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UDC 004

UTILIZATION OF OLP METHOD IN THE ANALYSIS OF A ROBOTIC 3D SCANNING PROCESS

Łukasz Sobaszek; Monika Woźniak; Daniel Szczypiór

Lublin University of Technology, Lublin, Poland

Summary. *In the paper the assessment of the feasibility of using a selected off-line robot programming environment in the design process of a robotic 3D scanning process was presented. First of all, basic information about modern industrial robots implementations were outlined. Secondly, a developed virtual model of an analyzed robotic cell was described. Moreover, analyses on selected aspects of the considered issue were discussed. The study has confirmed that utilization of OLP method is very useful and needed for improvement of robotic production processes.*
Key words: *industrial robot, robotics 3D scanning, off-line programming.*

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Statement of the problem. One of the modern measures of the development of manufacturing systems is the increasingly widespread utilization of industrial robots [1]. Undertaking robotic projects is noticeable not only in large corporations, but increasingly in small and medium-sized enterprises. The increasing implementation of robots bring a lot of benefits [2]. Robots were used mainly in dangerous processes in the past. Nowadays, a significant number of implementations involve the use of robots in jobs where there is a shortage of skilled workers, the work is monotonous or the execution of individual operations requires extreme precision [3]. Consequently, industrial robots are also increasingly used for quality control with 3D scanners [4]. However, the development of a robot program for this type of work indicate the need to conduct a thorough analysis of many aspects of the process. It is therefore necessary to use appropriate supporting solutions such as the OLP (off-line programming) method [5].

Analysis of the available investigations. The issue of designing robotic workstations is the subject of many scientific papers [6–10]. Researchers very often focus mainly on a thorough analysis of the robot's working paths. Because planning the right trajectory allows the robot to perform its tasks properly, this problem analysis is very important [6]. An additional aspect is a thorough analysis of detailed process parameters [7]. For example, in the work [8], the authors address the issue of shortening robot movement paths by analyzing the trajectory coordinates. In turn, in the work [9] authors propose a solution aimed at appropriate path planning with simultaneous force control in the process of robotic grinding. Moreover, the aspect of the occurrence of collisions between elements of the infrastructure of robotic workstations is very often raised [10]. The authors of the works propose solutions to avoid this type of situation. Increasingly, the problems of robot utilization are also subjected to multi-criteria analysis, where the analysis of correlation between shortening paths, minimizing costs, excluding collisions and reducing robot failure rates are the aim of the study [6, 11–12].

An issue closely related to the planning of robot paths is the appropriate use of modern robot programming tools [5]. In the field of robot programming, a lot of work is also being carried out to create and develop new solutions, and consequently to simplify

Corresponding author: Łukasz Sobaszek; e-mail: l.sobaszek@pollub.pl

and speed up the programming process [13]. The current trend is to develop methods dedicated to solving specific problems. The current trends concern methods covering: workshop-oriented, task-oriented, virtual reality, symbol- and diagram-based, using gestures and verbal commands [5].

It should therefore be concluded that every robotic process should be analyzed in detail. A helpful tool in this area can be robot programming using the methods and tools of the OLP class.

The objective of the work is to assess the possibility of a selected off-line robot programming environment utilization in the design process of robotic 3D scanning workstation and robot path planning.

Developed model of robotic 3D scanning cell. In order to carry out research work in the K-ROSET environment a model of a robotic 3D scanning workstation was developed. The software makes it possible to simulate the work of the robot, analyze cycle times, potential collisions detection and analyze the position of the robot's placement on the station. K-ROSET allows off-line programming of the robot in AS language, which is implemented in the form of a set of motion commands, signal handling, gripper control, etc. The developed program can be easily copied to the robot controller (using a USB memory stick or Ethernet connection), which significantly speeds up the process of creating and developing applications [14].

The main components of the designed workstation included a Kawasaki RS003N industrial robot, an Artec Space Spider scanner and an Artec turntable (Figure 1). Models of the individual components were obtained from available libraries or developed using CAD software based on the actual parameters of the component devices. The initial arrangement of the components was determined based on the main parameter of the robot, which is its maximum reach of 620 [mm]. The detailed parameters of the devices are shown in Table 1.

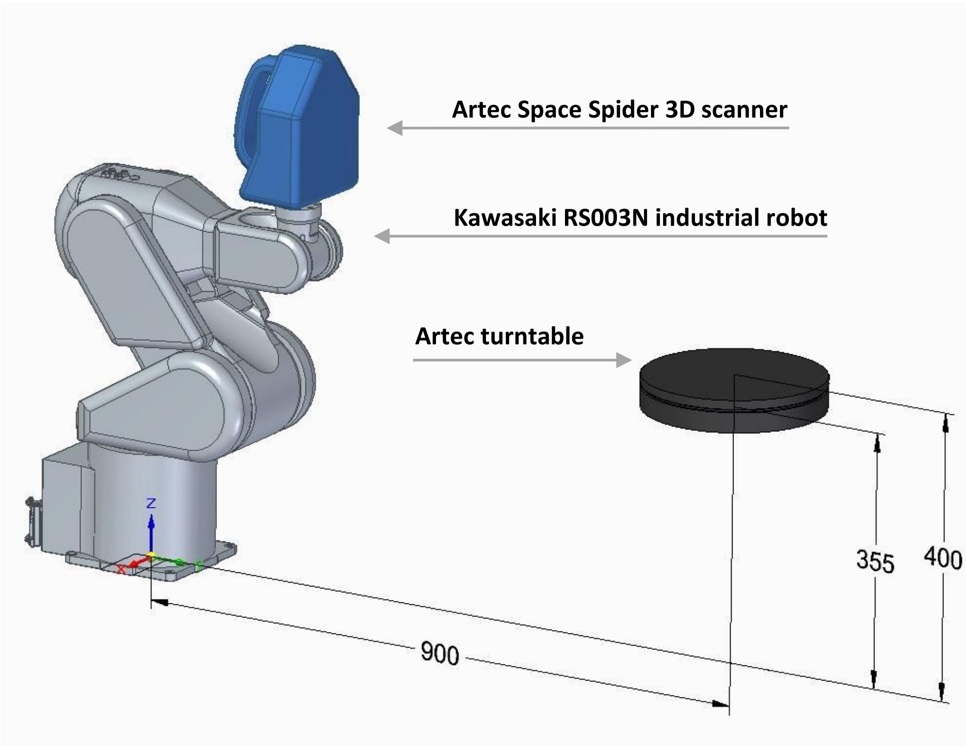

Figure 1. The main components of the designed workstation and their location (dimensions in [mm])

Table 1

Parameters of the devices [15, 16]

Workstation component	Device specification
Kawasaki RS003N industrial robot	Type: articulated robot Number of degrees of freedom: 6 Repeatability: ± 0.05 [mm] Maximum load: 3 [kg] Maximum speed: 6000 [mm/s] Power unit: brushless servo drive Mass: 20 [kg]
Artec Space Spider 3D scanner	3D resolution: up to 0.1 [mm] 3D accuracy at a distance: up to 0.03% per 1000 [mm] Light source: LED lamp (blue light) Working distance: 170–300 [mm] Data acquisition speed: up to 1,000,000 points/second Main output formats: OBJ, STL, ASCII,CSV, XML, DXF Dimensions: 190 × 130 × 140 [mm] Mass: 0.85 [kg]
Artec turntable	Full rotation time: 13 [s] Maximum object weight: 3 [kg] Compatible 3D scanners: Artec Space Spider or Spider Dimensions: 250 × 250 × 45 [mm] Mass: 0.72 [kg]

The main assumption during the design of the robotic scanning process was that the robot would move its arm along a trajectory consisting of three main points (Figure 2). Based on the assumed points location, the sequence of movements of the robot will be as follows:

1. Robot's TCP to the scanning position move (#*point1*).
2. Scanning proces execution (rotate of the turntable).
3. Robot's TCP to the scanning position move (#*point2*).
4. Scanning proces execution (rotate of the turntable).
5. Return to home position (#*base*).

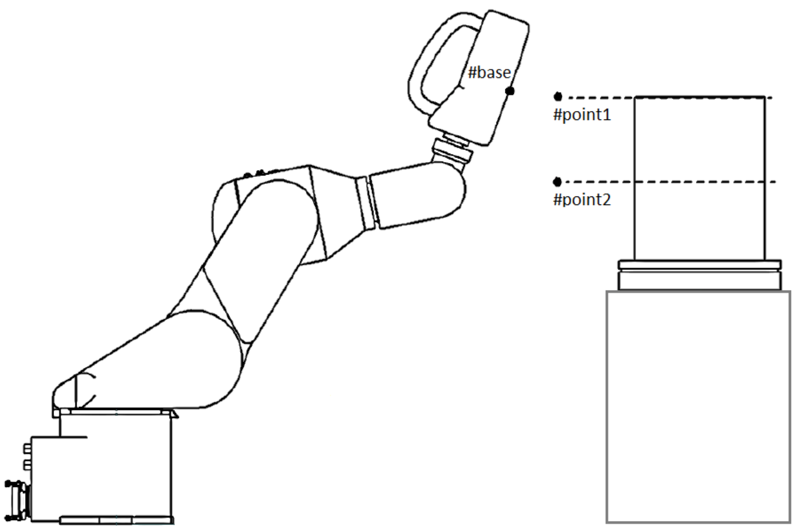

Figure 2. Main points of robot's trajectory

Based on the assumptions, a workstation model was developed in the selected OLP environment, supplementing it with appropriate additional elements (Figure 3). Moreover, the key points of the robot's trajectory were defined. The coordinates of the trajectory points were determined on the basis of geometric parameters and the operating ranges of the devices (robot and scanner). The centre of the robot's base was taken as the main reference point.

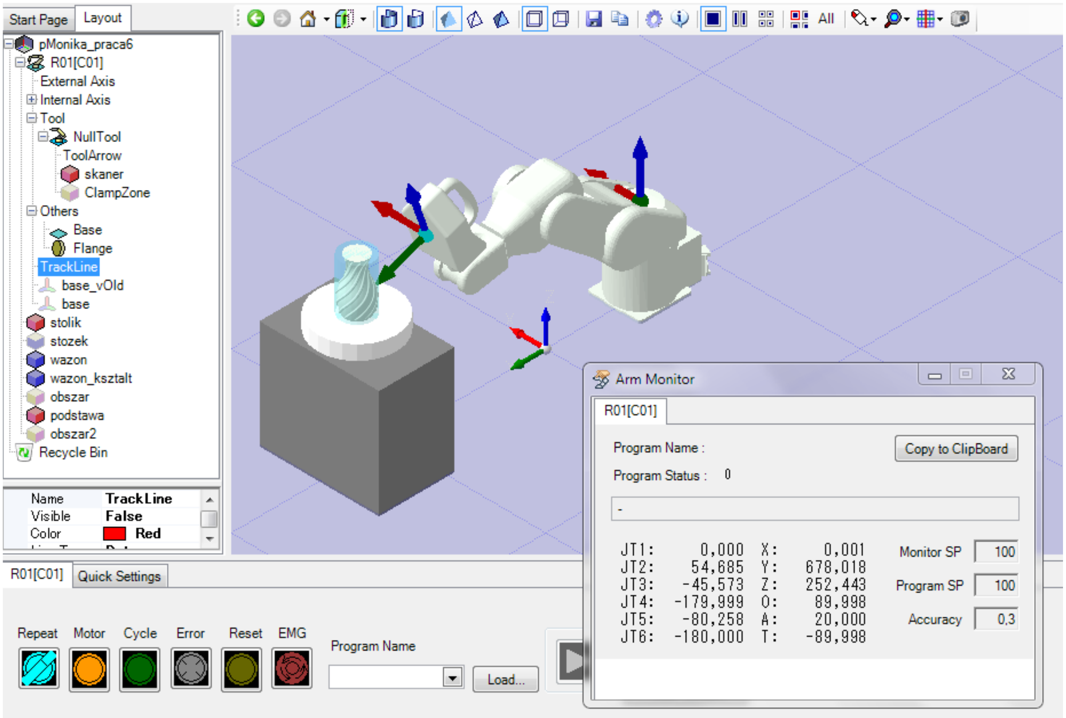

Figure 3. Virtual model of analyzed workstation developed in the OLP software and Arm Monitor tool utilization

The development of the virtual workstation allowed the implementation of the robot programming process and verification of the correctness of the assumptions made.

Research and analysis carried out. The development of the virtual workstation allowed to start the analysis of the robotic scanning process. The conducted research included:

1. Development and verification of the correctness of the developed robot program.
2. Evaluation of the correspondence between the points of the robot's trajectory and the working area of the scanner.
3. Potential collisions detection.

In order to realize the first point of the assumed analysis, a robot program was developed to carry out the process of 3D scanning. In the test case scanned object was a vase with a cylindrical shape. Using the built-in commands of the AS language, as well as using the dimensions of the scanned test object (height and diameter), a robot control program was obtained. The simulation confirmed that the program achieves a assumed trajectory. An important aspect of the robot's program verification was to obtain information about the robot's arms positions as well as information on whether the robot movement being performed is outside the working range (Figure 3).

In the next stage of the research, the built-in tool for generating simple geometric shapes was used. To make it easier to control the simulations carried out, two semi-transparent cylinders were additionally placed on the scanned object to represent the minimum and maximum range of the scanner (Figure 4). In order to realize the correct execution of the scanning process, the scanner should be located in the space between them. Using the tool confirmed that the key points of the process (*#point1* and *#point2*) are in the given range, thus proceeding to the next point of the assumed work – collision detection.

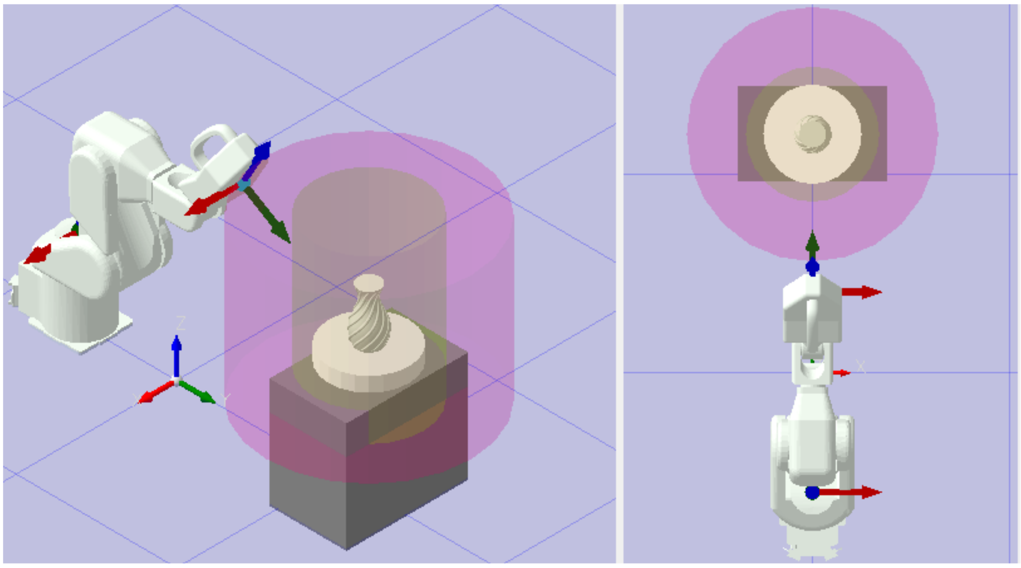

Figure 4. Examination of robot and scanner working distances compliance

Using the collision detection tool, pairs between which collisions are to be detected were defined. After defining the mentioned relations, the robot's operation was simulated. As subsequent simulations were carried out, it was necessary to make modifications to the robot's control code. This is because the analysis showed that various components of the robot or scanner collided with the platform or test object (Figure 5).

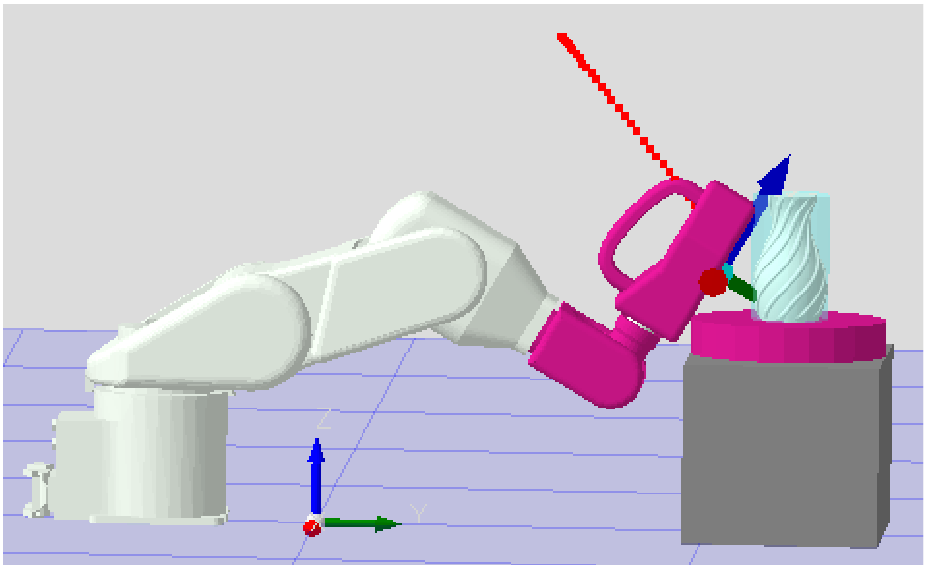

Figure 5. Robot and turntable collision detecion

As a result of the analysis, it became necessary to increase the distance between the robot and the platform with the table. However, this did not give the robot a large enough range of motion, so the last necessary modification turned out to be increasing the height at which the scanned object was placed by changing the dimensions of the platform. The analysis of the robot's movement finally made it possible allowed to determine the positions, so that the scanner was always in the right position in relation to the scanned object, and the individual arms did not send information about errors in position.

Conclusions. Robotic cells designing requires wide knowledge and the need to extensive analysis. Therefore, a key aspect of this process is the use of appropriate methods and tools to which OLP systems belong. This paper presents an assessment of the feasibility of using a selected off-line robot programming environment in the design process of a robotic 3D scanning process. By performing simulations, it was possible to reduce the time of the entire process and reduce the complexity of the robot's movement. The detection of collisions during the tests showed how risky it would be to test the code directly in the real robot (due to the possibility of damage to the scanner or other components of the workstation). The next stage of the presented research should involve the implementation of the workstation in a real environment and further testing of the generated code. The realized work proved that the use of off-line robot programming tools allows to eliminate errors, properly verify the solution, reduce the risk of failure, as well as software errors. Therefore, it should be concluded that the use of OLP methods is a key requirement during modern design and testing of robotic solutions.

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ВИКОРИСТАННЯ МЕТОДУ OLP В АНАЛІЗІ ПРОЦЕСУ РОБОТИЗОВАНОГО 3D СКАНУВАННЯ

Лукаш Собашек; Моніка Возняк; Даніель Щипьор

Люблінський технологічний університет, Люблін, Польща

Резюме. *Одним із сучасних заходів розвитку виробничих систем є все ширше використання промислових роботів. Робототехнічні проекти помітні не лише у великих корпораціях, а й у малих і середніх підприємствах. Упровадження роботів приносить багато переваг. Раніше роботів використовували переважно в небезпечних процесах. Нині значна кількість реалізацій передбачає використання роботів на роботах, де не вистачає кваліфікованих працівників, робота є монотонною або виконання окремих операцій вимагає надзвичайної точності. Отже, промислові роботи також все частіше використовуються для контролю якості за допомогою 3D-сканерів. Проте розроблення роботизованої програми для такого виду робіт свідчить про необхідність проведення ретельного аналізу багатьох аспектів процесу. Тому необхідно використовувати відповідні допоміжні рішення, такі, як метод офлайн програмування. Проектування роботизованих клітин вимагає широких знань і необхідності ретельного аналізу. Тому ключовим аспектом цього процесу є використання відповідних методів та засобів, до яких належать OLP-системи. У статті представлено оцінювання доцільності використання вибраного автономного середовища програмування робота в процесі проектування роботизованого процесу 3D-сканування. Перш за все, викладено основні відомості про впровадження сучасних промислових роботів. Проводячи моделювання, вдалося скоротити час усього процесу та зменшити складність руху робота. Виявлення колізій під час тестів показало, наскільки ризиковано було б тестувати код безпосередньо в реальному роботі (через можливість пошкодження сканера або інших компонентів робочої станції). По-друге, описано розроблену віртуальну модель аналізованої роботизованої клітини. Крім того, було обговорено аналіз окремих аспектів розглянутого питання. Наступним етапом представлених досліджень має стати впровадження робочої станції в реальне середовище й подальше тестування згенерованого коду. По-друге, описано розроблену віртуальну модель аналізованої роботизованої клітини. Крім того, обговорено аналіз окремих аспектів розглянутого питання, що використання засобів автономного програмування роботів є дуже корисним і необхідним для вдосконалення роботизованих виробничих процесів, дозволяє усунути помилки, належним чином перевірити рішення, знизити ризик збою, а також програмних помилок. Отже, можна зробити висновок, що використання методів OLP є ключовою вимогою під час сучасного проектування й тестування робототехнічних рішень.*

Ключові слова: *промисловий робот, робототехнічне 3D сканування, офлайн програмування.*

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