Application of Image Recognition for Control of Robotized Production Line

[1]Miroslav PETRO, [2]Peter PAPCUN, [3]Ján JADLOVSKÝ

Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Slovak Republic

[1]miroslav.petro@student.tuke.sk, [2]peter.papcun@tuke.sk, [3]jan.jadlovsky@tuke.sk

***Abstract* — This article focuses on the issue of image recognition for the need to ensure feedback for robot manipulators on the production line. The task was to design and implement a software solution in the programming language C# that can recognize the end point of manipulators by using the Kinect camera system and would be able to determine the real position of this point. For the purpose of the production line control, it was necessary to design and implement a control application of PLC which implements the control of all components of the production line, the calculation of kinematic tasks and two technological processes. The end of this contribution incorporates presented methods of experimental verifications of the above mentioned solution as well as the achieved success rate and limits of application for the image recognition and control application.**

***Keywords* — Kinect, image recognition, PLC, EmguCV, robotized production line**

I. INTRODUCTION

In the Laboratory of Computer Control System Design of Technical University in Košice, there is a model of robotic production line which is able to run several different technological processes. The aim of our work was the implementation of applications to recognize images taken by a camera system Kinect, and also the implementation of the control program for a robotic production line. The task was to provide feedback to the manipulator by using a Kinect device and to increase the precision of movement of these manipulators.

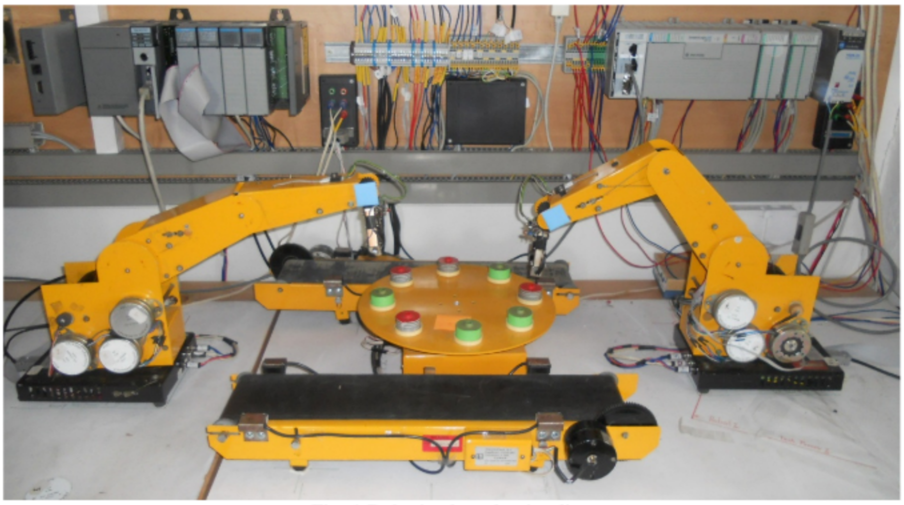

Fig. 1 Robotized production line

II. KINECT DEVICE

A. *Possibilities of using Kinect*

Kinect is designed primarily for its use in the entertainment industry as an input device for game consoles. Kinect is equipped with a USB connector and an SDK package, so this device can be used for other purposes. We specified the list of areas where this equipment can be operated, for example:

a) Medicine – patients with neuromotor disorders have lost ability of fine movements. Those people have to frequently practice this kind of movements. In therapy, the Kinect could be applied as a support to practice precise movements and to motivate patients in a fun way. Patients playing simple games could achieve a significant improvement in their disorders.

b) Education – in context of new educational methods and progressive informatization of schools, Kinect appears to be an excellent tool to involve students in the learning process, which, thanks to the recognition of gestures and movements, can make lessons much more interactive and interesting.

c) Design – the ability to scan an object in its 3D form or interact with it provides new opportunities for designers.

d) Marketing – new interactive ways of presenting products may significantly change the marketing industry. Interactive advertising posters would undoubtedly constitute an interesting concept.

e) Sports – nowadays, there are applications thanks to which Kinect can track the user's exercise and actively intervene in the exercise plan to encourage and assist the user during the execution of the exercise. Professional athletes can appreciate Kinect in the context of checking the correct execution of movements of the sport.

f) Production – Kinect can be applied in the process of controlling robotic environment as a feedback sensor. This paper is focusing on this possible use of Kinect.

g) Transport – Kinect could be a form of a warning system against vehicle collisions with pedestrians. Thanks to the optimized hardware for recognition of the human figure. It could quite accurately determine the location of pedestrians and warn the driver before a possible collision.

B. Limitations of Kinect

The usage of Kinect device has also some limitations. The first limitation is the relatively low resolution of cameras which can be restrictive in the process of product quality control, or in sectors where high accuracy is required. The relatively low resolution offers also a depth map. The principle of pattern projection in space and focus on the changes can sometimes be insufficient, especially for complex products whose components can cast shadows on the rest of the product, so the depth of this product cannot be mappable. It is also necessary to mention the range of depths that Kinect can handle. Minimum resolvable depth is 800 mm and maximum 3500 mm, which may sometimes be insufficient. The depth map may not be reliable for objects which can not reflect illumination. It is also not recommended to use Kinect outdoors, because the infrared sensor may not work correctly with direct sunlight.

The possibilities of using Kinect are quite wide and depend on application requirements. The use of Kinect is not appropriate in extreme environments which may occur in certain types of industry (e.g. metallurgy). Usage of multiple Kinect devices is also not recommended because of the projected image overlaps. Such mutual interference can cause significant faults in sensing of depth or make it completely impossible.

III. Realization

A. Image recognition

The task was to design and implement an application which can provide feedback for a manipulator using Kinect device. To achieve this task, it was necessary to use the method of computer vision. In practice, there is no fixed procedure for processing images and image recognition, so we designed our application in a way that can be generally described by the following points:

- Image capture: The first step in the process of image recognition was the image capture and synchronization of color images with the depth map.
- We used the averaging filter which operates on the principle of replacing the original color of the pixel with arithmetic average of the color values of its surroundings, in order to suppress the noise in the image. Surroundings of the filtered point are determined by the size of the mask (usually a square shape) which gradually shifts the image that passes through all the points. We used a mask of size 3x3px, for eliminating noise while there was only a minimal blur of edges in the image.
- For the purpose of segmentation we used a method called simple thresholding.

Thresholding is technique when all the pixels of image are included in to the foreground or to the background. There must be certain threshold value, which is the boundary between the foreground and background. The segmentation technique is assumed that the foreground is different from the background in color or brightness, so this technique works best for images with high rate of contrast. The result is new binary image

• On this modified binary image where each pixel can have one of two values indicating affiliation to an object or a background, we used the method to search contours. Thanks to the method FindContours() from the library EmguCV.dll, contours that represent the outlines of individual objects were found. These contours represent a polygon with many sides, because the principles on which the camera works do not allow scanning of perfectly smooth objects. Therefore, on the discovered contours, we were able to apply the method which implements Douglas-Peucker algorithm. The aim of this algorithm is to make smoothed contours with reducing the number of vertices which are representing the object. When we choose an appropriate accuracy, the obtained lines represent the smoothed contours of the object.

• This solution also searches for extremely large and extremely small objects (such as shadows), which put unnecessary strain on system resources. Therefore, we have to put in conditions where we test whether the found contour contains more than 500 pixels and less than 10000 pixels. This test filters random noise.

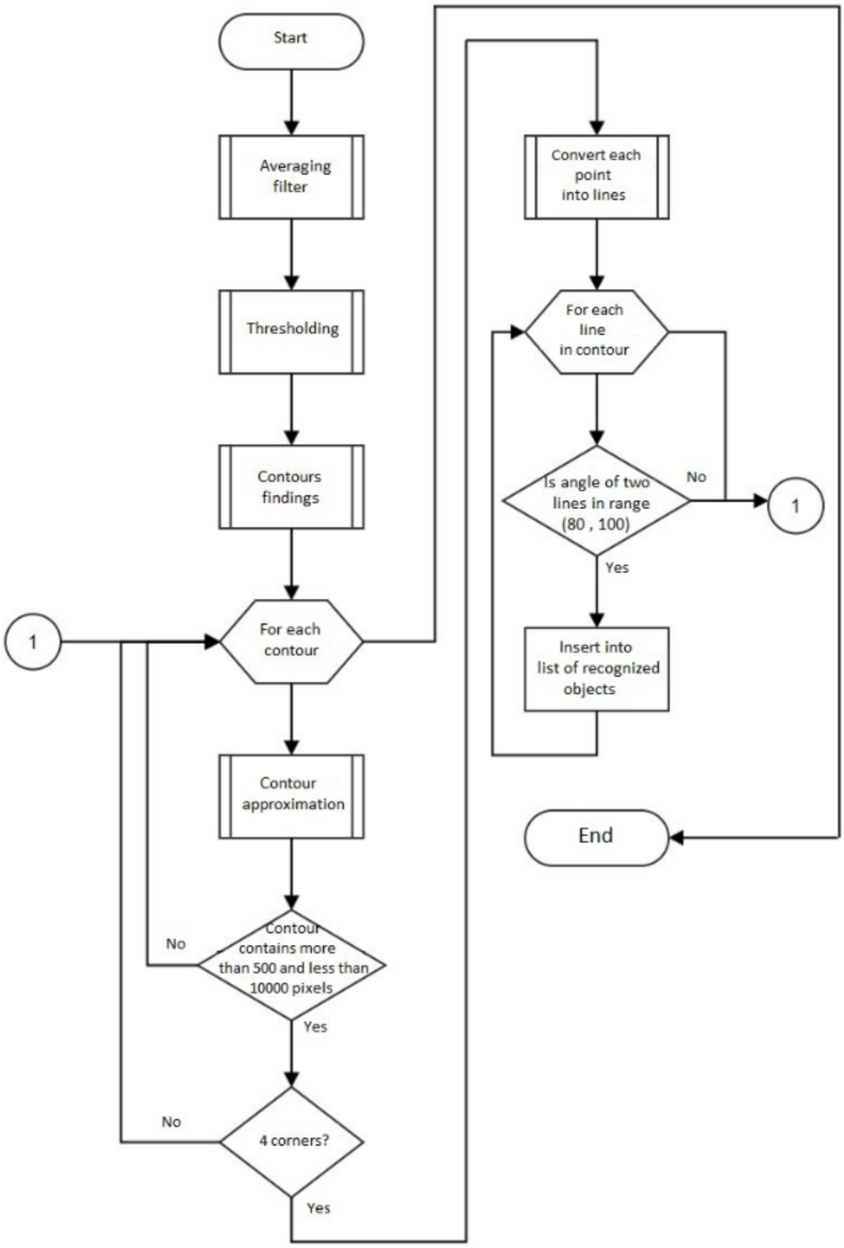

Fig. 2 Flowchart of image recognition

B. Control application

The application of PLC will be responsible for the control of the whole production line. The control program includes the control of stepper motors including feedback from the image recognition application, survey data from the sensors and calculations of kinematic tasks which control the whole technological process.

Gear mechanism of robotic arm can slip during the process of reaching new position. This can cause the difference between the requested and the real position. The information about the difference of the requested and the real position is transformed into action. The result of this action is correction of the real position of the robotic arm. The desired position is defined by running technological processes, or by the user, and real position is determined by a camera system which is used for image recognition. After the completion of capturing the real position of the robotic arm, these coordinates are sent into the PLC. The feedback is computed from the result angles from inverse kinematics where input parameters represent the real position coordinates of the manipulator. These values are compared with the desired values of the angle of robot joints. Each joint is calculated by the correction according to the equation. The calculated value is the correction of the system error which occurred after the slip of mechanism.

For each joint, correction values are entered into the robot control which then performs a movement to correct the wrong position with new input angle values. After completing the movement, it will restart the camera system for new verification of the corrected arm position. The whole process of correction ends when the difference of each of the real coordinates is less than five millimeters. The whole process of position correction is a feedback that compares output data about the behavior of the system (real position) to the input data (desired position).

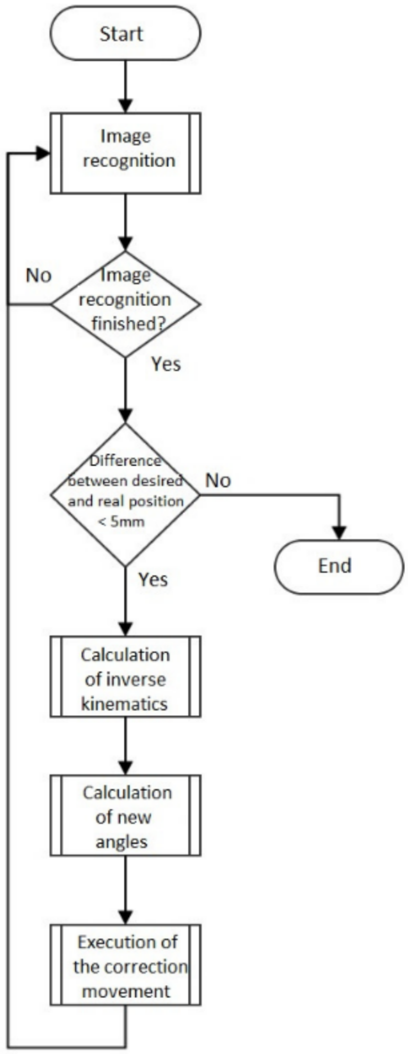

Fig. 3 Flowchart of feedback

IV. Experimental verification

First experimental verification was aiming to check the accuracy of manipulators with feedback. In this test, we set the manipulators to predefined positions. After changing the position of the robotic arm with external force, we monitored the accuracy of returning the manipulator to the desired position. In 5 rounds of testing, we tried ten times to turn these manipulators. Out of 50 tests, 48 of them showed that the manipulator corrected its position.

Then, in 5 rounds of 20 tests, we tried to produce the results without feedback. The difference in the results was noticeable, because manipulators got into the right position only 4 times.

The second experimental verification was testing feedback and color recognition during the first technological process. We were interested in the number of correctly identified colors of products and products which were correctly picked up from the rotary conveyor by manipulators. This technological process was launched ten times and each launch contained 8 color identifications and pickups. The result of this testing was represented by 71 absolutely correct pickups and 75 correct color recognitions.

The third experiment involved testing of color recognition and accuracy of the manipulator in the second technological process. We were testing the number of correctly identified colors of products, correctly picked products from the conveyor line and the accuracy of product positioning as requested by the operator. This technological process was also launched ten times and each launch contained at least 6 color identifications and pickups. This experiment had 93 color recognitions, 93 pickups of a product from the conveyor line, 60 putting off in to the pallet and 33 putting off on to the second conveyor line in sum. At the end of the experiment, 76 products were picked up correctly and 7 products were properly picked up but fell out from the gripper of the robotic manipulator during the maneuver. The last 10 products slipped from gripper during the process of grasping.

V. Conclusion

Achieved percentage rate represented by successful picking up of products from the conveyor clearly increased, as well as the speed and the quality of technological processes and elimination of the need for constant calibration of manipulators. It also recognized the color of products in a satisfactory amount of times. A correct operation in the image recognition applications can influence the changing light conditions or improper calibration settings of the camera system.

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