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Force Measurement of Robotic Arm for Electrode Pasting Application

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Abstract: Robotic application has been globally increasing for the past decade because robots are able to perform task faster, more precise and longer with high efficiency than human. However, recent development advance in robotics especially in industrial field, have highlighted the implementation of robotic arm in various application. For instance, TDK Electronic SDN BHD suggest to apply pasting operation process using UR 10 robot. This application by UR 10 is not common and never been done before in any industry yet. Thus, this project aims are to investigate force measurement of the robotic arm to determine whether it is suitable for pasting operation by using Braccio TinkerKit robot as a prototype before real implementation on real industrial robot. Both UR 10 and tinker kit robot arm has six Degree of Freedom (DOF); for UR 10 is consist of Base, Shoulder, Elbow, Wrist 1, Wrist 2 and Wrist 3. While for TinkerKit it consists of Base, Shoulder, Elbow, Wrist Vertical, Wrist Rotation and end effector (Gripper). The movement of the TinkerKit robotic arm is depending on the rotation of the servo motor that will be programmed by Arduino Integrated Development Environment (IDE), the microcontroller of this project. This program will calibrate the robot arm for force measurement at three different positions. The results obtained with proper analysis is to determine the force performance of robotic at different joint. The findings of this study are expected to benefit both industries sector and education sector.

Keywords: Robotic Arm, Pasting Process, Force Measurement.

1. Introduction

In this research, the idea of using UR10 robot for electrode pasting has been purposes by TDK Electronics (Malaysia) SDN. BHD company. The pasting operation intended to implement in this study

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is where the UR 10 robot apply the active compound, paste into the electrode wafer and ensure that the wafer is fully filled with paste (Figure 1.2) by using pasting rubber which is end effector of UR10 robot.

However, the application is postponed due to the failure of UR10 robot to apply the desired force which is 25 N and the UR10 robot unable to maintain the control position. Therefore, to identify in details, they are willing to assist and provide a customizable platform for us researchers to explore and determine an accurate result of the failure factor. In other cases, we will collab with Hochschule Osnabrück to tackle issues related to the existing robot system by using Tinker Kit robotic arm as prototype. Thus, to obtain the desired result, force measurement is proposed in this study. By using the TinkerKit robot arm as prototype, it could help researcher to understand more practically about kinematic of robot arm system without risking damaging the real industrial robot arm. With the outcome, the researcher will able to utilize the knowledge they learnt on real application.

This study covers the investigation kinematic of UR10 robot and TinkerKit Robotic Arm in order to relate and apply it in pasting process operation. Thus, the purpose of this study is to determine if a collaborative robot suitable for pasting application or needed supporting devices to be able performing the pasting process for electrodes. This desired application is a new idea and never been done in any industry before using UR 10, therefore it is difficult since there is a dearth of general information available online and in scholarly articles. In order to test this, a preliminary test will be conducted out the position of movement UR10 robot. And an experimental test will be executed to test the overall system by integrating all the hardware and software. In relation, this study will be focus on force measurement by using TinkerKit robotic arm as prototype. The outcome of the result has the potential to serve the industry and company in term of assist them in determine the suitable robotic arm for the desired application. As a result, a framework for alternate solution and application of UR10 can be determined.

Figure 1.1: UR 10 with pasting rubber

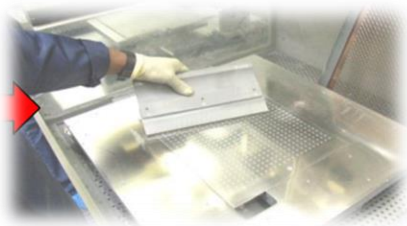

Figure 1.2: Step of Pasting Process

2. Literature Review

Globally, the field of robotic arms has dramatically advanced in recent years. As manufacturing and automation continues to develop and invent new types of robots with more functions and greater utility over time, the number of active industrial robots grow by about 14% by years. (Liu, H., & Wang, L., 2018). Human and robots both have their own advantages and limitations. However, the fields in which robots are used in industry, medical, cognition, space, undersea exploration, nuclear power plants, etc. are only a few examples out of many. Thus proved the fact that robotic system is much efficient than human.

In the beginning, industrial robot early versions were huge in size and had some odd proportions to a human arm. Although early industrial robots just attempted to imitate the kinematics and structure of the human hand, in the past 15 years' robotic arms have developed to be considerably more resemblant to the human arm with more comparable performance, reliable and precise which lead to the implementation of robotic in industry to increase in production, manufacture high-quality products at affordable price, and to match customer expectations.

Robots do not have the same needs as humans nor do companies need to abide by employment laws which will result in a higher-quality output with more precision in much shorter time thus it is typically made to take on repetitive tasks so that workers can concentrate on more involved tasks. Although some may regard robots and AI as technologies to replace human employment, the International Federation of Robotics believes that fewer than 10% of professions might be entirely automated. Thus, most likely in future these technologies will come together and open up a whole new era which the world should be prepared for to fulfil customer needs and demand.

2.1 UR 10 Robot

The UR10 from Universal Robots is the biggest in the UR series. This collaborative robot is designed for tougher, more durable activities, with a payload capacity of 10 kg and a range of 1300 mm. The application best suited for this cobots are to automate complex motions such as simulating the movement of a human arm, high mix production with frequent part changeover and reprogramming and relatively low cycle time requirements. The German Technical Inspection Association (TUV) has validated and certified this cobot's safety system.

However, the key trade-off for this type of robot is it has slower speeds which are required since it is invented for safe human-robot collaboration thus inevitably mean longer cycle times.

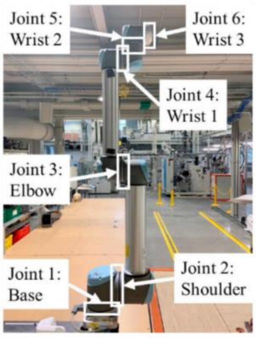

Figure 2.1 Joint of UR 10

2.2 Braccio TinkerKit Robotic Arm

The TinkerKit Braccio is a small fully operational robotic arm with six degrees of freedom (DOF). It is an Arduino-controlled robotic arm. The device is powered with 5 Volts and can use up to 5A of electricity (includes power supply). It may be put together in many ways to do a variety of functions, such moving items, pick and place and many more. Depending on the intended use, an additional attachment such as a camera or solar panel may be made. There are many other ways the Braccio may extend the range of your devices.

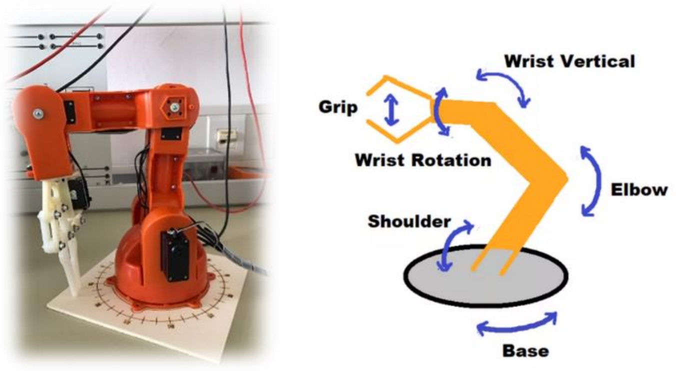

Figure 2.2 Joint of TinkerKit

2.3 Arduino Uno

Arduino Uno the first USB board that Arduino develop. It is much simpler to use compared to the other boards such as Arduino Mega board, etc. this board is based on an ATmega328p microcontroller and the pinout, or the design of the extension pins, is a crucial component of its architecture since it enables board expansions to several shields and modules. The Arduino UNO has 14 digital pins, a USB port, a power jack, and an ICSP (In-Circuit Serial Programming) header in addition to 6 analog pin inputs. The external power supply is automatically used to power the Arduino UNO. It can also use the USB to get power. The Arduino board's USB port is used to link the board to a computer through a USB cable. The cable functions as the board's power supply and serial port. Because of its innovative dual functionality, made it simple to operate.

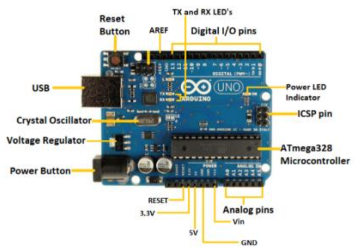

Figure 2.3 Arduino Uno Board

2.4 Arduino Integrated Development Environment (IDE) Software

Using the Arduino IDE, we can program the Arduino UNO. The application used for integral development on all boards is called the Arduino IDE. The foundation of all projects and the whole Arduino system is the multiplatform, Java-written Arduino IDE. The setting is developed in this way to be welcoming anyone who are not involved in the software creation process. The IDE includes a code editor that has features like syntax highlighting or automated code engraving. It also enables the compilation and transmission of programs to the Arduino surface. Make files and programs that run from the command line often don't require any further modification, making them easier for programmers to use.

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2.5 Strain Gauge Transducers

A sensor known as a strain gauge measures electrical resistance that changes in relation to variations in strain. It turns the applied force, pressure, torque, etc., into an electrical signal which can be measured.

Strain is caused by force, and the strain gauge measures it by detecting a change in electrical resistance. After that, data collection is used to acquire the voltage measurement.

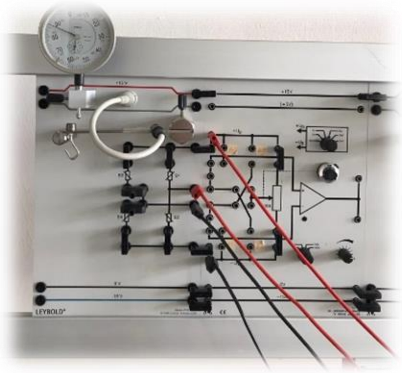

Figure 2.4 Strain Gauge Transducers

3. Methodology

The methodology chapter includes the procedure and technique that will be used including the device, equipment, processes, parameters, software and hardware to meet the objective for this study. In this study, the robotic arm that used is Braccio TinkerKit robot arm provided by Hochschule Osnabrück. For this case study, a force measurement of TinkerKit robot arm will be analysis to find the relation between the movement and force for pasting application. be used. The workflow and steps needed to be conduct for this case study will be breaking down into details. Figure shows the flow chart for the methodology of this study.

3.1 Setting up TinkerKit Robot Arm

Assembling process take place when all the parts needed has been gathered. All components were assembled based on the guide book of this robot arm accordingly. The robotic arm is assembled. The joints are connected by using screws, hexagon nuts, flat washers and springs. Servo motors is connected to the braccio shield. This robotic arm consists of six servo motors, two SR 311 and four SR 431. Figure 3.1 show the complete designed after assembled.

Figure 3.1 Fully Assembled TinkerKit Robot Arm

3.2 Determination of Reference Value for Force Measurement by Voltage Calibration

This experiment examines the relationship between mass and voltage. Initially, the strain gauge transducer is connected with the 34401A digital multimeter. Next, set up the DC-power supply for digital multimeter at 5V-3A as the robotic arm's motors are powered by 5V, and can use up to only 5A. After the digital multimeter is set up, a slotted mass hanger will be hook at the strain gauge transducer's hook to be measured. Mass range from 100g to 1000g will be use for the measurement. The purpose this experiment is to calibrate the mass in form of voltage.

Thus, results of the calibration the (in Millivolts, mV) will be obtained. The data of the experiment conducted will be tabulated into a table form and presented in the form of graph and will be use as reference for force measurement that will be done by the TinkerKit robotic arm. Figure 3.2 shows the example of experimental setup for 500g.

Figure 3.2 Example of Experimental Setup for 500g

3.3 Integration of Coding Programming for TinkerKit

Software system is the crucial key in this study in order to automate the whole process. In this project, Arduino Integrated Development Environment (IDE) is used as the software developed, controlled and manipulated the TinkerKit robotic arm. This software will be used to develop the project code, debug it, and compile it. This software will also verify and test the written program for errors; it is opensource software that assists in uploading a program to the Arduino UNO microcontroller.

First, the concept of robotic arm programming by Arduino IDE is studied. Then, a coding is developed in order to move the robotic arm as desired. After that, the robotic arm is programmed to apply force in three different positions. The flow chart below explains the process of Arduino IDE software for the implementation.

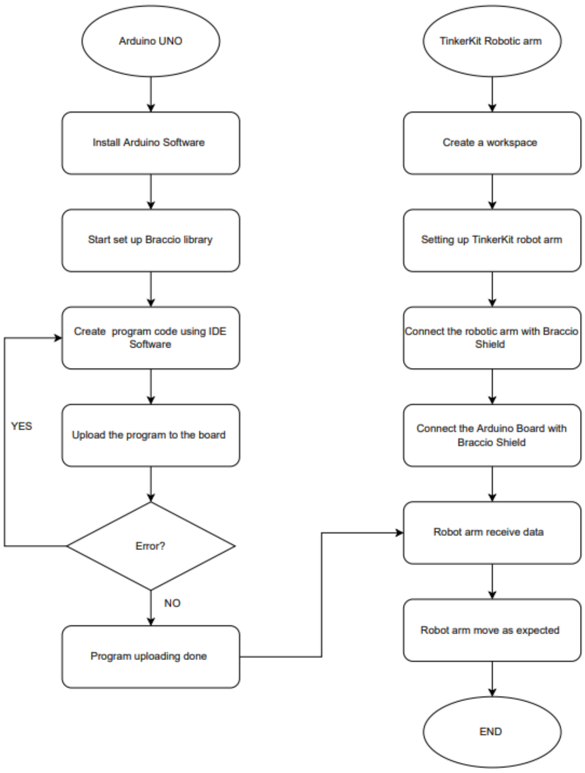

Figure 3.3 Flowchart of Arduino UNO and TinkerKit Robot Arm Setup

4. Results and Discussion

By using Arduino IDE software, TinkerKit robot arm is developed to grab the hook and pulling force downward at three different joints. The values obtained will be recorded for ten times. The result and the performances of the robotic arm will be obtained, analyses and discuss. The result obtained are based on the ability of robotic arm to withstand force according to the command from Arduino software. The capability of the robotic arm to apply force by the servo motor is analysed and discussed.

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4.1 Data Analysis for Voltage Calibration.

Table 4.1: Reference Value for Force Measurement

x axis (mass, g)	y axis (Voltage reading, mV)
100	0.119
200	0.238
300	0.357
400	0.474
500	0.590

600	0.710
700	0.826
800	0.945
900	1.064
1000	1.182

Based on the table 4.1 observation, it shows that measured weight and voltage has a linear relationship. A linear relationship is describing when a line is graphed in the xy plane between two variables. As the slotted mass added, the value of voltage increasing.

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4.2 Data Analysis for force Measurement

The purpose of this study is to collect data based on the TinkerKit robot arm movement by using Arduino IDE software. Table 4.2 shows Result Data of TinkerKit Robot at joint M4, M3 and M2 in millivolts and Table 4.2 shows the Result Data of TinkerKit Robot at joint M4, M3 and M2 in grams.

No	M4, Vertical Wrist (mV)	M3, Elbow (mV)	M2, Shoulder (mV)
1	0.630	0.496	0.402
2	0.659	0.513	0.398
3	0.675	0.508	0.382
4	0.645	0.491	0.361
5	0.630	0.502	0.411
6	0.651	0.525	0.378
7	0.662	0.520	0.373
8	0.643	0.497	0.391
9	0.625	0.502	0.398
10	0.656	0.518	0.385

Figure 1: Result Data of TinkerKit Robot at joint M4, M3 and M2 in millivolts

No	M4, Vertical Wrist (g)	M3, Elbow (g)	M2, Shoulder (g)
1	533.9	418.6	337.8
2	558.5	432.9	334.5
3	572	428.7	321
4	546.6	414.3	303.4
5	533.9	423.6	345.4
6	551.7	443	317.6
7	561	438.8	313.4
8	544.9	419.4	328.6
9	529.7	423.6	334.5
10	555.9	437.1	323.5

Figure 1: Result Data of TinkerKit Robot at joint M4, M3 and M2 in grams

4.3 Discussion

For joint M4, the value obtained is in the range between 0.625 to 0.750 millivolts. The average value at M4 is 0.6476 millivolts. Next for joint M3, the value obtained is in the range between 0.491 to 0.525 millivolts. The average value at M3 is 0.5072 millivolts. Next, for joint M2, the value obtained is in the range between 0.361 to 0.411 millivolts. The average value at M2 is 0.3879 millivolts.

Next, the values obtained from digital multimeter in millivolts will be converted to grams. The conversion of these value is by using simple mathematic method which is cross multiply by refer to the reference value at Table 4.1. The purpose of this conversion is to determine maximum weight a robotic arm able to withstand.

For joint M4, the value obtained is in the range between 529.7 to 572 grams. The average value at M4 is 548.81 grams. Next for joint M3, the value obtained is in the range between 414.3 to 443 grams. The average value at M3 is 428 grams. Next, for joint M2, the value obtained is in the range between 303.4 to 345.4 grams. The average value at M2 is 325.97 grams.

In this study, before setting up the environment of this experiment, calibration of voltage was conducted using slotted weight from 100 g to 1kg to establish the value for reference for force measurement. Within the scope of preparatory studies, movement of TinkerKit robotic arm was stimulated. Next, the main result expected for this study is to determine and measure the ability of a robotic arm to apply forces. Furthermore, future research can improvise data presentations and create collaborative robotic systems that are interactive with humans such as UR 10 robot. As a result, force measurement could be a good implementation to investigate the limit of robotic arm. UR 10 robot can perform a force measurement by using a suitable sensor to identify the maximum force it can withstand.

5. Conclusion

In this project, a force measurement of TinkerKit robotic arm has been conducted. In this investigation, the maximum force of the tinker kit robot arm for the load cell is 572g which is 5.6 N at joint M4. When the force exceeds 5.6 N, the tinker kit robot arm will be lifted from the ground or the movement of the robotic arm will be restricted by its own limitation. Hence, this research study may provide an in-depth examination of educational robotic frameworks, which may aid in the selection of appropriate real training platforms based on individual demands and budget restrictions. It might also be a valuable source of knowledge for researchers working on robotics training systems. Based on the result outcome, the demonstration of the force measurement analysis produced success findings as a preliminary outcome. Furthermore, this research is to conduct a feasibility study on the pasting operation and the integration of a robotic system and to construct a force measurement for the robotic arm.

As the conclusion, by using a simpler and affordable robotic arm kit as prototype can benefit and be a useful visualization to help the industries and researcher to study and investigate effectiveness and capability of a robotic arm manipulator before further solidify the theories they have learned and implement it in real life application.

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References

[1] Ajwad, S. A., Asim, N., Islam, R. U., & Iqbal, J. (2017). Role and review of educational robotic platforms in preparing engineers for industry. *Maejo International Journal of Science and Technology*, *11*(1), 17.

[2] Yildirim, M. Y., & Anutgan, M. (2020). Development of an industrial robot arm education kit based on object recognition and robot kinematics for engineers. *Selçuk-Teknik Dergisi,* 19(4), 47-65.

[3] Wescoat, E., Krugh, M., & Mears, L. (2021). Random forest regression for predicting an anomalous condition on a UR10 cobots end-effector from purposeful failure data. *Procedia Manufacturing*, *53*, 644-655.

[4] Kana, S., Lakshminarayanan, S., Mohan, D. M., & Campolo, D. (2021). Impedance controlled human–robot collaborative tooling for edge chamfering and polishing applications. *Robotics and Computer-Integrated Manufacturing*, *72*, 102199.

[5] Hirzinger, G., Bals, J., Otter, M., & Stelter, J. (2005). The DLR-KUKA success story: robotics research improves industrial robots. *IEEE Robotics & Automation Magazine*, *12*(3), 16-23.

[6] Lobov, A., Lastra, J. L. M., & Tuokko, R. (2003, November). A collaborative framework for learning robot mechanics: RIO-robotics illustrative software. In *33rd Annual Frontiers in Education*, *2003. FIE 2003.* (Vol. 2, pp. F4E-12). IEEE.

[7] Agrawal, N. K., Singh, V. K., Parmar, V. S., Sharma, V. K., Singh, D., & Agrawal, M. (2020, March). Design and development of IoT based robotic arm by using Arduino. In *2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC)* (pp. 776-780). IEEE.

[8] Rivas, D., Alvarez, M., Velasco, P., Mamarandi, J., Carrillo-Medina, J. L., Bautista, V., ... & Huerta, M. (2015, February). BRACON: Control system for a robotic arm with 6 degrees of freedom for education systems. In *2015 6th International Conference on Automation, Robotics and Applications (ICARA)* (pp. 358-363). IEEE.

[9] Yoshikawa, T. (2000, April). Force control of robot manipulators. In *Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No. 00CH37065)* (Vol. 1, pp. 220-226). IEEE.

[10] Bicchi, A., Salisbury, J. K., & Brock, D. L. (1993). Contact sensing from force measurements. *The International Journal of Robotics Research*, *12*(3), 249-262.

[11] Su, H., Qi, W., Yang, C., Aliverti, A., Ferrigno, G., & De Momi, E. (2019). Deep neural network approach in human-like redundancy optimization for anthropomorphic manipulators. *IEEE Access*, *7*, 124207-124216

[12] Manzoor, S., Islam, R. U., Khalid, A., Samad, A., & Iqbal, J. (2014). An open-source multi-DOF articulated robotic educational platform for autonomous object manipulation. *Robotics and Computer-Integrated Manufacturing*, *30*(3), 351-362.

[13] Kang S., Kim K., Lee J., Kim J., 2016, Robotic vision system for random bin picking with dual-arm robots, 2016 International Conference on Measurement Instrumentation and Electronics (ICMIE 2016), Munich-Germany, 1-5.