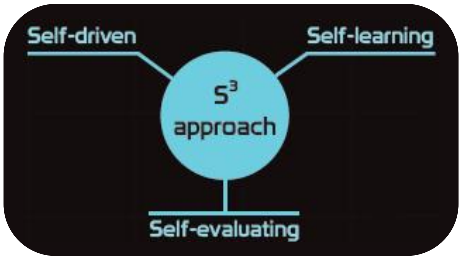
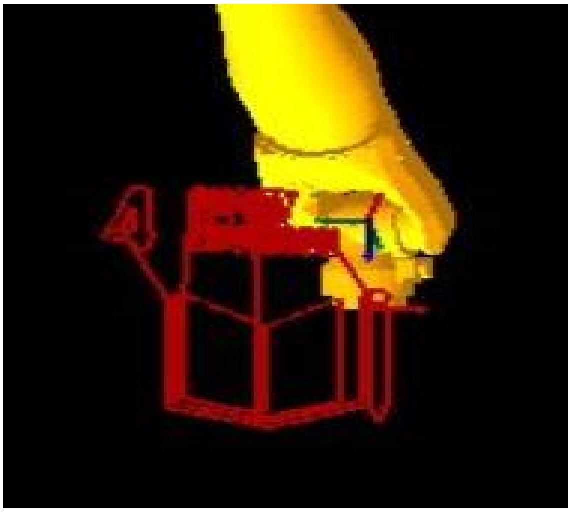
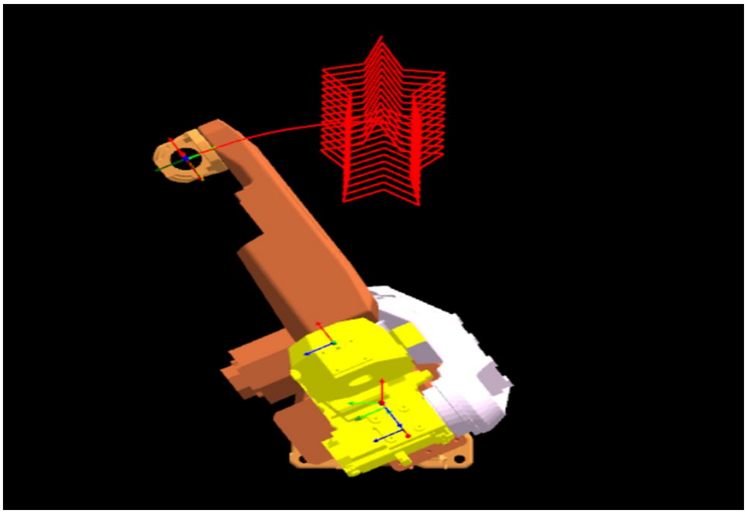
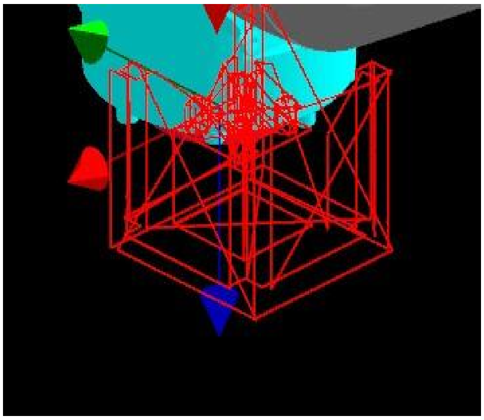
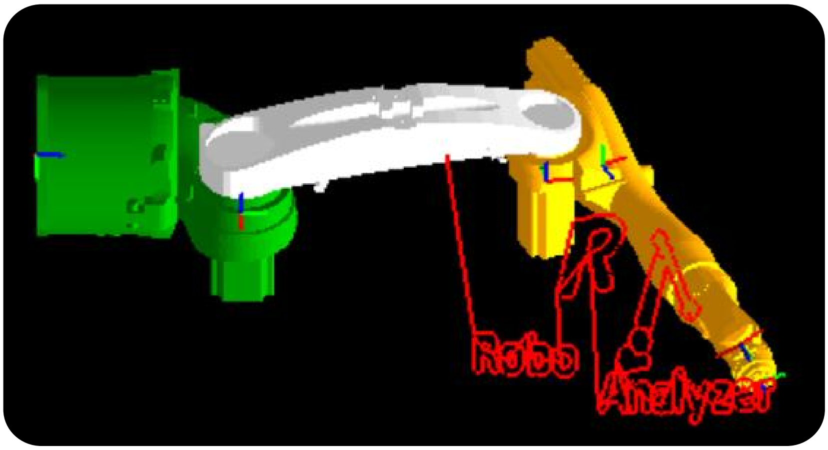



# ROBOANALYZER-BASED ONLINE/OFFLINE COMPETITION ROC 2024 (VERSION 5.0)










**Proceedings of ROC Enclave on Nov 9, 2024**

**IIT Delhi, New Delhi**

# Timeline

| Date | Description | Remarks |
|---|---|---|
| June 29, 2024 | First Online Meeting of ROC Organizing Committee | Initial round of discussions on when and how to conduct ROC 2024. |
| July 24, 2024 | Second Online Meeting of ROC Organizing Committee | Dates and modalities were finalized. |
| July 5, 2024 | Call for Participation Announced | Registration starts. |
| July 20, 2024 | Deadline for Registration | 103 registrations received |
| July 15, 2024 | Announcement of Teams | 25 teams announced |
| Aug 16th & 17th 2024 | ROC Kickstart | Workshop held in Pune |
| September 14, 2024 | Interaction Session 1 | The teams were reorganized into 25 groups. |
| September 28, 2024 | Interaction Session 2 | The teams were reorganized into 10 groups. |
| October 14, 2024 | Interaction Session 3 | Concluding interaction session for ROC 2024. |
| October 28, 2024 | Submission of Final Task | Submissions competed by 10 teams. |
| November 1, 2024 | Peer Evaluation | Evaluations completed by 10 teams. |
| November 9, 2024 | ROC Conclave at IIT Delhi | Planned as scheduled. |

# Schedule of ROC Conclave at IIT Delhi on Nov 9, 2024

| Time | Description |
|---|---|
| 8:45 to 09:15 | Registrations @ ME Seminar Hall (Block 2, 422), IIT Delhi |
| 09:15 to 09:30 | Welcome by Ms. Krunali Kadam |
| 09:30 to 10:30 | Inaugural Talk<br>Prof. S. K. Saha |
| 10:00 to 10:30 | ROC Journey<br>Dr. Abhijit Boruah |
| 10:30 to 11:00 | AMoRA: Modular Robotic Arm and RoboAnalyzer<br>Dr. Rajeevlochana G. Chittawadigi |
| 11:00 to 11:30 | Tea Break |
| 11:30 to 13:00 | Presentations by 6 Teams |
| 13:00 to 13:45 | Lunch |
| 13:45 to 14:15 | Robotics Technologies @ SVR Robotics<br>Ms. Krunali Kadam |
| 14:15 to 14:45 | Robot Simulation in Virtual/CAD Environment<br>Dr. Aik-Siong Koh (Hybrid Mode) |
| 14:45 to 16:15 | Presentations by 4 Teams |
| 16:15 to 17:00 | Results Announcement and Valedictory Function |
| 17:00 to 17:30 | Photo Session and High Tea |

# Introduction to ROC

A survey by the National Association of Software and Service Companies reported that India produces 15 Lakhs of engineering graduates every year of which 2.5 Lakhs only succeed in getting engineering job. In another report by India Today dated November 2019, it was stated that 80 percent of Indian engineers were unemployed in 2019. This indicates that a large percentage of our graduates lack the skills that employers need.

RoboAnalyzer-based Online/ Offline Competition (ROC) was rooted to address these issues. ROC was started by the Embedded Systems and Robotics Laboratory, Tezpur University in collaboration with the two main developers of it, Professor Subir K. Saha from IIT Delhi and Dr. Rajeevlochana G. Chittawadigi, Amrita Vishwa Vidyapeetham, Bengaluru Campus. It aims to develop creative thinking ability for instilling technology-management skills among the budding engineers to create innovative solutions for indigenous problems.

In ROC spanning from 2020 to 2024, the young minds have been trained with the knowledge of robotics, which acted as the platform to develop skills of collaborative learning, creative thinking, time management, respect to multiculturalism through the motto of "Self-Driven, Self- Learning and Self-Evaluating" (an S3-approach of learning). All the activities of the participants are systematically recorded online (www.tezu.ernet.in/erl and www.roboanalyzer.com) for ready reference by the prospective learners and employers. Enthusiastic participation of young minds from India, Hong Kong, Romania have been encouraging to take the ROC to next higher levels every year.

In 2024, ROC geared up with the collaboration of SVR Robotics, Pune and ROC Conclave has been introduced on November 9 , 2024 in IIT Delhi.

Prof. Nayan M. Kakoty
Tezpur University, Assam

# Journey of ROC

It is a great pleasure to see that we could continue ROC, i.e., RoboAnalyzer (RA) based Online Competition, for the fifth consecutive year since COVID period in 2020. In this edition, we are meeting physically at IIT Delhi for the final presentations. I thank SVR Robotics Pvt Ltd for sponsoring this event.

I am eagerly looking forward to the young students who are making their efforts to come from far way distances. At the same time, this booklet which resembles a conference proceedings will provide as much value as a proceeding does, mainly, in the area of various usages of the RA software.

Thanks to Nayan, Rajeev and Abhijit for being with the ROC since its inception.

Special acknowledgments to the team members of SVR, Mr. Viinod Atpadkar, Ms. Krunali Kadam & Ms. Maya Dhanani, ROC 2023 participant Mr. Krushna Tathe as a support member, and to all others including participants for making their efforts to conduct this event.

As the abbreviation sounds let us "rock" the show!

Prof. Subir K. Saha
IIT Delhi

# Importance of Indigenous Products

Robotics has been a technologically advanced topic ever since the first set of industrial robots were developed in 1960's. Thereafter many developing countries have successfully designed robots and deployed them in industries, space, healthcare and on field.

Though one can start using foreign products, the following are the main problems associated with it:

1. **Technical knowhow is Missing:** The users get the product as a black box and any suitable changes to suit Indian demand may not be possible or it could be slow to implement by the parent company.

2. **Over Dependent on Others**: In situations like Covid-19, the technologies imported from abroad have a lot of dependencies and may stop or slow down the productivity in the country.

3. **Import Costs:** Any product imported has to be paid in Customs Duty and hence the cost of the product almost gets doubled, thereby making them expensive.

To overcome all of these, we should strive hard to develop products inhouse and ensure that there is an ecosystem for it to prosper ahead and serve its purpose.

Significant attempts have been made by Indian organizations and companies to leave a mark in the field of robotics. Some of them are DRDO, CSIR Labs, ISRO, MTAB, Systemantics, TAL, IdeaForge, GreyOrange, Addverb, Botlab Dynamics, SVR Robotics Pvt Ltd and Orangewood to name a few.

On similar notes, the development of RoboAnalyzer software was actively started in 2009 in the Mechatronics Lab at IIT Delhi, New Delhi, under the able supervision of Prof. Subir K. Saha. It has been almost 14 years since then and we have been able to touch the lives of thousands of teachers, students and researchers who begin engaged in learning robotics.

The feedback from the users has motivated us to keep up the development of RoboAnalyzer. We look forward to younger members to join our team, and one way to get involved and get our attention is by participating in RoboAnalyzer based Online Competition (ROC) held every year.

Finally, we wish all the participants of ROC 2024 to succeed in their lives and help the country in making it independent, along the lines of "Atmanirbhar Bharat".


Dr. Rajeevlochana G. Chittawadigi

Amrita Vishwa Vidyapeetham, Bengaluru Campus

# Story of RoboAnalyzer as a Product

RoboAnalyzer has been in active development since 2009 at IIT Delhi. It was distributed for free through its website www.roboanalyzer.com since then.

Due to its simple-to-use interface and extensive utility, it has been used by teachers and students to teach and learn the concepts of Denavit-Hartenberg (DH) parameters, forward and inverse kinematics, forward and inverse dynamics, motion planning, etc.

However, as time progressed, the following observations were made:

1. As RoboAnalyzer was freely available, many labs and institutes in India were not able to spend their allocated budget to buy RoboAnalyzer. Many of them bought robot simulation software developed from other countries. This not only allowed money from India going abroad, but also gave an impression that the foreign products were better.

2. Any item obtained for free may not be valued by end-user. This is similar to having an open-gym in a park. As it is available for free, users may not use it optimally thinking they can use it anytime. However, if one signs up for a membership in a gym by paying upfront, the individual shall likely start using the gym to recover the amount paid.

Based on the above two arguments, SVR Infotech could convince Prof. S. K. Saha and Dr. Rajeevlochana G. Chittawadigi to let us own up the Commercialization Rights for RoboAnalyzer and an MoU was signed between FITT-IIT Delhi and SVR Infotech on Feb 2, 2022.

RoboAnalyzer Version 8 onwards has been sold by SVR Infotech and so far 405 licenses have been sold to 15+ institutes/organizations. With the new modules and potential addition of hardware integration with RoboAnalyzer, we are confident of making the software grow further and help the teachers, students and researchers.

ROC 2024 is another avenue where we would like to reach out to the users of RoboAnalyzer and we are very proud to be associated with it.

Looking forward to capture some great talents during ROC 2024.

Mr. Viinod Atpadkar

CEO

SVR Robotics Pvt Ltd

# Team No. B2

Nehal Rane, Harshit Bharambe, Manav Jori and Saheli Sarkar

## Workflow

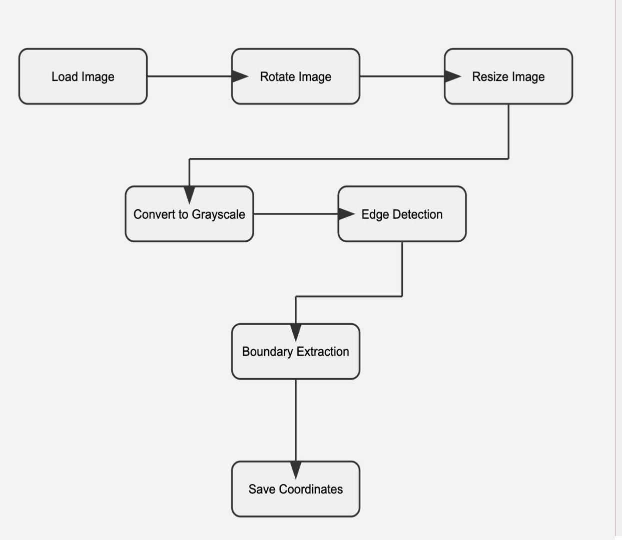
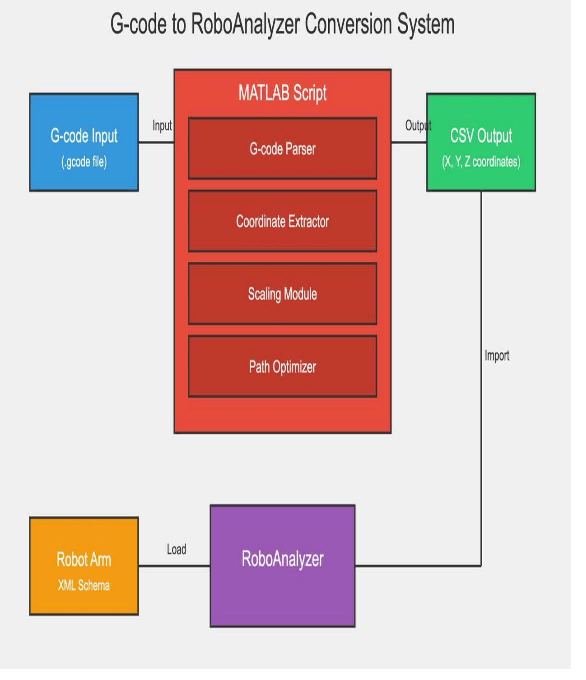
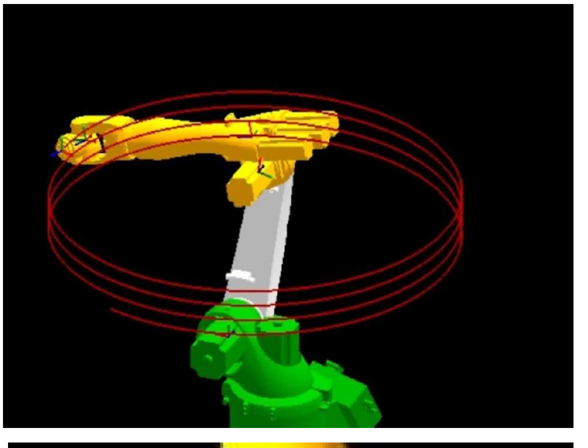
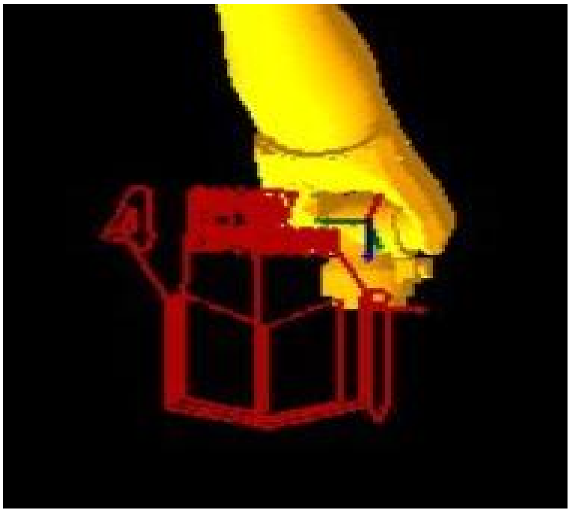



fig. Image-to-Coordinates Flow



## Motion in VRM

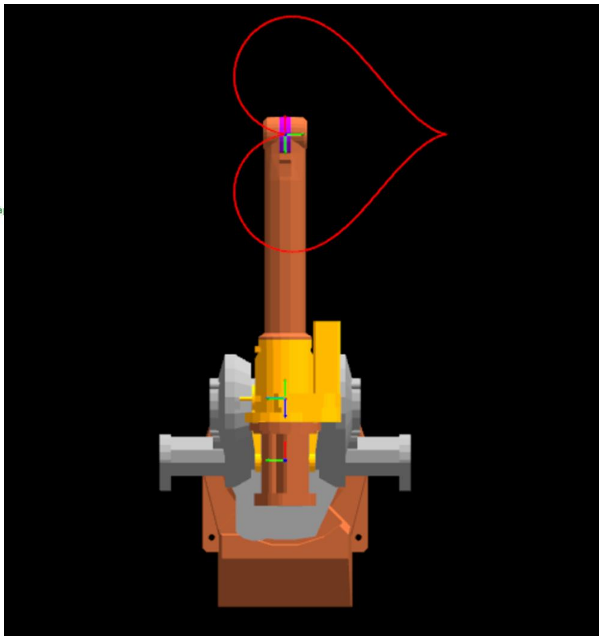


# Team No. B5

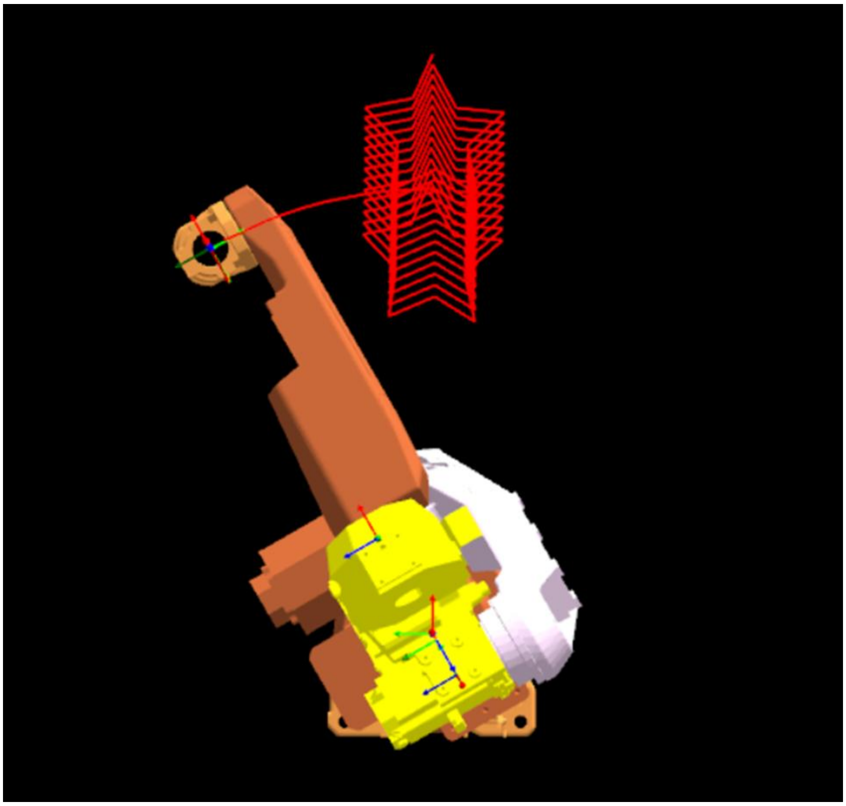
Adarsh Ramvishal Yadav and Varsha Megha V

## MATLAB Code to generate 3D Trajectory

```matlab
% MATLAB code to generate a star shape with initial XYZ values and save to CSV

% Parameters
scale_factor = 10;  % Scaling factor for size adjustment

% Initial XYZ values for the 6R robot
initial_x = 790;
initial_y = 0;
initial_z = 1150;

% Number of points in the star
n_points = 5;

% Star radius
r_star_outer = scale_factor * 10; % Radius for outer points
r_star_inner = scale_factor * 5;   % Radius for inner points

% Angle theta for the star points
theta_star = linspace(0, 2*pi, 2*n_points + 1);  % Include first point again to close the sha

% Parametric equations for the star
x_star = zeros(1, 2*n_points + 1);
y_star = zeros(1, 2*n_points + 1);
for i = 1:n_points
    % Outer point (tip of the star)
    x_star(2*i - 1) = r_star_outer * cos(theta_star(i * 2 - 1)) + initial_x;
    y_star(2*i - 1) = r_star_outer * sin(theta_star(i * 2 - 1)) + initial_y;

        % Inner point (dips of the star)
        x_star(2*i) = r_star_inner * cos(theta_star(i * 2)) + initial_x;
        y_star(2*i) = r_star_inner * sin(theta_star(i * 2)) + initial_y;
    end

    % Close the star shape by repeating the first point
    x_star(end) = x_star(1);
    y_star(end) = y_star(1);

    % Z-coordinate
    z_star = zeros(size(x_star)) + initial_z;

    % Combine x, y, z into one matrix
    coordinates = [x_star', y_star', z_star'];

    % Save the coordinates to a CSV file
    csvwrite('star_shape.csv', coordinates);

    % Display the star shape with initial XYZ offsets
    figure;
    plot3(x_star, y_star, z_star, 'r', 'LineWidth', 2); % Star in red
    grid on;
    title('Star Shape with Initial XYZ (x, y, z)');
    xlabel('X-axis');
    ylabel('Y-axis');
    zlabel('Z-axis');
    axis equal;
    hold off;
```



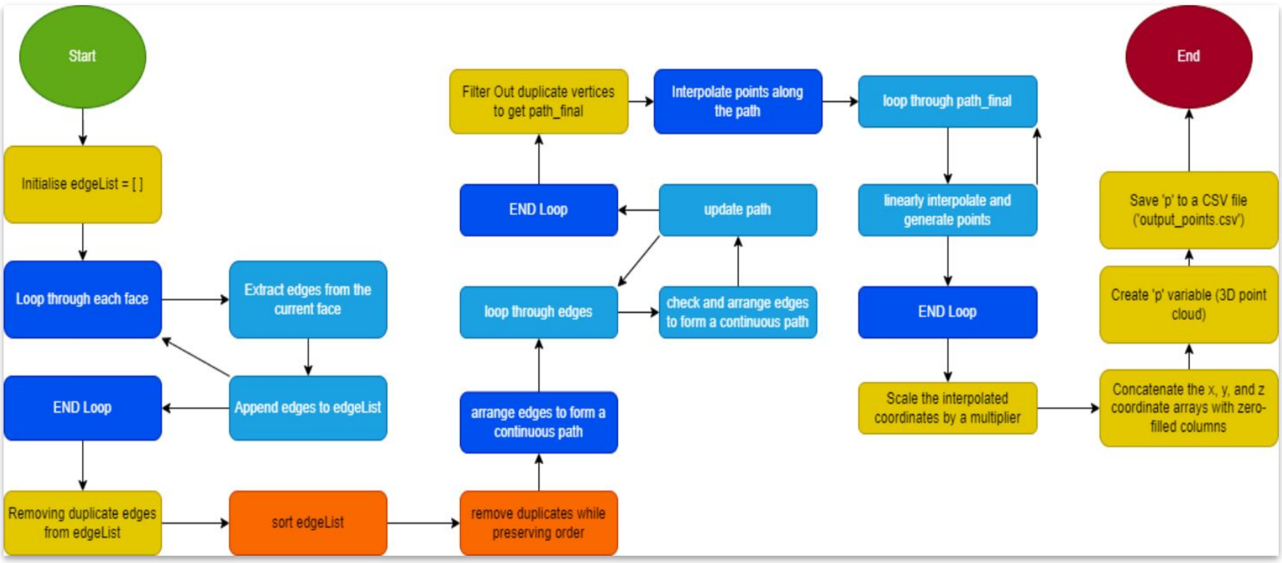
## Motion in VRM



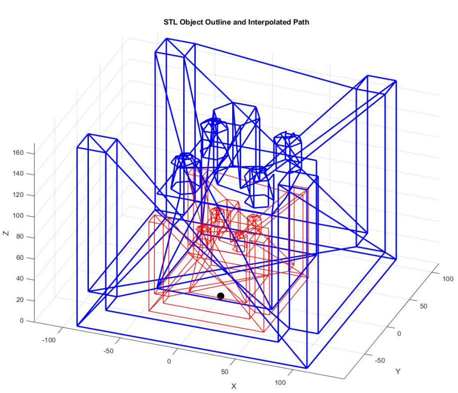
Team No. E3

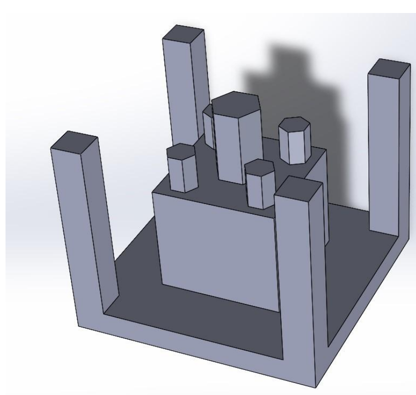
Rudra and Siddhi Bodhe

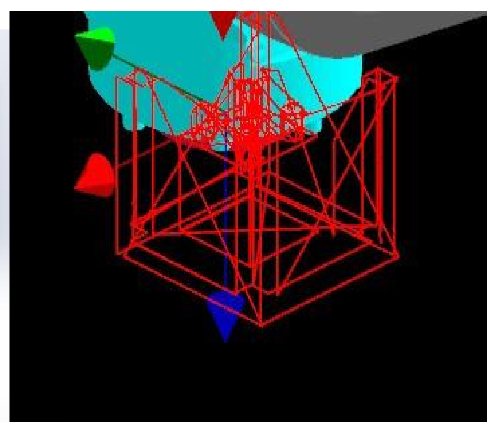
## MATLAB Program Algorithm for 3d Object Perimeter Tracing



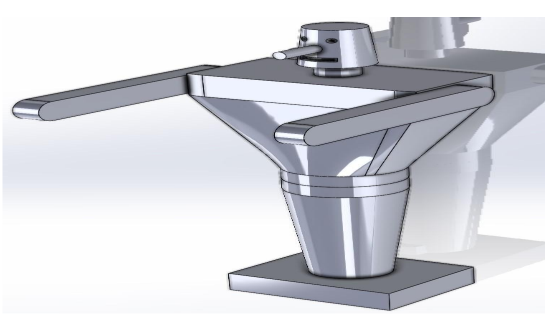

## Results of 3D Object Tracing With 6R Manipulator in VRM

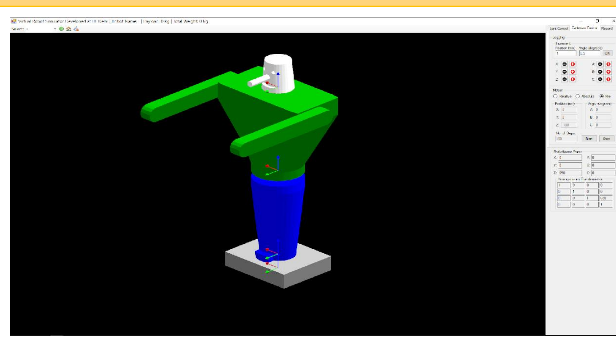




## Humanoid Robot Added in VRM

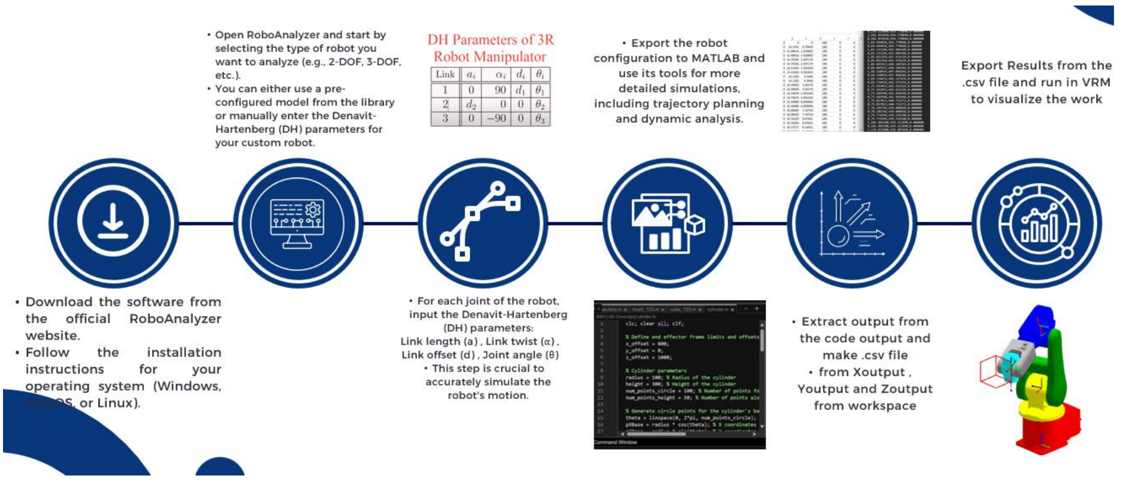




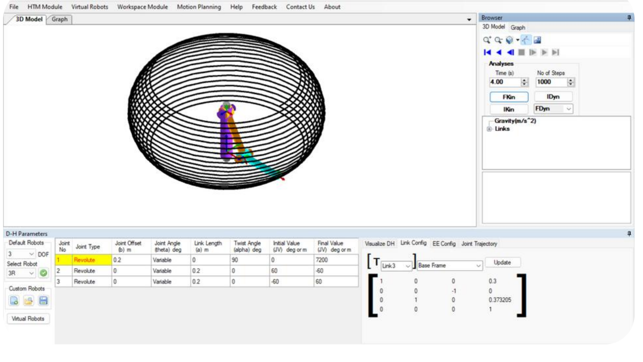
# Team No. E5

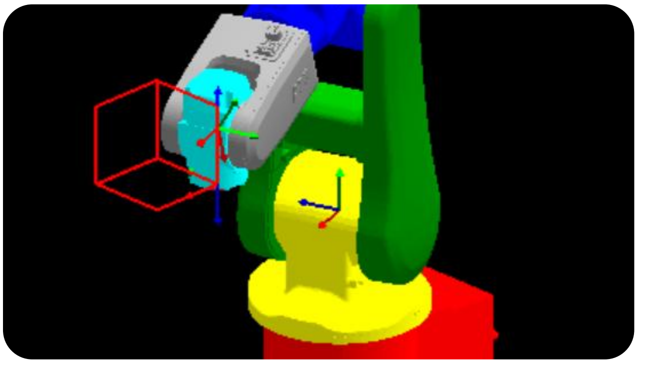
Ruchita Arun Zope

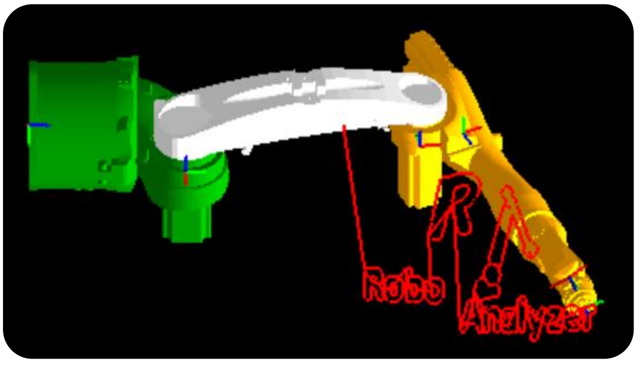
## Methodology

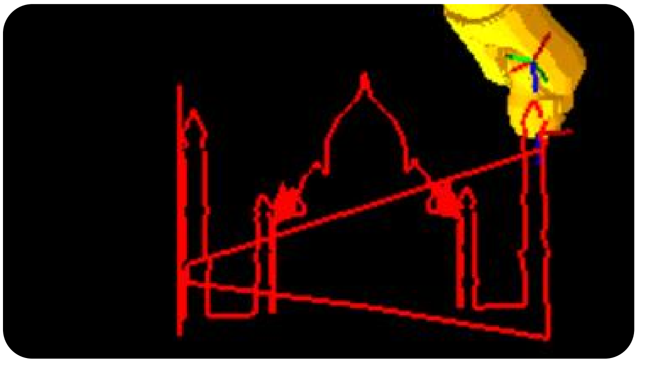



## Motion in VRM







The RoboAnalyzer based Online/Offline Competition (ROC) as Virtual Summer Internship
5th July – 9th November 2024
Conducted by Prof. Nayan M. Kakoty (Tezpur University), in collaboration with Prof. Subir K. Saha (IIT Delhi),
Dr. Rajeevlochana G. Chittawadigi (Amrita Bengaluru) and Industry Partner SVR InfoTech, Pune

# Integration of RoboAnalyzer and 3D Printing: A G-Code to Coordinate-Based Automated Fabrication System

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## 1. Introduction

This project explores the integration of the RoboAnalyzer Virtual Environment with 3D printing technology to create an automated system capable of generating objects based on specific coordinate inputs. RoboAnalyzer, a versatile and user-friendly simulation software, enables us to study the forward and inverse kinematics of robotic arms. In our project, we have developed a novel system that translates G-code, a standard in computer-aided manufacturing, into coordinate data for RoboAnalyzer. This process involves using MATLAB to convert image files into a series of XYZ coordinates, which are then simulated within the RoboAnalyzer environment. By doing so, we bridge the gap between simulation and real-world application, allowing us to validate the kinematics of the robotic arm before actual 3D printing Through this integration, our system serves a dual purpose: it acts as an educational tool for understanding robotic kinematics and DH parameters, while also enabling the fabrication of objects by following precise 3D spatial data. The optimization of this setup can further be enhanced by implementing inverse kinematics, allowing the robotic arm to efficiently reach target positions with minimal computation. This not only maximizes efficiency but also paves the way for more complex object creation by minimizing errors in path planning and execution. Our project aims to create a seamless link between simulation and fabrication, enhancing learning and accessibility in robotics, and providing a basis for future developments in automation and custom manufacturing. By demonstrating the potential of RoboAnalyzer to work alongside physical 3D printing systems, this study displays a practical application of robotics in manufacturing, with broader implications for industries where precision is paramount.

## 2. Project Architecture and Workflow

The main architecture of our project cantered around a G-code to RoboAnalyzer conversion system. This approach enabled us to use G-code files as input, transforming complex design and manufacturing data into a format compatible with the RoboAnalyzer virtual environment. The following describes our project's workflow in detail:

1. G-code Input and Conversion: We initiated the process by feeding a G-code file into a MATLAB script. This code, commonly used in 3D printing and CNC machining, contains instructions for layer-by-layer object construction. The MATLAB script parsed the G-code, converting it into a CSV file containing X, Y, and Z coordinates.
2. RoboAnalyzer Integration: After generating the CSV file, we imported it into the RoboAnalyzer environment. This step required loading the CSV data as an XML file into RoboAnalyzer, ensuring compatibility with the software's kinematics visualization tools. This allowed for effective simulation of robotic arm movements based on the input coordinates.
3. Image-to-Coordinate Mapping and Character Plotting: We extended our project to include image-to-coordinate mapping, allowing us to simulate object shapes directly from images. Additionally, we implemented character plotting, enabling the simulation of text-based objects, further broadening the potential applications of our system.
4. Optimization through Inverse Kinematics: Throughout the project, we explored the possibility of enhancing precision by integrating inverse kinematics. This would provide the ability to refine the path planning of the robotic arm, optimizing movement efficiency and accuracy in the 3D printing process.
5. Integration with 3D Printing: Our ultimate objective was to bridge RoboAnalyzer's virtual environment with physical 3D printing systems. By translating precise coordinate data into robotic movement, we aimed to create an automated 3D printing process that could fabricate objects from coordinate-based simulations.

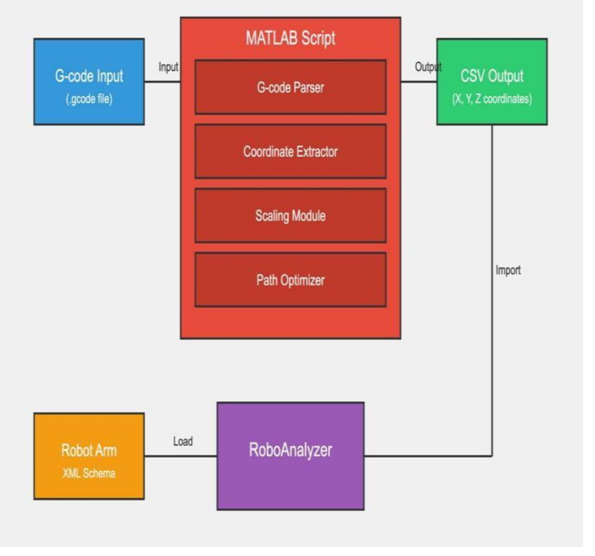



Figure1. G-Code to Roboanalyser conversion system

### 2.1. Image-to-Coordinates

The flow involves several steps to transform an image into coordinate data. First, the image is loaded, rotated if needed, and resized to standard dimensions. It is then converted to grayscale to simplify processing, followed by edge detection to highlight boundaries. From the detected edges, boundary extraction isolates the contours, and these are saved as coordinates. This streamlined process converts visual data into coordinate points, useful for applications like robotic path planning or 3D modelling.

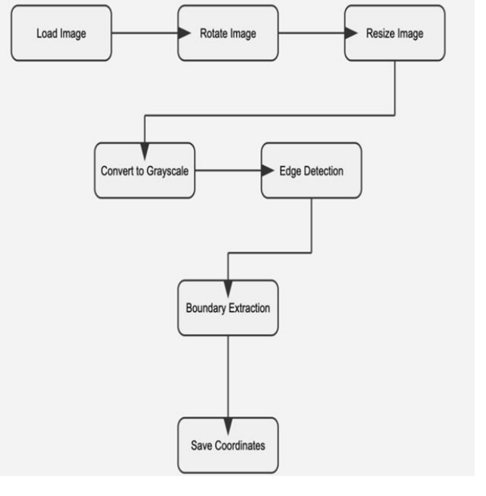



Figure 2. Image to Coordinates Flow

### 2.2. Characters Plot

This flow outlines the process of converting user input into a CSV file of character coordinates. It begins with User Input which is processed to identify individual characters (Character Processing) and then converted into coordinate points (Coordinate Generation). The next steps involve Spacing Calculation to determine appropriate character spacing and Coordinate Assembly to organize the points. These assembled coordinates form a matrix

(Matrix Formation), which is then exported as a CSV file. This process is useful for generating coordinate-based data for character visualization or plotting.

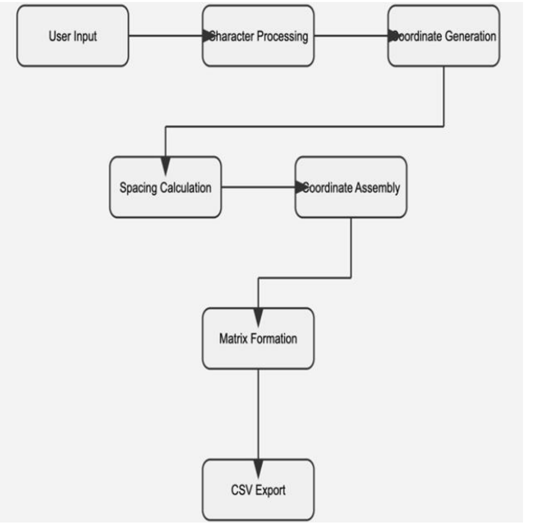



Figure 3. Character Plot

## 3. Outcomes

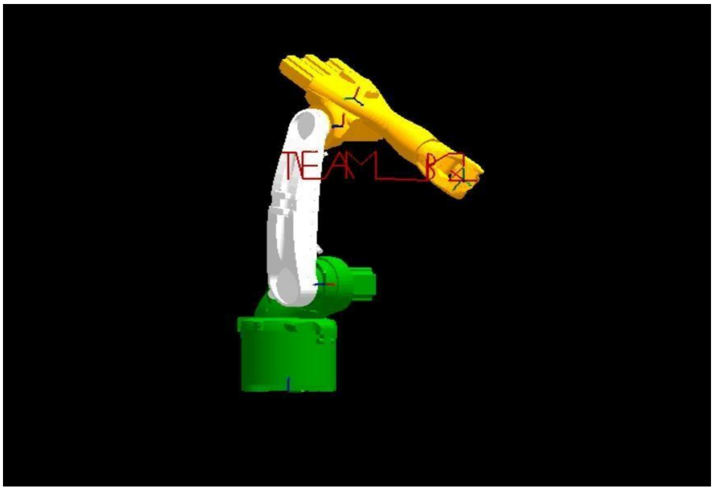
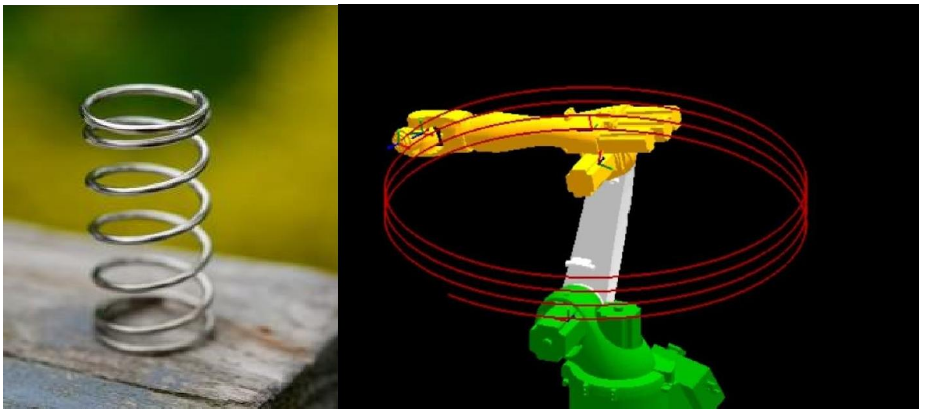


Figure 4. TEAM B2



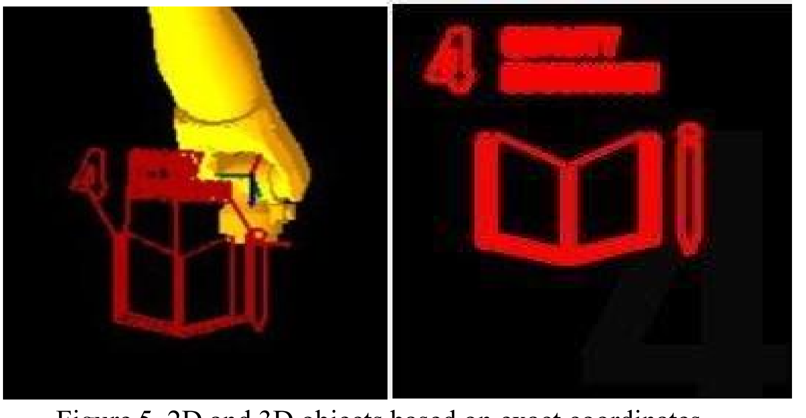


Figure 5. 2D and 3D objects based on exact coordinates

## 4. Results and Discussions

In this competition, we learnt about various robotics related concepts like degree of freedom, forward and inverse kinematics, DH parameters etc. Additionally, we also developed some soft skills like collaboration, teamwork, adaptability, presentation and many more. It helped us in gaining more insights and hands on experience on robotics.

## 5. Acknowledgment

We want to thanks to RoboAnalyzer team who uploaded the helpful videos in tutorial from which helped for successful completion of our task.

## 6. Reference

1 Krisbudiman, A., Nugroho, T.H. and Musthofa, A., 2021. Analysis industrial robot arm with Matlab and RoboAnalyzer. *International Journal of Advanced Engineering, Management and Science*, *7*(3), pp.75-80.

2 Rajeevlochana, C.G. and Saha, S.K., 2011, February. RoboAnalyzer: 3D model based robotic learning software. In *International Conference on Multi Body Dynamics* (pp. 3-13).

3 Sadanand, O.R., Sairaman, S., Sah, P.B., Udhayakumar, G., Chittawadigi, R.G. and Saha, S.K., 2015, July. Kinematic Analysis of MTAB Robots and its integration with RoboAnalyzer Software. In *Proceedings of the 2015 conference on advances in robotics* (pp. 1-6).

4 Video Lecture on RoboAnalyzer website RoboAnalyzer - RoboAnalyzer: 3D Model Based Robotics Learning Software: Home Page

5 Matlab

# Drawing 2D & 3D Paths with a 6-DOF Robotic Manipulator: A RoboAnalyzer Approach

**Adarsh Ramvishal Yadav***

*Robotics and Automation Engineering,

K. K. Wagh Institute of Engineering Education and Research, Nashik-422003, India, infinityy1008@gmail.com

## 1. Introduction

The RoboAnalyzer-based Online/Offline Competition (ROC) 2024, organized by Prof. Subir K. Saha (IIT Delhi), Dr. Rajeevlochana G. C. (Amrita Bengaluru), and Prof. Nayan M. Kakoty (Tezpur University), in collaboration with the industry partner SVR Robotics Pvt. Ltd., Pune, revolved around the theme of achieving the United Nations Sustainable Development Goals (SDGs) through robotics.

Our project focused on SDG 9: Industry, Innovation, and Infrastructure, emphasizing the role of robotics in building resilient infrastructure, fostering innovation, and promoting sustainable industrialization. This initiative aimed to demonstrate how advanced robotic solutions can contribute to global sustainability objectives while addressing real-world challenges.

## 2. Methodology

Our project utilized MATLAB and RoboAnalyzer to create and analyze robotic trajectories and explored the integration of multiple tools for 2D image generation using a 6-DOF robotic manipulator in the Virtual Robot Module of RoboAnalyzer.

### 1. Design Approach

Sustainable Focus: Aimed to support SDG 9 by addressing challenges in automated manufacturing systems.

Tools Used: Canva, Inkscape, CAD2Shape, MATLAB, and RoboAnalyzer.

### 2. Implementation Steps for 2D Image Drawing

Design and Conversion Process:

Step 1: Created 2D images in Canva and saved them as SVG files.

Step 2: Imported the SVG files into Inkscape software to convert them into DXF format.

Step 3: Used CAD2Shape to convert the DXF files into CSV format, obtaining X, Y, Z coordinate data in an Excel sheet.

Step 4: Manually defined the theta values in the Excel sheet to ensure compatibility with RoboAnalyzer.

Step 5: Input the corrected CSV file into the Virtual Robot Module of RoboAnalyzer to draw the 2D images using a 6-DOF robotic manipulator.

Trajectory Design:

MATLAB was used for generating trajectories and simulating tasks such as welding and additive manufacturing.

## 3. Results and Discussions

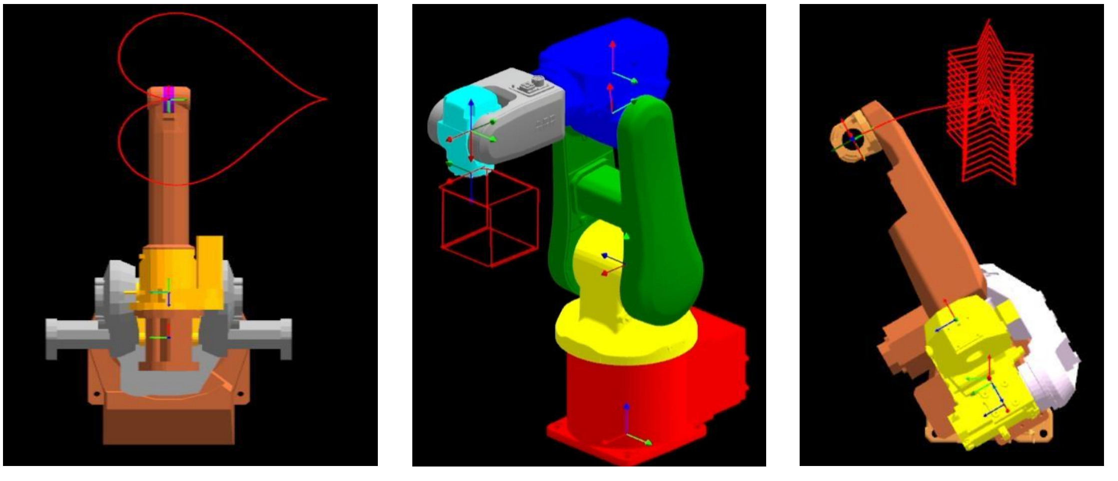


Figure 1: Drawing 2D and 3D Trajectories

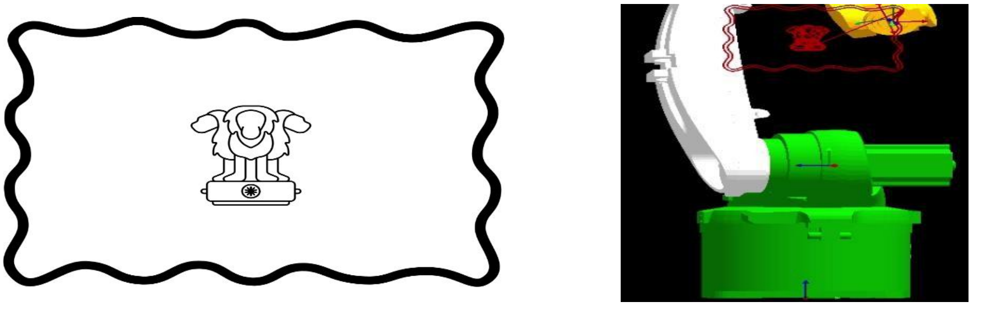



Figure 2: Image to VRM Output

**Applications:**

- Successfully implemented the process to draw precise 2D images in RoboAnalyzer, demonstrating its potential for industrial applications such as laser cutting, welding, and precision manufacturing.
- Highlighted the use of articulated robots for pick-and-place tasks and additive manufacturing in industries such as electronics, pharmaceuticals, and food processing.

**Outcome:** Generated collision-free, accurate robotic trajectories for both 2D and 3D designs, showcasing efficiency in industrial task execution.

**Sustainability Impact:** Showcased how robotics can reduce human effort and enhance energy efficiency in industrial processes.

## 4. Conclusion

This project demonstrated the seamless integration of multiple software tools to achieve precise robotic simulations and trajectory planning. By contributing to SDG 9, our work underscores the role of robotics in fostering sustainable automation solutions.

## 5. Acknowledgements

We extend our gratitude to Prof. Subir K. Saha, Dr. Rajeevlochana G. C., and Prof. Nayan M. Kakoty for their guidance, and to SVR Robotics Pvt. Ltd. for their support and sponsorship. Special thanks to the organizers of ROC 2024 for providing this platform for innovation.

## 6. References


1 Saha. S. K., 2014. Introduction to Robotics (2nd edition). McGraw-Hill.

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4 MATLAB. https://www.mathworks.com/products/matlab.html (Accessed: October 2024)

5 United Nations Sustainable Development Goals. https://sdgs.un.org/goals (Accessed: October 2024)

6 Canva. https://www.canva.com/en_in/ (Accessed: October 2024)

7 Inkscape. https://inkscape.org/ (Accessed: October 2024)

8 CAD2Shape2020. https://www.guthcad.com/download/cssetup.exe (Accessed: October 2024)

# Motion Planning of 6R Virtual Robots in RoboAnalyzer to Draw Perimeters of 3D Objects Using MATLAB and Importing a Custom Humanoid Robot in Virtual Robot Module

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## 1. Introduction

The ROC-2024 competition showcased robotics' potential in complex environments, emphasizing movement beyond linear paths or flat surfaces. This project utilized inverse kinematics to map and trace the perimeter of images and 3D objects with precise robotic control. MATLAB was used to analyze 3D models and generate an ordered coordinate list along the object's edges, which guided the robotic arm's end-effector. These coordinates were integrated into RoboAnalyzer's Virtual Robot Module (VRM), converting them into joint angles to simulate motion.

Additionally, a humanoid robot was incorporated into the VRM module, extending the simulation's scope to replicate more dynamic and versatile tasks. This integration highlights the adaptability of the system for applications requiring precision, such as medical procedures or advanced manufacturing. The synergy between MATLAB and RoboAnalyzer provided a robust solution for advancing robotic motion in intricate 3D environments.

## 2. Methodology

### 1. Drawing images in VRM

Black and White Images were analyzed using MATLAB to extract boundaries and generate CSV files. These guided 2R and 6R robots in tracing images with optimized paths and precision.

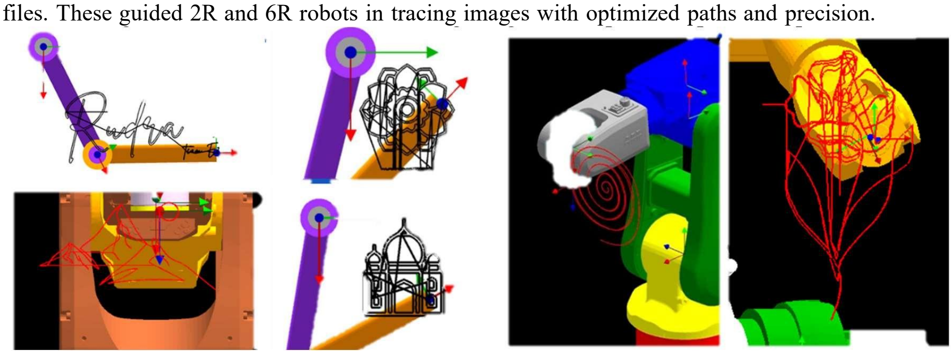

Figure 1: Output in of images drawn in VRM

### 2. Tracing 3D models in VRM

#### 1. 3D Model Creation and STL File Preparation:

Any 3D modeling software may be utilized for this, provided that the file is saved in the .stl format. An STL file is essential because it converts all faces into triangles upon saving, thereby simplifying the subsequent step.

#### 2. Using MATLAB to get coordinates of all the edges of the model and exporting them to a CSV file

The **`stlread()`** function extracts a triangulation of the `.stl` file, comprising vertices (`Points`) and face connectivity (`ConnectivityList`). The program processes this triangulation to determine and sort edge start and endpoints, arranging them into a continuous path while taking into account a tolerance to skip edges which wouldn't contribute much to the overall shape defintion. Linear interpolation generates a coordinate list for the end effector, which is saved as a CSV file via `writematrix()` for VRM utilization.

### 2.2.3. Output from VRM

RoboAnalyzer's Virtual Robot Module (VRM) is highly user-friendly, requiring only the input of the generated .csv file to perform inverse kinematics for any type of robot. Presented below are a few results from the VRM simulations:

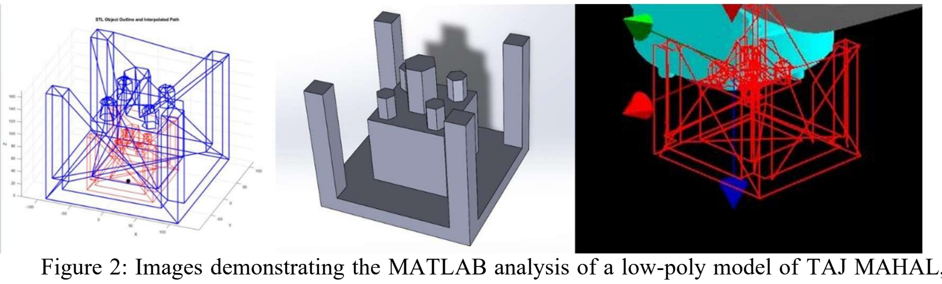

Figure 2: Images demonstrating the MATLAB analysis of a low-poly model of TAJ MAHAL, it's STL file, and the output in VRM.

## 2.3. Adding a Custom Humanoid Robot to VRM

A 3-DOF humanoid robot was integrated into the Virtual Robot Module (VRM) by designing its components in SolidWorks and generating a detailed .xml file. The file defined the robot's joint types, limits, and link properties while also specifying colors and configurations, ensuring seamless integration and realistic simulation in the virtual environment.

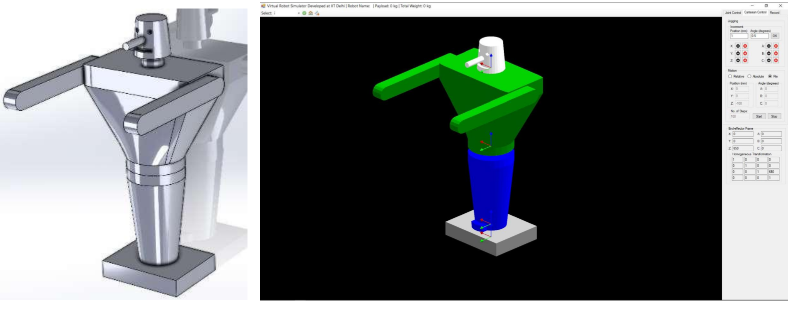

Figure 3: Design of the Humanoid Robot in SolidWorks and the Imported model in VRM

## Results and Discussions

The ROC-2024 competition explored robotic motion in 3D environments using RoboAnalyzer and MATLAB. Images and 3D objects were analyzed to generate paths for robotic arms to trace perimeters with precision. A humanoid robot was also integrated into RoboAnalyzer's Virtual Robot Module, showcasing adaptability for advanced applications like surgical tasks or 3D printing.

## Resources

- GitHub Repository of all the MATLAB Codes:
  https://github.com/Rudy8k/ROC_Team_E3.git
- YouTube Playlist of Videos Demonstrating working of Robots in VRM:
  https://www.youtube.com/playlist?list=PL7k_2mOzFOSMtMtzKGQf5nhEdib64sE8r


## Acknowledgements

We would like to thank **Prof. Nayan M. Kakoty**, **Prof. Subir K. Saha** and **Dr. Rajeevlochana G. Chittawadigi** for providing us with this opportunity to work on this project and also creating very detailed and informational lecture series on RoboAnalyzer which greatly helped us in this endeavour.

We would also like to extend our thanks to **Ms. Krunali Kadam** for aiding us in tasks throughout the competition.


## References


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2 RoboAnalyzer. (2024). Video Lectures. Retrieved August 12, 2024, from http://www.roboanalyzer.com/video-lectures.html

3 Saha. S.K.: Introduction to Robotics (2nd edition). McGraw-Hill, 2014.

# Designing and Visualizing Robotic Tasks for Sustainability Using MATLAB and VRM

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## 1. Introduction

The RoboAnalyzer-based Online/Offline Competition (ROC) 2024, hosted by IIT Delhi in collaboration with SVR Robotics Pvt. Ltd., Pune, and supported by Prof. Subir K. Saha, Dr. Rajeevlochana G. C., and Prof. Nayan M. Kakoty, encouraged participants to leverage robotics for achieving the United Nations Sustainable Development Goals (SDGs).

This project specifically explored the potential of robotics in industrial automation, construction, and infrastructure maintenance to enhance efficiency, reduce energy consumption, and promote sustainability. Through the use of RoboAnalyzer and MATLAB, the project simulated various robotic tasks aligned with SDG 9: Industry, Innovation, and Infrastructure.

## 2. Methodology

The project utilized RoboAnalyzer software and its Virtual Robot Module (VRM) for designing and simulating robots capable of performing tasks in industrial and construction environments.

### 1. Setup and Configuration

1. Installation and Setup:

Downloaded RoboAnalyzer from its official website and installed it.

Configured the robot model by inputting Denavit-Hartenberg (DH) parameters, including link length (a), link twist (α), link offset (d), and joint angle (θ).

2. Simulation in MATLAB:

Exported robot configurations to MATLAB for detailed simulations, including trajectory planning and dynamic analysis.

Extracted X, Y, and Z coordinate outputs to generate a CSV file for VRM.

3. Visualization in VRM:

Input the CSV file into RoboAnalyzer's VRM for simulating robotic tasks and visualizing the robot's motion.

**2.2 Demonstrations**

Using the VRM, various intricate shapes and paths were simulated to showcase the versatility and precision of the robots. The following were successfully drawn:

- Pick and Place Operation
- Taj Mahal
- India Gate
- RoboAnalyzer Logo
- Personal Name

## 3. Results and Discussions

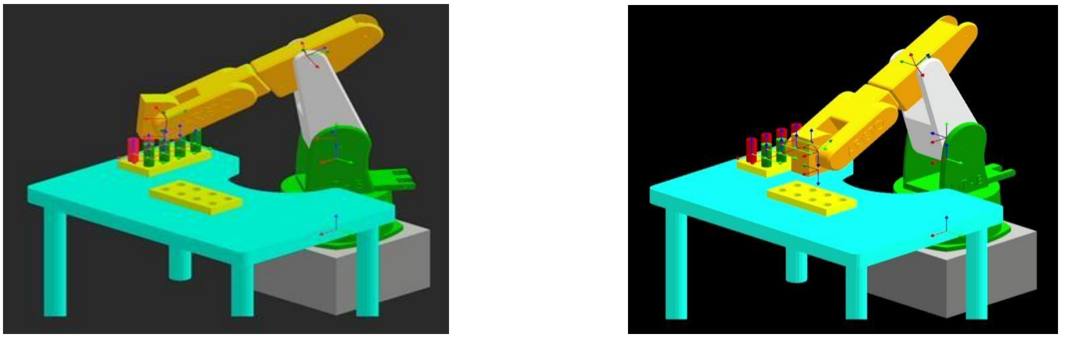
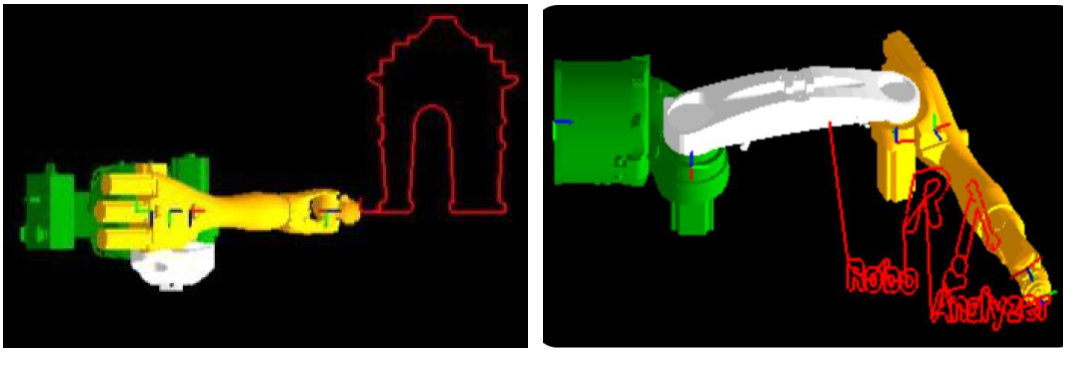


Figure 1: Simulated Pick and Place Operation



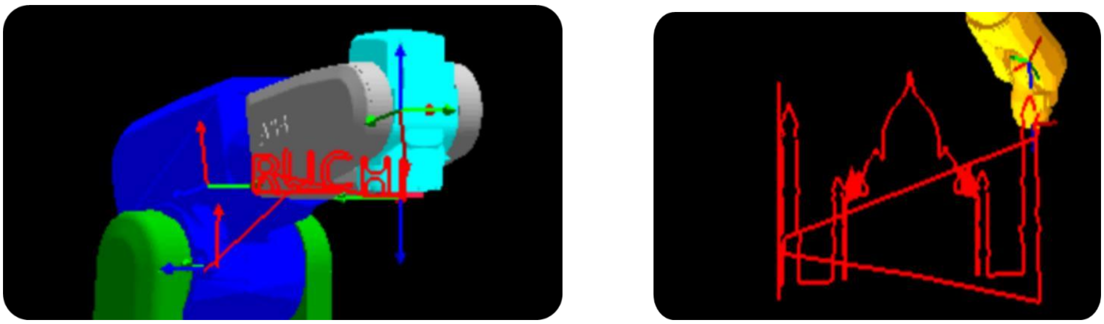



Figure 2: Image to VRM Output

**Applications:**

The project demonstrated the versatile application of robotics in industrial processes by simulating a Pick-and-Place Operation using RoboAnalyzer software. This operation highlights the ability of robots to:

1. Perform repetitive and precise tasks in industries such as manufacturing and assembly.
2. Enhance efficiency in material handling and component placement.
3. Improve workplace safety by automating tasks in hazardous environments

**Outcomes:**

- Successfully executed and visualized the Pick-and-Place operation in RoboAnalyzer's Virtual Robot Module (VRM).
- Showcased the precision and reliability of robotic systems in industrial automation tasks.
- Demonstrated the potential of robotics to reduce human effort, minimize errors, and optimize industrial workflows.

## 4. Conclusion

This project successfully illustrated how robotics can contribute to achieving SDG 9 by enhancing industrial automation and promoting sustainability. The use of RoboAnalyzer and MATLAB enabled the design and simulation of precise robotic tasks, paving the way for more resilient and innovative infrastructure solutions.

## 5. Acknowledgements

I extend my gratitude to Prof. Subir K. Saha, Dr. Rajeevlochana G. C., Prof. Nayan M. Kakoty, and SVR Robotics Pvt. Ltd., Pune, for their guidance and support. Special thanks to the ROC 2024 organizers for providing this incredible opportunity to innovate and learn.

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1 Saha. S. K., 2014. Introduction to Robotics (2nd edition). McGraw-Hill.

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6 Inkscape. https://inkscape.org/ (Accessed: October 2024)

7 CAD2Shape2020. https://www.guthcad.com/download/cssetup.exe (Accessed: October 2024)

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# Modality

This online & offline event “RoboAnalyzer based Online Competition (ROC) as Virtual Summer Internship” was conducted by Embedded Systems and Robotics Lab, Tezpur University, in collaboration with the two main developers of the RoboAnalyzer software, Professor Subir K. Saha, Indian Institute of Technology Delhi and Dr.Rajeevlochana G. Chittawadigi, Amrita Vishwa Vidyapeetham, Bengaluru & Industry Partner SVR Robotics.

# Previous Versions of ROC

Details and the results of ROCs held in 2020, 2021, 2022 and 2023 are available at www.tezu.ernet.in/erl and www.roboanalyzer.com

# Organizing Team

- Prof. Nayan M Kakoty, Tezpur University, Assam
- Dr. Abhijit Boruah, Dibrugarh University, Assam
- Dr. Rajeevlochana G. Chittawadigi, Amrita Vishwa Vidyapeetham, Bengaluru
- Prof. Subir K. Saha, IIT Delhi, New Delhi.
- Ms. Krunali Kadam, SVR Robotics

# Industry Partner and Sponsor