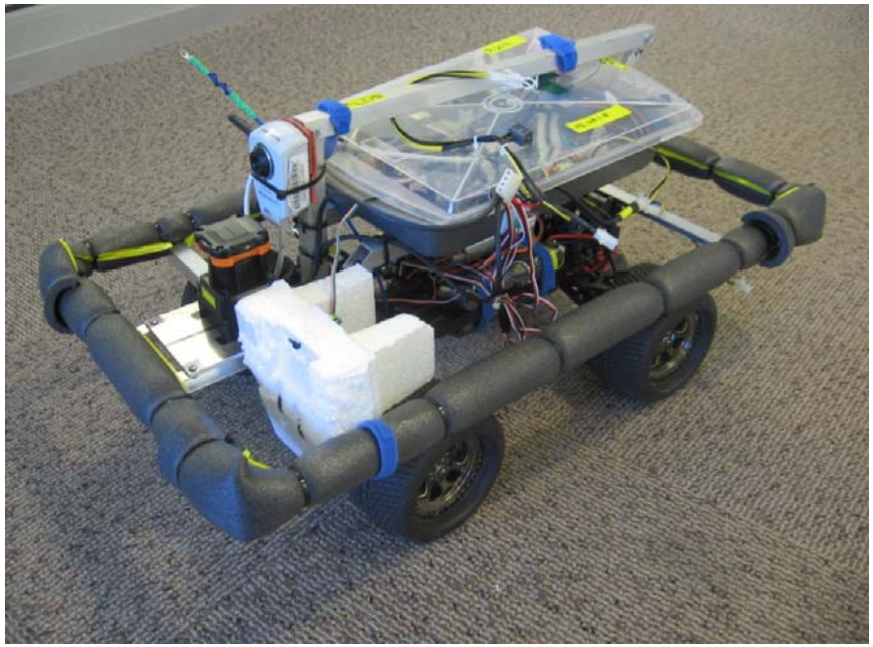


PIT/Pursuit Policy: On, Flee Policy: On



Surrogate Mobile Sensor Node Platform



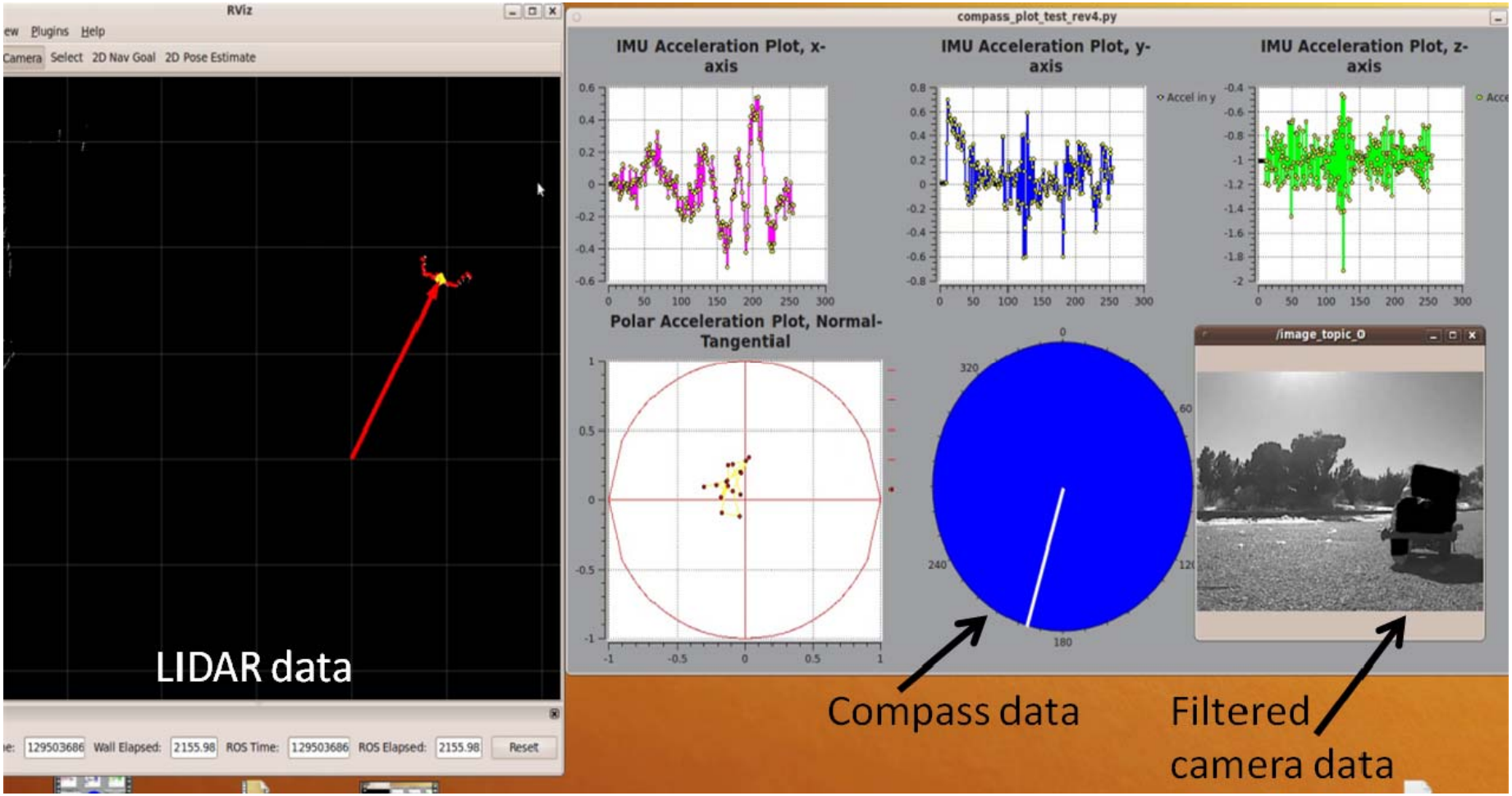


Chassis is commercially available Emaxx radio controlled truck, outfitted with roll bar and external frame.

On-Board Sensors:

- Cameras
- Compass
- LIDAR
- Accelerometers

Typical data available from mobile sensor node.



Field Testing Results

Manual Execution of the PIT Maneuver

Automatic Execution of the PIT Maneuver

Automatically Fleeing the PIT Maneuver

Accomplishments and Future Work

Future Work

•Try to better characterize the dynamic properties of the vehicle.
•Develop control policies to implement J-turns and reverse PIT maneuvers.
•Integrate these low-level control policies into a high level decision making framework (POMDP)

Conclusions

•Initial low-level control policies have been developed in simulation and have begun to be evaluated in small-scale field trials.
•Initial control policies and perception need additional development, but the basic ideas are showing promise.
•Work needs to go into evaluating the threat posed by agents in the environment.

Abstract:

In order to realize the wide-scale deployment of high-endurance, unattended mobile sensing technologies, it is vital to ensure the self-preservation of the sensing assets. Deployed mobile sensor nodes face a variety of physical security threats including theft, vandalism and physical damage. Unattended mobile sensor nodes must be able to respond to these threats with control policies that facilitate escape and evasion to a low-risk state. In this work the Precision Immobilization Technique (PIT) problem has been considered. The PIT maneuver is a technique that a pursuing, car-like vehicle can use to force a fleeing vehicle to abruptly turn ninety degrees to the direction of travel. The abrupt change in direction generally causes the fleeing driver to lose control and stop. The PIT maneuver was originally developed by law enforcement to end vehicular pursuits in a manner that minimizes damage to the persons and property involved. It is easy to imagine that unattended autonomous convoys could be targets of this type of action by adversarial agents. This effort focused on developing control policies unattended mobile sensor nodes could employ to escape, evade and recover from PIT-maneuver-like attacks. The development of these control policies involved both simulation as well as small-scale experimental testing. The goal of this work is to be a step toward ensuring the physical security of unattended sensor node assets.