On-line Tracking of Moving Objects via Camera DragonFly

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Abstract - *The contribution presents the process of two and three dimensional localization of the moving object using a camera system, possible remote data transmission through communication links and image acquisition problems. Moving object recognition is provided by one possible approach - frames difference method, which represents object tracking at any background, image processing was done in MATLAB and the application example is presented by online tracking of moving robot MINDSTORM*

Keywords - *Image acquisition, object recognition, 3-D model*

1. INTRODUCTION

Mathematical analysis of video sequences and motion modeling belong to an interdisciplinary area of digital signal and image processing [1] allowing detection, localization, identification and prediction of moving objects components. Applications can be found in engineering [2], biomedicine [3] and in many further disciplines. The paper is related to the extensive research of these topics including analysis of multiple marker association [4], geometric algebra application [5], specific methods of image features extraction [6] and position estimation [7].

2. IMAGE DATA ACQUISITION

Data acquisition can be realized by a camera system in the simplest case to detect the precise position of a selected object in the two or three-dimensional space. Fig. 1 presents the principle of the whole system arrangement using two cameras Dragonfly connected to the PC more in [8].

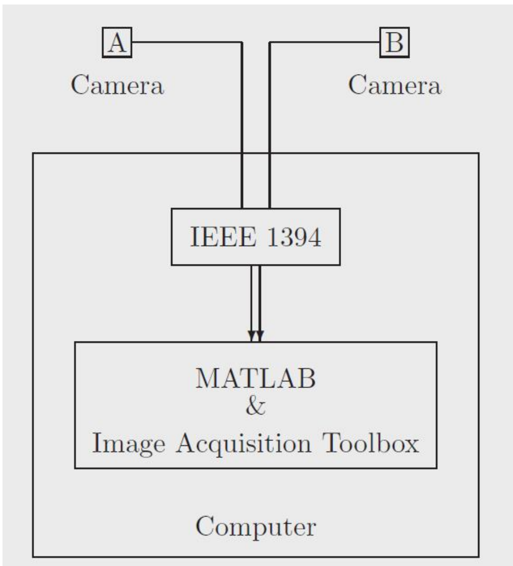

Figure 1 – Camera measurement system

The Dragonfly is an OEM-style IEEE 1394 board level camera providing control and flexibility for industrial machine vision tasks. Cameras used in the system have a color CCD sensor with 1024x768 resolution and 15 frames per second. Partial Image Format (sub-sampled) allows the user to transmit a sub-sampled 640x240 image at the speed up to 50 fps. The 6-pin 1394 standard cable provides the camera [8] with both power and a connection to computer having IEEE 1394 plug-in board, see Figure 1.

Figure 2 – Camera DragonFly

For transmission of images from cameras to PC the MATLAB Image Acquisition Toolbox has been used. The system has been based upon the Image Acquisition Toolbox supporting a wide range of image acquisition operations from the professional grade frame grabbers to USB-based Webcams. The toolbox allows the connection of hardware, its configuration, video preview, and transfer of the stream of images directly into the MATLAB environment for their analysis and visualization.

3. MOVING OBJECT DETECTION

The whole system presented in Fig. 4 consists of two cameras *A* and *B* located in the fixed distance *c*. For two dimensional tracking one digital camera is necessary, for three dimensional tracking at least two cameras are needed.

3.1 Calibration

Camera calibration is presented in Fig. 3. It is necessary to evaluate horizontal and vertical angles of camera(s). Using the calibration grid (according to the figure) placed in the distance *d* from camera it is possible to find both horizontal *shorizontal* and vertical *svertical* sizes of the figure. These parameters can then be used for evaluation of the limits of angles (using rectangular red and blue triangles).

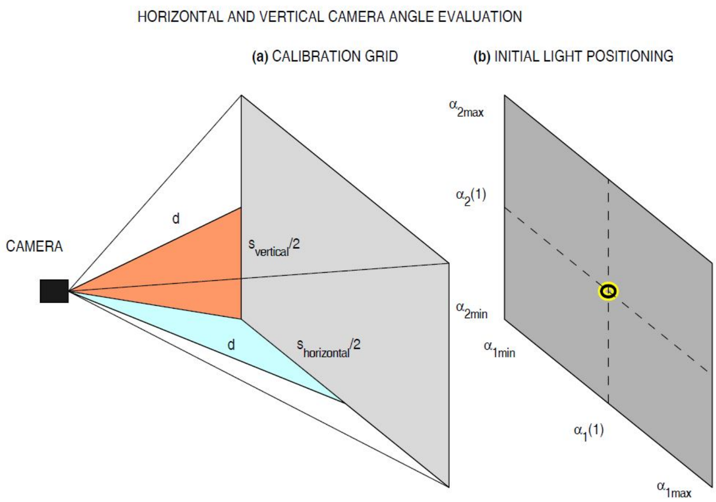

Figure 3 – Camera calibration

$$\alpha_{horizontal} = 2.arctg\left(\frac{s_{horizontal}/2}{d}\right) \tag{1}$$

$$\alpha_{vertical} = 2.arctg\left(\frac{s_{vertical}/2}{d}\right) \tag{2}$$

Finally, it is necessary to evaluate calibration straight-lines for horizontal and vertical directions.

3.2 Observation in two dimensional space

Generally, object recognition at any background using a digital camera is nontrivial problem. It is necessary to find the object and calculate its centre and position.

If the background has constant color which is different from the color of the object, only one object is recognized in the frame and one centre position is found. Otherwise, if the background has a difficult structure and its color is similar to color of the object, many possible objects are recognized and it is very complex task to find out which one is the right one.

One of possible approaches is the frames difference method. Firstly, the image of background (without moving object) is acquired. Then (at every sample time) this image is subtracted from the image of moving object. Constant parts of images are black (subtracted each other) and only tracked object remains. Images with and without subtracted background are shown at application example where the tracked object is presented by robot MINDSTORM, see Figures 4 and 5.

Figure 4 - Object and background with difficult structure

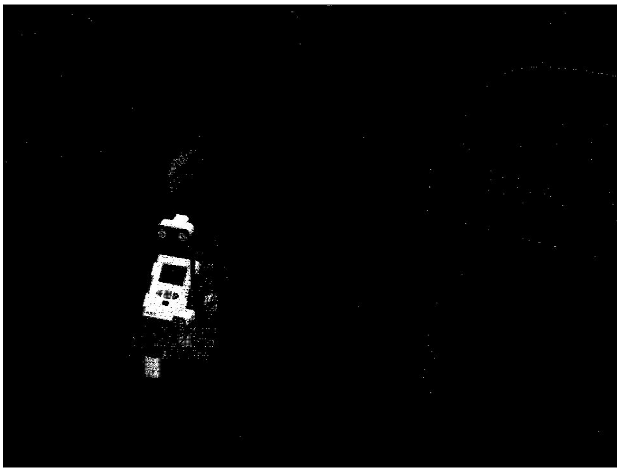

Figure 5 - Image after subtraction of background

Moving object tracking algorithm:

1. Initialize hardware
2. Calibrate the camera
3. Take the first frame of background (without moving object)
4. Take frames of moving object in the cycle
    i. Take the frame
    ii. Calculate the difference
    iii. Find the centre
    iv. Calculate the position

The example of result moving object trajectory is plotted in Figure 6.

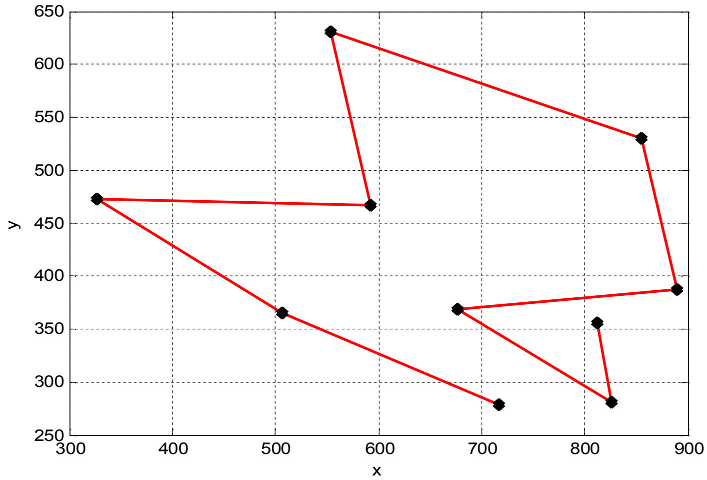

Figure 6 - Moving object trajectory in 2-D

3.3 Observation in three dimensional space

For observation in three dimensional space, it is necessary to track the object using multi-camera system (in our case two digital cameras in defined distance c).

Multiple Dragonfly's on the same IEEE-1394 bus are automatically synchronized to each other at the hardware level. The maximum deviation in the synchronization is 125 μs of each other as states the Dragonfly Technical Reference Manual. This synchronization of cameras has been verified by analysis of the record of the display of the counter counting 1 kHz pulses. It means that numbers on the display were changing thousand times per second. On the corresponding picture from each camera the same number on the display has been captured.

During the observation process precisely synchronized pictures taken with a chosen frequency by both cameras are acquired.

The situation in the k-th observation step is given in Fig. 7. The moving object can be detected using a simple thresholding method applied to individual images. Using the results of calibration it is possible to convert the row and column positioning of the object to horizontal $\alpha 1(k)$ and vertical angles $\alpha 2(k)$ in the case of camera A and to $\beta 1(k)$ and $\beta 2(k)$ angles in the case of camera B. For the k-th observation step the set of two pictures is acquired defining triangle ABC in the space with the top and front view presented in Fig. 7. Using the system of coordinates with the origin in the position of camera A and choosing the axis x in the direction of camera B and y axis in the plane of the object positioning it is possible to evaluate coordinates of point C for each set of camera observations. The top view enables to find the size of $b1(k)$ using the sine theorem and coordinates of point C in the form

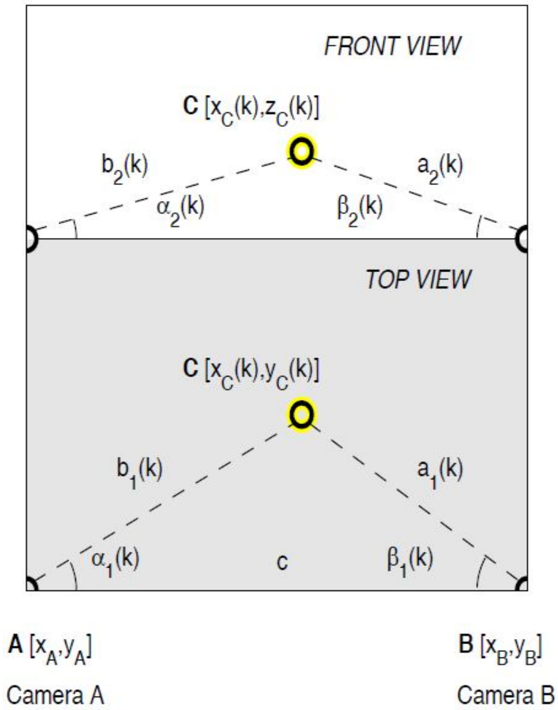

Figure 7 - Tracking object in 3-D

$$b_1(k) = \frac{c.\sin(\beta_1(k))}{\sin(\pi - \beta_1(k) - \alpha_1(k))} \tag{3}$$

$$x_C = b_1(k).\cos(\alpha_1(k)) \tag{4}$$

$$y_C = b_1(k).\sin(\alpha_1(k)) \tag{5}$$

The z coordinate of point C can be found in the similar way.

$$b_2(k) = \frac{c.\sin(\beta_2(k))}{\sin(\pi - \beta_2(k) - \alpha_2(k))} \tag{6}$$

$$z_C = b_2(k).\sin(\alpha_2(k)) \tag{7}$$

Definition of the three dimensional positioning of the moving object is given in this way in the chosen coordinate system for each set of camera images.
The example of result moving object trajectory is plotted in Figure 8.

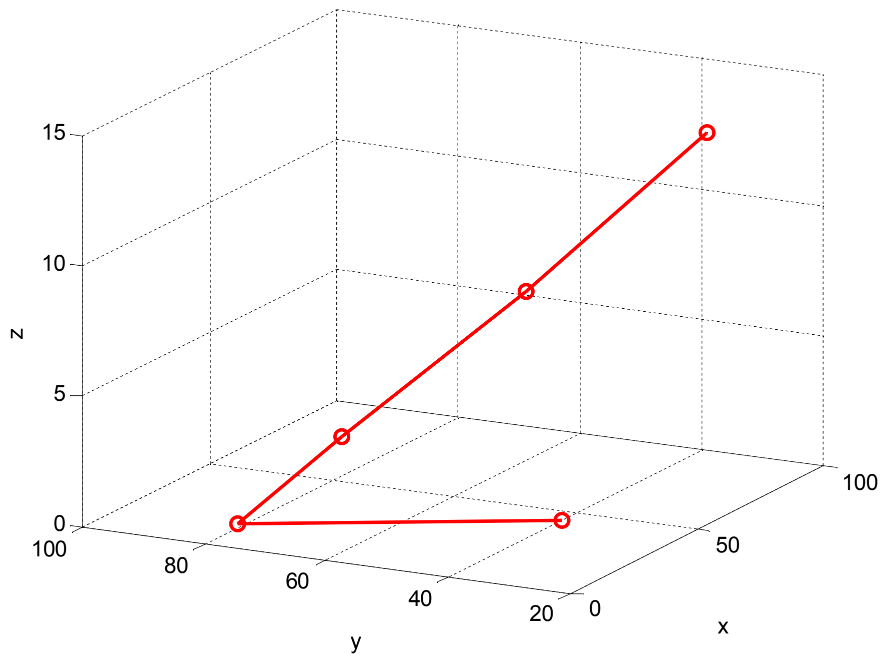

Figure 8 - Moving object trajectory in 3-D

5. CONCLUSION

The paper presents both technical principles of the moving object detection using the image acquisition toolbox and a videocamera system. Specific mathematical methods of image components localization for processing of each observed image are then used.

Firstly, one digital camera was used as a sensor, thus the trajectory in two-dimensional space was calculated. Then two synchronized digital cameras were used and 3-D reconstruction of moving object was done.

This methodology of object tracking is universal and usable for any object tracking at any background.

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