HackRush 2024 - IITGN Hackathon

What is a Hackathon?

A hackathon is an event where people collaborate to solve real-life problems in a finite span of time. Hackathons are popular competitive events in the software industry and in universities due to their benefits to both the participants and the organisers. A hackathon aims to solve a problem from scratch and develop a working prototype.

Watch this TEDx talk: https://youtu.be/6VakF2hZFPQ

Why participate?

For the participants, a hackathon is a fun and risk-free opportunity to showcase their talent, challenge themselves, network with peers, learn new skills, and give life to their ideas.

Team Registration

Team registration: https://hackrush-24.devfolio.co/overview

Website & FAQs

You can access the HackRush website from here.

You can access the FAQ document here.

Submission

Each problem statement has its own detailed submission guidelines. You can submit your solution here - https://forms.gle/iPcPjYwaJ6bXPr9e6

About this document

This document contains the problem statements for the HackRush 2024. You'll present your solution, or progress towards a solution, on **Sunday - April 14 2024, at 12 PM**.

In some problems, we want you to devise a solution to a particular (and mostly - very important) problem, given certain constraints. These are marked **[S]**.

Other problems are framed as competitions wherein participants will be pitted against each other, and winners will be decided at the end of the Hackathon. These problems are marked **[C]**.

The problem statements are not exhaustive. They are meant to give you a general idea about what the problem is and guidelines you should follow to solve it. We have only provided details if they are crucial for understanding the problem. Make your assumptions and prepare your models.

You can work in teams. You can consult friends and faculty (make sure you acknowledge this).

We're sure that solving some of these problems will teach you a lot. Even if you can't solve them completely - it should be a great learning experience.

Note: The respective stakeholders will decide the prize distribution for all the problem statements.

Problem Statements

1 [A]: E Gate [Track: Software Development]

Difficulty Level: Intermediate
Stakeholders: Reuben Devanesan , Kanishk Singhal

Background

- Our institute's current gate entry system relies heavily on manual verification processes, creating inefficiencies and security vulnerabilities.
- Every resident of IITGN must present their ID card upon entry, while outsiders visiting the college are required to exit from their vehicles and register their entry manually.
- This system not only causes delays but also lacks adequate security measures, as it is prone to human error and unauthorised access.
- Similar to the Mess QR code system, we could implement something to resolve this problem.

Features

The problem statement is open-ended, and we encourage participants to develop efficient and user-friendly system designs. Your application should also have a responsive interface, allowing users to utilise it from any device with internet connectivity.

To give a quick start we have provided the basic requirements and some additional features of the system below:

Basic Requirements:

- The system needs to be publicly accessible in the form of a website or application.
- One possible implementation of the system is it having three interfaces: Resident, Visitor and Security Personnel. More detailed information is below.

- Resident Interface:
  - Each resident of IIT Gandhinagar has their own permanent QR Code that can be scanned by the security guards. This can serve as an alternative to showing ID Cards / Email IDs as and when required.

- Visitor Interface:
  - Visitors should be able to register themselves to the website/ application.
  - They should be able to generate auto-expiring QR Code for their visit.

    - Auto-expiring QR Codes:
        - These QR Codes are generated for visitors only and are based upon the time of their entry and exit as put in by the user.
        - The QR Codes should expire as soon as the time is over and the user should be notified about the same.
        - On exit, these QR Codes need to be scanned again. One entry and one exit scan should expire the QR Code.

- Security Personnel Interface:
    - Each user should be able to scan the QR Code shown by the resident/visitor and then be able to verify the details of the person.
    - Security personnel should be notified of visitors whose QR Codes have expired but haven’t yet exited the campus (haven’t done the exit scan).
    - However, these notifications should be silent and easily dismissed.
- Your application should also maintain a centralised database of visitors, including their entry and exit times. This data will be accessible to authorised personnel for security and administrative purposes.

Extra Features:

- Guest Mode:
    - Similar to the visitor interface but for one-time visits (faster sign-in and one-time generation of auto-expiring QR codes)
- Residents can also generate auto-expiring QR Codes for their visitors and specify the time [within the stipulated maximum time] they are going to be visiting IITGN.
- Implement additional layers of visitor authentication, such as mobile phone verification, to ensure that visitors are who they claim to be before generating QR codes.
- Displaying the statistics and additional visualisations including frequency of visits through the day, etc.

Note: The above mentioned requirements are based on a sample system design proposed by the stakeholder. You are encouraged to come up with a more efficient and easy to use system and implement it.

Feel free to discuss your ideas with the stakeholders.

Development Resources:

We expect you to build a web application preferably. You are also *free to use the tech-stack of your choice* apart from the below mentioned:

- NodeJS, Django, PHP, MongoDB, MySQL, FastAPI, Postgres (backend & database)
- ReactJS, AngularJS, Bootstrap, HTML, CSS (frontend)
- Google Firebase (All in one service for faster development)

Submission Guidelines:

You will be asked to submit the following:

- Link to your deployed application.
- Link to your GitHub repository that contains all the code. Ensure that the visibility of the repository is set to public.
- A presentation [pptx or pdf] talking about your application: Tech Stack, Schemas, Challenges Faced, and Future Work.

1 [B]: Exploring the Future of Content Consumption and Creation

[Track: Software Development]

Stakeholder: Sanskar Sharma, Saatvik Rao

Introduction:
In today's digital age, how we consume and create content constantly evolves. Just as YouTube revolutionised video sharing and platforms like Vine and TikTok transformed it further with vertical video content consumption, we are now at the cusp of another shift in the content consumption landscape. This open-ended challenge invites participants to envision and develop a web application that explores the future of content consumption and creation.

Challenge Overview:
Participants are tasked with conceptualising and building a web application that redefines how users interact with content. This application should anticipate emerging trends and technologies, catering to content creators' and consumers' evolving preferences and behaviours. OR, you can just go haywire and show us your craziest ideas. We want you to tackle this challenge with all the creativity you have. And most importantly, we need you to have fun building it!

Deliverables:
At the end of the hackathon, you are expected to show a working demo of your project. We will conduct a presentation where you must present your demo to the judges.

This working demo should be a working web application. Bonus points if it is deployed.

"Everyone wants to create the most impressive website they've ever seen right from the start. They aim to showcase it for recognition and admiration from others, striving to produce something worthy of praise. Many of us aspire to build our dream website immediately and dazzle everyone with our skills. However, it's advisable not to pursue that ambition as your first website.

Attempting to create your dream website is akin to challenging the final boss at level one. You need to start by gaining some expertise through smaller tasks. You need to understand what type of developer you are and discover the kinds of websites you enjoy creating, not just those you enjoy browsing. Finding your style and carving out your niche in the world of web development is crucial. We all have a unique voice, and creating something small helps you find yours.

This doesn't imply that you must tediously go through tutorials or embark on numerous projects that may never see the light of day. Instead, it means you should develop a small website to release it and receive feedback to help you progress."

Resources:

- Frontend Deployment: https://vercel.com/docs/deployments/overview
- Server Deployment: https://docs.render.com/free

Submission Guidelines:

You will be asked to submit the following:

- Link to your deployed application.
- Link to your GitHub repository that contains all the code. Ensure that the visibility of the repository is set to public.
- A presentation [pptx or pdf] talking about your application: Tech Stack, Schemas, Challenges Faced, and Future Work.

2. Cyber Security: HackRushCTF [C]

Stakeholder: Pratyush Choudhary

This category introduces you to the world of **Hacking and CyberSec**. If you are interested in developing a deeper understanding of Computers, how attackers leverage vulnerabilities, and how to avoid them, this event is for you. The types of challenges will range from cryptography, poking holes in random parts of various software, and exploring the world of computer applications.

HackRushCTF will be a 36-hour Jeopardy-style Capture the Flag (CTF) event. Your main goal is to collect as many flags as possible. But wait, **what is a CTF**?
Refer here: https://ctfd.io/whats-a-ctf/

HackRushCTF is beginner-friendly, i.e., you don’t need prior knowledge in this field to participate. The only prerequisite is an interest in learning. Your greatest tool is Google/bing/quant/start page (shameless plugs for other privacy-focused search engines. Use Firefox + uBlock Origin, Don’t see Youtube Ads). You are free to use ChatGPT as well, though only because I had to make questions that it couldn’t solve by itself(here’s to hoping).

Please note that the flag value is dynamic, so the flag value decreases as more people solve it. Participants will decide the difficulty of the problem, so do keep that in mind ;)

Access the Challenges here: dashlander.me
Please submit your writeups here: {will be shared later}

Flag format: HRCTF{*}

Your submission of flags will only be considered valid if you provide a write-up of the challenge's solution. A write-up includes a systematic way of how you solved the challenge, what things worked for you, why they worked, any difficulties that you faced, etc. Here are some of the writeups provided for past CTFs that were conducted.
https://github.com/pratyush3757/iitgn-tech-council-ctf-writeups
https://github.com/Deus1704/QCTF_Solutions

At the end of the hackathon, you are supposed to give a presentation that will include the following:

- The write-ups of all the challenges that you solved
- Unsuccessful attempts at solving a challenge. The approaches that you considered, why they did not work etc.
- Your learnings.
- The Flags that you were able to achieve

The presentation should summarise all the work done by your team during the event time frame.

Important Instruction:

This event asks you to perform attacks, with our permission, against a set of targets that we are providing for this purpose. Attempting the same kinds of attacks against other systems without authorization is prohibited by law and institutional policies. You must not attack any system without authorization! You are required to respect the privacy and property rights of others at all times.

*** Ensure you agree to these terms before you begin your work.***

Here are some resources to get you started:
https://ctf101.org/
https://www.youtube.com/channel/UClcE-kVhqyiHCcjYwcpfj9w (liveoverflow)
https://picoctf.org/resources

3. ML Challenge [C]

Stakeholders: Dwip Dalal

Lost in Amazon Rainforest [100 points]

Picture this: you and your team of explorers are on an expedition in the dense and unpredictable Amazon rainforest. As night falls, the lush greenery transforms into a pitch-black maze filled with the unknown. In this scenario, survival hinges on your ability to navigate through the darkness, with only the sounds of the jungle as your guide.

The Setting:
Imagine you're part of a group of 10 people. Your mission was to traverse a specific part of the Amazon rainforest, but as fate would have it, you've lost your way. With darkness enveloping you and the dense forest coming alive with myriad sounds, the situation seems dire. However, not all hope is lost. Each member of your group is equipped with a cutting-edge device, a sound frequency-breaker, designed to be your beacon in this nocturnal chaos.

The Device:
This isn't just any device; it's your lifeline. When activated, it captures the sounds of the jungle, breaking them down into 32 distinct frequencies. This breakdown is crucial for the next step - using a machine learning algorithm pre-loaded on your device, you can identify which animal is making these sounds.

The Challenge:
Here's where you, the hackathon participants, come in. Your task is to refine, improve, or even redesign the machine learning algorithm that makes sense of these 32 frequencies. The goal is to create a system that's not just accurate but fast, capable of giving real-time feedback to the user about the potential dangers or safety of their surroundings based on the sounds detected.

Problem Statement:
Develop or enhance a machine learning model that can analyse sound frequencies to identify animal sounds in real-time. Your solution will help the lost explorers (users) understand their environment, recognize the presence of dangerous wildlife, and make informed decisions to ensure their safety and survival until they find their way back.

If you clear this round, that is, get more than 50% accuracy, then you will get access to round 2.

Platform: Kaggle Link

Resources:

- Libraries information
- Hugging Face
- Machine Learning

(Hints) Keywords: Contrastive Learning, Time-series processing

Judging Criteria (Round 1):
Position 1 on leaderboard = 100 points
Position 2 on leaderboard = 90 points
Position 3 on leaderboard = 80 points
And so on.

For Round 2: 50 point bonus who can clear it with 30% accuracy. And yes, round 2 is a suspense.

The test dataset will be up in 5 mins

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Hoping to see a strong fight among teams like last year :)

4. Algorithmic Optimization Problem

Stakeholders: More Yash Hiren 19110123, Mrigankashekhar Shandilya

Problem Statement

You are an events manager. Over the upcoming weekend, you have a lot of events lined up. Apart from that, you have a lot of clients who have to attend these events. Due to logistics issues, the number of people attending a particular event is capped by an upper limit. Also, different people have different levels of satisfaction with attending events, i.e. they would be more satisfied if they participated in a particular event than another.

While attending the events, a client needs to attend the entire event. Note that the timings of two events can very well clash.

Your task is to plan a schedule for each of the clients subject to the following conditions:

- You need to ensure that no person attends two overlapping events.
- You also need to ensure that no event is attended by people more than its limit.

You need to maximise the satisfaction of all the clients.

We consider two events to overlap if the end time of the first event is strictly more significant than the start time of the later event.

For eg.

- E_1 = (1,5) E_2 = (4,9) then E_1 and E_2 overlap
- E_1 = (1,5) E_2 = (5,9) then E_1 and E_2 don’t overlap

Input Format

Every test file contains the following.

- The first line contains two spaced integers ***N and M*** -the number of clients and the number of events.
- For the following ***N*** lines
  - The ***i***th line contains ***M-spaced*** integers ***S_1, S_2 ..., and $S_{M,}$*** where ***S_j*** denotes the satisfaction gained by the ***i***th client after attending the ***j***th event. $1 \le i \le N$ and $1 \le j \le M$
- For the Next ***M*** lines
  - The ***i***th line contains three spaced integers ***s_i, f_i*** and ***l_i*** - the start time, end time and the limit of the ***i***th event. $1 \le i \le N$

Output Format
You are expected to output N lines such that the ith line contains the following details about the client.

- A_i - the number of events attended by the ith client and A_i spaced integers denoting the event attended. (Print the event number in 1-indexed format).

Constraints

$1 \leq N \leq 1000$

$1 \leq M \leq 500$

$1 \leq S_i \leq 10$

$1 \leq s_i \leq f_i \leq 1e9$

$1 \leq l_i \leq 50$

Grading
You will receive a checker file and a few visible test cases to test your code.
Of course, you can generate your test cases to test your code locally.

For the final evaluation of the problem, we will add additional hidden test cases, and the solution with a maximum relative score for all test cases will be considered.

For eg.
For test case 1
Participant 1 has score = a (this is the max score)
Participant 2 has score = b
Score of participant 1 = a/a =1.00
Score of participant 2 = b/a

GitHub Link: Optimization
The link contains all the essential files needed to get started with the challenge.

Submission Guidelines:
You are expected to submit the link to your GitHub repository which should contain the following things.

1. Your code for the problem (make sure it runs within a reasonable amount of time) (1-2 minutes).
2. Instructions on how to run it.
3. Write up briefly describing the approach.

5. Quantitative Finance [C]

Stakeholder: Darsh Dalal , Rahul Chembakasseril

Volatility Forecasting Challenge

Volatility forecasting is a critical aspect of risk management and trading strategies. In this problem statement, we challenge you to develop a comprehensive trading strategy that leverages volatility predictions for selected stocks. You are free to choose the modelling technique that best suits your approach.

Problem Description:

Build a Volatility Forecasting Model:

Develop a model in Python for forecasting the future volatility of stocks. You can choose the modelling technique that aligns with your strategy - Utilise historical daily stock price data for the top 20 stocks by market capitalisation on the NSE.

Volatility Forecasting:

Implement your chosen model to predict future volatility for each selected stock. Your model should provide a reliable volatility estimate over a rational forecast horizon.

Trading Strategy:

Formulate a trading strategy based on the predicted volatility. Your strategy should capitalise on changes in volatility, adjusting positions accordingly. Ensure that the strategy is implemented in a Jupyter Notebook.

Backtesting:

Backtest your trading strategy using historical data from August 2018 to August 2023. Evaluate its performance against the selected stocks, considering transaction costs and other relevant factors.

Visualisations and Results:

Generate visualisations to illustrate the predicted volatility, trading signals, and the performance of your strategy. Present your results clearly and concisely in the Python Notebook.

Guidelines:

Model Selection:

You have the freedom to choose the modelling technique for volatility forecasting. Clearly explain your chosen approach and justify its suitability for the problem.

Dataset:

Utilise daily stock price data for the top 20 stocks by market cap on the NSE. Ensure that your dataset covers the backtesting period from August 2018 to August 2023.

Code Structure:

Maintain a well-structured Python Notebook with detailed explanations for each step of your analysis. Include comments in your code to enhance readability.

Submission:

You are required to submit a Word document explaining your chosen modelling technique, trading strategy, and results. Additionally, provide the Python Notebook containing your code, visualisations, and backtesting results.

Grading Criteria:

Criteria	Weight (%)	Description
Model Suitability and Explanation	30	Evaluate how well the chosen model aligns with the problem and the clarity of its explanation.
Effectiveness of Trading Strategy	20	Assessment of the profitability and robustness of the implemented trading strategy.
Risk Management Implementation	20	Evaluation of how effectively risk is managed within the trading strategy. (Sharpe ratio, Max drawdown, Turnover, etc)
Visualisations and Clarity	15	Assessment of the quality of visualisations and the clarity of presentation in the report.

Overall Performance	15	Evaluation of the overall performance of the strategy against the selected stocks.
Bonus	15	Additional points for exploring advanced variations of the chosen model or using ML techniques.

Resources:

- https://www.codium.ai/blog/statistical-modeling-with-python-how-to-top-libraries/
- https://blog.quantinsti.com/
- https://www.youtube.com/watch?v=qLIgx0S8D0w
- https://youtube.com/playlist?list=PLtqRgJ__TIq8Y6YG8G-ETIFW__36mvxMLad&feature=shared

Submission Guidelines:

- Link to your GitHub repository containing the Jupyter Notebook, PDF document (for only explanation of model selection, trading strategy)
- A presentation talking about your model selection, trading strategy and visualisations.

6. Competitive Programming - ICPC Style Contest [C]

Stakeholder: Mrigankashekhar Shandilya, Nimitt , Srivaths P 23110321, Dewansh Kumar

Individual Challenge (No Teams Allowed)
Competitive Programming ICPC Style Challenge is a 5-hour coding contest where you can show off your computer programming skills. The significance is - it gives you enough time to think about a problem, try different ways of attacking the problem, read the concepts, etc. If you're usually slow at solving problems and have ample time at hand, this is ideal for you. We also put in a lot of effort in getting quality problems, which would, in turn, foster your learning while solving them. These involve a variety of topics and you might need to read on some of them while trying to solve problems.

Contest Link: https://codedrills.io/contests/hackrush-2024?tab=overview

Rules:

- We have 7 problems in total.
- You can use any language of your choice to attempt these questions.
- Each challenge has a predetermined score.
- A participant's score depends on the number of test cases a participant's code submission successfully passes.
- If a participant submits more than one solution per challenge, then the participant's score will reflect the highest score achieved.
- Participants are ranked by score. If two or more participants achieve the same score, then the tie is broken by the total time taken to submit the last solution, resulting in a higher score.

You can see the current leaderboard on the HackerRank Page as well.

Resources:

- CP-Algorithms (a great resource for learning about different types of algorithms and problem-solving paradigms)

7. LuminaRush: Real-time inferencing of ML workloads

Stakeholder: Patel Vrajesh , Zaqi Momin

Description:
This project involves implementing a Convolutional Neural Network (CNN) to classify images from the CIFAR-10 dataset on an FPGA, specifically the Basys3 board. The primary goal is to achieve a minimum accuracy of 70% on the CIFAR-10 dataset. The choice of CNN architecture is left to the discretion of the implementer. However, the emphasis lies on maximising the model's accuracy and minimising the inference time by employing approximate computing and quantization. The use of FPGA technology provides an opportunity to optimise the microarchitecture for efficient parallel processing, which is crucial for real-time inference applications. Techniques like quantization can help reduce the computational requirements, while approximate computing can trade off precision for faster computations. The challenge lies in striking the right balance between accuracy and inference time while harnessing the capabilities of FPGA to achieve optimal performance on the CIFAR-10 image classification task. You may refer to the microarchitecture described in the "Resources (the first)." Kindly note that you cannot implement all the hardware on Basys3 since Basys3 needs more LUTs to accommodate all the hardware described in the paper provided.

Deliverables:
It is up to the team to ponder how to design a miniature microarchitecture (or a completely new one) that maximises the FPGA utilisation. The following are the major deliverables of the problem:

1. Train a CNN model on the CIFAR-10 dataset. Note that training can be done on your machines.
2. Implement a hardware design that can perform convolution operations on the FPGA board.
3. Establish the connection between the implemented hardware and the software to show the inference of CIFAR-10 on the FPGA. You may use any of the communication protocols for data transfer. The most primitive protocol is UART.

Distribution of Points:

In case of partial Implementation,

1. 15 Points – Training the CNN model.
2. 25 Points – Establishing communication between the board and your machine.
3. Extra 10 Points – If UART is NOT the communication protocol.

Note: The points will be awarded relatively and dynamically if the implementation is entirely done. The points will change based on the other team's performance.

System Requirements:

1. At least 4 core 8GB RAM machine (recommended) with Vivado installed. A lighter version of the software will also work.
2. Ensure that the Basys3 board is added to the board repository of the Vivado.

TLDR;

ML Workload: CIFAR-10

CNN: Of your choice

Minimum Accuracy Requirement: 70%

Evaluation Criteria: Minimum inference time while maximising accuracy. (Min. Accuracy = 70)

Resources:

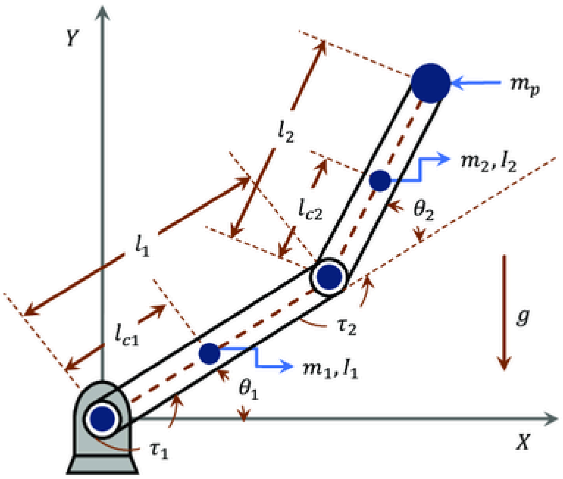
1. https://people.eecs.berkeley.edu/~ysshao/assets/papers/shao2019-micro.pdf (Example Hardware Design)
2. https://kaggle.com/competitions/cifar-10 (CIFAR 10 Dataset)
3. https://www.kaggle.com/code/roblexnana/cifar10-with-cnn-for-beginer (CNN with CIFAR10)
4. https://www.rohde-schwarz.com/in/products/test-and-measurement/essentials-test-equipment/digital-oscilloscopes/understanding-uart_254524 (UART)
5. https://youtu.be/Fms2Qwkbu1g?si=vKqZEpbjyEAptZWm (UART)
6. https://www.youtube.com/watch?v=sald8OCNNhQ (Systolic Array)
7. https://www.youtube.com/watch?v=6__GxkslqbcU (Basys3)
8. https://www.youtube.com/watch?v=tOwMmBI__XNo (Basys3)
9. https://www.youtube.com/watch?v=yKXiRIGK7DI (Vivado for Beginners)

8. Robotics: A ROBORIG ADVENTURE

Stakeholder: Anavart Pandya , Kush Patel

The Story of RoboRig:

Meet RoboRig, a 2R manipulator with a heart of steel and circuits of determination. With its trusty revolute joints, RoboRig embarks on a quest to conquer the challenges laid before it, guided only by the wit and wisdom of its human companions.



Notations		
m_1, m_2	-	Masses of link 1 and link 2
m_p	-	Mass of a payload
l_1, l_2	-	Lengths of link 1 and link 2
τ_1, τ_2	-	Torques for link 1 and link 2
I_1, I_2	-	Centroid inertia of link 1 and link 2
l_{c1}, l_{c2}	-	Distances from the joint of link 1 and link 2
θ_1, θ_2	-	Positions of link 1 and link 2
g	-	Gravity

Parameters:-

- *L1* - 1 unit
- *L2* - 2 unit
- *m1* - 1 kg
- *m2* - 2 kg

Recommended Simulation Window:- Matplotlib or Pygame
Team Size: 1-2
Time: 36 hours

Problem Statement:

In this HackRush challenge, participants will be tasked with programming a 2R manipulator, a robotic arm consisting of two revolute joints, to accomplish intricate tasks. Represented by our whimsically named arm, "RoboRig," your objective is to harness the power of the Python programming language to manoeuvre RoboRig through a maze of challenges.

Level 1: Navigating the Cartesian Plane [10 Points] (Difficulty: Easy)

Participants must utilise their programming prowess to command RoboRig to navigate to a specified position on the Cartesian plane. Armed with the knowledge of kinematics, you must guide RoboRig through the intricate pathways of the plane, ensuring it reaches the designated destination flawlessly. The desired destination point on the Cartesian plane must be clearly indicated, allowing easy visualisation of the target location. This ensures that participants can accurately assess whether RoboRig's end effector has reached the intended position or not.

Designated destination : (-1.75 , 2.0)

Judging Criteria:

- Accuracy of positioning: 6 points
- Code: 4 points

Level 2: Following the Smooth Trajectory [20 Points] (Difficulty: Easy)

In this phase of the challenge, participants will guide RoboRig through a journey of graceful curves, navigating a circular path with elegance and poise. Your objective is to program RoboRig to follow a jerk-free trajectory, demonstrating mastery over kinematic control. The task involves guiding RoboRig along a predefined circular trajectory with precision and smoothness. Participants must not only ensure that RoboRig traverses the circular path accurately but also maintains a continuous motion throughout the journey. Clear visualisation of both the desired trajectory and the trajectory followed by RoboRig is essential. The simulation should distinctly display the circular path and RoboRig's movement, enabling easy assessment of whether the end effector reaches the intended trajectory. Submit the .csv file along with code and simulation results, which may contain three columns-(time, X-coordinate, Y-coordinate).

Trajectory: Circle [Center- (0 , 2.1) , Radius- 1]

Judging Criteria:

- Accuracy of trajectory following: 15 points
- Code: 5 points

Level 3: Dynamic Trajectory Manoeuvring [30 Points] (Difficulty: Medium)
In this dynamic challenge, participants are tasked with equipping RoboRig with the ability to navigate a circular path smoothly and jerk-free using dynamic control. Building upon the foundation laid in previous levels, participants must tackle the added complexity of dynamic motion control, ensuring RoboRig's trajectory remains seamless and precise. As in previous levels, participants must define a circular trajectory for RoboRig to follow. The circular path should be clearly indicated, facilitating easy visualisation of both the desired trajectory and RoboRig's movement. Unlike static kinematic control, dynamic control involves accounting for factors such as inertia, acceleration, and external forces. Participants must implement algorithms to adjust RoboRig's motion dynamically, ensuring smooth and jerk-free movement along the circular path. Clear visualisation of both the desired trajectory and the trajectory followed by RoboRig is crucial for accurate evaluation. The simulation window should distinctly display the circular path and RoboRig's movement, enabling easy assessment of whether the end effector reaches the intended trajectory. Submit the .csv file along with code and simulation results, which may contain three columns-(time, X-coordinate, Y-coordinate)

Trajectory: Circle [$x = sin\frac{\pi}{2}t$, $y = cos\frac{\pi}{2}t$, total time = 4 sec]

Judging Criteria:

- Accuracy of dynamic trajectory following: 15 points
- Code: 10 points
- Smoothness of movement: 5 points

Level 4: RoboRig Rampage: Tripling the Trouble [40 Points] (Difficulty: Hard)
In this advanced challenge, participants will work with a planar 3R manipulator consisting of three revolute joints. Building upon the previous levels, participants must execute motion control for circular trajectory. The objective is to ensure smooth motion while avoiding singularities and addressing redundancy by minimising its kinetic energy as an optimization scheme. Participants must construct a curved path between two points within the workspace, avoiding singularities and maintaining smooth motion throughout. Develop equations of motion for the manipulator to implement feedforward control. This involves predicting the desired joint space trajectories based on the planned trajectory. Resolve redundancy in the manipulator using an optimization scheme aimed at minimising kinetic energy. This optimization scheme ensures efficient use of the manipulator's degrees of freedom while maintaining smooth and efficient motion. Submit the .csv file along with the code and simulation results.

$$Optimization\ Function = \frac{1}{2}q_{dot}^{T}q_{dot}$$

Trajectory: Circle [$x = sin\frac{\pi}{2}t$, $y = cos\frac{\pi}{2}t$, total time = 4 sec]

[*Hint*: Trajectory → Optimization → Inverse Dynamics → Forward Dynamics → Forward Kinematics
$\dot{q}_{desired} = \left(J^{+}\dot{X}_{desired}\right) + (I - J^{+}J)w$ Where J^{+} is the pseudoinverse of J. The term $(I - J^{+}J)w$ represents the null space optimization]

Parameters:-

- *L1* - 2 unit
- *L2* - 1 unit
- L3 - 1 unit
- *m1* - 2 kg
- *m2* - 1 kg
- *m3* - 1 kg

Judging Criteria:

- Minimization of kinetic energy: 15 points
- Accuracy of trajectory following: 15 points
- Code and Approach: 10 points

Reference

- https://www.kramirez.net/Robotica/Tareas/Kinematics.pdf
- Matplotlib Tutorials
- Pygame Tutorials
- https://www.youtube.com/playlist?list=PLLy_2iUCG87AjAXKbNMiKJZ2T9vvGpMB0
- https://hades.mech.northwestern.edu/images/7/7f/MR.pdf

***NOTE**: Participants' submissions will be evaluated based on both their code implementation and the visualisation provided in the simulation window. When code runs, the RoboRig should follow the trajectory in real-time.*