Cover Page صفحة

عنوان المشاركة

PathGuide cane

: الملخص

تُعد عصا باث–جايد للمسح المكاني حلاً مبتكراً صُمم خصيصاً لمعالجة تحديات التنقل والحركة التي يواجهها الأفراد من ذوي الإعاقة البصرية في البيئات الداخلية ومن خلال الاستفادة القصوى من تقنيات المسح المكاني والذكاء الاصطناعي واستشعار الحركة، يعمل هذا المشروع على تحويل العصا التقليدية من مجرد أداة بسيطة إلى أداة ملاحية متطورة للغاية. فهي تعمل كجسر يردم الفجوة بين الكشف التقليدي عن العوائق وبين نظام التوجيه الداخلي الذكي والفعال، حيث توفر توجيهات دقيقة وفورية في الوقت الفعلي للمساعدة في التنقل داخل المساحات الداخلية المنزلية بأمان وثقة.

ومن الناحية التاريخية، كانت تقنية المسح المكاني تُستخدم بشكل أساسي في مجالات التصميم الداخلي لرسم خرائط المساحات وتوزيع الأثاث، أما الآن فهي تعمل بمثابة "عين رقمية" لضعاف البصر، مما يساعد في خلق خريطة ذهنية واضحة وحية لما يحيط بالمستخدم. تعتمد منهجية المشروع على تقنية المسح المكاني ثلاثي الأبعاد، حيث تقوم الكاميرا بإنشاء خريطة رقمية للبيئة يتم تحليلها بواسطة الذكاء الاصطناعي لتقديم تعليمات ملاحية دقيقة. ويعتمد النظام على عصا ذكية مزودة بمستشعرات تعمل بالموجات فوق الصوتية ووحدة قياس القصور الذاتي لتتبع الاتجاهات والزوايا والتحركات بدقة، حيث ترتبط هذه العصا بتطبيق على الهاتف المحمول يمسح البيئة ويخلق خريطة رقمية يحللها النظام لتقديم توجيهات مباشرة عبر اهتزازات ملموسة في مقبض العصا.

ويتكون هذا النظام تقنياً من مكونين رئيسيين: العصا الذكية المجهزة بمستشعرات كشف العوائق ومحرك الاهتزاز، وتطبيق الهاتف المحمول الذي يقوم بالمسح البيئي وتخزين البيانات. وعندما يصدر المستخدم أمراً، يقارن التطبيق البيئة المباشرة بالخريطة المخزنة لتحديد الموقع الدقيق. ويتبع ذلك سير عمل تشغيلي من ثلاث مراحل: تبدأ بمسح

البيئة، ثم التعرف على المساحة وتأكيد الاتجاهات، وصولاً إلى مرحلة التوجيه عبر الاهتزازات لمساعدة المستخدم على البقاء في مساره الصحيح أو تصحيح أي انحراف.

إن الابتكار الحقيقي في هذا المشروع يتمثل في التحول الجذري من أنظمة تنبيه العوائق السلبية التي تكتفي بالتحذير، إلى أنظمة التوجيه النشطة والفعالة؛ فالعصا لا تكتفي برصد العوائق، بل تفهم طبيعة المكان وتقدم اتجاهات فورية تشبه أنظمة الملاحة الداخلية. وهذا يهدف إلى تمكين الاستقلالية الشخصية، وتعزيز النشاط البدني، وتقليل المخاطر الصحية التي قد تنتج عن صعوبة الوصول. وبما يتماشى مع رؤية السعودية ٢٠٣٠ يساهم المشروع في بناء توسعه إلى أماكن مغلقة أخرى ذكية شاملة تعزز إمكانيات الوصول للجميع. وفي نهاية المطاف، تمثل عصا باث-جايد للمسح المكاني قفزة نوعية في الابتكار التكنولوجي والتصميم المرتكز على الإنسان، مما يمنح الأفراد استقلالية وثقة أكبر وجودة حياة أفضل.

Summarization:

The PathGuide SpatialScan cane is an innovative solution specifically designed to address the navigation and mobility challenges faced by individuals with visual impairments in indoor environments. By maximizing the use of spatial scanning technologies, artificial intelligence, and motion sensing, this project transforms the traditional cane from a simple tool into a highly sophisticated navigational device. It acts as a bridge, closing the gap between traditional obstacle detection and an intelligent, efficient indoor guidance system, providing precise, real-time directions to help navigate indoor home spaces safely and confidently.

Historically, spatial scanning technology was primarily used in interior design for mapping spaces and furniture layout. Now, it serves as a "digital eye" for the visually impaired, helping to create a clear and vivid mental map of the user's surroundings. The project’s methodology relies on 3D Spatial Mapping technology, where the camera creates a digital map of the environment that is analyzed by AI to provide accurate navigational instructions. The system depends on a smart cane equipped with ultrasonic sensors and an Inertial Measurement Unit (IMU) to accurately track directions, angles, and movements. This cane is linked to a mobile application that scans the environment and creates a digital map, which the system analyzes to provide direct guidance through haptic vibrations in the cane's handle.

Technically, this system consists of two main components: the smart cane equipped with obstacle detection sensors and a vibration motor, and the mobile application that performs environmental scanning and data storage. When a user issues a command, the app compares the immediate environment with the stored map to determine the exact location. This is followed by a three-stage operational workflow: beginning with scanning the environment, then recognizing the space and confirming directions, and finally, the guidance phase via vibrations to help the user stay on the correct path or correct any deviation.

The true innovation of this project lies in the radical shift from passive obstacle alert systems that merely warn, to active and effective guidance systems. The cane does not just detect obstacles; it understands the nature of the place and provides immediate directions similar to indoor navigation systems. This aims to empower personal independence, enhance physical activity, and reduce health risks resulting from accessibility difficulties. In line with Saudi Vision

2030, the project contributes to expanding into other inclusive smart indoor spaces that enhance accessibility for all. Ultimately, the PathGuide SpatialScan cane represents a qualitative leap in technological innovation and human-centered design, granting individuals greater independence, confidence, and a better quality of life.

Introduction

In the modern era, technology has become a vital tool for improving the lives of individuals with disabilities, significantly contributing to the provision of effective solutions to the challenges they face. Among these challenges, visual impairment stands out as one of the major issues affecting millions of people worldwide. Vision is one of the essential senses we rely on to interact with our surroundings, and when this ability is affected, individuals are forced to rely on other means and tools for navigation and interaction with the environment. Visual impairment greatly impacts daily life, leading to challenges such as difficulty in navigation, social isolation, and psychological distress.

Over the years, significant developments have been witnessed in the design of assistive devices, with continuous innovation focusing primarily on outdoor environments or isolated obstacle detection. Many current innovations and existing devices have successfully employed ultrasonic sensors and smart cameras to identify objects and barriers in front of the user, providing auditory or vibrating alerts to prevent collisions. However, these innovations often stop at the boundary of "detection" without offering any form of active guidance or navigational orientation. Even the most advanced systems are frequently designed for open spaces, leaving a critical gap when it comes to the specific needs of indoor mobility.

The fundamental gap in current innovations is that most solutions provide only a "safety net" rather than a functional "roadmap." While a user might be alerted to a wall or a chair, these alerts are insufficient because they don't provide the directional context needed to navigate. To solve this, we can look at current Spatial Scanning technologies, which are highly advanced and widely used for professional furniture scanning and detailed interior mapping to create "digital twins." Although these tools have mastered the art of documenting every inch of a room's dimensions, they have been strictly limited to design purposes and haven't been utilized to guide the blind. This lack of spatial guidance means that even with a smart device, a visually impaired person remains trapped in a cycle of detecting obstacles without knowing their actual path, leaving them dependent on others for directional instructions inside their own homes or specific buildings.

To address this, the PathGuide SpatialScan Cane aims to develop an innovative, integrated system that repurposes this scanning technology to shift the focus from simple obstacle avoidance to intelligent indoor orientation. By combining advanced Artificial Intelligence, motion sensing, and computer vision, this project introduces a system that doesn't just "see" obstacles, but "understands" the environment. It matches live surroundings with a pre-mapped visual database to provide precise instructions. Furthermore, the system empowers the user through a sophisticated feedback mechanism that distinguishes between immediate physical dangers and directional path corrections. By bridging the gap between sensing and guidance, the PathGuide SpatialScan Cane transforms the navigation process into a confident, goal-oriented experience, granting users the autonomy to move freely and purposefully within any indoor space

Methodology

The core of this project relies on Spatial Mapping. The system uses the camera to create a comprehensive 3D digital twin of the environment (as shown in the spatial scanning of rooms). This digital map serves as the foundation for the AI to determine precise paths, allowing the system to locate the user within this spatial context and send accurate navigation commands to the smart cane. This methodology aims to develop a technical framework that integrates hardware sensing with mobile-based Artificial Intelligence to facilitate safe indoor navigation.

System Design

The proposed system will consist of two main units: the Physical Sensing Unit (The Smart Cane) and the Intelligent Processing Unit (The Mobile Application). To ensure a seamless wireless connection, the two units will communicate via a Bluetooth module. Furthermore, the entire hardware system will be powered by an integrated battery embedded within the cane's handle to ensure portability.

The Smart Cane Components

The cane will be integrated with an Arduino microcontroller to serve as the central processing unit. To ensure safe and directed navigation, the following sensing technologies will be explored:

• Obstacle Detection: An Ultrasonic sensor will be utilized to measure distances and detect physical barriers in real-time.

• Orientation Tracking: An Inertial Measurement Unit (IMU) will be incorporated to monitor the user's movement and detect changes in direction.

• Feedback Mechanism: A vibration motor will be embedded in the handle to provide tactile alerts, ensuring a non-intrusive way to communicate with the user.

Mobile Application & AI Processing

The smartphone application acts as the central controller by linking the Camera to the Artificial Intelligence (AI). The system allows the user to perform a 3D/Panoramic scan of the rooms, capturing the entire environment as a single spatial map. The AI then recognizes the image and its location within this map and stores these visual features in the memory for future use.

The Mechanism

1. Scanning and Processing: The camera performs a wide-angle scan of the room, sending a comprehensive data feed to the Image Classification Model within the app.

2. Recognition and Spatial Storage: The AI instantly analyzes the features of the entire scanned area to identify locations, then saves this spatial map in the Local Memory as a reference.

3. Linking and Control: Once the live view matches any part of the stored spatial map, the application issues a command via Bluetooth to the Arduino in the cane.

4. Initiating Movement & Voice Guidance: When the user issues a voice command for a destination, the AI matches the live feed with the stored 3D map to determine the user's precise centimeter-level location. Upon

confirmation, the app sends real-time signals to the cane to trigger the vibration motor if a deviation occurs, guiding the user accurately until a voice notification confirms arrival.

The Navigation Procedure

The core of this project will follow a three-phase operational workflow:

• Phase One: Environment Mapping: A sighted assistant uses the application to perform a comprehensive scan of various rooms to create a visual reference database stored locally.

• Phase Two: Intelligent Room Recognition: When the user issues a voice command, the system activates the camera and compares the live surroundings with the stored spatial map.

• Phase Three: Guidance and Feedback Strategy:

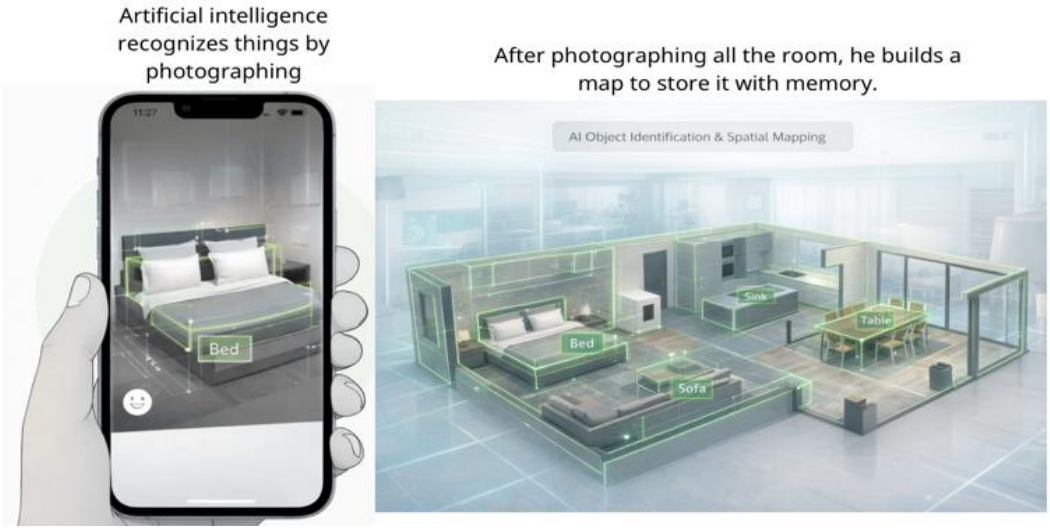
• In the Correct Path: The system remains silent as long as the user is moving correctly toward the target.

• In Case of Deviation: If the system detects a wrong turn or an off-course movement, the vibration motor in the cane is triggered immediately.

• Upon Arrival: The application provides a voice notification to confirm arrival.

To validate the system, the project will test the accuracy of the sensors in detecting various objects and audit the firmware code for efficient real-time data processing. It will also measure the success rate of the AI model in recognizing rooms under different lighting conditions and verify the Bluetooth communication protocols between the app and the Arduino to ensure zero-

latency command delivery. Finally, it will evaluate the efficiency of the vibration alerts in guiding the user safely."



Expected Impact

• Achieving Personal Autonomy & Quality of Life: Empowering users to rely entirely on themselves for daily tasks, turning routine movements—like reaching the kitchen or restroom—into spontaneous actions, making the home environment digitally accessible and stress-free.

• Prevention of Physical Health Issues: The system contributes directly to the user's health; by facilitating independent access to restrooms, it helps prevent urinary tract infections and bladder issues caused by delayed movement. Additionally, it encourages physical activity, which improves cardiovascular health and blood circulation.

• Improving Physical Activity: Breaking the "stationary lifestyle" often forced upon the blind due to the fear of collisions. This innovation motivates users to walk and stay active indoors, improving their overall physical fitness.

• Psychological Empowerment: Replacing the feeling of helplessness with a sense of control and confidence. This reduces psychological distress and frustration caused by getting lost, leading to higher morale and mental well-being.

• Bridging the Technical Gap: Repurposing Spatial Scanning technology—originally used for furniture and interior design—into a vital navigation tool that serves human independence and accessibility.

• Creating a Roadmap for the Future: Setting the foundation for smart indoor navigation in hospitals, airports, and malls, making the world more inclusive and accessible for everyone.

In conclusion, the PathGuide SpatialScan Cane represents a pioneering model in harnessing technology to serve humanity. It does not merely offer a traditional tool for obstacle avoidance, but rather grants the visually impaired a "Digital Insight" that perceives spatial dimensions and creates a safe, independent roadmap. By repurposing Spatial Scanning technology—which was long confined to the design and furniture sectors—this research proves that true innovation lies in bridging technical gaps and transforming them into solutions that touch the quality of human life.

This innovation represents a qualitative leap that transcends being just a technical project; it clearly aligns with the goals of Saudi Vision 2030 in

empowering individuals with disabilities, fostering inclusive smart cities, and raising quality of life indicators, based on the belief that individual empowerment is the cornerstone of nation-building. Ultimately, this innovation is not just a smart cane; it is a promise of a future where technology grants the visually impaired their right to move freely and independently.