J. Res. Technol. Eng. 4 (4), 2023, 117-126

Journal Of Research Technology & Engineering
www.jrte.org

DESIGN AND DEVELOPMENT OF A PICK AND PLACE MECHANISM FOR PLACING STICKERS ON T-SHIRTS

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Received: 29 Sep 2023; Revised: 02 Oct 2023; Accepted: 02 Oct 2023; Available online: 10 Oct 2023

Abstract: Nowadays the industry is rapidly moving from automation to robotization to enhance productivity and efficiency while delivering uniform quality. Though garment industries have been expanded all over Sri Lanka, a major problem identified is using a manual process to place stickers. Currently, garment industries are using labour power for sticker placing, therefore facing a lot of production issues. The main objective of this project is to develop a prototype module of a pick and place mechanism for placing stickers on a specific place on t-shirts manufactured in garment industries. This introduced mechanism belongs to the cartesian type of pick and place mechanism that travels on three cartesian axes (X, Y, and Z). These three axes of the mechanism move to their respective locations based on linear actuators. This mechanism is built entirely using a Raspberry Pi-based system and provides commands as ordered by all the data generated by it. This is a programmable mechanism that picks up a sticker from the sticker box, uses the image processing concept, and places it in the location identified by the camera module. The image processing algorithms are used to reduce the response time and increase the object recognition efficiency. A vacuum unit with a suction cup is used to pick and place the sticker at the appropriate location. For the proposed mechanism, a 15 mm diameter, rubber suction cup was used, operated by a vacuum which was generated through a vacuum pump. When compared to a manual process, this automated mechanism demonstrated the ability to place 15 stickers per minute leading to an increase in the system efficiency by 50%. Accordingly, the developed mechanism improved the accuracy, efficiency, and repeatability therefore, the sticker placing manual process could be replaced by the developed low-cost eco-friendly method successfully.

Index Terms: Image processing, Linear actuators, Object recognition

1 Introduction

Nowadays, the garment industry can be defined as the highest industrial employment generator and the highest foreign exchange earner as the garment sector is provided a considerable contribution to the Gross Domestic Production (GDP) [1]. As the main responsibility of the garment industry, it continually provides end-users with the required product quality at the correct time due to increased competition and product diversification. With the rapid development of industries, companies started to automate the system to reduce the labor cost which meant decreasing the amount of non-value-added activities [2].

Robots are not only a machine and it is the best method to maximize the productivity of the industries [3]. One of the most commonly used works is picking and placing objects from one place to another place [4]. The pick and place robots are very essential to reduce human errors and are widely used in various fields in the world such as manufacturing, packaging, etc [5]. Generally, the cartesian robots move in three orthogonal axes X, Y, and Z according to the cartesian coordinates. These three axes are generally made from some form of linear actuators. At present, Sri Lankan garment industries are using manual operations for the majority of sticker placing activities. The major problems identified in this current method are time-consuming, labor-intensive, less operational accuracy and efficiency, and high cost of production.

2. Problem Identification and Research Gap

Currently, most of the work in the Garment industry has been automated, with only a small percentage of the robots being produced to pick and place the stickers on t-shirts. Moreover, it was found that these used pick and place robots have many problems [5], [6]. When using manual methods for this operation, dimensional accuracy may be mismatched throughout the process. Also, supplying an accepted quality product according to the given requirement of the customers is the main responsibility of the industry and the customers always expect high-quality products from manufacturers without any defects. Otherwise, it may be a serious matter. Therefore, dimensional accuracy is a factor that should be highly concerned during the production stage. Though some operations had been automated, sticker pick and placing operation is currently carried out manually. Therefore, the major problem identified at present is time-consuming. *Moreover*, it is hard to find research on pick and place robots in garment industries. Even though there are existing scholarly articles that have discussed the finding related to foreign contexts and foreign industries, those may not be applicable to Sri Lanka. With this kind of background, this study will be carried out to fill the empirical and knowledge gap in the field.

3. Aims and Objectives of the Study

3.1 Aims

This study aims to design and fabricate a more efficient and accurate method for picking and placing stickers on t-shirts for the garment industry.

3.2 Objectives

- To design and develop an Automated Pick and Place Mechanism
- To develop a mechanism to reduce unnecessary time consumption and labor power per unit in the current sticker placing operation carried out by the garment industry
- To design and develop a user-friendly Automated Pick and Place Mechanism for Garment industries in Sri Lanka
- To increase productivity and effectiveness of the operation areas
- To minimize the mistakes of the sticker placing process

To increase the dimensional accuracy

4. Literature Review

A low-cost flexible robot handling method for pick and place tasks was introduced by Kato et al. [7]. This proposed flexible robot arm is mainly used for picking up and positioning lightweight objects. This is done by using two DC motors and a single-step motor. The system also consists of a control system with an encoder, motorist, and Arduino Uno. Here, two pieces of polycarbonate were 3D printed to attach the silicon bars to the actuators. The step uses a wire connected to the motor to control the bending point of the flexible connector here. Furthermore, the flexible robot uses a hand-held wire mechanism to partially or partially reduce the excessive vibration generated by the flexible connector thread. Experimental results have confirmed that the flexible silicone connector retains more than twice its weight. It also proves that the backward motion of objects is faster than the forward motion by the use of a flexible robotic arm. The robot also uses a suction cup unit to pick and place it in the correct position. However, being able to carry very little weight at a time is a major drawback here.

A design of pick-and-place robots was introduced by Kumar et al.[8]. The pick-and-place robot is a microcontroller-based mechatronic system. It detects the object, picks that object from the source location, and places it at the desired or expected location. In this case, infrared sensors are used to detect the object. These infrared sensors are detected the presence of an object as the transmitter-to-receiver path for the infrared sensor is interrupted by the placed object. The component of the robot can be identified as structure, power source, actuation, touch, vision, and manipulation. Mechanical grippers are used for a range of small objects. But vacuum grippers are used to handle large objects.

A validation and placement of object planners for robotic pick and place tasks was proposed by Harada et al. [9]. This object placement planner consists of offline and online phases. The offline phase clustering of the polygon model (object and environment) with each cluster region by approximated by a plan region. The object orientation is planned by choosing a pair of clusters in the online phase. Then, the posture of an object is placed at a user-assigned point in the environment. A few types of tests are done and can be named convexity test, contact test, and stability test. Also, the object pose was planned to satisfy gravitational equilibrium. These issues can be expressed in five ways. Environmental issues, object model issues, stability issues, extension issues, and robustness.

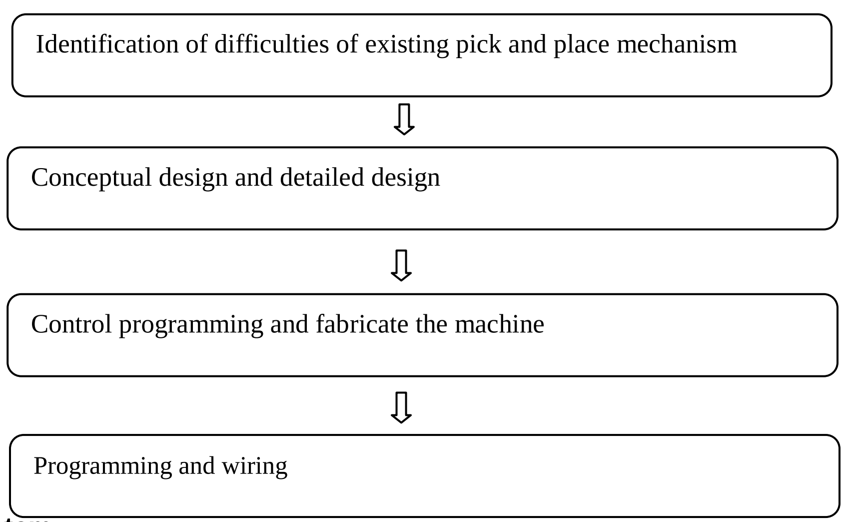
A robotic picking and placing of novel objects in the clutter with multi-affordance grasping and cross-domain image matching was introduced by Pukkella et al.[10]. This pick-and-place system is handled a wide range of object categories without needing any specific task specification training data for novel objects. For success, this is agnostic of the object-grasping framework to map from visual observations to actions. After that, it is recognized as grasped objects by matching them to their product images. It has the highest affordance and recognized pick objects with a classification of cross-domain image framework that matches observed images to product images. Also, object recognition is done by an algorithm trained only on known objects. There are four types of grasping primitives which are suction-down grasps, suction-side grasps, grasp-down grasps, and flush grasps [11]. This system has several advantages like the algorithm is affordance-based grasping model-free and agnostic to object identities and generalized to novel objects without re-training. Also, the category recognition algorithm is worked without specific task data collection, and the framework of grasping supports multiple grasping modes with a multi-functional gripper. An inverse kinematic analysis of 4 DOF pick and place arm robot manipulators using the fuzzy logic controller was presented by Dewi et al. [12]. The design of this robot consists of four links with robust flexibility in the x, y, and z-coordinates axis. Inverse kinematics and fuzzy logic controller (FLC) applications are used. It has precise and smooth motion. The robot arm manipulator discussed in this research is a pick-and-place robot to move the harvested tomatoes to a packing system. Robot motion can be designed using inverse kinematics [13]. Because to generate the desired trajectory, the robot follows the generated trajectory. The smoothness of gripper motion is ensured by applying fuzzy logic controller (FLC) utilizing the input from proximity sensors attached to the starting position of the target and robot's end-effector. These proximity sensors are used to detect the availability of tomatoes and sense the distance between the gripper and the tomato. The angle of the gripper opening decides the parameters from inverse kinematics to ensure the right gripping position in holding the tomato. Data collection for this work is divided into two steps arm robot motion data and gripper data. The limitation of this work can be expressed as errors in robot positions and orientations occur due to the servo gears do not allow the motor to rotate precisely. Also, the rounding calculation that unavoidable to the limited microprocessor memory.

5. Materials and Methodology

5.1 Materials

For the proposed mechanism, Raspberry Pi 4, camera module, NEMA 17 stepper motors, vacuum unit with rubber suction cup (15 mm diameter), power supply unit and jumper wires, ball bearings, threaded bar with T8 screw, wood, and steel box bars were used as major components of the mechanism.

5.2 Methods



5.3 Automated system

This automated sticker pick and place mechanism mainly consists of some steps. First, the t-shirt was moved along the conveyer belt and held on the machine bed. When the t-shirt was moved under the robot, the conveyer belt was stopped. Then, the three axes (X, Y, and Z) of the machine were moved and picked the sticker from the sticker bucket respectively. The suction cup with a vacuum unit was associated to pick the sticker from the bucket properly. Finally, the camera module detected the correct placement of the sticker on the t-shirt, and according to the correct placement detected, the sticker was placed automatically. As mentioned earlier, the workspace design incorporated a belt conveyor that picked the sticker from the sticker bucket and placed it on the t-shirt through linear axes. There were 90 degrees angles of the moment. After placing the sticker in the correct place on the t-shirt, the x-axis was moved toward the sticker bucket to repeat the same procedure. The working principle of the automated system is shown below in Figure 8.

5.4 Image Processing Technique

In this project, the design is based on the image processing concept. Here, the image processing concept is mainly used for the recognition and detection of the proper location where the sticker should be placed [14]. This includes the selection of visual sensors and a camera module was used as the visual sensor. Image processing tools include image processing techniques and computer programming languages. In this study, python was used as the programming language. The following steps had been included throughout the process:

- Step 1 - Acquisition and Enhancement of Image of T-shirt
- Step 2 - Sticker Recognition
- Step 3 - Controlling the axes using a signal

The following steps were involved in the design of the pick and place mechanism:

- Material selection
- Specifications of mechanism
- Conceptual design
- Experimental design

5.5 Material Selection

Table 01 shows the selection of components for the proposed system. Task 01 is the selection of X, Y, and Z drives. The existing pick and place robots are driven by X, Y, and Z axes using linear modules, rack & pinion, belt and pulley, chain, etc. But in this project, thread bars were used. The cost of thread bars was not higher and easy to design. The rack & pinion have smooth running because it is very expensive. The thread bars, linear bearings, linear bars, T8 28 screws all were interconnected. It could be easy to prepare, control and assemble. The screw gives higher torque, better precision, and smoother travel than the belt-driven.
Task 02 is the selection of a gripper. The existing pick-and-place robots are used pneumatic, vacuum, 2DOF, complex grippers, etc. But this project is mainly based on garment industries' sticker placing activity. Normally, the stickers are a very smooth thing. In this situation, mechanical grippers couldn't be used because it has become a reason to damage the sticker. Therefore, this project used a suction cup with a vacuum unit to pick and place the stickers on the t-shirts proper

Table 01. Selection of the components

	Method				
	M 01	M 02	M 03	M 04	M 05
Task 01	Rack and Pinion	Belt and Pully	Driven by wheels	Thread Bar	Pre-Assembled modules
Task 02	Vacuum	Pneumatic	Servo electric	Hydraulic	Mechanical Design
Task 03	Servo motor	Stepper motor	AC motor	DC motor	Gear motor
Task 04	Proximity sensor	Limit switch	IR sensor		
Task 05	Photoelectric	Electromechanical	Ultrasonic	Camera module	Capacitive
Task 06	Arduino	Raspberry Pi	PLC	ESP 32	NODE MCU

Task 03 is the selection of a motor. The existing pick and place robots are used servo motors to provide power to linear actuators. In this project, three stepper motors were used (Nema 17 HS4401: detent torque - 2.2Ncm, hooding torque - 40Ncm, motor weight - 280g). It was very simple in design and easier to use. The fact that stepper motors are easier to get was another big reason and they were more popular than servo motors due to their reliability and performance. Also, the servo motors don't have a grand and can divide between them. Moreover, the stepper motor is an electromechanical device that converts electrical power into mechanical power. It is a brushless synchronous electric motor that can divide a full rotation into an expansive number of steps.

Task 04 is the selection of an appropriate mechanism for controlling position. IR sensors are appropriate for their accuracy in detecting the presence or absence of objects. They can provide precise positional feedback, crucial for a pick and place mechanism to ensure that stickers are picked and placed accurately.

Task 05 is the selection of a method for object detection. The selection of a camera module for object detection is based on several compelling reasons. Camera modules capture visual data, which is rich in information and also the camera-based object detection is non-contact, meaning it does not require physical contact with the objects being detected

Task 06 is the selection of a controller. The existing pick-and-place robots are used PLC Programming with HMI, and Arduino as the controllers. However, they are very expensive. Arduino is a microcontroller; it runs one program and is difficult to perform multitask programming. It is not suitable for Industrial projects because it reacts to vibration and noise. The Raspberry Pi is a mini-computer with Raspberry Pi OS. It can run multiple programs at a time. It is suitable for industrial applications. So, raspberry pi was used in this project as the processor.
Here, the construction of the body structure of the mechanism is also important. The existing cartesian-type pick and place robots are used Aluminum Alloy for the building of structures. Normally, Aluminum Alloy cannot be welded and it can be an Aluminum mount or revert. In this project, steel box bars, and wood were used to fabricate the structure because it has low cost and eco-friendly feature.

5.6 Specifications of mechanism

Table 02: Automated system in proposed pick and place mechanism

Specification	Value
Number of Axes	03
Horizontal reach	400 mm
Vertical reach	340 mm
Drives	Stepper motors, servo motor
Gripper Type	Suction cup

5.7 Conceptual design

In this project, an automated pick and place mechanism was designed based on an image processing technique, and the design used three coordinates (X, Y, and Z system). The components used were stepper motors, thread bars, connecting bars, baller bearings, and so on. In the first case, developed the following design by Solid Works. After all of the parts were modelled, they were assembled using the necessary constraints and relationships. The components list was completed at the end and the following are the primary components of this system. However, due to the high cost of the entry form and some efficiency issues, the following design was modified.

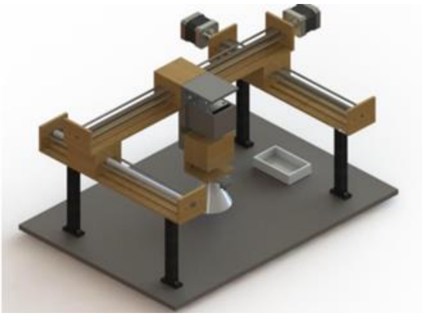


Fig 1. Conceptual design of the proposed system

5.8 Experimental design

Some modifications were done by considering the previously mentioned shortcomings. In the previous design Z axis was rigid so the camera module was not able to detect the t-shirt due to this rigid structure. Therefore, it was changed by design it simple. Five stepper motors were used in the previous design and it was changed to three stepper motors and a servo motor due to the complexity

Fig. 2. Experimental design of the proposed system

The suction cup was one of the special parts of this mechanism and was used as a sticker pick-up device in the vacuum gripper. Suction cups come in a variety of sizes and materials, but most are constructed of polyurethane or rubber and can be utilized at temperatures ranging from -500°C to 200°C. In our mechanism, a 50mm diameter, rubber suction cup was used and it was operated by a vacuum. The vacuum was generated through a vacuum pump. 'as able to pick up stickers safely and quickly.

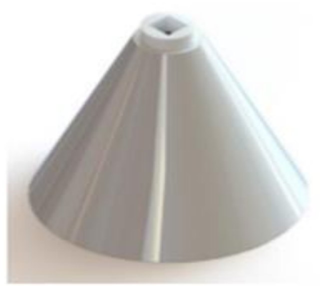


Fig. 3. Suction cup design

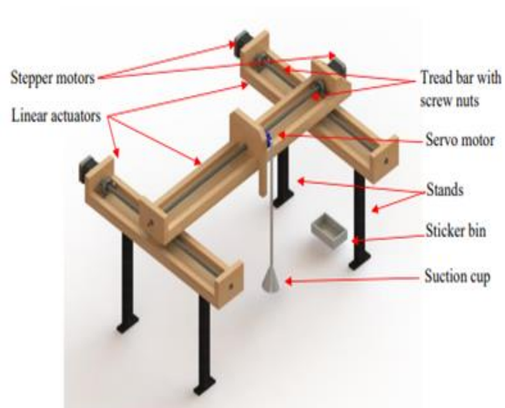


Fig 4. Main parts of the system

6. RESULTS AND DISCUSSION

Box bars and I shafts were used to fabricate the machine structure and hold the structure respectively. Those box bars were welded to make the structure and shafts were connected to the box bars using bearings, nuts, and bolts. Thread bars were used to transmit the power from the motor to the machine through a stepper motor. As a Microprocessor, Raspberry Pi was used to get and give signals to the machine. Considering the calculations, the motor speed was taken as 800 rpm which is one of the available rated motor speeds.

Fig 5.Parts fabrication stage

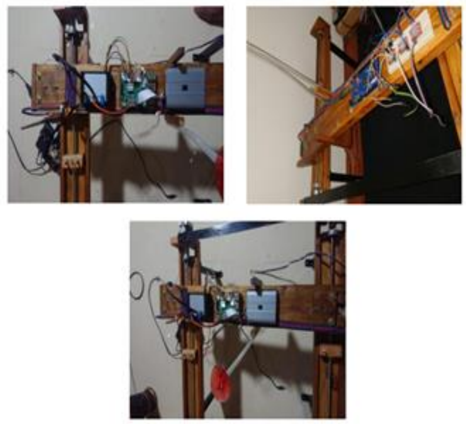


Fig 6.Parts Assembly Stage

Fig 7. Wiring stage

The Microprocessor is the brain of the machine. The Raspberry Pi 4 Model B+ is the latest product in the Raspberry Pi, boasting an updated 64-bit quad-core processor running at 1.4GHz with a built-in metal heatsink, dual-band 2.4GHz, and 5GHz wireless LAN with 40 GPIO pins [15]. A GPIO pin that is set as an input will allow a signal to be received by the Raspberry Pi that is sent by a device connected to this pin. A voltage between 1.8V and 3.3V will be read by the Raspberry Pi as HIGH and if the voltage is lower than 1.8V will be read as LOW [16]. The pins used a lot of digital pins. All of the components were attached and communicated with the Raspberry Pi board. This board has plenty of room and opportunities to maintain the simplicity and effectiveness of the Raspberry platform. The stepper motors were controlled by the DVR 8825 Motor driver. The driver has a built-in translator for easy operation. This reduces the number of control pins to just 2, one for controlling the steps and the other for controlling the spinning direction. The driver offers 6 different step resolutions viz. full-step, half-step, quarter-step, eighth-step, sixteenth-step, and thirty-second-step. The motor supply requires an appropriate 34 decoupling capacitor close to the board. The DRV8825 driver has three-step size (resolution) selector inputs viz. M0, M1 & M2. By setting appropriate logic levels to these pins, we can set the motors to one of the six-step resolutions. The machine 3 axes were given full step which means M0, M1 & M3 were low modes. The motor driver's output channels were broken out to the edge of the module with B2, B1, A1 & A2 pins. The channels were attached to the stepper motor, this side was given 12V power. Before using the motor, there's a small adjustment that needs to make. It needs to limit the maximum amount of current flowing through the stepper coils and prevent it from exceeding the motor's rated current. All three stepper motors were connected to the A1, A2, B1, and B2 pins of the motor driver DRV 8825 board. STEP and DIRECTION pins of the DRV8825 were connected to the GPIO pins of the Raspberry Pi board. The camera module was attached to the Raspberry Pi board. The relay Switch is attached to a ground pin and a GPIO pin, the purpose of the relay was to switch on the vacuum when needed.

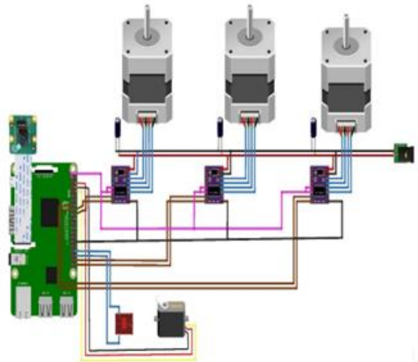


Fig 8. Programming structure

Figure 9. Testing stage

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

It was able to achieve the objectives mentioned earlier by developing a prototype model of three axes automated sticker pick and place mechanism. The developed mechanism was a successful one. It was developed with a very good dimensional accuracy which was capable to sense the t-shirt that moves along the belt conveyor by image processing technique. This mechanism was relatively very efficient when compared to manual sticker pick and place operations carried out in the garment industry. In general, man always expects ergonomics due to the complexity of current operations. Therefore, the development of this kind of mechanism was useful to minimize the physical fatigue of humans in considerable amounts, increase the production rate per day in garment industries, and maximize the production process.

6.2 Recommendations

There would have been more developments and designs to expand and perfect this system if there had been more time allocated to work on it. The following is a list of tasks that should be completed to finish and perfect this project completely. It will be able to introduce feedback sensors to the developed mechanism that provide accurate results therefore the vacuum unit with a suction cup can pick the sticker from a precise place and can keep it in the correct place on the t-shirt where it should be. Developing the mechanism into angular coordination will be useful in the future to ensure the correct placement on the t-shirt if the t-shirts are held on the belt conveyor in different positions. This research study was only focused on placing the sticker on the t-shirt. In the future to make this cartesian-type mechanism much better, the sticker can paste on the t-shirt at once by an appropriate method. It will be better if the developments can be done considering both parameters at once like the t-shirt's size and the color. It will be useful to develop the mechanism by placing a sensor to detect the stickers which were fallen from the suction cup.

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