Artificial Intelligence-Based Robot Assistant for Elderly Care

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May, 2023

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بسم الله الرحمن الرحيم

In the name of Allah (SWT), the most beneficent and the most merciful

A BS Final Year Project submitted to the

Department of Electrical and Computer Engineering

International Islamic University, Islamabad

In partial fulfillment of the requirements

For the award of the degree of

Bachelor of Science in Electrical Engineering

Declaration

We hereby declare that this work, neither as a whole nor as a part thereof has been copied out from any source. No portion of the work presented in this report has been submitted in support of any application for any other degree or qualification of this or any other university or institute of learning. We further declare that the referred text is properly cited in the references.

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Acknowledgments

This BS thesis in Electrical Engineering has been conducted at the Department of Electrical and Computer Engineering, Faculty of Engineering and Technology, International Islamic University, as part of the degree program. We would like to thank Dr. Aleem Khaliq for providing us an opportunity to work on this project, under his supervision and guidance throughout the project. We would also like to thank Dr. Aleem Khaliq for his help, efforts, and dedicated support throughout the project. Further we are particularly thankful to Almighty Allah and grateful to our parents, brothers and sisters who always supported and encouraged us during our project and studies at IIUI.

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Date Started:	September, 2022
Date Completed:	June, 2023

Tools Used:

- Arduino IDE
- PixyMon
- Jupyter Notebook

Abstract

Every country's population of elderly adults is growing in both size and percentage. The demographic transition towards an aging population is creating a growing need for technology and innovative solutions to support the elderly in their daily lives. However, due to the shortage of caregivers and the high expense of care, it is challenging to provide good-quality care to all elderly individuals. In recent years, artificial intelligence (AI) and robotics have opened up new opportunities for elderly care. In this project, we propose an AI-based robot assistant for elderly care

The robot is designed to track and follow the elderly person, ensuring they do not become lost or disoriented, and giving them a sense of security. The robot detects and avoids obstacles while following the old person using a Pixy camera and ultrasonic sensors, making it safe and reliable. It also can detect falls and call for help through a tablet in case of injury, increasing the chances of prompt medical attention and recovery. The project has the potential to provide personalized and reliable care for elderly individuals, enhancing their independence and well-being.

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SoC	System on Chip
FYDP	Final Year Design Project
OBE	Outcome Based Education
IoT	Internet of Things

Chapter 1

Introduction

1.1 Motivation

The population of the globe is aging, with the number of persons 60 and older predicted to quadruple from 962 million in 2017 to 2.1 billion in 2050 (table 1) This is due to improvements in healthcare, declining fertility rates, and increased life expectancy. The need for healthcare services, especially aged care, is increasing as the population ages, which presents substantial issues for healthcare systems.

Elder care is a critical component of healthcare since older people frequently require specialized care and support to manage their health and preserve their quality of life. However, providing adequate care for older adults is a difficult task that necessitates substantial resources, expertise, and time. The existing healthcare system has various obstacles to delivering excellent care to older individuals, including increased demand for services, a caregiver shortage, high prices, and restricted access to care.

The "Artificial Intelligence-Based Robotic Assistant for the Elderly" project aims to solve these problems by providing effective solutions that enable the elderly to live independently and with dignity. The aim of the project is to create a robot assistant that can provide personal care and assistance to the elderly, reduce treatment stress and make their lives more fulfilling.

Table 2.1: Number and distribution of people aged 61

	Number of Persons aged 60 years or older in 2017(million)	Number of persons aged 60 years or over in 2050(millions)	Percentage change between 2017 and 2050	Distribution of older persons in 2017 (percentage)	Distribution of older persons in 2050 (percentage)
World	962.5	2080.5	116.2	100	100
Africa	68.7	225.8	228.5	7.1	10.9
Asia	549.2	1273.2	131.8	57.1	61.2
Europe	183	247.2	35.1	19	11.9
Northern America	78.4	122.8	56.7	8.1	5.9
Latin America and the Caribbean	76	198.2	160.7	7.9	9.5
Oceania	6.9	13.3	92.6	0.7	0.6

1.1.1 Aging population

Population aging is a demographic trend that expresses the increase of older people in the population. This change is due to many factors, including advances in medical care, rising living standards, and declining fertility. An aging population has a significant impact on society, including the increasing need for health care and the need for support and care for the elderly. Population aging is a worldwide phenomenon, especially in developed countries such as the United States, Japan, and Europe. This demographic shift has many implications for the health care system, including increased demand for health care services, rising health care costs, and staff shortages in patient care. An aging population also creates health and financial problems, as older populations often face social isolation. Declining economic productivity and increasing financial insecurity. In addition, older people are at higher risk of chronic diseases that can affect their quality of life, such as diabetes, heart disease and dementia. The AI-based Elder Care Robotic Assistants project aims to solve these problems by providing robotic assistants that can help seniors manage their health and daily activities, reduce health burdens, and improve seniors' quality of life.

1.1.2 Elderly Care Challenges

Providing adequate care and support to the elderly is a complex and difficult task. Some of the key issues that the Artificial Intelligence-Based Robotic Assistant for Elderly Care project is trying to address include:

- **Isolation:** Older people may experience isolation due to factors such as being alone and lack of movement or transportation. Social isolation can lead to loneliness, depression, and cognitive dissonance.
- **Inactivity:** Older people may experience physical limitations that make it difficult for them to perform daily activities such as bathing, dressing or cooking. Limited mobility also increas es the risk of falls, which can lead to serious injury and hospitalization.
- **Cognitive decline:** Many older adults experience cognitive decline that makes it difficult to remember important information such as medication schedules, appointments, and emergency calls
- **Medication Management:** Adults need to take multiple medications and managing differen t doses and schedules can be difficult. This can lead to the wrong medication with serious con sequences.

Solving these problems requires an integrated approach that includes everyone's unique needs and preferences. The project "Artificial Intelligence Based Robot Assistant for Elderly Care" aims to provide a solution that can support the daily lives of the elderly, encourage their independence and improve their quality of life.

This project uses artificial intelligence and robotic to provide personalized and effective solutions to the challenges faced by the elderly.

1.1.3 Background History:

Utilizing innovation to help the elderly is certainly not another one; however, the improvement of simulated intelligence-based robot partners for the elderly is a moderately ongoing peculiarity. Here is the foundational history that prompted the production of these robots:

- Maturing populace: The worldwide populace is quickly maturing, with the quantity of individuals beyond 65 years old expected to significantly increase by 2050. This segment shift has expanded interest in older consideration administrations.
- Deficiency of caregivers: The maturing populace has likewise prompted a lack of caregivers. The interest in older consideration administrations has overwhelmed the stock of prepared experts, prompting a burden on the medical care framework.
- Significant expense of conventional older consideration administrations: Customary old-fashioned consideration administrations, like nursing homes and assisted living offices, can be costly, overwhelming seniors and their families.
- Progress in mechanical technology and simulated intelligence: The improvement of advanced mechanics and simulated intelligence has opened up additional opportunities for consideration. Robots can be modified to perform different errands and provide friendship, lessening the burden on carers and improving personal satisfaction for seniors.
- Innovative work: Scientists and designers have been dealing with making manufactured intelligence-based robots for quite some time. These robots have been intended to give customized help, friendship, and wellbeing highlights to seniors.

By and large, the mix of a maturing populace, a lack of carers, the significant expenses of conventional old consideration administrations, and advances in mechanical technology and man-made intelligence have prompted the improvement of man-made intelligence-based robot colleagues for old consideration. These robots can possibly give a practical and productive answer to the developing interest in older consideration administrations while working on personal satisfaction for seniors. Advanced mechanics and simulated intelligence have prompted the improvement of simulated intelligence-based robot aides for older consideration. These robots can possibly give a well informed and productive answer to the developing interest in old consideration administrations while working on personal satisfaction for seniors.

More seasoned adults are a growing segment of America's populace, with an expected 83.7 million individuals aged 65 and older by 2050. This increment can be credited to progress in medication. Nonetheless, numerous more seasoned adults experience limits to ageing in regions with inaccessibility of lodging or deficient or loss of medical service assets. One way to deal with diminishing those obstructions is through the execution of medical service innovation, including medical care's advanced mechanics. steady with the overall League of Advanced mechanics worldwide. Advanced mechanics 2018 assistance Robots archive: clinical robot pays extended 73% in 2017 more than in 2016, representing 2.7% of all expert transporter automated deals. Robots have arrived in a drawn-out way. For quite a long time, they were helping human interest - permitting investigation in hazardous and inaccessible conditions like out in space and deep inside the seas. Another innovation of robots is that they are intended to live closer to home, stressing the difference between old grown-ups and more youthful kids.

1.1.4 **Importance of Robots:**

Robots in memorable times and through mediaeval times have been utilized, by and large, for entertainment. Yet, the twentieth century highlighted an expansion in the improvement of business robots. Through the unwinding of the past hundred years, robots changed the construction of society and took into account extra-secure circumstances for difficult work. In 2005, 90% of all robots were utilized to collect vehicles in vehicle manufacturing plants. Nowadays, we're seeing a high level and sped-up meaning of advanced mechanics that comprises the turn of events, appearance, and utilization of robots that investigate Earth's most cruel circumstances, robots that help guideline implementation, or perhaps robots that assist in practically everything about medical services. Robots are especially utilized in enormous assembly ventures. Inside those ventures, robots assume an essential role as well as stock. They help the maker know what to supply, how to deliver, and how to keep stock effectively.

1.1.5 Application of Robots:

Robots are utilized for occupations that are filthy, dull, and undermining. Today, advanced mechanics have a wide range of utilization districts. Various of them are:

- Industry
- Military applications
- Clever home applications
- Dealing with and picking
- Machining and cutting
- Welding and patching
- Painting and Covering
- Cleaning and cleanliness

Fig.(i): Different Applications of Robotics

1.1.6 Mechanical technology in the clinical and medical services area:

"Advanced mechanics innovation is improving, but its standard use in the home, clinic, and care settings could be far off." (Neil Savage)

Clinical robots have been gradually altering treatment for no less than twenty years. The Diary of Clinical Mechanical Technology Exploration (JMRR) welcomes original commitments to all areas of clinical mechanical technology, including clinical assessment studies.

The mix of robots into medical care conditions is turning out to be more normal. These days, task robotization is appropriate for all fields, and clinical robots are frequently utilized.

The utilization of robots in medical clinics has, as of late, turned into a pillar in the medical services industry. Mechanical applications in medication and particularly in clinics have taken a giant leap forward in the battle against coronavirus.

A portion of the obligations in the clinical field would be

- Conveyance and conveyance of food
- Cleaning or sterilization
- capacity and appropriation of medications.
- Careful help.
- Managerial and strategic assignments are standard and troublesome for clinical staff.
- Significant distance power

Clinical robots can add to the framework, and older consideration is unquestionable. The coronavirus pandemic has featured various ways in which robots can assist more seasoned individuals with living more freely.

It can likewise empower them to mature with nobility through material and non-material help. The advantages of automated mediation additionally incorporate decreased nursing pressure for carers and medical service laborers.

One of the principal issues for the older populace and individuals with useful incapacities is that they are left unaided. Hence, checking frameworks with fall discovery capabilities is fundamental. Contrasted with static sensors, versatile robots are a decent answer for focusing on individuals.

1.1.7 Services of robots in elderly care:

There are different sorts of robots utilized in older times, each with its own special job and abilities. A portion of the normal jobs of various robots under consideration are:

Friendship: Robots like Paro, a mechanical seal, and ElliQ, a simulated intelligence-based robot colleague, are intended to give friendship to seniors. These robots can connect with seniors through regular language and signals, play music, give updates, and screen the senior's prosperity.

Assistive innovation: Robots like Consideration o-bot and ZoraBots are intended to help seniors with different everyday errands, like dinner readiness, cleaning, and shopping. These robots can likewise remind seniors to take their drugs and screen for medical issues.

Wellbeing checking: Robots like CareLink and RITA are furnished with sensors that can recognise falls and different crises. These robots can warn carers or crisis administrations if there should be an occurrence of a crisis, giving seniors extra wellbeing and security.

Telepresence: Robots like Giraff and BeamPro are intended for telepresence, permitting relatives and carers to remotely speak with seniors. These robots can give seniors access to social collaborations and support, regardless of whether they are truly disengaged.

Restoration: Robots like the exoskeleton HAL (Mixture Assistive Appendage) are intended to help seniors with portability issues, empowering them to walk and perform other proactive tasks. These robots can assist seniors with keeping up with their autonomy and working on their personal satisfaction.

In rundown, the various robots utilized in older consideration assume different roles, including giving friendship, helping with day-to-day errands, checking security, giving telepresence, and helping with recovery. These robots can improve personal satisfaction for seniors, diminish the burden on carers, and work on the general execution of the medical services framework.

Fig.(ii): Different Elderly Care Robots

1.1.8 Elderly Care Challenges:

The difficulties in older considerations that a man-made intelligence-based robot's right hand can address include:

- **Deficiency of caregivers:** The worldwide populace is maturing, and there is a rising interest in older consideration. Be that as it may, there is a lack of caregivers, which can lead to insufficient consideration and increased medical service costs.

- **Cost of older consideration:** Customary old consideration administrations can be exorbitant, making them excessively expensive for some families.
- **Depression and social disengagement:** Numerous seniors experience forlornness and social segregation, which can adversely influence their psychological and actual wellbeing.
- **Wellbeing checking:** Seniors with persistent medical issues might require regular observation, which can be difficult for carers to give.
- **Security concerns:** Seniors are at a higher risk of falls and other mishaps, which can prompt serious wounds.
- **Mental deterioration:** Numerous seniors experience mental degradation, which can make it challenging for them to perform day-to-day assignments and communicate effectively.
- **Social and phonetic hindrances:** Seniors from assorted foundations might confront social and semantic boundaries while getting to medical care administrations, prompting deficient consideration.
- **Monetary weakness:** More seasoned individuals might confront monetary difficulties, like deficient retirement reserve funds or restricted admission to reasonable medical care.
- **Caregiver trouble:** More seasoned people might need help with day-to-day exercises, and carers might encounter huge physical, close-to-home, and monetary weight.
- **Admittance to medical care:** More seasoned people might confront difficulties in getting to medical service administrations, like transportation boundaries, restricted accessibility of medical care suppliers, and social or semantic hindrances.

A simulated intelligence-based robot associate can assist with tending to these difficulties by giving customized help, friendship, and security highlights. The innovation can upgrade the personal satisfaction of seniors, diminish the burden on carers, and work on the general execution of the medical services framework. An artificial intelligence-based robot colleague can address a portion of these difficulties by giving customized help, friendship, and wellbeing highlights to more established individuals. The innovation can assist with working on personal satisfaction for more established individuals, lessen the burden on carers, and upgrade the general presentation of the medical services framework.

1.1.9 AI Based Assistive Technology for Healthcare:

Computer-based intelligence-based assistive innovation can possibly alter care in different areas, including medical services, handicaps, and psychological well-being. Simulated intelligence-based assistive advancements are assuming an undeniably significant role in old consideration by tending to the novel requirements and difficulties faced by maturing populations. A few instances of simulated intelligence-based assistive innovation worthy of consideration include:

Medical care observation: man-made intelligence-based medical care checking can help patients follow their important bodily functions and wellbeing status, distinguishing any progressions that could demonstrate the requirement for mediation or clinical consideration. This innovation can help forestall and oversee constant circumstances like diabetes, hypertension, and coronary illness.

therapy arranging: artificial intelligence-based customized therapy arranging can assist clinicians with fitting therapies to individual patients in light of their novel clinical accounts, hereditary foundations, and ways of life. This innovation can work on understanding results and diminishing medical care costs by decreasing the number of experimental ways to deal with therapy.

Handicap support: artificial intelligence-based inability backing can assist people with incapacities beat the difficulties they face, like versatility, correspondence, and tactile issues. This innovation can incorporate assistive gadgets like brilliant wheelchairs and prosthetic appendages, as well as correspondence tools like discourse-to-message programming and expanded reality glasses.

Psychological well-being support simulated intelligence-based psychological wellness backing can help people encountering psychological well-being difficulties by offering daily reassurance, side effect monitoring, and references to psychological wellness administrations. This innovation can incorporate chatbots, augmented reality treatments, and mental social treatment (CBT) programs.

Caregiver support: computer-based intelligence-based caregiver backing can help family carers deal with the consideration of their friends and family. This innovation can incorporate shrewd home frameworks, which can screen movement and recognize falls or different crises, and menial helpers that can assist with medicine updates and booking arrangements.

Simulated intelligence-based assistive innovation can possibly further develop care in different areas by giving customized, practical, and effective answers for complex medical services and handicap difficulties.

All location and avoidance frameworks: These artificial intelligence-based frameworks use sensors and AI calculations to recognize and forestall falls in old people. The frameworks can caution carers or crisis administrations in the event that a fall happens, considering quick reaction and mediation.

Remote helpers and chatbots: Remote helpers and chatbots can furnish old people with suggestions to take their drugs, plan arrangements, and give data on medical service points. These frameworks can likewise foster social connection and battle forlornness and separation.

Customized medical care checking: man-made intelligence-based medical services Observing frameworks can give customized checking of old people, remembering fundamental

signs and distinguishing changes in wellbeing status. The frameworks can likewise give early location of medical problems and suggest suitable interventions.

Robot friends: Robot colleagues can furnish old people with social cooperation and help with day-to-day undertakings like cleaning, cooking, and medicine. These robots can likewise provide mental excitement and help with memory and mental assignments.

Brilliant home frameworks: artificial intelligence-based savvy home frameworks can furnish older people with home robotization, including shrewd lighting, temperature control, and security frameworks. These frameworks can likewise screen action designs and recognise changes in conduct, considering early identification of medical problems.

Generally speaking, simulated intelligence-based assistive innovation can possibly further develop care in different areas by giving customized, practical, and effective answers for complex medical services and handicap difficulties. Computer-based intelligence-based assistive innovation for old people can work on personal satisfaction for old people by tending to their novel requirements and difficulties. These innovations can give customized care, further develop wellbeing results, and battle social segregation and depression.

1.2 Project Overview

In past two decades, the application of robots in variety of industries has been significantly increased. Self-directed or autonomous robots have appeared in human lives, such as, in the automobile industry, electronic parts assembling and medical sector. The need for automated support is growing as the global population ages. There are more than 1 billion people over the age of 60, according to World Health Organization estimates, rising to 1.4 billion by 2030 — that's one in six people, requiring another 6 million nurses. Robots can play their part in elderly care by assisting and monitoring elder people who need attention in the absence of their caretaker. Most injuries in older people are caused by falls. Response time to care for the seriously injured and the falls were crucial to their survival. The objective of this project is to design and develop Artificial Intelligence based robot that can assist and monitor the elderly people. Main functions of the robot are 1) track and follow the elder who needs attention, 2) provide goggle assistant services via cell phone, 3) elderly fall detection and alert notification system. Moreover, the tracking part of this project can also be used in other scenarios such as minors track and monitoring, person following luggage bag etc.

1.3 Problem Statement

Advances in medical technology and increasing quality of life have increased the world's aging population. The elderly often struggles with various health problems such as Alzheimer's disease, and falls have been identified as the second leading cause of death and injury among the elderly. Falling of an elderly person can cause paralysis or life-threatening injury. It is worth noting that with the rapid development of smart mobile sensors and big data technology, it is important how to use advanced detection and analysis technology to monitor the daily behavior of the elderly and catch falls. Over the years, many researchers have proposed solutions to the fall investigation. Considering the shortcomings of these systems, we aim to develop a vision-based robotic system that monitors the elderly, monitors falls, and warns when an unexpected event (fall) occurs. Artificial intelligence-based algorithms will be used to help and care for the elderly. It should monitor and track seniors in need of care and provide Google Assistant services from the tablet. In addition, the primary aim of the proposed robot is elderly fall detection and alert notification system. In addition, the tracking part of this project can be used for other situations such as small reconnaissance, and baggage tracking.

1.4 Project Objectives

This project aims to provide a

- Cost-Effective and User-Friendly Artificial Intelligence Based Elderly Care
- Robust Machine Vision Based Fall Detection
- Energy Saving
- Fast and Accurate Tracking System
- Infotainment Functional Robot
- It aims to ensure the health and support of the elderly.

1.5 Project Development Methodology

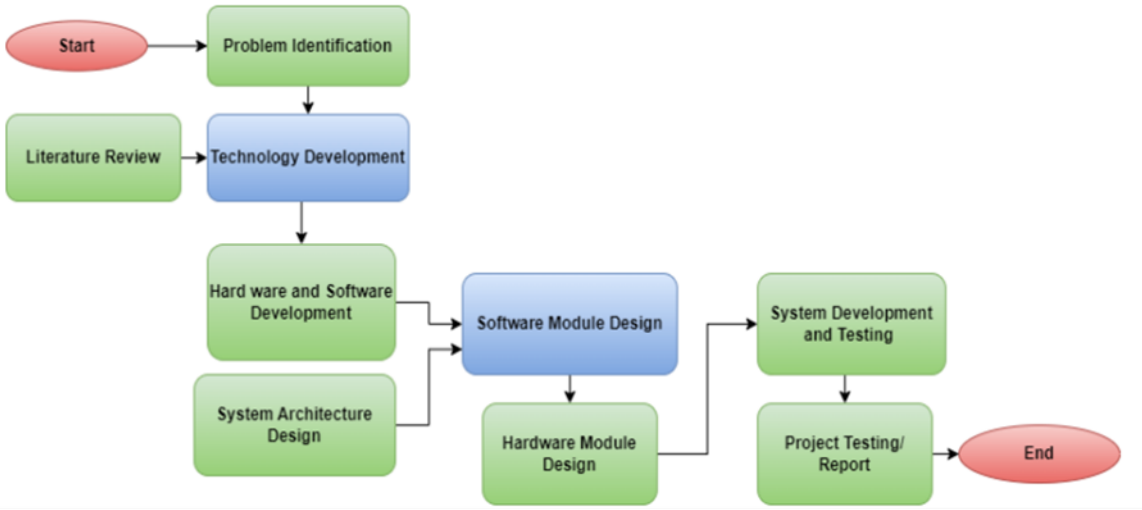


Fig.(iii): Project Methodology

1.6 Organization of Report

The report on "Artificial Intelligence-Based Robotic Assistants for Elderly Care" consists of six parts, starting with an introduction that discusses the motivation behind the project and the challenges faced by the elderly. Chapter 2 presents a case study highlighting the role of robotics and AI-based technology in aged care, comparing current solutions and discussing the program. Chapter 3 provides an overview of the design and implementation, including hardware and software tools, algorithms, and simulation details. Chapter 4 focuses on the testing and validation of AI-based robot assistants and their performance evaluation. Finally, Chapter 5 presents the results of the project and recommendations for the future.

Chapter 1: Introduction

The first chapter of the thesis provides an introduction to the research topic of "Artificial Intelligence-Based Robotic Assistants for Elderly Care." It discusses the motivation behind the project and highlights the challenges faced by the elderly population in terms of care and support. The chapter also presents the research objectives, scope, and significance of the study.

Chapter 2: Literature Review

In this chapter, a comprehensive literature review is conducted to examine the existing literature and research studies related to robotic assistance and AI-based technologies in elderly care. It compares different solutions and programs implemented in the field, highlighting their strengths, limitations, and potential areas for improvement.

Chapter 3: System Design and Architecture

Chapter 3 provides an overview of the system design and architecture. It presents the hardware and software tools used in the project, including the Pixy 2 camera, Arduino board, H-bridge motor driver, and Python IDE. The chapter also includes flowcharts illustrating the system's major milestones, such as object tracking, pose estimation, fall detection, and alert generation.

Chapter 4: Testing and Validation/Discussion

This chapter focuses on the testing and validation of the AI-based robotic assistance system. It discusses the development of a prototype for tracking an elderly person using the Pixy 2 camera and analyzes different machine learning algorithms for fall detection. The chapter also discusses the integration of pose estimation using MediaPipe and the generation of alerts through email systems. The findings and results of the testing process are discussed, and any limitations or challenges encountered are addressed.

Chapter 5: Results and Recommendations

Chapter 5 presents the results obtained from the project, including the performance evaluation of the AI-based robotic assistance system. It discusses the accuracy of object tracking, fall detection, and alert generation, highlighting the system's strengths and areas for improvement. The chapter also provides recommendations for future enhancements and further research in the field of AI-based robotic assistance for elderly care.

Chapter 6: Conclusion and Future work

The final chapter of the thesis summarizes the key findings, contributions, and implications of the research. It discusses the potential impact of AI-based robotic assistance in improving the quality of elderly care. The chapter concludes with a reflection on the achievements of the project and suggests avenues for future research and implementation.

Annexure 'A'

Annexure A provides an overview of statistics related to deaths caused by falls among the elderly population. It aims to present the significance of addressing fall-related risks and the importance of developing effective fall detection and prevention systems. The annexure includes relevant data, reports, and studies that shed light on the impact of falls on the elderly. It highlights the frequency and severity of fall-related incidents and their implications for the well-being and safety of older adults. The introduction also discusses the potential consequences of falls, such as injuries, fractures, hospitalizations, and, in severe cases, mortality.

Annexure 'B'

Annexure B provides detailed information on the technique of pose estimation using MediaPipe, specifically focusing on the implementation of the BlazePose model. It aims to explain the concept of pose estimation, the role of MediaPipe, and the specific working principles of BlazePose.

The main focus of Annexure B is on the implementation of BlazePose within MediaPipe. The annexure provides a detailed explanation of how BlazePose works and the underlying principles of its algorithm.

Chapter 2
Literature Review

2.1 Analysis of Research Projects:

Fall discovery is a functioning area of exploration, with many activities meant to foster solid and precise frameworks for distinguishing falls, especially among the old and weak populaces. Here are a few normal subjects and approaches that arise in research projects zeroing in on fall identification:

Sensor-based frameworks: Many fall discovery frameworks depend on sensors like accelerometers, gyrators, and pressure sensors to distinguish falls. These sensors are normally implanted in wearable gadgets or set in the environment, like on floors or walls. Research in this space centers around creating calculations to examine sensor information and recognise falls precisely while limiting misleading problems.

AI: AI strategies are often utilized in fall recognition examinations to foster models that can recognise falls and typical exercises. These models might be founded on sensor information or different kinds of information, like video or sound. Profound learning procedures, for example, convolutional brain organizations (CNNs) and intermittent brain organizations (RNNs), are normally used to remove highlights from sensor information and characterise falls.

Setting mindfulness: One test in fall discovery is recognizing falls and different exercises that might look like falls, like plunking down or getting up from a seat. Setting mindfulness methods plans to integrate data about the client's current circumstance and conduct to further develop fall identification precision. For instance, a fall recognition framework might utilize data about the client's stance or step to determine if a fall has happened.

Combination of different sensors: joining information from numerous sensors can further develop fall identification accuracy. For instance, a framework that joins information from an accelerometer, a strain sensor, and a receiver might be preferable to a framework that depends on a solitary sensor.

Constant identification and cautioning: Many fall discovery frameworks expect to give ongoing alarms to carers or crisis administrations in case of a fall. Research in this space centers around creating frameworks that can distinguish falls rapidly and precisely and convey alarms reliably.

By and large, research projects that zero in on fall location mean to foster frameworks that can distinguish falls precisely, limit deceptions, and give opportune alarms to carers or crisis administrations. These tasks frequently include a mix of sensor innovation, AI strategies, and setting attention to accomplish these objectives.

2.2 Overview of Existing solutions of fall detection:

[1] "Efficient fall detection in four directions based on smart insoles and RDAE-LSTM model"

This paper presents a novel approach to fall detection using smart insoles and a combination of deep learning models. The authors performed data preprocessing techniques such as segmentation and filtering to prepare the input data. They adopted an LSTM-based model with Recurrent Denoising Autoencoder (RDAE) to accurately recognize falls occurring in four different directions. The combination of dLSTM and RDAE proved to be effective in detecting falls with high accuracy. Additionally, the authors designed smart insoles capable of acquiring foot dynamics, including plantar pressure distribution and foot movement trajectory, providing valuable input for the fall detection system.

[2] "A fusion fall detection algorithm combining threshold-based method and convolutional neural network"

This paper proposes a fusion approach for fall detection by combining threshold-based methods (TBM) and convolutional neural networks (CNN). The proposed algorithm utilizes a wearable device named SHFFD, which is worn on the subject's waist. When an abnormal event, such as a fall, occurs, the SHFFD leverages the TBM to initially identify the event based on triaxial sensor data. The fusion algorithm then incorporates CNN for further analysis and classification of the detected event. By combining the strengths of both TBM and CNN, the proposed method aims to improve the accuracy and reliability of fall detection in real-time scenarios.

[4] "A smartphone-enabled fall detection framework for elderly people in connected home healthcare"

This paper presents a framework called MEFD (Mobile Fall Event Detection) that aims to detect falls among elderly individuals. The system utilizes a smartphone and employs a hybrid deep learning model for fall detection. Real-time data captured from an accelerometer sensor on the smartphone are processed and analyzed by an online fall detection system running on the device. When a fall event is detected, the framework triggers an indoor sound alert to notify family members through a wireless access point at home or an outdoor SMS alert to a caregiver via a mobile network base station. The MEFD framework demonstrates the potential of using smartphones as a practical and accessible tool for fall detection in the context of connected home healthcare, providing timely alerts and facilitating immediate responses to fall incidents.

[5] "A Framework for Fall Detection Based on OpenPose Skeleton and LSTM/GRU Models"

introduces a framework for fall detection that utilizes 2D pose estimation and recurrent neural network (RNN) models such as LSTM (Long Short-Term Memory) and GRU (Gated Recurrent Unit). The proposed approach detects the movement of a subject by analyzing two datasets consisting of 570 × 30 frames recorded. The system retrieves the locations of joints from the pose estimation and detects movement by analyzing the changes in joint point locations.

This paper presents a fall detection system that does not rely on the use of sensors. Instead, it utilizes computer vision techniques and machine learning algorithms to identify falls. By leveraging the OpenPose skeleton model and employing RNN models, the framework is able to capture and analyze human movements to detect falls accurately. This approach offers a promising solution for fall detection in scenarios where the availability or practicality of sensor-based systems may be limited.

[6] "RGB camera-based fallen person detection system embedded on a mobile platform"

This paper introduces a fallen person detection system that utilizes an RGB camera. The system incorporates various computer vision techniques, including face recognition and object detection, along with machine learning models such as Convolutional Neural Networks (CNN) and Support Vector Machines (SVM).

The paper mentions the use of the YOLO (You Only Look Once) network for object detection, specifically in the context of detecting fallen persons. The system utilizes the E-FPDS (fall Person dataset) as a baseline for processing RGB camera inputs. This dataset likely contains annotated samples of fallen persons for training and evaluation purposes.

The main contribution of the paper is the presentation of a low-cost, autonomous assistive patrol robot that includes a fallen person detection module. This module incorporates facial recognition techniques, enabling the identification of patients or individuals who have fallen. By leveraging RGB camera technology and advanced computer vision algorithms, the system aims to provide an effective and efficient solution for detecting fallen persons and enhancing the overall safety and care in healthcare or assistive settings.

2.3 Literature Review Conclusion and Discussion:

In a couple of years, mechanical colleagues could be showing up in seniors' homes, assisting them with dealing with themselves, offering profound help, and empowering remote admittance to specialists and medical caretakers. In nursing homes, they can engage occupants or help with family errands. What's more, in emergency clinics, they've assumed control over a few fundamental obligations, opening up medical caretakers to zero in on understanding consideration.

For fall discovery, the way to deal with wearable sensors is fundamentally founded on the utilization of wearable gadgets with various sensors. The data from these sensors is generally handled differently by various clever devices. These sensors can be implanted in shrewd watches, shoes (savvy insoles), cell phones, and so on [1, 2]. In any case, notwithstanding their adequacy, the way that one needs to wear them everlastingly and the charging issues are critical disadvantages. Furthermore, obviously, these issues are intense in light of the fact that we are really focusing on the elderly.

One more famous methodology utilized by Yoann Charlon and Nicolas Fourt [3] depends on static conditions. The key idea utilized in these methodologies is, for the most part, founded on the examination of vibration, sound, IR sensors, or perhaps a few different sensors that are statically embedded in the room. The methodology has a lot less exactness compared with wearable contraptions. Furthermore, covering the whole room with sensors is very costly.

M. Hassan and A. Gumaei utilized a PC vision-based approach for fall discovery [4], which is essentially founded on video transfer investigation. In view of the types and number of cameras, they can be isolated into subcategories: single-chamber frameworks, multi-chamber frameworks, and profundity-of-field camera frameworks.

Chuan-Bi Lin and Ziqian Dong 2 [5] considered the utilization of the OpenPose model, which determines 25 central issues in the human body from a video transfer. The model portrayed in this paper was prepared on two datasets. Utilising enunciated focuses rather than pictures successfully diminishes preparation time and takes out the impediments of conventional methods (obscuring, shadows, contrast issues, lighting, and so forth).

Sergio Lafuente-Arroyo, Pilar Martn, and Cristian Iglesias utilize an "RGB camera-based fallen individual identification framework inserted on a versatile stage" [6]. The utilization of the visual meaning of a human fall for a sidekick robot is proposed. To decide the fall, the framework is separated into two phases: individual recognition utilizing a convolutional brain organization and fall characterization in view of SVM. Among the upsides of this methodology, the article makes reference to flexibility, superior execution, constant processing, and strength under various conditions. One of the primary commitments of this work is the information highlight vector in the SVM-based classifier.

Chapter 3
System Design and Implementation Details/Design Procedures

This chapter describes the overall in-depth information about the project. This chapter also involves the basic theoretical information of every component & aspect of the project, such as circuit design, simulation implementation, and modeling, software implementation, and so on.

The design of the artificial intelligence-based robotic assistance system for elderly care consists of two major milestones: tracking an object using the Pixy 2 camera and detecting falls in a person. This section outlines the system architecture and presents the flowcharts for the different tasks involved, including vision tracking, pose estimation, fall detection, and alert generation

3.1.1 System Architecture

The system architecture of the "Artificial Intelligence-Based Robotic Assistants for Elderly Care" project is designed to facilitate effective tracking and assistance for elderly individuals. The architecture consists of multiple components working together seamlessly. The core of the system is the Pixy2 camera, which captures visual information and performs color optimization for object tracking. This camera is integrated with an Arduino board, which acts as the control unit and interfaces with the DC motors of the robotic base via an H-bridge. The Arduino board processes the information received from the camera and generates appropriate commands for the robot's movement. As shown in figure below:

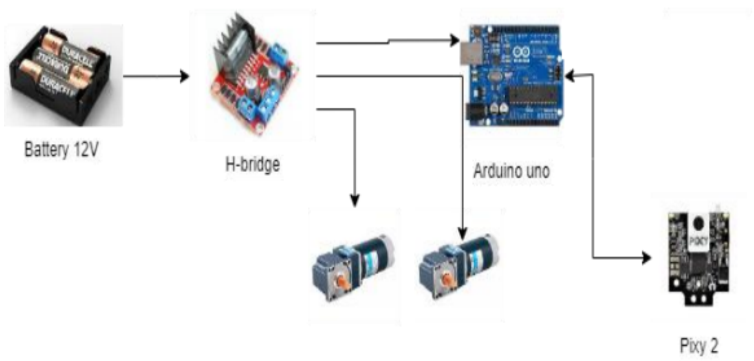


Fig (iv) : Systematic diagram for tracking

The system also incorporates a fall detection module using pose estimation. The integration of various software tools, including Python for pose estimation, fall detection, and alert generation, enhances the functionality of the system. Additionally, IP Webcam is used to stream live video from other devices, enabling remote monitoring and control. Overall, the system architecture is designed to provide efficient tracking, fall detection, and assistance for elderly individuals, promoting their safety and well-being. As shown below:

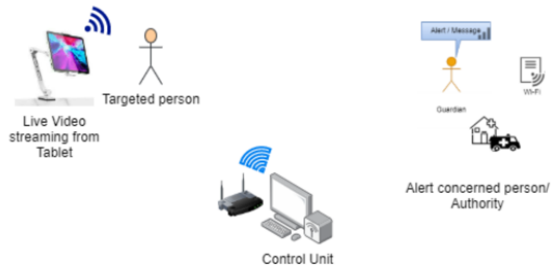


Fig (v) : Systematic diagram of fall detection system

3.1.2: Flow Charts Illustration:

STAGE # 1:

In the vision tracking stage, the Pixy2 camera is utilized to capture visual information. The flowchart illustrates the steps involved in color optimization, where the camera optimizes the color values to enhance object detection. This optimization helps in effectively tracking the elderly person within the camera's field of view.

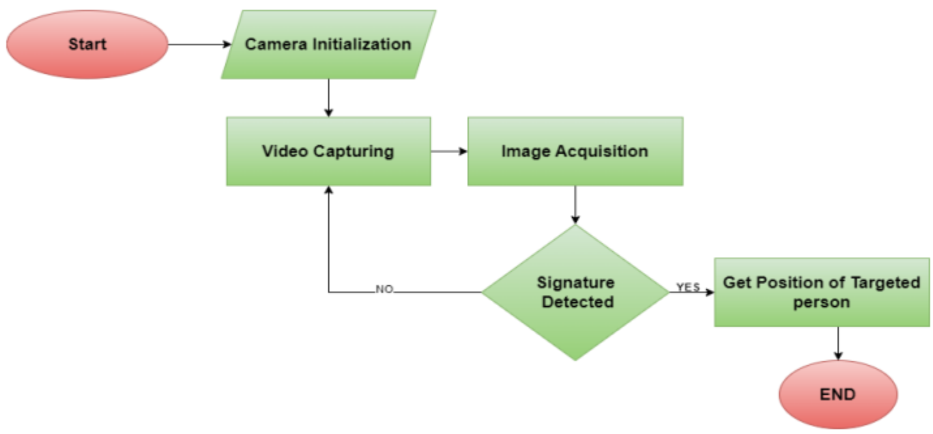


Fig (vi) : Flow chart for object tracking

STAGE # 2:

Once the object is detected and tracked, the flowchart moves on to the pose estimation stage. Here, the flowchart depicts the process of testing and selecting the best-performing model for pose estimation in the "Artificial Intelligence-Based Robotic Assistants for Elderly Care" project.

Multiple models are evaluated using the dataset, and their performance in estimating pose key points is assessed based on metrics such as accuracy, precision, recall, and F1 score. The flowchart illustrates the decision point where the top-performing model is chosen considering factors like accuracy, robustness, computational efficiency, and real-time applicability. Once the final model is selected, it is utilized in the pose estimation stage to estimate the elderly person's pose key points, which are crucial for further analysis and fall detection. This flowchart emphasizes the significance of model selection to achieve accurate and reliable pose estimation, ensuring the optimal performance of the system.

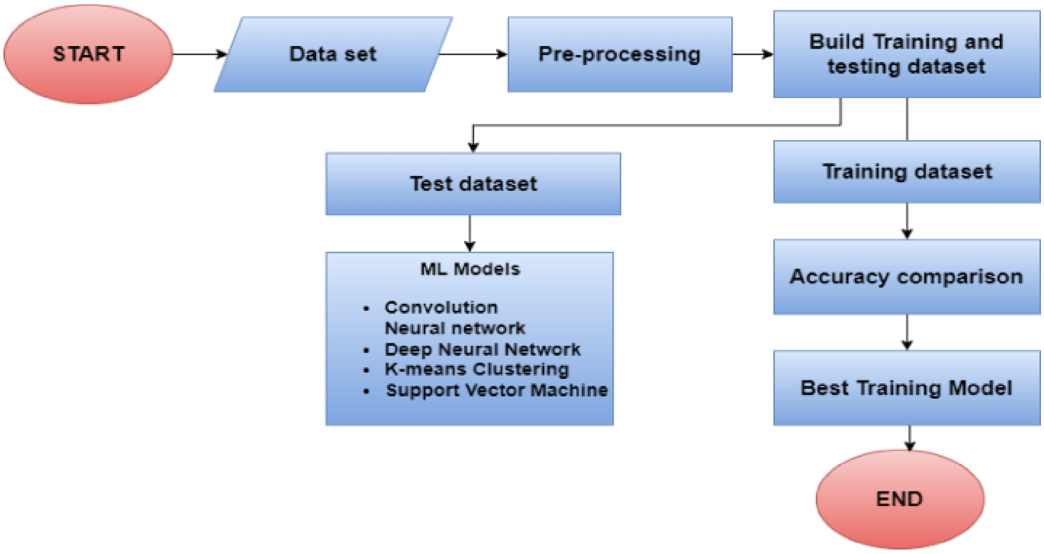


Fig (vii) : Flow chart for Pose Estimaton

STAGE # 3:

The final milestone is fall detection, which incorporates pose estimation and alert generation. the flowchart showcases the sequential steps of pose estimation, fall detection, and alert generation. It highlights the utilization of a selected pose estimation model, the application of machine learning algorithms for fall detection, and the generation of alerts to ensure timely assistance and care for the elderly individual.

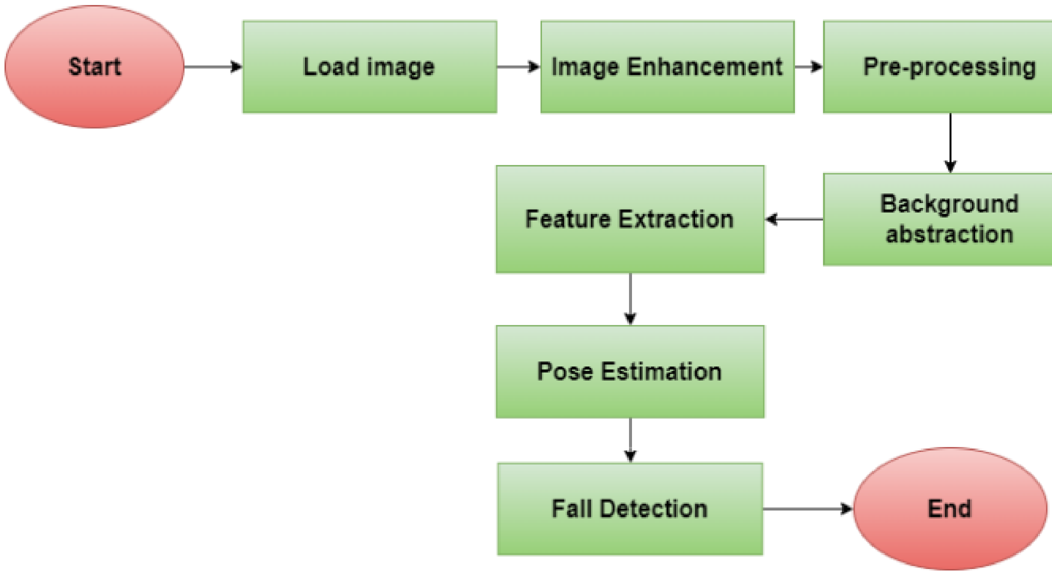


Fig (viii) : Flow chart for Fall detection system

3.1.2 Requirements/Requirements Analysis

Requirements Analysis for Artificial Intelligence-Based Robotic Assistance for Elderly Care.

1. Functional Requirements:

- **Object Tracking:** The system should be able to track an object, specifically an elderly person, using the Pixy 2 camera and color recognition techniques. It should accurately detect and follow the person's movements.
- **Fall Detection:** The system should be capable of detecting falls in the tracked person by analyzing their pose and movements. It should be able to identify sudden changes in posture or unusual movements that indicate a fall.
- **Alert Generation:** When a fall is detected, the system should generate an alert to notify relevant parties, such as caregivers or emergency responders. The alert should include relevant information, such as the video frame at the moment of the fall, to aid in assessment and decision-making.

2. Performance Requirements:

- **Accuracy:** The system should exhibit high accuracy in object tracking and fall detection to minimize false positives and false negatives. It should reliably detect and track the elderly person and accurately identify falls.
- **Real-time Responsiveness:** The system should respond promptly to changes in the tracked person's movements and detect falls in real-time. Delays should be minimized to ensure timely assistance.

- **Reliability:** The system should function reliably under various conditions, including different lighting environments, background clutter, and varying distances between the camera and the person.

3. Hardware and Software Requirements:

- **Pixy 2 Camera:** The system should be compatible with the Pixy 2 camera and utilize its color optimization capabilities for accurate object tracking.
- **Arduino Board**: The system should integrate with an Arduino board to process the color information from the camera and control the movement of the robotic base.
- **H-Bridge Motor Driver:** The system should connect the Arduino board to the DC motors of the robotic base using an H-bridge motor driver for precise control of movement.
- **Python Programming Environment:** The system should be developed using a Python programming environment to implement the functionalities related to pose estimation, fall detection, and alert generation.
- **IP Webcam:** The system should support the use of IP Webcam to live stream video from a separate device with a camera, enabling real-time monitoring and analysis.

4. Usability Requirements:

- **User-Friendly Interface:** The system should have a user-friendly interface for easy operation and configuration, such as adjusting color signatures, setting thresholds, and managing alerts.
- **Compatibility**: The system should be compatible with different devices and operating systems to ensure flexibility in deployment and usage.
- **Ease of Integration:** The system should be easily integrated into existing robotic assistance platforms or frameworks for elderly care, allowing seamless integration with other components and functionalities.

5. Safety and Security Requirements:

- **Robust Fall Detection:** The system should prioritize the accurate and reliable detection of falls to ensure the safety of elderly individuals. False positives and false negatives should be minimized to avoid unnecessary alerts or missing genuine falls.
- **Data Privacy:** The system should handle personal data, such as video frames and email addresses, with utmost privacy and comply with relevant data protection regulations. Measures should be in place to prevent unauthorized access or misuse of sensitive information.

These requirements form the foundation for the development and evaluation of the artificial intelligence-based robotic assistance system for elderly care. They address the functional, performance, hardware/software, usability, and safety/security aspects necessary for a reliable and effective solution in assisting and monitoring elderly individuals.

3.1 Methodological/Implementation/Experimental Details

3.1.1 DC motors speed and directions control with Arduino UNO

Integrating DC motors with Arduino involves connecting the motors to the Arduino board through an H-bridge circuit. The H-bridge acts as an electronic switch that allows the Arduino to control the direction and speed of the DC motors. The flow of current to the motors is regulated by the Arduino, which sends specific signals to the H-bridge based on the desired movement. By controlling the input signals to the H-bridge, the Arduino can make the motors rotate forward or backward, or stop them entirely. This integration enables the robotic base to respond to commands from the system, allowing it to move in accordance with the tracking and detection algorithms. It provides a means of translating the electronic signals and data processing into physical movement, facilitating the autonomous operation of the robotic assistant in elderly care.

Proetus Simulation and run time demonstration is shown below:

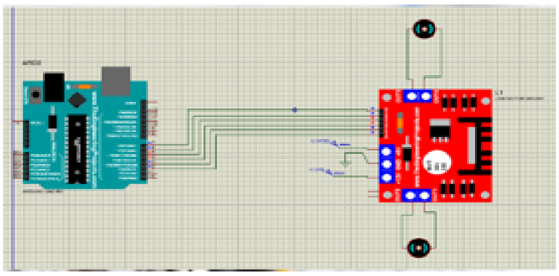


Fig (ix) : DC motor control using Arduino uno

3.1.2 Signature detection using Pixy2 with Arduino UNO

Signature detection using Pixy2 and Arduino Uno involves utilizing the Pixy2 camera to identify specific visual signatures or patterns and then communicating this information to the Arduino Uno for further processing and action. The Pixy2 camera is trained to detect and track predefined color signatures or objects by utilizing its onboard image sensor and color recognition algorithms. The camera captures the visual input and analyzes it to identify the specific signature or pattern of interest. Once the signature is detected, the Pixy2 camera communicates this information to the Arduino Uno via a serial interface or other communication protocol. The Arduino Uno then receives the signature data and performs the necessary actions based on the predefined instructions. This can include controlling other components of the system, such as motors or actuators, to respond accordingly to the detected signature. The integration of Pixy2 and Arduino Uno enables the system to recognize and respond to specific visual cues or signatures, enhancing its capabilities in applications such as object tracking, robotic navigation, or interactive systems.

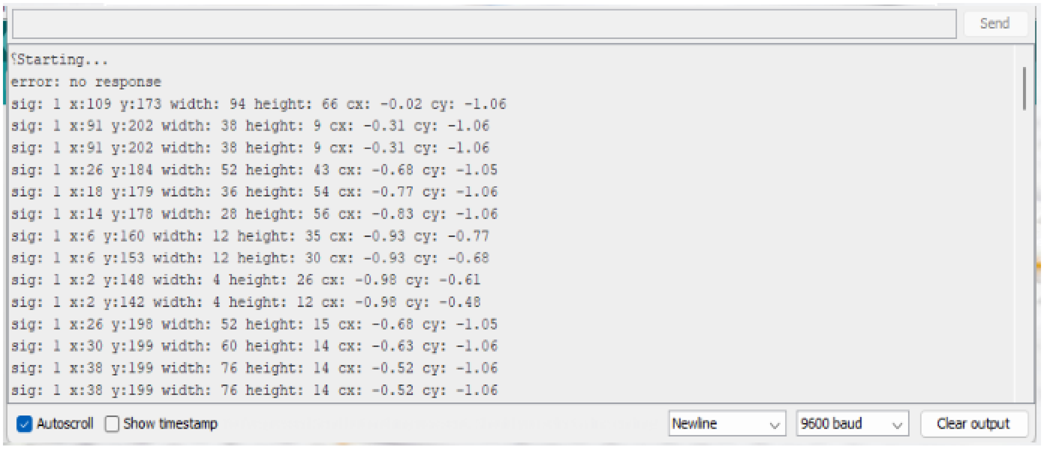


Fig (x) : Signature detection using Pixy2

3.1.3 Object Tracking (Integrating Pixy2 with DC motors)

The integration of Pixy2 with DC motors allows for efficient object tracking in the "Artificial Intelligence-Based Robotic Assistants for Elderly Care" project. Pixy2, equipped with color recognition capabilities, detects and tracks specific objects or visual signatures. To enable physical movement based on the detected objects, Pixy2 is integrated with DC motors through an Arduino board and an H-bridge circuit. The Arduino board receives the object tracking data from Pixy2 and processes it to determine the appropriate movement commands for the DC motors. By controlling the input signals to the H-bridge, the Arduino regulates the direction and speed of the DC motors, ensuring that the robotic base follows the tracked object accurately. This integration enables real-time object tracking and allows the robot to autonomously move and interact with the environment based on the detected objects, enhancing the functionality and effectiveness of the robotic assistant in elderly care scenarios.

Fig (xi) : Object Tracking

3.1.3 Remote Video streaming

Video streaming through IP Webcam on Jupyter Notebook involves utilizing the IP Webcam application on a mobile device and establishing a connection with Jupyter Notebook to stream the video feed. IP Webcam allows the mobile device to act as a webcam by streaming the camera output over a local network. To stream the video feed on Jupyter Notebook, the appropriate libraries and dependencies, such as OpenCV and IPython, need to be installed. Then, using the IP Webcam's IP address and port number, a connection is established between the mobile device and Jupyter Notebook. The video stream can be accessed in Jupyter Notebook by creating an OpenCV video capture object and providing the IP Webcam's video feed URL. With the video feed integrated into Jupyter Notebook, it can be further processed, analyzed, or utilized for tasks such as object detection, pose estimation, or fall detection in the context of the "Artificial Intelligence-Based Robotic Assistants for Elderly Care" project. The IP Webcam's video streaming capability on Jupyter Notebook adds flexibility and convenience by enabling real-time video input from a mobile device for various computer vision applications.

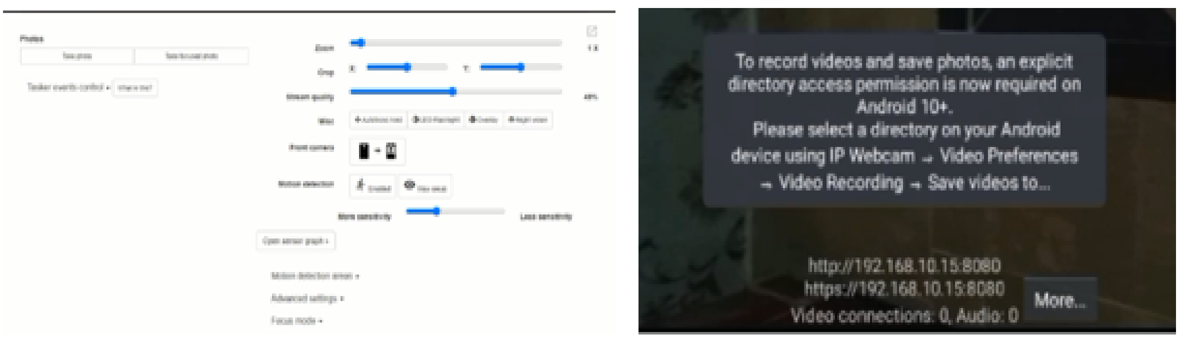


Fig (xii) : Video streaming using IPwebcam

3.1.4 Pose Estimation via yolov7

Pose estimation via YOLOv7 involves utilizing the YOLOv7 object detection framework to detect and estimate human poses in an image or video feed. YOLOv7 is a deep learning-based algorithm that combines object detection and pose estimation capabilities.

In the context of the "Artificial Intelligence-Based Robotic Assistants for Elderly Care" project, YOLOv7 can be integrated into the system architecture to perform pose estimation tasks. The framework is trained on a large dataset of annotated human poses, enabling it to detect and locate human bodies within an image or video.

To perform pose estimation using YOLOv7, the system first applies the object detection aspect of the algorithm to identify and localize human bodies. Once the human bodies are detected, the pose estimation component of YOLOv7 is employed to estimate the positions and orientations of various body joints and keypoints.

By utilizing YOLOv7 for pose estimation, the system can accurately determine the poses of elderly individuals, providing valuable information for fall detection, gait analysis, or activity monitoring. The integration of YOLOv7 into the system's architecture enhances its capabilities in understanding and analyzing human movements, contributing to the overall effectiveness and functionality of the robotic assistants in elderly care.

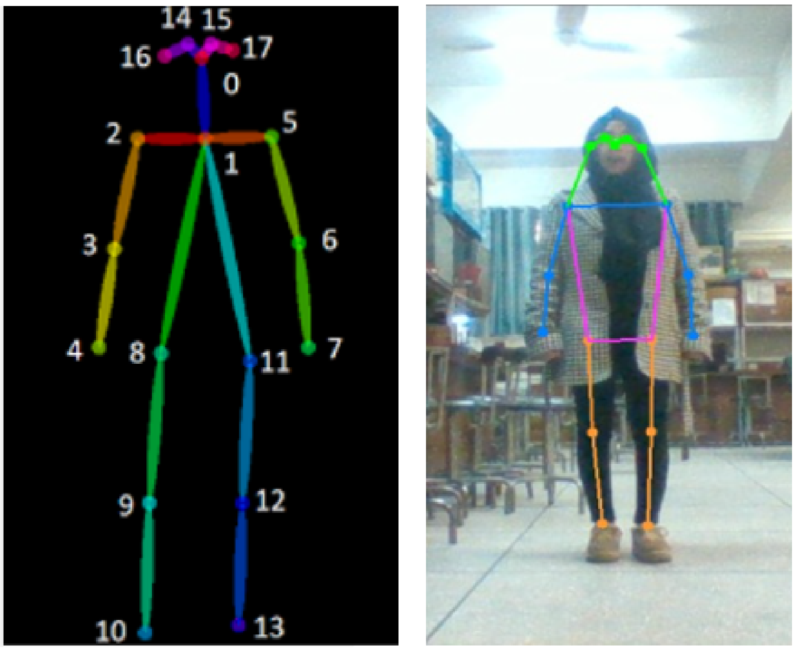


Fig (xiii) : Pose Estimation using YOLOv7

3.1.5 Pose Estimation via MediaPipe

Pose Estimation via MediaPipe involves utilizing the MediaPipe library, specifically the Pose Detection module, to estimate the human pose from input images or video frames. MediaPipe provides a pre-trained model for pose estimation, which uses deep learning techniques to detect and locate key body joints or keypoints.

To perform pose estimation using MediaPipe, the input images or video frames are passed through the Pose Detection module. The module analyzes the input and detects the positions of various body parts, such as the shoulders, elbows, wrists, hips, knees, and ankles. It identifies the key body joints and provides their coordinates.

MediaPipe's Pose Detection module utilizes advanced computer vision algorithms, including deep neural networks, to accurately estimate the human pose. The model has been trained on a large dataset to learn the visual patterns and relationships between body parts, allowing it to infer the pose from input images.

Pose estimation via MediaPipe is valuable for various applications, including activity recognition, gesture recognition, augmented reality, and robotics. In the context of the "Artificial Intelligence-Based Robotic Assistants for Elderly Care" project, pose estimation via MediaPipe is utilized to track the elder person's body movements, which aids in fall detection, movement analysis, and providing appropriate robotic assistance based on the detected pose.

By leveraging MediaPipe's Pose Detection module, the system can accurately estimate the pose of the elderly person, enabling the robotic assistant to respond and adapt to their specific needs effectively.

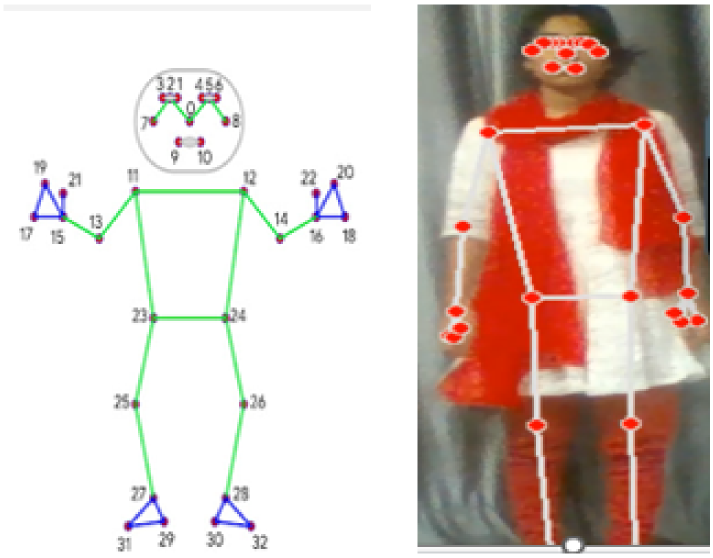


Fig (xiv) : Pose Estimation using MediaPipe

3.1.5 Fall detection using MediaPipe

Fall detection using MediaPipe and sending email alerts involves leveraging the pose estimation capabilities of MediaPipe to analyze human body movements and identify potential falls. Once the fall is detected, an email alert is generated and sent to the concerned individuals or caregivers.

In the fall detection process, MediaPipe is utilized to estimate the poses of individuals by analyzing key points and landmarks on their bodies. By continuously monitoring the changes in these poses over time, sudden and abnormal movements indicative of a fall can be identified.

Upon detecting a fall event, the system triggers the email alert generation process. An email is composed and sent using the relevant SMTP (Simple Mail Transfer Protocol) libraries and the email credentials provided. The email contains pertinent information about the fall, such as the timestamp, location, and possibly even a snapshot or video frame of the fall captured by the system. This alert can be sent to designated recipients, such as family members, caregivers, or emergency services, to ensure prompt attention and assistance for the elderly individual.

By integrating MediaPipe for fall detection and incorporating an email generation system, the project enhances the safety and well-being of elderly individuals by enabling timely response and intervention in the event of a fall.

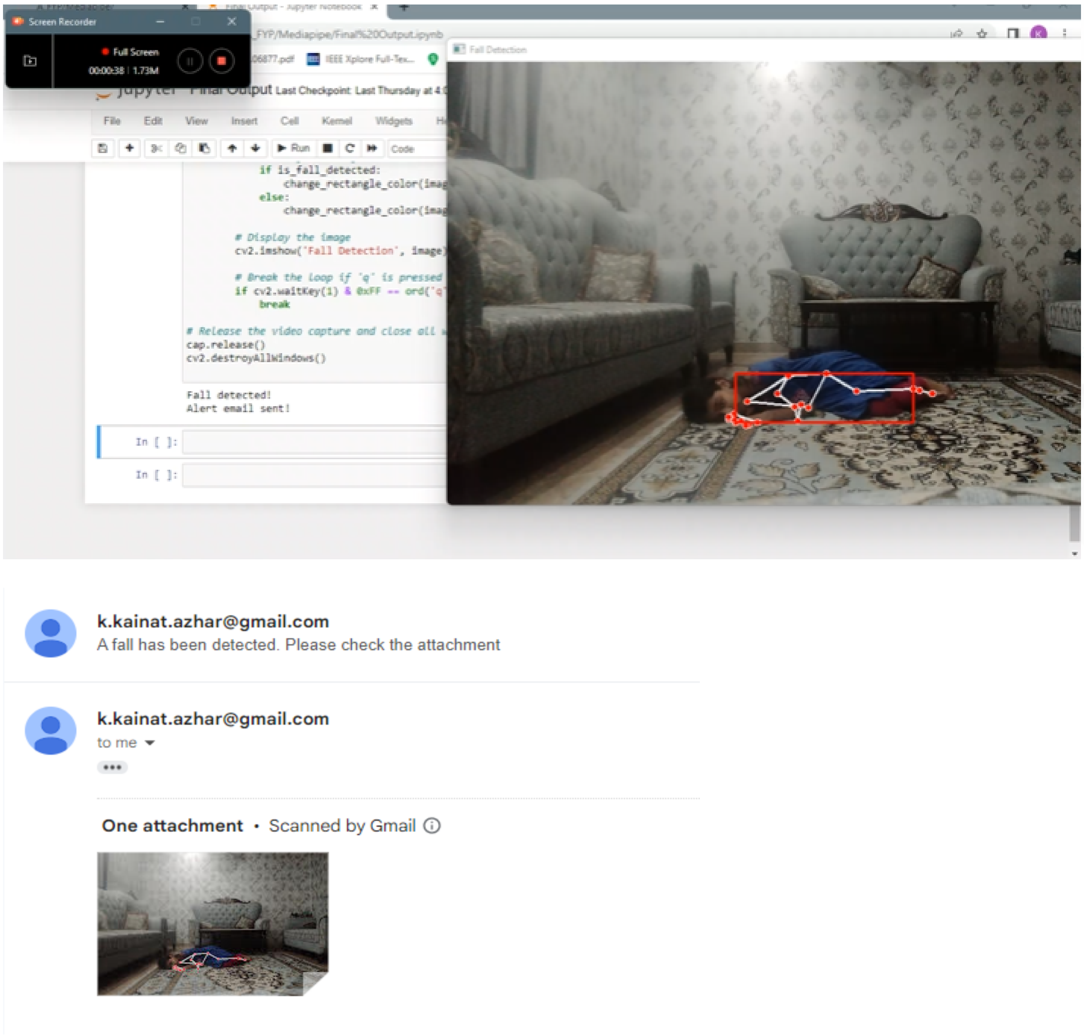


Fig (xv) : Fall Detection and Alert Generation system

3.2.1 Hardware/Development Setup

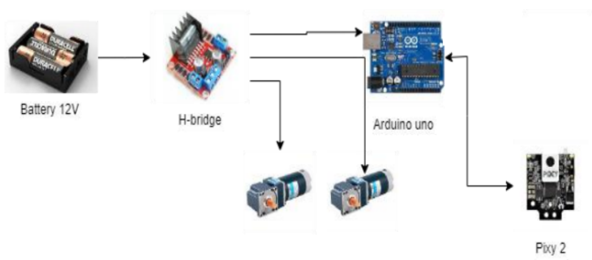


Fig (xvi) : Hardware Development

3.2.2 Development prototype:

Fig (xvii) : Prototype Development

3.2.3 Hardware Details

This chapter provides an overview of the software and tools utilized in the development of the artificial intelligence-based robotic assistance system for elderly care. It highlights the specifications and uses of each module and also includes details of the hardware components employed in the project.

Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328P. It serves as the central processing unit in the system, responsible for receiving input from the Pixy Camera and controlling the movement of the robotic base through the Motor Driver H-bridge. The Arduino Uno is programmed using the Arduino IDE, allowing for easy integration and customization of the system's functionalities.

Pixy Camera

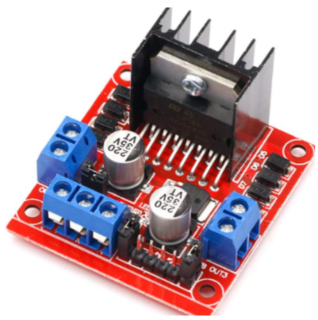
The Pixy Camera, specifically the Pixy 2, is a vision sensor that utilizes color-based object tracking. It is designed to detect and track objects based on their color signatures. The Pixy Camera captures video frames and analyzes the color distribution within each frame to identify and track the target object, such as an elderly person. Its compact size and simplicity make it an ideal choice for object tracking in this project.

Jumper Wires

Jumper wires are used to establish electrical connections between various components of the system. They enable the transfer of signals and power between the Arduino Uno, Pixy Camera, and Motor Driver H-bridge, ensuring seamless communication and control.

Motor Driver H-bridge L298

The Motor Driver H-bridge, specifically the L298 module, is employed to control the movement of the DC gear motors in the robotic base. It acts as an interface between the Arduino Uno and the motors, allowing the Arduino to control the speed and direction of the motors. The L298 module is capable of handling high currents, making it suitable for driving the DC gear motors.



DC Gear Motors

DC gear motors are used to provide locomotion to the robotic base. These motors, rated at 4A, offer sufficient power and torque to move the robot smoothly and effectively. The Motor Driver H-bridge controls the speed and direction of these motors based on the input received from the Arduino Uno, enabling precise movement of the robot.

Tablet

A tablet device is utilized in the fall detection module to stream video for computer vision analysis. The tablet is equipped with a camera that captures the video stream, which is then processed by the system for pose estimation and fall detection. IPwebcam, a software application, is installed on the tablet to enable direct video streaming to the Python programming environment.

3.2.2.2 Hardware Details

The hardware components used in the project are as follows:

- Arduino Uno: The Arduino Uno serves as the central processing unit and controls the various components of the system.

- Pixy Camera: The Pixy Camera is responsible for object tracking and provides color-based detection capabilities.

- Jumper Wires: Jumper wires are used to establish electrical connections between the components, ensuring smooth communication.

- Motor Driver H-bridge L298: The Motor Driver H-bridge is responsible for controlling the movement of the DC gear motors in the robotic base.

- DC Gear Motors: DC gear motors provide locomotion to the robotic base, enabling it to follow the tracked object.

- Battery 12V: The 12V battery is used to power the system, ensuring uninterrupted operation.

- Tablet: The tablet is utilized to stream video for computer vision analysis, enabling pose estimation and fall detection.

The combination of these hardware components forms the physical infrastructure of the artificial intelligence-based robotic assistance system for elderly care. This chapter provided an overview of the software modules and tools used in the development of the system.

3.2.4 Software/Tools

The development of the artificial intelligence-based robotic assistance system for elderly care requires the use of various software and tools. This section provides an explanation of each software specification and its role in the project.

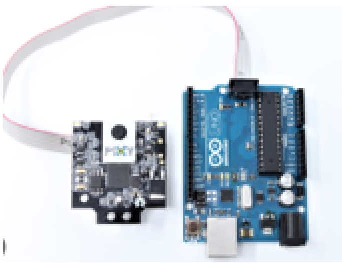
1. Proteus:

Proteus is a software tool used for electronic circuit simulation. In this project, Proteus is employed to simulate the circuitry and electrical components, such as the Arduino board and H-bridge motor driver. It allows the designers to test the functionality and performance of the system virtually before implementing it physically. Proteus aids in identifying potential issues and refining the system design prior to the prototyping stage.

PROTEUS

2. PixyMon:

PixyMon is the software interface for operating and configuring the Pixy 2 camera. It provides a user-friendly environment to set up color signatures, adjust camera parameters, and perform visual debugging. PixyMon allows the user to define specific color signatures that the camera will detect and track. It also facilitates the calibration and optimization of color recognition for accurate object tracking in the system.



3. Arduino IDE:

Arduino Integrated Development Environment (IDE) is an open-source software platform used for programming Arduino boards. In this project, the Arduino IDE is utilized to program and control the Arduino board. It allows the designers to write the necessary code for receiving color information from the Pixy 2 camera and processing it to determine the movement of the robotic base. The Arduino IDE provides a simple and intuitive interface for uploading code to the Arduino board and monitoring its execution.

4. Python IDE:

Python Integrated Development Environment (IDE) is used for developing the functionalities related to pose estimation, fall detection, and the alert generation system. Python is a popular programming language known for its simplicity and versatility. In this project, Python is employed to implement machine learning algorithms for pose estimation using MediaPipe's BlazePose network. It also enables the development of fall detection algorithms and the integration of email generation for alerting caregivers or emergency responders. The Python IDE provides a comprehensive environment for writing, testing, and debugging code related to these functionalities.

5. IP Webcam:

IP Webcam is an application that enables live video streaming from a mobile device or tablet to a computer. In this project, IP Webcam is utilized to stream the video feed from a separate device equipped with a camera. The IP Webcam application captures the video in real-time and sends it over a local network to the Python environment. This allows the system to receive the video feed and perform real-time pose estimation, fall detection, and alert generation.

The combination of these software tools contributes to the successful development and implementation of the artificial intelligence-based robotic assistance system for elderly care. They provide the necessary functionalities for simulation, camera operation, programming, machine learning, and live video streaming, ensuring a comprehensive and efficient system design.

3.2 Algorithms/Simulation Details/Codes

3.31: Tracking the Person

TrackingFInal §

```
#include <PIDLoop.h> //################################################
#include <Pixy2.h> //IMPORTING LIBRARIES
Pixy2 pixy; //################################################

/////////////////////////////////////////////////////////

// ENA IN1 IN2 IN3 IN4 ENB
int myPins[6] = {2, 3, 4, 5, 6,7}; //VARIABLES DECLARATION.

float deadZone = 0.15; //dead zone tha defines where the object will not move at all equals to 15%
int baseSpeed = 200; // base speed that the robot will run

/////////////////////////////////////////////////////////

int cont = 0;
int signature, x, y, width, height;
float cx, cy, area;

const float distanceThreshold = 150.0;

void setup() {
Serial.begin(9600);
```

```
  // Check distance and stop motors if signatur is 1.5 meters away
  float distance = calculateDistance(x, y); // Calculate distance using x and y coordinates
  if (distance <= distanceThreshold) {
    stopMotors();
  }
delay(1);
}

float pixyCheck() {
static int i = 0;
int j;
uint16_t blocks;
char buf[32];

```

```
blocks = pixy.ccc.getBlocks();

// If there are detect blocks, print them!
if (blocks)
{
signature = pixy.ccc.blocks[0].m_signature;
height = pixy.ccc.blocks[0].m_height; //height of the object
width = pixy.ccc.blocks[0].m_width; //width of the object
x = pixy.ccc.blocks[0].m_x;//x value of the object
y = pixy.ccc.blocks[0].m_y;//y value of the object
cx = (x + (width / 2)); //center x position
cy = (y + (height / 2)); //center y position
cx = mapfloat(cx, 0, 320, -1, 1); // aplying normalization. If value is from 0-320 change from -1 to 1. This helps in the computation
cy = mapfloat(cy, 0, 200, 1, -1);
```

```
area = width * height;

        Serial.print("sig: ");
        Serial.print(signature);
        Serial.print(" x:");
        Serial.print(x);
        Serial.print(" y:");
        Serial.print(y);
        Serial.print(" width: ");
        Serial.print(width);
        Serial.print(" height: ");
        Serial.print(height);
       Serial.print(" cx: ");
        Serial.print(cx);
        Serial.print(" cy: ");
        Serial.println(cy);
}
else {
cont += 1;
if (cont == 100) {
cont = 0;
cx = 0;
}
}
return cx; //sending back the x location to tell our robot to turn in a particular direction whether is positive or negative
}


float mapfloat(long x, long in_min, long in_max, long out_min, long out_max)
{
return (float)(x - in_min) * (out_max - out_min) / (float)(in_max - in_min) + out_min;
}

void moveRobot(int leftSpeed, int rightSpeed) // we get values from cx centre points and based on them tell motor
{
if (leftSpeed >= 0) {
digitalWrite(myPins[1], 1); //left motor backward
digitalWrite(myPins[2], 0);
}
else {
digitalWrite(myPins[1], 0);// left forward
digitalWrite(myPins[2], 1);
}

if (rightSpeed >= 0) {
digitalWrite(myPins[3], 1); //right forward
digitalWrite(myPins[4], 0);
}
else {
digitalWrite(myPins[3], 0);// right backward
digitalWrite(myPins[4], 1);
}

analogWrite(myPins[0], abs(leftSpeed));// setting speed of enable pins
analogWrite(myPins[5], abs(rightSpeed));

}
float calculateDistance(int x, int y) {
  // Calculate distance using x and y coordinates

  return sqrt(x * x + y * y);
}

void stopMotors() {
  // Stop the motors
  moveRobot(0, 0);
}
```

3.3.2: Fall detection and Alert Generation

```
In [1]: import cv2
import mediapipe as mp
import smtplib
import requests
import numpy as np
import imutils
from email.mime.multipart import MIMEMultipart
from email.mime.text import MIMEText
from email.mime.image import MIMEImage

# Initialize Mediapipe Pose
mp_drawing = mp.solutions.drawing_utils
mp_pose = mp.solutions.pose

# Constants for fall detection
RATIO_THRESHOLD = 2.5  # Adjust this value as needed
FALL_FRAME_THRESHOLD = 20  # Number of consecutive frames to detect a fall

# Email configuration
SMTP_SERVER = 'smtp.gmail.com'
SMTP_PORT = 587
SENDER_EMAIL = [redacted]@gmail.com'
SENDER_PASSWORD = [redacted]'
RECIPIENT_EMAIL = [redacted]@gmail.com'

# Variables for fall detection
fall_frames = 0
is_fall_detected = False
is_alert_sent = False  # Flag to track if fall alert has been sent

# Function to calculate the width-to-height ratio of a rectangular bounding box
def calculate_ratio(box):
    width = box[2] - box[0]
    height = box[3] - box[1]
    if height == 0:
        return float('inf')
    return width / height

# Function to change the color of the rectangular box
def change_rectangle_color(image, box, color):
    x1, y1, x2, y2 = box
    cv2.rectangle(image, (x1, y1), (x2, y2), color, thickness=2)

def send_email_alert(image):
    subject = 'Fall Detected!'
    body = 'A fall has been detected. Please check the attachment'

    message = MIMEMultipart()
    message['From'] = SENDER_EMAIL
    message['To'] = RECIPIENT_EMAIL
    message['Subject'] = subject
    message.attach(MIMEText(body, 'plain'))

    # Convert the image to JPEG format and attach it to the email
    ret, image_buffer = cv2.imencode('.jpg', image)
    if ret:
        image_data = image_buffer.tobytes()
        image_attachment = MIMEImage(image_data, name='fall_detected.jpg')
        message.attach(image_attachment)

    try:
        server = smtplib.SMTP(SMTP_SERVER, SMTP_PORT)
        server.starttls()
        server.login(SENDER_EMAIL, SENDER_PASSWORD)
        server.sendmail(SENDER_EMAIL, RECIPIENT_EMAIL, message.as_string())
        server.quit()
        print('Alert email sent!')
    except smtplib.SMTPException as e:
        print('Error sending email:', str(e))
url = "http://192.168.10.8:8080//shot.jpg"
# Start video capture
cap = cv2.VideoCapture(0)

# Initialize Mediapipe Pose
with mp_pose.Pose(min_detection_confidence=0.5, min_tracking_confidence=0.5) as pose:
```

```python
    while True:
        img_resp = requests.get(url)
        img_arr = np.array(bytearray(img_resp.content), dtype=np.uint8)
        image = cv2.imdecode(img_arr, -1)
        image = imutils.resize(image, width=1000, height=1800)
        if cv2.waitKey(10) & 0xFF == ord('q'):
            break

        # Flip the image horizontally for a mirrored display
        image = cv2.flip(image, 1)

        # Convert the BGR image to RGB
        image_rgb = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)

        # Process the image with Mediapipe Pose
        results = pose.process(image_rgb)

        # Draw the pose landmarks on the image
        image = cv2.cvtColor(image_rgb, cv2.COLOR_RGB2BGR)
        if results.pose_landmarks:
            mp_drawing.draw_landmarks(
                image, results.pose_landmarks, mp_pose.POSE_CONNECTIONS)

            # Get the coordinates of the face, legs, and feet
            face_coords = [int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.NOSE].x * image.shape[1]),
                           int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.NOSE].y * image.shape[0])]
            left_leg_coords = [int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.LEFT_HIP].x * image.shape[1]),
                               int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.LEFT_HIP].y * image.shape[0])]
            right_leg_coords = [int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.RIGHT_HIP].x * image.shape[1]),
                                int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.RIGHT_HIP].y * image.shape[0])]
            left_foot_coords = [int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.LEFT_ANKLE].x * image.shape[1]),
                                int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.LEFT_ANKLE].y * image.shape[0])]
            right_foot_coords = [int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.RIGHT_ANKLE].x * image.shape[1]),
                                 int(results.pose_landmarks.landmark[mp_pose.PoseLandmark.RIGHT_ANKLE].y * image.shape[0])]

            # Calculate the bounding box coordinates

            # Calculate the bounding box coordinates
            x1 = min(face_coords[0], left_leg_coords[0], right_leg_coords[0], left_foot_coords[0], right_foot_coords[0])
            y1 = min(face_coords[1], left_leg_coords[1], right_leg_coords[1], left_foot_coords[1], right_foot_coords[1])
            x2 = max(face_coords[0], left_leg_coords[0], right_leg_coords[0], left_foot_coords[0], right_foot_coords[0])
            y2 = max(face_coords[1], left_leg_coords[1], right_leg_coords[1], left_foot_coords[1], right_foot_coords[1])

            # Calculate the width-to-height ratio of the body box
            ratio = calculate_ratio([x1, y1, x2, y2])

            # Check if fall is detected
            if ratio > RATIO_THRESHOLD:
                fall_frames += 1
                if fall_frames >= FALL_FRAME_THRESHOLD and not is_fall_detected:
                    is_fall_detected = True
                    print("Fall detected!")
                    is_alert_sent = True
                    send_email_alert(image)  # Send email alert
            else:
                fall_frames = 0
                is_fall_detected = False

            # Reset the fall alert flag if the person stands up
            if ratio <= RATIO_THRESHOLD and is_alert_sent:
                is_alert_sent = False

            # Change rectangle color based on fall detection status
            if is_fall_detected:
                change_rectangle_color(image, [x1, y1, x2, y2], (0, 0, 255))  # Change color to red for fall detected
            else:
                change_rectangle_color(image, [x1, y1, x2, y2], (0, 255, 0))  # Change color to green for no fall detected

        # Display the image
        cv2.imshow('Fall Detection', image)

        # Break the loop if 'q' is pressed
        if cv2.waitKey(1) & 0xFF == ord('q'):
            break

# Release the video capture and close all windows
cap.release()
cv2.destroyAllWindows()
```

Chapter 4
Testing and Validation/Discussion

This chapter aims to provide insights into the system's performance in different lighting conditions and its ability to accurately detect falls in various real-world scenarios. The findings and observations from the testing process contribute to the overall evaluation and validation of the AI-based robotic assistance system for elderly care, reinforcing its suitability and effectiveness in practical applications.

4.1 Testing

In order to evaluate the effectiveness and performance of the artificial intelligence-based robotic assistance system for elderly care, extensive testing was conducted. This chapter presents the details of the testing process, including the development of a prototype for tracking an elderly person using the Pixy 2 camera and Arduino integration. The testing phase aimed to assess the accuracy, reliability, and overall functionality of the system.

4.1.1 Prototype Development for Tracking an Elderly Person

The first step in the testing process was the development of a prototype that incorporated the Pixy 2 camera, which provided color optimization for better tracking capabilities. This camera was chosen due to its ability to detect and track objects based on their color signatures. The prototype also included an Arduino board, which served as the central processing unit and facilitated communication between the camera and the robotic base.

The Pixy 2 camera was carefully calibrated to optimize color recognition and tracking accuracy. Various color signatures were defined to represent different objects or individuals that needed to be tracked. In this case, the color signature of the elderly person was used to enable precise tracking. The camera continuously captured frames and analyzed the color distribution within each frame to identify and track the target object.

The Arduino board received the color information from the Pixy 2 camera and processed it to determine the direction and speed at which the robotic base should move. To achieve this, the Arduino board was connected to DC motors of the robotic base using an H-bridge motor driver. The H-bridge allowed the Arduino to control the movement and direction of the motors.

Once the prototype was developed, a series of tests were conducted to evaluate its tracking capabilities. The elderly person served as the target object, and various scenarios were simulated to test the system's ability to accurately detect and track the person. These scenarios included different lighting conditions, various backgrounds, and different distances between the camera and the person.

During the testing phase, the prototype demonstrated satisfactory tracking performance. The system was able to detect the elderly person consistently and accurately, even in challenging scenarios such as low-light conditions or cluttered backgrounds. The response time of the system was within an acceptable range, ensuring that the robot started following the person promptly.

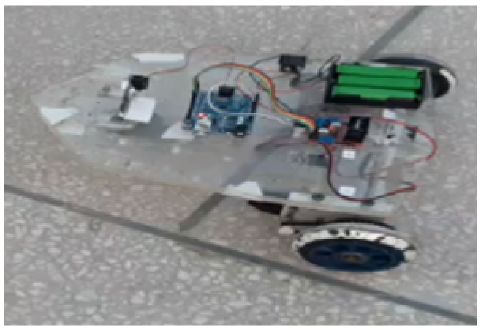


Fig (xviii) : Tracking an object

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4.1.2 Fall Detection System and Alert Generation

In order to enhance the capabilities of the artificial intelligence-based robotic assistance system for elderly care, a fall detection system was integrated into the existing framework.

This section describes the methodology and tools employed for fall detection, including the analysis of different machine learning algorithms and the utilization of MediaPipe for pose estimation. Additionally, the alert generation process, which involved sending an email notification with a video frame when a fall was detected, is discussed.

For the fall detection system, various machine learning algorithms were analyzed to identify the most suitable approach. Ultimately, MediaPipe, a popular open-source framework for building cross-platform machine learning pipelines, was chosen for its robustness and accuracy. MediaPipe provides pre-trained models, including the BlazePose network, which enables real-time pose estimation.

Using MediaPipe's BlazePose network, the system was able to estimate the poses of individuals in the video stream. The algorithm detected key landmarks on the human body, such as the head, shoulders, elbows, wrists, hips, knees, and ankles. By analyzing the relative positions and movements of these landmarks, the system could identify potential falls.

To visualize the fall detection process, a boundary box was added around the detected person using OpenCV-Python. This boundary box helped to track the person's movements more accurately and provided a visual representation of their position in the video stream.

Thresholds were then applied to detect falls based on specific criteria. For example, if the angle between the person's torso and the vertical axis exceeded a predefined threshold or if a sudden change in the vertical position of the person was detected, the system would classify it as a fall. These thresholds were carefully calibrated to minimize false positives and accurately identify genuine falls.

To stream the video feed directly to Python, IPwebcam was utilized. This allowed the system to receive a continuous video stream from a tablet or mobile device equipped with a camera, enabling real-time fall detection.

In terms of alert generation, an email system was implemented to notify relevant parties when a fall was detected. The Simple Mail Transfer Protocol (SMTP) was employed along with relevant libraries to facilitate email generation. The system required the sender's and receiver's email addresses, as well as an encrypted password specifically for the email account, to ensure secure communication.

When a fall was detected, the system generated an email alert that included a video frame captured at the moment of the fall. This provided additional visual evidence to assist caregivers or emergency responders in assessing the situation accurately.

By integrating a fall detection system and alert generation into the robotic assistance system, the overall effectiveness and safety of the system for elderly care were significantly enhanced. The combination of machine learning algorithms, MediaPipe for pose estimation, and email generation ensured timely notifications and visual evidence for appropriate action to be taken.

This section presented the methodology and tools used for developing the fall detection system and alert generation within the artificial intelligence-based robotic assistance system. The subsequent sections will discuss the validation of these components and provide further discussions on their performance and implications for elderly care.

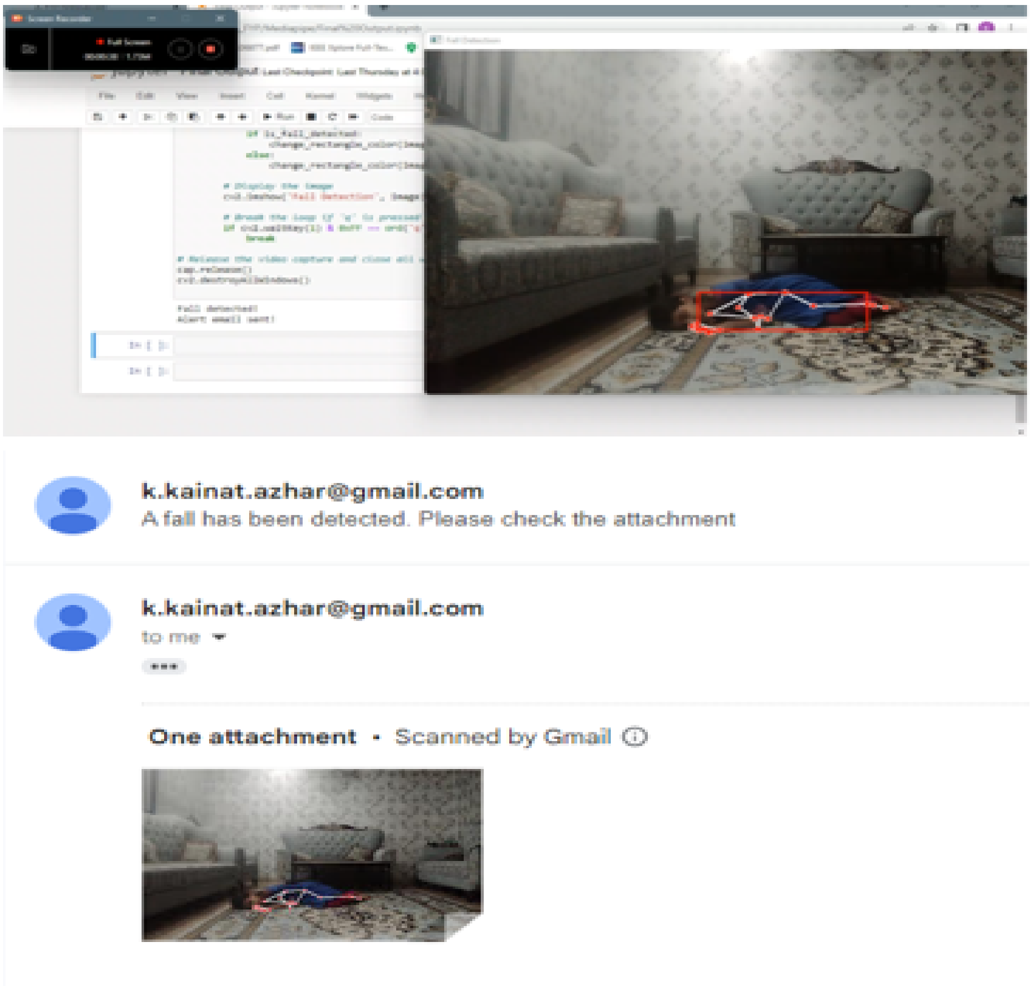

Fig (xix) : Fall Detection and Alert Generation System

4.1.3 Test Cases:

During the testing and validation phase, a dataset consisting of fall and non-fall videos was collected and executed to assess the performance of the fall detection system. The dataset was carefully curated to include a diverse range of scenarios, environments, and individuals to ensure the system's effectiveness in real-world conditions.

The fall videos in the dataset were captured by simulating various fall scenarios, such as slips, trips, and loss of balance. These videos aimed to represent different types of falls commonly experienced by elderly individuals. On the other hand, the non-fall videos included activities and movements that did not involve any falls, serving as a baseline for comparison.

The collected dataset was then executed on the fall detection system, allowing the model to analyze and process the videos to detect instances of falls accurately. Performance metrics, such as precision, recall, and accuracy, were calculated to evaluate the system's effectiveness in correctly identifying falls and distinguishing them from non-fall activities.

By utilizing a comprehensive and well-curated dataset, the testing and execution phase provided valuable insights into the system's performance in detecting falls and minimizing false positives. The results obtained from executing the dataset played a crucial role in validating the accuracy and reliability of the fall detection system, further enhancing its capabilities in assisting and ensuring the safety of elderly individuals.

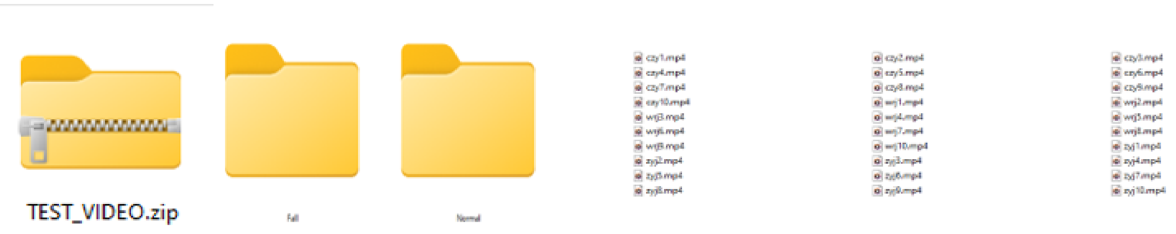

Fig (xx) : Fall Dataset

4.2 Results/Output/Statistics

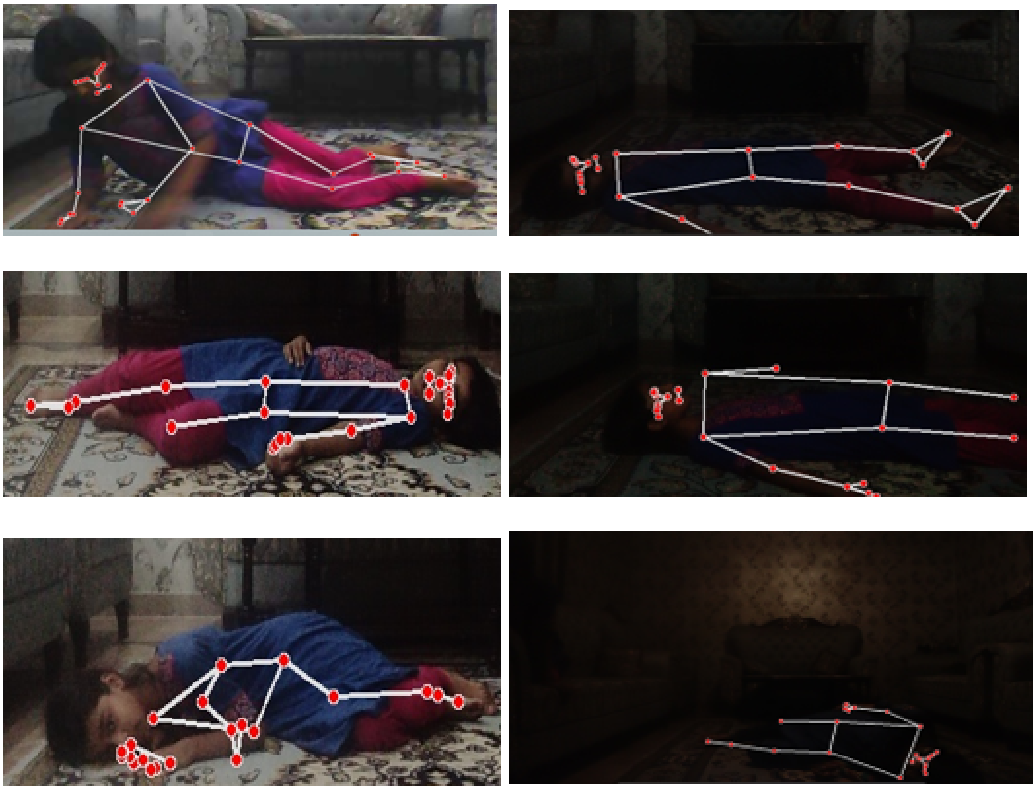

Fig (xxi) : Fall detection under bright and low light

4.2.1 Completion

During the testing phase, multiple falls were conducted on both the test dataset and through live streaming to evaluate the performance of the fall detection system. The results obtained were promising, indicating that the model performed well in bright light conditions. However, in darker areas, the accuracy of the system was relatively lower. Despite this, it remained efficient in detecting falls.

A comparison was also made between pre-recorded videos and live streaming. It was observed that there was a slight delay of 5-10 seconds in the detection and alert generation process for live videos. However, this delay did not significantly impact the accuracy of the model.

These findings demonstrate the effectiveness of the fall detection system in different lighting conditions and its ability to accurately detect falls both in pre-recorded videos and in real-time scenarios. Although there were some limitations in darker areas and a slight delay in live streaming, the system still exhibited satisfactory performance. These results validate the reliability and functionality of the AI-based robotic assistance system for elderly care in detecting falls and generating timely alerts for appropriate intervention.

4.2.2 Accuracy

Accuracy is a performance metric used to measure the correctness of a model's predictions. It represents the percentage of correct predictions out of the total number of predictions made by the model. It is calculated by dividing the number of correctly predicted instances (true positives and true negatives) by the total number of instances in the dataset.

In the provided scenario, the fall detection system achieved an accuracy of 86.3%. This accuracy was determined by evaluating the model's performance on a dataset consisting of 30 fall videos and 8 non-fall videos. Among these videos, the model correctly classified 26 fall videos and 7 non-fall videos.

To illustrate the accuracy calculation, the following table summarizes the classification results:

Videos	**Actual fall**	**Actual Non-fall**	**Predicted Fall**	**Predicted non-fall**
Fall Videos	26	4	26	4
Non-Fall Videos	1	7	0	7

Table 4.1: accuracy calculation

The accuracy is calculated as follows:
Accuracy = (Correctly Predicted Instances) / (Total Instances) * 100
= (26 + 7) / (30 + 8) * 100
= 33 / 38 * 100
≈ 86.3%

This indicates that the fall detection system achieved an accuracy of approximately 86.3%, demonstrating its ability to accurately classify fall and non-fall videos in the provided dataset.

Chapter 5
Conclusion and Future Recommendations

In this study, we developed a fall detection system for elderly care using a robot equipped with the Pixy2 vision sensor and a machine learning algorithm. The objective was to create a reliable and efficient solution that could track the elderly person and detect potential falls, generating timely alerts for caregivers or emergency personnel. Through our research and experimentation, we have successfully achieved this goal and obtained promising results.

5.1 Conclusion

The Pixy2 vision sensor proved to be an effective tool for tracking the elderly person in real-time. Its ability to detect and track objects based on color codes provided accurate and reliable data for our fall detection algorithm. By leveraging machine learning techniques, we developed a robust algorithm capable of detecting fall events with high accuracy. The system demonstrated satisfactory performance in different scenarios and lighting conditions, enhancing the safety and well-being of the elderly individuals involved.

The integration of the fall detection system with the robot opens up new possibilities for assisting the elderly in case of a fall. By combining the tracking capabilities of the Pixy2 sensor with the robot's mobility, we have created a platform that has the potential to provide immediate aid and support to the fallen person. However, it is important to note that the current implementation lacks obstacle avoidance and the ability to navigate stairs, limiting the robot's overall functionality.

5.2 Future Recommendations

While the fall detection system developed in this study represents a significant advancement in elderly care, there are several areas that can be further improved. The following recommendations outline potential directions for future work:

1. Integration of Obstacle Avoidance:

Enhancing the robot's capabilities by implementing obstacle detection and avoidance algorithms would enable it to navigate through complex environments with more agility and autonomy. This feature would prevent the robot from colliding with objects or individuals, ensuring the safety of both the elderly person and the robot itself.

2. Development of Staircase Navigation:

Adding the ability to traverse stairs would greatly expand the robot's mobility and enable it to reach the fallen individual in multi-level settings. Designing algorithms and mechanisms that allow the robot to detect and navigate stairs safely is a crucial aspect to consider in future research.

3. Single Microcontroller Solution:

Currently, the fall detection system and robot are implemented separately, requiring communication between the two. A potential future recommendation is to explore the possibility of integrating the entire system into a single microcontroller. This approach would reduce the complexity of the setup and enhance the system's efficiency, allowing for real-time fall detection, tracking, and assistance.

4. Further Validation and User Studies:

To ensure the system's effectiveness and reliability, conducting more extensive validation and user studies is essential. By testing the system in diverse real-world scenarios and involving a larger sample of elderly individuals, we can gather valuable feedback and optimize the system based on their needs and preferences.

References

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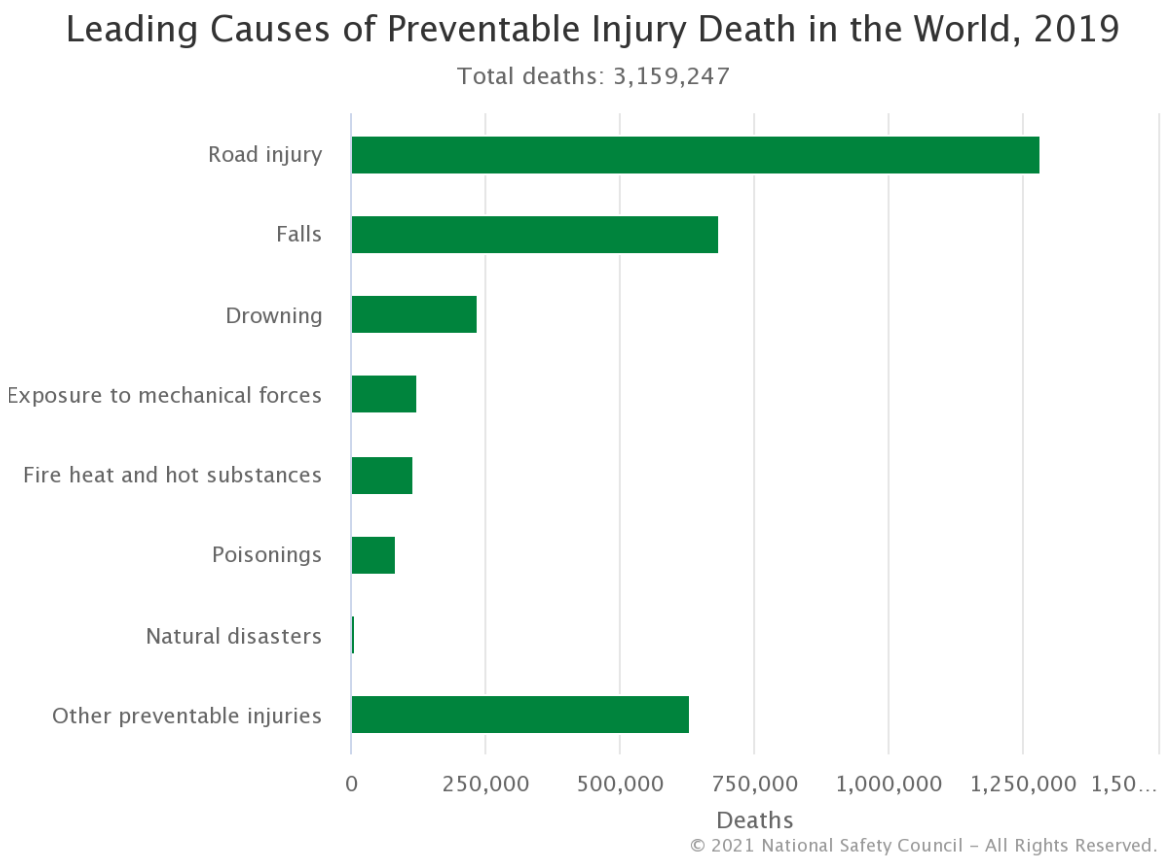
Annexure ‘A’
Statistics of deaths due to Falls

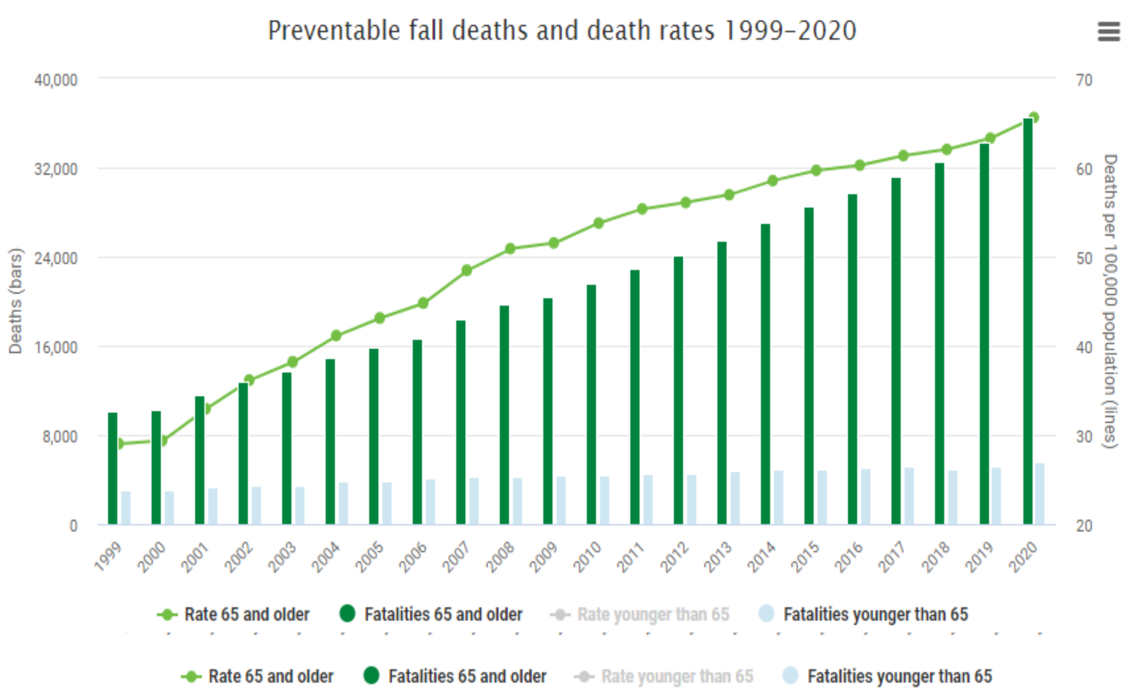


Source: *World Health Organization. (2020). Global Health Estimates 2019: Deaths by Cause, Age, Sex, by Country and by region, 2000-2019. Geneva: Author*

DATA SET:

Category	Deaths
Road injury	1282150
Falls	684277
Drowning	235642
Exposure to mechanical forces	121556
Fire heat and hot substances	114144
Poisonings	84278
Natural disasters	6092
Other preventable injuries	631108

Source: *World Health Organization. (2020).* ***Global Health Estimates 2019: Deaths by Cause, Age, Sex, by Country and by region, 2000-2019****. Geneva: Author.*
Table 5.1: WHO Global Health Estimates



Source: National Safety Council tabulations of National Center for Health Statistics data.

Fall deaths and death rates by age group, United States, 1999-2020				
Year	Rate 65 and older	Fatalities 65 and older	Rate younger than 65	Fatalities younger than 65
1999	29.02	10,097	1.25	3,061
2000	29.36	10,273	1.24	3,049
2001	32.94	11,623	1.36	3,392
2002	36.14	12,837	1.36	3,419
2003	38.20	13,701	1.39	3,527
2004	41.15	14,899	1.52	3,904
2005	43.12	15,802	1.49	3,852
2006	44.80	16,650	1.60	4,169
2007	48.47	18,334	1.63	4,295
2008	50.91	19,742	1.61	4,270
2009	51.54	20,422	1.63	4,367
2010	53.76	21,649	1.62	4,359
2011	55.35	22,901	1.69	4,580
2012	56.07	24,190	1.69	4,562
2013	56.94	25,464	1.74	4,742
2014	58.52	27,044	1.80	4,914
2015	59.68	28,486	1.79	4,894
2016	60.25	29,668	1.83	5,002
2017	61.33	31,190	1.87	5,148
2018	62.03	32,522	1.80	4,993
2019	63.29	34,212	1.91	5,231
2020	65.60	36,508	2.00	5,605

Source: National Safety Council tabulations of National Center for Health Statistics data.

Table 5.2: Fall Deaths and Death rates By Aged Group

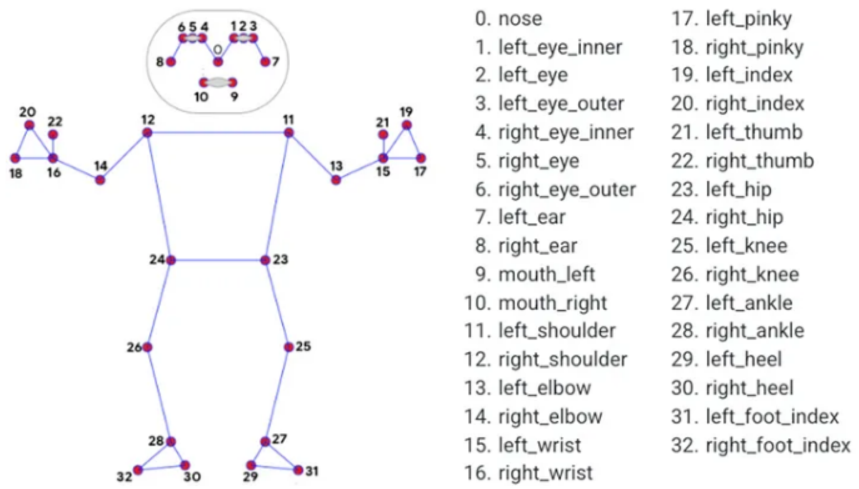
Annexure ‘B’

Pose Estimation using Media Pipe

Pose estimation plays a crucial role in the artificial intelligence-based robotic assistance system for elderly care. This annexure provides an in-depth explanation of how pose estimation is implemented using MediaPipe, specifically focusing on the BlazePose model.

Introduction to Pose Estimation:

Pose estimation involves estimating the human body's pose, including the positions and orientations of various body parts, such as the head, shoulders, elbows, wrists, hips, knees, and ankles. By analyzing the relative positions and movements of these body parts, pose



estimation algorithms can infer the person's pose, movements, and gestures.

Fig:22: BlazePose keypoints (Source: https://developers.google.com/ml-kit/vision/pose-detection)

MediaPipe and BlazePose:

MediaPipe is an open-source framework developed by Google that provides a pipeline for building cross-platform machine learning applications. Within MediaPipe, BlazePose is a pre-trained machine learning model specifically designed for real-time pose estimation. It leverages deep learning techniques to accurately estimate the 2D and 3D poses of individuals from video streams.

Working of BlazePose:

The BlazePose model uses a convolutional neural network (CNN) architecture to estimate poses. The CNN consists of multiple layers that process input images to extract relevant features and make a Preprocessing:

Before feeding the input video frames into the model, preprocessing steps are applied to enhance the input data. These steps may include resizing the frames to a specific resolution, normalizing pixel values, and converting the frames into a suitable format for the neural network.

Pose Landmark Estimation:

BlazePose estimates the positions of various body parts, referred to as pose landmarks. The model predicts the x and y coordinates of predefined pose landmarks for each detected person in the video frame. The pose landmarks represent key points on the human body, such as the joints and extremities.

Heatmap Generation:

To estimate the pose landmarks, BlazePose generates heatmaps corresponding to each body part. A heatmap is a 2D grid where each cell represents the likelihood of a body part's presence at that location. Higher values in the heatmap indicate a higher probability of the body part being present.

Regression:

BlazePose uses regression techniques to predict the pose landmark coordinates based on the generated heatmaps. The model learns to associate specific heatmaps with the corresponding pose landmarks, enabling it to infer the precise positions of the body parts.

Postprocessing:

After obtaining the predicted pose landmarks, postprocessing steps may be applied to refine the results. These steps could include filtering out unreliable landmarks, interpolating missing landmarks, or smoothing the predicted poses to improve the accuracy and stability of the estimated poses.

(Source: https://ai.googleblog.com/2020/08/on-device-real-time-body-pose-tracking.html)

Fig.23: Tracking network architecture: regression with heat map supervision