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SELF-LOCALIZATION OF ANONYMOUS ROBOTS FROM AERIAL IMAGES

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Abstract

This paper presents three different methods for the localization of identical robots thanks to aerial pictures available at regular time intervals. Robots are anonymous, they do not have any identifier allowing self-identification and they cannot communicate with each others. Robots are moving in their environment. The proposed localization methods rely on these movements, through the analysis of angular or distance variations. Simulation is used for the evaluation of the methods.

1 Introduction

Robots localization is of key importance for cooperative control [1]. In multi-robots systems, when robots use the positions of others robots to compute their own position, the problem is called *cooperative localization* [2]. In [4] the authors express the difference between *relative mutual positions* and *absolute mutual localization* depending on robot's frame, if they are fixed or moving. In most works about cooperative localization methods, robots are not anonymous. In the works of Franchi & al, robots are anonymous. In [3] the authors develop an algorithm based on a particle filter to compute relative mutual positions, however, robots have the ability to communicate with each other to send and received poses with an index.

In our work, we assume that an aerial camera is available and it takes, periodically, pictures of a fixed area where all the robots are present. All robots are identical and are unable to communicate with each others. Their initial position is unknown. They have odometric sensors to mesure their rotation and linear speed. Camera sends to the robots, at regular intervals, pictures of the area on which all the robots appear, as illustrated on Figure 1. Camera is the single point of centralization. The challenge, for each robot, is to localize itself on the pictures. In the second part, the three formulations for localization are described, experiments and results are presented in, respectively, the third and the last part.

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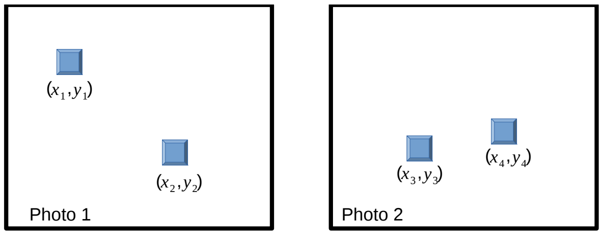

Figure 1: All robots receive, at regular time intervals, the same pictures and compute the coordinates of all anonymous robots. The question is: who am I?

2 Problem formulation

2.1 Angular variation

This first method is the simplest. It is necessary that camera can mesure positions and orientations of each robot. The localization begins with the reception of a first picture (date t_1). Each robot r records all the orientations θ_{i_r} of all the robots. At the same time, each robot realizes a random constant rotation in the same sense until the reception of the second picture (date t_2). Then, each robot records again the angles $\theta_{f_r} f$ of all the robots. Each robot knows its own rotation speed ω between the two dates. Robot r compares $\omega.(t_2 - t_1)$ with $\theta_{f_r} - \theta_{i_r}$ in order to estimation its position.

2.2 linear speed variation

This method uses the Pinhole camera model. Camera has its coordinate system and a image plane parallel to axes X and Y. Robots moved on a floor plan. It is assumed that the two plans are parallel as illustrated on Figure 2.

One Robot m wants to realize its self-localization among n robots. When it receives picture 1, it realizes a linear move at a random speed until the reception of picture 2. The robot realizes the distance R to R' (d_0). Between pictures 2 and 3, the robot moves again linearly at a different random speed. The robot m realized the distance R' R"(d_1). The projection distances on the camera plane are d'_0 and d'_1. The robot knows its ratio $a = \frac{d_0}{d_1}$, and with Thales theorem it comes that $a = \frac{d'_0}{d'_1}$. Finding the robot positions on each of the three pictures consists

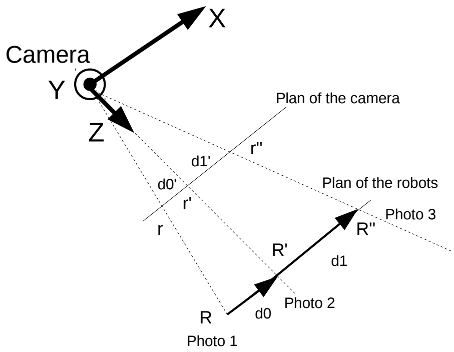

Figure 2: A robot realizes a linear motion between positions R, R', R", coordinates on pictures 1, 2, 3 and r, r', r" the projections on the camera plane.

in finding $min|a-r|$, where r is a matrix (dimension (n^3)) of all the possible ratios for all the distances between the 3 pictures. It is possible to reduce the matrix dimension r if we consider the linearity of 3 points from 3 pictures (dimension becomes n).

2.3 Localization during a random motion

N robots move according to differents trajectories. For expressing their movement we use the Char model:

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{pmatrix} = \begin{pmatrix} \cos(\theta) & 0 \\ \sin(\theta) & 0 \\ 0 & 1 \end{pmatrix} . \begin{pmatrix} v \\ r \end{pmatrix}$$

x, y are the coordinates of robots, θ represents the difference between speed angular vector and X axis, v and r are respectively the linear and the rotation speeds.

The movement of the robot between two positions is illustrated in Figure 3.

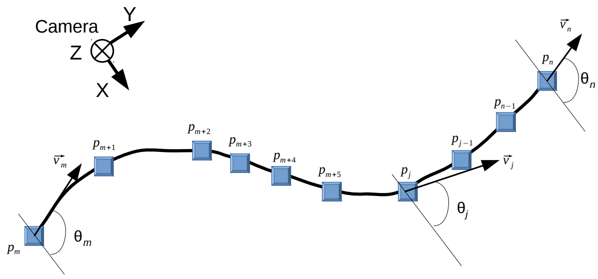

Figure 3: Robots positions from place p_m to p_n with intermediate positions p_j discretized

Using the Taylor tranformation $f(x_0 + h) = f(x_0) + hf'(x_0) + h\epsilon(h)$, we prove that Char model becomes:

$$\begin{pmatrix} x_n - x_m \\ y_n - y_m \end{pmatrix} = \delta t \sum_{j=m+1}^{n} \begin{pmatrix} \lambda.\cos(\theta_m + \delta t \sum_{k=m+1}^{j} r_k) \\ \lambda.\sin(\theta_m + \delta t \sum_{k=m+1}^{j} r_k) \end{pmatrix} v_j$$

δt is the discretization time and we assume that $\lambda = \frac{f}{Z}$ in Pinhole model is known. The only unknown variable is θ_m. This means that if there is an existing identical θ_m for two coordinates between two consecutive pictures, we know the initial and final coordinates of the robot. We have solved this system for the self-localization only with two consecutive pictures.

3 Main results

To experiment the methods, we used the multi-robot simulator Player-stage and augmented reality software Artoolkit to determine coordinates. We tested only with 2 anonymous robots. The frequency of pictures was 10 seconds.

Self-localization Method	sucess rate
Angular variation	96.9%
linear speed variation*	84%
localization during motion	83.9%

* we have considered the linearity movement between 3 pictures.

4 Conclusion

We have presented three methods for self-localization in a multiple anonymous robots system. We have showed that the three methods have a success rate greater than 80%. Each of these methods have advantages and disadvantages, but in all the cases, robots received all of the anonymous coordinates set of the multi-robots system.

References

[1] J. Spletzer, A.K. Das, R. Fierro, C.J. Taylor, V. Kumar and J.P. Ostrowski, *Cooperative Localization and Control for Multi-Robot Manipulation*, Procesing of the IEEE/RSJ International Conference on Intelligent Robots and Systems(IROS), 2001.

[2] D. Fox, W. Burgard, H. Kruppa and S. Thrun, *A probabilistic approach to collaborative multi-robot localization*, Auton. Robots, vol. 8, no. 3,pp. 325-344, 2000.

[3] A. Franchi ,G. Oriolo and P. Stegagno, *Mutual Localization in a Multi-Robot System with Anonymous Relative Position Measures*, IEEE/RSJ Int.Conf. on Intelligent Robots and Systems, St. Louis, MO, pp 3974-3980, 2009.

[4] A. Franchi ,G. Oriolo and P. Stegagno, *Probabilistic Mutual Localization in Multi-Agent Systems from Anonymous Position Measures*, 49th IEEE Conf. on Dcision and Control, Atlanta, GA, pp 6534-6540, 2010.