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Lightweight robot manipulator for TVET training using FDM technique

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ABSTRACT – In Malaysia, TVET institutions are the key feeders for skilled human capital in robotic revolution economy. It is essential to engage TVET students by creating new, affordable robotics platforms for them to involve in current technologies at a fraction of the cost. This study presents the design and simulation of a six-axis robot manipulator for TVET training. The robot will the printed using FDM technique and ABS filament. ABS is a rigid material, suitable to build a sturdy structure to mount stepper motor at each of the six joints. To suit TVET training, each axis uses stepper motor incorporated with encoder, allowing step-input control, which is more accurate. The encoders act as feedback. In SolidWorks 2018 simulation, the total weight of the robot is 8.4 kg with an estimated fabrication cost of RM 9,900. This cost is comparably economical compared to other robot manipulators of the same size in the market.

1. INTRODUCTION

The world is embracing the Fourth Industrial Revolution (IR4.0), driven by nine pillars of technological advancement. They are; Autonomous Robot, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things, Cybersecurity, The Cloud Computing, Additive Manufacturing, Augmented Reality, and Big Data and Analytics [1]. As one of the key elements in IR4.0, robots have been widely used in various areas such as manufacturing, agriculture, retail and services [2]. To date, there are 1.1 million working robots and machines worldwide and 80% of the work in the manufacturing of a car are done by machines [3].

In Malaysia, TVET institutions are one of the key feeders for skilled and knowledgeable human capital in the area of robotics. This is because Malaysia has realized the importance of technical and vocational education and training (TVET) in spearheading the country's excellence in economic and technological development [4]. Thus, it is essential to engage students in this field further by creating new, affordable robotics platforms through which they can involve themselves in current technologies at a fraction of the cost.

Most industrial robotics producers such as ABB, KUKA, MOTOMAN, and FANUC do provide robotic educational packages based on their smallest robot available. Nonetheless, due to their rigid structure, strict safety measures need to be adhere to [5]. This will incur additional costs to the institution. Therefore, a lightweight six-axis robot is more suitable for use in educational setting. A lightweight robot system requires less cost and is safer when in contact with human because it will generate less momentum when in motion compared to metal structure.

One of the available techniques to construct a lightweight structure of robotic arm manipulator is by using Fused Deposition Modelling (FDM). With this method, polymer-based filament such as acrylonitrile butadiene styrene (ABS), polylactic acid (PLA) or nylon is extruded in semi-liquid form through heating process and deposited layer by layer until a 3D object is formed. It provides a trade-off between strength and cost. This is vital in a lightweight robot configuration. Its ease of use and fast time from design to manufacture also makes FDM printers prevalent in small manufacturing enterprises, design offices, and private residential [6].

Therefore, this study aims to design a six-axis lightweight robot manipulator using FDM to produce a TVET educational kit. This robot is small and compact in size compared to its large industrial counterparts. Besides training, this robot can also be advertised to small and medium businesses who seek to increase their productivity through automation.

2. METHODOLOGY

The methodology begins with studying existing designs of robot manipulators with the same payload. Using open-access assembly drawing of a desktop-size robot by Chris-Annin [7] as reference, design modifications were made in SolidWorks 2018 (Figure 1). This process considers the size of motors to be used, mechanism (belts, gears etc.) and the type of material to make up the robot's body using FDM. The tooth-belt transmission mechanism was selected for joint 1 until joint 5 due to easy integration into the CAD design. Joint 6 (the gripper) uses direct connection to the motor.

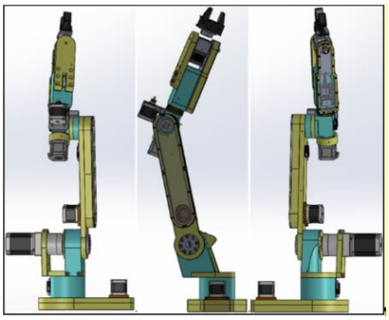

Figure 1 CAD drawing in SolidWorks 2018

Each of the six joints uses stepper motor integrated with encoder to suit its educational function. The control employs step input which is more accurate and the encoder functions as feedback. ABS was selected as it is a rigid type of material, suitable to build a sturdy structure to mount stepper motor at every joint. Though nylon and carbon fibre are also suitable, they are more expensive.

3. RESULTS AND DISCUSSION

Figure 2 shows a simulation of the robot structure using ABS filament for the robot body. Analysis shows that the estimated weight of the arm structure is 5.5 kg. Adding the weight of the stepper motors used to move the arm add another 2.9 kg, making the overall weight of the robotic arm to be 8.4 kg.

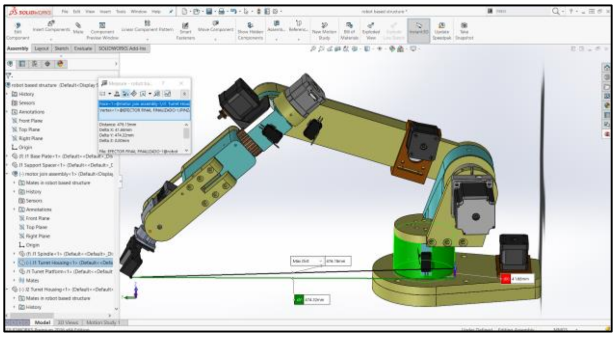

Figure 2 Simulation using ABS as the FDM material

Next, Table 1 shows the comparison of the manipulator with other available robotic arms with the same functions and payload. Between the DOBOT and e.DO, the maximum payload is 1 kg. Thus, the proposed manipulator should be able to pick-up the same amount of payload. DOBOT Magician is the cheapest and lightest but only consists of 4 DOF. The manipulator for TVET on the other hand gives more value and the capability is comparable to e.DO robotic arm, which costs significantly higher.

4. CONCLUSION

This paper shows the preliminary design works of a six-axis robotic arm for TVET education purposes. The arm should be capable of lifting load not more than 1 kg. Simulation results show the overall weight of the manipulator is 8.4 kg. This is comparable with other existing manipulators in the market. Future works will include the kinematics analysis of the robotic arm.

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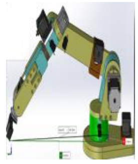
Table 1 Comparison of the lightweight manipulator for TVET with similar robot arms in the market.

Attribute	DOBOT Magician	e.DO	Lightweight Manipulator for TVET
Physical Look	 [8]	 [9]	
Purpose of Robot	Practical training education	Pick and Place and Educational	Pick and Place and Educational
No. of Axis	4	6	6
Payload	500g	1kg	1kg
Max. Reach	320mm	478mm	470mm
Total Weight	7.2 kg	11.1 kg	8.4 kg
Controller	DOBOT Integrated Controller	e.DO Control Logic native ROS	Custom PC based control
Structure Material	Aluminium Alloy 6061, ABS engineering plastic	Composite plastic reinforced with fiberglass	ABS
Price (RM)	6,120	25,500	9,900

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