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REAL TIME LOCALISATION OF A MOBILE ROBOT USING WEBCAM DATA

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ABSTRACT

Localization is one of the most important functions for the mobile robot navigation. Most of previous position estimation methods calculate current position and orientation of mobile robot by applying various localization schemes with the information obtained from internal sensors which are set on the mobile robot, or by recognizing an artificial landmark attached on the environment. Several drawbacks about them have been brought up. To avoid these inconvenient, a new localization method that calculate in real time the absolute position of the mobile robot by using external camera fixed on the ceiling in the indoor environment is proposed. Besides, this approach provide a low expensive solution using a Webcam. The effectiveness of the proposed localization algorithm is demonstrated through the experiments.

Index Terms— Real time Localization, Webcam Data, Mobile Robot Navigation, Object Segmentation.

1. INTRODUCTION

During the last decades, the useful range for robots has gradually spread to a wide variety of areas. Mobile robots are especially being used as a substitute for humans or to do simple work that is either in or outside. In such a mobile robot system, getting exact information on its current position is very important. At all times, the mobile robot must know instantly its current position and that of the objective. There are two position-estimation methods applied in navigation systems, i.e, absolute and relative positioning.

1.1. Relative localization

It is realised through the measurements provided by sensors measuring the dynamics of variables internal to the vehicle. The incremental encoders are the typical inertial sensors. These sensors are fixed on the axis of the wheels or the rotation axis of the vehicle. The disadvantage of this method is that the errors of each measurement are accumulated. This heavily degrades the estimates of the position and orientation of the vehicle, especially for long and winding trajectories [1].

1.2. Absolute localization

It is based on the use of sensors measuring some parameters of the environment in which the robot is operating. A set of sonars is generally used as an external sensory device. The infra-red sensors are implemented on the robot and measure the distance with the environment. These sensors are also widely utilized for the guidance of autonomous vehicles with obstacle avoidance in unknown environment [2] and [3]. The major disadvantage of absolute measurements is their dependence on the characteristics of the environment.

1.3. Data Fusion

In order to compensate these drawbacks, some researchers presented a localization method that fuse data coming from odometers and sonar sensors by applying Hybrid Kalman Filter Fuzzy Logic Adaptive Multisensor Data Fusion Architectures [4] and [5]. And an other researcher adapted the position and the orientation of a mobile robot through a weighted Extended Kalman Filter (EKF) [6] and [7]. These methods need much calculation for a mobile robot to perform a task. Other disadvantages are either the short range of used senors and necessity to know the initial position of the robot. Contrary to the methods mentioned above, which reduced the position error with relative positioning sensors, the following method provides an absolute position regardless of a reference image, the distance moved and speed of a mobile robot.

And some researchers presented a method that estimates a position of a robot using a CCD camera fixed on ceiling of the corridor by calculating the distance moved and time of a mobile robot [8]. Another way that is presented for a robot equipped with a CCD camera, calculates its position by recognizing a characteristic topography and compares it with the model image saved in memory [9]. A last researcher presented a method that calculates the position of a robot in order to intercept a moving target through visual feedback [10]. The most important disadvantage of

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these methods is the necessity to know the initial position of the robot. In this work, the new localization method is illustrated in Figure 1. A camera installed on the ceiling of the test environnement is utilized for the localization of the mobile robot. The experimental results show the effectiveness of the algorithm proposed. The system compensates for robot positioning by means of the following sequences. First, the system calculates the reference system by using reference image. Secondly, the algorithm recognize whether the object in the image is the robot or not, with a Webcam. If the object is the robot, the system calculates its position.

This article is organized in the following way. The model of the robot is described in section 2. The object segmentation through image process and position estimation algorithm are described in section 3. Finally, section 4 contains the results of the experimental tests applied to the mobile base.

2. KINEMATIC MODEL

In this work a unicycle robot is considered with a differential architecture having two independent motors to drive the left and right wheels. The kinematics equations, which relate the linear and angular velocities of the robot to the angular velocity of each wheel can be expressed as :

$$\dot{x}(t) = \vartheta(t)\cos(\theta(t)) \qquad (1)$$

$$\dot{y}(t) = \vartheta(t)\sin(\theta(t)) \qquad (2)$$

$$\dot{\theta}(t) = \omega(t) \qquad (3)$$

Where ϑ and ω are the linear and angular velocities of the robot. These velocities can be represented as follows:

$$\vartheta = \frac{(\omega_l + \omega_r)R}{2} \qquad (4)$$

$$\omega = \frac{(\omega_l - \omega_r)R}{D} \qquad (5)$$

ω_l and ω_r : Angular velocities of the two driving wheels measured by proprioceptive sensors.
$R = 15.62$ mm : radius of the driving wheel.
$D = 53$ mm: tread between driving wheels of the robot Khepera II

We denote respectively by equations (6) and (7) the state vector of the vehicle and the control vector.

$$X(t) = \begin{bmatrix} x(t) & y(t) & \theta(t) \end{bmatrix}^T \qquad (6)$$

$$u(t) = \begin{bmatrix} \vartheta(t) & \omega(t) \end{bmatrix}^T \qquad (7)$$

3. OBJECT SEGMENTATION AND LOCATION ALGORITHM

This approach is based on two steps. The first one consist on the image pre-processing. The second one is the transformation from image coordinates to real coordinates.

3.1. Image pre-processing

We extract the pixels coordinates of the reference system using regions properties of a reference image, which is captured and stored in advance. This image describes the test environnement of the mobile robot limited by four landmarks placed on the corners. Figures 2 and 3 described this reference image.

In this paper, we applied a binary mask for removing illumination image noises, and selected images which have $640 * 480$ pixels for an image. The filtering method that has been adopted is a morphological one. Through labeling, we separate objects and search for their features [11]. Then, to recognize whether object is the robot or not, we used regions properties (areas and centroid) of an input image which is being input consecutively.

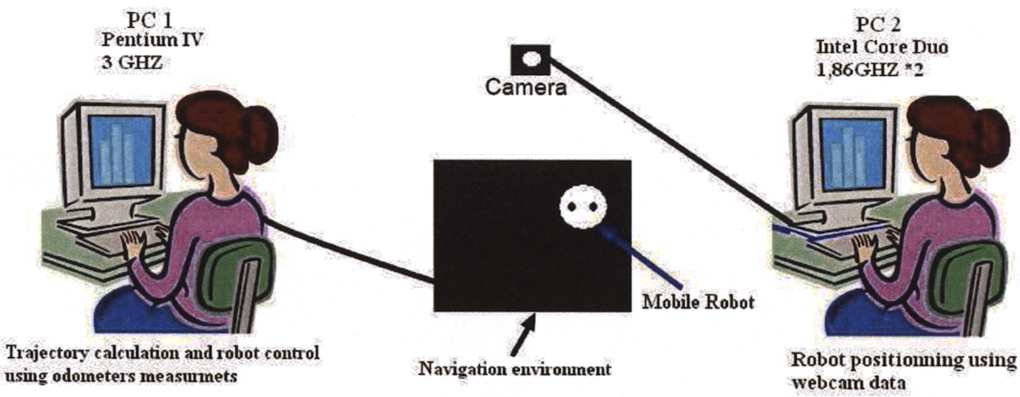

Figure 1. Overview of the Khepera II robot system

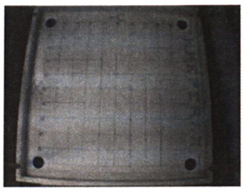

Figure 2. Reference Image

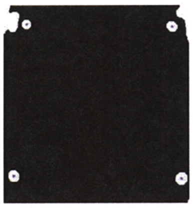

Figure 3. Binary reference image with four landmarks centroids

3.2. Transformation from image coordinates to real coordinates

We obtain the real image coordinates by a simple difference between the pixels coordinates either of the robot and of the reference system. The resulting coordinates are multiplied by a constant coefficient. This coefficient is calculated based on the real distance between the landmarks and the distance in pixels. Figure 4 described the positioning architecture adopted.

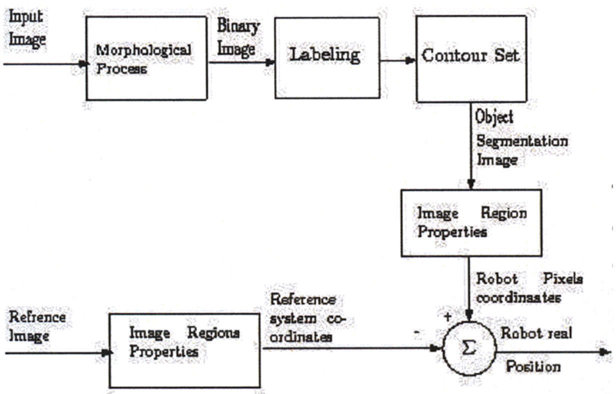

Figure 4. Segmentation and positioning architecture

4. EXPERIMENTAL RESULTS

The method proposed in the previous sections has been implemented and tested on experimental mobile robot developed at the Swiss Federal Institute of Technology Lausanne. The system consists of a robot controlled via a serial communication from the PC 1 as shown in Figure 1. The terminal configuration for the host computer PC1 must be set to 57600 Baud, 8 bit, 1 start bit, 2 stop bit and no parity. The robot is equipped with two encoders mounted on the left and right wheels and height infrared sensors. The host computer PC 1 executes the task of calculating the trajectory and determining the robot position using odometers measurements. However PC2 is reserved to estimate the position of the robot using visual system. The communication with the webcam is ensured via USB port, with a simple protocol to acquire data. The experimental tests are carried out with the Matlab environment. The experimental set up and the robot Khepera II are shown in Figure 5 and 6.

Figure 5. Basic module of the robot Khepera II

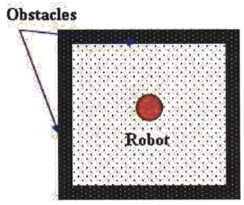

Figure 6. A Map of the in-door environment

4.1. Experiment 1

The purpose of the first experiment is to show the application of the segmentation method in the localization of the mobile robot with the webcam data compared to the measurement of odometers. Figures 7 and 8 show respectively the original input images and the segmented images with robot centroid's in image coordinates. In this experiment, the robot have to attempt a target defined by the coordinates($x = 400mm, y = 400mm$) with linear velocities $2pulses/10ms$ which is equivalent to $1.6cm/s$ with the unit for the speed is the $pulse/10ms$. The result of this experiment is presented in Figure 9. To control the robot we adopted a kinematic model with only encoders measurements. There exists an approximately 2cm deflection along the x and y axis but the encoders measurements are erroneous as shown in Figure 10. However using our scheme, the robot trajectory was very similar to the real one.

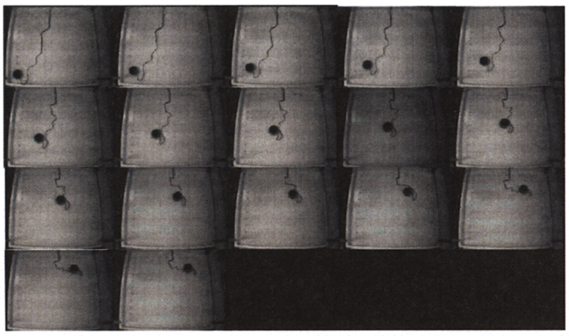

Figure 7. 17 frames of the original input image

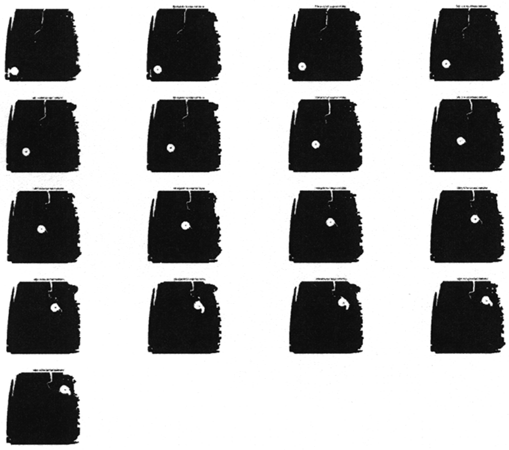

Figure 8. Different robot positions in image coordinates (Frames must be read from the left to the right).

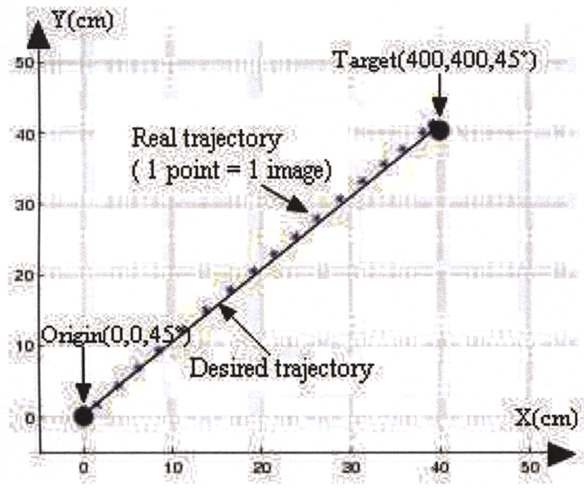

Figure 9. Robot localization using webcam data with $(velocity = 1.6cm/s)$

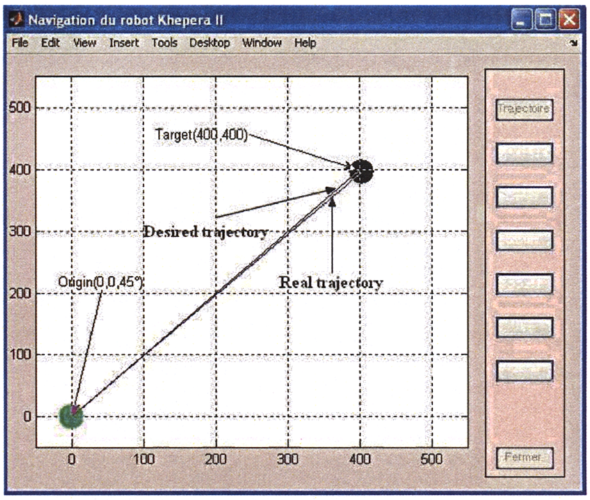

Figure 10. Robot localization with linear trajectory using encoders measurements $(velocity = 4cm/s)$

4.2. Experiment 2

The purpose of the second experiment is to show the effectiveness of the new method in a circular trajectory. The result of this experiment is presented in Figures 10 and 11. In this experiment, the robot have to follow a circular path defined by the radius $(150mm)$ with the linear velocity $4cm/s$. We noticed that with the encoders signals the deflection along the x and y axis increased. However by adopting webcam data, the robot trajectory was very smooth.

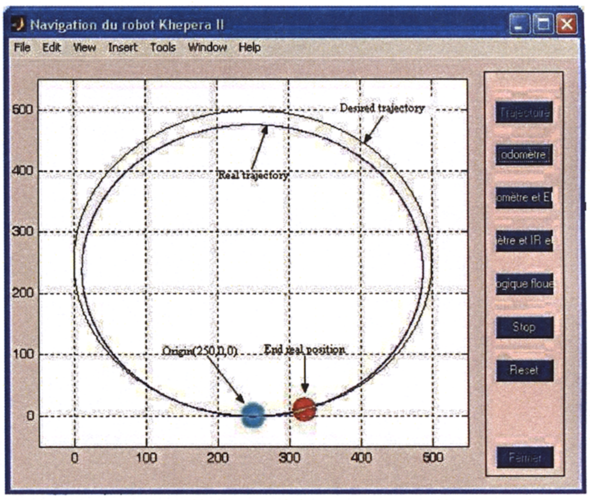

Figure 11. Robot localization with circular trajectory using encoders measurements $(velocity = 4cm/s)$

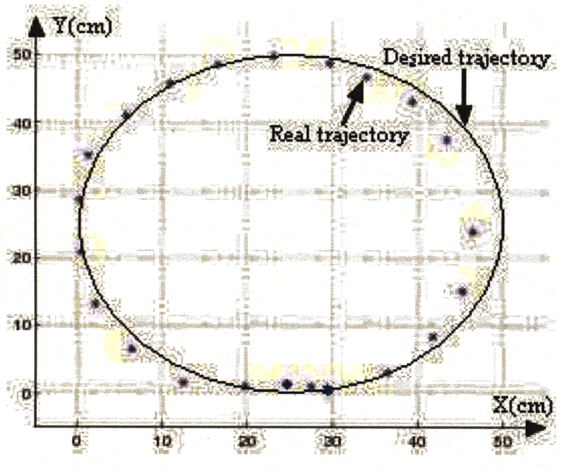

Figure 12. Robot localization with circular trajectory using webcam measurements($velocity = 4cm/s$)

4.3. Performance evaluation

The position estimation method is applied with different linear velocities. During this path, we calculated the average time processing which is about 1.4366 seconds. Besides the communication configuration between PC 2 and the webcam ensure an image acquisition rate about 4.922 seconds. These functions make it possible to still evaluate the obtained performances by the webcam data.

5. CONCLUSION

In this work, a new real time localization method with a fixed camera is proposed, which utilized the external monitoring webcam information under the Matlab software. When a mobile robot is moving, we used the kinematic model with the encoders measurements to control it. The new method ensure the mobile base position estimation through the mathematic and geometric analysis of mobile robot image. The efficiency of the proposed method is proofed through experiments and comparison with positioning using encoders signals. This method ensure automatic initial position determination. For a future research topic, an efficient processing DSP is necessary to reduce the time processing and correct the real time localization. To further improve the position estimation, an other research task using data fusion deserve to be taken into account.

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