https://doi.org/10.36315/2024v2end075
Education and New Developments 2024

DEVELOPING EDUCATIONAL TOOLS FOR EFFECTIVE TEACHING INDUSTRIAL ROBOTICS IN TWO- AND FOUR-YEAR DEGREE INSTITUTIONS

Mason Petersen, Prarthana Hedge, Ravi Thakur,
Brendon Lakenen, & Aleksandr Sergeyev
Department of Applied Computing, Michigan Technological University (USA)

Abstract

Experiential learning is a crucial component of effective education methodology, allowing students to apply theoretical knowledge gained in classrooms to real-world scenarios. The industrial robotics curriculum is very common in two- and four-year institutions due to the high demand for specialists in the field. However, due to the high cost of the hardware and limited options for prebuild end-effectors that can be implemented in the educational environment, custom solutions for various end-effectors must exist. Michigan Technological University has an advanced industrial robotics curriculum in the Mechatronics program. In this paper, the authors provide details on the design, development, and implementation of the custom vacuum end-effector developed for palletizing purposes.

Keywords: *Robotics, end-effector, experiential learning, mechatronics.*

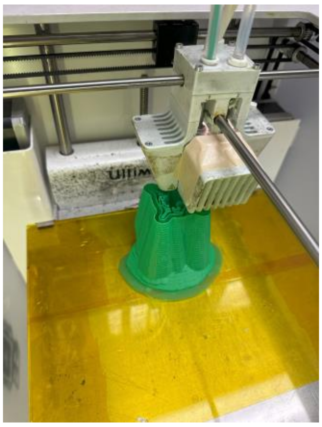
1. Introduction

Experiential learning is a crucial component of effective education methodology, allowing students to apply theoretical knowledge gained in classrooms to real-world scenarios. It bridges the gap between theory and practice, providing a more holistic understanding of electrical engineering concepts. Experiential learning provides students with hands-on opportunities to develop critical skills, making them better prepared for the challenges they may face in their careers. Michigan Technological University has an advanced industrial robotics curriculum in the Mechatronics program. In this paper, the authors provide details on the design, development, and implementation of the custom vacuum end-effector developed for palletizing purposes. The study aims to identify and analyze the design considerations of foam vacuum grippers, providing a research-based model tested in a production setting. The research-based model focuses on three vacuum maintenance methods: check valve grippers, port metered grippers, and foam valve grippers. The chosen method, port metered gripper, balances cost-effectiveness, manufacturability, and performance. Foam vacuum grippers are used in industry for a wide variety of tasks. Their design allows them to handle most objects that have at least one mostly flat surface. Foam vacuum grippers work by creating a high flow low pressure vacuum over a large area, then placing a sheet of specially engineered Ethylene Propylene Diene Monomer (EPDM) foam on the vacuum surface. The sheet of foam allows for the gripper to conform to the contours of the part(s) being handled. Most commonly, foam vacuum grippers are used for palletizing operations.

An ideal foam vacuum gripper is designed for pick and place operations where the products are located in a flat plane with respect to each other. Additionally, an ideal gripper design allows product(s) to be handled even if they do not cover the complete surface of the gripper. In the event where a product does not completely cover the gripper’s vacuum ports, there needs to be a way to maintain vacuum to handle the product. The three most common gripping technologies of vacuum maintenance are check valve grippers port metered grippers, and foam valve grippers (JOULIN, n.d.). There are advantages and disadvantages to each method. The check valve gripper (JOULIN, n.d.) is capable of maintaining a very high vacuum when there are uncovered ports, because the vacuum flow closes the check valve when the port is uncovered. However, it has many moving parts making it more expensive to manufacture and cannot be inverted as the check valves will block the air flow. Port metered grippers (JOULIN, n.d.) have no moving parts and limit airflow with small orifices. Yet, require the product to cover more than half the surface for handling, because the design will have a continuous vacuum leak from uncovered ports. Foam valve grippers (JOULIN, n.d.) have smaller ports in the foam that are used to limit air flow. When these ports are not covered the vacuum flow pulls the small foam ports closed giving it the effect of a check valve, but it has the advantage of functioning inverted, where a check valve gripper cannot. However, the foam valve gripper requires a relatively high airflow to close the orifices. It should also be noted that both port metered, and foam valve grippers have very small orifices that can be clogged by debris and prevent vacuum, a check valve gripper on the other hand can pass larger debris and as a result can be used in more rugged environments.

The vacuum limiting method chosen for the research-based model design, development and implementation for this graduate student project was the port metered gripper. This is due to the check valve gripper being too complex to manufacture and out of budget for the project. The foam valve Gripper was a desired candidate but proved to be difficult to source. As the foam gripper replacement foam suppliers did not manufacture foam with small enough vacuum ports to function as foam valves. The port metered gripper on the other hand could be manufactured using the universities 3D printing and metal machining facilities, as seen in Figure 1.

Figure 1. Manufacturing Processes: CNC Mill Machining and 3D printing.



The system is constructed around a FANUC CERT Cart which employs an LR-MATE 200iD robot. The gripper's pneumatic system consists of the research-based gripper model, a venturi vacuum generator, and a digitally controlled pneumatic directional control valve. The supply pressure, is controlled by a directional control valve that is actuated by a digital output on the robot controller, is set to 60 PSI. When the pressure is allowed to flow through the directional control valve it enters into a venturi vacuum generator which uses the pressurized air to create a low-pressure high flow vacuum. The vacuum outlet of the venturi is connected to the foam gripper that is attached to the end of the robot.

2. Design

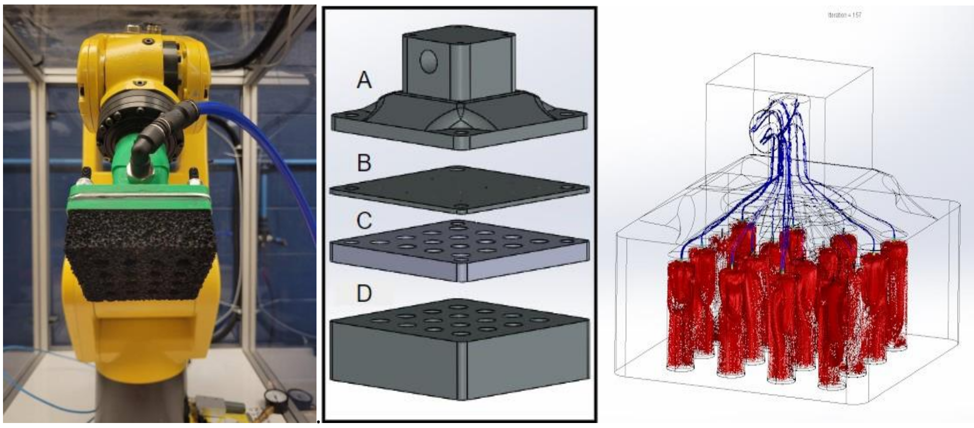
There are ten components that make up the vacuum gripper. These components are made up of various materials including polylactic acid (PLA), 6061-T6 aluminum, specialized engineered foam and various bonding adhesives. The main body is made up of PLA, 3D printing would allow for a lighter part and also allow a more complex structure. The orifice plate is made up of 6061-T6 aluminum, a CNC mill was used to properly locate the 0.5 mm holes in the plate. Several different plates with different size offices were tested in order to select the best fit for production. It was determined that the best size orifice for this gripper was 0.5 mm in diameter. The foam used was ordered from Millibar Robotics, this foam is a specialized foam used for robotic vacuum grippers. There are four grade 8 M-8 bolts that hold the assembly together which makes it easy to disassemble the gripper to make simple design changes. There is a coating of rubber gasket on each side of the orifice plate, this is to ensure there is no air leakage throughout the gripper assembly. The mac payload at 100% coverage was calculated to be 1.25 Kg, at 75% coverage it was 0.48 Kg, and at 50% it was 0.01 Kg. Additionally, a computational fluid dynamics (CFD) simulation, shown in Figure 2, was conducted to analyze the air flow through the gripper. The environmental pressure is shown in red and the vacuum flow streams are shown in blue, it can be seen that there are no obstructions to the flow.

3. Fanuc robot programming and production

Several programs have been created to achieve palletizing function utilizing the developed soft vacuum end effector. The team tested several objects to palletize cardboard and foam boxes, breadboards, and 3D printed apples. To handle each type of parts, individual programs were created and successfully run in production. The overall results followed the initial expected outcome of the vacuum foam gripper.

The decisions of material choice and griper choice proved to be successful and superior to other options. The CFD proves that the design and testing worked as advertised. The robotic workcell before and after palletizing processes is shown in Figure 3. Various objects have been picked from the floor and palletized in the cardboard container.

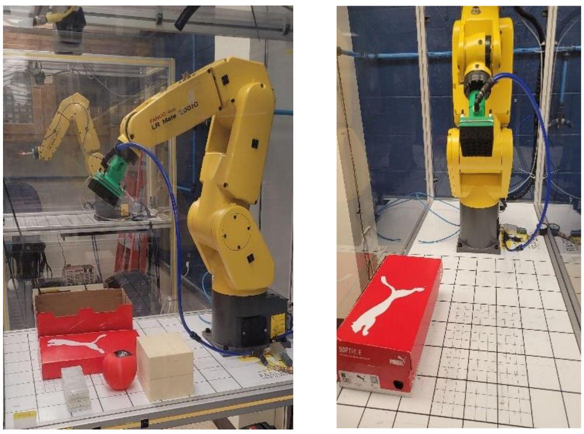
Figure 2. Gripper Design and Construction Features. A) Main Body (Polylactic Acid (PLA)), B) Orifice Plate (6061-T6 Aluminium Plate), C) Mounting Plate (Polylactic Acid (PLA)), D) Engineered Foam (Ethylene Propylene Diene Monomer. Right picture shows CFD Simulation Results.



4. Conclusion

Despite the challenges and limitations faced in this research, the project contributes valuable insights to the field, laying the groundwork for future developments in foam vacuum gripper technology. It was concluded that at least half of the grippers foam must be covered to get the proper vacuum force to lift items. The majority of this issue was alleviated after installing an orifice plate with smaller orifices and a venturi vacuum generator. Also, the versatility of the vacuum gripper is superior to suction cup grippers. Foam vacuum grippers can be used in a larger range of applications than a suction cup gripper. The foam gripper is also less sensitive to deformation and porosity than conventional suction cups. The findings presented herein provide a basis for further exploration, encouraging future research endeavors to refine and expand upon the capabilities of foam vacuum grippers in industrial settings. As industries increasingly adopt automation and robotics, the knowledge gained from this project becomes instrumental in enhancing the efficiency and versatility of gripper technology. The details provided in this article will allow other schools around the world to build and incorporate in the robotics and mechatronics curriculum the proposed end-effector expanding experiential learning opportunities to the students.

Figure 3. Robotic Workcell before and after Production.



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