USV Autonomy Research Proposal

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Previous and Current Work

Starting conditions:The MAS is located at airbases and receives multiple requests for service including:

- Location to visit;
- Number of air-vehicles required;
- Earliest time of 1-st visit;
- Latest time of 1-st visit;
- Minimum duration per visit;
- Maximum interval between visits.

Mission Objective:

Air-vehicle(s) to be assigned to request and the corresponding paths to take to the service request; (variations to requests with minimal change if it cannot be met.)

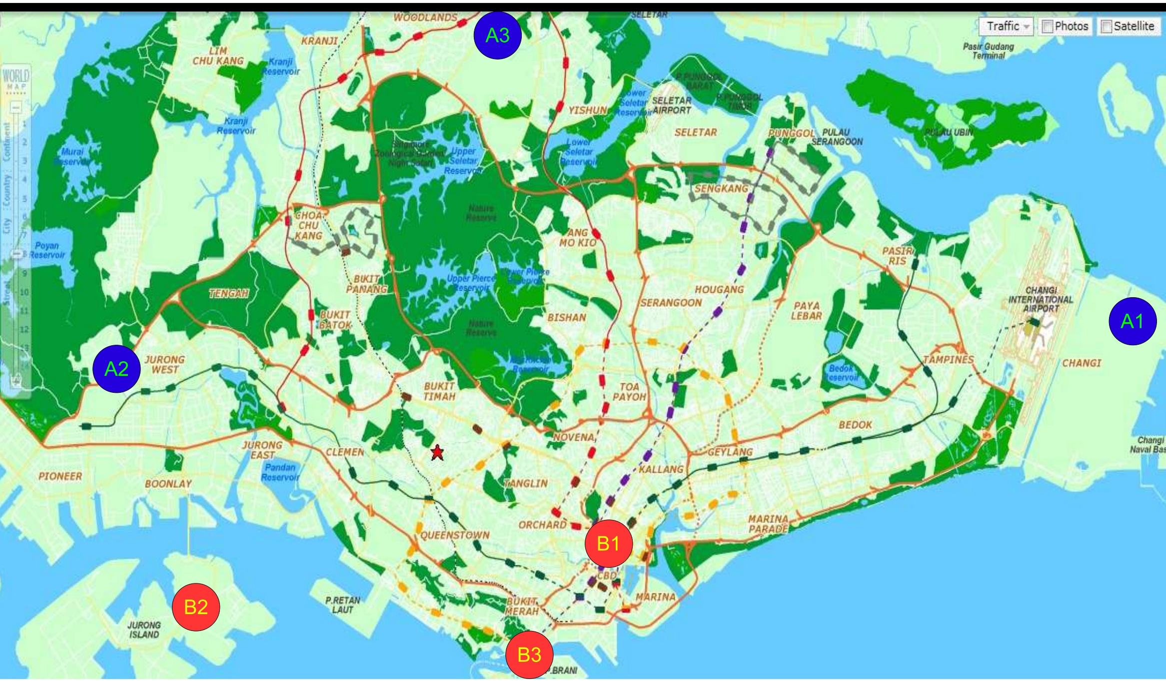
That:

Maximize the number of service requests that can be serviced.

Constraints:

Air-vehicle performance and dynamics.

Previous and Current Work

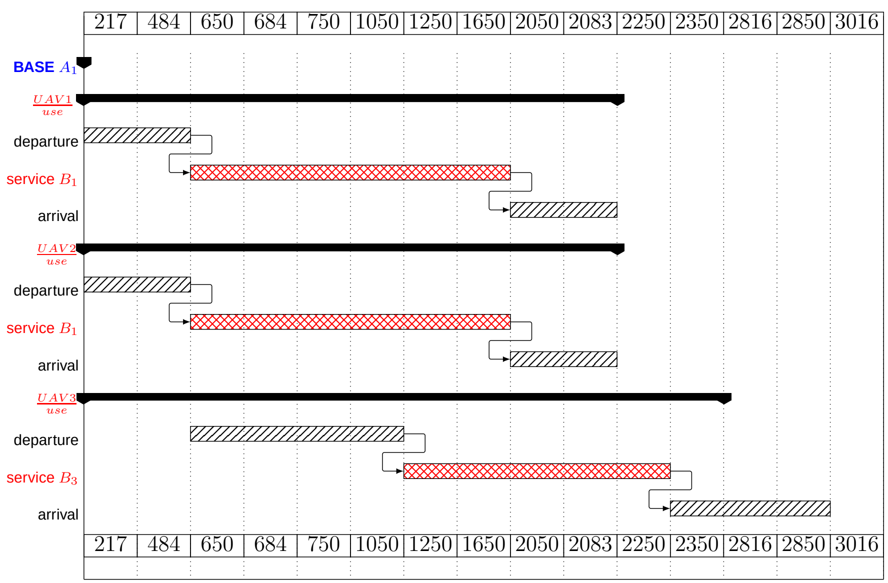


3 airbases located:

- Changi(3);
- Jurong West(3);
- Woodlands(1).

Service requests from:

- Raffles Place(2);
- Jurong Island(2);
- Sentosa(3).

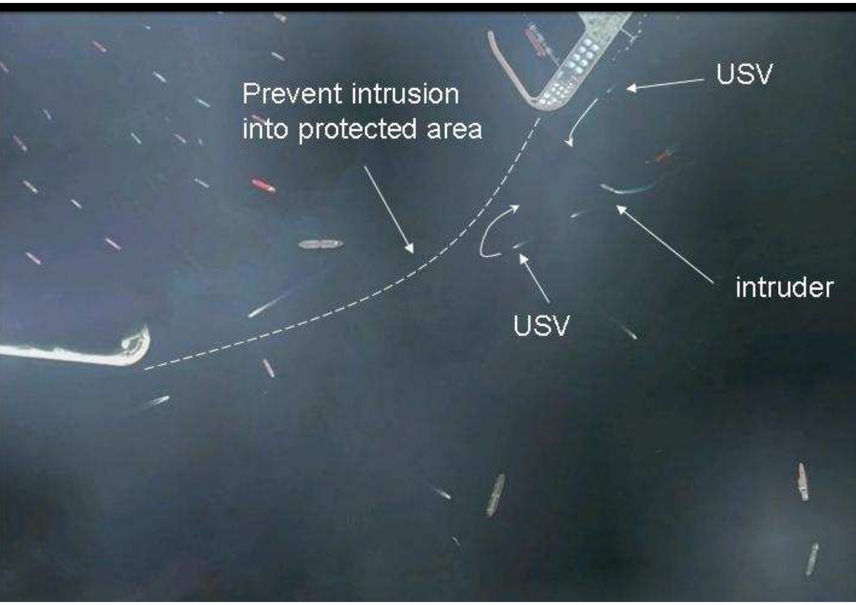


The proposed method are:

- iterative,
- exact,
- finite,
- relaxed.

The ideas of this method can be applied to various nature of assignment problems, such as patrolling problem for team of USV.

USV Pursue, Intercept, Block



Problem

- An intruder that adopts cunning strategies may break a hand-crafted, rule-based pursue, intercept, block logic;
- It is not clear if the current platform maneuverability is sufficient to counter such an intruder.

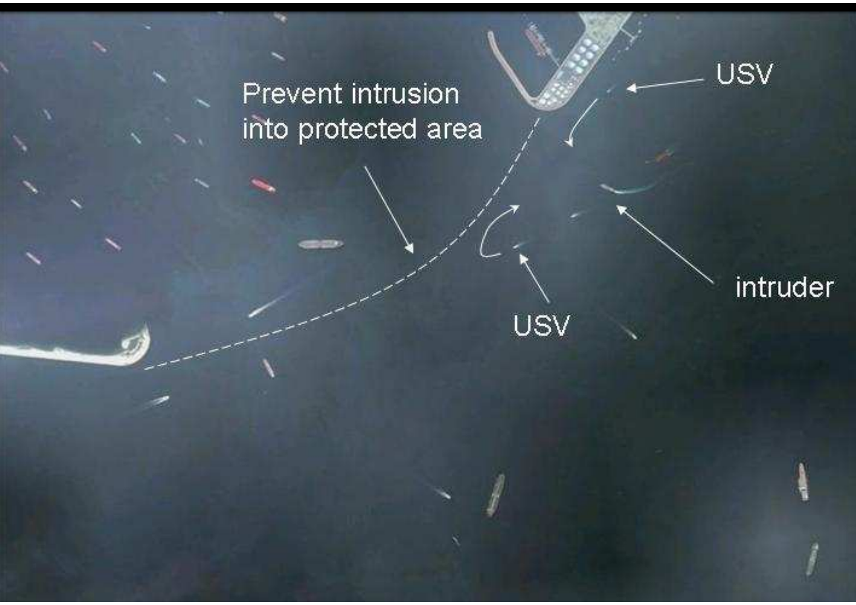
Challenge:

- How to develop a logic to counter a cunning intruder?
- Can the current platform counter such an intruder given the logic? If not, how maneuverable should the platform be?
- Can two of such current platforms counter such an intruder?.

In the most classic cases the unknown control functions for E and P is determined as "$minmax$" solution. In other words, it is proposed that the control function of E is a worst case for better choice of pursuer P or vice versa, i.e.

$$J(u^0, v^0) = \min_u \max_v J(u, v)$$

Evader & multiple Pursuers case

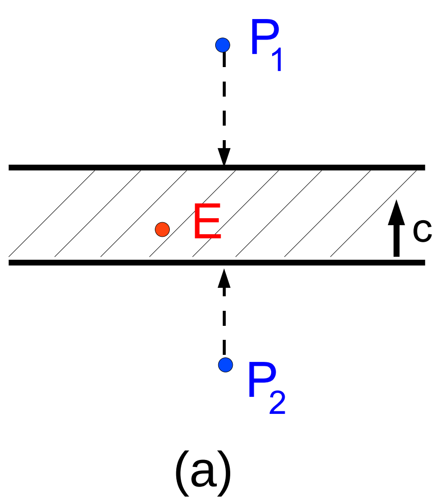


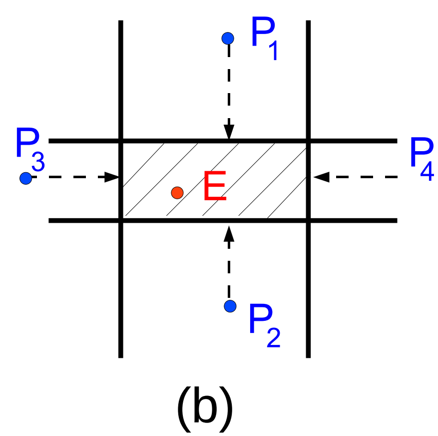
Consider the game of three objects E (evader) and P_1 (pursuer 1), P_2(pursuer 2). Also assume that motion law of these objects are described as follows

$$\begin{cases} \dot{e} = u_e \\ \dot{p_1} = u_1 \\ \dot{p_2} = u_2 \end{cases}$$

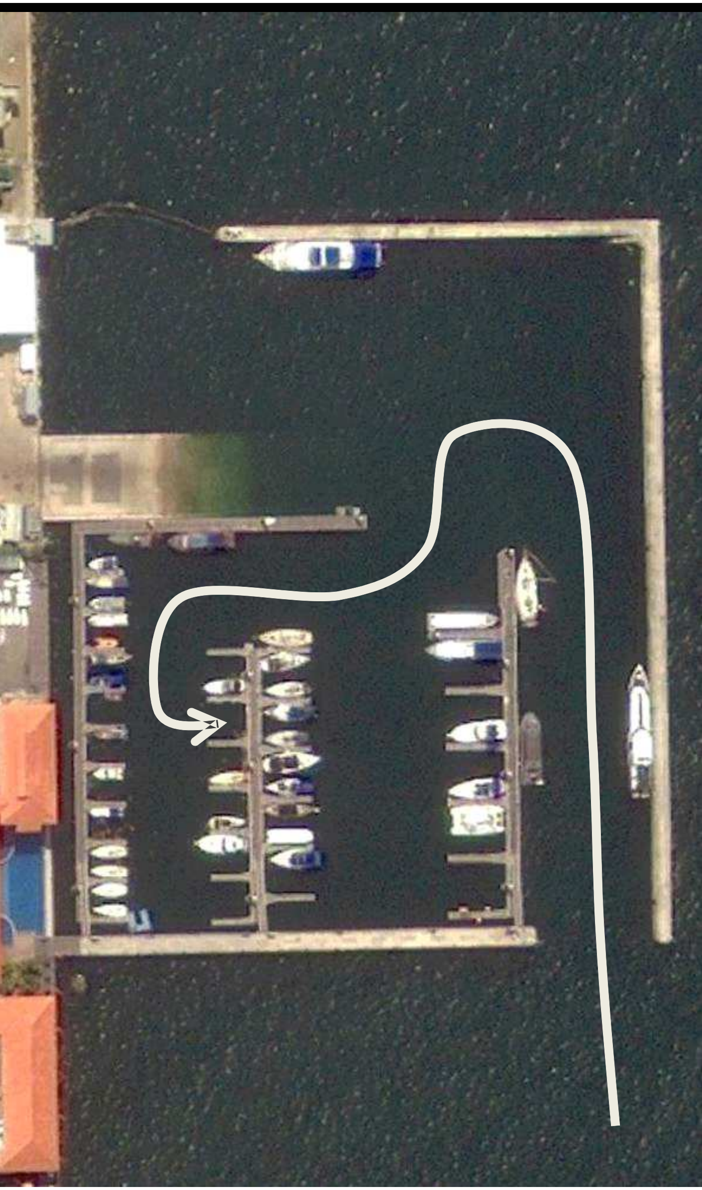
The problem here is to construct the control functions in order to capture the E in a strip

$$\begin{cases} c'p_1 - c'p_2 \longrightarrow \min \\ c'p_2 \leq c'e \leq c'p_1 \end{cases}$$





Controller Design for USV Docking



Problem

- To dock a boat using onboard sensors, involving motion planning and control.

Challenge:

- To perform the operation safely and close to the same level of performance as when driven by a human;
- To perform the operation using on-board sensors.

Idea (synthesis)

(D.W. Bushau, Brunowski P., Fillipov A. F., Sussmann H.)

Aim:to construct the closed optimal system that describes the optimal trajectories only

$$T \longrightarrow \min_{U}, \qquad \text{subject to} \qquad \frac{\partial x}{\partial t} = Ax + bu, \;\; \{x\} \mapsto 0$$

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$\Downarrow$

$$\frac{\partial x}{\partial t} = Ax + bv(x)$$

Classical time optimal problem without phase constraints.

Idea (synthesis)

$\Downarrow$

Construct optimal controller satisfying:

$$\frac{dx(t)}{dt} = Ax(t) + bv(x)$$

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$$Question : When \quad do \; we \quad need \quad to \quad switch?$$

$$Answer : use \; optimality \; condition \; of \; the \; supporting \; control \; function.$$

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Differential equations for the switching moment as initial position function:

$$G\frac{\partial \tau}{\partial s} + Q = \frac{\partial h}{\partial s}, \quad P\frac{\partial \tau}{\partial z} = \frac{\partial h}{\partial z}$$

Synthesis control is $u^0 = \pm 1$ in accordance with obtained switching time functions:$\tau(s, z)$

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In our case : switching manifold of optimal control

Example

maximize the terminal cost functional

$$\max_{|u|\leq 1} J(u),\ J(u) := x_2(1)$$

over the control system

$$\frac{dx_1(t)}{dt} = x_2, \frac{dx_2(t)}{dt} = u(t),$$
$$x_1(s) = z_1,\ x_2(s) = z_2,\ \ t \in [s, 1],\ x_1(t), x_2(t) \in \mathbb{R}$$

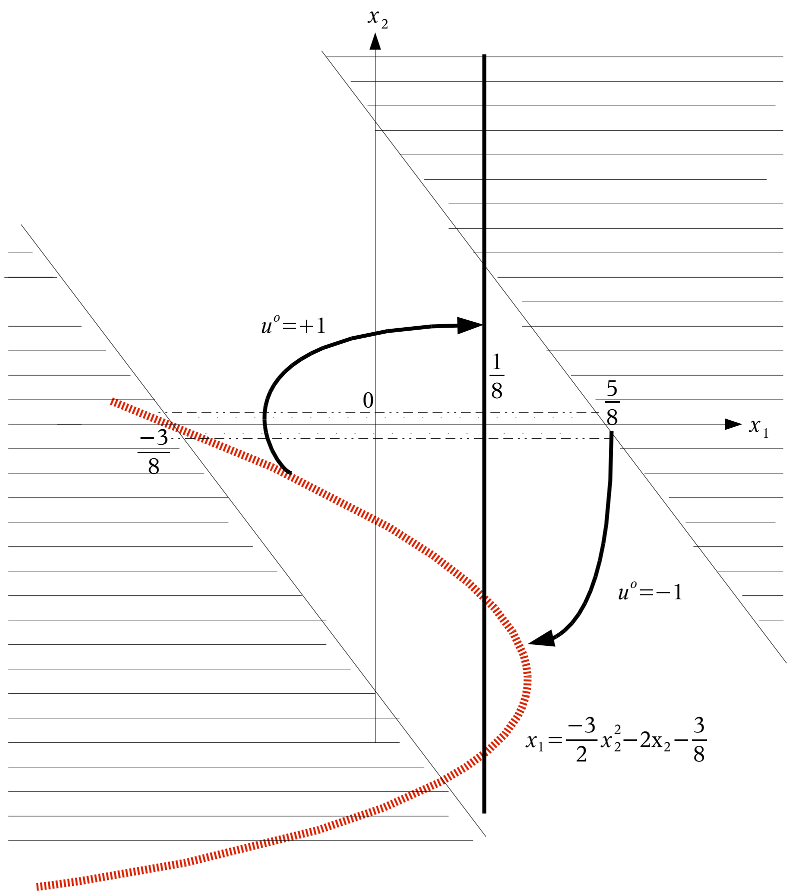
subject to the following constraints on control and state variables

$$|u(t)| \leq 1, \qquad x_1(1) = 1/8,$$

Example

The given parametric description can be transformed to the typical regular synthesis pictures. For example, let the disturbances are realized along the line of the form

$\Upsilon_1 : z_2 = \beta = 0, -\infty \leq \beta \leq +\infty$

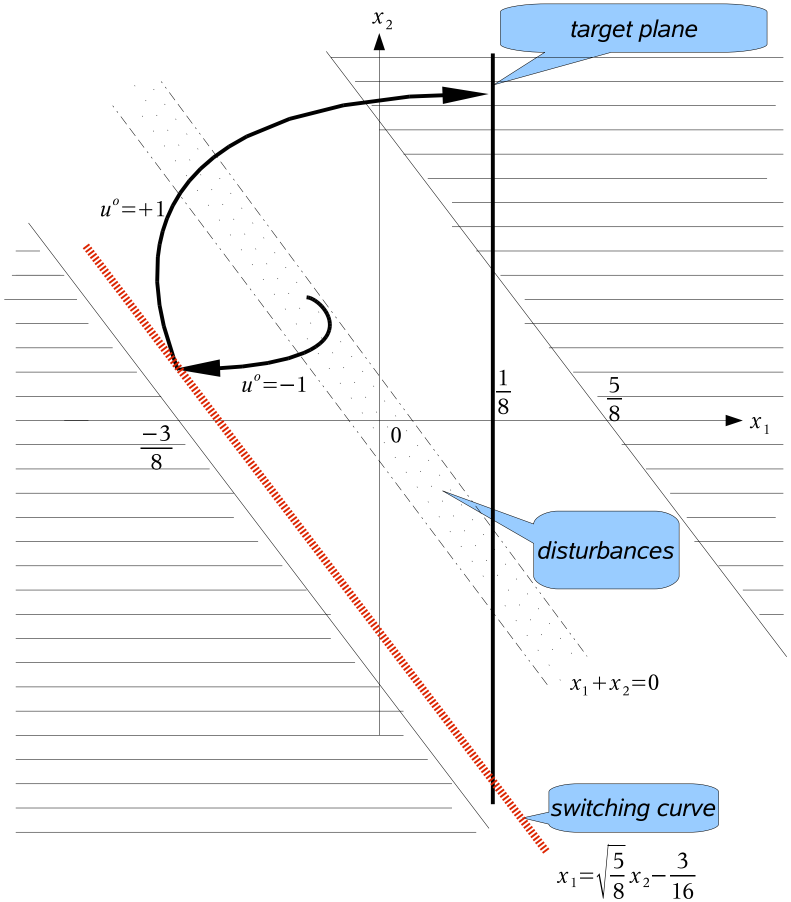


then the switching curve is the parabola

$$Z_c(\Upsilon_1):\; x_1 = -\frac{3}{2}(x_2)^2 - 2x_2(1-\beta) + \beta - \frac{3}{8}$$

Example

If the disturbances are active only along the line $\Upsilon_2: \; z_1 + z_2 = \alpha$,



then the switching curve is the line $Z_c(\Upsilon_2): x_1 = -\sqrt{5/8 - \alpha}x_2 + \frac{\alpha}{2} - \frac{3}{16}$.

Questions to USV experts

1. First question is regarding the accuracy of the dynamics model of the station in order to be clear about the model structure.
2. Is it known dynamics equations of controlled objects, written in a state space formalization (i.e. by differential equations for state and control input functions)?
3. In case when there is no differential equations for state and control functions, what kind of information are available from the station to boat(s) throw periodical broadcasting (for example, station position coordinates, velocity and so on)

The aim of our questions is to find an adequate problem statement of mutual interests for station-keeping (approaching) processes. What kind of subproblems can be considered as an starting position

- Deterministic problem statement;
- Maneuvering station;
- Not maneuvering station with noncompletely defined motion, imperfect measuring;
- Maneuvering station,imperfect measuring;
- Indeterministic models, imperfect measuring.

The end

Thank you !