Vision Assisted Robotic Deburring of Edge Burrs in Cast Parts

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Abstract

In the present day batch production scenario the time taken to program the deburring robot for each batch is one of the major concerns in the industry. In the batch production scenario deburring robots are programmed by operators via so-called "Teach" or "Offline" programming methodologies and require costlier work holding devices. Both these methodologies have associated weaknesses like a high programming time especially when each batch of workpiece has a different shape. Moreover offline methodology cannot carry information of the real work piece. In this paper, a Vision-Guided Robotic System (VGRS) methodology for the deburring of workpieces to eliminate the weakness of "Teach" or "Offline" programming methodologies is proposed. In this proposed system the shape of two-dimensional workpiece is acquired for each workpiece and the robot-language program is generated automatically from the workpiece shape data and finishing condition data. The proposed method is verified by experiments using the robot system. This method provides a compact and inexpensive finishing robot system which reduces the programming time.

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1. Introduction

Presently industrial robots are majorly used for welding, painting and deburring cast parts in automobile production lines, and for circuit chip insertion in electronic equipment manufacturing lines. Majority of these robots are programmed manually by the robot operators in the shop floor by teaching the robot and allowing it playback the taught motion. This process of teaching the robots has to be done each time when the type of the product changes. Therefore, this is an onerous task, especially when each workpiece has different shape. Hence, there is a huge requirement for developing a robot deburring system that could be programmed automatically without much interference from the operator and within short time.

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T. Thomessen et al [1] developed a new programming method for grinding robots that automatically scans the workpiece geometry by a contour tracking system. H. Nakamura et al [2] has developed an offline robot programming system for automobile body spot welding process. M. Jinno et al [3] developed a force controlled robot for grinding, chamfering and polishing using a task-oriented robot language with force control method for following the edges of the workpiece to be deburred.

Asada and Izumi [4] have proposed an automatic programming method from operator motion data, and Thomessen et al [1] have proposed a contour tracking system for automatic programming. N Asakawa et al [5] developed an automatic chamfering system using a industrial robot for the case of hole on free-curved surface. H. Zhang et al [6] developed a practical 6 DOF robot on-line path generation method for robotic deburring of cast aluminium wheels using hybrid force and visual methodology. But in these methods, operators have to write robot language programs offline for each workpiece, the operator motion data has to be acquired, or robots have to track the contour for each workpiece. Therefore these methods are not suited to completely automating the finishing tasks for workpieces of various shapes.

In conventional systems, the relative positions of workpieces and manipulators must be accurate. Operators have to place workpieces accurately on working tables or pallets. Also, conventional systems need pallet positioning systems and workpiece carrying systems that have high precision. Therefore conventional systems are expensive.

In this paper teach less robot system for two-dimensional workpieces with various shapes and thicknesses using computer vision has been proposed. The robot system does not require workpiece shape information to be included in the CAD data or to be input by the operator. In this paper, the configuration of the proposed system and flow of the finishing tasks are first outlined. Then the workpiece shape data acquisition method and the automatic robot program generation method are described. Finally, the proposed method is shown through experiments using the robot system.

2. Proposed robot system

2.1 Proposed robotic deburring system

In the present day batch production scenario robotic deburring system requires costlier work holding devices to precisely position the workpiece in order to achieve dimensional accuracy. To make the finishing system inexpensive and compact the proposed finishing system uses vision sensors for identifying the orientation, position and shape of the workpieces. The proposed teach less finishing system as shown in Fig. 1 consists of a five axis vertical articulated position-controlled manipulator. Its payload is 1 kg and its maximum reachable length is 610 mm. A rotary-type deburring tool having rotational speed of 1000 rpm was mounted to the end-effector, a machine vice to hold the workpiece, a camera stand with camera, a robot system controller and an image analyzing and processing system as shown in Fig. 1. The steps involved in the deburring process are as given below.
The workpiece to be deburred is held in a machine vice placed on the base plate of the camera stand.

The SCORBASE ER 4u software for robot is started.

The robot program for deburring is executed that calls the image processing software ViewFlex 2.9.

The image processing software detects the position of each corner in the workpiece and sends the data to the deburring program written in SCORBASE software.

The robot performs the deburring operation in the edges of the workpiece according to the program written in SCORBASE software.

The finished workpiece is taken out from the vice and next unfinished workpiece is loaded in the vice for carrying out the next cycle.

The proposed is thus a teaching less robot system for removing burrs in the edges of the workpiece. It is a highly effective system in reducing the programming time for each change in the workpiece. The cost of the system also is less as does not require any additional fixture to be made for holding the parts.

2.2 Workpiece preparation

In this research work, to verify the proposed deburring tool path generation method, a series of experiments were conducted. The workpiece (Fig. 2) is prepared from nylon sheets of 10mm thick using hack saw machine. These burrs resemble burrs produced in casting. The deburring task involves removing the burrs in the edges of the workpieces using a rotating deburring tool held by the robot gripper as shown in Fig.3.

![Fig.2. Workpiece cut from plastic sheet.](image)

2.3 Finishing task analysis

The robot manipulator movements during the execution of the deburring program are classified into the approach motion, finishing motions (deburring motions) and withdrawal motion. The movement pattern for approach and withdrawal motions has fixed patterns as shown in Fig. 3. Therefore the program code for these motions has been generated beforehand as the height between the workpiece and deburring tool are known. To complete the deburring task and determine the finishing motions the position of the tool, the deburring direction of the tool, orientation of the tool with the workpiece and feed velocity of the tool has to be determined. The desired feed velocity was decided before starting the deburring operation. Fig. 3 shows the relationship between the tool position and the tool orientation, the pressing direction, and the workpiece contour shape. The tool position, tool orientation, and pressing direction are determined from the position of edges in the workpiece. Therefore it is possible to generate the robot language programs for finishing motions automatically by acquiring the position of edges in the workpiece using image processing.
3. Acquisition of workpiece contour data

3.1 Comparison of workpiece contour acquisition methods

One of the major steps in automating the deburring is to acquire the workpiece contour data. There are mainly three types of workpiece contour acquisition methods. They are; by retrieving contour data from CAD data of the workpiece, using contour tracking method, and using image processing method. It is impossible to get the orientation and position of the workpiece on the deburring workstation using only CAD data, while the method of contour tracking is more time consuming. On the other hand image processing method provides the orientation, position, and shape of the workpiece on the deburring workstation in a short time.

3.2 Workpiece shape data acquisition

The workpiece to be deburred is placed below the web camera of the deburring system and securely held in a vice. The following operations are performed step by step to get the shape data of the workpiece using image processing software Matrox Inspector’s.

3.2.1 Loading an image file into Matrox Inspector’s

The image of the workpiece is captured into the current frame in the Image Processing Tool by the help of snap command in the Matrox Inspector’s software interface.
3.2.2 Performing a histogram on the whole image

Initially a basic histogram operation is performed over the current image to find the intensity distribution graph of the entire color image as shown in Fig.5. The histogram graph displays the three color bands present in the image.

![Fig.5. Histogram of the image using the ViewFlex software.](image)

Inspector can only perform blob analysis on 8-bit or 16-bit unsigned, one band images. To simplify the statistical analysis of the image, the color image is converted to an 8-bit, unsigned grayscale image. After conversion, the statistical graphs generated will show only one band, instead of three. Working with a grayscale image is useful since it will be needed to perform blob analysis later on.

3.2.3 Removing random noise from an image using a filter

Although the noise in the image leads to variation in pixel intensity, the distribution is relatively random; therefore, the noise in the image can be removed using a smoothing filter. Since a narrow histogram curve will indicate that there is a more uniform area, the number of times the filters should applied is determined based on the histogram of the flat area. From the change in the histogram of the small region, it is seen that the background noise is reduced and the region has a more uniform value.

3.2.4 Blob analysis

The blob analysis is performed over the entire gray scale image, so that the number of edges can be determined in the workpiece. The first step will be segmentation, that is, providing pixel intensity threshold values that is between the maximum background value and the minimum foreground value returned from the previous line profile.
such that edges (blobs) are white (foreground object) and the background is black. Then, the image processing software obtains some statistical information about each blob.

Since there are small artifacts after segmentation, which will affect the blobs and to have Matrox Inspector ignore these, a minimum area for the blob analysis search is given as input to the software as shown in Fig.6 (a).Blob analysis command is executed to calculate the specified features (minimum area and features related to centroid). A blue line outlining analysis each edge that has an area above the specified minimum is displayed along with the workpiece as shown in Fig.6 (b).

3.3 Workpiece data file

In addition, an All Results table is displayed which shows the blob, and lists all blobs meeting specifications, including the coordinates of each blob’s centroid to determine the position and orientation of the edges in the workpiece as shown in Fig.7 (a).

The obtained data (co-ordinates of the corners in workpiece) is then transferred to the actual robot coordinates as shown in Fig.7 (b). using inbuilt ViewFlex software. These robot coordinates are stored as data table in the ViewFlex software.
4. Methodology for Automatic program generation

4.1 Automatic program generation procedure

The method of automatic program generation is given in Fig. 8. The deburring program required for finishing the workpiece is automatically generated using the acquired workpiece data file from the image processing system and the given finishing condition data file that is provided in advance. The initial tool orientations, the desired force, the tool feed velocities, and so on are included in the finishing condition data file. It is not depend on the workpiece shapes.

![Automatic programming steps](image)

**Fig. 8 Automatic programming steps**

4.2 Automatic program generation method

4.2.1 Approach and withdrawal motion

An example of approach motions is shown in Fig. 9. Approach motions include surface detection motions and edge detection motions to handle position errors determined by image processing. Approach and withdrawal motions have fixed pattern. Therefore, they are described in relation to the approach point or end point of finishing. The finishing condition data file contains the approach point defined relative to a workpiece surface or edge and includes the initial orientation of the tool.

![Example of approach motions](image)

**Fig. 9 a) Surface detection; b) Edge detection; c) Finishing Task; d) Withdrawal motion**

4.2.2 Finishing motion

Finishing motions are determined using workpiece shape data. The force control motion command is assigned to each straight line. As shown in Fig. 9, the generated reference trajectory at the corner consists of a withdrawal motion, an orientation change motion, and an approach motion in the deburring task.
4.3 Robot-language program

To perform the deburring operation the SCORBASE software is started to calculate deburring path based on real-time identification of edges. The SCORBASE program while executing gets the data from ViewFlex software and performs the deburring operation.

![Fig. 10 Microscopic image](image)

5. Summary

In this paper an attempt has been made to develop a teaching-less robot system for deburring workpieces having burrs on the edges using image processing system. This system does not require the contour shape data from the CAD profile or by manual entry of the data by the robot operator. In this work the image processing system is used to capture the image of the workpiece. This image of the workpiece is then processed to acquire the edges to be deburred by segmentation of the edges into straight lines. The robot language program for each workpiece is generated automatically from the workpiece shape data and finishing condition data.

The proposed method was verified through experiments using the robot system. The robot picked up a workpiece whose shape was not previously known on the workpiece stand by itself and carried out the finishing tasks using the automatically generated robot-language program. The proposed system does not require pallet positioning systems and special workpiece holding systems. Therefore this method provides a compact and inexpensive finishing robot system which reduced the programming and workpiece-setting time on the operators.

References