WISEST SRP 2021

Robot Seeding Mechanism Design and Application

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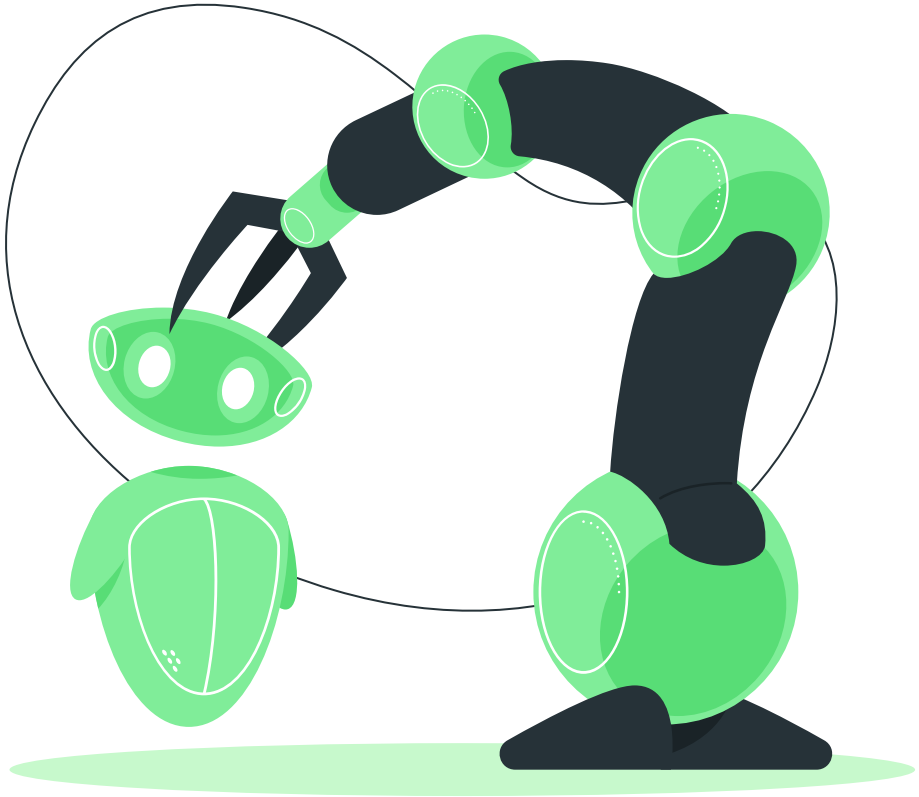

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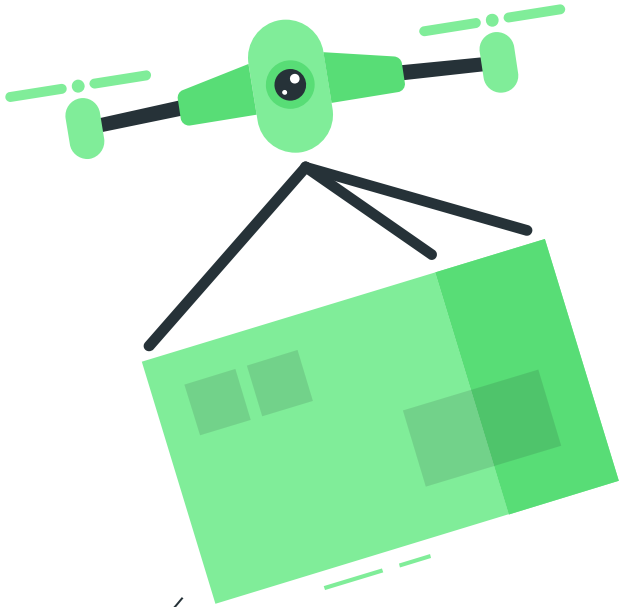
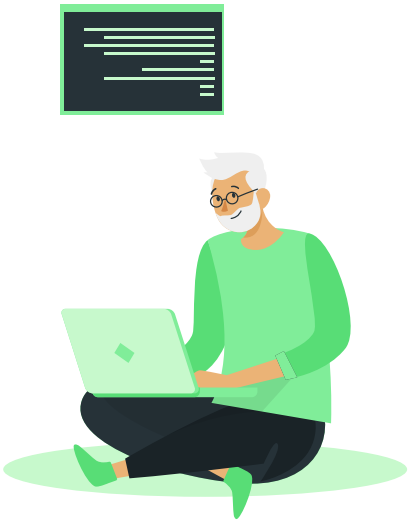
Introduction



What is a Seed Planting Robot and What is it For?

A seed planting robot functions in order to move, grip, and release seeds of various shapes and sizes. It usually consists of three main parts: the “arm”, which guides and positions the grabbing mechanism, the “hand”, which is the mechanism that grips and releases the seed, and the drivetrain, which is used to mobilize the robot. Drive trains are optional, such as for stationary planters. For my specific assignment, I was tasked with building a “hand” for a stationary planting robot. This robot would be used in both hydroponics and aquaponics by placing the chosen seeds in a Rockwool cube, where it will germinate. The plant will then be transferred to various hydroponic and aquaponic systems where it will remain. The objective for the grabbing mechanism is to make an efficient and precise design that won’t damage or compromise the seed.

Importance of the Robot Seeding Mechanism



In the past, putting the seeds into the Rockwool cubes for germination was all done by hand by the researchers. This process was lengthy and not viable for being time-efficient large-scale germination projects. By automating this step of the process, it saves time and labor. In addition to this, by incorporating robotics into this process, it is easier to ready large batches of seeds for germination.


Background
Research

Research into the mechanisms primarily used for seed planting on stationary robots allowed insight into three end effector designs that would fit the project requirements well.

1

A Vacuum Gripper

2

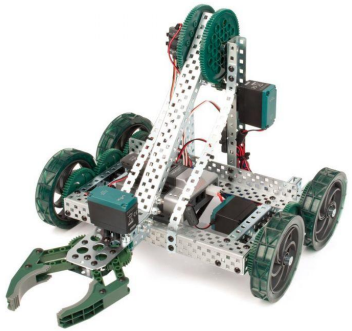
A Claw Apparatus

3

A Bellows Gripper

To meet the requirements of the assignment and perform well, the design I chose would need to be able to pick up a seed (at max two), hold it without causing physical damage to it, and place it accurately in the Rockwool germination cubes.

Claw Apparatus



Vex Clawbot design by Timothy Mehring (2016)

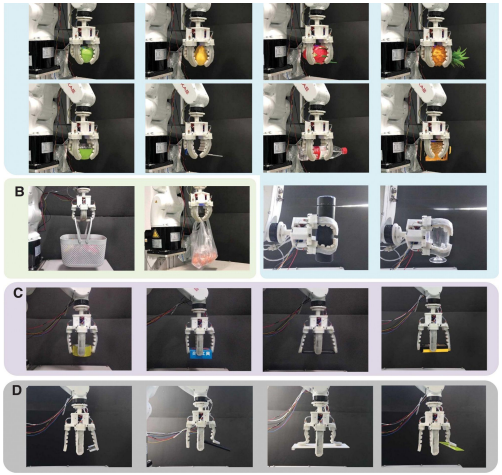
Of the three designs I researched, the claw apparatus is arguably the most adaptable. While the design operates off the simple principal of using two or more prongs to grip objects, there is a significant deal of variability on it's design. Some designs integrate "Interchangeable grippers with carefully designed geometries (that) provide better adaptability on oddly shaped objects." (Erlingsson et al., 2016) which allows them to be more universal in its function. The claw design in *Axiomatic Design of a linear motion robotic claw with interchangeable grippers* is an example of a more elaborate apparatus that uses a Servo motor in order to have precise control over its speed, linear position, and acceleration. On the simpler end of design, some claw apparatuses are two pronged and motor driven, such as the Vex Clawbot. This design is less complex, and operates using parallel claw pieces achieved by interlocking gears that are turned by simple motors. (Mehring, 2016)

The claw design is beneficial for seed planting because of its adaptable nature. The ability to make a simplistic design can be beneficial for time efficiency. With this in mind, this design has several crucial drawbacks in terms of functionality. Importantly, this design relies on putting pressure on the object in order to lift it. For an object as delicate as a seed, this can cause damage that may prevent it from germinating properly. In addition to this, the dropping mechanism needs to be accurate in its placement in the Rockwool cubes. A claw apparatus runs the risk of inaccurate drops, especially if padding is added to cushion the seed. Importantly, this makes the claw bulkier and harder to get closer to the drop site. The claw design is also not as accurate with picking up a limited number of seeds from a container, especially if they are smaller in stature like carrot seeds. For this design, it is integral that a limited and controlled amount of seeds are placed in each Rockwool cubes in order to get the best growing result.

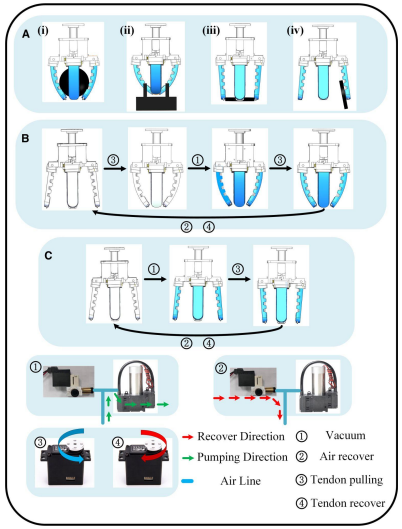
Rockwool cubes

Bellows Gripper

A gripper that uses bellows is effective in soft handling and flexibility. With this in mind, there are many different ways the design is used. Some designs utilize a four pronged structure and pneumatics in order to imitate a human hand, such as the design shown in *Multimode Grasping Soft Gripper Achieved by Layer Jamming Structure and Tendon-Driven Mechanism* (Fang et al., 2021). This particular gripper is similar to some claw designs, but is more adept at holding abnormal or slippery objects. Other designs have an internal bellows gripper, and are used for picking up hollow objects efficiently while minimizing damage.



Bellows gripper featured in *Multimode Grasping Soft Gripper Achieved by Layer Jamming Structure and Tendon-Driven Mechanism*

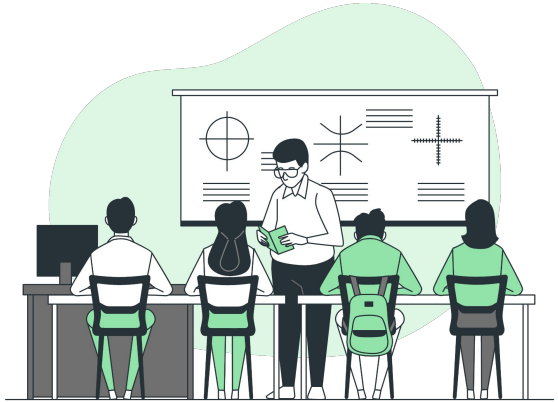


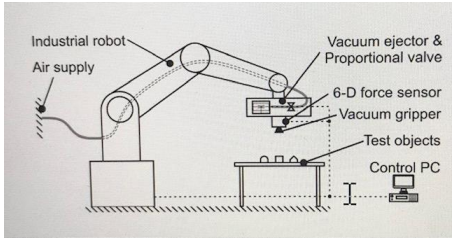
Designs in *Multimode Grasping Soft Gripper Achieved by Layer Jamming Structure and Tendon-Driven Mechanism*

This apparatus is highly effective in picking up abnormally shaped objects, making it well suited for the variable shapes and sizes of potential seeds. Additionally, this style of gripper is softer in style, which lessens the risk of damaging the seed. With this in mind, this style faces similar problems that the claw design does. Because it relies on grabbing the seed, it runs the risk of damaging it. Additionally, it similarly has challenges in grabbing a limited amount of small objects. This design is similar to the claw in its ability to accurately drop a small object in a limited space. Overall, this design is more effective than a regular claw, but still has some drawbacks to its functionality.

Vacuum Gripper

The vacuum gripper is a pneumatic based apparatus that utilizes suction in order to grip objects. This design is fairly similar in its different renditions, with minor differences in how the apparatus achieves suction. One design relies on an “...an off-board pump to evacuate the air from the gripper.” (Amend et al., 2012). Additionally, it uses a gripper that “passively conforms to the shape of a target object.” (Amend et al.,2012). Other designs, such as a robot based experimental setup in *Modeling of vacuum grippers for the design of energy efficient vacuum-based handling processes*, (Gabriel et al., 2020) operate similarly.





Experimental setup in *Modeling of vacuum grippers for the design of energy efficient vacuum-based handling processes*, (Felix Gabriel, Markus Fahning, Julia Meiners, Franz Dietrich, Klaus Dröder, 2020)

The vacuum gripper is highly adaptable to abnormally shaped objects, such as a seed. Further, it also can be used effectively for objects of varying weights by increasing or decreasing the suction. In addition to this, the small attachment can allow the arm to get closer to the drop area, allowing for more accurate placement. The vacuum gripper itself can have a small suction area, thus making the amount of seeds picked up to be more controlled. With this in mind, this particular design is more tricky, as the amount of suction must be carefully controlled so it does not intake smaller objects that it is trying to pick up. Additionally, objects that are heavy but fragile would not be suitable for this design because of the proportional nature of the weight and suction level. Granted, this design flaw would not affect the function of the seed planting robot and does not need to be taken into account. Overall, the vacuum gripper would be highly suited to the assignment.

Design

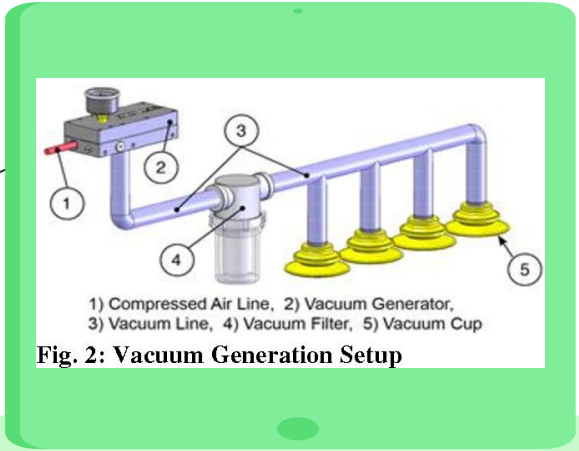


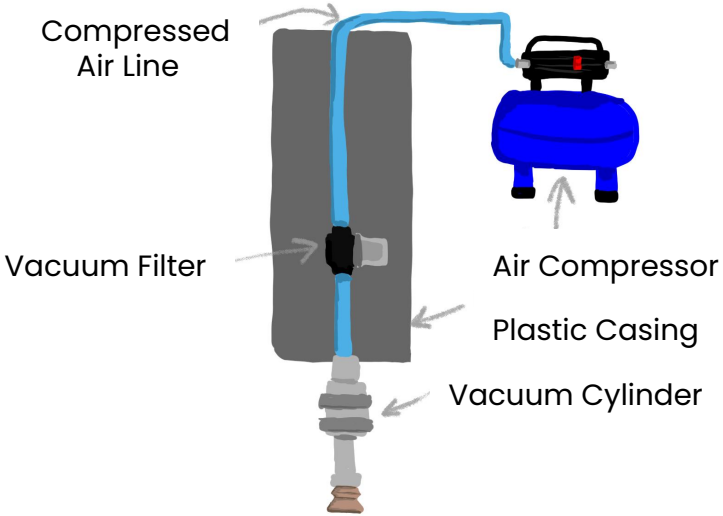
Fig. 2: Vacuum Generation Setup

Image from DESIGN CONSTRAINTS OF VACUUM GRIPPER OF ROBOTS – AS A PICK AND PLACE OPERATING TOOL. (2016)

Basic Gripper Planning

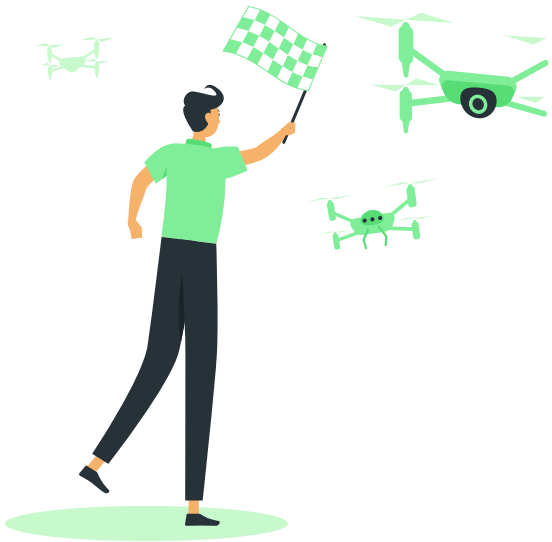
The conducted research found that a vacuum gripper would be the most suitable design for this particular task. Specifically, the design that I wanted to incorporate was one that functioned using an air compressor or compressed air. The gripper I wanted to make would function much like the one in *Design of an Integrated Gripper with a Suction System for Grasping in Cluttered Environment* (Kang et al., 2019) and *Vacuum Suction Robot Arm* (MERT Arduino & Tech., 2020). The key components I need to incorporate into the mechanism are an air compressor, vacuum cylinder (this incorporates both as a vacuum generator and a suction cup), and a vacuum filter.

Gripper Sketch



Remote Control

For operating the mechanism, I plan to use an air compressor with a microcontroller. A Microcontroller similar to computer, and is typically dedicated to performing a single task. It is usually comprised of four key components: a central processing unit, memory, a system clock, and peripherals. The CPU performs all the logic operations or calculations to allow the microcontroller to function. The memory on the microcontroller allows it to store information for it to be reused later on. This is similar to the function of a hard drive and RAM on a computer. The system clock controls the speed that the microcontroller processes data, and is based off an oscillator. A microcontroller inputs and receives information through the use of peripherals. An example of this in a computer is a keyboard or a mouse. By using a microcontroller, it allows the user to add intelligence to a system. The advantages of utilizing this component is their cost-efficiency, energy efficiency, and their reusability. (Microchip Technology 2010)



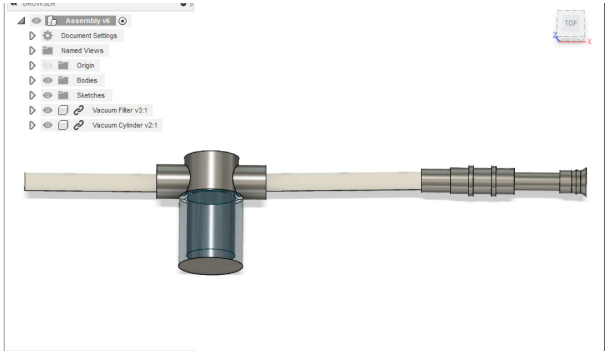
Fastening

For fastening the arm and the end effector together, I incorporated built-in grooved coupling on the top of the casing. This allows the end effector to screw into the arm in a time effective manner. In addition to this, it allows the arm to switch out what end effector it has attached depending on what task it needs to complete.

Final Design

For the 3D design, I started by making the three key components: the vacuum cylinder, vacuum filter, and air compressor. After I finished modelling the major parts, I incorporated the compressed air line and used it to connect the filter and cylinder. Additionally, I made a basic casing to enclose the vacuum filter and will attach to the robotic arm. In the model, I made the casing from a translucent material so you can view the inside components. In the actual design, it will likely be made from an opaque plastic similar to the rest of the arm so that the weight difference of the gripper will not hinder the efficiency of the rest of the robot.

Inside Mechanism



(Link to inside mechanism)

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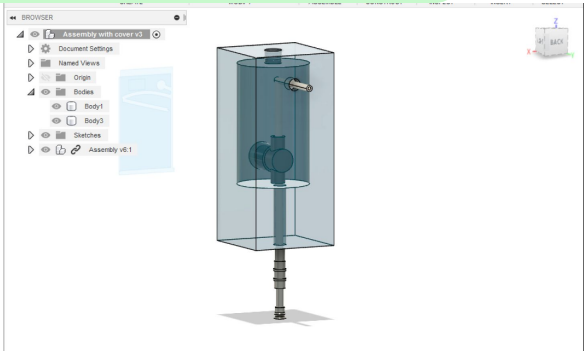
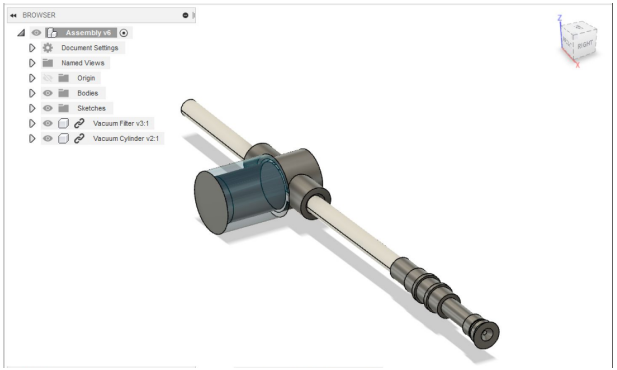
Suction Gripper With Cover





(Link to suction gripper with cover)

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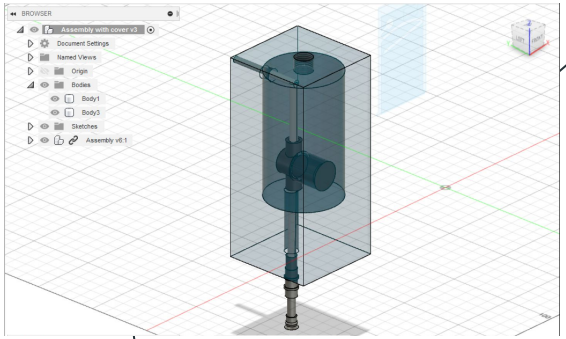

End Effector on the Robot Arm

(Link to full assembly)

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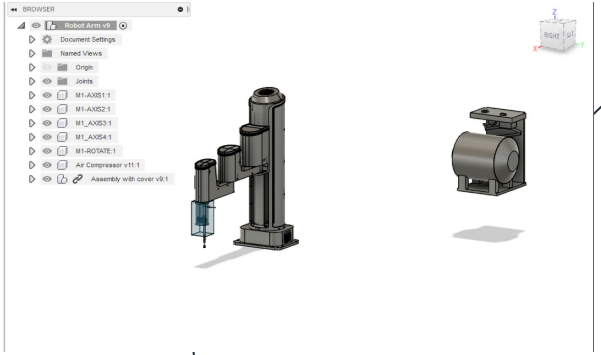
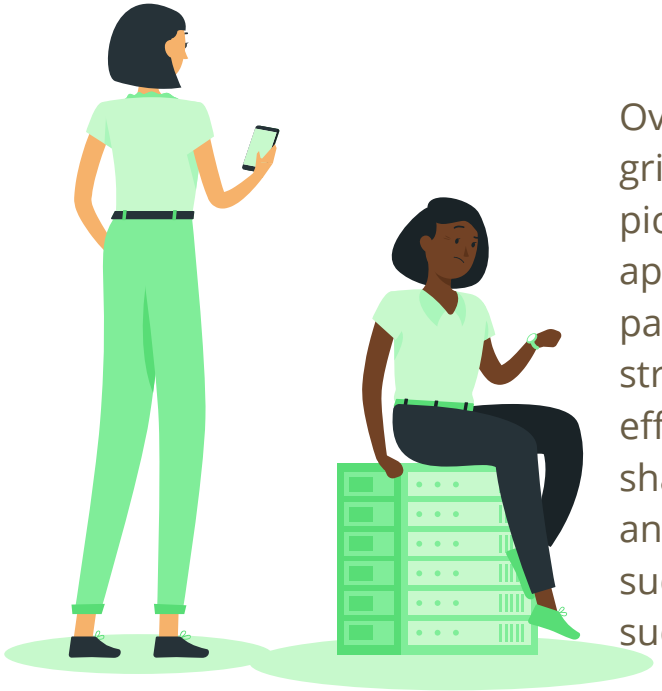
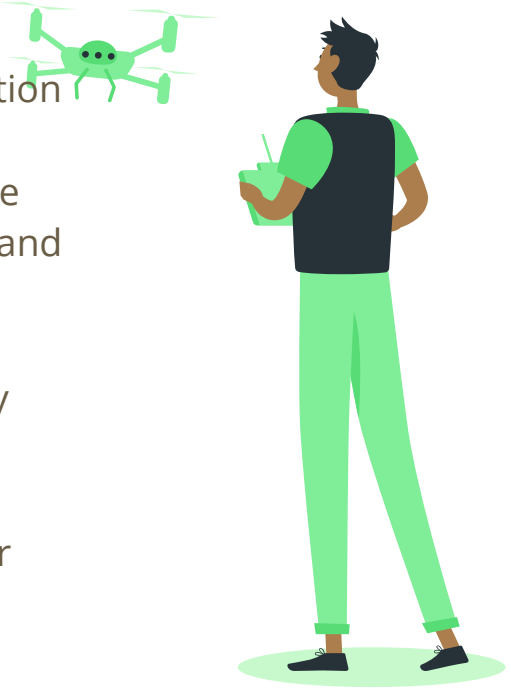
Full Assembly With Air Compressor

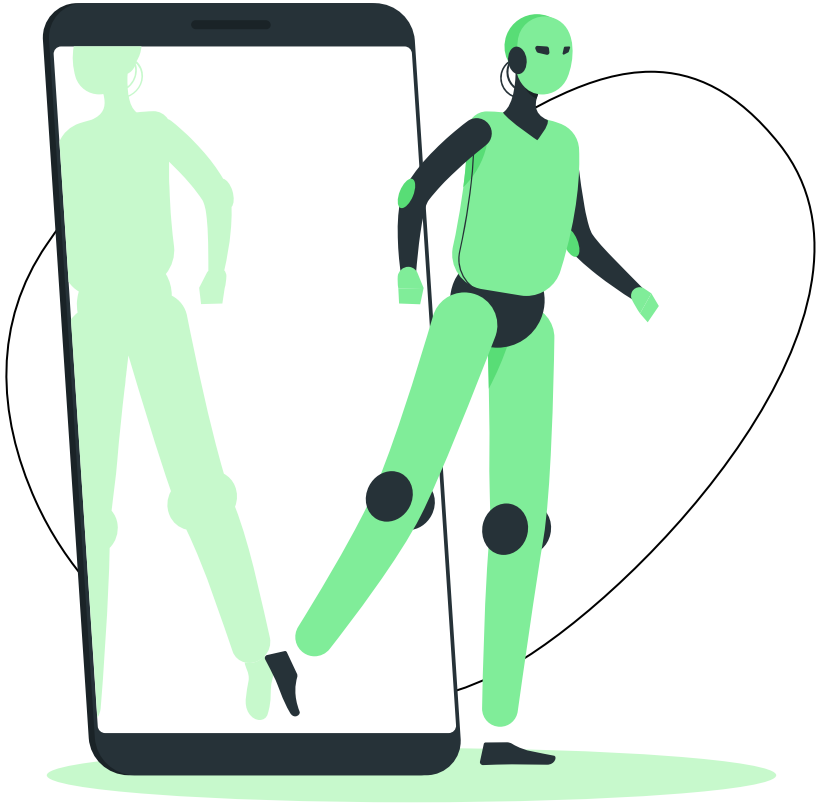


Conclusion



Overall, my research concluded that a suction gripper would be most suitable to seed picking and placing. This design can also be applicable to other jobs in manufacturing and packaging due to its adaptable and straight-forward design. The suction end effector is effective in handling abnormally shaped objects as well as a variety of sizes and weights effectively by increasing the suction power and the vacuum cylinder (or suction cup) size.





Acknowledgments

I would like to extend a huge thank you to WISEST, my Principal Investigator Dr. Rafiq Ahmad, my direct supervisor Rabiya Abbasi, my fellow SRP researchers, and my sponsors for making this project possible.

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