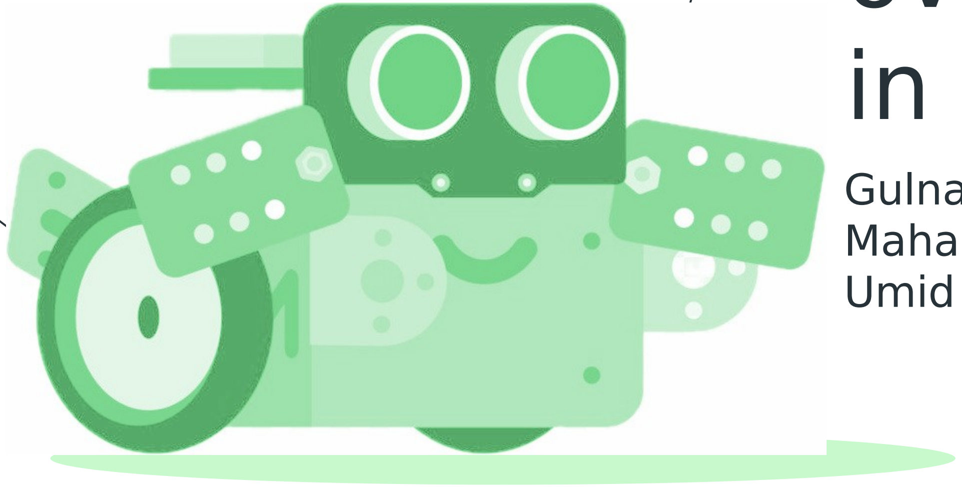

Mobile Robot controlled with overhead camera in the room

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Project Plan

Motivation

Growing interest in leveraging computer vision due to advancements in computing power and sensor affordability

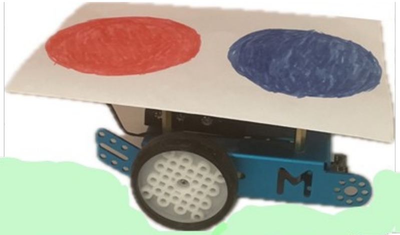
Aim to demonstrate effectiveness of vision-based control in enhancing robot navigation and task execution capabilities

Focus on wheeled mobile robots (WMRs) known for mechanical simplicity and energy efficiency

Utilization of vision as a primary sensor and feedback mechanism for autonomous robotic systems

Project Proposal

1. Aim is to develop mobile robot capable of autonomous navigation with the camera equipped on the top of the room
2. Project focuses on implementing robotic systems using computer vision and control technology
3. Capable of navigating through obstacles, following predefined paths, and interacting with the environment in real-time



Problem statement

The project focuses on utilizing a differential drive system for navigation to achieve reliable and predictable robot motion for various applications.	The Computer Vision and Control Algorithms should be adapted and used to achieve the desired operation that presents a unique opportunity to enhance the capabilities of wheeled mobile robots	It should be adaptable and versatile so that i can be implemented in various real life applications.

Goals and subgoals

1

Ensure accurate curve drawing on images

2

Recognize and interact with multiple objects

3

Translate curves into motion commands

4

Implement detection and control mechanisms

Tasks and sub tasks

2 3

1  4

1 Hardware Setup

Procure and assemble components for the mobile robot system.

2 Software Design

Computer vision and navigation algorithms.

3 Integration

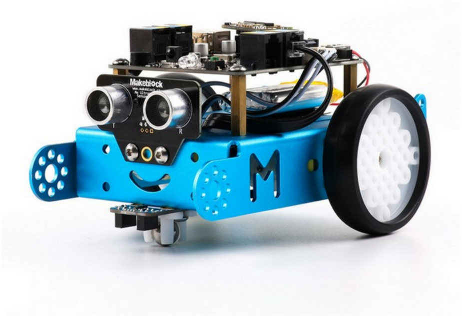
Integrate software for real-time operation

4 Testing

Test in simulated and real-world environments

Key idea of our system/solution

- Camera detection and color filtering
- Path generation
- Controlling equations and finding their wheel velocities based on the errors
- Bluetooth communication to a device
- Robot movement control



Key Challenges and Learnings

Challenges encountered

- Bluetooth connectivity issues.
- Sensor calibration difficulties.
- Algorithm tuning challenges.

Solutions implemented

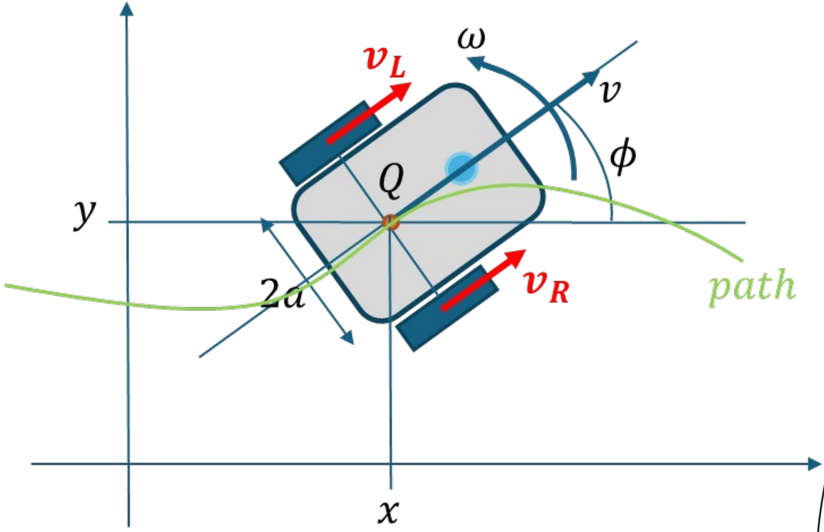
1. Ensured proper pairing and configuration of Bluetooth devices.
2. Adjusted sensor calibration parameters.
3. Fine-tuned control algorithms based on observed performance and feedback.
4. Installed mBot’s official software for resolving connectivity issues.
5. Implemented camera filters, color mask, and contrast level modification to address lighting problems.

Differential Drive Mobile Robot: State variables and Inputs

- If we write v_R and v_L in terms of v and ω:
  $v_R = v + a \cdot \omega, \quad v_L = v - a \cdot \omega.$

- Or we can find the inverse relation:
  $v = \frac{v_R + v_L}{2}, \quad \omega = \frac{v_R - v_L}{2a}.$

- Differential equations representing the system:
  $\dot{x} = v \cdot \cos(\phi)$
  $\dot{y} = v \cdot \sin(\phi)$
  $\dot{\phi} = \omega$

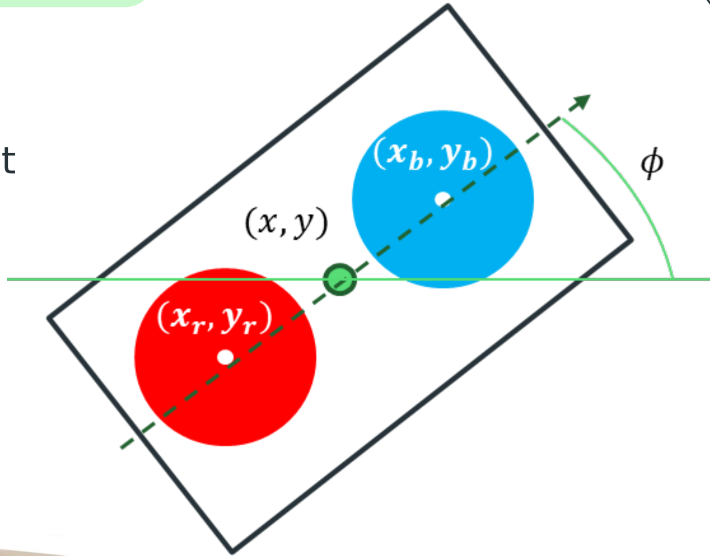


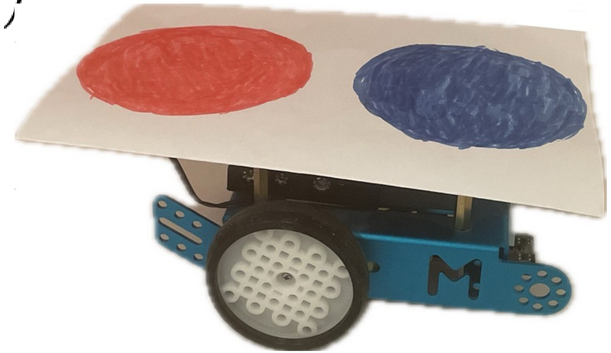
Color Filtering and State Measurement

- Developed a function to compute angle and midpoint between two coordinates:

$$(x, y) = \frac{(x_b, y_b) + (x_r, y_r)}{2}$$

$$\phi = arctan2\left(\frac{y_b - y_r}{x_b - x_r}\right)$$





Closed-loop Control Algorithm

$$v(t) = K_x \tilde{x}_r + v_d \cos(\tilde{\phi}_r)$$

$$\omega(t) = K_\phi \sin(\tilde{\phi}_r) + K_y v_d \tilde{y}_r + \omega_d$$

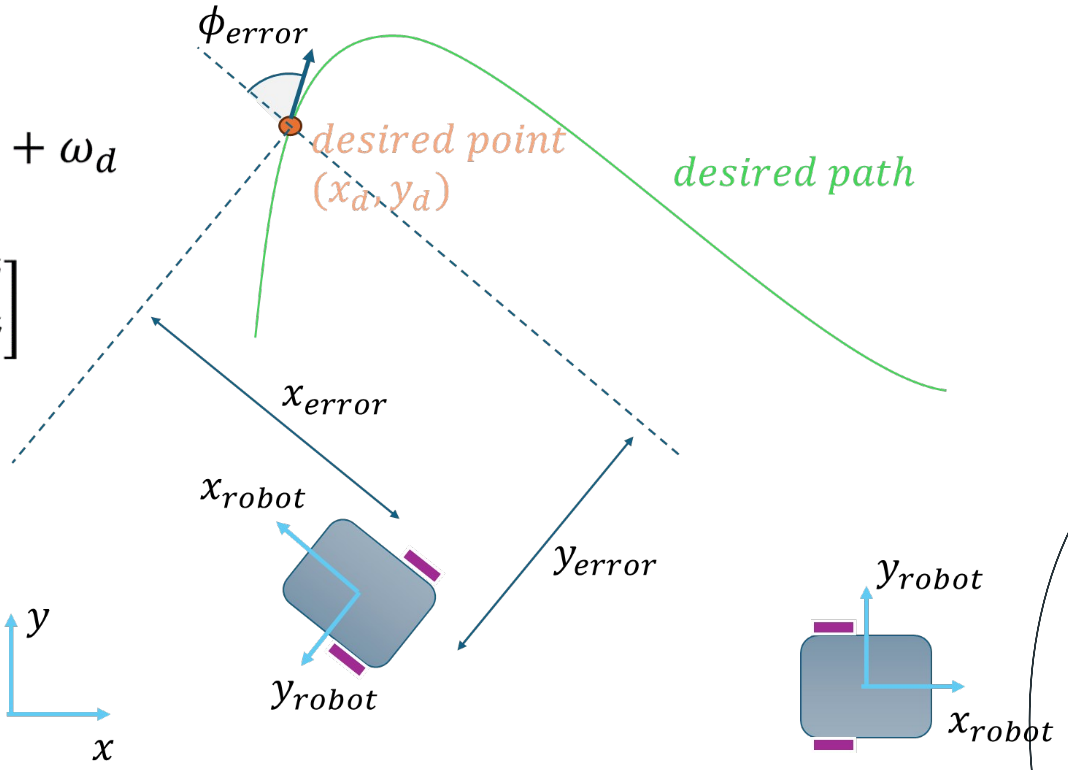
$$\begin{bmatrix} \tilde{x}_r \\ \tilde{y}_r \end{bmatrix} = \begin{bmatrix} \cos(\phi) & \sin(\phi) \\ -\sin(\phi) & \cos(\phi) \end{bmatrix} \begin{bmatrix} \tilde{x} \\ \tilde{y} \end{bmatrix}$$

$$\tilde{\phi}_r = \tilde{\phi}$$

$$\tilde{x} = x_d - x$$

$$\tilde{y} = y_d - y$$

$$\tilde{\phi} = \phi_d - \phi$$



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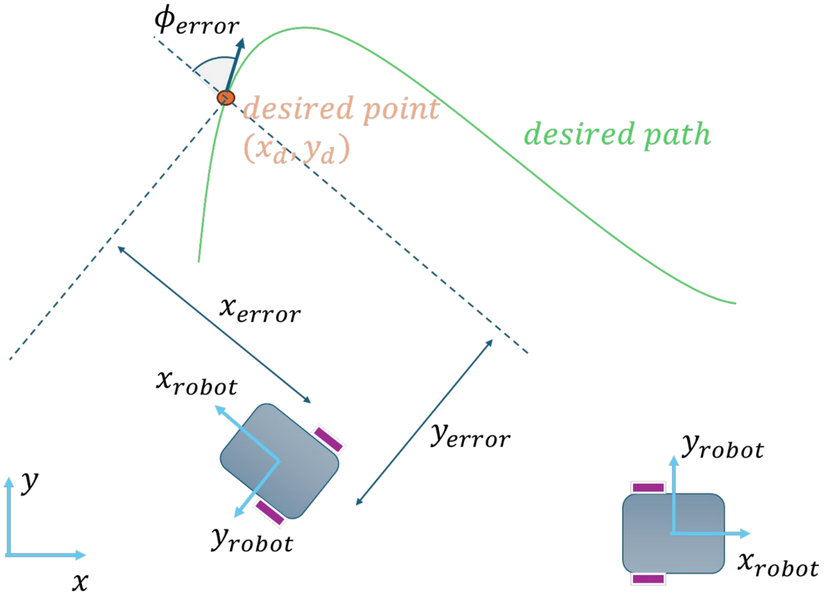
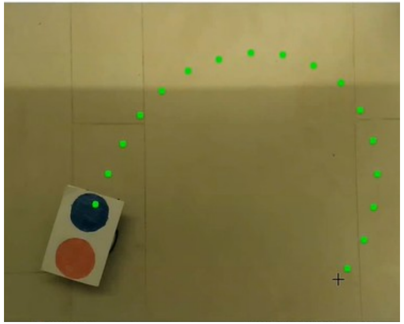


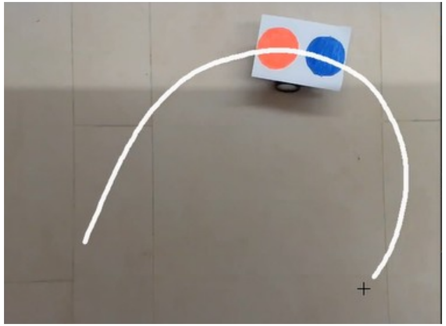
$$v(t) = K_x\big(\cos(\phi)\,(x_d - x) + \sin(\phi)\,(y_d - y)\big) + v_d \cos(\phi_d - \phi)$$

$$\omega(t) = K_\phi \sin(\phi_d - \phi) + K_y v_d\big(-\sin(\phi)\,(x_d - x) + \cos(\phi)\,(y_d - y)\big) + \omega_d$$

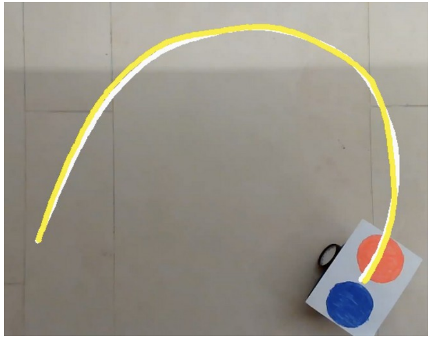
Results of our program



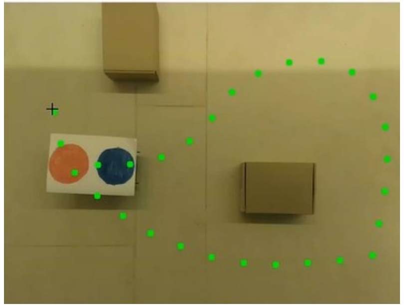
The program receives inputs from a user.

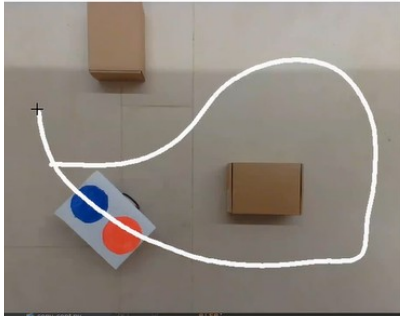


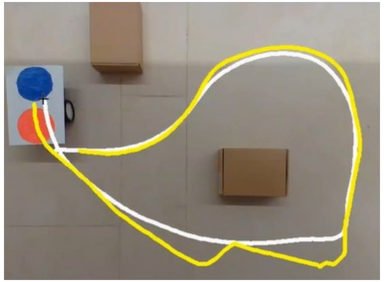
The, it generates interpolated spline.



Consequently, the robot follows the desired path.







https://youtu.be/KMb_yVf1dzM?si=k7MTMMmtXibFk3rM

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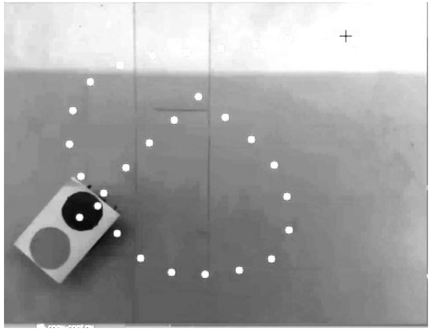

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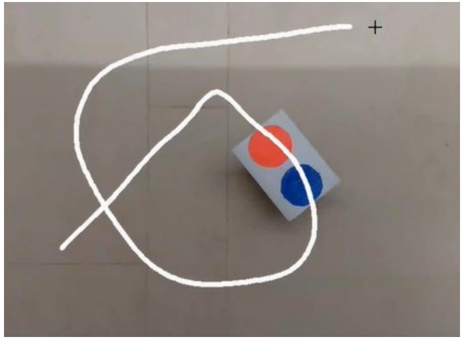

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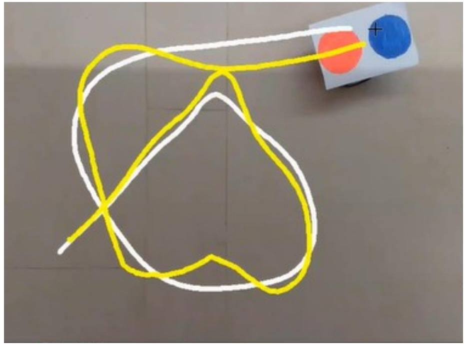

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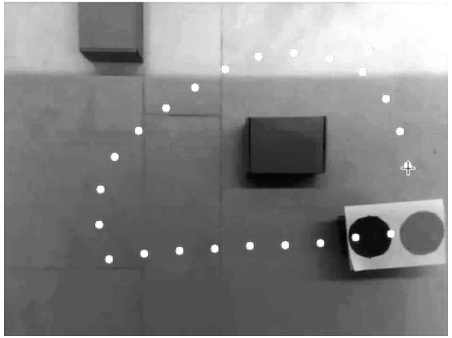
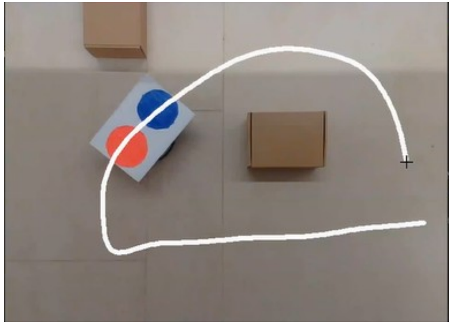
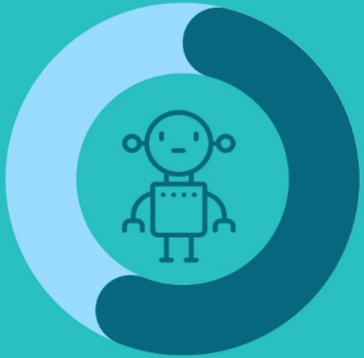




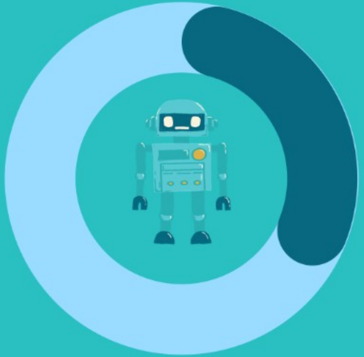
Sensor Integration

Integrating color detection and path tracking functionalities provided valuable insights into the robot's environment, enabling it to adapt to changing conditions



Algorithm Optimization

Fine-tuning control algorithms and parameters significantly influenced the robot's navigation and trajectory following capabilities,



Communication Protocols

Bluetooth communication facilitated seamless interaction between the robot and external devices, enhancing its versatility

Conclusion/Future Work

Control Algorithm Optimization

Future iterations could focus on further optimizing control algorithms to enhance navigation accuracy, real-time responsiveness, and stability, possibly by exploring new control strategies or implementing machine learning techniques.

Controlling several robots for further collaboration

Sensor Enhancement

Improving sensor capabilities, such as integrating additional sensors like LiDAR or depth cameras, could enhance perception and situational awareness, addressing blind spots or limitations in obstacle detection and localization.

Can be implemented detection based on technique as QR code

Autonomous Decision-Making

Enhancing autonomous decision-making capabilities through advanced planning and decision-making algorithms could enable the robot to perform more complex tasks

Performing more complex tasks will assist in improving and speed up the overall process

Any questions?