Autonomous Robot for Elderly Safety and Assistance

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Abstract: In the context of home automation, the challenge is to design a robot that can autonomously navigate within a home environment to reach an elder person located in different rooms, such as the hall, kitchen, or bedroom. The robot must be capable of avoiding obstacles, considering the lighting conditions within the home, and responding to gestures made by the elder person. The problem involves determining why the robot should choose specific paths based on these parameters, ensuring that it moves efficiently and safely while adapting to the dynamic environment of a home. This challenge is crucial in enhancing the quality of life for elderly individuals by providing them with assistance and ensuring their safety.

To solve the above problem, the robot can use a combination of smart technologies. First, it can use path planning algorithms like A* or Dijkstra's algorithm to find the safest and quickest way to reach the elder person. These algorithms help the robot figure out the best path while avoiding obstacles like furniture or other objects in the home. The robot can also use sensors to detect how bright or dim the lighting is in each room, adjusting its movements so it can see and navigate better, even in low light. Additionally, the robot can be equipped with cameras or motion sensors to recognize gestures made by the elder person, such as waving a hand or pointing. These solutions are combined and integrated using the PYNQ-Z2 board, which is ideal due to its reconfigurable nature, allowing for the flexible implementation of complex algorithms and real-time processing. This integration ensures that the robot can intelligently navigate the home environment, making it a valuable component of a home automation system that supports elderly care.

1. INTRODUCTION

As our population ages, providing assistance and ensuring the safety of elderly individuals in their homes becomes increasingly important. This project focuses on creating an autonomous robot designed to navigate within a home environment, helping elderly people by reaching them in different rooms like the hall, kitchen, or bedroom. The robot will be equipped to avoid obstacles, adapt to varying lighting conditions, and respond to gestures made by the elder person. By leveraging advanced technologies, this robot aims to enhance the quality of life for seniors, allowing them to remain independent while receiving the support they need.

The robot's ability to navigate effectively is essential for its role in elderly care. It will utilize various sensors to detect obstacles in its path, ensuring it can safely move around furniture and other items in the home. Additionally, the robot will adjust its navigation based on the lighting conditions, ensuring visibility and safe operation. Importantly, the robot will recognize and respond to gestures, enabling the elder person to communicate their needs effectively. By combining these features, the robot will not only assist the elderly in daily tasks but also provide peace of mind for their families, knowing that their loved ones are supported by a reliable and responsive system.

2. PROBLEMSTATEMENT

Elderly individuals in a home environment often face mobility challenges due to various factors such as age-related physical limitations, chronic health conditions, and the natural decline in strength and balance. These challenges can make it difficult for them to move independently between rooms like the hall, kitchen, or bedroom, significantly impacting their daily lives and overall well-being. As a result, many elderly individuals may experience feelings of isolation, frustration, and dependency, which can contribute to a decreased quality of life.

This mobility issue creates a pressing need for continuous assistance to ensure their safety and well-being. Without reliable support, elderly individuals may struggle to access essential areas of their home, such as the kitchen for meal preparation or the bathroom for personal care. Additionally, the risk of falls and accidents increases when they attempt to navigate their environment without assistance.

3. PROPOSEDSOLUTION

To develop an autonomous robot that can effectively assist elderly individuals in a home environment, several key functionalities must be implemented. The robot will need to navigate through various rooms, avoid obstacles, adapt to changing lighting conditions, and respond to gestures made by the elderly person. This entails a robust integration of sensors, algorithms, and control system.

3.1 PATHPLANNINGREQUIREMENTS

A* ALGORITHM

A* is a popular path finding algorithm used to find the shortest path between a starting point and a destination. It's especially useful in navigation because it efficiently finds paths through spaces with obstacles. The algorithm works by checking possible paths from the start to the goal, always selecting the path that appears shortest and avoids obstacles, while aiming to reach the destination quickly.

DIJKSTRAS ALGORITHM

Dijkstra's Algorithm is a popular path finding algorithm that finds the shortest path between nodes in a graph. It is widely used in navigation systems because it efficiently finds the quickest route from a starting point (source) to a destination, moving through interconnected nodes. In our context, these nodes could represent different rooms or areas within a home

PROBABILISTIC ROAD MAP (PRM)

The Probabilistic Roadmap (PRM) algorithm is a popular path-planning method used to navigate in complex environments. It works by building a map(or "roadmap") of possible paths that the robot can follow. This roadmap is created by randomly selecting points in the environment and connecting them based on certain criteria, like distance and obstacle-free paths.

4.FACERECOGNITION

Working of face recognition:

Face recognition is a biometric identification technique that uses unique characteristics of an individual's face to identify them. It works by detecting the face and measuring facial features in an image. Most facial recognition systems work by comparing the face print to a dataset of known faces. If there's a match, the system can identify the individual. However, if the face print isn't in the database; the system can't identify the individual. The technology works by using cameras or other sensors to capture images of faces, and then analysing various characteristics such as the distance between the eyes, the shape of the jaw line, and other unique facial features.

The software then compares these characteristics to a dataset of known faces to identify or verify the individual's identity. Facial recognition technology has many applications, including security and law enforcement, authentication and identification, and marketing and advertising and facial recognition technology is often used for security purposes, such as identifying criminals or preventing identity theft. However, it has also raised concerns about privacy and civil liberties, particularly when used in public spaces without the consent or knowledge of those being monitored.

Facial recognition works by analyzing and comparing various unique characteristics of an individual's face to a database of known faces.

Facial recognition works in three steps:

i) Alignment and detection

ii) Analysis

iii) Recognition or Identification

GESTURERECOGNITION

Working of Hand gesture recognition:

Hand gesture recognition is a technique used to identify specific hand signs and movements by analyzing hand landmarks and mapping them to predefined actions. It works by detecting the hand and measuring the positions of key points on the hand in an image or video stream. The system compares these positions to a set of known gestures to recognize the action being performed. This technology is often used in human-computer interaction, gaming, sign language interpretation, and other hands-free control systems. The technology captures images using a webcam or other video input device and analyzes various hand characteristics such as finger positions and relative distances. Based on these characteristics, the system maps the hand shape to a known gesture. Hand gesture recognition systems have many applications, including virtual reality, robotics, and smart home control. However, achieving high accuracy remains a challenge due to variations in lighting, hand orientation, and occlusions.

Hand gesture recognition works in three steps:
i) Hand Detection and Alignment
ii) Feature Analysis
iii) Gesture Recognition or Classification

HARDWARE INTEGRATION WITH PYNQ-Z2 BOARD

The PYNQ-Z2 is a development board designed for Python productivity and FPGA-based applications. It is built around the Xilinx Zynq-7000 SoC, which integrates a dual-core ARM Cortex-A9 processor with a programmable FPGA. This board is widely used in machine learning, image processing, embedded systems, and IoT applications due to its high- performance capabilities and flexibility.

ENTIREBOARDCONNECTIONS

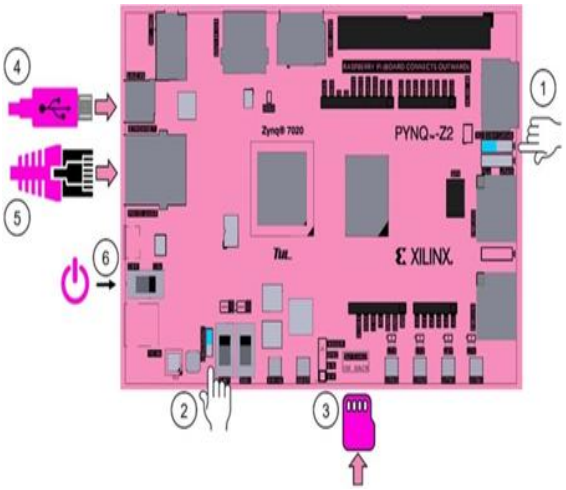

Fig7.3.5EntireBoardConnections

CONNECTIONESTABLISHMENT

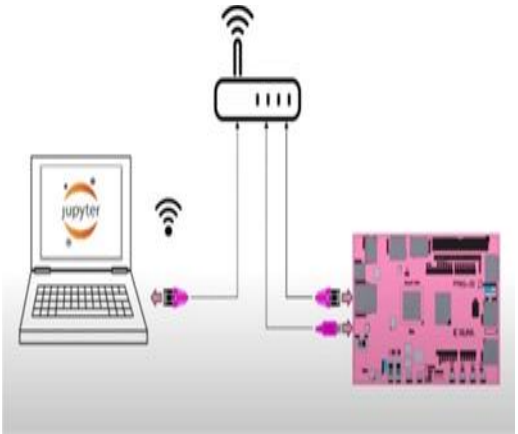

Fig7.3.6ConnectionEstablishment

5.RESULTS

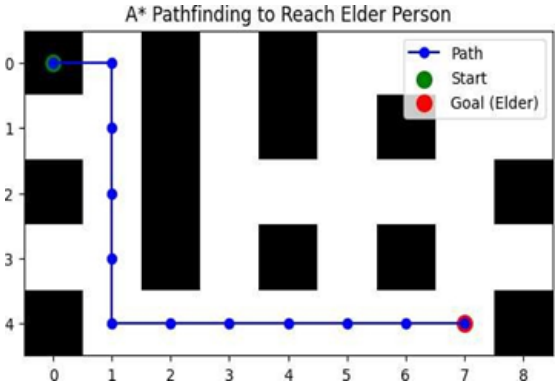

*Fig8.1.1PathPlanningusingA*Algorithm*

Robot needs to move to the Kitchen.
Path found:[(0,0),(0,1),(1,1),(2,1), (3,1),(4,1),(4,2),(4,3),(4,4),(4,5),(4,6),(4,7)]
Execution Time (Speed): 0.000218seconds Distance (steps): 11 steps Accuracy (1= perfect): 1.00

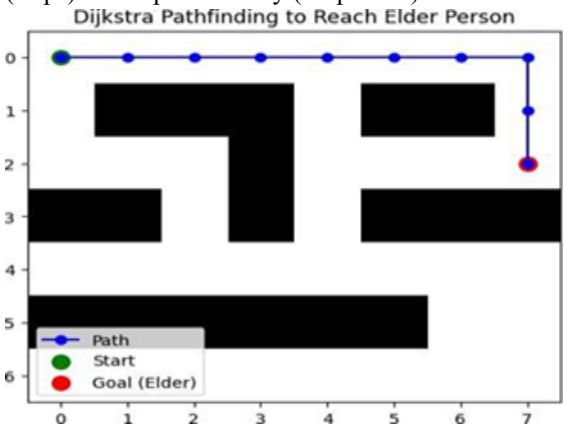

Fig8.1.2Path Planning using Dijkstra Algorithm

Robot needs to move to the Hall.
Path found:[(0,0),(0,1),(0, 2)(0,3),(0,4),(0,5), (0, 6) ,(0,7),(1,7),(2,7)]
Execution Time (Speed): 0.000159 seconds Distance (steps): 9 steps Latency per step: 0.000018 seconds/step Accuracy (1 = perfect): 1.00

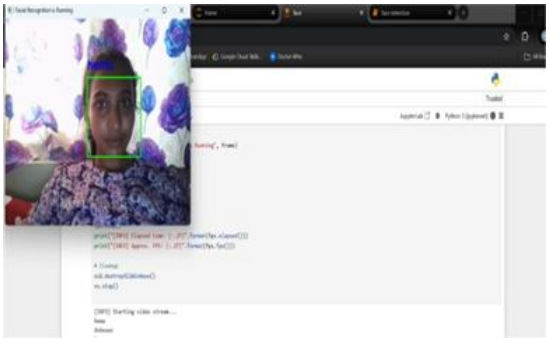

Fig8.3.2MatchedFace

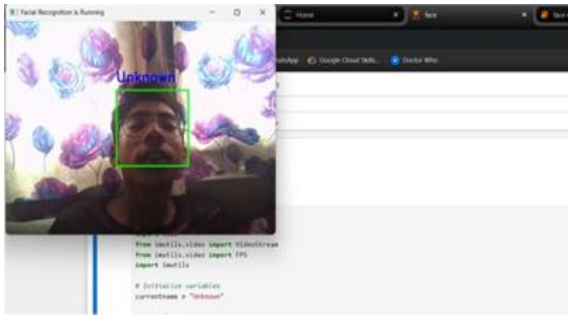

Fig8.3.3UnknownFace

GESTURE RECOGNITION:

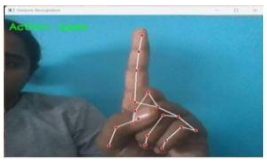

Fig a. Gesture recognized as one

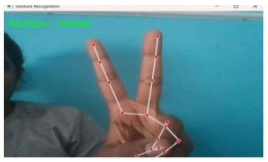

Fig b. Gesture recognized as two

c. Gesture recognized as three

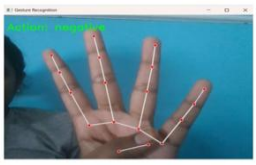

Fig d. Gesture recognized as four

ROBOTWITHPYNQ-Z2:

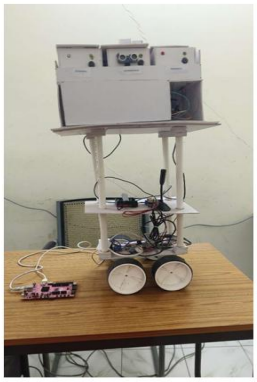

Fig: e. Front View

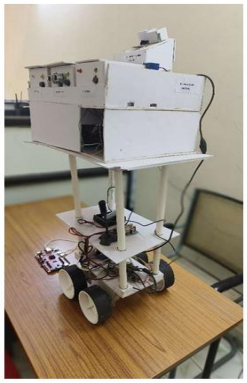

Fig: f. Side View

Fig: ROBOTWITHPYNQ-Z2

CONCLUSION

This project successfully implemented A* and Dijkstra's algorithms to navigate a robotic system in a home environment, ensuring safe and efficient paths to reach elderly individuals. By utilizing predefined grid layouts, we simplified the complexities associated with grid conversion into a 2D format, allowing for accurate path finding and obstacle avoidance. The algorithms effectively calculated optimal routes, demonstrating their robustness in real-time applications. The robot successfully reached the target locations, showcasing the effectiveness of these algorithms in enhancing elderly safety and assistance.

The robot was made adaptable to varying lighting conditions, ensuring reliable performance in different home environments. Face and gesture recognition were effectively implemented using Jupyter on the PYNQ-Z2, enabling the robot to identify individuals and respond to specific gestures. The system demonstrated robust real-time processing, optimizing accuracy and efficiency while operating within hardware constraints. Overall, it achieved its objectives, creating a smart and interactive robotic assistant capable of enhancing elderly care and home automation.

REFERENCES

[1] "Obstacle Avoidance and Path Planning Methods for Autonomous Navigation of Mobile Robot ", Kornél Katona, Husam A. NeamahandPéterKorondi, Published:1 June 2024.

[2] "Socially Aware Robot Obstacle Avoidance Considering Human Intention and Preferences", Trevor Smith, Yuhao Chen, Nathan Hewitt, BoyiHu, Yu Gu, Published: 5 July 2021.

[3] "Application of Deep Learning for Object Detection ", Ajeet Ram Pathaka, Manjusha Pandeya, Siddharth Rautaray, Published:2018.

[4] "Analyzing the effects of human-aware motion planning on close-proximity human- robot collaboration" Lasota PA, Shah JA, 2015

[5] "Using human attention to address human–robot motion. "PaulinR, FraichardT, Reignier P 2019

[6] "Gesture controlled robot using image processing." Kaura, Harish Kumar, Vipul Honrao, Sayali Patil, and Pravish Shetty. International Journal of Advanced Research in Artificial Intelligence 2, no. 5 2013.

[7] "Design and implementation of web based virtual mobile robot laboratory for engineering education." Solak, Serdar, ÖnderYakut and EmineDogruBolat. Symmetry 12, no. 6 (2020): 906

[8] "Design, Implementation, and Performance Evaluation of aWeb-Based Multiple Robot Control System." Rajapaksha, U.U., Chandimal Jayawardena, and Bruce A. MacDonald Journal of Robotics 2022 (2022)

[9] "Obstacle detection by evaluation of optical flow fields from image sequence", W.Enkelmann, Image V is. Comput., no.9, pp.160-168, 1991.
[10] "Face alignment and detection via 6d of, face pose estimation". Albiero, V.; Chen, X.; Yin, X.; Pang, G.; Hassner June 2021.