BrailleBot: The Autonomous Guide for the Visually Impaired

- **Challenges Faced by the Visually Impaired:**
  - Difficulty navigating complex environments (stations, hospitals, etc.) without consistent assistance.
  - Dependence on human help, which may be unreliable or unavailable.
- **Purpose and Scope of BrailleBot:**
  - Autonomous, personalized guidance for blind individuals in various public spaces.
  - Indoor and outdoor navigation, covering complex areas like metro stations and hospitals.
- **Core Features of BrailleBot:**
  - Guided Navigation: Offers precise routing using LiDAR and accurate mapping.
  - Elevator Integration: Interfaces with elevators for easy floor-to-floor access.
  - Voice Interaction: Communicates with users via voice assistance.
  - Safety Indicators: Equipped with an emergency light tower to signal the robot’s presence.
- **Social Impact:**
  - BrailleBot fosters independence, promoting accessibility and inclusion in public spaces.

BrailleBot Design: Power and Sensors

Estimated Total Power Consumption and Operating Time for 8 Hours

Mixed Active/Idle Usage: Approximately 440Wh capacity required for 8 hours

Active Power Consumption: ~55W, Idle Power Consumption: ~6.3W

Component	Model	Specifications	Power Consumption
Battery Pack	Anker PowerHouse II 400 or Equivalent	388Wh capacity, Lithium-Ion	–
Additional Battery Pack	Second pack for 440Wh total	Connected in parallel	–
Drive Motors	Maxon DCX 22S High Torque Motor	12V, 4000 RPM	~15W each
Motor Controller	Roboclaw 2x7A Motor Controller	Dual-channel, with feedback	2W
Charger	Nitecore D4 Intelligent Charger	Fast charging, auto shut-off	10W (during charge)

Component	Model	Specifications	Power Consumption
LiDAR	RPLIDAR A3	360-degree FOV, 25m range	~8W
Ultrasonic Sensors	MaxBotix MB1040	Range: 20-765cm	0.2W each
Camera	Intel RealSense D435i	RGB and depth sensing, IMU	1.6W
Environmental Sensor	Bosch BME280	Temperature, humidity, pressure	~0.003W
Emergency Light Strip	Adafruit NeoPixel RGBW Strip	High brightness, customizable	10W

BrailleBot Design: Navigation and Software

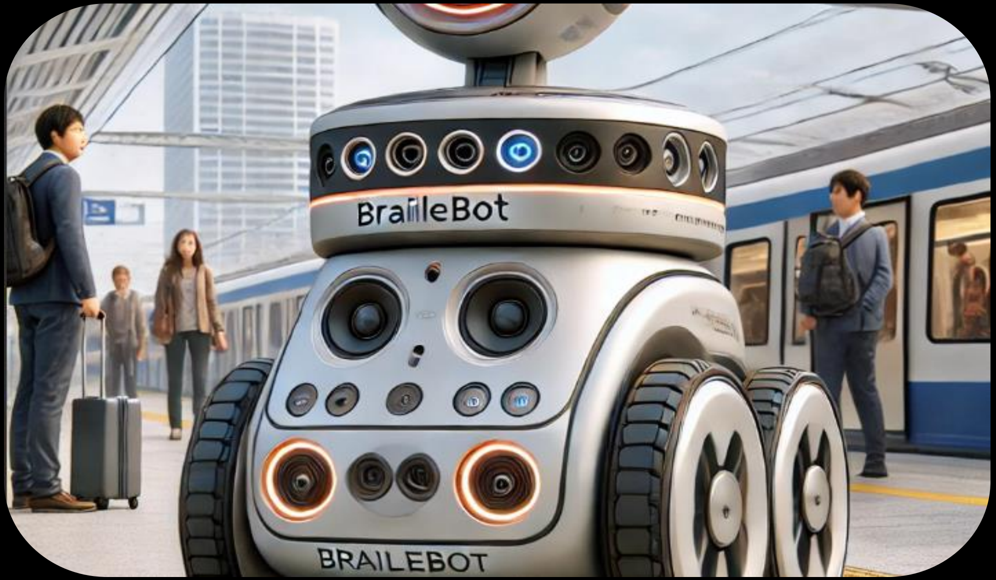
NAVIGATION SYSTEM

- **Mapping and Localization**
  - LiDAR (RPLIDAR A3): 360-degree scanning for real-time spatial mapping.
  - SLAM: Uses LiDAR and camera data to map environments and localize BrailleBot.
- **Obstacle Detection and Avoidance**
  - Ultrasonic Sensors (MaxBotix MB1040): Prevents close-range collisions.
  - Depth Camera (Intel RealSense D435i): Assists in obstacle detection and object recognition.
- **Path Planning**
  - Navigation Algorithms: Uses A* and Dijkstra algorithms for optimal pathfinding.
  - Elevator and Door Access: IoT-enabled systems for multi-level navigation in buildings.

SOFTWARE ARCHITECTURE

- **Operating System**
  - ROS2 for coordinating sensor data, motor control, and path planning.
  - **Artificial Intelligence**
  - Meta LLM: Provides user interaction for answering questions and navigation assistance.
  - Computer Vision Algorithms: Processes camera data to recognize signs and environmental cues.
- **Control and Feedback**
  - Motor Control: Managed by Roboclaw motor controller for smooth and precise movements.
  - Safety Protocols: Emergency stop if obstacles detected or off-path deviation occurs.
- **IoT Connectivity**
  - Elevator and Door Communication: Interfaces with smart building systems for multi-floor navigation.

BrailleBot Design: Control and Interaction



- **System**
  - **ControlMotor Control**
    - Roboclaw 2x7A Motor Controller: Manages dual closed-loop control with high torque and precision.
    - Encoder Feedback: Uses quadrature encoders to monitor speed and position for accurate path correction.
    - PID Controller: Ensures smooth acceleration and deceleration for safe navigation.
  - **Emergency Stop System**
    - Sensor Fusion for Proximity Detection: Combines ultrasonic and LiDAR to maintain dynamic safety zones.
    - Remote Stop Feature: Allows staff to remotely stop BrailleBot via Bluetooth, enhancing safety.

- **User Interface**
  - **Meta LLM Integration**
    - Voice Processing: Meta LLM for natural language understanding, enabling complex command handling.
    - Multi-Language Support: Interprets commands in multiple languages for broader accessibility.
    - Command Parsing: Detects and prioritizes navigation-related keywords for rapid response.
  - **Auditory Feedback**
    - Adaptive Sound Levels: Automatically adjusts volume based on ambient noise levels.
    - Directional Audio Feedback: Stereo speakers provide spatial awareness for user direction.
    - Distinctive Alert Tones: Unique tones signal movements, waypoints, or obstacles.
  - **Visual and Haptic Signals**
    - Emergency Light Strip: Customizable RGB LED indicates status (e.g., green for active, red for stop).
    - Haptic Feedback Module: Integrated in cane holder, provides vibration feedback for commands and alerts.

Technical Summary and Social Impact

- **Technical Summary**
  - Objective: Autonomous assistive navigation for visually impaired users in complex environments.
- **Core Components:**
  - Navigation: High-resolution LiDAR (RPLIDAR A3) with SLAM, multi-sensor fusion (LiDAR, ultrasonic, IMU) for real-time mapping and obstacle detection.
  - Control Architecture: Dual closed-loop motor control (Roboclaw 2x7A), PID tuning for precise movement.
  - User Interaction Module: Meta LLM for contextual voice command understanding, haptic and auditory feedback with adaptive audio.
  - Safety Mechanisms: Proximity-based emergency stop, RGB status signaling, remote stop functionality
- **Advanced Social Impact**
  - Enhanced Spatial Accessibility: Assists visually impaired users with sensor fusion and adaptive algorithms for safe, context-aware navigation.
  - Promoting Inclusion in Public Infrastructure: IoT integration enables BrailleBot to interact with infrastructure elements, setting a precedent for inclusive design globally.
  - Catalyst for Assistive Robotics Research: Scalable framework adaptable to future advancements in perception, HRI, and autonomous navigation, supporting broader inclusivity.