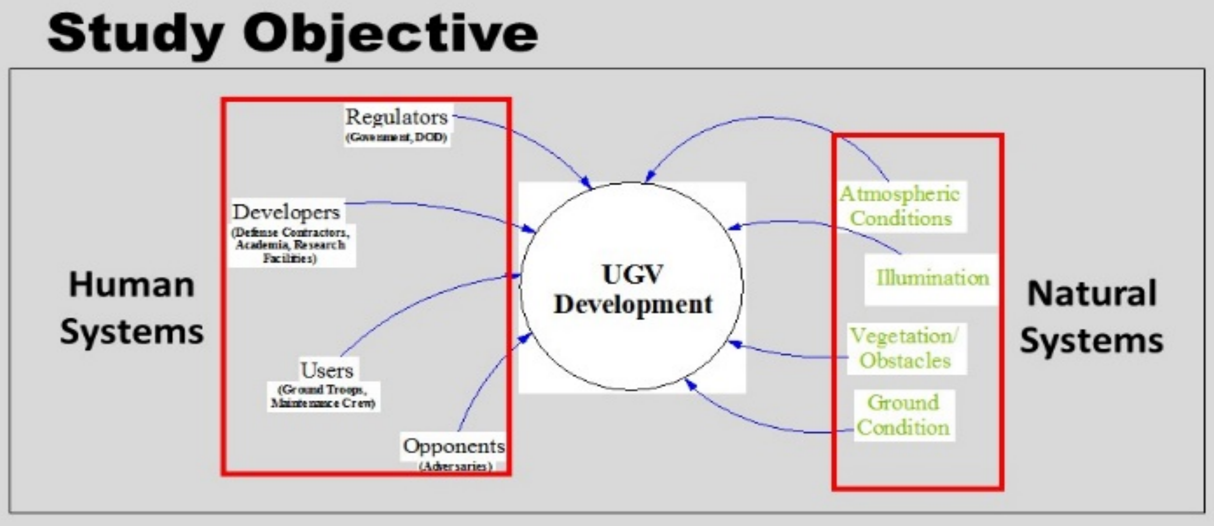
Temasek Defence Systems Institute

Temasek Defence Systems Institute

Systems Engineering Approach to Develop Guidance, Navigation & Control Algorithms For Unmanned Ground Vehicle

Lim Eng Soon
Singapore Army

Study Objective



…to develop a rapid prototype of an autonomous ground platform capable of navigating through designated waypoints while detecting and avoiding obstacles during maneuver…

…capable of identifying potential targets at its designated terminal waypoint…

…environment for the vehicle will be in a cluttered terrain with varying light conditions…

Candidate Technologies & Implemented Architecture

Sensors:

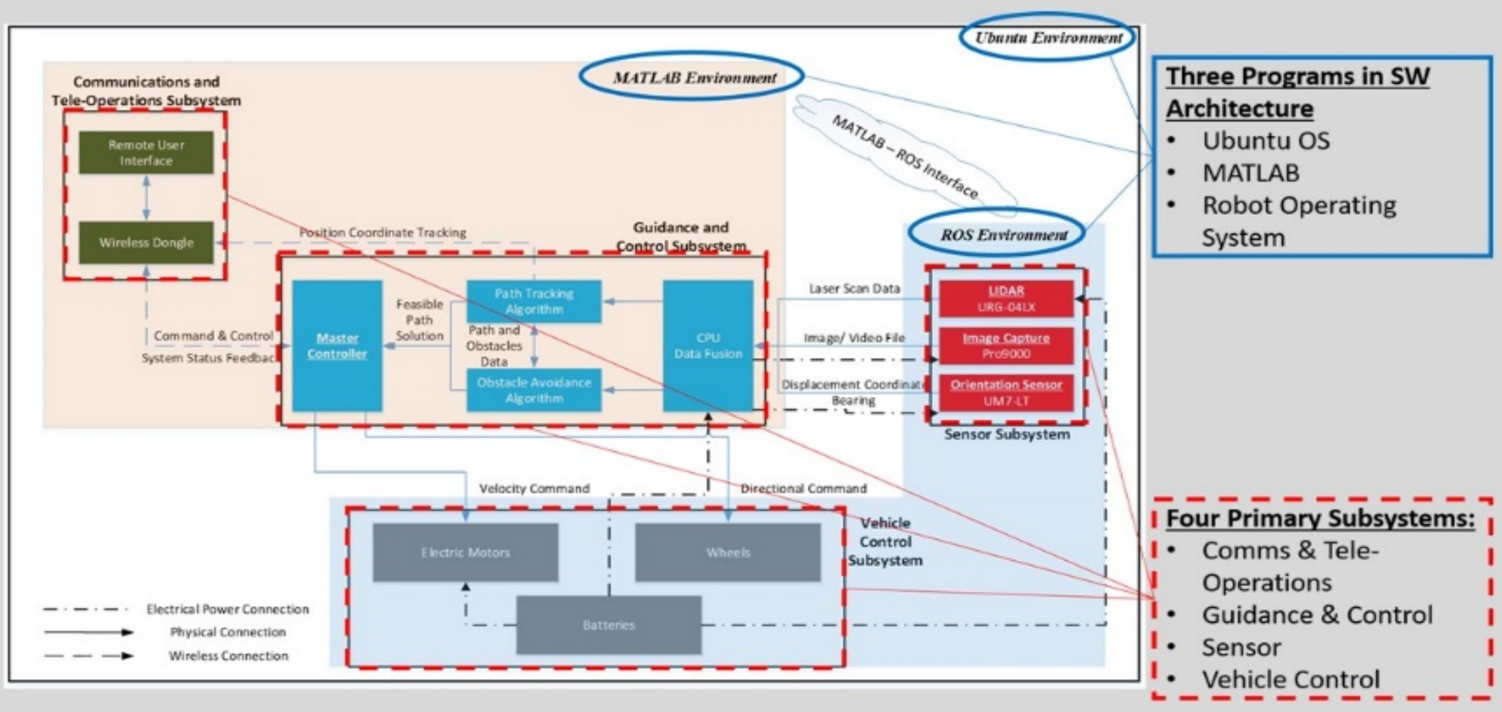
Algorithm	Advantages	Disadvantages
Acoustic Sensor	• Simple implementation	• Poor angular resolution • Require multiple sensors
LIDAR	• Good angular resolution • Fast sensor response and feedback	• Susceptible to environmental conditions
Light Sensor	• Simple implementation • Passive sensor, no signature	• No angular/ range resolution • Require multiple sensors
Image Camera	• High resolution of vicinity • Passive sensor, no signature	• Computationally intensive
Radiofrequency	• Good angular resolution • Fast sensor response and feedback	• Costly • Susceptible to noise and jamming

Obstacle Avoidance:

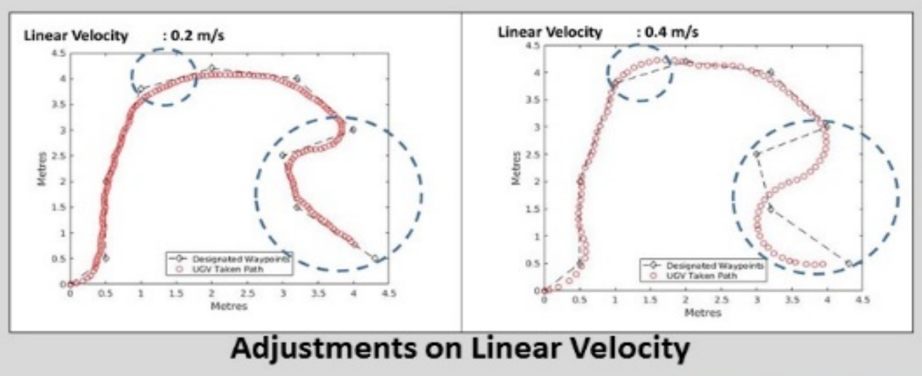
Algorithm	Performance	
	Efficiency	Time to Arrive
Bug Algorithm	• Low; Reactive • Only reactive to obstacles upon contact	• High; • Movement in one direction to avoid obstacles
Potential Field Method	• Low; Reactive • Require pre-msn planning and knowledge of AO	• Low; • Global route, localized obstacle avoidance
Vector Field Histogram	• Medium; Proactive • Dependent on sensors' accuracy & sensitivity	• Medium; • Localized obstacle avoidance
Vision-based method	• High; Proactive • Dependent on sensors' accuracy & sensitivity	• Medium; • Computational and time intensive
Hybrid Navigation Algorithm	• High, Proactive • Require pre-msn planning and knowledge of AO	• Low • Computational and time intensive

Path Following:

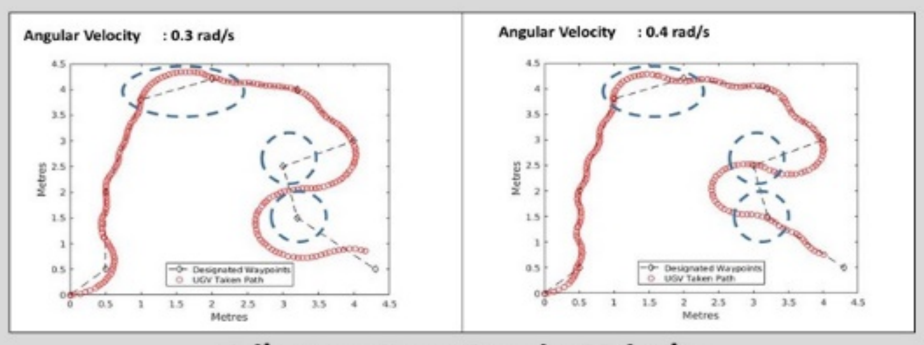
Algorithm	Advantages	Disadvantages
Follow-the-Carrot	• Simple implementation	• Tend to oscillate • Poor performance around bends
Pure Pursuit	• Simple implementation	• Tend to oscillate, but much better than FTC
Vector Pursuit	• System able to achieve intended orientation at terminal point	• High complexity and computationally intensive



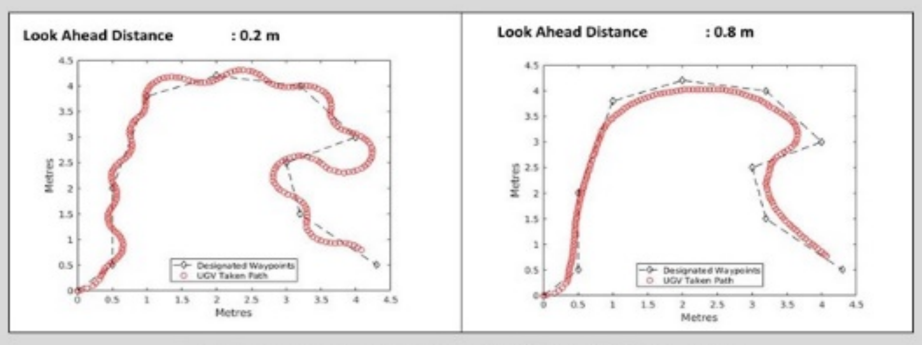
Findings – Pure Pursuit Path Following



Adjustments on Linear Velocity



Adjustments on Angular Velocity

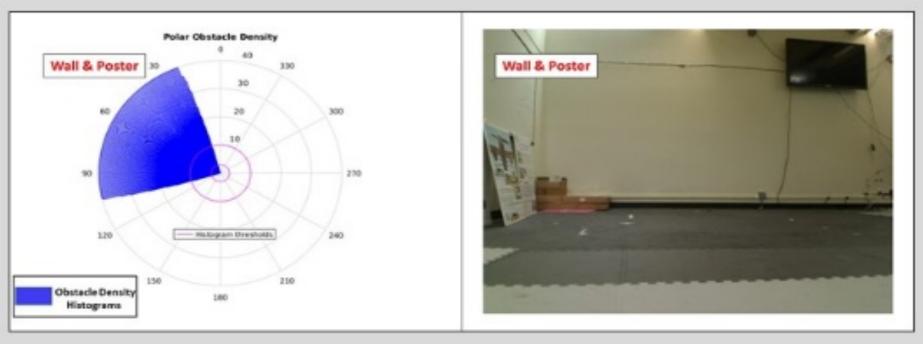


Adjustments on Look-Ahead Distance

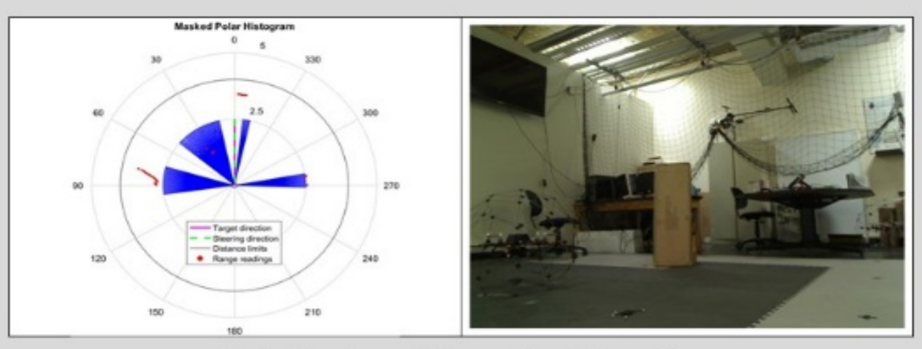
Stability of system's maneuver is closely linked to the following three tuning parameters:
- **linear velocity affects overall movement speed,**
- **angular velocity affects dexterity to negotiate bends,**
- **look-ahead distance affects overall movement stability.**

Findings – Vector Field Histogram Obstacle Avoidance

1. Detection of Obstacles



2. Derivation of Obstacle Density

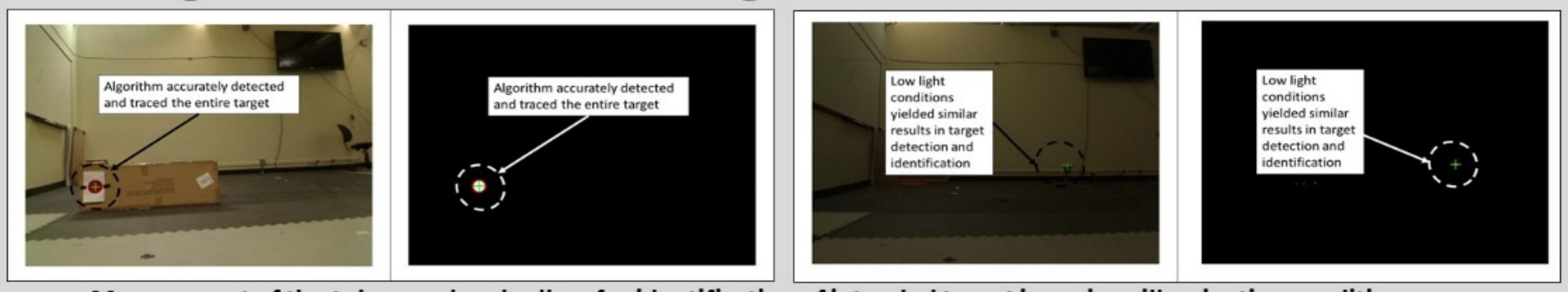


3. Selection of Steering Direction

Obstacle avoidance goes through three levels of data reduction for deriving optimal path and are as follow:
- **detection of obstacles by on-board LIDAR,**
- **feedback from sensors gives perception of obstacle presence,**
- **selection of steering direction from candidates according to intended direction.**

Efficiency of vector field histogram method is affected by the following:
- **the detection range and resolution of sensor to give more reaction time,**
- **the tuning of thresholds to ensure that available routes are indeed obstacle free.**

Findings – Vector Field Histogram Obstacle Avoidance



Management of the tolerance levels allow for identification of intended target in various illumination conditions

Efficiency of feature recognition is affected by the following:
- **color deviation tolerance,**
- **expected shape factor to be identified in the binary image.**

NUS National University of Singapore