*Internship report at Anand Diagnostic Center.*

# Design of Robotic Automation Solution

***Submitted by:***

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*Under the guidance of*

**Dr. D. Sethuram**

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**6 months ( Jan 4th - June 25th)**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**PES UNIVERSITY**

(Established under Karnataka Act No. 16 of 2013)

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# PES UNIVERSITY, BANGALORE

(Established under Karnataka Act No. 16 of 2013)

**Department of Mechanical Engineering**

## CERTIFICATE

This is to certify that **AVVA SAI PRANAV** bearing **SRN PES1201800861** has interned in the area of **"ROBOTIC AUTOMATION"** under the supervision of **Prof. D.Sethuram,** during the session Aug-Dec 2021 for a period of **six weeks (01/09/2021 – 29/11/2021),** in partial fulfilment for the award of degree of B. Tech. in Mechanical Engineering of PES University.

Internal Guide
**Prof. D.Sethuram**
Dept. of ME,
Professor

**Chairperson**
Dept. of ME, PESU

# DECLARATION

I hereby declare that I have undergone an internship at Anand diagnostic centre from a period of 1/9/2021 -29/11/2021 under the guidance of Dr. D Sethuram, Professor, Mechanical Department, PES University, and submitted in partial fulfilment of the credits for the degree of **Bachelor of Technology in Mechanical Engineering** of **PES University** has not been submitted to any other university or institution to award any degree.

Avva Sai Pranav

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**ACKNOWLEDGEMENT**

I would like to express my gratitude to my guide **Dr. Sethuram, Prof Venkatrangan, and Dr. Sujay Prasad,** for their continuous guidance, assistance, and encouragement throughout the development of this internship.

I take this opportunity to thank **Dr. Rajesh Mathivanan, Chairperson, Department of Mechanical Engineering, PES University,** for all the knowledge and support I have received from the department.

I would like to thank **Dr. B.K. Keshavan, Dean of Faculty, PES University,** for his help.

I am deeply grateful **to Dr. M. R. Doreswamy, Chancellor, PES University, Prof. Jawahar Doreswamy, Pro-Chancellor – PES University, Dr. Suryaprasad J, Vice-Chancellor, PES University** for providing to me various opportunities and enlightenment every step of the way.

Finally, this internship could not have been completed without the continual support and encouragement from my parents and friends.

## ABOUT THE COMPANY

Anand Diagnostic Laboratory (ADL)[1] is one of India's leading medical laboratories and is known for delivering reliable, fast, and affordable diagnostic services. One of the few stand-alone laboratories in Karnataka to be set up by a pathologist and the first to automate many laboratory processes, including some aspects of pre-analytics such as automated sample tube labeling and sample sorting.

ADL was incorporated on 8h May 1974, under the leadership of Dr. A.V. Ramaprasad. He is currently supported by his family, including Dr. Jayaram, Dr. Sujay Prasad, Ms. Sheela Ashok, and Ms. Smitha Jayaram.

The central testing unit of ADL is situated in Shivajinagar, Bangalore, in a 5-story building with approximately 60,000 Sq.Ft. ADL has also set up client facilities (collection centers) in various parts of Bangalore city and Mysuru. Furthermore, ADL has pioneered the World's First Drive-Through Blood Collection Service at Shivajinagar.

***VISION***

It is delighting customers by constantly exceeding their expectations in terms of quality, service, value, and time.

***MISSION***

- Quest for excellence reflects in everything we do.
- We continuously evaluate our performance.
- We exceed customer expectations and improve our standard of excellence.
- Everyone in the organization feels the spirit of excellence.

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# 1.COMPANY REQUIREMENTS

Anand Diagnostic Center is known for pioneering in the field of automation of their diagnostic laboratory, and they strongly believe in the continuation of such industrial automation. They ensure they can always uphold industry standards and expectations by implementing them and being aware of the latest technological advancements in the field. As presented by Dr. Sujay Prasad, the problem statement was to provide a robotics solution for test tube segregation and racking.

Anand Diagnostic Center receives more than 2000 samples daily. There is a requirement of registering each batch and segregation of the said batch into the respective departments.

There is an existing solution in the form of a test tube segregator based on a conveyor belt system. However, there are a few significant drawbacks in terms of accuracy and the lack of automation in the process of racking and stacking the test tube into trays. The drawbacks of the current system require intensive manual labor to verify if all test tubes have undergone scanning and, in some instances, manually scan and enter the error flagging test tubs. The lack of a racking and stacking implementation leads to manual labor for stacking and racking. This is arduous and time-consuming; it can also lead to errors and a mix of test tubes due to the number of test tubes handled in the facility.

The facility is highly automated, where the testing in each department is handled through automation. The initial receiving of blood samples, i.e., registration, is the bottleneck for Anand Diagnostics due to the lack of automation in that sector.

The flow of the regular working day in the registration sector is as follows: The registration process begins outside of Anand diagnostic lab, wherein the samples are tagged and indicated to the center of their arrival. Upon arrival at the center, they are first unpacked from their covers and screened to verify their tagging in the database. They are then dropped in the hopper of the test tube segregator.


Fig. 1: Sample test tube Segregator

A test tube segregator is a compact device whose sole purpose is to scan the barcode as provided on the body of the test tube and drop it into its respective bins. Errors due to barcode readers or misaligned barcode stickers will be detected, and these test tubes segregated into a separate error bin. There is no feedback shoot connecting the error bin and the hopper; hence the operator should manually pick up the test tubes collected at the error bins and drop them back into the hopper for the second scan. After segregation of the batch into respective departments, manual racking and stacking are required. Each racked set of test tubes requires a manual batch entry to be generated for logging and tracking purposes. Autonomy in racking has not been integrated into the system yet.

As the whole process of collection was quite transparent, the regions of improvement were quite clear. Our solution must be an upgrade to what already exists and must provide hands-free operation in areas that operators previously assisted.

The biggest priority is eliminating manual labour to reduce the number of errors and time taken for the registration process. Another consideration for the solution would be the reproducibility of the system in other departments for archiving purposes. The elimination of human resources is also so that the resources used in the current registration department can be diverted to elsewhere cognitive tasks play a higher priority.

## 2.ROLES AND RESPONSIBILITIES

After my onboarding onto the internship, we were run down about the problem statement by a visit to the diagnostic center. In the visit to the diagnostic center, we were shown the procedure every test tube sample in the center goes through. Every sample starts its journey from outside the diagnostic center through the registration process, sorting batch creation into the various departments—the transportation used from the registration center to each department. We were also exposed to the testing process in the hematology department, wherein the diagnostic tests were conducted through conveyor belt-based systems. The Departments also contained a section for archiving. During the visit, we were explained the complete process details and allowed the team to take the floor space dimensions and vital information required to design the replacement test tube segregator system. We were also exposed to the industry standards of maintenance and the amount of online monitoring systems go through to ensure the highest service condition of the machines.

After the field visit, we were able to understand all the requirements of our client. Our team proposed two solutions for the existing problem: one uses a 4DOF robotic arm with a single axis gripper and wrist camera; the other uses a combination of conveyor belts and several picks and place arms in a single station.

The design of the robot was divided into three subdomains mainly:

1) Design Domain

2) Sensors and Electronics

3) Power Systems

4) Software

I was a part of the design domain and ensured good conversations between all the domains. The design domain could implement the decision taken by other departments, and the requirements of the design domain are considered during the decision-making process. I also played a role in the overall design process and required various considerations which range from IoT, electronics and software development.

# 3.SCOPE OF WORK

## 3(A).SEPTEMBER

Programmable mechanical arms, which could be standalone robots or parts of a complex mechanical system, are known as robotic arms. Their function is similar to human arms, which are highly efficient in pick and place applications. As our problem statement had aligned, we chose the implementation of the robotic arm. Another reason for the decision of a robotic arm is the ease in replicating such a system and the wide range of use case scenarios. Robotics arms were already in use for the archiving process in the diagnostic lab; hence we would be able to provide a multipurpose solution. Pick and place robots handle repetitive tasks while freeing human workers to focus on more complex work.

Our proposed idea suggests using a robotic arm to pick up the test tubes dropped through a hopper, move to the barcode scanner for scanning the test tube and place it in the rack provided in another location within its workspace range. To begin the process of design, we have a few design considerations and limitations, which are as follows:

- Floor space area (length x width): 1000mm x 500mm.
- Test tubes weigh under 150 grams (we have assumed this value to be 250 grams for an improved factor of safety).
- Must be modular and easily movable.
- Overall weight should be under 13 kgs.
- Overall cost should be under ₹1,25,000.

As mentioned before, the robotic arm needed to be weighed as light and structurally as small as possible without significant depreciation in its performance. This is because the laboratory planned on relocating it to different workstations depending on the facility's requirements.

Once all the design considerations and requirements were set, we began by looking at current industry-grade robotic arms and replicating them to match our requirements. The software used in the design process was Solidworks for CAD models and Ansys for analyzing the static and dynamic stability of the components:

The structure of the robotic arm can be divided into two sections:

a) Actuators

b) Reinforcement structures(links)

The next step in the process was discussing which kind of actuators to use for the robotics arm. The two actuators that were considered were stepper motors and servos.

| **Parameter** | **Servo** | **Stepper** |
|---|---|---|
| Cost | High | Low |
| Torque | Moderate | Moderate |
| Speed | High | Moderate |
| Precision | Excellent | Good |
| Tuning Difficulty | Moderate to high | Low |

Table 1: Comparison of Servo and Stepper

The trade off between the cost and precision were considered. Servos come with an in-build feedback system hence the extra price. Similar feedback can be achieved in a stepper motors by installing magnetic encoders at the end of the stepper motor shaft, hence the trade off is well under the design limits. The other consideration is that servo motors are break if its under too much of a load, such as if its holding a position and you force it in a different direction, or if its trying to a position and something is blocking it, it will burn out. This could be a potential problem. In the end Neema motor series was chosen as it was an industrial standard and had a wide range of online support.

The layout of the robot was also well discussed as it is an essential factor in the design process. An overhead camera was added to act as a safety mechanism. Using contour detection and line detection, a safety implementation was designed wherein if a person enters inside the workspace range, the robot would stop automatically. The next consideration was the scanning of the test tube barcodes. We decided to have a separate barcode reader for the following reasons:

- The robot moves from the unsorted test tube bins to the sorted test tube bins. Hence it would be easier to program a fixed path and have the scan process happening there.
- This would also mean that the end effector weight can be decreased substantially.
- There is no requirement for a roller mechanism as the bar code scanner technology has come far enough to pick up the correct code even if a few lines are hidden.

It was later decided to add another camera to the end effector, which would serve as the robot's eyes. Raspberry pi was taken to be the choice of board to interface with all the above components and also to ensure that the image processing part of the implementation runs smoothly.

## 3(B).OCTOBER

In October, the complete design process began where we chose to design worm gear as the gearbox for Neema motors. Worm gear drives are compact and are usually used in high torque applications. In addition to its high load-bearing capacity, worm gear drives are also non-back drivable. This means that any load applied against the output shaft will not rotate the worm gear. This is an essential characteristic for a robotic arm since they usually have a lot of overhang weight (including the payload). We do not want them to drop the load when powered off.  Figure 2 shows the cad model of the worm gearbox.

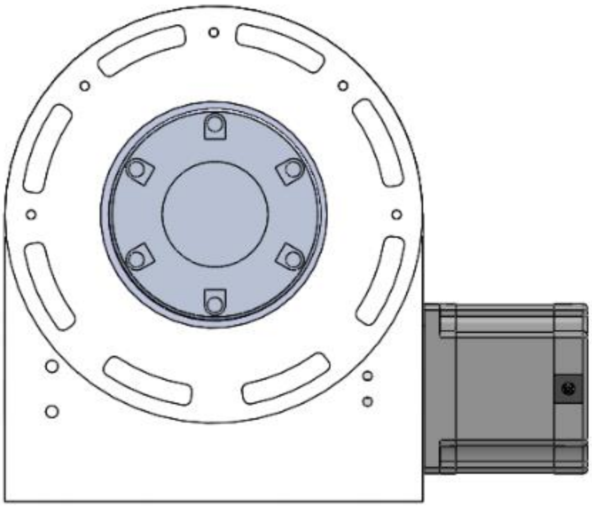


Fig. 2a. Worm gearbox (Front view)

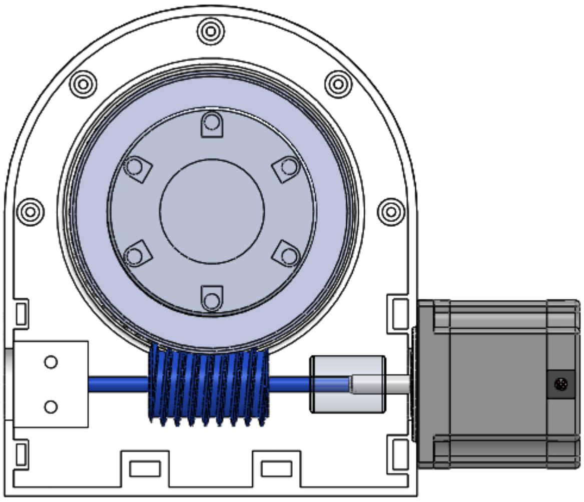
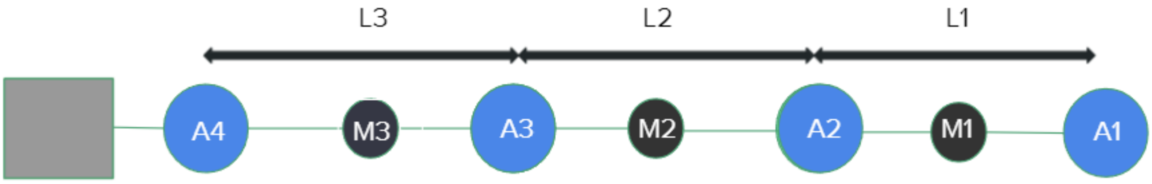


Fig. 2b. Worm gearbox (internal view)

The actuators were 3d printed using PETG and tested for their performance. Our choice of the motor was a NEMA 17 stepper motor. The material of choice was PTEG(Polyethylene Terephthalate Glycol), as weight was a significant consideration, and metal fabrication of gears would increase the manufacturing price. As the gear reduction was lower than usual, Aluminium can easily be substituted by PTEG. PETG is a polymer used as a filament in 3d printing parts that need to be strong and resist warping due to heat. In our application, strength and heat are both inevitable. The motors heat up to around 70 degrees under continuous operations, and using regular polymer will melt the polymer itself.  Another way to use polymers without worrying too much about warping is by installing passive heat sinks around one of the faces of the motor. This way, you reduce the risk of running into maintenance issues and improve the overall system's longevity.

In the month of October the technical parameters of links and joints were also finalized as shown below:




A1 → Payload mass
M1 → End effector mass
L1 → Length of End effector
T1 → Wrist joint torque
A2 → Joint 3 mass
M2 → Link 2 mass
L2 → Length of second link
T2 → Second link joint torque
A3 → Joint 2 mass
M3 → Link 1 mass
L3 → Length of first link
T3 → First link joint torque
A4 → Base mass
T4 → Base rotation torque

| Model | A1 (kg) | M1 (kg) | T1 (kgcm) | A2 (kg) | M2 (kg) | T2 (kgcm) | A3 (kg) | M3 (kg) | T3 (kgcm) | A4 (kg) | M4 (kg) | Total weight (kg) (excluding the payload) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| With gear drives | 0.25 | 0.75 | 12.5 | 0.7 | 0.5 | 74 | 1.65 | 1 | 233.25 | 2.1 | 0.3 | 7.25 |

Table 1. Torque required at the respective joints for a payload of 1kg.

| Model | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| With gear drives | NEMA 17 (4.2kgcm) + Cycloidal drive (8:1) | NEMA 17 (4.2kgcm)+ Worm gear box (3:1) | NEMA 23 (10.1kgcm) + Worm gear box (30:1) | NEMA 23 (18.9kgcm) + Worm gear box (30:1) |

Table 2. Combination of motors and gear boxes used at the respective joints.

All the above torque calculations are made for a payload of 1 kg.

The gear box used for wrist rotation is a cycloidal drive. It offers a gear reduction of 8:1 in its current configuration. Figure 3 shows the cad model for the cycloidal gear box.

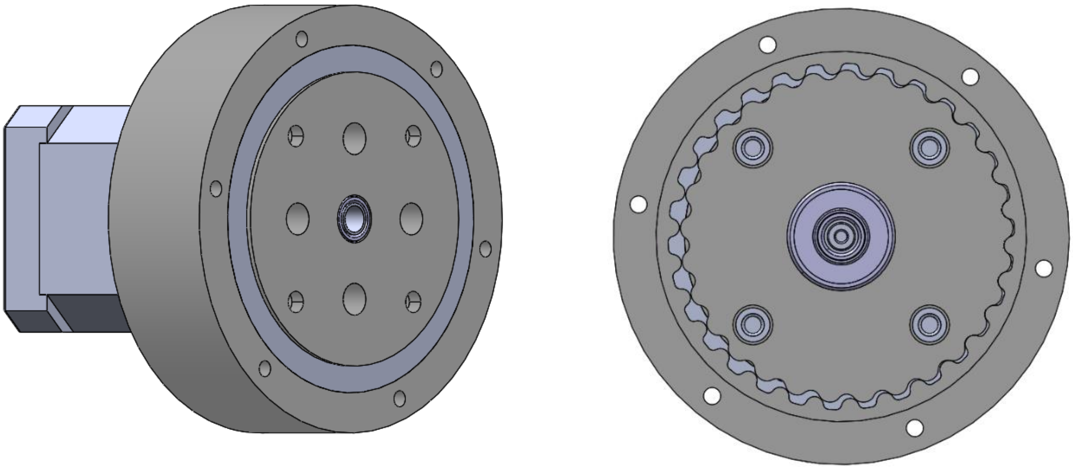


Fig. 3: Cycloidal gear drive

## 3(C).NOVEMBER:

In November, the prototyping/manufacturing phase began. The end effector design was also was a priority for the month. We chose a two-finger gripper to serve our application because of its simplicity in design and its capability to perform pick and place operations with ease. The first iteration of the end effector design was an encompassing gripper. Such grippers are modular and provide a gripping force of over 3.5N, resulting in a torque of around 0.5 Nm. A separate camera mount must be designed. It is also required that slots be made on the gripper area to allow force-torque sensors. Upon discussion, the usage of spur gears and a four-bar mechanism was decided; hence the design of the gripper was changed to as shown in Figure 4.

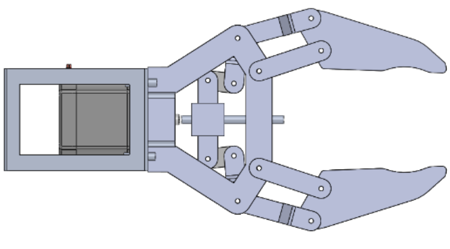


Figure 4: Encompassing gripper

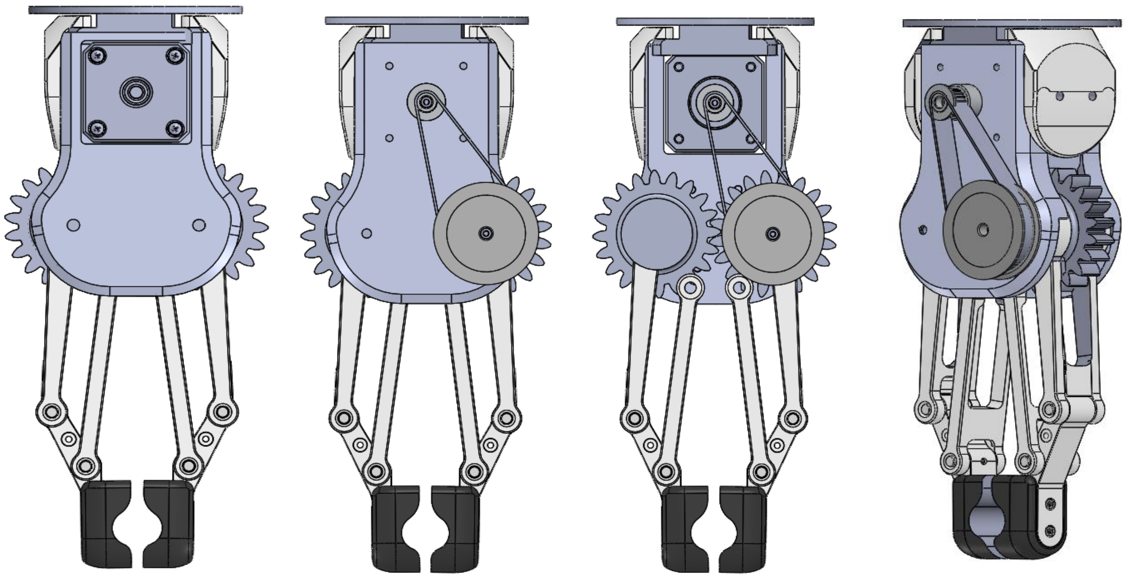


Fig. 5: Two claw gripper.

The wrist camera is required to detect the test tubes and the position of the test tube cap so that the gripper can lift the test tube using its cap. A modular camera mount has been designed that can easily be mounted onto the robotic arm's wrist with no hassle whatsoever. Dowel pins (figure 8) have been provided to precisely locate the orientation of the interface. The camera sensor is positioned well above the end effector to increase its Field of View, which the end effector should not obstruct. The camera sensor is chosen for this purpose is the Raspberry pi camera. With the following specifications:

- Sony IMX477R stacked, back-illuminated sensor, 12.3 megapixels.
- Output: RAW12/10/8, COMP8
- Back focus: Adjustable (12.5 mm–22.4 mm)
- Lens standards: C-mount, CS-mount (C-CS adapter included)
- IR cut filter: Integrated
- Ribbon cable length: 200 mm
- Tripod mount: 1/4”-20

Fig. 6: Camera Module

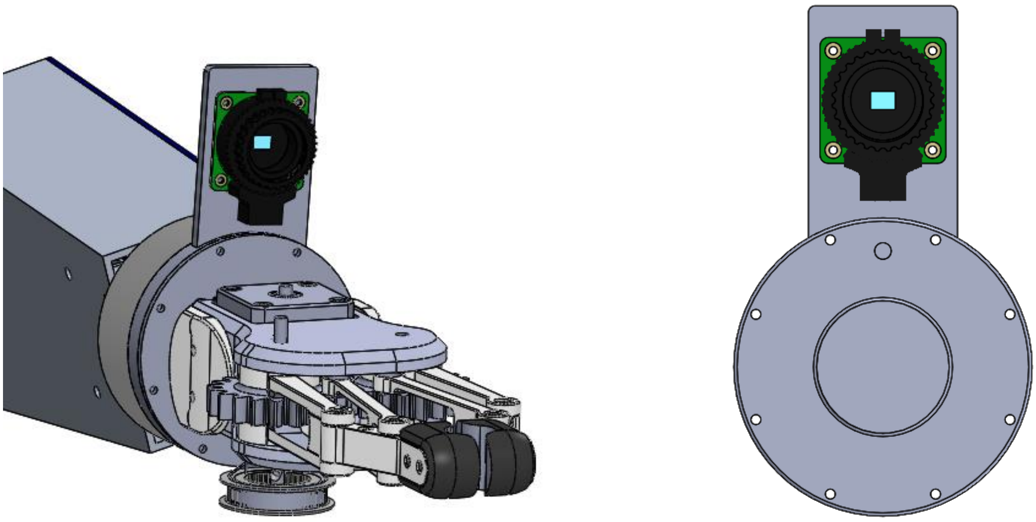


Fig. 7: Camera adapter

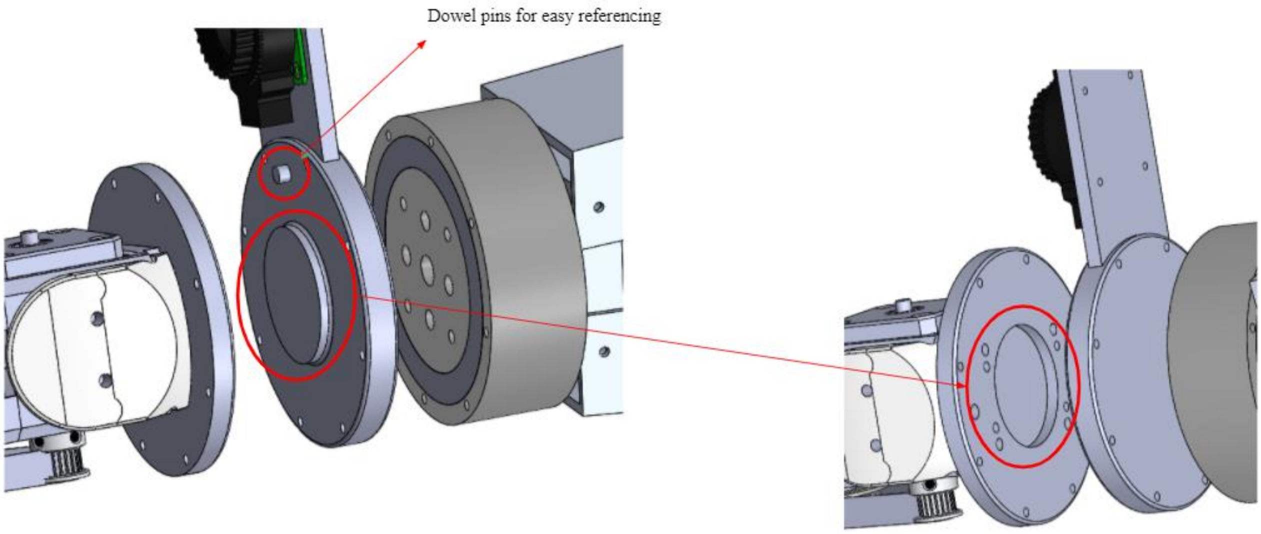



Fig. 8: Interfacing of camera adapter

The last consideration for the grippers were the Force torque sensors. A force torque (FT) sensor is an electronic device that is designed to monitor, detect, record and regulate linear and rotational forces exerted upon it. In other words, the FT sensor in a robotic or mechanical system can be compared to the micro-receptors in skin that equip animals with the sense of "touch." The plan of action was to order a Force torque sensor but it was found to be sold only in bulk to manufacturers. There were no means of acquiring it hence, the back up plan was to use a force sensing strip.

Fig. 9: Force sensing sensor

As this would allow for the detection of test-tube when placed between the two grippers and would be a suitable replacement for the force torque sensors.

Figure 10 shows the prototype of the gear box that was built and tested.

Fig. 10: Manufactured Gear Box

Overall, the final robotic arm is expected to resemble figure 11. The length of the robotic arm at full extension is 920mm (650mm without the end effector). The overall weight is a little over 13kgs.

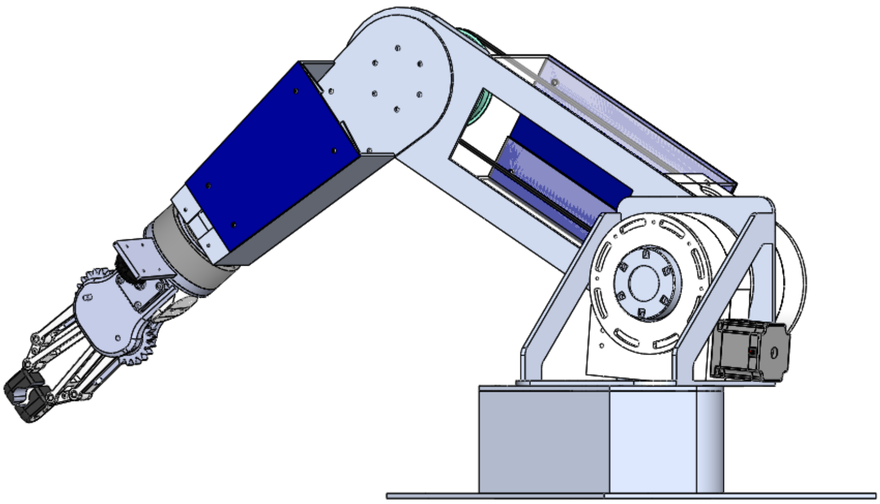


Fig. 11: Robotic Arm

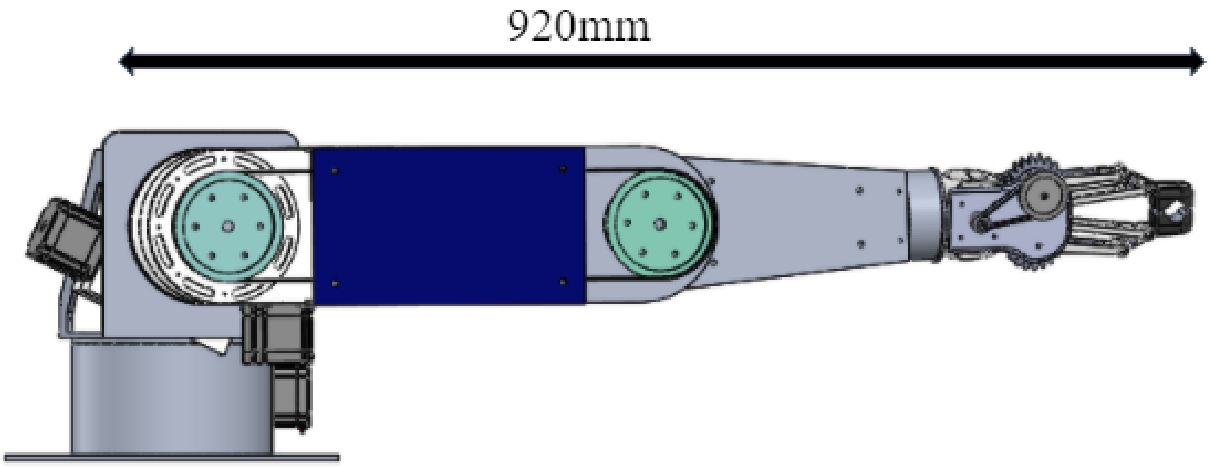



Fig. 12:  Robotic Arm fully extended

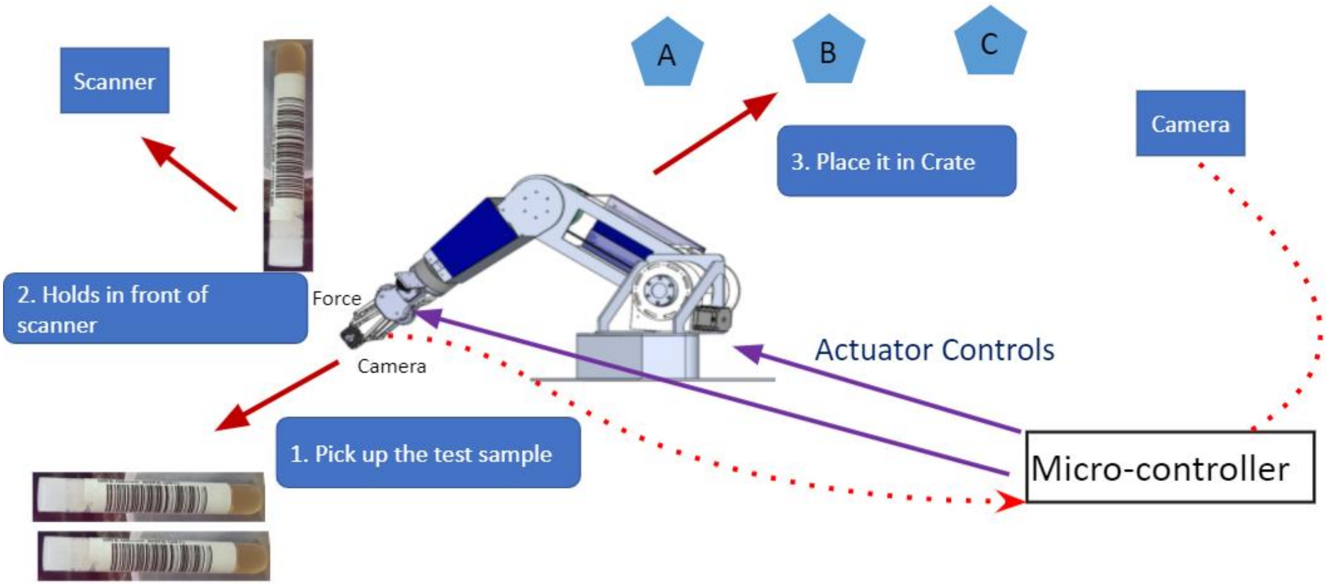



Fig. 13: Task sequencing

On the computational side the following was accomplished:

- Contour Detection of the hand
- Detection of the barcode using sensor as a primary check.

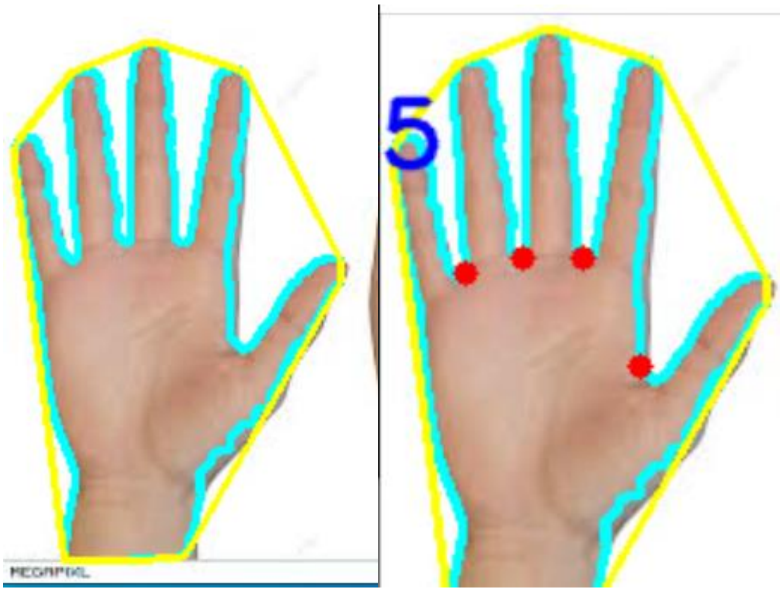



Fig. 14: Hand Contour Detection

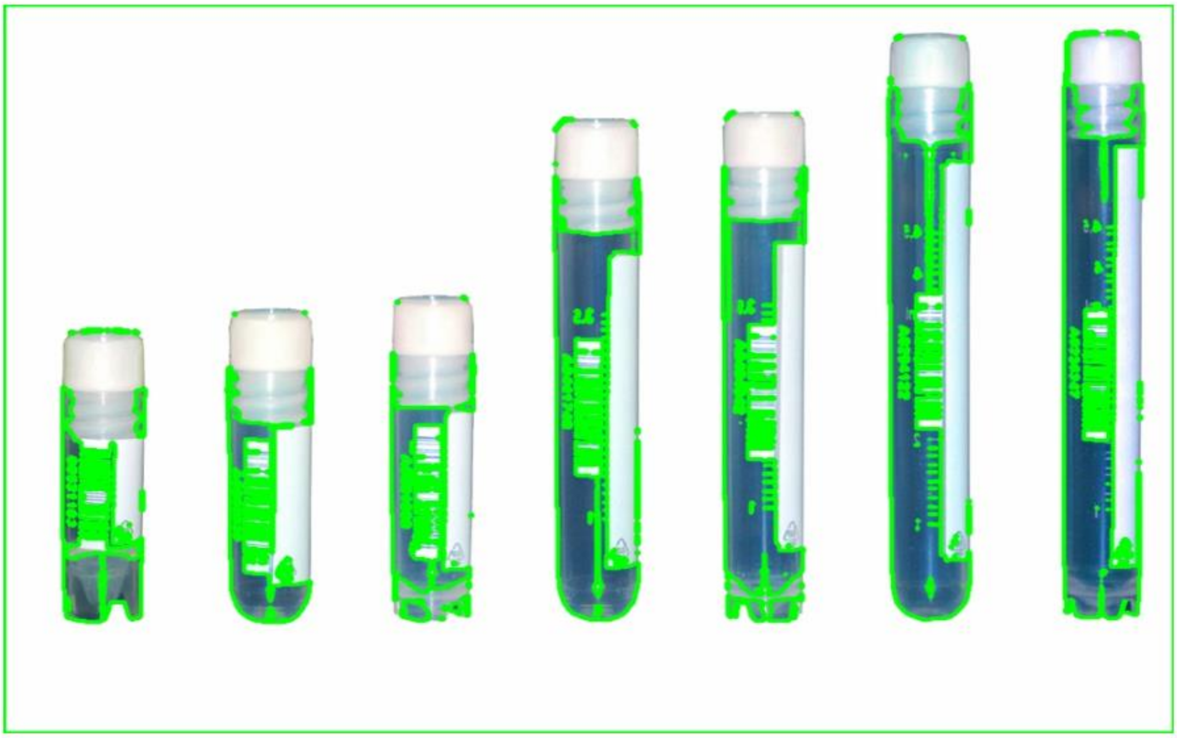


Fig. 15: Contour detection of test tubes

# 4.CONCLUSION AND EXPERIENCE

I learned the workings and inner mechanisms of an automated laboratory and the entire workflow. I was also introduced to the world of industrial and product design. I learned of the importance of innovation in corporate companies, especially those that manufacture products. I was sensitized to the design process and understood how it plays a crucial role in bringing client interest, how it benefits the company in the long run and how design helps create and increase brand value. I understood the importance of interdomain design process interaction and was exposed to industry-standard sensors and standards. It helped me improve my understanding of a variety of domains and how to interconnect them. This being my first internship and experience in the corporate world, was a huge source of knowledge.

Through this internship:

- I was exposed to different types of work and career options.
- I learned how to design aesthetically pleasing presentations.
- Developed better communication and interpersonal skills.
- Learned how to brainstorm, ideate and visualize new ideas.
- I was given a lot of exposure by my mentors on navigating the corporate world.
- I understood Industry standards and the importance of inter-domain cooperation for design.

## 5.REFERENCES

[1] Anand Diagnostic Center: https://www.anandlab.com/