JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Saksham 2.0: A Quadruped Robot for Assistive technology and Tourism Applications

[1]Chaitali Kanad Godse, [2]Atharva Khetale

[1]Assistant Professor, [2]T.E student
[1]Computer Department
[1]Watumull Institute of Engineering and Technology, Ulhasnagar, Thane.

Abstract: Saksham is a quadruped robot designed to support individuals with disabilities while enriching tourism experiences. Featuring advanced mobility solution and a user-friendly interface, the robot delivers versatile assistance across various environments. This paper explores the robot's design, capabilities, and module integration, highlighting its potential as a game-changing assistive device. Proposed future improvements include AI-driven analytics and multilingual interaction features to expand its functionality.

Index Terms **– Quadruped Robot, Assistive Technology, Tourism, Robotics.**

I. INTRODUCTION

The challenges faced by disabled individuals in mobility and access to critical assistance remain a significant barrier to inclusivity. [1] According to the World Health Organization (WHO), over 1 billion people worldwide experience some form of disability, with mobility impairments affecting a large portion of this population. [1] Similarly, tourists navigating unfamiliar terrains often struggle with accessibility, language barriers, and a lack of personalized guidance. [2] These challenges highlight the urgent need for innovative solutions that combine advanced robotics, artificial intelligence, and human-centric design [3].

Saksham 2.0, a quadruped robot, will be designed to serve as a versatile assistant for both disabled individuals and tourists. Its robust mobility system will enable it to traverse varied terrains, while its health monitoring and safety features will ensure reliable assistance for users. Equipped with an intuitive interactive interface, the robot will adapt to user commands and provides real-time feedback.

What will set Saksham 2.0 apart from existing assistive robots is its ability to combine multiple functions into a single device—mobility enhancement and personalized navigation. While there are robotic systems that assist in mobility, few integrate these features in such a seamless manner. Saksham's design will emphasizes accessibility, ease of use, and real-time adaptation to its environment, making it suitable for a variety of user needs, from disabled individuals to tourists exploring new areas.

The primary objectives of Saksham include:

1. Enhancing mobility for disabled individuals through terrain adaptability.
2. Providing personalized navigation and information services for tourists.

This paper presents the design and functionality of Saksham prototype, and the further structural design and software developments which will be implemented in Saksham 2.0 by focusing on its modular architecture, integration of advanced technologies, and potential applications. By trying to bridging the gap between robotics and assistive technology, Saksham will aim to make environments more accessible and user-friendly, fostering inclusivity and transforming how we approach urban accessibility and tourism.

II. SYSTEM ARCHITECTURE AND IMPLEMENTATION

The following is the basic design of the Saksham prototype which include the following hardware and software specifications

2.1 Hardware

The hardware consists of

2.1.1 Frame

The frame of Saksham is made of PVC sheet offering properties such as lightweight, durability and low cost. [4]. This material choice ensured that the robot was sturdy enough to support its components while remaining agile. Proper weight distribution is crucial for the robot's stability. The design is made in such a way that the robot could move effectively without tipping over.

2.1.2 Servo motors

A servo motor is an electric motor that allows for precise control of angular position. It incorporates a position feedback mechanism to accurately control its motion. The term 'servo' is derived from 'servomechanism', which is a system that uses feedback to automatically provide a controlled power level or force to move and hold an object at a certain position.[5]
Servo motors are responsible for driving the robot's legs, enabling it to move across different terrains. These motors provide precise control over the movement of each leg, ensuring stability and flexibility in walking. A The microcontroller is used to control these motors, by following predefined gait patterns to simulate natural walking motions.

2.1.3 Microcontroller

The microcontroller used is an Arduino Uno microcontroller as the main controller for the robot. Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; [8] It handles the coordination of servo motors and processed sensor inputs, allowing for efficient control of the robot's movements.

2.1.4 Camera

An ESP 32 camera is used for image and video capture. The ESP32-CAM is a small size, low power consumption camera module based on ESP32. It comes with an OV2640 camera and provides onboard TF card slot.[6] It integrates Wi-Fi and Bluetooth, making it ideal for projects requiring wireless communication and video capabilities.[7]

2.1.5 Wheels and Grippers

Custom Rubberized Pads and Wheeled Attachment made of Silicone rubber with an anti-slip texture are used which enhance terrain adaptability and provides wheeled locomotion for flat surfaces.

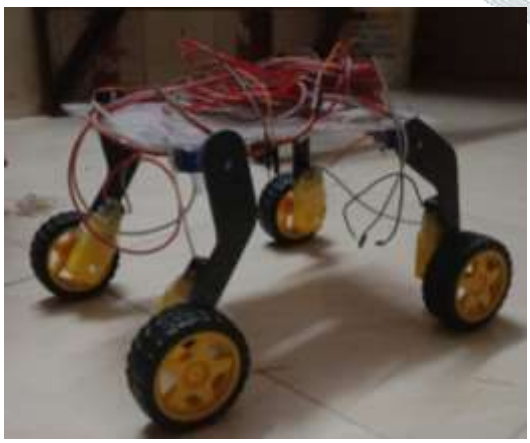

Fig 1: Saksham prototype

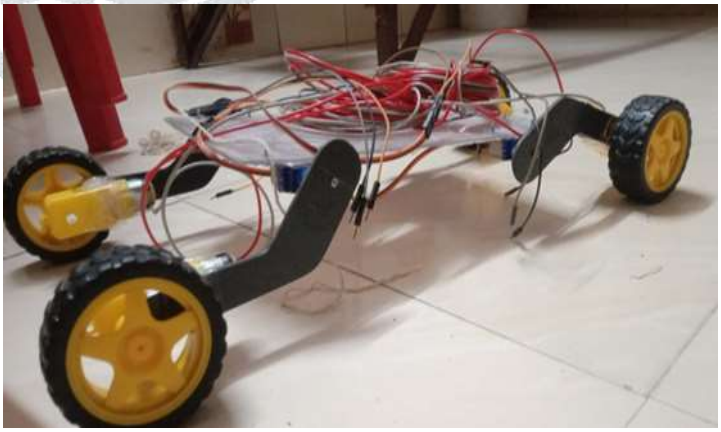

Fig 2: Saksham prototype

2.2 Software

Custom algorithms are developed to control the robot's movements. These algorithms included walking patterns, and turning sequences, all of which were programmed into the microcontroller. Arduino's programming language is used to write the code for the robot.

For object detection a program written in python and with the YOLOV5 model for real time object detection is implemented. The program utilizes the pre-trained YOLOv5s model, which is downloaded and loaded via the PyTorch Hub. [9] It processes live video feed from the camera. Each video frame is passed through the YOLOv5 model for object detection. In the output we can see annotated video frames with detected objects and bounding boxes.

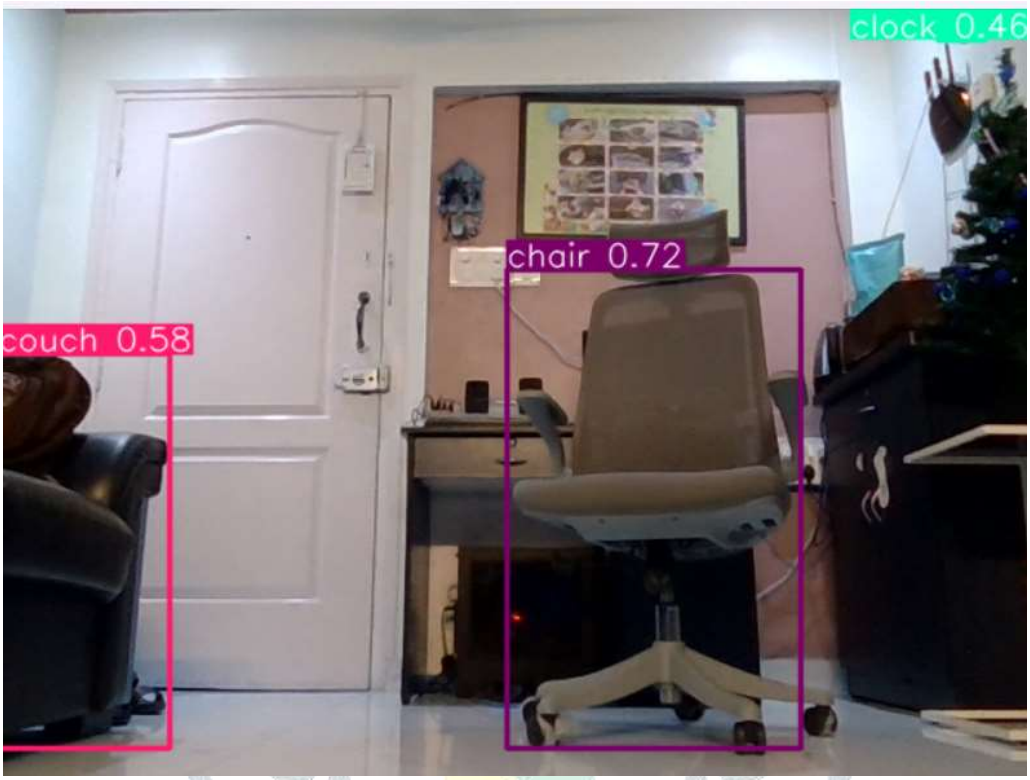

Fig 3: Object Detection

III: PROPOSED MODEL AND STRUCTURAL DESIGN FOR SAKSHAM 2.0:

The basic design of the Saksham prototype will be composed of three primary layers: the Hardware Layer, the Software Layer, and the Connectivity Layer. These layers work will together to ensure the robot operates effectively, providing assistance to both disabled individuals and tourists. This section provides a detailed overview of each layer, its components, and the technologies which will be integrated into the system.

3.1 Hardware Layer

The hardware layer serves as the physical infrastructure for the Saksham 2.0 robot, including the sensors, actuators, power systems, and processing units. The hardware is essential for collecting environmental data, enabling movement, and powering the robot's various functionalities. The hardware layer comprises:

3.1.1 Head or Upper Unit

The head will be rounded and made from ABS plastic. An Intel RealSense D455 camera will be mounted which provides 3D depth sensing for navigation and interaction [10] The ReSpeaker Core will capture voice from any direction, while a compact 5W speaker will deliver clear audio.[11] We will also try to integrate is a 7-inch capacitive touchscreen (1280x800 resolution) display which will serve as the user interface and displays information.

3.1.2 Torso

The torso will be redesigned as a rectangular cuboid with rounded edges. The Frame will be made of Aluminum 6061 as it has an excellent strength-to-weight ratio [12]. The Outer Shell from ABS plastic, offering durability and impact resistance. We will try to

incorporate 3 Compartments One for the Battery Housing wherein a Lithium-ion battery pack (48V, 15Ah) which will be placed in the lower torso for better balance. Another for the control system which is an NVIDIA Jetson Orin Nano which will handle AI and robotic control tasks [13]. Also, an additional 5L internal compartment will be designed to carry lightweight items like medication, maps, or snacks.

3.1.3 Legs

Legs will be rebuilt with carbon fiber for strength and lightness, which provide three degrees of freedom (DOF) for dynamic movement. Each leg will have three segments: Upper Leg (hip to knee), Lower Leg (knee to ankle), and Foot. Stainless-steel ball bearings will ensure smooth and durable motion. The Foot Pads made of Silicone-based rubber will ensures a good grip, with pressure sensors mounted for terrain feedback.[14]

3.2 Software Layer

The software layer will govern the processing of data collected by the sensors, as well as the decision-making algorithms that guide the robot's actions. It will be responsible for ensuring the robot operates autonomously while integrating mobility, and user interaction.

3.2.1 Mobility Control Module

The mobility control module will enable Saksham 2.0 to navigate its environment efficiently. It uses the data from the sensors to plan and execute movements. We will use path planning algorithms like A* or D* Lite to determine the most efficient path to its destination while avoiding obstacles. These algorithms compute the shortest path based on real-time data from LIDAR, ultrasonic sensors, and cameras.[15]

3.2.2 Gait Generation Algorithms

Gait generation algorithms will be used to determine the walking pattern of the robot. Depending on the terrain and movement requirements, these algorithms adjust the robot's gait to maintain stability and reduce energy consumption. Common gaits include walking, trotting, and running.[16]

3.2.3 Stability and Balance Control

Stability control algorithms ensure that the robot maintains balance, particularly when moving over uneven surfaces.[16] Feedback from the IMU and actuators is used to continuously adjust the robot's posture, preventing falls and ensuring safe movement. IMU (Inertial Measurement Unit) integrates accelerometers, gyroscopes, and magnetometers to track the robot's orientation and movement.[18]

3.2.4 Navigation System

The navigation system is responsible for determining the robot's location and planning its movement across the environment. It consists of several key technologies:

3.2.4.1 GPS Integration

Saksham 2.0 will use GPS for outdoor navigation, providing location data to help the robot navigate across large, open areas. This is especially useful for guiding tourists in unfamiliar locations.[28]

3.2.4.2 Obstacle Detection

Ultrasonic and LIDAR sensors detect obstacles, which the robot avoids by recalculating its path.

3.2.4.3 Personalized Navigation

This feature customizes the robot's behavior based on the specific needs of individual users.
AI-based learning algorithms identify user preferences, including walking speed and terrain adaptations. The robot will be able to Adjusts its gait and speed according to the user's profile. It can also provide personalized assistance, such as enabling stair-climbing or uneven terrain traversal

3.3 Connectivity

The connectivity layer ensures that Saksham 2.0 can communicate with external devices, cloud services, and users remotely. It facilitates real-time data sharing, remote monitoring, and updates

3.3.1 Cloud Integration

The cloud architecture will enable real-time communication, data storage, and processing for the robot, mobile apps, and web portal. It ensures seamless integration of features like health monitoring, navigation, and user interaction.[18]

3.3.1.1 Data Ingestion Layer

This layer will handle real-time data collection from the robot and user devices. A device like a Raspberry Pi or Jetson Nano will preprocess the data locally before sending it to the cloud. MQTT or HTTP/HTTPS protocols will be used for secure and lightweight communication.[20]

3.3.1.2 Cloud Processing Layer

This layer will process incoming data and provides computational power for advanced functionalities. Cloud platforms like AWS, Google Cloud, or Azure host AI/ML models will be used for tasks like Path planning and navigation optimization, emotion and facial recognition.[18] Speech-to-text and text-to-speech APIs will be used for voice interaction. Language translation APIs for multilingual support.

3.3.1.3 Data Storage Layer:

This layer will store user and robot data securely for analysis and historical records. The Structured data (e.g., user profiles, health logs) will be stored using MySQL/PostgreSQL database The Unstructured data (e.g., text inputs, images) will be stored using MongoDB database. Cloud-native solutions like AWS RDS or Google Cloud Firestore can be used for high availability.[19][21]

3.3.1.4 Application Layer

This layer is an interface for users and administrators to interact with the robot. In Mobile Application it will Connect to the cloud for real-time data and robot control. For a website it will be used to manage dashboard for advanced management, analytics, and reporting. An API Gateway will manage requests between the apps, the robot, and the cloud.

3.3.1.5 IoT Communication and Management Layer

This layer will manage communication between the robot and the cloud. IoT Platforms like AWS IoT Core, Azure IoT Hub, or Google IoT can be used for device management. For Real-Time Communication we can use WebSockets or MQTT to achieve low-latency updates.[22]

3.3.1.6 Security Layer

This layer will ensure that data and communication are secure and private. For Encryption, we can use TLS for data in transit.[23] And AES-256 for data at rest. OAuth 2.0 can be used for secure user logins. Also we can provide Certificate-based authentication for the robot.[24]

3.3.1.7 Cloud Architecture

The Cloud Architecture will include the following

1. Robot and Edge Gateway: Local computation and data relay.
2. IoT Platform: Manages device-to-cloud communication.
3. API Gateway: Handles requests between apps and cloud.
4. Compute Services: Hosts AI models and performs processing tasks.
5. Databases: Securely store data.
6. Mobile/Web Apps: Interface for users.

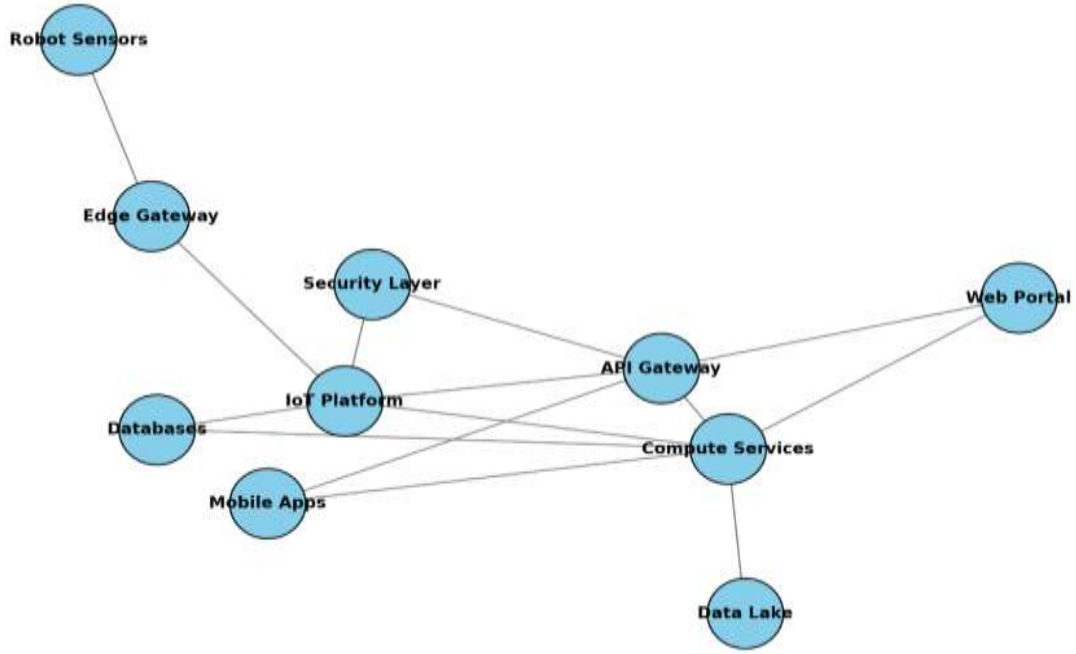

Fig 4 Cloud Architecture diagram

3.3.2 Mobile App Integration

A mobile application can be developed which can serve as an interface for remote control and monitoring**.** This application will allow the users to control Saksham's movements.[26] It can also be used for configuring the robot, accessing real-time data, and interacting with the robot's system remotely.

3.3. 2.1. Home Screen

The home screen will be the central hub for navigation across different functionalities. It will contain the following:

- Large, vibrant buttons each for Navigation Assistance, Emergency, Settings and Fun Activities.
- A status bar at the top showing: Battery status, GPS location, current operational mode**.**
- Background: Light, minimal with calming tones (pastels or light blue).[27]

3.3.2.2 Navigation Assistance Screen

This screen will assist with location-based needs and will contain the following design features:

- Interactive Map on which Current location and accessible routes can be marked and we can highlight destinations like tourist spots or nearest hospitals.[28]
- Speech Command Button: These buttons can be used by the user for interaction with the robot, users can say: "Take me to [location]."
- Live Navigation Panel: It will display step-by-step directions or audio guidance for visually impaired users.

3.3.2.3. Emergency Assistance Screen

This screen will give Quick access to emergency help The Design Features include:

- Big Red Button: "Call for Help" This line will be prominently displayed on this button.
- Live Camera Feed: Will show the robot's surroundings for remote viewing by caregivers.

- Contact List: A Contact list will contain quick-dial buttons for emergency contacts.[29]

3.3.2.4 Fun Activities Screen

The purpose of this screen is to provide entertainment and positivity. It can include the following:

- Joke Generator Button: A section that displays random jokes or fun facts.
- Games Section: Memory puzzles or trivia can be accessible through large buttons.
- Daily Quotes: Inspirational messages will be displayed with beautiful visuals.

3.3.2.5. Settings Screen

This Screen will be used to customize the robot's features. It may include the following:

- Toggle for accessibility features like Voice commands, High contrast mode.
- Users can change their language preferences.
- Users can manage saved locations and contacts.[30]

IV KEY DESIGN PRINCIPLES

The following are key features and design considerations which will be used while building Saksham 2.0

4.1Ergonomics and Accessibility

The robot's design will prioritize ease of use for a wide range of users.
The height will be adjustable between 70 cm to 1.2 m, ensuring suitability for users of varying heights and for different environments. Interaction Points like buttons and a touchscreen will be strategically mounted at chest height for optimal accessibility.

4.2 Mobility and Navigation

A robust leg mechanism allow traversal across uneven terrains and stairs. A real-time obstacle avoidance system can be generated using LIDAR and depth cameras.

4.3 Connectivity and Remote Monitoring

IoT capabilities will allow seamless integration with other devices.
Remote monitoring through a mobile application will provide convenience.to users and caregivers.

4.4 Safety and Durability

Stress testing will insure ensure long-term reliability under varied conditions. IP65-rated casing can be used for weather resistance.

V APPLICATIONS

5.1 Search and Rescue Operations

Quadruped robots equipped with advanced obstacle detection can navigate debris-filled or hazardous environments to locate survivors during disasters.[31]

5.2 Agriculture

Robots can assist in field monitoring, crop health analysis, and navigating through uneven terrains to manage farmlands effectively.[32]

5.3 Surveillance and Security

These robots can be deployed for patrolling and security monitoring in challenging terrains or remote locations.[31]

5.4 Military Applications

Quadruped robots can support logistics, reconnaissance, and hazard detection in combat zones.

5.5 Construction and Maintenance

Robots can assist in navigating construction sites for inspection, material transport, and structural analysis.[32]

5.6 Environmental Monitoring

Robots can be used for data collection in forests, glaciers, and underwater terrains for scientific research and conservation efforts.

5.7 Urban Planning and Maintenance

Quadruped robots can navigate urban areas for tasks such as inspecting infrastructure, detecting faults, or cleaning.[32]

5.8 Healthcare Assistance

Robots can be used in elder care, providing assistance in navigating environments that may be challenging for humans.

VI FUTURE SCOPE

6.1 Enhanced Sensing and Perception

Future research can focus on incorporating advanced sensing technologies like LiDAR, depth cameras, and ultrawideband sensors to improve obstacle detection accuracy and efficiency.

6.2 Integration with AI

Leveraging AI and machine learning algorithms can enable predictive analysis and adaptive decision-making for dynamic environments.

6.3 Energy Efficiency

Studies on optimizing power consumption during obstacle detection and navigation could extend operational runtime and improve sustainability.[33]

6.4 Scalability

Exploring modular and scalable designs can make obstacle detection systems adaptable for various robot sizes and terrains.

6.5 Collaborative Robotics

Implementing swarm robotics for coordinated obstacle detection and navigation could open doors for applications in large-scale operations like disaster management and industrial automation.

6.6 Human-Robot Interaction

Developing intuitive interfaces and control mechanisms for effective communication between humans and robots in challenging terrains.[33]

6.7 Real-time Processing

Future studies can focus on optimizing algorithms for real-time data processing, ensuring immediate response to dynamic changes in the environment.

6.8 Environmental Adaptation

Research can explore materials and designs to make the robots capable of operating in extreme weather conditions or hazardous environments.

VII CONCLUSION

The advancements in quadruped robots for obstacle detection signify a monumental leap in robotics and automation. This study has explored key methodologies and technologies enabling precise navigation in complex environments. With robust sensing, adaptive algorithms, and efficient design, these robots hold the potential to revolutionize industries ranging from agriculture to defence.

Future research should address challenges in energy efficiency, real-time data processing, and environmental adaptability to further enhance these systems. As quadruped robots evolve, their applications will continue to expand, enabling safer, more efficient operations in diverse domains. The journey of integrating robotics into daily human activities not only highlights technological innovation but also promises a future where robots work seamlessly alongside humans to overcome the most challenging environments.

VII Acknowledgment

We would like to express our heartfelt gratitude to the management and faculty of Watumull Institute of Engineering and Technology, Ulhasnagar, for providing the resources and support needed for this project.

We also extend our appreciation to our peers and colleagues who provided constructive feedback and motivation. Lastly, we are deeply grateful to our families and friends for their unwavering support and understanding during the development of this project.

References

[1] World Health Organization. 2021. Disability and Health. https://www.who.int/news-room/fact-sheets/detail/disability-and-health.
[2] VoxTours. 2024. Role of Tour Guide Systems in Accessibility. https://voxtours.com/role-of-tour-guide-systems/.
[3] Chen, Y., et al. 2024. Innovative Robotics for Accessibility. https://arxiv.org/abs/2407.11830.
[4] RTPrototype. No date. What is PVC? https://www.rtprototype.com/what-is-pvc/.
[5] Testbook. No date. Servo Motor. https://testbook.com/electrical-engineering/servo-motor.
[6] Evelta. No date. ESP32-CAM Camera Module Based on ESP32. https://evelta.com/esp32-cam-camera-module-based-on-esp32/#productDescription.
[7] Evelta. No date. ESP32-CAM Camera Module Based on ESP32. https://evelta.com/esp32-cam-camera-module-based-on-esp32/?srsltid=AfmBOooY1uXe50Hie726sf7cXcrvSVig2F5yxjOeRWcVhlBUkQud3OmY.
[8] Arduino. No date. Arduino UNO Rev3. https://docs.arduino.cc/hardware/uno-rev3/.
[9] Ultralytics. No date. YOLOv5. https://github.com/ultralytics/yolov5.
[10] Intel RealSense. No date. Depth Camera D455. https://www.intelrealsense.com/depth-camera-d455/.
[11] Seeed Studio. No date. ReSpeaker Core. https://wiki.seeedstudio.com/ReSpeaker_Core/.
[12] Wikipedia. No date. 6061 Aluminium Alloy. https://en.wikipedia.org/wiki/6061_aluminium_alloy.
[13] NVIDIA. No date. Developer Portal. https://developer.nvidia.com/.
[14] Frontiers in Mechanical Engineering. 2024. Path Planning and Stability Control of Quadruped Robots. https://www.frontiersin.org/journals/mechanical-engineering/articles/10.3389/fmech.2024.1448681/full.
[15]ResearchGate. No date. Path Planning Based on ADFA Algorithm for Quadruped Robot. https://www.researchgate.net/publication/333586043_Path_Planning_Based_on_ADFA_Algorithm_for_Quadruped_Robot.
[16] MATEC Web of Conferences. 2023. Rapid Design and Prototyping of Autonomous Systems for Accessibility. https://www.matec-conferences.org/articles/matecconf/pdf/2023/15/matecconf_rapdasa2023_04022.pdf.
[17] ResearchGate. No date. Gait Planning and Stability Control of a Quadruped Robot. https://www.researchgate.net/publication/301251941_Gait_Planning_and_Stability_Control_of_a_Quadruped_Robot.
[18] SBG Systems. No date. Inertial Measurement Unit (IMU) Sensor. https://www.sbg-systems.com/inertial-measurement-unit-imusensor/#:~:text=An%20IMU%2C%20standing%20for%20Inertial,the%20heading%20requirement%2C%203%20magnetometers.
[19] Amazon Web Services. No date. Amazon RDS. https://aws.amazon.com/rds/.
[20] Microsoft Azure. No date. IoT Hub. https://azure.microsoft.com/en-us/products/iot-hub/.
[21] Google Cloud. No date. Firestore Documentation. https://cloud.google.com/firestore/docs.
[22] Mozilla Developer Network. No date. WebSocket API. https://developer.mozilla.org/en-US/docs/Web/API/WebSocket.
[23] Internet Society. No date. TLS Deployment. https://www.internetsociety.org/deploy360/tls/.
[24] Auth0. No date. OAuth & OpenID Connect Professional Guide. https://auth0.com/resources/ebooks/oauth-openid-connect-professional-guide.
[25] Amazon Web Services. No date. AWS Architecture Center. https://aws.amazon.com/architecture.
[26] ResearchGate. No date. The Potential of Microacoustic SAW- and BAW-Based Sensors for Automotive Applications. https://www.researchgate.net/publication/3431015_The_Potential_of_Microacoustic_SAW-_and_BAW Based_Sensors_for_Automotive_Applications-A_Review.
[27] Interaction Design Foundation. No date. User Interface Design Guidelines: 10 Rules of Thumb. https://www.interaction-design.org/literature/article/user-interface-design-guidelines-10-rules-of-thumb.
[28]Google Maps. No date. Getting Started with Google Maps Embed API. https://developers.google.com/maps/documentation/embed/get-started.
[29] Medium. No date. Best Practices for Designing User-Friendly Interfaces for UI/UX Designers. https://medium.com/@uidesign0005/best-practices-for-designing-user-friendly-interfaces-for-ui-ux-designers-0b761c85ce48.
[30] W3C. No date. Testing and Evaluation. https://www.w3.org/WAI/test-evaluate/.
[31] Robotics247. No date. 5 Real-World Applications of Quadruped Robots. https://www.robotics247.com/article/5_real_world_applications_of_quadruped_robots.
[32] How to Robot. No date. Expert Insight on Quadruped Robots. https://howtorobot.com/expert-insight/quadruped-robots.

[33] ResearchGate. No date. Advancements, Challenges, and Future Perspectives in Quadruped Robots: A Survey. https://www.researchgate.net/publication/382499798_Advancements_challenges_and_future_perspectives_in_quadruped_robots_A_survey.