Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

NON-CONVENTIONAL MILLING USING INDUSTRIAL ROBOT

Tadeusz Mikołajczyk, Robert Polasik

University of Technology and Life Sciences in Bydgoszcz
Al. Prof. Kaliskiego 7, 85-796 Bydgoszcz, Poland
tel.: +48 53 3408743
e-mail: tami@utp.edu.pl
e-mail: robpol@utp.edu.pl

Abstract

The system for 3D sculpture surface cutting using robot, based on a 2D picture was described in this paper. Picture pixels analysing system, using procedures of 3D tool path-hybrid; radial and X-Z Cartesian coordinates system, milling was presented. The original ROBOART software, designed for IRb60 robot milling, using special milling tool connected with robot wrist was showed and analyzed.

Keywords: *picture analyse, milling, robot machining, non-conventional milling*

1. Introduction

The kinematic possibilities of robots [1,2,6] and applied software [11] make possible their use in many different jobs. Robots for surface machining are used in cutting [2,3,4,6,10] and grinding [2,6,8,11] processes. These solutions are cheaper than conventional numeric control machine sytems. Most surface processing with robots are programmed using CAD geometry model [6,10,11]. IRBCAM supports external axes, which can extend the workspace. Typical accuracy that can be achieved with an ABB IRB-type robot is 0.3 mm, with a repeatability of 0.1 mm and a workspace volume with radius up to 3.9 m. New idea of robot machining can be used for unknown surface geometry machining [6,8,9] and using robots for turning [6,10] or rapid prototyping [5,6].

Some CAM applications (ARTCAM [11], BOBCAD-CAM ART [12], BMP2CNC2 [13]) are useful to make a 3D CNC machining tool paths, based on a 2D picture.

Fig. 1. Example of picture

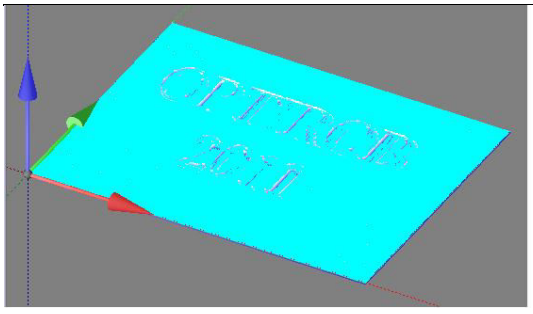

Fig. 2. Picture from fig. 1 interpreted using BMP2CNC2

Picture's shadow or grayscale is quantified to: adjust Z-axis depth, different tool overlaps, depths and tool radius. Final sizes of X-Y output can be scaled and stored into CNC files that could run with most computer numerical control routers and mills. Example of virtual model 2D image interpretation (fig. 1) is showed on Fig. 2 (made, using BMP2CNC2 DEMO - 12600 G-Code lines, simulate milling time 4 h 40 min).

The new idea of 3D robot machining model, using 2D picture, elaborated in Production Engineering Department, University of Technology and Life Sciences (Bydgoszcz - Poland) is described in this article. Principles of idea and special 3D milling tool path software for IRb60 industrial manipulator are presented and discussed below.

2. IRb 60 robot control system

In the Department's of Production Engineering technological laboratory works on the use of robots for manufacturing have been conducted for many years [3-10]. For these jobs the IRb60 industrial robot with a modified control system was used. Robot was controlled using computer. In this system the manual control panel was combined with the computer via a special interface with 16 relays, controlled by the LPT [7] (Fig. 3).

Direct use LPT interface due to the number of channels did not provide the control capabilities of all robot's five axis, gripper and speed settings. To exhaust all robot's controll possibilities for increase the number of supported transmitters multiplexer was used. But this limited the possibility of use only one sequence of robot's movements at the selected speed from the palette of available values. This is a serious limitation of the developed system control. At the same time, due to the use of mechanical relays, control ability is limited by steps providing the possibility to obtain high-precision displacement and variable speed control.

Control system for IRb60 allows controlling movements of the robot head in one plane in the X-Z Cartesian coordinates directions x, z (Fig. 4). This possibility comes from the construction of control system ensuring the submission of rotation in two axes to obtain horizontal and vertical movements of the wrist. Lateral movement is performed in a radial coordinate system around the robot rotation axis (Fig.4).

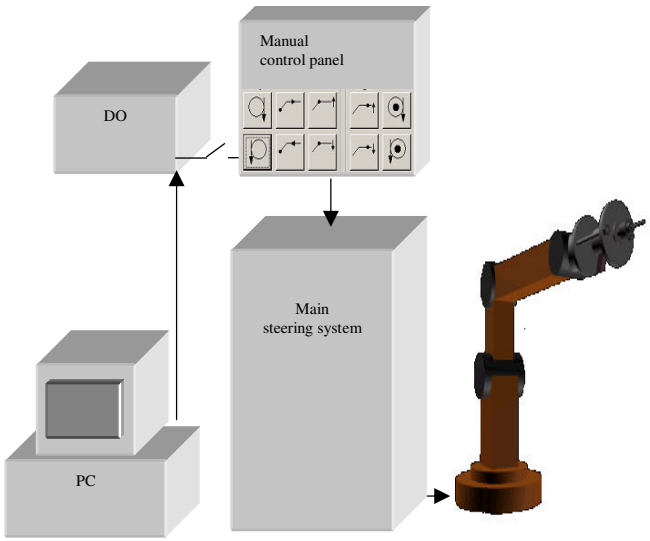

Fig. 3. IRb60 control system [7]

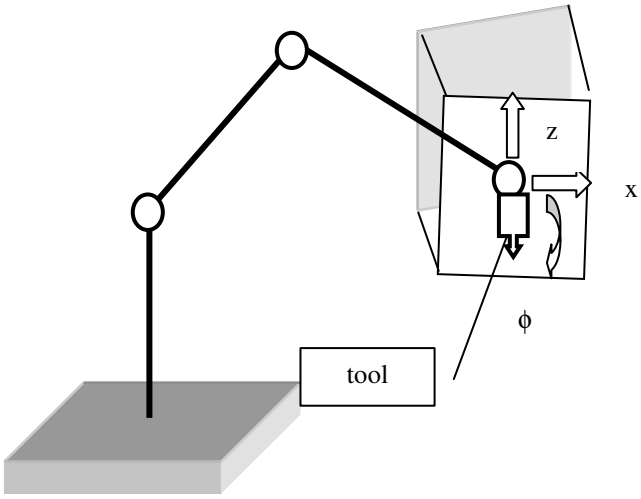

Fig. 4. IRb60 coordination of wrist move

3. Machining system solution

For to the IRb60 robot, according with kinematics constraints and the implemented control system, the concept of pixel image analysis and robot control system for surface machining were developed.

3.1. Pictures analysis

The essence of the applied control solutions relief treatment is use of image's scans due to the brightness level of pixels and the proper interpretation of these values on the axis z displacement scale. This enables to a 3D visualization of the analyzed image (Fig. 5). Modernized process was used for surface machining using robot. To avoid unnecessary operations in the radial transformation for the Cartesian system a hybrid Cartesian-radial robot system of image analysis was made (Fig. 6). This simplified the procedure for machining tool tracks correction in accordance with the local gray-level image by the trajectory consistent with the radial robot system.

Developing a machining procedure procured in three steps. In the first step analysis of the image, selection the area of picture for robot milling was made (Fig. 5). The second one determined the trajectory of tool movement in the horizontal plane in accordance with the selected machining area (Fig. 6). This meant the creation of grid tool movements with successively increasing arc radius of the robot head rotation. This data was saved in a G-Code. In the third stage after switching to the machining process the movement of the robot wrist was followed with tool in accordance with the established trajectory. The x_i - y_i position in radial system was calculated (Fig. 7, Fig.8), which illustrates the visualization of the trajectory of the tool tip. The tool's "vertical" movements depend on the pixels brightness and the scale of the interpretation, adopted by gray shades. In the case of graphic black-and-white image obtained possessed two levels in height.

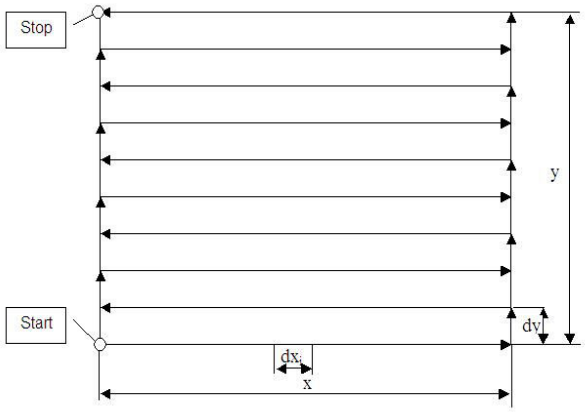

Fig. 5. Area of picture analyse

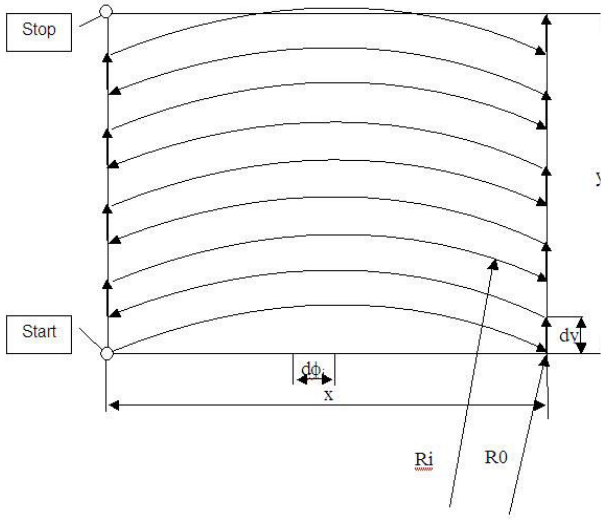

Fig. 6. Trajectory of picture pixels analyse

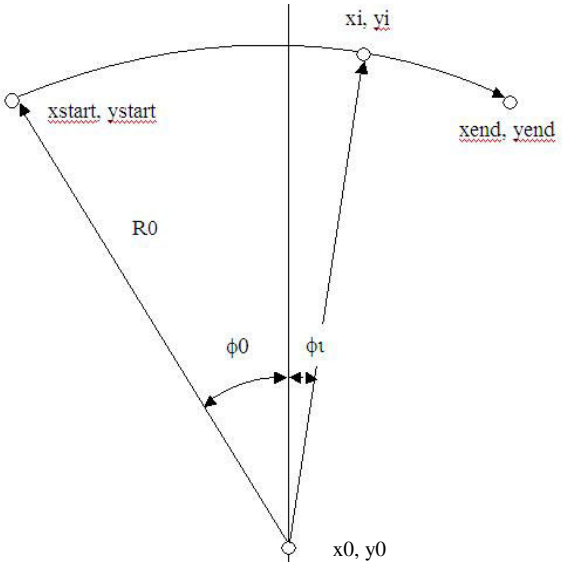

Fig. 7. Coordination of radial system

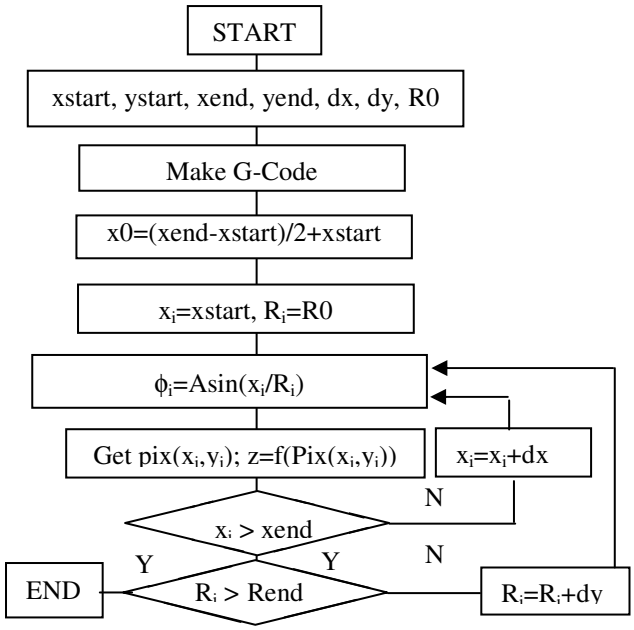

Fig. 8. Algorithm of radial system calculation

3.2. Machining control software

The ROBOART control software (fig. 9) was developed in VB6 environment, according to the approach presented.

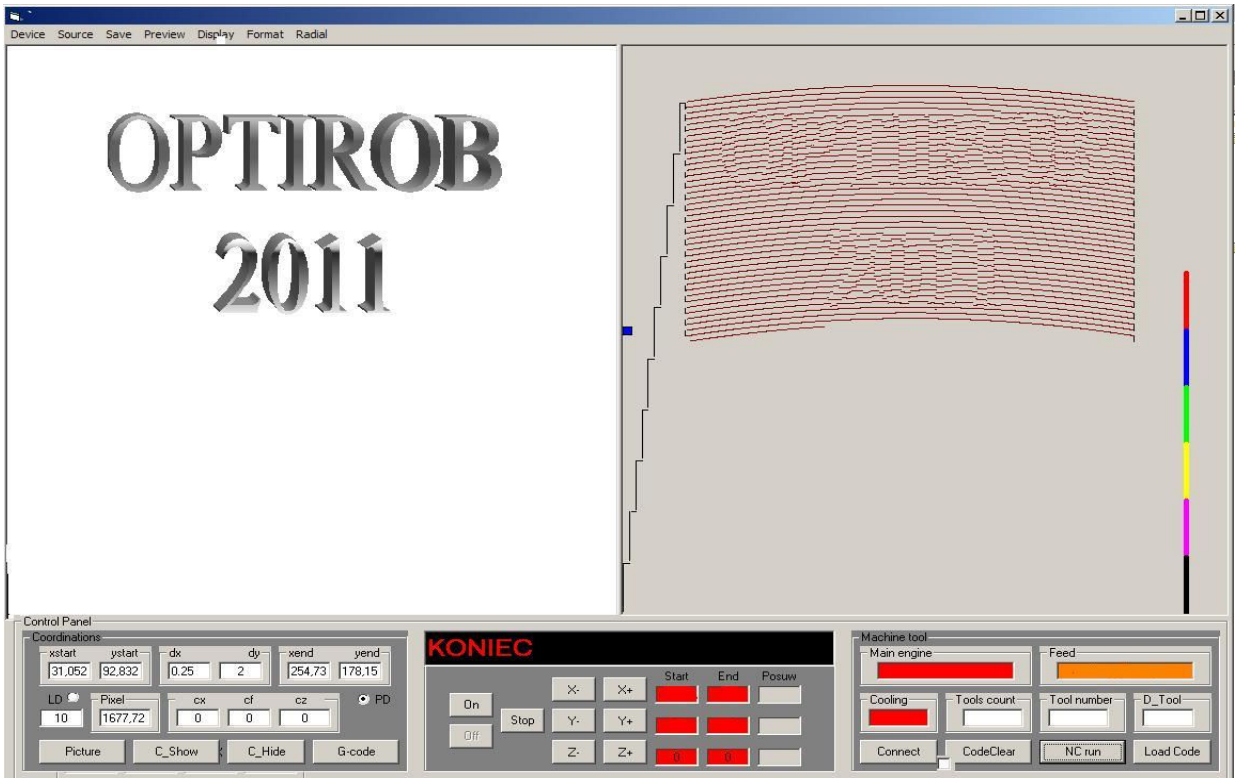

Fig. 9. Main form of ROBOART software

The developed program includes a manual control panel for robot‘s movements. It can be used to bring the tool in machining zone. In addition, the program includes:

a) USB camera panel,
b) image analysis panel,
c) visualization processing panel,
d) trajectory code tool panel.

Selection of an area of image analysis (indicating the area of processing) is performed by two corner points of the image (corners: lower left and upper right). After entering the distance between the lines of the trajectory G-Code is generated (G-Code button) according to which stage of processing is done with on-line analysis of image pixels, by starting with NC run button. The results of this analysis are transferred to the robot. The trajectory of the robot commands are added to the vertical displacement imaging according to the generated file G-Code (fig. 9). Source images for the processing of the robot may be placed in a file or simultaneously obtained by using a USB camera.

4. Conclusions

Presented in the paper CAM system is a novel application of the working robot. By using the robot kinematics in accordance with the procedure significantly reduced, in compare with number of the BMP2CNC2 code orders. Because of direct control of the IRb60 robot via a PC control code has been reduced to a minimum. The G-Code analysis system is used to control the acquisition of information about the state of pixels in the image and also on-line used to control vertical machining tool movements.

The developed system is in a trial phase. An additional advantage of the system is able to directly obtain an image from a system connected by USB camera. It’s important end expected to carry out tests according to the time-consuming processing of automatically generated programs.

5. Acknowledgements

We would like to especially thanks the students of Division of Production Engineering, the Faculty of Mechanical Engineering from University of Technology and Life Sciences (POLAND, Bydgoszcz). They participated in the old generation of IRb60 robot computer system control works and developments. This created the possibility to perform very progressive jobs [3-10].

References

[1] Chen, Y. H., Hu, Y. N., *Implementation of a robot system for sculptured surface cutting. Part 1. Rough machining*. International Journal Advanced Manufacturing Technology, v. 15, pp. 624-629, 1999.

[2] Hu, Y. N., Chen, Y. H., *Implementation of a robot system for sculptured surface cutting. Part 2. Finish machining*. International Journal Advanced Manufacturing Technology, v. 15, pp. 630-639, 1999.

[3] Latoś, H., Mikołajczyk, T.: *Surface shaping with industrial robot*. 1st International Conference “Optimization of the Robots and Manipulators” OPTIROB-2006, Predeal, Romania, University “POLITEHNICA” of Bucharest, Faculty IMST, Department MSP, pp. 265-269, Romania, 2006.

[4] Latoś, H., Mikołajczyk, T., *Virtual aid design of geometric and kinematics flexible tools*. XII Workshop on Supervising and Diagnostics of Machining Systems. Virtual Manufacturing, pp. 145-152, Karpacz, Poland, 2001.

[5] Lewandowski, J., Mikołajczyk, T., *Rapid prototyping using robot*, 10th Int. Conf. Automation/Robotics in Theory an Practice, ROBTEP'2010, pp. 201-206, Slovakia, Bardeov, July 2010.

[6] Mikołajczyk, T., *Manufacturing Using Robot*, Procedings of 2010 Int. Conf. on Mech. Eng. Rob. and Areo. ICMERA'2010, pp. 26-35, IEEE. (printed Chengdu, China), Bucharest, Romania 2010.

[7] Mikołajczyk, T., *Modernisation of IRb60 industrial robot steering system*. The 2nd edition of the international conference Optimization of the Robots and Manipulators, OPTIROB'2007, University "POLITEHNICA" of Bucharest, Faculty IMST, Department MSP, pp.149-152, Predeal, Romania 2007.

[8] Mikołajczyk, T., *The robot machining system with surface shape active control*. The 2nd edition of the international conference Optimization of the Robots and Manipulators, OPTIROB'2007, University "POLITEHNICA" of Bucharest, Faculty IMST, Department MSP, pp. 205-209, Predeal, Romania 2007.

[9] Mikołajczyk, T., *Robot application to surface finishing*, Journal of Polish CIMAC, Vol. 5, Nr 3, pp. 107-112, 2010.

[10] Mikołajczyk, T., *Robot Turner,* 5th int. conf. Optimiz. of the Robots and Manip., OPTIROB'2010, Calimenesti, Romania, Univ. "POLITEHNICA" of Bucharest pp. 312-316, Romania, 2010.

[11] www.artcam.com (acces date: 27.02.2010).

[12] www.bobcad.com/products/software/v24/art (acces date: 27.02.2010).

[13] www.8bitsoft.com/Windows/Graphic-Apps/CAD/bmp2cnc/ (acces date: 27.02.2010).