Multi-Robot Coordination Algorithm to Direct-Intercept and Surround a Target

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Abstract— We have proposed an algorithm for multi-robot path planning in order to surround a stationary or dynamic target by using a phase neural oscillator. The self-collision between the robots as well as collision with obstacle are avoided. The robots reach the target keeping equally distributed angles around it.

Let us consider $n$ robots having diameter $D$. With $i$-th robot at position $(x_i, y_i) \in \mathbb{R}^2$, radial distance with respect to target at $(x_T, y_T) \in \mathbb{R}^2$ is $r_i \in \mathbb{R}$. The target is single, and it is either static or moving in straight line with a constant velocity. The main purpose of the research is to implement the synchronized motion of the robots towards the target while avoiding self-collision, and obstacles, and the robots should have the phase difference of $\frac{2\pi}{n}$ while reaching the target.

A target moving with $V_T$ is proposed as stationary virtual target $(x_{TV}, y_{TV})$ and taking velocity of robots $V > V_T$. From above figure, since $\theta_{T-i} = \sin^{-1} \left( \frac{V_T \sin(\theta_{T-i})}{V} \right)$ satisfied, thus we have:

$$S_T = \max(S_{T-i}) = \frac{r_i \sin(\theta_{T-i})}{\sin(\frac{2\pi}{n} - \theta_{T-i} - \theta_{T-i})}$$

Then radial distance of robots from virtual target is $r_{T-i} = \sqrt{S_T^2 + r_i^2 - S_T r_i \cos(\theta_i)}$ and the time to go as $t_{max} = \frac{S_T}{V}$. For static target i.e., $V_T = 0$, $r_{T-i} = r_i$ and $(x_{TV}, y_{TV}) = (x_T, y_T$).

The angular coordinate of $i$-th robot around the virtual target $(x_{TV}, y_{TV})$ is $\{ \theta_i \in \mathbb{R} | 0 < \theta_i < 2\pi m, m \text{ is an integer} \}$ such that $\theta_1 < \theta_2 < \cdots < \theta_n$. For $i$-th robot the estimated new value of $\theta_i$ is given as follows:

$$\theta_i(t+1) = \theta_i(t) + \left( \sum_{j=1}^{n} W_{ij} \sin(\theta_j(t) - \theta_i(t) - \phi_{ji}(t+1)) + \zeta \right) \Delta t$$

where

- $\phi_{ji}(t+1)$: the desired phase difference between $j$th and $i$th robot:

$$\phi_{ji}(t+1) = \phi_{ji}(t) + \left( \frac{2\pi(j-i)}{n} - \phi_{ji}(t) \right) \left( \frac{1}{1 + e^{-X_{ji}(t)}} \right)$$

$$\phi_{ij}(t+1) = -\phi_{ji}(t+1)$$

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References