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# ROBOT MANIPULATOR USAGE FOR MEASUREMENT IN PRODUCTION AREAS

Measuring and inspection works in production process using laser scanners attached to the robot manipulators are more and more used in different ways and purposes. The aim of this article is to study and analyze the usage of 3D measuring devices attached to the robot manipulator according to determine the range and the purpose of such industrial measurements. Different scanning devices are applied in production areas with varying purposes, such as 3D scanning of the new product, in order to inspect and find defects. Attached to the robot manipulator, scanners or laser measuring devices are able to scan every object in range of a robot, which makes the measuring process very flexible. Several tests with 3D scanners were performed to find out the optimal conditions and configuration for production purpose. As a result, knowledge base suitable for different production areas was developed. Thus, it would be feasible to have a common database to be implemented in different production areas.

## 1. INTRODUCTION

The possibility of fast and precise measurements by using measurement tools attached to the robot manipulator has raised up a wide interest in fields of production and quality control. There are many ways to use those devices in different purposes. It is possible to find weaknesses in structure, inspect detail’s geometry, make a digital copy of its geometry and put it into an assembly in the drawing made in CAD software.

However, previous researches [1],[2],[6] have not properly determined the field and range of the usage of 3D robot scanning. There is clear need for a methodology of such a robotic measurement systems to evaluate their suitability according to object size and geometrical complexity.

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## 2. HARDWARE OVERVIEW AND METHODOLOGY

This section will give an overview of different types of manipulators and measuring devices attached to them.

### 2.1. ROBOT MANIPULATORS

The introduction of industrial robots is an accelerating trend of the recent years. Between 2005 and 2008 the number of new robots built was approximately 110,000 per year. From 2011 onwards, it exceeded the verge of 150,000 robots, and in 2014 the number was 229,000 [14]. Major exploiters of robots are automotive and electronics industries.

There are many different manipulator manufactures in the world. The most well-known brands are Kuka, ABB, Motoman, Fanuc, Comau, Panasonic, Nachi, Adept, Kawasaki, OTC, Hirata, ESAB, Hyundai, Honda, Deneb, Lincoln, etc. Experimental part given in this paper was done by using ABB IRB 1600 robot manipulator with 100 N lifting abilities.

Industrial robots have a wide field of usage depending on the possibility to automate the production technology. For a long time period the development of robotics was motivated by mass production only. Those appropriate tasks like welding, painting, assembly, parts feeding, packaging e.c.t) were in the focus. Today, the cost and ease of deployment of robots have made the usage available to small-scale production and small businesses as well. This forces robot and software makers to develop applications that meets also needs of SME [9] production.

As it was mentioned before – robot manipulators can be used in different areas: welding (arc welding, spot welding, friction welding), product packaging and palletizing, assembly process, finishing, gluing, painting, machining (wood, plastic, aluminum), cutting (laser cutting, plasma cutting), surface scanning for the purpose of measuring (laser scan), or inspecting. This list is not exhaustive and that shows how widely industrial robots are used in the development of the manufacturing processes.

Some authors of this article have experienced in the field of industrial robotics in arc welding (MIG/MAG) uptake [7]. Its implementation, deployment and appropriateness of the SME environment have been covered in previous articles [4],[5]. As was researched [10], in case of parts with reflective surfaces the selection of proper 3D scanning orientations can significantly reduce outlier extensity. Thus scan path planning knowledge has value in case of using industrial robot manipulators, where repeating paths is configurable.

The purpose of this article is to further analyze novel technological processes where industrial robots can be implemented to increase productivity. Those novel fields are 3D measurement tasks, inspection works and quality control. The emphasis is to develop methodology suitable for SME-s having a need for flexible and rapid measuring-inspection solutions. During the research a knowledge base of different products (profiles, materials, colors) was developed in order to be measured/inspected by the industrial robot solution.

## 2.2. ROBOT-AIDED 3D SCANNING

Nowadays optical 3D scanners are gaining more usage in production as non-contact quality assurance tools with high capability. Non-contact type scanners (optical scanners) have some advantages over contact type scanners (CMM). Because of high accuracy and capability, they are mostly suitable in quality control systems where large datasets of geometry must be observed. These are suitable for both - small (i.e. measuring the wear of cutting inserts with high resolution) and large objects (i.e. castings or welding constructions) [6],[7],[8],[9]. Non-contact scanners are also preferred as they can be used in automated scanning processes with a robot manipulator. For example, in the automotive industry for automated online quality control to check geometrical errors occurring during manufacturing process [13].

Considering the working principle, mainly two different types of scanners are used [11]: 3D laser scanners and Structured Light Scanners. 3D laser scanners may use laser triangulation, time of flight or phase shift method. Laser triangulation is accomplished by projecting a laser line or point onto an object. Then a sensor is capturing laser beam reflections at a known distance from the laser source.

Laser triangulation is most used because it has the following advantages over other methods:

- can be used in various indoor lightings,
- can be used to scan parts of any material,
- provides excellent measuring resolution.

A disadvantage of the laser triangulation method is laser beam is not eye safe.

The other common scanning method is structural light or white light scanning. This technique utilizes 2D light pattern (zebra stripes) which are projected and moved on the object surface. At the same time two CCD cameras are recording the pattern and through triangulation the complex surface parameters are calculated. The advantages of white light scanning are following:

- provides good accuracy,
- fast measurement,
- eye safe.

Disadvantages of the white light method are:

- sensitive to ambient light,
- cannot be used to scan shiny surfaces,
- some trouble to scan very detailed parts with many ribs and sharp features.

In the experimental part we used two types of scanners. The first model was ATOS II 400 optical 3D scanner from GOM (Fig. 1). ATOS utilizes structural light method and its measuring speed is 1.4 million points in 7 seconds [12],[13]. Sphere spacing error of ATOS system is 0.026 mm according to 3D scanner standard VDI 2634. Scanning resolution is 0.17 mm. ATOS uses uncoded markers which have been glued on the object surface and used for merging different scanning images.

The second model was Nikon MMDx100, together with the K600 Touch Probe System and ABB IRB robot called also as Nikon K-Robot Automated Scanning System (Fig. 2). Nikon MMDx100 scanner work principle is based on laser triangulation and its scanning accuracy is 10 μm. Overall accuracy for the Nikon system is depending on the measuring zone size. For the zone II the accuracy is 90 μm + 25·L μm [15].

Fig. 1. 3D scanning by ATOS II 400


Fig. 2. Scanning by Nikon K-Robot scanning system

During the measurement procedure the object should not been moved with respect to K600 tracking head. Nikon K-Robot is optimized for production environments that require full-time part inspection in changing environments. With the K-Robot Automation software fully automated scanning tasks can be done with optimal speed.

### 2.3. METHODOLOGY OF MEASURING

The measurement setup is similar to [3], but instead of turntable a tracking head was used. Measurement system consists of many different parts: PC with software, measuring 3D head, tracking head, manipulator and controller. For measuring the sensors attached onto the measuring head must be seen by remote stand, whereas three of them should be seen at the same time. Otherwise, the software will not recognize the measured product. Also, there are two different laser scopes going from 3D head – laser line and laser point, they must be as close as possible to each other while the object is measured.

In the measurement process it needs to be confirmed that all dark/shadowed areas are covered. It means that for every measured object the manipulator movement driving program must be unique. Every manipulator producer has their own curve design software. ABB, which robot is being used by Department of Machinery in Tallinn University of Technology, has RobotStudio software. For the robot mentioned above, manual programming (flex-pendant) is possible as well. By moving robotic manipulator with the help of Joystick, you determine the manipulators track points, speed and curve passage percentage.

## 3. RESARCH OF FIRST-TIME OBJECT INSPECTION

For first-time measurements, which means that picked up object is being scanned for the first time, preparations are needed. Different environmental conditions and characteristics of the measured object must be taken into account. For instance, parameters like environment temperature, mirror zones, lights, furniture etc. must be observed before processing. In addition, from the object point of view, the surface of the object and its placement are remarkably important. The size and geometrical shape of the object must be considered before one starts creating the measuring program. All objects shown in the current work were chosen randomly according to their surface, material and geometrical form differences.

Measurement device should be properly attached to the robotic manipulator and a suitable program of the manipulator movement should be created. Both of those tasks influence the amount of measuring points. The more measuring points are acquired from the object, the more precise the CAD model is. Different drive parameters will help us to increase the amount of measuring points. When forcing a robotic manipulator software program to lower the speed of the manipulator, more measuring points will be captured. Low speed is an option only in case of measurements that are non-time-critical like in educational processes or in art. Then the option is lowering the measurement zone in scanning software.

### 3.1. OBJECT INSPECTION WITH NIKON 3D SCANNER

The first inspected object is a low power frequency converter with dimensions 150x70x147mm (see on Fig. 3, left-side). The measured object is made of aluminum and plastic. The object has a simple geometrical form. The running program lasted 18 minutes and there were 61 steps in the movement program. As a result, all scanned object lines can be seen on right-side of Fig. 3. The few scanning errors have been marked with red circles.

The second inspected object is a blade with dimensions 144x76x40mm (see on Fig. 4, left). The measured object is made of 3D printed plastic. The object has a simple and round geometrical form. The running program lasted 2 minutes and the number of movement program steps was 31. The result can be seen on Fig. 4, right-side.


Fig. 3. Inspected object 1 (original and result)

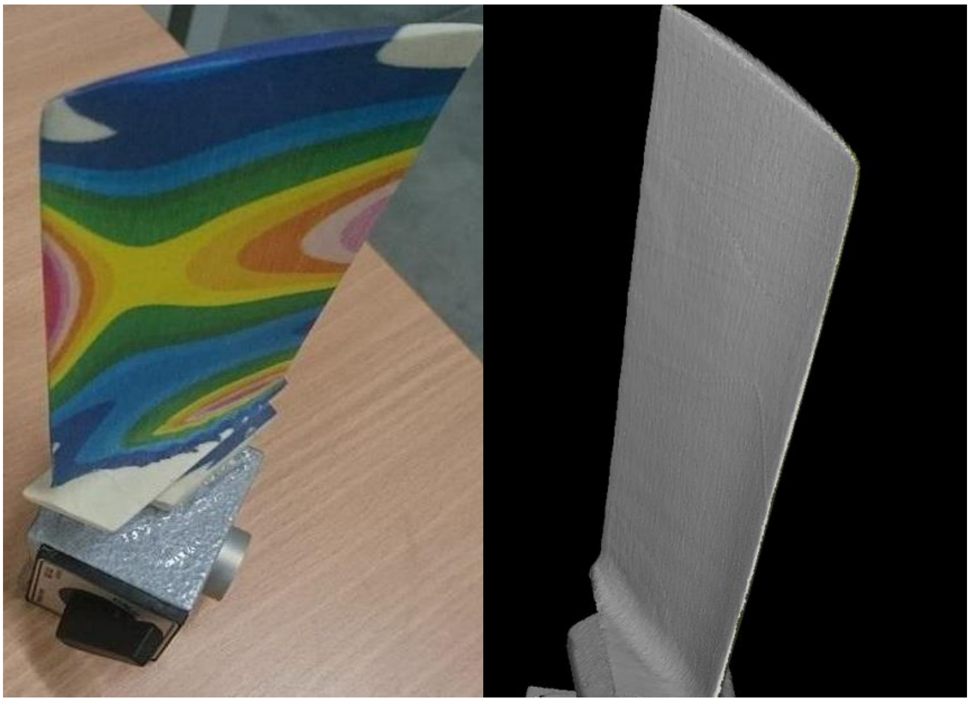

Fig. 4. Inspected object 2 (original and result)

The third inspected object is a part of a ball with diameter 175 mm (see on Fig. 5, left-side). The measured object is made of rubber. The object has a round geometrical form. The running program lasted 5 minutes and the number of movement program steps was 64. The result can be seen on Fig. 5, right-side. The scanning errors have been marked with red again.


Fig. 5. Inspected object 3 (original and result)

### 3.2. ATOS AND NIKON INSCPECTIONS COMPARISON

Additional inspection of those three objects were done with ATOS white light scanning system. It was done manually in a purpose to have the precise inspection model of the object as much as it is available to do with this system. This process is not described in the current paper but it will be described later in the other article.

Table 1. Objects – Global comparison (mm)

| Object | 1 | 2 | 3 |
|---|---|---|---|
| Number of valid points | 307 799 | 544 115 | 524 432 |
| Maximum Deviation | 1.758 | 4.962 | 8.707 |
| Minimum Deviation | -1.903 | -2.499 | -9.312 |
| Range | 3.662 | 7.461 | 18.018 |
| Mean Deviation | 0.122 | 1.787 | 0.187 |
| Sigma | 0.086 | 1.540 | 1.005 |
| Root Mean Square | 0.150 | 2.359 | 1.023 |

Comparison of the same objects inspections between manual ATOS scan and automated NIKON scan were performed. Inspection with ATOS system were taken as initial value, because it was done manually and every measured object area was covered.

Measurement done by NIKON 3D scanner attached to the robot manipulator was compared with this initial value. Deviation is shown in tables – numbers show the difference between NIKON system values to the initial values measured with ATOS system. Deviation tables and pictures are shown also to have a better visual overview (see on Table 1 and Fig. 6, 7). Surface deviation analysis were used to obtain the results.

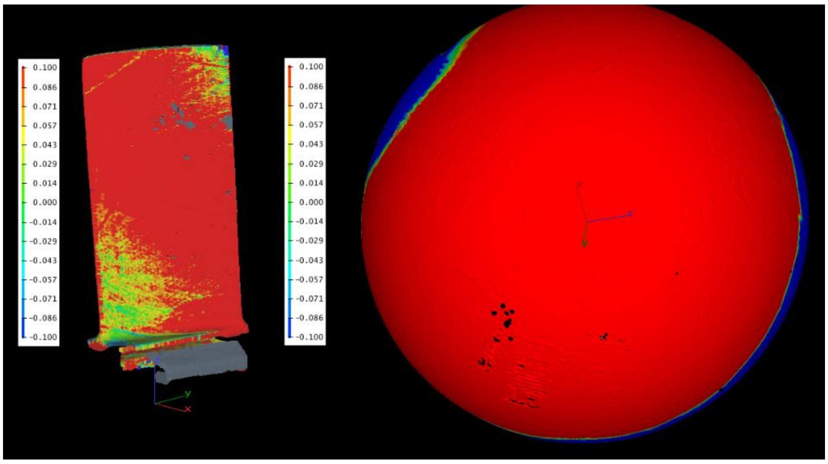


Fig. 6. Deviation analysis of Objects 1 and 2

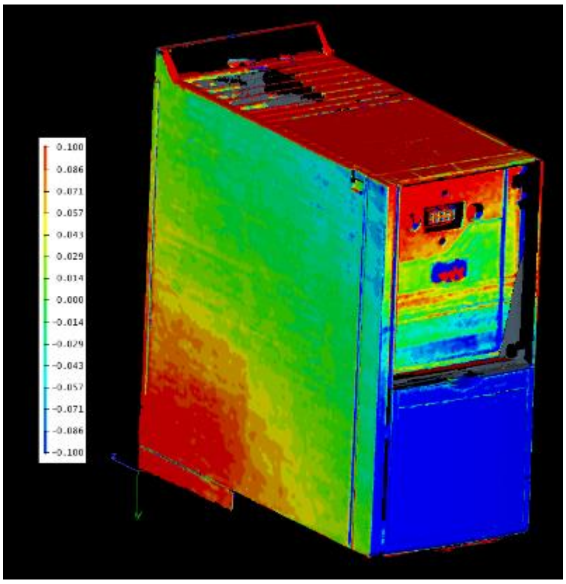


Fig 7. Deviation analysis of Object 3

## 4. RESULTS AND DISCUSSION

The result of the first-time measurements of three objects have shown us different approaches and the direction to move ahead. Methodology for each type of object is being developed. Generally, the scanning for Object 2 and Object 3 took essentially less time than scanning Object 1 due to experimentations with scanning speed. The fastest scan speed was chosen for Object 2 and the slowest for Object 1. It provided an insight that lower speed does not necessarily give the best result.

Analyzing the measurement results of Object 1, we see that it is not ideal. On the points 1 (Fig. 3), we see the shadow issue, when the laser head measured this side only from up to down and appeared a blank zone on the CAD model. To avoid it in the future, all hard places on the object must be scanned from different directions. Point 2 (Fig. 3) appeared because of the changes in distance between measuring head and object. As the laser line and point must be as close to each other as possible while measuring a flat surface, in case of some deviations (bump), it must be considered that the measuring distance will be still the same, and not to lose the measurement points.

Analyzing the measurement results of Object 2, it can be said that the measurements were successful and previous mistakes from Object 1 were corrected. It can be seen that there are no shadow areas on the result.

The measurement results of Object 3 were successful, but only one issue appeared during the scan, as it seen on Point 1 (see on Fig. 5). There are some losses in the scanned surfaces structure, which are the result of surface reflection, mirroring the surface at this point. The light was falling mostly into this place on the object.

The inspection results comparison done with two different systems have shown us, that the 3D scan using laser scanner is more detailed as a resolution is higher. Deviations were in the reason that NIKON system measures more details as letters, surface changes, paint. This have shown, that more accurate inspection can be done using laser 3D scanner.

### 4.1. AREA OF USAGE

The area of usage in this technology is large. It can be used in every type of production – e.g. food, machinery, electronics, and medicine.

It can be used in every manufacturing process as an online geometry inspection. Experiments of inspection of 3D printed details have been done to determine their shape and size preciseness. Moreover, a choosing process for spare parts in repair business is possible as well, according to the measured object. After it is converted into a CAD model, all dimensions are determined. According to this information right spare parts can be chosen.

In medicine this technology can be used in the branch of prosthetics and others related to that technology.

### 4.2. EASE OF USAGE/EDUCATION, LEARNING PROCESS

To use measuring devices attached to the robot manipulators, the person responsible must have different knowledge. First of all, knowledge about controlling the robot must be as good as possible. How to program its movement; use its software, control with flex pendant - all that is more than important in order to succeed in the scanning process. Knowledge of programming language is an advantage.

If a person knows how to use a robotic manipulator then it is easier to use the measuring head properly. One must surely know how to calibrate it, run it and what rules must be considered while measuring. By knowing all the basic processes mentioned above, one can proceed every type of measuring and control. So this type of basic trainings is unavoidable for every engineer related with automated measuring mechanics in production lines, educational process and in arts.

### 4.3. FUTURE INVESTIGATIONS

In the future, the methodology for each type and size objects must be carried out correctly. It will help carry out one-time measurements with minimum changes to the software to create the needed models quickly. It will be a big step forward to helping small organizations with no massive manufacturing capacities.

## 5. CONCLUSION

Analysis of robot manipulators and different technologies of measurement devices which can be attached to them was carried out. Measurement systems were configured and set up to measure different types of objects.

Three different objects were measured. The analysis of the results provided us with conclusions about the methodology of measurement. From those results we can see what must be considered in each type of measurement and what to work on in the future.

The next step should be creating a measurement methodology for different objects and gathering the data into one database for the different usage purposes.

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