Probabilistic Pursuit-Evasion Games

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Pursuit-Evasion Game Scenario

A team of ground and aerial pursuers attempts to capture evaders in a finite but unknown environment

Pursuers build a probabilistic map of the environment and follow a pursuit policy to minimize the capture time

Pursuers use cameras to sense the environment and GPS, INS, etc. to localize themselves in the map

Our approach

Map building and pursuit-evasion games are combined into a single probabilistic approach

Implementation is done using a hierarchical architecture for multi-agent coordination, control and vision-based sensing

Map Building

Measurements: Position of pursuers $\mathbf{p}_t$, evaders $\mathbf{e}_t$ and obstacles $\mathbf{o}_t$

$$\mathbf{Y}_t = \{\mathbf{y}_1, \ldots, \mathbf{y}_t\} \qquad \mathbf{y}_t = \{\mathbf{p}_t, \mathbf{e}_t, \mathbf{o}_t\}$$

Evader Map:

$$p_e(x, t|Y_{t-1}) = \mathrm{P}(\mathbf{x}_e(t) = x|\mathbf{Y}_{t-1} = Y_{t-1})$$

Measurement step: $\mathrm{P}(\mathbf{x}_e(t) = x|\mathbf{Y}_t = Y_t)$ — Sensor Model

Prediction Step: $\mathrm{P}(\mathbf{x}_e(t+1) = x|\mathbf{Y}_t = Y_t)$ — Motion Model

Pursuit Policies

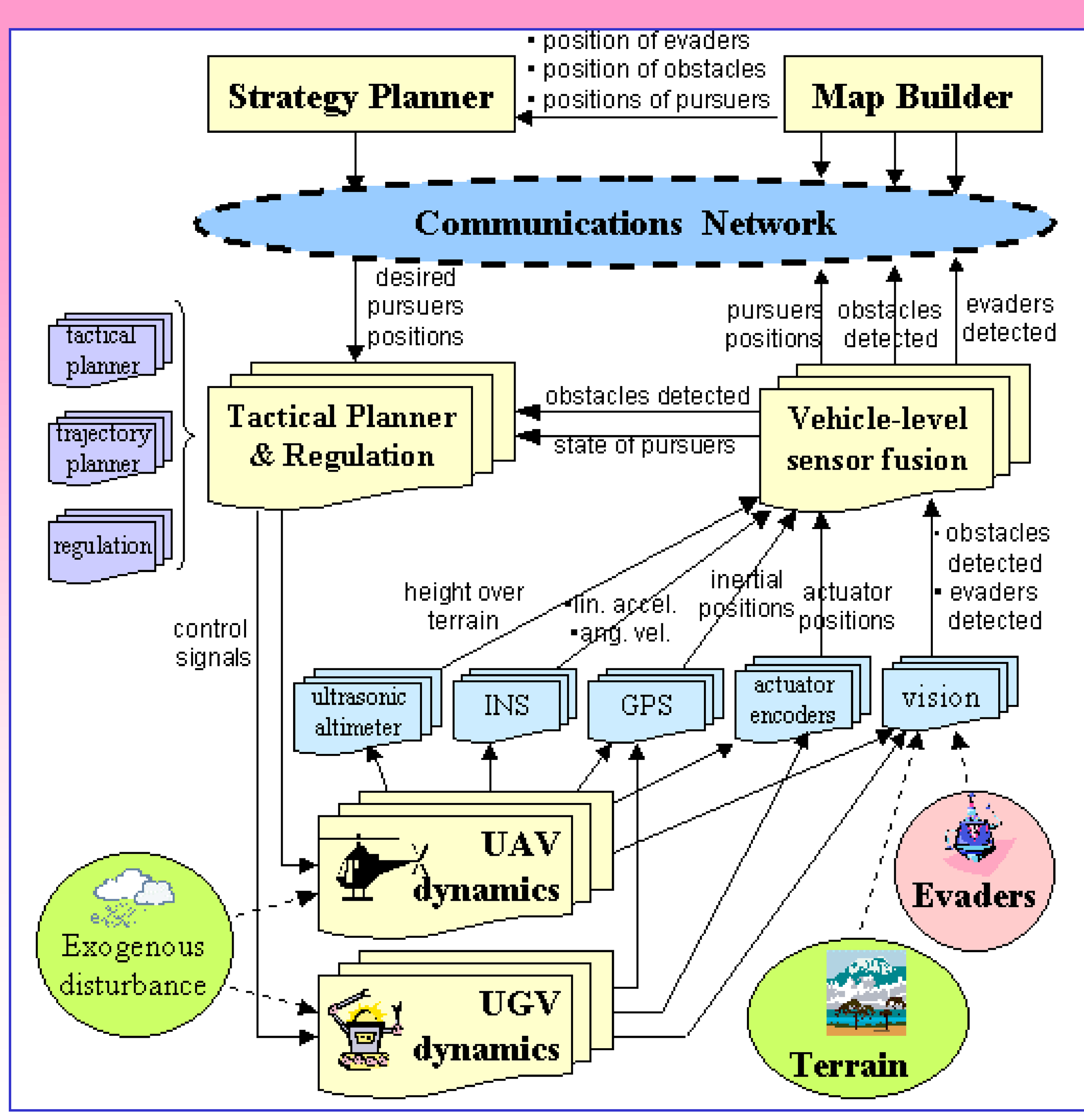
Pursuers move to the cell in the map with maximum probability of having an evader

$$\mathbf{u}_{t+1} = \operatorname*{argmax}_{x \in \mathcal{U}} \; p_e(x, t+1|Y_t)$$

Local-max Global-max

The expected capture time is finite

System Architecture: Design and Implementation



Map Builder: builds probabilistic maps with the location of obstacles and evaders. It is implemented in MATLAB.

Strategy Planner: it is responsible for high-level intelligent control of the vehicles, i.e. the pursuit policy. It is implemented in MATLAB.

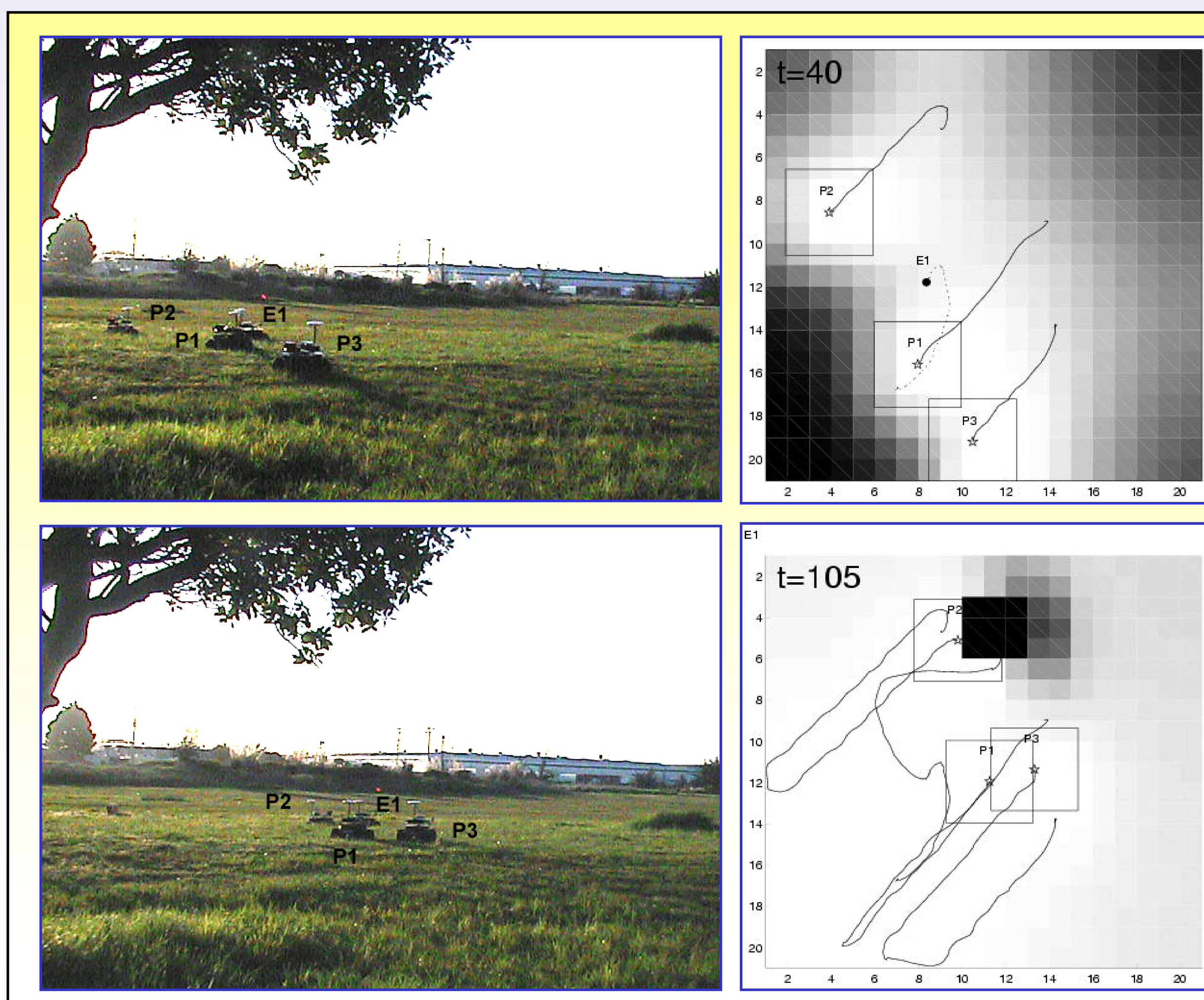
Communication: sends sensor information from the vehicles to the map builder, and desired positions from the strategy planner to the vehicles.

Tactical planner: converts strategic plans into a sequence of way points or flight modes used by the trajectory planner and regulation layers to produce a realizable and safe trajectory. Implemented in C++/QNX/Linux

Sensors: vehicles are equipped with cameras for sensing the environment and GPS, INS, sonars and laser range finders for localization.

Vehicles: custom-designed UAVs based on Yamaha R-50 and R-MAX helicopters, and ActivMedia Pioneer 2-AT UGVs.

Experimental Results



Pursuit Policy: The global-max policy outperforms the local-max policy

Evasion Policy: It takes longer to capture an intelligent evader

Evader Speed: It takes longer to capture a slow or fast random evader

Visibility Region: Perspective visibility outperforms omnidirectional visibility

Exp 1: 3 pursuers & 1 evader

White = low prob.
Black = high prob.

Table 1: Experimental Results

Exp	Purs. Policy	Purs. Speed	Evad. Policy	Evad. Speed	Visib. Region	Capt. Time
1	G-max	0.3	Rand	0.1	Omni	$105s$
2	G-max	0.3	Rand	0.1	Trap	$42s$
3	G-max	0.3	Rand	0.5	Trap	$37s$