Simulated Environment for Language-Guided Robot Manipulation using Natural Language Commands

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PROBLEM STATEMENT

1. Develop advanced language understanding and response mechanisms for robots using the PyBullet library and tailored NLP tools in a simulated environment.

2. Address the challenge of enabling robots to interpret and execute natural language commands within the Language-Guided Manipulation System.

3. Explore solutions to enhance communication between humans and robots through effective natural language processing.

4. Provide insights into improving human-robot interaction by integrating sophisticated language comprehension and response systems.

5. Advance the field of robotics by demonstrating the potential of natural language-driven control in simulated environments.

ROBOT MANIPULATION COMMANDS

The following are the voice commands that the robot recognises and it performs unit movements corresponding to the direction mentioned in the command and for pickup it moves till the object is reached:

- Left
- Right
- Forward
- Backward
- Pickup

TOOLS AND LIBRARIES USED

NLP

1. SpeechRecognition
2. spaCy
3. PyAudio
4. NLTK

Robotics

1. PyBullet
2. PyBullet_Data

ROBOT MODEL - R2D2

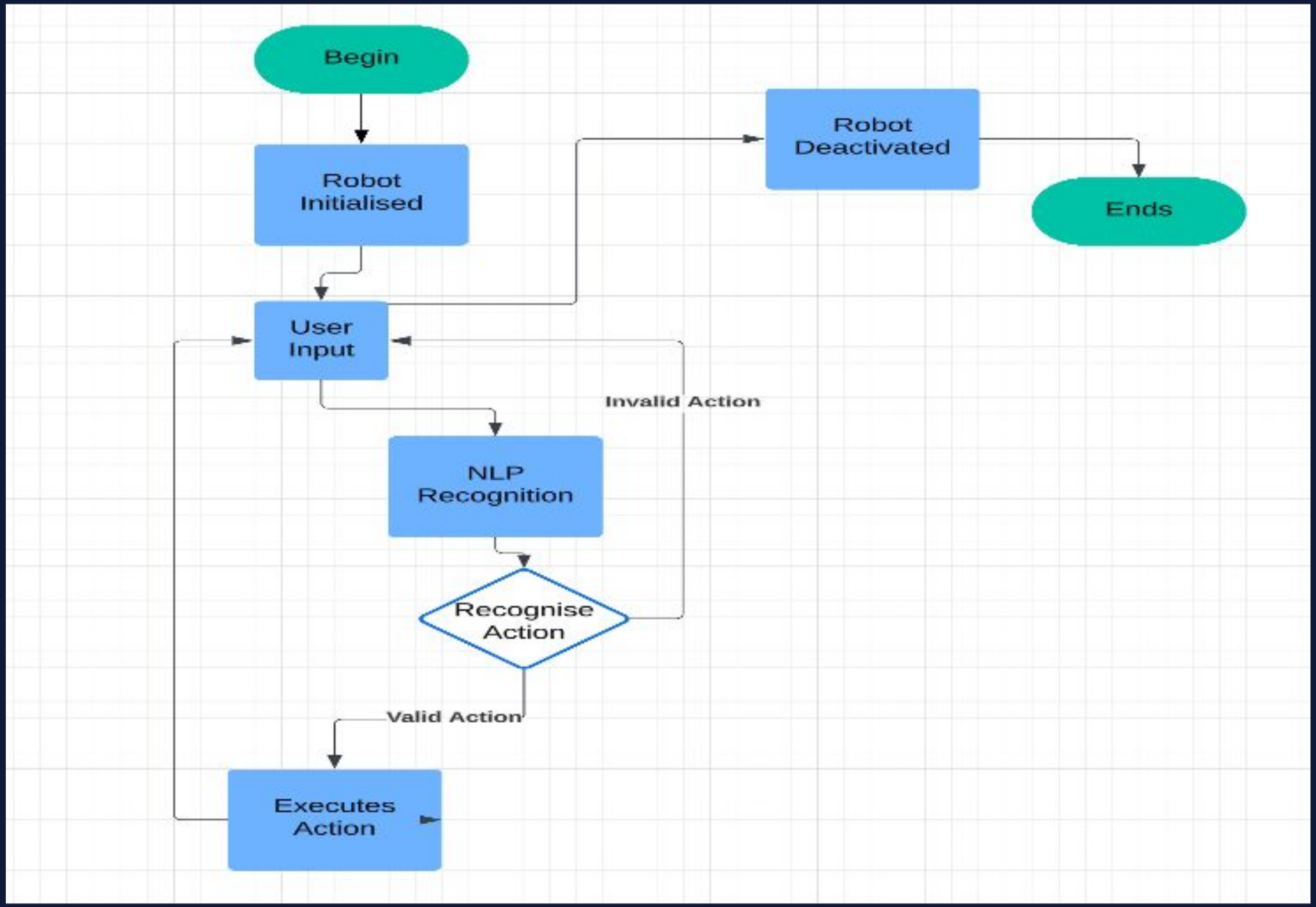
Links: axis, leg1, leg2, body, head, rod, box.
Joints: leg1connect, leg2connect, tilt, swivel, periscope, boxconnect.

Geometry: Each link has specific geometrical shapes (cylinder, box, sphere) with defined sizes, and the joints have specific motion limits and axes

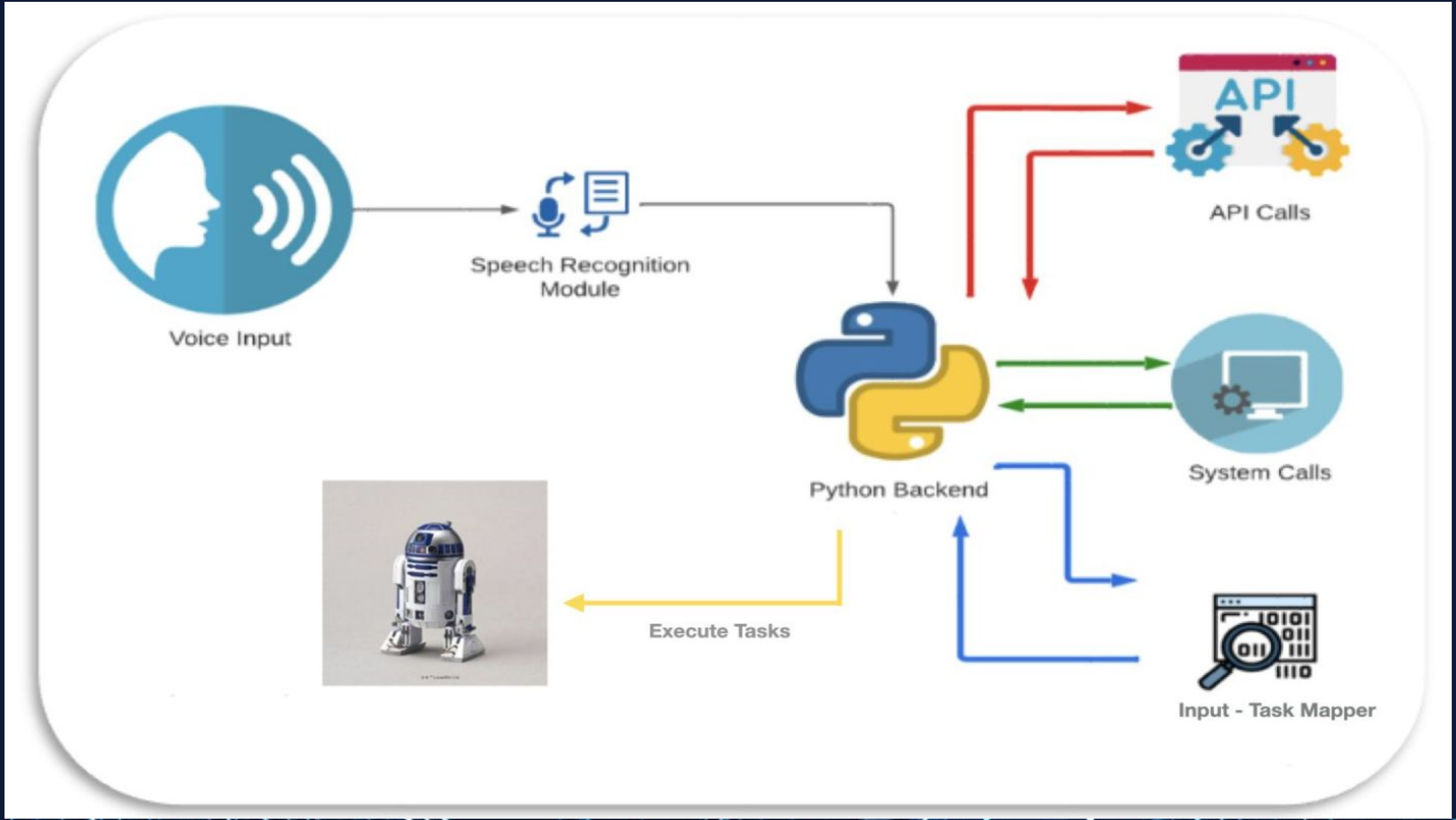
Colors: Gray, White & Blue.

Collision Properties: Collision aspects are defined for each link with specific geometries and contact coefficients.

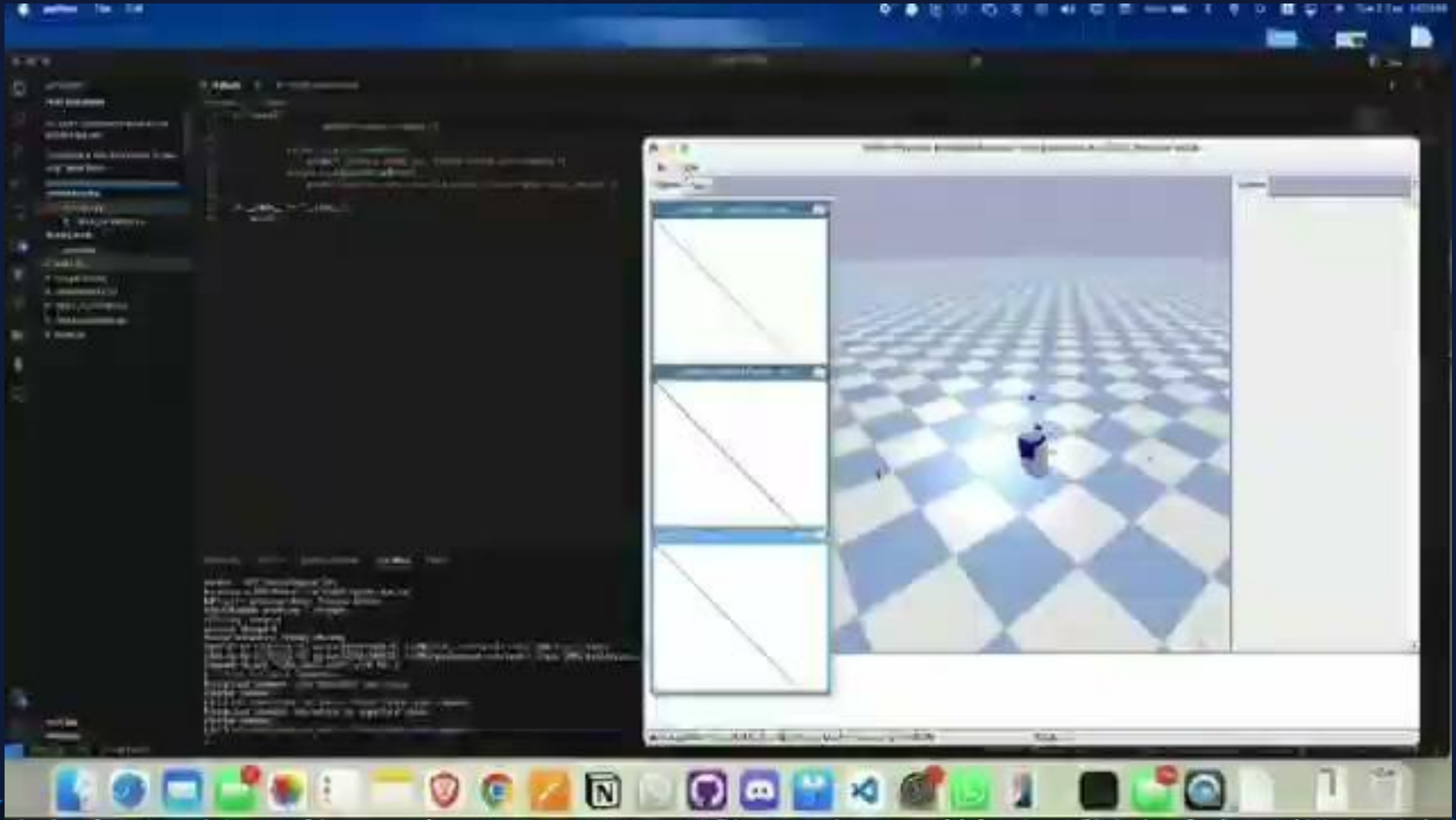
FLOW DIAGRAM



SYSTEM DIAGRAM



DEMO

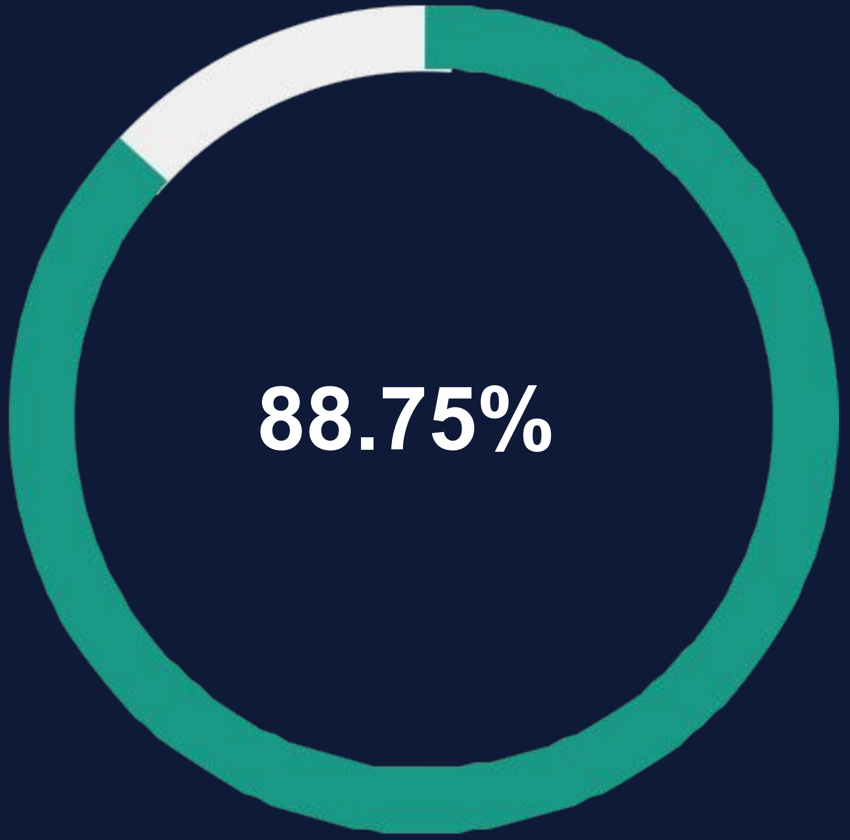


EVALUATION METRICS

We tested this by inputting commands for around 80 times 71 were successful.

Accuracy of Language Understanding = (Correctly interpreted inputs) * 100
—-- = 88.75%
(Total Inputs)

Quickest Processed Command	Slowest Processed Command
Forward	Right



EVALUATION METRICS

Latency

$$L = ResponseTime - InputReceiptTime$$

- **Upon calculating the time interval between the receipt of the command and the execution of the same by the robot we calculated a latency of 2.5ms**

REAL WORLD APPLICATIONS

1. **Healthcare**: Aids patients with limited mobility.
2. **Military**: Handles supplies in remote locations.
3. **Construction**: Transports tools and materials.
4. **Autonomous vehicles**: Responds to voice navigation commands.
5. **Assembly lines**: Moves components efficiently.

FUTURE WORK

1. Incorporating Multilingual Support: Use advanced speech-to-text engines and NLP models trained on multilingual datasets to handle linguistic variations effectively.

2. Extend the project to operate in physical environments using actual robotic systems, bridging the gap between simulation and real-world execution.

3. Focus on challenges like real-time processing, sensor integration (e.g., cameras for object recognition), and environmental uncertainties (e.g., obstacles, lighting changes).

4. Implement advanced robotic manipulation capabilities, such as handling fragile or irregularly shaped objects, by integrating vision-based grasp planning and tactile feedback systems.