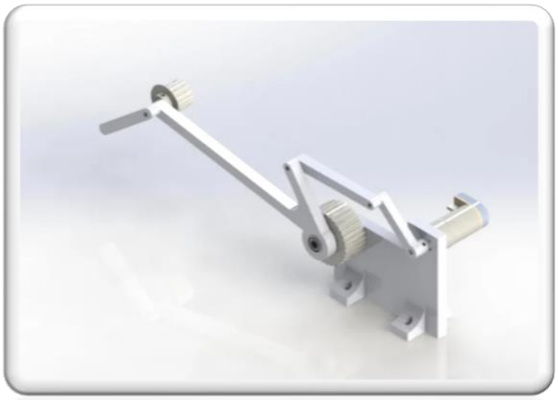
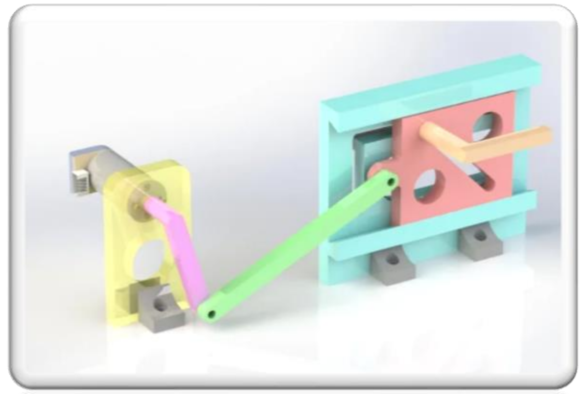
Design and Fabrication of TWO Rotational Pick-and-Place Mechanism





Course: Design of Mechanisms

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Spring 2024

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Abstract

This project presents the design, fabrication, and evaluation of two 3D-printed rotational pick-and-place mechanisms developed for a mechanical engineering design. The primary objective was to create efficient and reliable mechanisms capable of accurately picking up objects from a designated location and placing them at a desired position through rotational motion. Utilizing 3D printing technology, the mechanisms were designed to leverage its flexibility, precision, and ease of prototyping.

Designed mechanisms incorporate innovative design features, including optimized belt and gear systems, lightweight yet robust structural components, and precise actuation controls to achieve smooth and accurate rotational movement. The design process involved extensive use of CAD software (SolidWorks) for modeling. Prototypes were produced using a high-resolution 3D printer, allowing for rapid iteration and refinement of the designs.

The successful implementation of these mechanisms not only fulfills the academic requirements but also provides a practical foundation for future advancements in automation and robotics. The insights gained from this project will contribute to the ongoing development of more sophisticated and efficient pick-and-place systems in industrial applications.

Key Skills: Teamwork, Mechanical Design, 3D-printing

Introduction

The 3D printed pick and place rotational mechanism is an innovative project designed to automate the task of picking up objects and placing them in designated locations with precision and efficiency. This setup leverages the versatility of 3D printing technology to create a compact, cost-effective, and highly functional robotic system suitable for various applications in both industrial and research settings.

The mechanism features a rotational design, which allows for a broad range of motion and flexibility compared to traditional linear pick and place systems. By utilizing rotational joints and arms, this setup can efficiently handle tasks that require precise angular positioning and movement. The system is driven by a combination of motors and control electronics, orchestrated through a microcontroller platform such as Arduino, ensuring seamless operation and programmability.

This project stands out for its accessibility and ease of customization. The components are designed using SolidWorks and printed using standard 3D printing materials, making it possible to rapidly prototype and iterate on the design. This approach not only reduces the cost but also allows for quick adjustments and enhancements based on specific requirements.

The primary applications of this pick and place mechanism include automated assembly lines, material handling, and educational robotics. Its ability to be programmed for various tasks makes it a versatile tool in any automation setup. The design emphasizes simplicity and robustness, ensuring that even those with limited experience in robotics and automation can build and operate the system successfully.

Overall, this 3D printed pick and place rotational mechanism embodies the principles of modern automation: adaptability, precision, and efficiency, packaged in a user-friendly and cost-effective solution. Whether for industrial applications or educational purposes, this project serves as a testament to the potential of combining 3D printing with robotics to achieve innovative and practical solutions.

Design

After reviewing common pick-and-place mechanisms, we brainstormed several different options that would meet the desired requirements. Ultimately, two mechanisms were selected, designed, and fabricated as part of this project. The main steps in the design process are outlined below.

Software Tools: During the initial phase, CAD software, specifically SolidWorks, was used to design the pick and place mechanism. The base, arms, joints, and end-effector were sketched to create a comprehensive model. All moving parts were designed with precise clearances to ensure smooth rotation and movement.

Component Specifications: The dimensions for each part of the mechanism were carefully defined, considering the size and weight of the objects the mechanism would handle to ensure appropriate scaling. PLA was selected as the primary material for 3D printing due to its ease of use, although ABS was also considered for parts requiring higher durability.

Design Considerations: Rotational joints and gears were incorporated into the design to enable the required movements. The arms were designed with sufficient length to reach and manipulate objects within the intended workspace. Mounting points for motors were included, and the routing of wires and placement of electronic components were planned to avoid interference with moving parts.

Let’s explore the advantages and unique features of the mechanisms designed by our team.

1st Design

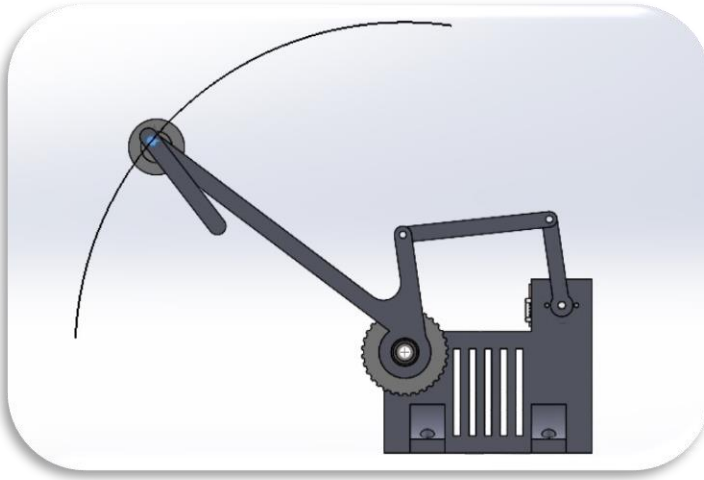


Figure 1 First design Mechanism

This design leverages a gear and belt mechanism to transmit power and change the orientation of the end effector, along with a crank-rocker mechanism to deliver torque from the motor. There are two gears; the lower gear has exactly twice the radius and number of teeth as the upper gear. Both gears are designed based on the T5 standard, ensuring that belts are accessible and precise. The lower gear is fixed, while the upper gear, which is attached to the end effector, rotates reversibly: 90 degrees relative to the ground reference and 180 degrees relative to the connected link (which has two branches). With each full rotation of the motor, the gripper picks an item from the ground, lifts and rotates it, places it in the highest position, and then returns to the initial location. This process can also work in reverse, picking from an upper position and placing in a lower one.

2nd Design

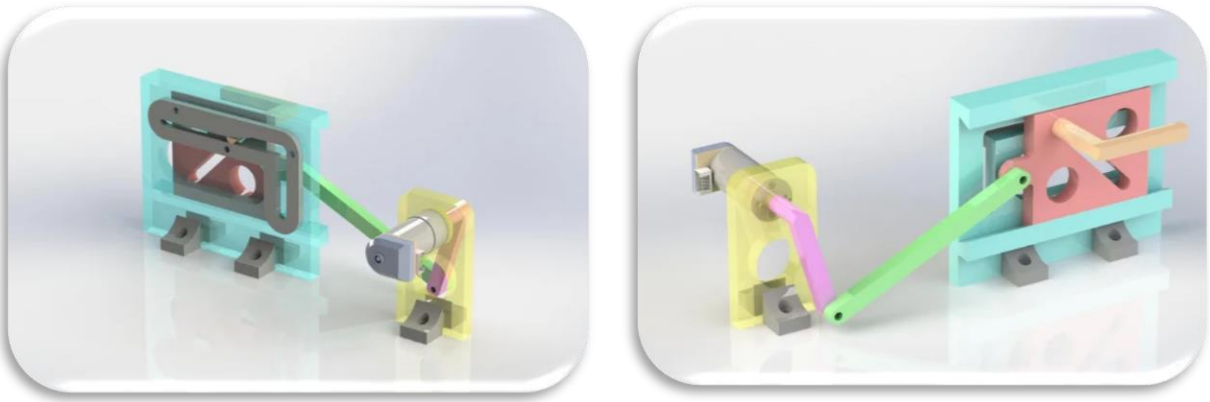


Figure 2 Second Design (back view & front view)

In the second approach, mechanical constraints are employed to achieve the goal of 90-degree rotational pick-and-place. A continuously rotating motor and a crank-rocker mechanism are used, but a slider converts the rotational movement into prismatic motion. The slider has a diagonal groove that allows the end effector to move up and down. By sliding and embedding grooves in the slider link and base support, we create a mechanism that starts at the lower part with the end effector in the downward position. When the mechanism reaches a part called the "ramp," the end effector is forced to rotate a quarter turn. The motions are more visible and understandable in the attached videos (relevant links are in the last section).

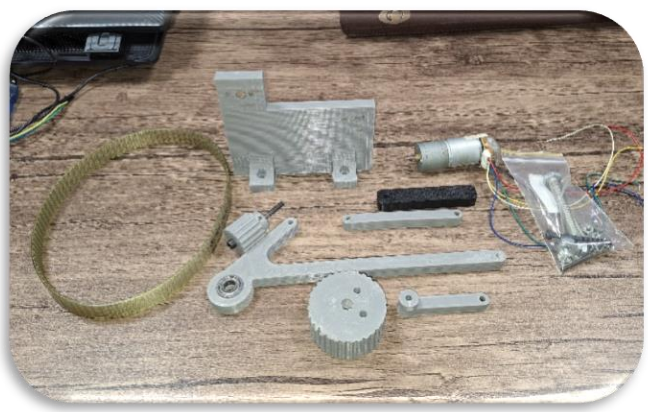
Implement Design

Print Components

3D Printing Preparation: The CAD designs were converted into STL files. Using Cura as the slicing software, the files were prepared for 3D printing, configuring settings such as layer height, infill density, and print speed based on the material used.

Printing Process: Each component was printed separately. The 3D printer was properly calibrated to avoid issues such as warping or layer shifting. The printing process was closely monitored to detect and correct any errors early, especially for larger or more complex parts.

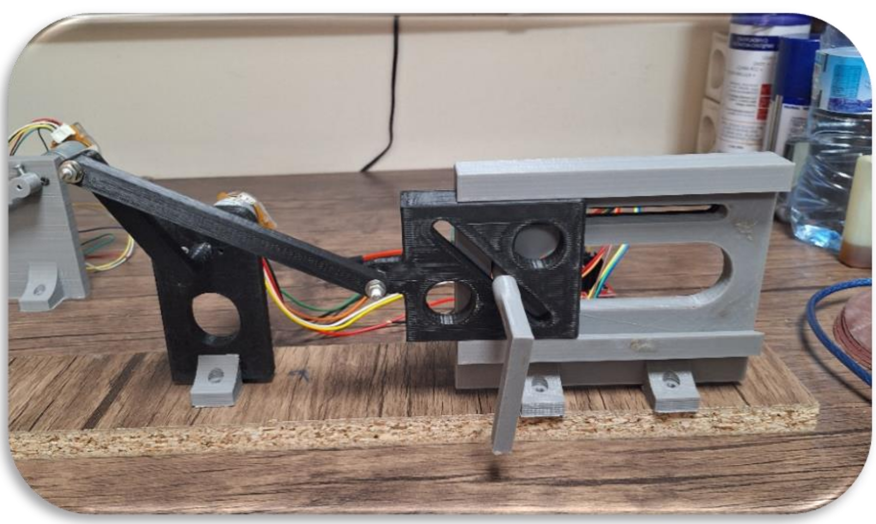
Post-Processing: After printing, the parts were removed from the build plate and cleaned off any support material. The parts were then sanded and smoothed to remove any rough edges or imperfections, ensuring smooth movement and better fit during assembly.



Assemble the Mechanism

Gathering Tools and Materials: All necessary hardware for assembly, including screws, nuts, bolts, bearings, and additional fastening components, were collected. Tools such as screwdrivers, wrenches, and pliers were also gathered.

Assembly Procedure: Following the CAD design, the base was assembled first, and then the arms were attached. Rotational joints were installed and their movement was verified to ensure they moved freely without excessive friction or play. The end-effector was then attached to the arm. Depending on the design, the end-effector could be a gripper, a suction cup, or another tool suitable for the intended application.



Control System

Electronics Setup: An Arduino microcontroller was chosen to control the mechanism. Connections for DC motor, Motor driver and Arduino board were planned as shown in Fig3. Motor drivers were used to manage the power requirements of the motors.

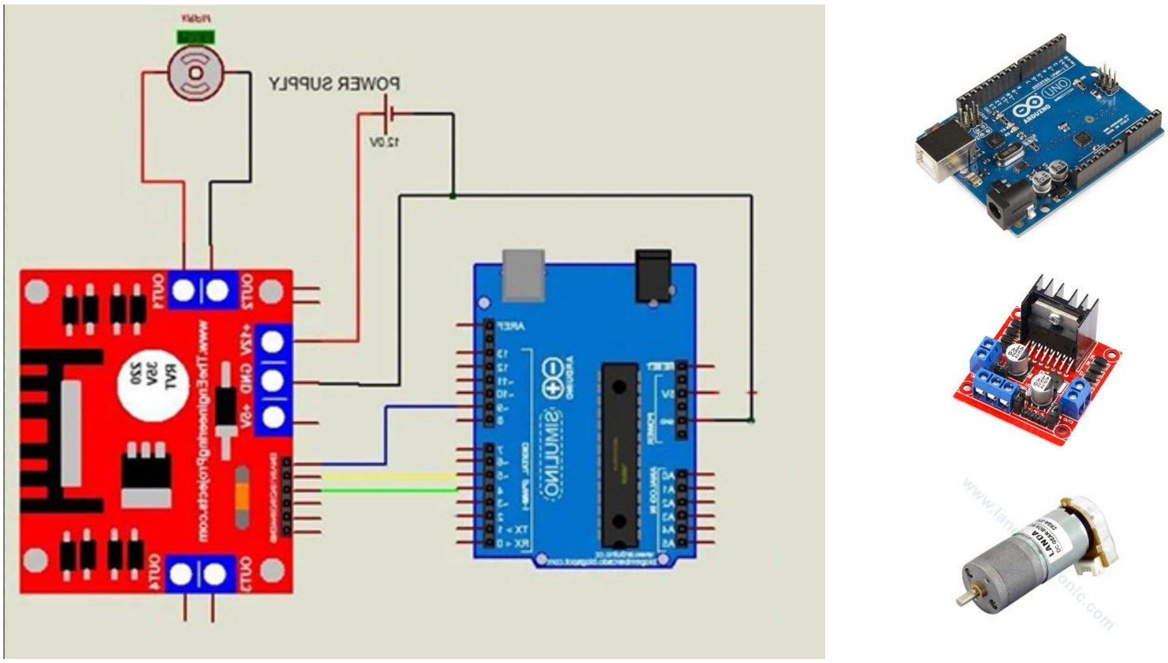


Figure 3 Circuit and Electronic Components

Programming: The control code to operate the pick and place tasks was developed. The microcontroller was programmed to control the motors. The code was tested and debugged to ensure accurate movement and positioning.

```
/////// Define pins and modes ///////
int motor1pin1 = 5;
int motor1pin2 = 4;

void setup() {
  pinMode(motor1pin1, OUTPUT);
  pinMode(motor1pin2, OUTPUT);
  pinMode(9,   OUTPUT); }

/////// Define Direction and Speed ///////
void loop() {
  //Controlling speed (0   = off and 255 = max speed):
  analogWrite(9, 200); //ENA   pin
  digitalWrite(motor1pin1,   HIGH);
  digitalWrite(motor1pin2, LOW);}
```

Test and Calibration

Initial Testing: The mechanism was powered up and initial tests were conducted to verify basic functionality. Each part was checked to ensure it moved as intended and any mechanical issues were identified. The system's response to input commands was verified, ensuring that the motors functioned correctly. Since we found some mistakes, we repeated necessary mentioned steps and tested mechanism again.

Calibration: Control parameters were fine-tuned for precise movements. Motor speed, acceleration, and other parameters were adjusted to achieve smooth and accurate operation. The end-effector was calibrated to ensure it could pick and place objects accurately within the desired range.

Conclusion and Relevant Linkes

By completing this project, we gained invaluable knowledge about mechanisms and how to design and construct new mechanisms for specific purposes.

A huge shoutout to our course instructor and teaching assistants for their guidance and support.

Supplementary materials, including STL files, videos of the moving mechanisms, codes, and pictures, are uploaded to the following GitHub repository.

https://github.com/AlivGH/Pick-and-Place-Mechanism

Additionally, we have uploaded a step-by-step construction guide to the AUTODESK Instructables website.

1st Design

https://www.instructables.com/3D-Printed-Rotational-Pick-and-place-Mechanism/

2nd Design

https://www.instructables.com/3D-Printed-Pick-and-Place-Mechanism/