DOI: https://doi.org/ 10.53052/9788367652148.15

Peter FORGÁČ[1], Vladimír TLACH[2]

Opiekun naukowy: Ivan ZAJAČKO[3]

GENEROWANIE TRAJEKTORII ROBOTA PRZEMYSŁOWEGO PORUSZAJĄCEGO SIĘ PO UKSZTAŁTOWANEJ POWIERZCHNI REPREZENTOWANEJ PRZEZ KRZYWĄ

Streszczenie: Trajektoria, na podstawie której wykonywany jest ruch robota przemysłowego, jest jedną z kluczowych części programu sterującego. Niniejszy artykuł opisuje możliwości generowania trajektorii dla krzywej reprezentującej element o złożonym kształcie - mianowicie podeszwę buta. Pierwszą opcją jest utworzenie trajektorii w natywnym oprogramowaniu RobotStudio. Druga opcja wykorzystuje neutralne oprogramowanie do programowania i symulacji Visual Components.

Słowa kluczowe: robot przemysłowy, robotyzacja, generowanie trajektorii, podeszwa.

GENERATING THE TRAJECTORY OF AN INDUSTRIAL ROBOT TO MOVE ON A SHAPED SURFACE REPRESENTED BY A CURVE

Summary: The trajectory based on which the movement of an industrial robot is performed is one of the key parts of the control program. This paper describes the possibilities of creating a trajectory for a curve that represents a complex shape element - namely the sole of a shoe. The first option is to create the trajectory in the native RobotStudio software. The second option uses the neutral programming and simulation software Visual Components.

Keywords: industrial robot, robotization, trajectory generation, sole.

1. Introduction

Among the highest goals of almost every production is to achieve fast, high-quality production as cheaply as possible. Achieving the aforementioned production characteristics is often very challenging. The result depends primarily

[1] Ing., University of Žilina, Faculty of Mechanical Engineering, Department of Automation and Production Systems, peter.forgac@fstroj.uniza.sk
[2] Ing. PhD., University of Žilina, Faculty of Mechanical Engineering, Department of Automation and Production Systems, vladimir.tlach@fstroj.uniza.sk
[3] doc., Ing. PhD. University of Žilina, Faculty of Mechanical Engineering, Department of Automation and Production Systems, ivan.zajacko@fstroj.uniza.sk

on the complexity of the product, the technology, the finances, and the time available. Industrial production is nowadays reaching a high level, especially with the significant implementation of automation and robotization in various production operations. It is automation and robotization that has an impact on productivity and other important aspects that are closely related to the economics of manufacturing.

This paper deals with the implementation of industrial robot in the footwear industry. It is the robotization of the hitherto manually performed operation of trimming excess material from shoe soles. Specifically, the creation of the trajectory that needs to be created for the movement of the industrial robot is addressed. The motion trajectory has to be formed around the circumference of the shoe sole. The creation of the trajectory for the industrial robot can be approached from several perspectives. This paper provides options for creating the necessary trajectory in an off-line programming environment. To solve this task, it is also necessary to set up the coordinate systems and make corrections in the real working environment of the robot. The whole task was created for the application of the ABB IRB 2600-12/1.65 industrial robot.

2. Excess material removal technology

The main motivation for solving this problem is to replace human labor with industrial robots. Up to now, this operation has been performed manually by workers, but occupational diseases (in particular carpal tunnel syndrome) occur during the performance of this task.

The aim is therefore to robotize the process of trimming excess sole material to the required quality. The excess material is produced during the direct injection of the polyurethane compound into the mold cavity, which is in contact with the shoe upper [1], [2]. In this way, the shoe sole is formed directly on the upper of the shoe, see figure 1. In the injection molding process, this compound is forced by high pressure at the mold parting plane around the entire circumference of the sole.

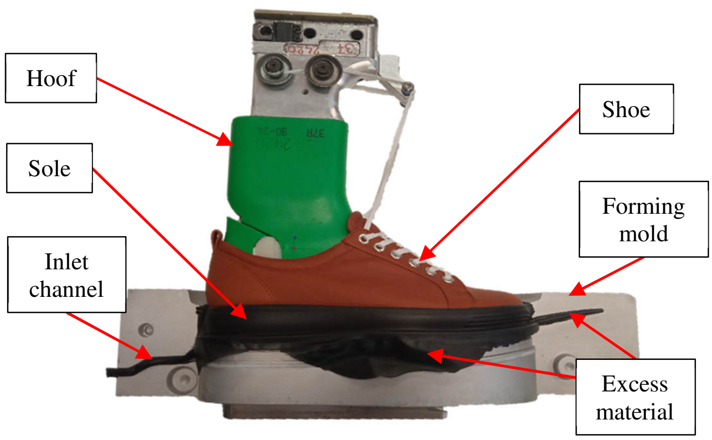

Figure 1. View of the shoe after direct sole injection surgery

The material, shape, and direction of the excess sole material depend on the shoe model. Thus, the resulting trajectory generation solution should be easily applicable to different sole shapes depending on the shoe model. Before selecting the trajectory generation method, it was necessary to determine the technology by which the excess material would be removed. To address this issue, the previously developed designs of the complex robotic cell of this workstation were used as a basis. The resulting design of the robotic workstation is constructed in such a way that a static tool (knife) is used, in the workspace of an industrial robot. The robot manipulates the shoe relative to the statically positioned knife (Figure 2), which results in the gradual trimming of excess material. The above working arrangement implies the use of an external TCP (Tool Center Point) [3].

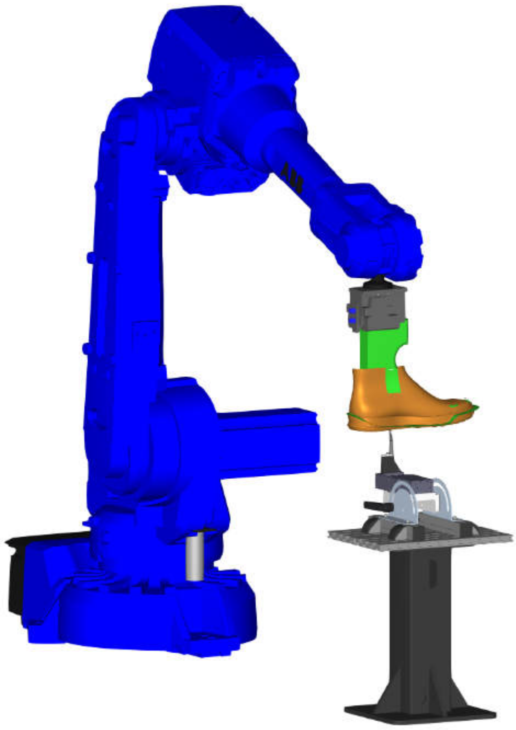

Figure 2. Manipulation of an industrial robot with a shoe against a static tool

3. Trajectory generation options

Creating a robot control program using off-line programming is possible in various programming and simulation software. The basis of such programming is to have a model of the basic parts of the workstation. The model of the shoe - the main part for the trajectory creation, was provided by the company for which the project was solved and thus it was possible to use off-line programming. At the beginning of the solution, the use of two software tools was considered. A native tool from ABB

(RobotStudio), in which it is only possible to work with robots from the manufacturer ABB [4]. The second alternative is to use the neutral programming and simulation software Visual Components, where it is possible to work with robots from different manufacturers [5]. For the task of generating the robot trajectory, Visual Components software was chosen in which off-line programming was carried out. RobotStudio was used for the final modification of the program in the real environment of the robot, directly during testing.

The first step to creating the control program was to upload the shoe model into the CAD/CAM/CAE system Creo Parametric. Here an assembly was created consisting of the hoof model, shoe, and gripper head. To import the model assembly into most CARC systems, a neutral STEP file format must be selected when exporting [6].

The edges or sharp parts on the sole of the shoe can serve as one of the options for defining trajectory points during off-line programming in RobotStudio software. For the need of such a trajectory creation, which would be able to achieve the desired trimming quality, it is advisable to set the step size to smaller values. Setting the step size to smaller values represents a denser distribution of the points used to create the trajectory curve. Creating the trajectory in this way would be a time-consuming solution in terms of off-line but also additional on-line programming.

Due to the unavailability of the RobotStudio software license and the reasons mentioned above, off-line programming of the robot in Visual Components software was chosen, where the trajectory can be generated based on the path creation tool - Path Statement [7]. This approach to trajectory generation represents a significant reduction in the time required to create the control program.

4. Creation of the management program

A necessary step for creating a control program is to import the modified shoe model into the Visual Components software. It was then necessary to assign and appropriately orient the coordinate system for the shoe assembly model, which in this case is the effector. By making the tool statically located in this application, the TCP setting is needed directly on it. In this case, this is the setting of a so-called external TCP, which is placed at an experimentally determined location on the cutting edge of the knife.

The control program of the industrial robot for this operation is divided into one main program (Main), which contains two subroutines (sequences). The sequence labeled S represents the subroutine designed to perform the substitution and thus the appropriate adjustment of the coordinate systems and the subsequent correction. The second sequence already contains the individual coordinates of the points that plot the trajectory necessary for the cropping process.

The second subroutine (Figure 3), i.e., the sequence designed for the trimming process itself, contains the definition of the tool and user coordinate systems. This definition follows from the previous sequence intended for setup. The definition of the coordinate systems is followed by the PTP motion, which is used to zoom in and position the shoe appropriately for the tool. The advantage of the PTP motion is its speed, which results from a motion that both starts and ends simultaneously for each single axis of the robot [8].

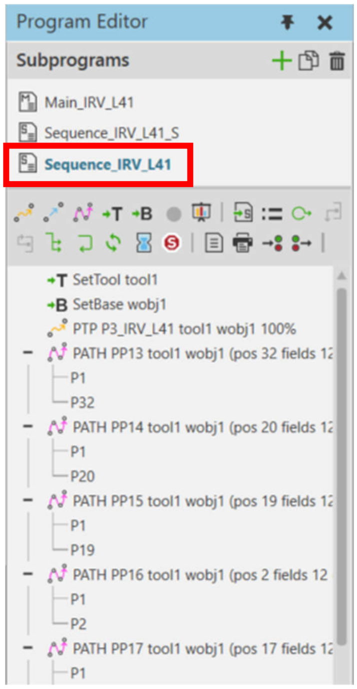

Figure 3. Breakdown of the subroutine for the trimming process

The Visual Components software tool Path Statement was used to create a trajectory around the perimeter of the sole that is shape complex. Using this tool it is possible to distribute points along a selected edge of the model (Figure 4). This is to determine the curve for the need of path generation. When using this tool it is possible to set the density and distance of the points from the described curve. Due to the complexity of the shape of the model edge, the points have been divided into several groups see figure 3, to describe the given shape as accurately as possible [7].

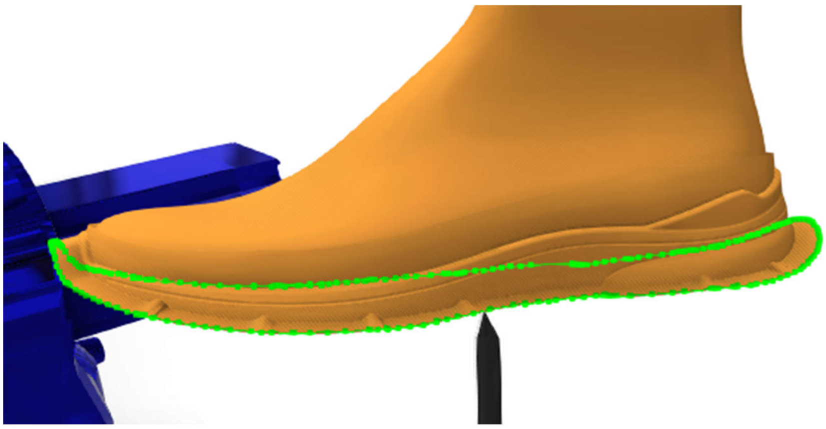

Figure 4. Display of points on the sole forming a trajectory

Path determination or point placement using the Path Statement tool is only possible on more pronounced shape features such as sharp edges. This can cause inaccuracies on some parts of the sole due to the different positions of the sharp edge of the excess material and the parting plane of the mold at the sole location, which can be seen in figure 5. Based on this observation, it is possible to determine in advance where adjustments to the tool coordinate system will be necessary. Such an estimate can also be used to predict the complexity of additional modifications to the control program.

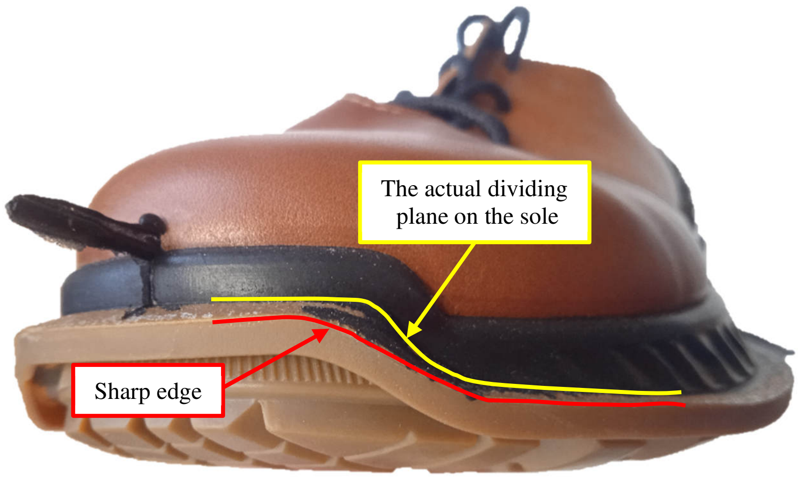

Figure 5. Display of actual and generated trajectory

After creating the necessary movements for the industrial robot, it is necessary to simulate the entire process, thus unnecessary and duplicate movements or collision states can be detected [9]. In the case of a satisfactory course of robotic trimming in a virtual environment, a control program can be generated. The generation of the control program is performed for a specific robot model using an integrated postprocessor that is part of the Visual Components software [10].

5. Modification of the management programme

The generated control program was then uploaded to the control system of the industrial robot. Subsequently, it was possible to work in the on-line programming environment via the Teach pendant, or for greater convenience, modifications to the control program were made on a PC connected directly to the robot's control system. In the generated control program it was necessary to make several modifications aimed at:

- changing the motion command,
- changing the logic of the coordinate systems,
- changing the termination of the motion commands from FINE to z100.

All the mentioned modifications had to be made additionally, mainly due to the lack of complexity of the Visual Components software postprocessor for the robot used. This drawback is due to the integrated postprocessor.

The control program thus constructed could be further modified during real testing. During the real tests, the most frequent modifications were made to the position and orientation of the Tool1 tool coordinate system. Such an adjustment was necessary for a suitable position of the shoe relative to the tool to achieve the desired trimming quality. The necessity of the necessary adjustments to the Tool1 tool coordinate system arises from the aforementioned position and orientation of the actual and generated trajectories mentioned in chapter 3. Such an adjustment made it possible to place the TCP point of the tool at the location of the parting plane located on the sole.

6. Conclusion

The trajectory for the movement of an industrial robot is one of the basic parts of the control program to perform the required operation. In this paper, a description of a possible approach to trajectory generation over a shape-intensive surface – the sole of a shoe - is presented. A possible approach to creating the necessary trajectory in the native software RobotStudio and the neutral software Visual Components has been described.

It follows that the off-line creation of such a trajectory in the RobotStudio software described above is time-consuming but on the other hand, would not require additional modifications to the program to such an extent. The creation of the trajectory in Visual Components software is simplified by the Path Statement tool. This tool allows the creation of a path along any edge of the model regardless of its shape. For complicated shape features such as the sole of a shoe, the Path Statement tool is a significant simplification of trajectory creation. By being a neutral software tool, the integrated postprocessor is not quite perfect, which consequently requires the aforementioned program modifications.

The above description of the chosen trajectory generation in both programming and simulation software is used to define and then select the optimal choice for the intended application. Thus, the choice of the appropriate software from the two mentioned above depends mainly on the industrial robot used and the shape complexity of the desired trajectory.

Acknowledgement: This work was supported by the Slovak Research and Development Agency under the contract No. APVV–16–0283.

LITERATURE

1. PINZASHOES: Direct Injection Process (DIP) and Pouring Method for PU Soling onto Footwear | Shoes and More. Accessed: Mar. 09, 2023. [Online]. Available: *https://pinzashoes.wordpress.com/2012/08/06/direct-injection-process-dip-and-pouring-method-for-pu-soling-onto-footwear/*
2. DESMA: DESMA Shoe Machinery | Boots. Accessed: Apr. 07, 2023. [Online]. Available: *https://www.desma.de/en/machines/boots/*

3. MICHALČÍK J.: #05 TCP a súradnicové systémy / DailyAutomation. Accessed: Nov. 5, 2023. [Online]. Available: *https://www.dailyautomation.sk/05-programovanie-robotov-tcp-a-suradnicove-systemy*
4. ABB: ABB RobotStudio: programovací softvér pre simulácie. Accessed: Nov. 15, 2023. [Online]. Available: https://abbrobotika.sk/abb-robotstudio-studio-ktore-uci-cloveka-komunikovat-so-strojmi/?gclid=CjwKCAiAjfyqBhAsEiwA-UdzJFM_CnqZXVkyh-5z5MXjTMwZxeWQSzVcufDjtgbSQgdjivCNBaPjgBoCdHkQAvD_BwE
5. Visual Components: Product Overview - Visual Components 4.8. Accessed: Nov. 10, 2023. [Online]. Available: Https://Www.Visualcomponents.Com/Products/
6. Kuric I., Košturiak J., JanáčA., Peterka J., Marcinčin J.: Počítačom podporované systémy v strojárstve. Žilina: EDIS, 2002.
7. Visual Components: Teaching Robots with Visual Components. Accessed: Nov. 11, 2023. [Online]. Available: *https://www.visualcomponents.com/resources/blog/teaching-robots-visual-components/*
8. VITRALAB: Příručka Automatizační a robotická technika, Košice, Sep. 2011.
9. FUSKO M.: #07 Simulácia výrobných systémov / DailyAutomation. Accessed: Nov. 15, 2023. [Online]. Available: *https://www.dailyautomation.sk/simulacia-vyrobnych-systemov*
10. Čuboňová N.: Počítačová podpora programovania CNC strojov, 1. Žilina, 2012.