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MOBILE ROBOT TRACKING USING IMAGE PROCESSING

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Abstract: *During the evaluation of autonomous mobile robot navigation routines the determination of true robot position on its track is essential. The paper presents simple yet reliable method of tracking robot position using processing of images acquired from the devices positioned above the operation space. The method consists of two steps for each image: detection of the robot in image space and transfer of its coordinates to operation space.*

Keywords: ***Mobile robot, image processing, object tracking.***

1. Introduction

To evaluate the quality of localization and path planning routines (Včchet 2011) with real robots, the determination of true position of the robot must be performed. This paper proposes simple yet reliable method of tracking the position of the robot based on the processing of robot images acquired by bird eye positioned camera. The method was used when the quality of Extended Kalman filter based localization was evaluated, as described by Krejsa (2012), focused on the utilization in the prototype of presentation robot Advee (Ripel 2011).

Proposed method consists of two steps. During the first stage the position of the robot in the image space is found, using the detection of marks placed on the robot. In the second stage found coordinates are recalculated into operational space, providing the correction of imprecise image acquiring device mounting, optic flow imperfections, etc.

2. Detection in image space

The sequence of the robot images is acquired from the digital camera mounted above the operational space, as indicated on Fig. 1.

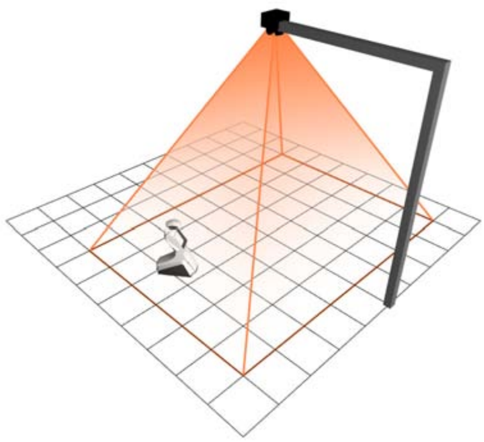

Fig. 1. The principle of image acquiring

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Two devices were used to acquire the images, differing in resolution and optical systems, in particular Canon 350D with Canon EF20/f2.8 lens and Pixelink PLB-762G camera with Edmund Optics SZ110M lens. Both devices were positioned 3650 mm above the operational space of the robot. Two white marks with diameter of 21.5mm were placed on the sides of the robot in 607mm relative distance. The mounting of the devices is illustrated on Fig. 2.

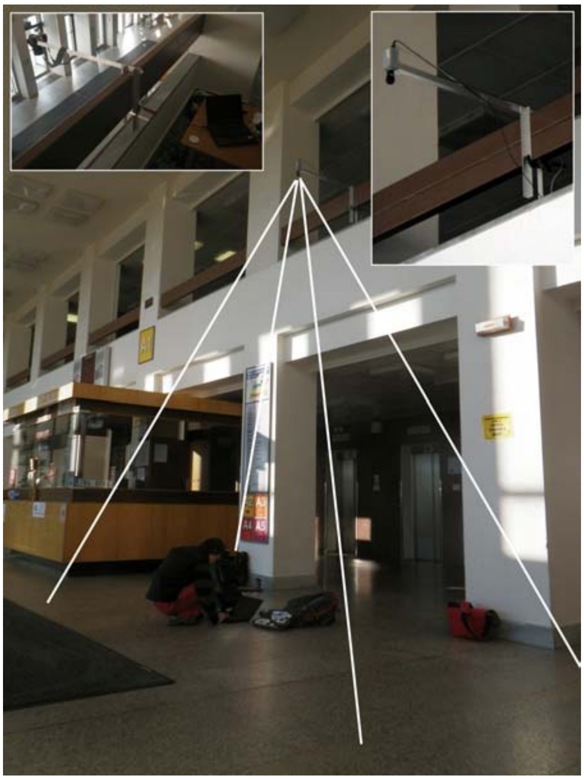


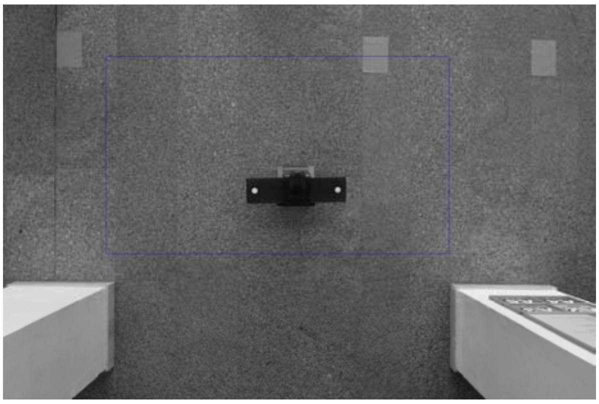
Fig.2. Image acquiring - particular devices mounting

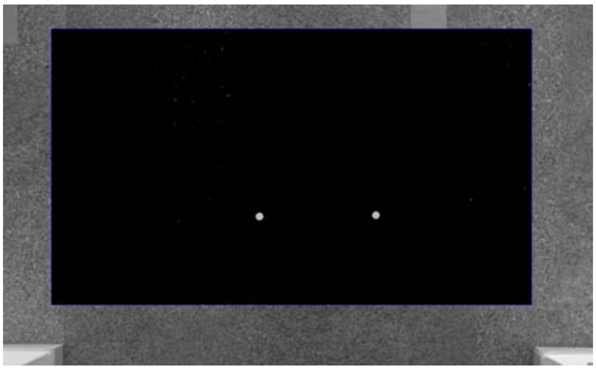
Different optics result in different field of view and therefore the covered operational space. Canon 350D chip has the resolution of 3456 x 2304 pixels and with given optics covers the area of 4.7 x 3.3m, with the final resolution of 1.4mm/pixel. Pixelink camera chip has the resolution of 752 x 480 pixels, covers the area of 10.1 x 6.5m thus producing the final resolution of 13mm/pixel.

Both devices are controlled from the computer, frame rate was set to 1s for the Canon camera due to the duration of image data saving, frame rate for the Pixelink camera was set to 0.5s, even though several experiments were performed with higher frame rates (Pixelink device is capable of maximum 60 fps).

Image data were acquired and saved and then processed offline, therefore there was no demand for optimized image processing with respect to computational requirements. Acquired images were processed in following way, with examples of actual images shown on Fig. 3:

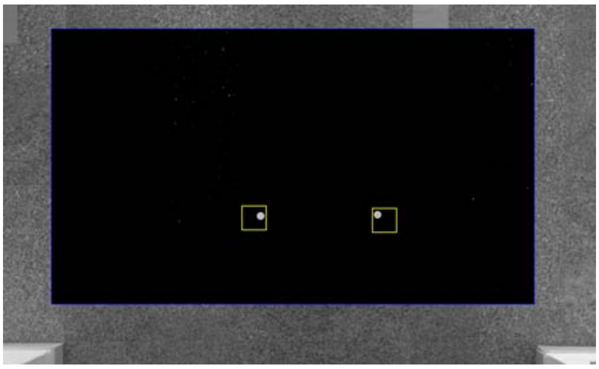
- Format processing: raw to grayscale; region of interest (ROI) determination
- Thresholding ROI with given adaptive threshold value
- Evaluation of the intensity sums of rectangular image blocks uniformly covering the region of interest, with parametrically given overlay.
- Determination of priority blocks by sorting the blocks according to the intensity sum and selection of the blocks with given minimal distance in image space.
- Calculation of precise position of the marks in priority blocks using COG procedure.

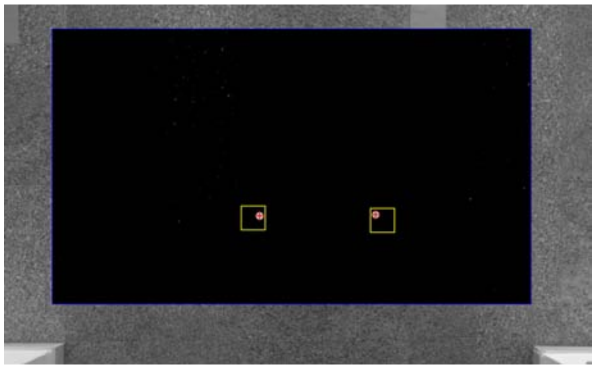




Original image in grayscale with ROI

ROI thresholding





Detected priority blocks holding the condition of minimal distance

Determination of exact position using COG procedure for priority blocks

Fig. 3. Image processing of acquired images

Images are processed in batch, with constant parameters of block sizes, its overlay and minimal distance between the blocks. Other parameters are variable during the processing, in particular the threshold and region of interest boundaries. Image processing outputs the positions of detected marks in image space in the form of text file for further processing.

3. Recalculation to operational space

Once the position of the marks is found, the next stage is to determine the position of the marks in the operational space. Due to the imperfections in camera mounting and optical flow the values can not be simply multiplied by a constant, but the nonlinear transformation is necessary. The transformation uses the set of calibration points in the operational space, for which the real position $[x_r, y_r]$ is known and corresponding position in image space $[x_o, y_o]$ can be found. The points from both operational and image space are first centered into the center of image space and then transformed to polar coordinates. Thus the coordinates $[\rho_r, \varphi_r]$ and $[\rho_o, \varphi_o]$ are obtained. The transformation from image to operational space is then performed using polynomial of the 4th order:

$$\begin{aligned}\rho_r = \; & a_0 + a_1\rho_o + a_2\varphi_o + a_3\rho_o\varphi_o + a_4\rho_o^2 + a_5\varphi_o^2 + a_6\rho_o^2\varphi_o + a_7\rho_o\varphi_o^2 + \\ & a_8\rho_o^3 + a_9\varphi_o^3 + a_{10}\rho_o^3\varphi_o + a_{11}\rho_o\varphi_o^3 + a_{12}\rho_o^2\varphi_o^2 + a_{13}\rho_o^4 + a_{14}\varphi_o^4 \\ \varphi_r = \; & a_{15} + a_{16}\rho_o + a_{17}\varphi_o + a_{18}\rho_o\varphi_o + a_{19}\rho_o^2 + a_{20}\varphi_o^2 + a_{21}\rho_o^2\varphi_o + a_{22}\rho_o\varphi_o^2 + \\ & a_{23}\rho_o^3 + a_{24}\varphi_o^3 + a_{25}\rho_o^3\varphi_o + a_{26}\rho_o\varphi_o^3 + a_{27}\rho_o^2\varphi_o^2 + a_{28}\rho_o^4 + a_{29}\varphi_o^4\end{aligned}$$

To determine the unknown coefficients of the polynomial, at least 30 equations are required, represented by 15 calibration points. In performed experiments dozens of points were used, determining the coefficients by least squares optimization.

Quality of the transformation was verified using translation motion of the robot through the whole observed region and checking the distance between the marks, that should remain constant during the motion. Pixelink camera distortion was found substantially smaller, however due to the lower resolution and larger viewing angle of the optics the average error in the distance is higher. In particular the standard deviation is 0.43 mm for the Canon camera and 2.92 mm for Pixelink camera. In both cases, however, the values correspond to subpixel precision of marks detection in image space.

The example of comparison of true trajectory detected from image processing and the estimate generated by Extended Kalman filter based localization technique for the experimental robot Leela is shown in Fig. 4.

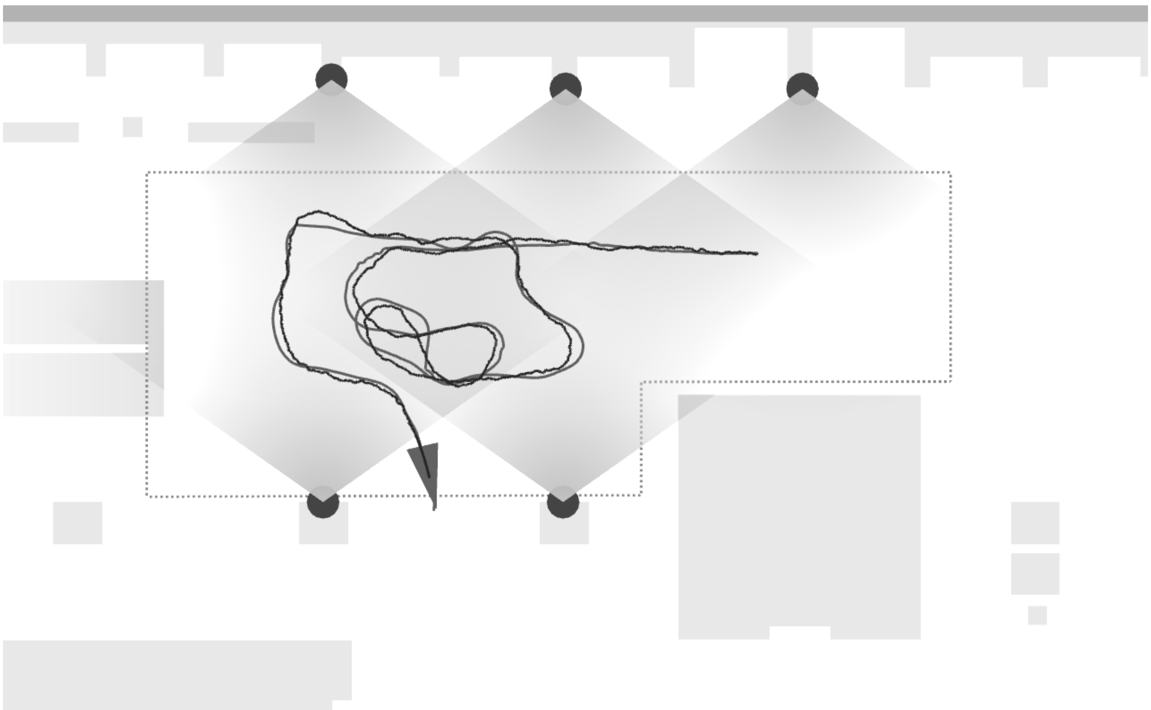


Fig. 4. Comparison of true trajectory of the robot and EKF based localization estimate

4. Conclusions

Presented method is simple and easy to implement. The processing was performed offline, but the computational requirements are low enough to perform online tracking. The method depends on possibility to mark the robot with at least two markers. The precision of the method depends on the rate between the image resolution and covered operational space, the image detection can reach subpixel precision.

Acknowledgement

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References

Krejsa J., Věchet S. (2012): Infrared beacons based localization of mobile robot, *Electronics and Electrical Engineering*, 1(117), 2012, pp. 17-22

Věchet S., Krejsa J. (2011): Concurrent mapping and localization based on potential fields, in Proceedings of *Engineering Mechanics 2011*, Svratka, pp. 647-650

Ripel T., Hrbáček J. (2011): Complex mechanical design of autonomous robot Advee, in *Mechatronics, recent technological and scientific advances*, Springer, pp. 121-130