Efficient Redistribution of Heterogeneous Swarm Robots for Building Security

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Motivation

In a community of heterogeneous swarm robots, each robot has their own unique capabilities. Given these different capabilities, they need to adapt to specific needs of the desired task. Quantifying the capabilities would increase the efficiency in the redistribution.

Objective

Find an optimal policy to redistribute heterogeneous swarm robots based on their capabilities.

Factors: optimal transition rates, convergence time

Approach

$$\boldsymbol{q}^{(s)} = [q_1^s, q_2^s, \dots, q_U^s]$$

$\boldsymbol{q}^{(s)}$, species vector

s, number of robot species

U, number of traits in the community

Current Method:

$$Q_{s,U} = \begin{cases} 0, \text{if species } s \textbf{ does not } \text{have trait } u \\ 1, \text{if species } s \textbf{ does } \text{have trait } u \end{cases}$$

$$\boldsymbol{Q} = (q_{ij}) \epsilon \mathbb{R}^{s \times U}$$

Proposed Method:

$$Q_{s,U} = \{n, \text{number of trait } u \text{ for each species}$$

$$\boldsymbol{Q} = \begin{bmatrix} u_{1,1} & \cdots & u_{1,U} \\ \vdots & \ddots & \vdots \\ u_{s,1} & \cdots & u_{s,U} \end{bmatrix}$$

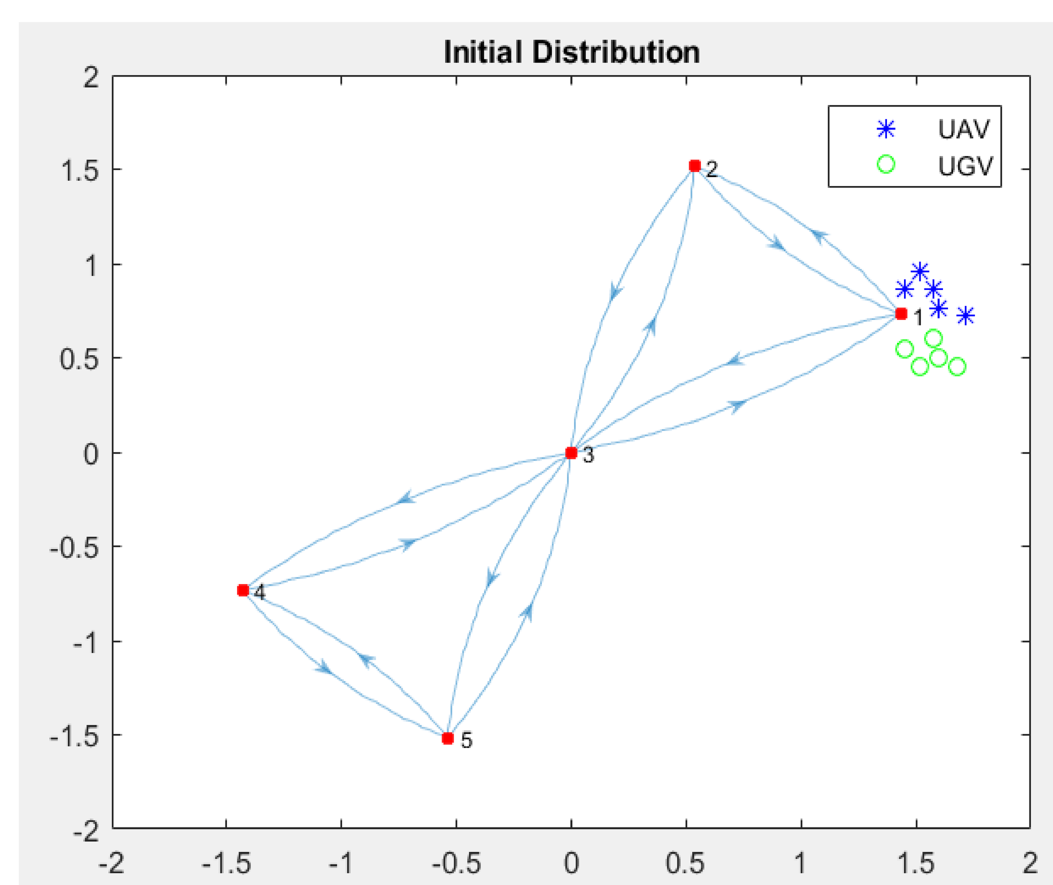
Reference:

A. Prorok, M. A. Hsieh, V. Kumar, Fast Redistribution of a Swarm of Heterogeneous Robots, International Conference on Bio-inspired Information and Communications Technologies, 2015

Implementation

The case we are proposing considers two species (UAVs and UGVs) of robots, with 5 robots in each species, to monitor a building based on the windows and doors present.

Given knowledge of the initial robot distribution and each species' traits,



$$\boldsymbol{X(t)} = [x^{(s)}(t)]$$

$$x^{(s)}(t) = [x_1^{(s)}(t), \dots, \ x_M^{(s)}(t)]^T$$

$\boldsymbol{X(t)}$, distribution of robots with respect to time

$x^{(s)}(t)$, distribution of robots for each species

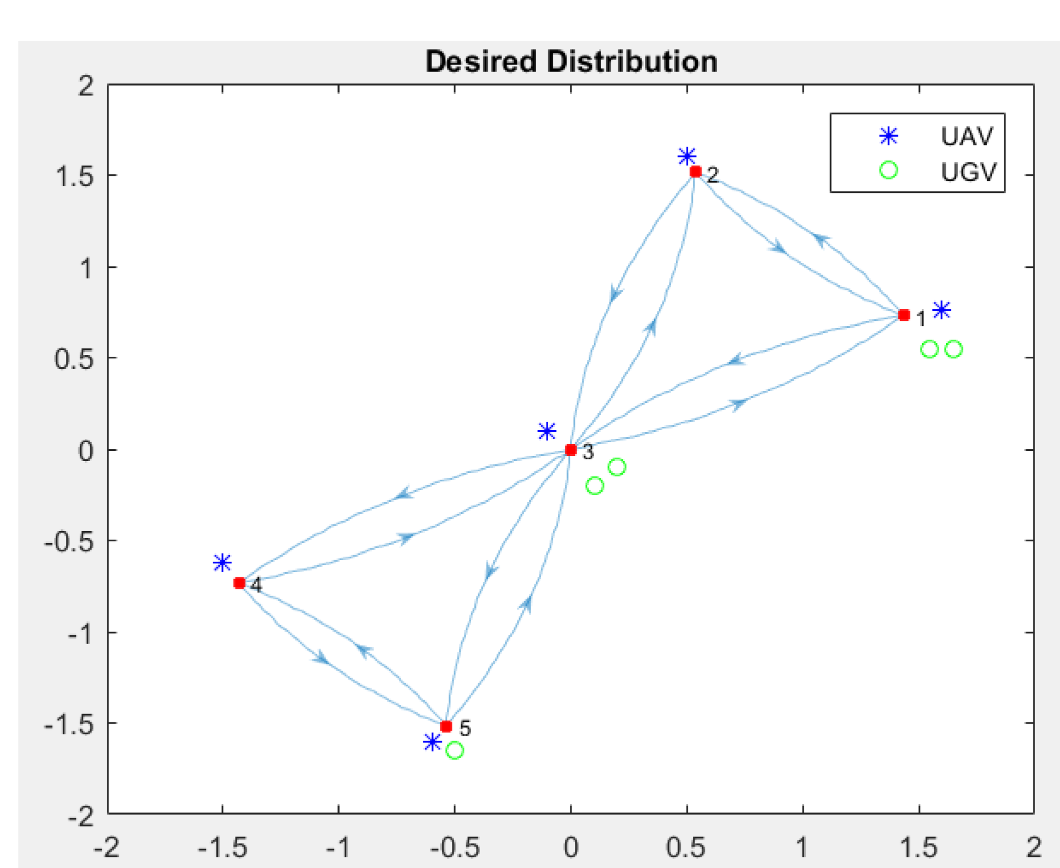
M, number of tasks

$$q = \begin{cases} UGV \quad 3 \text{ cameras} \quad 1 \text{ Lidar} \quad 2 \text{ Infrared} \\ UAV \quad 1 \text{ Camera} \end{cases}$$

We can minimize the objective error function, E, and use it to obtain the optimal rate matrix for the distribution of capabilities and the optimal convergence time. The error function is given as,

$E = \bar{Y} - Y(t)$, where $\bar{Y}$ is the desired distribution of robot capabilities and $Y(t)$ is the distribution of capabilities with respect to time. $Y(t)$ is given as,

$\mathrm{Y}(t) = X(t) \cdot Q$



$$\bar{Y} = \begin{bmatrix} 3 \text{ cameras} & 2 \text{ cameras} \\ 1 \text{ Lidar} & - \\ 2 \text{ Infrared} & 2 \text{ cameras} \\ 1 \text{ camera} & - \\ 1 \text{ Lidar} & 1 \text{ camera} \end{bmatrix}$$

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