A VISION METHOD PROPOSED FOR TRACKING CONTINUOUS PLANE CURVES

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Abstract: *This paper presents a vision method for tracking continuous plane curves. The purpose of the research is to develop a method for tracking step by step a continuous and plane curve, when the start point of the curve is known. The method is used for industrial robot learning. The method proposes the usage of "Positioning Along Line" camera tool. The main idea for the method is to move the camera in order for the intersection point between a side of the square and curve of the current step to correspond to the centre point of the square of the new step. The results obtained using this method can be improved if the square side is decreased, by increasing the precision.*

Key words: *vision, guidance, continuous curves.*

1. Introduction

Automation is creating a future where robots develop the world. Intelligent machines are already changing the way we live, work and expand our experiences. Vision-guided robotics is a maturing sector that has potential for significant technological advancement. End-users are surprised by the wide range of applications that vision-guided robots currently perform reliably [5].

Robotics technologies research is shifting its focus from applications to human-centered applications. The ultimate goal is to reduce fatigue, augment the power and improve the quality of daily life of all humans in general and elderly people in particular. Typical application modes include cooperation, assistance, tele-operation and entertainment. In cooperation mode the robot is physically guided by a human operator during a task. In assistance mode, physical interaction may be either for short duration, or the robot is physically connected to the person's body for a comparatively long time. In tele-operation, a person normally interacts with a small master robot, whereas entertainment robots are generally smaller in size [10].

Over the past three decades, considerable research and development effort has been dedicated to navigation devices using the vision [7], [4], [8].

Miguel Angel Sotelo, Francisco Javier Rodriguez et al. create a color vision based system intended to perform stable autono-mous driving on unmarked roads. This implies the development of an accurate road surface detection system that ensures vehicle stability [12].

Vivek Sujan and Steven Dubowsky present a multi-agent algorithm for a manipulator guidance task based on cooperative visual feedback in an unknown environment. The algorithm uses the measured scene infor-

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mation to find the next camera position based on new information content of that pose [14].

An important task for autonomous industrial robotic systems is the interception of moving objects. In order to achieve this objective, an on-line robot-motion planning technique that utilizes real-time sensory feedback about the object's motion is needed [3].

Toon Goedeme, Marnix Nuttin et al. present a novel system for autonomous mobile robot navigation. With only an omni directional camera as sensor, this system is able to build automatically and robustly accurate topologically organized environment maps of a complex and natural environment. It can localize itself using such a map at each moment, including both startup and using knowledge of former localizations [6].

Unmanned air systems are prime candidates for tasks involving risk and repetition, or what the military calls the "Dull, dirty and Dangerous". For tasks that involve tracking, reconnaissance and delivery, one objective of unmanned air systems is to accurately determine the location of ground-based objects [1].

According to Marr's paradigm of computational vision, the first process is an extraction of relevant features. Based on these features, further processing involving semantics is performed to solve a given visual task [9].

In feature extraction methods, Gaussian derivative kernels are frequently utilized. Blurring of the image due to convolution of these kernels gives rise to feature measures different from the intended value in the original image. G.J. Streekstra, R. Van den Boomgaard and A.W.M. Smeulders propose to solve this problem by explicitly modeling the scale dependency of derivates combined with measurement of derivates at multiple scales [13].

Cordelia Schmid and Andrew Zisserman describe the geometry of imaged curves in two and three views. They described a set of algorithms for automatically matching individual line segments and curves between images [11].

Applications of machine vision for industrial robots fall in two main areas: Guidance Vision for Robots and Automated Visual Inspection. The distinction between these areas is blurred at present, as image processing is marked by being much smarter [2].

In this paper a method for tracking continuous plane curves is presented. These continuous plane curves can be an object shape, an edge between two objects etc.

2. A Vision Method Proposed for Tracking a Continuous Plane Curve

The problem consists in the tracking of a continuous curve, drawn on a plane surface, using a vision system. The tracking starts from a known point: start point.
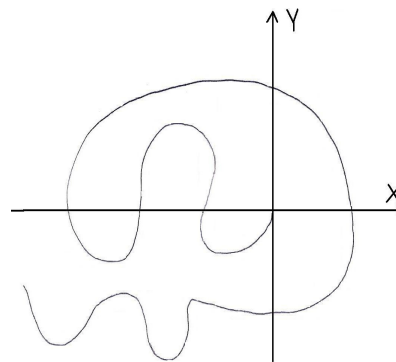

Fig. 1. *Example of continuous curve*

This method is used for tracking a considerable number of curves (as it can be seen in Figure 1).

In Figure 1 the start point is the same with the origin point of the XOY coordinates system.

To solve the problem we have used the vision tool of our camera: Positioning Along Line.

The following data from the tool were used:

- the result of the tool (1 if an edge detection intersects this tool, otherwise 0);

- the offset of the tool (the distance, in pixels, between the start point of the tool and the point where an edge detected intersects the tool).
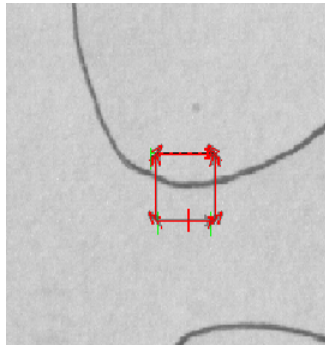

Fig. 2. *Vision tools used*

To implement the method, there were used eight "Positioning along line" tools (see Figure 2). From the horizontal and vertical tools (long ones) is used the offset distance and from the other is used the result (1 or 0).

Horizontal and vertical tools create a square, and each side of the square must not intersect with another. At 45 or 135 degrees (depending on circumstances) other four tools are placed. These are used to determine if the curve passes or not by a corner area (in the corner area it's possible that the curve intersects none of the long tools).

In this paper a step by step method is proposed. Initially the camera goes to the start point. In this case the curve intersects a single side of the square (Figure 3a).

The square centre of the old step corresponds to the start point (origin of the XOY coordinate system).

The main idea of the method consists of determining the displacement on X and Y coordinates in order for the centre of the square of the new step to correspond to the

intersection point of the curve with a side of square from the current step. Afterwards, camera moves to this new point and starts another step.
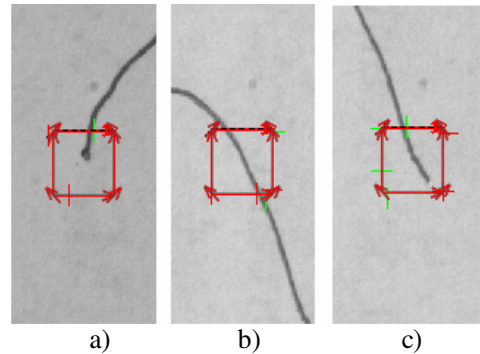

a)   b)   c)

Fig. 3. *Start, intermediary and stop positions of the camera*

When the camera sees an intermediary zone (somewhere between start and finish point) the curve intersects two sides of the square (Figure 3b). In this case there are two intersection points. The method has to select the point which is not placed at the side of the centre square of the old step. For that it must compute the distances between this intersection points and the centre point of the square from the previous step. All the time the point with the longer distance is selected. Therefore the displacement sense of the motion is obtained (it's important that the camera moves in one way only).

If the camera is placed into an intermediary zone and at the next step the curves intersects a single side of the square (Figure 3c), at the next step the camera will stop moving (here is the finish point of the tracking).

3. Implementation and Results

For testing this method a Mitsubishi RV-2AJ robot and a Cognex DVT 515 camera were used. The camera was installed on the robot hand in order to be able to make our tests.

The connection between the camera and the robot was made using a Lab Windows CVI application. This application runs on a PC with a serial and Ethernet free ports. Using the serial port, the Lab Windows CVI application communicates with the robot. On this port the application sends to the robot a command to start a new step of tracking and the displacement, in pixels, on X and Y coordinates for robot moving. After our tests, it was deduced that 15 pixels correspond to a millimetre for robot moving. The robot moving was made in XOY coordinate system, so the relation presented previously is true for any moving of the robot.

On Ethernet port the application communicates with the camera. We used for that the socket technology. On the camera flash memory the program with tools was uploaded in the form presented in the previous chapter. On the camera's software a foreground and a background scripts were made. The foreground script was used to obtain the information from each tool. The background script was used to creating a socket, listening to a client and communicating to Lab Windows CVI application. On this communication a client - server architecture was practically created: the camera plays as server and the PC as client. Using this connection the camera sends to the PC the data obtained from the positioning tools.

The trigger input used for image acquisition is connected to a digital robot output; in order for the image acquisition to be controlled by the robot.

The Lab Windows CVI application sends a command to the robot to start a new step. After the image is inspected, the PC application receives the information from the camera, computes and sends it to the robot the displacement on X and Y coordinates. These elements have been calculated using the methods presented in the previous chapter. In our research the side of square presented in chapter 2 was 60 millimetres long.

For example, consider the situation presented in Figure 2. Consider that the next centre of the square is at the intersection between curve and the right side of the square.

The X displacement is, in this case, 30 pixels and Y displacement is absolute value from subtract between the offset of the right vertical tool and 30 value (a half of the side of square long).
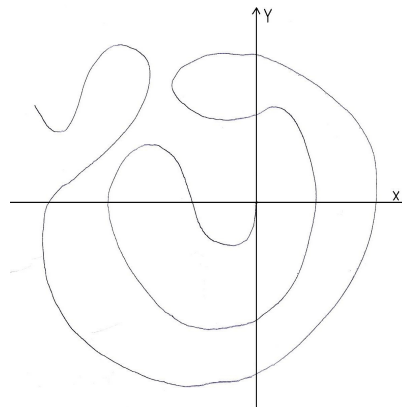

Fig. 4. *The drawn curve*

One of the curves on which the method was tested is presented in Figure 4. The figure was drawn on a free piece of paper. In Figure 4 XOY coordinate system is presented in addition.
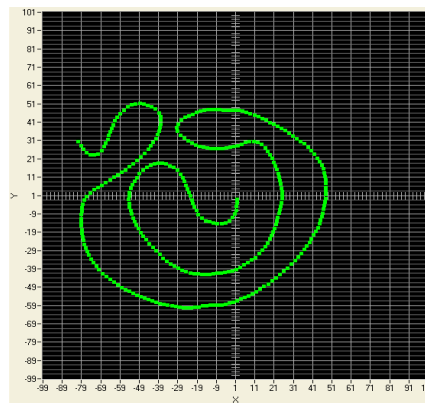

Fig. 5. *The results of tracking*

In Figure 5 is presented the result for the tracking when the system follows the curve presented in Figure 4. Each green point plotted in Figure 5 represents the point for the centre of the square for each step of moving.

It can be observed that the form of the curve presented in Figure 5 is similar to the curve presented in Figure 4. If the side of the square is 60 pixels long the precision of tracking is 2 millimetres. If it decreases, the precision increases, but the time of the tracking for the same curve increases too.

4. Conclusions

The tests prove that the method is good and efficient. At the beginning, the robot moves into a known point. The system knows that this point is the start point. The paper with the curve is into a position where the start point of the robot corresponds to the start point of the curve. If this position is changed, the method doesn't work. In our future research, we want to develop a method for searching the start point of the curve.

The proposed method works properly with continuous curves. If the curve has critical points, in this case it's possible that the method creates mistakes.

In order for the method to work properly it's important for the curve to be continuous. If it is intermittent, it's possible that the tracking stops at the first interruption.

The method uses plane curves. In our future research we will try to develop a method for spatial curves tracking.

The method doesn't work properly when another curve intersects the proposed curve. In this case the system doesn't know what curve to track. In our future research, we want to develop also a solution for this problem.

This research can be used in some types of application, for example learning a plane object's contour, learning a plane contour between two objects. After the system learns the trajectory, the robot can move on this one. The system can be used with success for creating a welding robot. First the robot learns the contour between two objects and then the robot moves on this learned trajectory for welding these objects.

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