NAVIGATION SYSTEM FOR
AN INTELLIGENT ROBOT IN MONITORING AND PROTECTING TODDLERS

Project ID: 2023-326

Final Draft Report

Thuduhena R.S

IT20185466

Dissertation was submitted in partial fulfillment of the requirements for the B.Sc. Special Honors degree in Information Technology Specialized in Computer Systems and Network Engineering

Department of Computer Systems Engineering

Sri Lanka Institute of Information Technology

Sri Lanka

September 2023

DECLARATION

I declare that this is my own work, and this proposal does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

Name	Student ID	Signature
Thuduhena R.S	IT20185466	

The above candidate has carried out research for the B.Sc. Dissertation under my supervision.

Signature of the Supervisor: _______________ Date: _________9/9/2023__________

ABSTRACT

Robotics (R), Machine Learning (ML), and Artificial Intelligence (AI) can be known as mostly used terms in this era since it has brought tremendous change in the industry of Information Technology (IT). The proposed system has been designed to address the growing concerns of parents and caregivers regarding the safety of their young children. With the rise of technology and automation, there is a need for innovative solutions that can provide effective monitoring and protection for toddlers, especially in situations where direct supervision may not always be possible, which is going to be enriched with Robotics, Open CV related technologies, Machine Learning, and Artificial Intelligence (AI). We plan to have functionalities such as (1) a toddler-proof robot navigation system with obstacle avoidance and safe movement. (2) To establish virtual monitoring of the toddler's surroundings to provide parental oversight and detect unauthorized hazards. (3) Develop system also offers reliable alerts based on child behavior. (4) Develop interactions with robots that are more effective and familiar to toddlers and their activities. Mentioned above are the primary functions that will concern this system. The intelligent robot proposed in this paper has the potential to significantly improve the safety and well-being of toddlers while also providing peace of mind for parents and caregivers.

Key Words – R-Robotics, AI-Artificial intelligence, ML-Machine learning, and IT- Information technology.

ACKNOWLEDGEMENT

The successful completion of the undertaken research project would not have been possible without the invaluable support and guidance of numerous individuals. I would like to express my profound gratitude to my esteemed Supervisor, Professor Sanath Jayawardena, and my Co-Supervisor, Mrs. Rangi Liyanage, whose unwavering mentorship steered me in the right direction and enabled me to achieve the predefined objectives within the stipulated time frame. Furthermore, I extend my heartfelt appreciation to my dedicated fellow team members: W.R. Laksan, R.M.S.S. Weerarathne, and M.A.K.D.B. Maddepola, whose collective efforts were instrumental in ensuring the successful and reliable outcome of this project. I also wish to acknowledge the invaluable support and guidance provided by the Research Project module Coordinators at the Sri Lanka Institute of Information Technology (SLIIT). Their precious instructions played a pivotal role in translating our research aspirations into tangible reality. Once again, I would like to express my deepest gratitude to all those who contributed to the realization of this research endeavor.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Description
AI	Artificial Intelligence
ML	Machine Learning
COCO	Common Object in Context
CV	Computer Vision
IMU	Inertial Measurement Unit
R	Robotics
IP	Image Processing
GOTURN	Generic Object Tracking Using Regression

1 INTRODUCTION

1.1 Background & Literature Survey

In our fast-paced modern world, where parents juggle demanding schedules filled with work commitments, domestic responsibilities, and the essential duties of parenting, the challenge of ensuring the safety and well-being of their toddlers becomes ever more complex. Fortunately, with the relentless march of technological progress, we find ourselves on the brink of a groundbreaking innovation: the development of an intelligent robot designed to lend a helping hand to parents in the vital task of monitoring their children and identifying potential dangers. In this research, we will explore the potential benefits and implications of introducing such a robot into households. We will examine its ability to detect common hazards like open windows or unsecured cabinets, its capacity to provide real-time updates to parents, and the ethical considerations surrounding the use of technology in child-rearing. Additionally, we will investigate the potential impact on children's development and whether the presence of a robot caregiver may hinder or enhance their independence and social skills. Ultimately, this research aims to shed light on the future of parenting and the role that intelligent robots may play in ensuring the safety and well-being of our youngest family members. We present a comprehensive concept for an intelligent robot, engineered to remotely oversee children and promptly alert parents to any concerning situations.

The proposed project encompasses the creation of a highly capable robot equipped with a multifaceted array of monitoring functionalities tailored to the unique needs of childcare. This intelligent guardian will not only possess the ability to keenly observe and interpret a toddler's behavior but will also possess the capability to identify and assess potential risks that could pose a threat to a toddler's safety. Moreover, this innovative robot will extend its watchful eye to encompass the child's immediate environment, continuously tracking critical factors such as temperature, humidity, oxygen levels, and more.

However, this robot is not limited to passive observation; it will actively engage with the toddler's needs and desires. For instance, it can play soothing music based on the child's cues, whether the little one is in the midst of a peaceful nap or expressing distress through crying. To further enhance its protective role, the robot will be outfitted with specialized sensors and advanced camera systems designed to promptly detect any unauthorized presence within the child's vicinity, whether it be a curious household pet or any other potential risks that may emerge. Crucially, the proposed robot will possess autonomous navigation capabilities, ensuring its ability to safely and intelligently maneuver around the child, even in unpredictable scenarios. This feature will enable it to follow the toddler's movements closely while effortlessly circumventing any obstacles that may appear in its path. This capability is instrumental in ensuring the child's safety while maintaining a non-invasive presence.

The potential of robotics to revolutionize everyday life and enhance our overall quality of life is becoming increasingly evident as technological advancements continue to push the boundaries of what is possible. In this context, the development of a robust robot navigation system emerges as a central focus, particularly when dealing with the unpredictable nature of toddlers. It is imperative to establish a reliable and efficient navigation system, one that can adeptly navigate around these young, ever-moving individuals while skillfully avoiding obstacles, in order to create a robot capable of safe and practical use in a child's environment.

A system like this could allow robots to autonomously navigate in places where young children are found, improving safety and efficiency in childcare centers, households, and public spaces. The task has several challenges. One challenge is that the robot needs to be able to recognize and avoid obstacles. Another challenge is that the robot needs to respond appropriately to unpredictable behavior. Lastly, the robot needs to ensure safe movement when it is close to people. Nevertheless, with the swift advancements in robotics technology and the implementation of machine learning techniques, the prospect of developing a robot navigation system that is impervious to manipulation by young children is becoming increasingly viable. Parents, caretakers, and society as a whole have a significant responsibility when it comes to monitoring and safeguarding toddlers from potential harm. Intelligent robots have the potential to play a significant role in monitoring and safeguarding toddlers due to their ability to provide an extra layer of protection and assistance. In this literature review, we will examine the latest advancements in intelligent robots designed to monitor and safeguard toddlers. Our main focus will be on the navigation systems of these robots (1).

The authors of this paper suggest the utilization of an intelligent robot to oversee and aid young children. The core of the robot's navigation system was built using a Simultaneous Localization and Mapping (SLAM) algorithm. Additionally, the device was equipped with a depth camera and ultrasonic sensors in order to accurately detect obstacles and effectively prevent any potential collisions with them. The main objective of the robot was to monitor the young child and provide aid in case of an emergency. The robot was tested in a simulated environment, and the results showed that it could effectively watch over the toddler and help in emergencies (1).

The aim of this paper was to suggest a smart robot designed to safeguard young children by detecting and avoiding obstacles. The robot's navigation system utilized a stereo camera and a 2D laser scanner to detect possible dangers and determine a safe path for the child. The robot's voice recognition system was capable of identifying the toddler's voice and responding accordingly. The proposed robot was placed through its paces in a simulated setting, and the results demonstrated that it was able to successfully navigate around obstructions and keep the child safe (2).

In the context of this research paper, the authors introduced an innovative approach centered around a semantic segmentation-based intelligent robot for the purpose of monitoring and aiding toddlers. The robot's navigation system was meticulously designed, incorporating a depth camera alongside a cutting-edge semantic segmentation algorithm. These components were instrumental in enabling the robot to not only track the toddler's movements with remarkable precision but also to assess potential risks in real-time. The robot had the capacity to promptly help in situations where it detected an imminent danger to the child's well-being. To rigorously evaluate the robot's performance, comprehensive simulations were conducted, yielding compelling results that demonstrated its efficacy in closely monitoring children and intervening effectively during emergencies (3).

Furthermore, the research delved into the realm of reinforcement learning as a pivotal technique to empower an intelligent robot with the ability to safeguard toddlers. The robot's navigation system was underpinned by a reinforcement learning algorithm, which facilitated its capacity to acquire and adapt navigation strategies over time. This adaptive learning process allowed the robot to become proficient in both protecting the toddler and navigating around potential obstacles with agility and precision. In order to rigorously assess the capabilities of this reinforcement learning-powered robot, a series of simulated scenarios were meticulously executed, culminating in findings that unequivocally showcased its remarkable ability to learn and execute protective actions on behalf of the toddler (4).

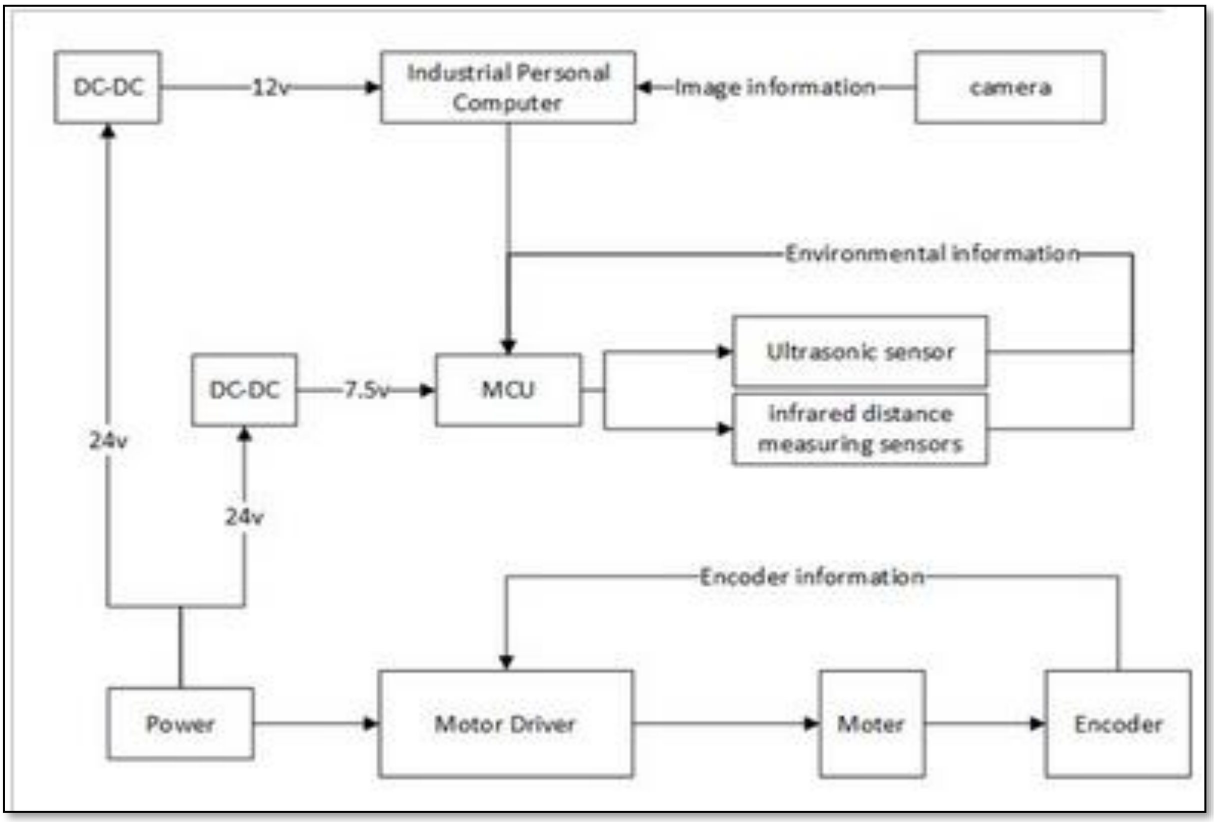


Figure 1: Composition of mobile robot system

In this research paper, presenting a new and advanced robot that uses multiple sensors to combine information and make intelligent decisions. The main purpose of this robot is to help toddlers navigate their surroundings in a safe manner. The main focus of this robot's abilities is its advanced navigation system. This system relies on a multi-sensor fusion algorithm to enhance its performance. The algorithm skillfully integrates data collected from various sensors, such as a depth camera, a 2D laser scanner, and an inertial measurement unit (IMU). The depth camera is very important because it gives accurate 3D spatial information about what's around the robot. The robot can use this extensive data to gain a detailed understanding of the toddler's surroundings, including where there might be obstacles. At the same time, the 2D laser scanner improves our understanding by constantly identifying and charting barriers in the present moment. The IMU is an important component that provides crucial data regarding the robot's orientation and acceleration. This information is vital for maintaining stable and precise navigation.

The robot is able to provide valuable assistance to toddlers as they move around their surroundings, thanks to a collaborative network of sensors. The toddler guidance system possesses the ability to recognize and examine possible barriers and dangers, enabling it to create immediate plans to safely direct the toddler. Additionally, the robot has been designed with the capability to actively offer its assistance, guaranteeing that it can effectively intervene whenever necessary. Extensive simulations were performed in a controlled environment to assess the practicality and effectiveness of this multi-sensor fusion-based robot. The experiments clearly show that the robot is capable of effectively guiding and assisting toddlers. The innovative approach in sensor fusion not only enhances the robot's navigation capabilities but also represents a significant advancement in the field of intelligent robotics, specifically in the areas of childcare and assistance (5).

In this research paper, we will explore the topic of intelligent obstacle avoidance for robots that are equipped with ultrasonic sensors. Ultrasonic sensors have typically been used for simple obstacle avoidance on predetermined paths. However, their shortcomings become evident in more complicated situations, like avoiding pits or reacting to moving obstacles. In order to address these limitations, this study presents a novel approach that integrates various sensors to greatly improve the robot's ability to avoid obstacles. The integration includes the utilization of an infrared range sensor and visual information, which enhances the functionalities of the ultrasonic sensor. The infrared range sensor is very important because it helps the robot detect ground depressions along its wheel path. This is crucial for navigating uneven terrain accurately.

The ultrasonic sensor is used to measure distances to nearby obstacles and can also identify road signs, which enhances its ability to avoid obstacles intelligently. Moreover, the utilization of a camera aids in the visual identification of road signs, thereby enhancing the robot's perception. By combining data from various sensors, the robot is able to navigate on its own and make smart decisions to avoid obstacles. Machine learning techniques, such as Cascade Classifiers, are commonly employed to differentiate road signs by considering their color and shape. This helps to guarantee precise interpretation and appropriate response.

The outcome of combining multiple sensors is a mobile robot that is very independent and has advanced abilities to avoid obstacles. The robot uses advanced logic to independently avoid obstacles and plan its path. This is achieved by combining information from multiple sensors. The infrared sensor is responsible for detecting ground depressions. The ultrasonic sensor measures obstacle distances and also recognizes road signs. Additionally, the camera is used to detect visual cues. All of this information is then processed and relayed to the robot's main controller. Microprocessors are responsible for managing environmental data and transmitting control commands to execution units.

The design's practicality and reliability are supported by a thorough examination of the ultrasonic sensor, infrared distance measurement sensors, and the road sign recognition model. These components were extensively tested in complex environments that were intentionally set up by hand. This comprehensive analysis offers strong evidence for the effectiveness of the design. This represents a significant advancement in the progress of autonomous robots that can navigate difficult terrains and intelligently react to different obstacles [6],[7].

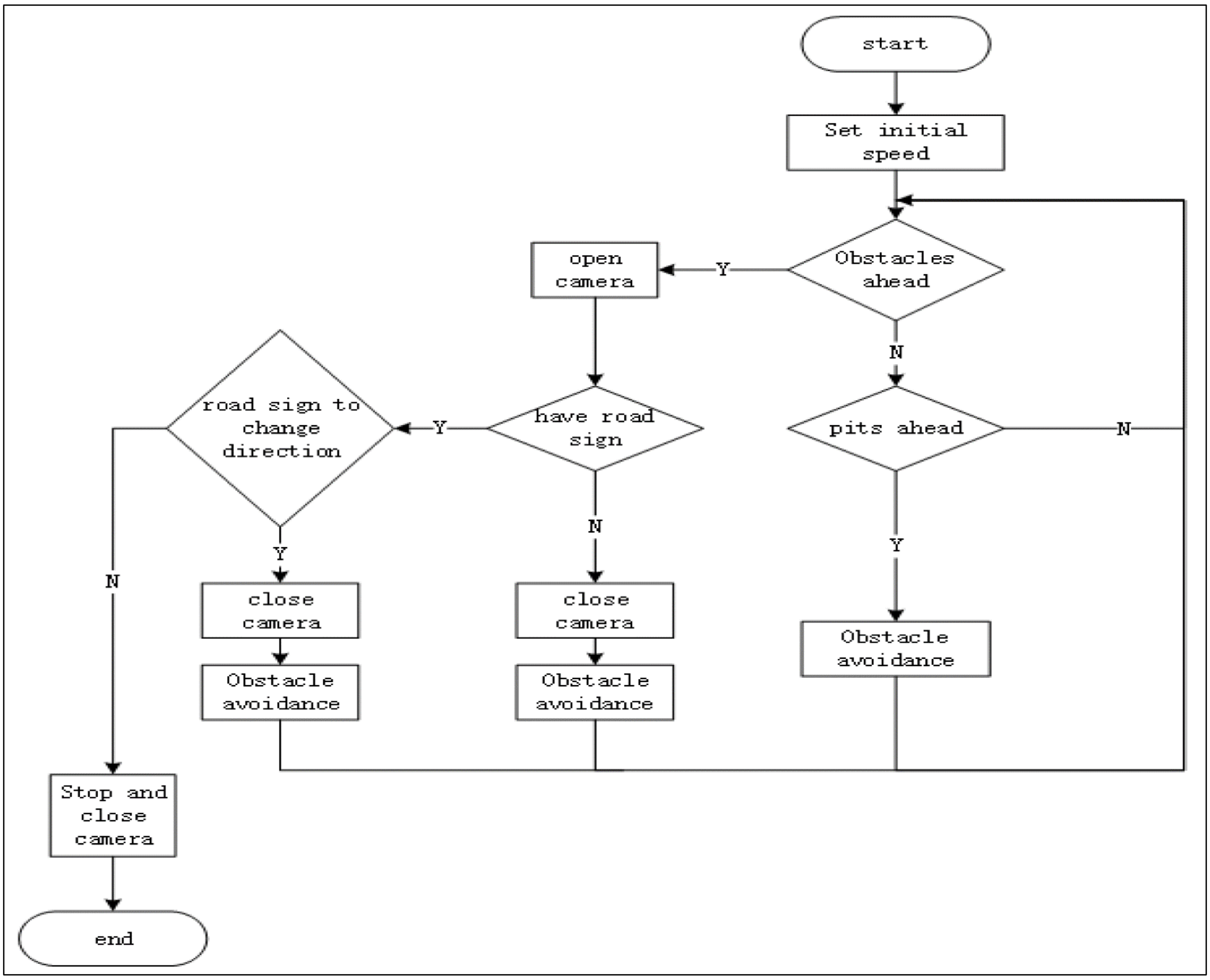


Figure 2 : Block diagram of obstacle avoidance program Composition of mobile robot system.

1.1.1 Data Set

i. YOLO data set - A ground-breaking development in the field of deep learning, the YOLO architecture is designed for real-time object detection applications. YOLO is unique in that it can quickly and precisely locate and categorize objects within an image or video frame in just one neural network pass. Because of its unique approach's remarkable efficiency, this technology is a great fit for applications where processing speed and low latency are critical. Fundamentally, YOLO uses a grid-based approach, dividing the input image into grid cells and assigning each grid cell the task of predicting objects that are located inside its borders.

YOLO predicts several bounding boxes for every grid cell, along with the class probabilities and objectless scores that go with them. These bounding box predictions include important data, such as the height, width, and center coordinates, all in relation to the grid cell's dimensions. Each bounding box's objectless score serves as a crucial predictor of the possibility that the box actually contains an object of interest. Sensibly, bounding boxes with lower objectless scores are removed since they are thought to be background or false positives. In parallel, YOLO estimates bounding box class probabilities, which express the likelihood that an object falls into a given class category. Several object classes can be detected simultaneously by this adaptable architecture within a single grid cell.

YOLO uses anchor boxes, which are predefined bounding boxes with different aspect ratios and scales, to improve the accuracy of its localization. In order to match the actual shape and size of the objects being detected, the model modifies these anchor boxes in accordance with its predictions. Over time, YOLO has undergone several iterations, including YOLOv3, YOLOv4, and YOLOv5. These iterations have introduced advanced training techniques, feature pyramid networks, and architectural enhancements. By balancing speed and accuracy, these iterations push the limits of real-time object detection. Yolo’s design principles, crucially, emphasize speed without sacrificing accuracy. Because of its elegant architecture, YOLO can operate at speeds close to real-time or in real time, which makes it an effective tool for industries like robotics, autonomous cars, and surveillance systems.

In addition, YOLO's open-source design has fostered a thriving developer and research community. In the field of computer vision, this cooperative ecosystem has led to a multitude of implementations and modifications suited to particular use cases, encouraging creativity and information sharing. Within the vast array of applications, YOLO has emerged as a significant player. Its adaptability spans a wide range of applications, such as surveillance, facial recognition, autonomous vehicle pedestrian detection, object detection in photos and videos, and more. Its ability to deliver both speed and accuracy has cemented its standing as a useful tool in a variety of real-world applications.

ii. Mobile Net SSD V2 - Stands as a prominent deep learning architecture renowned for its prowess in object detection and real-time tracking, particularly within the constraints of mobile devices characterized by limited computational resources. The architecture ingeniously marries the efficiency of Mobile Net, a purpose-built design for lightweight convolutional neural networks (CNNs), with the advanced object detection capabilities of SSD (Single Shot MultiBox Detector). While Mobile Net SSD is predominantly celebrated for its object detection capabilities, it possesses the versatility to be adapted for object tracking, especially when employed on a frame-by-frame basis in the context of video sequences[8].

It is imperative to clarify that Mobile Net SSD v2 is predominantly harnessed for real-time object detection tasks. The notion of object tracking typically ventures into the realm of distinct techniques aimed at preserving the identity and continuity of objects across multiple frames within a video stream. These tracking methods include classical approaches such as Kalman filters and modern deep learning-based trackers like GOTURN (Generic Object Tracking Using Regression Networks), Deep SORT (Deep Simple Online and Realtime Tracking), or the widely used SORT (Simple Online and Realtime Tracking).

For a more tailored and insightful response or if you seek specific information regarding datasets, implementations, or applications that leverage Mobile Net SSD v2 for object tracking, kindly provide additional context or details, and I will be delighted to offer further assistance[9].

1.1.2 Preprocessing Techniques

The KLT Tracker, and the Mean-Shift Tracker are both examples of popular object tracking algorithms. Both of these algorithms are suitable for tracking a single object. When it comes to tracking a single object, the KLT tracker is a tried-and-true option that offers a high degree of versatility. This tracker primarily depends on tracking particular feature points or interest points located on the target object across successive frames. It performs exceptionally well in situations that involve relatively minor object deformations, changes in scale, and moderate occlusions. However, it may have difficulty when attempting to deal with scale variations that are more substantial or abrupt object rotations[10].

In contrast, the Mean-Shift tracker provides a reliable method for tracking non-rigidly deforming objects of varying appearances, making it an ideal choice for more complex tracking scenarios. This algorithm, which is based on a histogram, uses the color histogram of a target object in the initial frame to represent the object's appearance. The algorithm then adaptively shifts this histogram in order to locate the object in subsequent frames. The Mean-Shift tracker is a good option for dynamic tracking tasks because it performs exceptionally well in situations in which the appearance of objects significantly shifts as a result of changes in lighting conditions or deformations. In spite of this, it could have difficulty recognizing long-term occlusions, rapidly moving objects, or sudden changes in the appearance of objects. Shift specific requirements of your single-object tracking task will determine which tracker, KLT or Mean-Shift, is the better option for you to use. The KLT tracker is a valuable option to consider if you need to track a single distinctive feature on the object and require robustness against minor deformations. If, on the other hand, your tracking scenario involves objects that have varying appearances and non-rigid deformations, the adaptability of the Mean-Shift tracker may prove to be more effective. When looking for the algorithm that will work best for your tracking problem, it is essential to consider the specifics of your dataset as well as the nuances of your tracking issue. Additionally, for more difficult tracking tasks, modern trackers based on deep learning may offer superior performance, and it is worthwhile to world[11],[12].

1.2 Research Gap

When it comes to the quest to improve the safety of children and give parents and caregivers a sense of calm, the creation of robots that can watch over toddlers represents an exciting new frontier. In recent years, these robots have attracted a significant amount of attention due to the possibility that they can assist in supervising and protecting young children. They hold an enormous amount of promise because they are able to identify potential dangers, provide real-time supervision, and aid when it is required. Nevertheless, as this area of study continues to develop, it is becoming increasingly clear that there are significant research gaps that call for in-depth investigation and creative solutions.

One significant gap in research centers on the complex dynamics of human-robot interaction, particularly as it relates to the trust placed in children by their parents. Even though these robots are intended to improve the safety of children, their usefulness and widespread adoption will be contingent on their capacity to carry out meaningful interactions with caregivers and earn their confidence. A pressing requirement is presented in the form of an understanding of the factors that influence trust and acceptance, as well as the development of strategies to cultivate interactions that build trust.

In addition, there is a sizeable knowledge gap in the field of dependable object detection and recognition. Protective robots for infants and young children rely heavily on computer vision and various object detection algorithms in order to identify potential hazards and monitor the activities of children. Despite this, there is still a pressing demand for object detection and recognition systems that are more adaptable and robust. These systems need to be able to accurately recognize a wide variety of objects and actions in a variety of different environmental conditions, including challenging scenarios like low light and cluttered settings. They also need to be able to adapt to these conditions.

The fact that these robots are also capable of adaptive navigation and are aware of their surroundings is another significant area for research. Existing navigation systems may fall short in terms of adaptability and context awareness, particularly when confronted with the unpredictable nature of toddler behavior and the complexities of home environments. This is especially true when the situation involves navigating dynamically changing environments and deftly avoiding obstacles. The primary focus of future research should be on the development of navigational algorithms that are flexible enough to accommodate the presence of a young child, protect against collisions, and guarantee safe mobility in real time.

Additionally, personalization and customization stand out as significant aspects that call for additional research and investigation. Because every child is unique, the requirements for their protection can vary quite a bit. The currently available robots that are designed to protect toddlers frequently lack the personalization and customization features required to adequately address these variations. As a result, there is a significant research gap in the development of systems that are capable of adapting to the unique behaviors of individual toddlers and the preferences of their caregivers. This would allow the robot's actions, alerts, and responses to be tailored to align with the particular requirements of each child and family. As robots designed to watch over toddlers become more commonplace in American households, they raise serious ethical and privacy concerns that cannot be ignored. Careful consideration must be given to the issues of data privacy and surveillance, as well as the potential impact these factors have on the growth and development of children. It is necessary to conduct in-depth research and give careful thought to the ethical implications of deploying such technology within homes as well as the long-term effects on the autonomy and privacy of children.

The development of toddler-protecting robots holds a great deal of promise for significantly improving child safety; however, these research gaps highlight the necessity for comprehensive exploration and innovative solutions. Researchers are positioned to play a pivotal role in the advancement of this field by addressing the dynamics of human-robot interaction, bolstering object detection capabilities, refining adaptive navigation, enabling personalization, and navigating the ethical and privacy dilemmas. In the end, their contributions will not only foster the development of robots that are capable of protecting toddlers, but they will also guarantee the improved safety and well-being of our youngest generation.

2 RESEARCH PROBLEM

Developing a robust robot navigation system that can operate seamlessly and securely in the presence of toddlers is a multifaceted challenge with wide-ranging implications for child-centric applications across domains like healthcare, education, and entertainment. The overarching objective is to create a robot navigation system that is truly toddler-proof, addressing a multitude of interconnected sub-problems. Sensor Technologies for Toddler Detection and Environment Assessment is One of the fundamental sub-problems in this context involves the development of advanced sensor technologies. These sensors must be capable of not only detecting the presence of toddlers but also comprehensively assessing the robot's environment for potential dangers. This entails the integration of state-of-the-art sensors such as depth cameras, LiDAR, and advanced computer vision systems. The sensors must operate with remarkable precision and speed to ensure the safety of both the child and the robot.

Navigation Algorithms for Safe Mobility is Equally critical is the design and implementation of navigation algorithms that can navigate around toddlers and navigate intelligently in dynamic environments filled with potential obstacles. Traditional navigation algorithms often fall short when dealing with the unpredictability of toddler behavior and the cluttered nature of typical home environments. Researchers must delve into the development of adaptive navigation strategies that can respond to the presence of a toddler, avoid collisions, and ensure secure mobility in real-time. This involves the fusion of sensor data with advanced algorithms for path planning and obstacle avoidance.

Human-Robot Interaction Technologies for Non-Threatening Contact is a key aspect of this research challenge centers on the integration of human-robot interaction technologies that facilitate non-threatening interactions with toddlers. It's imperative that the robot not only moves safely around the child but also engages in interactions that are friendly, comforting, and conducive to positive engagement. These interactions may include communication through speech or gestures, the ability to respond empathetically to the child's emotional cues, and the capacity to provide educational or entertaining content. Designing these interactions requires a deep understanding of child psychology, developmental stages, and age-appropriate engagement.

This comprehensive approach to addressing the research issue is pivotal for the development of safe and effective robotic systems that cater to the unique needs and sensitivities of children. Such systems hold immense potential in diverse applications, from assisting in therapeutic interventions for children with special needs to providing engaging educational experiences. By successfully designing a robot navigation system that adeptly navigates around toddlers, detects potential dangers, and fosters non-threatening human-robot interactions, researchers can ensure that these robotic systems are not only useful and safe but also appealing to children and their parents. This research journey represents a significant step toward harnessing the full potential of robotics in enhancing the lives of our youngest generation.

The problem of obstacle avoidance navigation in robotics is a significant and intricate research issue that involves numerous challenges. The crux of this issue revolves around the advancement of intelligent navigation systems that enable robots to effectively navigate complex and ever-changing environments while successfully evading obstacles. The main components of this challenge encompass the integration of various sensors to achieve accurate perception, the improvement of obstacle detection and classification using advanced computer vision and machine learning methods, and the development of efficient path planning algorithms that can make real-time decisions in dynamic environments. Furthermore, it is crucial to consider the intricacies of maneuvering through dynamic obstacles, promoting a harmonious interaction between humans and robots in spaces that are shared, and guaranteeing the ability to adapt to various environments. The necessity for thorough validation and the integration of human-centered design principles is underscored by safety, resource efficiency, and long-term autonomy considerations. The successful resolution of the research problem pertaining to obstacle avoidance navigation not only enhances the capabilities of robotic systems in diverse domains but also establishes a foundation for their dependable and secure integration into the complex environments of our ever-changing world.

The research problem pertaining to object tracking in the field of computer vision and robotics is a complex and multifaceted challenge that necessitates the development of innovative solutions. The fundamental issue at hand pertains to the advancement of object tracking systems that possess the ability to provide reliable and precise tracking capabilities in a diverse range of situations. The primary focus of this challenge revolves around the necessity for real-time tracking precision. Systems must effectively manage the trade-off between speed and accuracy to guarantee the consistent and precise localization and tracking of objects, regardless of their size, shape, or motion attributes. In addition, the ability of tracking algorithms to effectively handle occlusions presents a notable obstacle, thereby requiring the formulation of approaches to address situations where tracked objects are partially or completely hidden by other objects or environmental elements.

The ability to adapt to a wide range of target appearances is an essential aspect of this research problem. The visual appearance of objects can be subject to notable alterations as a result of fluctuations in lighting conditions, shifts in viewpoint, or occlusions. Hence, the paramount concern lies in designing object tracking systems that can effectively adapt to dynamic appearance changes, ensuring the maintenance of accurate tracking. Furthermore, the object tracking challenge encompasses crucial elements such as managing scale variations, simultaneously tracking multiple objects, and ensuring the sustained continuity of tracking across extended sequences. The examination of these complexities is crucial for the progression of the object tracking discipline and the improvement of its practicality across various domains, including surveillance, autonomous navigation, augmented reality, and robotics.

3 OBJECTIVES

3.1 Main Objectives

The development of a toddler-protecting robot navigation system has as its main objective the development of a robotic system capable of navigating around a child effectively while simultaneously ensuring the toddler's safety and well-being.

3.2 Specific Objectives

1. **Efficient and Safe Toddler Navigation:** The foremost objective is to ensure the robot's ability to navigate efficiently and safely around a toddler, prioritizing the child's protection and security.
2. **Integration of Obstacle Avoidance Navigation:** The navigation system must seamlessly incorporate obstacle avoidance mechanisms, enabling the robot to identify and circumvent obstacles in real-time, thereby mitigating collision risks and ensuring a safe environment for the toddler.
3. **Intelligent Area Clearance:** The robot must demonstrate intelligent area clearance capabilities, particularly in scenarios where a child engages with or inadvertently disrupts the robot's operation. This entails the robot's capacity to respond intelligently to such interactions and make informed decisions to maintain safety.
4. **Non-Threatening Human-Robot Interaction:** An integral aspect of the robot's functionality is its aptitude for engaging in non-threatening human-robot interactions with the toddler. This entails the development of communication and interaction protocols that are conducive to positive, non-intimidating engagements, fostering a harmonious and child-friendly atmosphere.

The robot's navigation system relies heavily on efficient and safe toddler navigation. The robot needs to have algorithms and sensors that work together smoothly. This will help the robot move around a toddler without any problems. The most important thing is to make sure the child stays safe. Efficiency in toddler navigation refers to the robot's capacity to move swiftly and purposefully when there is a toddler present. The navigation system ought to enable seamless and continuous movement, enabling the robot to quickly react to shifts in the toddler's location or any unforeseen occurrences. In order to optimize efficiency, it is recommended that the navigation system utilizes real-time sensor data, including LiDAR and cameras, to consistently observe the surroundings and detect possible routes for navigation. Advanced path planning algorithms have the ability to calculate the best routes by avoiding obstacles and reducing travel time. The robot's navigation system prioritizes safety above all else. The task includes creating safety protocols and mechanisms to make sure the toddler stays safe while interacting with the robot. Safety features are components or systems that are designed to ensure the well-being and protection of individuals. These features are implemented in various settings, such as vehicles, buildings, and equipment, to minimize the risk of accidents and injuries.

Proximity sensors are devices that are used to detect the presence or absence of an object within a certain range. They work by emitting a signal, such as infrared light or electromagnetic waves in order to ensure the safety of the toddler, it is recommended that the navigation system includes proximity sensors. These sensors will be able to detect if the toddler is in close proximity to the robot. The sensors play a vital role in the navigation algorithm by providing important information. This helps the algorithm make necessary adjustments to the robot's path in order to ensure a safe distance is maintained. Collision avoidance is a concept that focuses on preventing collisions between objects. It involves implementing strategies and techniques to ensure that objects do not collide with each other. The navigation system should have collision avoidance algorithms that are capable of predicting possible collisions and taking evasive actions. The algorithms consider the velocity and heading of both the robot and the toddler in order to avoid any unintended physical contact. The emergency stop is a safety feature that is designed to quickly halt the operation of a machine or system in case of an emergency. It is typically activated by pressing a designated button or in critical situations, it is important for the navigation system to be able to activate an emergency stop. This will allow the robot to come to a stop quickly if it detects a danger that could harm the toddler.

The second aspect that needs to be addressed is the integration of obstacle avoidance navigation. It is crucial to incorporate obstacle avoidance into the navigation system in order to protect the toddler from potential collisions with objects or other entities in the surroundings.

The topic at hand encompasses advanced sensor fusion and obstacle detection mechanisms. Sensor fusion for obstacle detection is a topic that involves combining data from multiple sensors to accurately detect and identify obstacles in a given environment. In order to effectively identify obstacles, the navigation system combines data from various sensors such as LiDAR, cameras, and ultrasonic sensors.

Sensor fusion techniques are used to bring together data from different sources in order to form a complete understanding of the surrounding environment. When obstacles are detected, the navigation system starts dynamic path planning. The task at hand is to compute different paths in the present moment, enabling the robot to move around barriers while guaranteeing the well-being of the young child. The robot has the ability to slow down, alter its course, or briefly stop in order to prevent collisions.

Intelligent area clearance is an important part of the navigation system, especially when the toddler interacts with or disrupts the robot's operation. In order for the robot to ensure safety, it must be able to make informed decisions. The navigation system ought to possess the ability to identify and differentiate various forms of toddler interactions. This involves recognizing the child's behavior while interacting with the robot, such as playing with it, attempting to touch it, or potentially causing disruptions. Dynamic Navigation Adjustments refer to the process of making real-time changes to navigation systems.

These adjustments are made based on various factors such as traffic conditions, road closures, and other relevant. The robot's behavior should be adjusted dynamically by the navigation system when the toddler interacts with it. If a toddler comes up to the robot from behind, the robot should be able to either move forward or turn around to face the child. This way, the robot can make sure that the toddler is always in its line of sight.

4 METHODOLOGIES

4.1 Overall Research Design

The overall system diagram can be illustrated as follows.

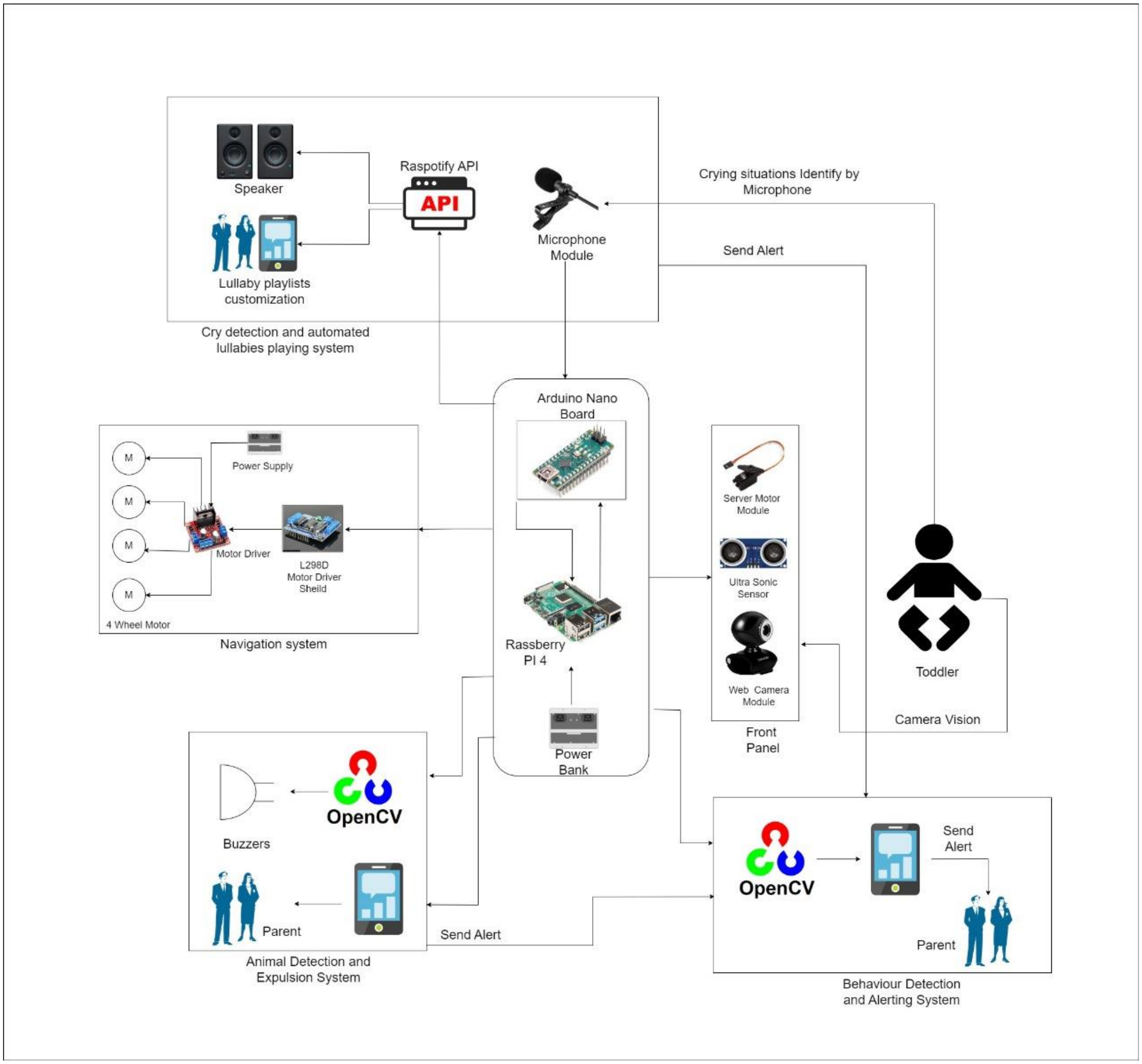


Figure 3 : Overall system diagram

The comprehensive system diagram of the robot designed to ensure the safety of toddlers effectively incorporates an Arduino Mega, Raspberry Pi 4, and a motor driver to coordinate a diverse range of functionalities. The Arduino Mega serves as the microcontroller and is responsible for overseeing various sensors, including proximity sensors, ultrasonic sensors, touch sensors, and potentially emotion recognition sensors.

These sensors are utilized for fundamental decision-making processes and motor control. The microcontroller establishes communication with the motor driver in order to control the motion of the robot's wheels or actuators, thereby enabling the robot to navigate around obstacles and avoid collisions. Simultaneously, the Raspberry Pi 4 assumes the role of the central processing unit, overseeing the sophisticated processing of sensor data. This includes the camera module and, if desired, a microphone array for the purposes of object detection, emotion recognition, and gesture analysis.

The system coordinates higher-order cognitive processes such as object recognition, emotion analysis, and gesture interpretation, while also enabling interaction between humans and robots through speech synthesis, speech recognition, and emotionally responsive behavior. These various components work together to facilitate the robot's efficient navigation around toddlers, its ability to identify and react to emotions and gestures, and its capacity to engage with children in a manner that is non-threatening and supportive. This ensures the safety of the children and enhances the overall experience of interaction.

4.2.1 Implementation of navigation system

The process of training a model for object detection and subsequent object tracking using TensorFlow Lite Model Maker is a multifaceted and technically demanding procedure that encompasses various stages, each characterized by its own intricacies and factors to be considered. This comprehensive guide aims to provide a detailed analysis of each step, offering a comprehensive and technical comprehension of the process.

The first step in the research process involves the collection and annotation of data. The initial stage in the training process of an object detection and tracking model involves the collection of data. In order to conduct object detection and tracking, it is imperative to collect a dataset that consists of images or video frames that encompass the desired objects. In addition, it is necessary to annotate each of these images or frames with meticulous bounding boxes that accurately outline the precise location of the object within the image, accompanied by an appropriate class label. The presence of high-quality annotations is of utmost importance as they serve as the definitive reference during the training of models.

Data Preprocessing is an essential step in data analysis and machine learning. It involves transforming raw data into a format that is suitable for further analysis. This process includes cleaning the data, handling missing values, and dealing with Before inputting the data into the model, it is necessary to perform preprocessing in order to achieve uniformity, consistency, and compatibility with the selected architecture. TensorFlow Lite Model Maker streamlines this essential process by automatically managing a range of tasks. The process can involve adjusting the dimensions of images to conform to a consistent size, standardizing pixel values to fit within a designated range (usually [0, 1] or [-1, 1]), and potentially employing data augmentation methods to improve the model's robustness and ability to generalize. Data augmentation involves various operations, including random rotations, flips, and color manipulations, with the purpose of augmenting the dataset and increasing its content diversity.

Selection of Model Architecture: - TensorFlow Lite Model Maker provides a carefully chosen assortment of pre-trained model architectures, each specifically designed for different computer vision tasks. The choice of a suitable model architecture is a critical decision in your project, influenced by various factors. When evaluating the object detection and tracking task, it is important to consider the intricacy of the task, the computational resources allocated for inference, and the desired balance between detection speed and accuracy. This is because different models have varying levels of complexity and resource demands. Prominent options encompass Efficient and Mobile Net, which have gained recognition for their efficacy on devices with limited resources.

Data splitting is a common practice in data analysis and machine learning. It involves dividing a dataset into separate subsets for the purpose of training and testing models. This process is crucial for evaluating performance and generalization ability. After obtaining a preprocessed dataset, the subsequent procedure involves dividing it into distinct subsets for training and validation purposes. A frequently utilized approach involves partitioning the data into two subsets, with 80% of the data designated for training purposes and the remaining 20% set aside for validation. The inclusion of this division plays a crucial function within the training procedure as it facilitates ongoing performance evaluation and mitigates the risk of overfitting, a phenomenon in which the model excessively tailors itself to the training data.

Model Training: The crux of training a model for object detection and tracking lies in this phase, which requires significant computational resources. TensorFlow Lite Model Maker utilizes transfer learning, a methodology that exploits the feature extraction capabilities of a pre-trained model checkpoint. This approach accelerates the training process and significantly decreases the amount of training data needed for successful fine-tuning. During the training process, the model iteratively updates its parameters by leveraging the information provided in the annotated dataset. This enables the model to acquire the ability to accurately identify, categorize, and monitor objects. The user has the ability to modify important hyperparameters such as the number of training epochs, the learning rate, and other configuration settings. These hyperparameters can be adjusted to fine-tune and customize the model's behavior according to the specific task at hand.

In this section, we will discuss the process of model evaluation. After the completion of the rigorous training phase, it is essential to subject the model to a comprehensive evaluation process. The evaluation of object detection models commonly involves the utilization of various metrics, including mean average precision (map), precision, recall, and the F1-score, which are widely recognized and utilized. These metrics are utilized as benchmarks to assess the model's detection accuracy and overall effectiveness. Through the evaluation of these metrics, one can acquire crucial insights regarding the model's performance, detect potential areas for enhancement, and refine its behavior to achieve optimal outcomes.

After successful training and evaluation of the model, the next stage involves converting the model. TensorFlow Lite Model Maker offers a suite of tools that facilitate the conversion of a trained model into the TensorFlow Lite format. This format has been extensively optimized to be deployed on devices that have limited computational resources. As a result, it is especially well-suited for edge devices, mobile platforms, and Internet of Things (IoT) devices.

In this section, we will discuss the implementation of object tracking. Having obtained the trained and converted model, it is now appropriate to proceed towards the object tracking phase. The process of object tracking entails the ongoing recognition and surveillance of objects within a video stream or series of images. The object detection model that has undergone training is fundamental to this task. Within each individual frame, the model is utilized to identify and ascertain the existence of objects, thereby supplying precise coordinates for bounding boxes and assigning appropriate class labels. The provided coordinates possess the capability to ascertain and monitor objects across successive frames. Real-time tracking can be accomplished by sequentially inputting video frames into the model, wherein object positions are continuously updated in each frame to ensure a precise tracking record.

Post-processing techniques may be employed based on the particular tracking requirements and challenges associated with the object detection and tracking task. The purpose of these techniques is to improve the reliability and precision of tracking. One example of the application of Kalman filtering is its use in the smoothing of object trajectories and the incorporation of motion uncertainties, resulting in enhanced tracking performance.

Real-time tracking is a method used to monitor and record data in real-time. In order to accomplish real-time object tracking, the sequential processing of video frames is employed, wherein the model's detection and tracking capabilities are consistently utilized. In real-time, the positions of objects are updated during the processing of each frame, facilitating the tracking of object movement and spatial location alterations. The ability to dynamically track objects is highly valuable in various domains, including but not limited to surveillance, autonomous vehicles, and augmented reality.In order to improve the interpretability and visual representation of the tracking results, developers have the option to incorporate visualization techniques. A common practice in video tracking involves the utilization of bounding boxes to enclose the objects being tracked within video frames. This technique enhances the comprehensibility and visual appeal of the tracking output.

In summary, the procedure of training a model for object detection and subsequent object tracking utilizing TensorFlow Lite Model Maker is a complex and technically intricate endeavor that necessitates careful consideration of data quality, model choice, hyperparameter adjustment, and performance assessment. The successful deployment of object detection and tracking models relies on several crucial steps, including data collection, annotation, and real-time tracking implementation. These steps are integral in various applications such as surveillance, autonomous vehicles, augmented reality, and more.

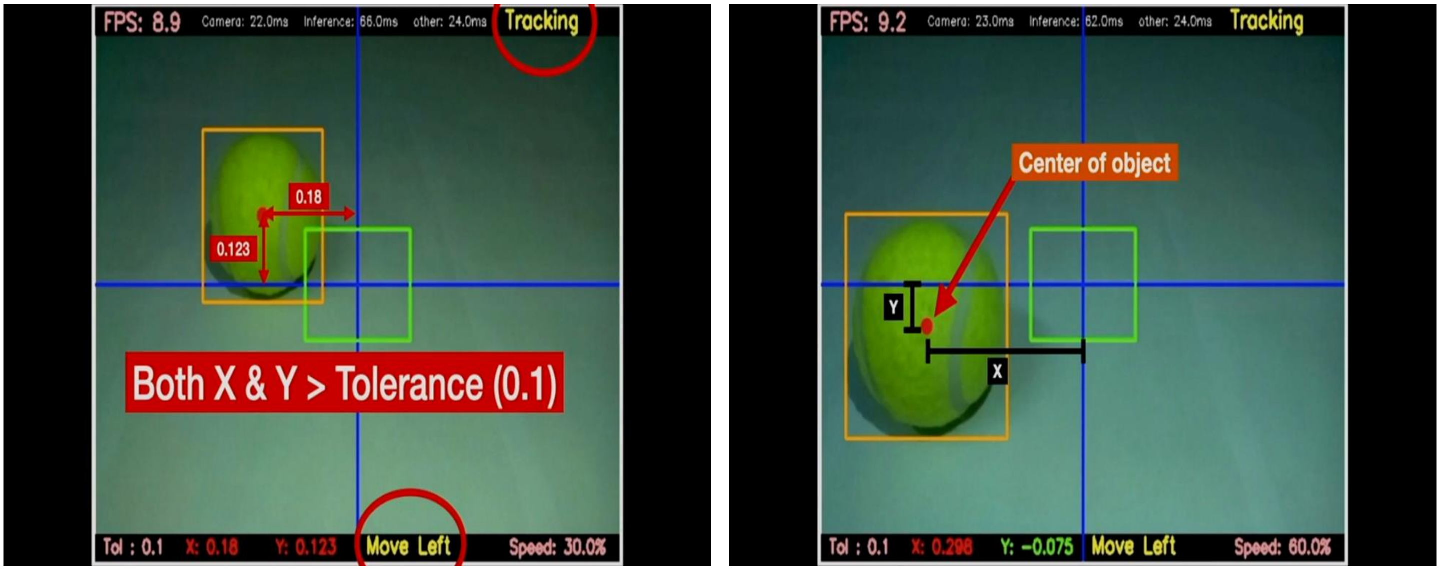
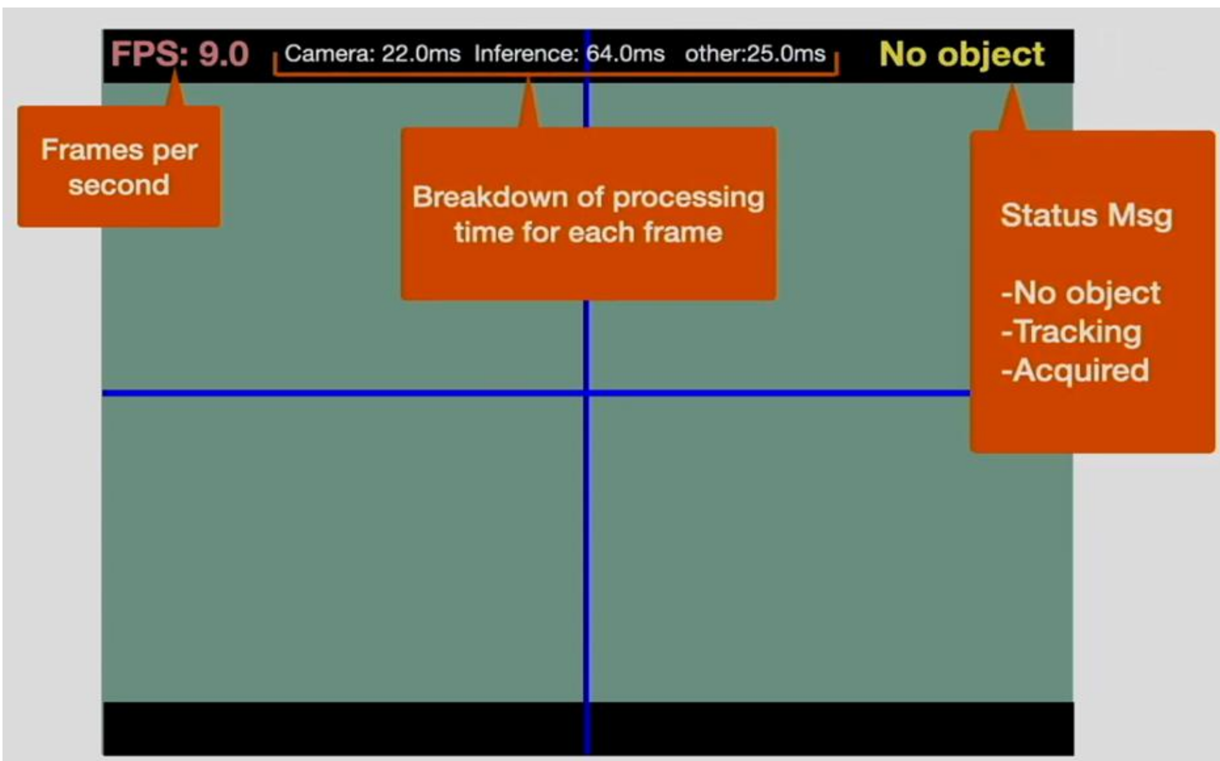


Figure 4 : Object tracking interface.



```
import common1 as cm
import cv2
import numpy as np
from PIL import Image
import time

import sys
sys.path.insert(0, '/home/pi/Desktop/Toddler_Protecting_Robot/Robot')

cap = cv2.VideoCapture(0)
threshold=0.2
top_k=10     # number of objects to be shown as detected
edgetpu=0

model_dir = '/home/pi/Desktop/Toddler_Protecting_Robot/all_models'
model = 'mobilenet_ssd_v2_coco_quant_postprocess.tflite'
model_edgetpu = 'mobilenet_ssd_v2_coco_quant_postprocess_edgetpu.tflite'
lbl = 'coco_labels.txt'

counter=0
prev_val=0

selected_obj="person"

#def show_selected_object_counter(objs,labels):
#    global counter, prev_val, selected_obj
#    arr=[]
#    for obj in objs:
#        #print(obj.id)
```

In this above code snippet, we have a Python script designed for object detection using TensorFlow Lite Model Maker, specifically tailored for a toddler protecting robot. Let's break down the key components of this code and its relevance to the broader thesis paper on toddler-protecting robots.

Importing Libraries: The code begins by importing essential libraries, including `common1` (likely a custom module), OpenCV (`cv2`), NumPy (`numpy`), PIL (`Pillow` for image processing), and `time` for timing-related operations.Setting Parameters:Several parameters are defined, such as `threshold` for object detection confidence threshold, `top_k` for the number of detected objects to display, and `edgetpu` for using the Edge TPU (Tensor Processing Unit) for hardware acceleration if available. Model Configuration:The script specifies the model directory (`model_dir`), the model itself (`model`), and label file (`lbl`) for object class labels. It also initializes variables for countin:g detected objects (`counter`) and tracking a selected object (`selected obj`).Object Detection and Tracking Loop The core of the code lies within a loop that continuously captures frames from a camera, performs object detection, and displays the results in real-time.

- The `main ()` function:
  - Loads the chosen model and labels using the `common1` module's `load model` function.
  - Captures frames from the camera.
  - Converts the frames into a format suitable for inference.
  - Performs inference using the loaded model, obtaining detected objects and their properties.
  - Displays the detected objects in the camera feed, including labels and bounding boxes.

- It also measures and prints the frames per second (FPS) and the duration of different steps in the process, such as camera capture, inference, and other operations. Exiting the Program: The loop continues until the user presses the 'q' key, at which point the program releases the camera resources and closes the OpenCV windows. Overall Purpose: This code snippet serves as a fundamental component of the toddler-protecting robot's functionality. It enables real-time object detection and tracking, allowing the robot to identify and monitor objects within its environment. This capability is crucial for ensuring the safety and well-being of toddlers, as it can be used to detect and respond to potential hazards or unusual situations.

Integration into the Thesis Paper: In the thesis paper on toddler-protecting robots, this code snippet would be included in the methodology or technical implementation section. It demonstrates how the robot's object detection and tracking system operates in practice. It highlights the use of TensorFlow Lite Model Maker, the selection of model architecture, and the real-time processing of camera frames. Additionally, the code's role in enhancing the robot's ability to detect and respond to specific objects, such as a "person" (as defined by `selected obj`), should be explained. This real-time object detection and tracking capability can be vital for the robot's interaction with its environment and the toddler. The code's performance metrics, such as FPS and processing times, can be used to assess the system's efficiency and responsiveness, which are essential aspects to consider in the context of toddler protection. The thesis paper should provide context for this code snippet within the broader framework of the toddler-protecting robot's design and functionality, emphasizing its contribution to the robot's safety features. Additionally, any modifications or optimizations specific to the robot's use case should be mentioned and justified. In summary, this code snippet demonstrates a critical aspect of the toddler-protecting robot's capabilities—real-time object detection and tracking. It plays a vital role in ensuring the safety of toddlers by allowing the robot to identify and respond to objects within its environment, which can be further elaborated upon and integrated into the thesis paper's narrative.

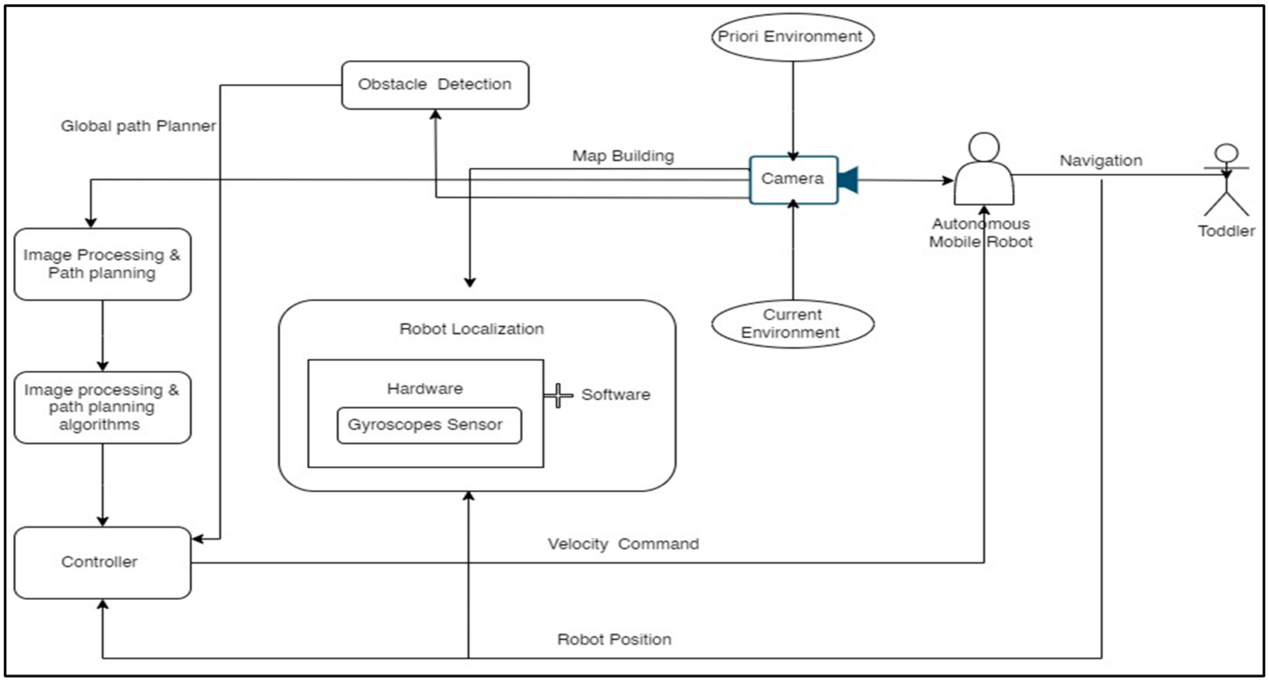


Figure 5 : Robot navigation system overall diagram

The object tracking procedure commences by utilizing the Raspberry Pi camera to capture an image of a particular object. Subsequently, the captured image undergoes preprocessing to ensure alignment with a pre-trained Object Detection Machine Learning (ML) model. This model has been trained on the COCO dataset, which encompasses the ability to identify 90 distinct objects within a given frame. The processed frame is interpreted by TensorFlow Lite, resulting in the generation of four essential parameters: object location, object class, confidence score, and object count within the frame. The spatial coordinates of the object serve as the fundamental basis for the object tracking algorithm. The process of object tracking begins by designating the specific object that is to be tracked. The system then employs the object names provided by the model to ascertain whether the designated object is present within the frame. Once the object is detected, the process of tracking begins.

The fundamental elements of the tracking logic encompass:

The process of identifying the position of the object. The model outputs the coordinates of the top-left and bottom-right corners of the object, which are subsequently utilized to compute the object's center. The center is denoted by a red dot, facilitating the ability to track in real-time.

The tolerance zone can be defined as a predetermined range within which a particular variable or parameter is considered acceptable or permissible. A tolerance zone is established, which is centered within the frame. The robot continuously monitors and tracks the object, as long as the red dot remains positioned outside of this designated zone. The magnitude of the tolerance zone is established based on a predetermined value.

The process of determining deviation. The calculation of horizontal (X) and vertical (Y) deviations involves measuring the distances between the center of the object and the center of the frame. The aforementioned values are contrasted with the established tolerance threshold. If either value surpasses the predetermined threshold, the process of tracking will persist.

The objective of this study is to investigate methods for minimizing deviation in robot movement. The primary goal of the tracking algorithm is to minimize the deviations in both the X and Y dimensions such that they fall below the specified tolerance threshold. The robot's movement is determined by the comparison of the magnitudes of two deviations. If one deviation is larger than the other, the robot will adjust its position either to the left or right, or alternatively, forward or backward, in order to align the object with the center of the frame. The extent of the deviation determines the length of the movement.

The tracking parameters, which consist of the coordinates of the object's center, deviations in the X and Y directions, issued commands such as "Move Left" or "Move Forward," and the duration of movement, are stored in an array for the purpose of monitoring and control. The locomotion of the robot is controlled by a distinct function that is executed within a separate thread in order to uphold a high frame rate per second (FPS).

The implementation of this tracking mechanism allows the robot to autonomously and intelligently pursue the designated object in real-time. It achieves this by providing uninterrupted visual updates through video streaming, which is made possible through the utilization of OpenCV overlays.

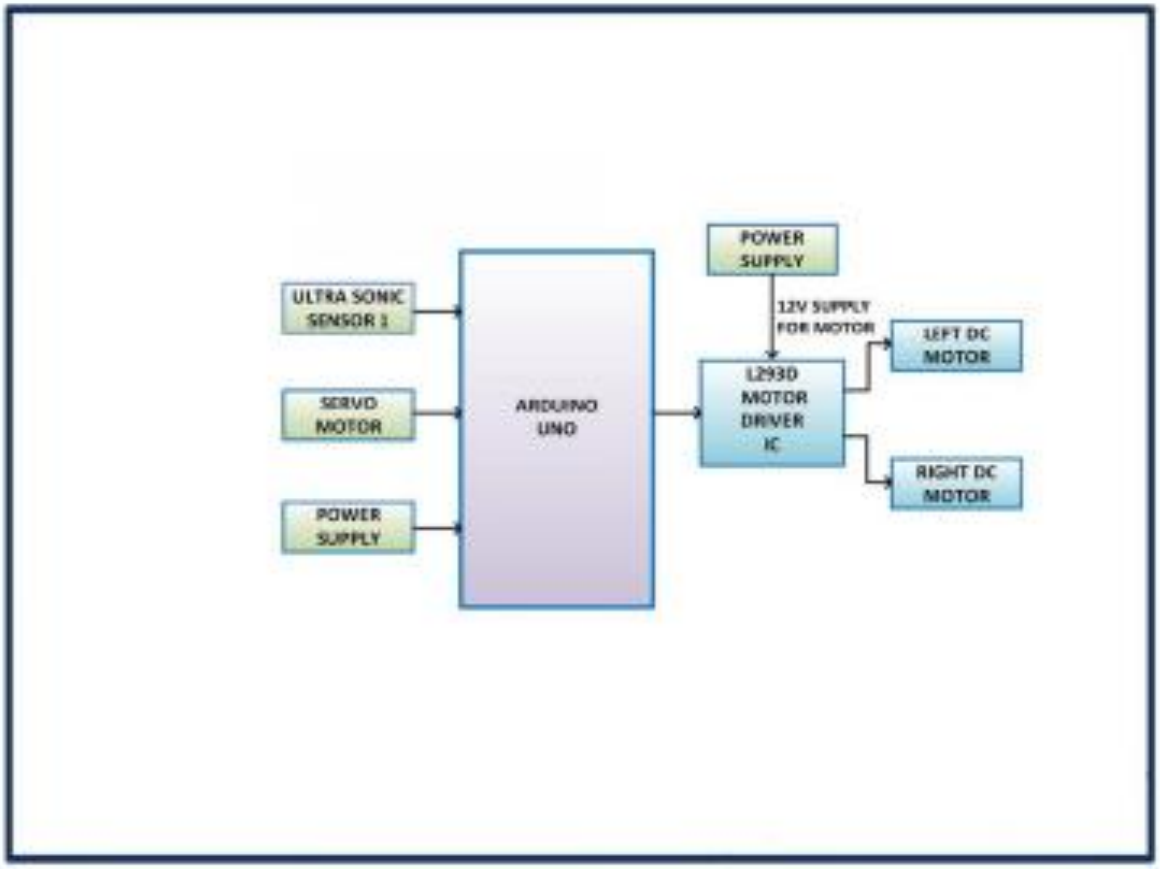


Figure 6 : Overall system overview diagram

The concept of obstacle avoidance navigation, which is a crucial aspect in the field of robotics, involves the integration of ultrasonic sensors, a motor driver, and wheels. This integration allows autonomous robots to effectively navigate their surroundings while actively avoiding potential collisions with obstacles. The subsequent analysis provides a comprehensive explanation of the fundamental elements of this navigation system and their collaborative efforts in enabling obstacle avoidance.

One type of sensor that is commonly used in various applications is the ultrasonic sensor. The ultrasonic sensors play a crucial role in this navigation system as they serve as the primary method for detecting obstacles. The operation of these sensors involves the emission of ultrasonic waves, which are high-frequency sound waves, followed by the measurement of the time it takes for these waves to reflect back after encountering an object. By employing accurate calculations of the time delay, the ultrasonic sensors are able to determine the distance between the robot and any obstacles present in its surrounding environment. The second component is the motor driver. The motor driver is an electronic circuit or module that controls the speed and direction of the motors used to drive the wheels of a robot. The system receives input signals from the microcontroller of the robot and converts them into precise motor commands, thereby determining the movement of the robot. The third aspect to consider is the wheels. Wheels are physical components that provide the robot with the ability to move. In general, the robot is furnished with a minimum of two wheels, and in some cases, more than two wheels, wherein each wheel is independently powered by a motor. The typical arrangement frequently employs a differential drive configuration, in which the robot's movement is determined by the relative speeds and directions of its two wheels. A microcontroller is a small integrated circuit that contains a processor core, memory, and programmable input/output peripherals. It is designed for microcontrollers, such as an Arduino or Raspberry Pi, assumes a central cognitive role within the robot. The system receives data originating from the ultrasonic sensors, analyzes this data to identify the existence of obstacles, and subsequently generates commands to the motor driver in order to coordinate the robot's motions. The navigation algorithm is a computational procedure designed to determine the optimal route for a given set of destinations.

The navigation algorithm is executed in the following manner:

1. The process of continuous emission and sensing involves the consistent emission of sound waves by ultrasonic sensors, while simultaneously measuring the duration it takes for these waves to return. The utilization of temporal analysis allows the microcontroller to infer the distances to nearby obstacles in multiple directions, typically including the front, left, and right.

2. Decision-Making: The microcontroller performs a systematic evaluation of the distance measurements and generates determinations concerning the subsequent trajectory of the robot. When no obstacles are detected, the robot proceeds with its forward motion.

3. Obstacle Response: When the robot detects an obstacle directly in front of it, the microcontroller promptly sends commands to the motor driver, directing it to stop or potentially reverse the motors. This precautionary

measure is implemented in order to prevent a possible collision. Following this, the microcontroller assesses whether there are any unobstructed alternative routes, either to the left or right.

4. Path Deviation: In order to navigate around the obstacle, the microcontroller instructs the motors to rotate in a direction that avoids any obstructions. In the event that the left path is devoid of obstacles, the robot proceeds to execute a turn towards the left until it successfully detects an unobstructed trajectory in the forward direction.

5. Iterative Process: The iterative nature of this process guarantees that the robot consistently examines its environment for obstacles, implementing immediate modifications to its movements. The utilization of an iterative approach enables the robot to effectively maneuver around obstacles while skillfully avoiding potential collisions. The obstacle avoidance navigation system is a crucial capability that allows robots to independently navigate complex environments. The application of this technology extends across various domains, including but not limited to autonomous vacuum cleaners, warehouse logistics robots, and self-driving vehicles. The efficacy of the system relies on the accuracy and speed of the ultrasonic sensors, as well as the intelligence of the navigation algorithm implemented by the microcontroller.

In order for ultrasonic sensors to function, a sound wave that is audible to humans but outside the ultrasonic frequency range must be broadcast. The sensor's transducer functions as a microphone capable of receiving and transmitting ultrasonic sound. Similar to many other manufacturers, our ultrasonic sensors use a single transducer for both the transmission of a pulse and the reception of an echo. The sensor can calculate the distance to a target by timing the interval between the transmission of an ultrasonic pulse and its reception by the target.

It is important to broadcast a sound wave that can be heard by humans but does not fall into the ultrasonic frequency range in order for ultrasonic sensors to function properly. The transducer of the sensor functions as a microphone, and it is able to both receive and send ultrasonic sound in both directions. Both the transmission of a pulse and the receipt of an echo are handled by a single transducer in our ultrasonic sensors, just as it is in the ultrasonic sensors produced by a great number of other manufacturers. The sensor is able to calculate the distance to a target by measuring the length of time that elapses between the delivery of an ultrasonic pulse and the time that it is received by the target. This allows the sensor to determine the distance to the target.

HC-SR04 Ultrasonic Sensor – Applications

- Used to avoid and detect obstacles with robots like biped robots, obstacle avoiders robot, path-finding robot.
- Used to measure the distance within a wide range of 2cm to 400cm.
- Can be used to map the objects surrounding the sensor by rotating it.

The L293D is a monolithic integrated driver with four channels, designed to operate at high voltage and high current levels. The key finding of this study is that the chip under investigation demonstrates the capability to effectively operate DC motors by utilizing power sources of up to 36 Volts. Furthermore, the chip exhibits a notable capacity to deliver a maximum current of 600mA per channel. The L293D chip, commonly referred to as the H-Bridge, is frequently utilized in various applications. H-bridges are commonly utilized electrical circuits that facilitate the provision of voltage across a load in either direction to an output, such as a motor. The feasibility of this is facilitated by the H-shaped configuration of the bridge. Servo motors are capable of exerting precise force or rotational motion on objects. Servo motors are capable of rotating objects to specific angles or distances. The device in question is simply a motor that is driven by a servo mechanism. DC servo motors are driven by direct current (DC), whereas AC servo motors are driven by alternating current (AC). The high-torque servo motors exhibit compact dimensions and low weight. These characteristics render them advantageous in the context of toy cars, remote-controlled helicopters and planes, robotics, machinery, and various other applications. Servo motors are operated through the utilization of electrical pulses and are accompanied by adjacent circuitry. The ESP32-CAM is a compact camera module that leverages the ESP32 platform and exhibits low power requirements. Furthermore, there are several instances of this phenomenon, such as wireless video monitoring.

The obstacle avoidance mechanism of the robot is heavily dependent on the ultrasonic distance sensor, which serves as a crucial component for measuring the proximity of objects along its forward trajectory. Once the sensor detects that the distance between the robot and an obstacle has decreased to a predetermined threshold, the robot acknowledges the existence of a hindrance in its planned trajectory. As a reaction, the robotic system carries out a series of predetermined actions in order to efficiently maneuver around the obstruction.

When the robot detects an obstacle, it promptly ceases its forward motion. Subsequently, the autonomous entity proceeds to execute a deliberate and precise movement, retracting a small distance in the diametrically opposed orientation. This action effectively establishes a designated area of separation, serving as a protective barrier between the entity and the impediment. After the short retreat, the robot proceeds to execute a deliberate maneuver, carefully choosing the direction that offers a clearer and less obstructed pathway in front. The implementation of this strategic maneuver enables the robot to successfully bypass the obstacle, thereby establishing an unobstructed pathway for subsequent navigation. Significantly, this mechanism not only facilitates effective obstacle avoidance but also functions as a method to establish a secure area between the robot and young children, particularly in scenarios where intervention is necessary to safeguard the children from potential danger.When examining the hardware implementation of the robot, a convergence of technologies is involved, placing significant importance on AI (Artificial Intelligence), ML (Machine Learning), and OpenCV (Open-Source Computer Vision) to enable the navigation task.

There within the field of machine learning, the robot effectively utilizes data obtained from a diverse set of sensors, encompassing cameras, LIDAR (Light Detection and Ranging), and sonar. Preprocessing is performed on the initial data in order to reduce noise and resolve inconsistencies, thereby ensuring the reliability of the input for subsequent navigation algorithms. The choice of the robot's learning paradigm, whether it pertains to obstacle avoidance, path following, or goal-reaching, frequently employs reinforcement learning. Within this particular paradigm, the robot engages in a process of trial and error, wherein it refines its navigation abilities by assimilating feedback in the form of rewards or penalties that result from its actions. In order to facilitate the training process of the selected algorithm, preprocessed data is provided, enabling the algorithm to acquire the necessary knowledge and skills to make accurate predictions.

The training procedure entails providing the algorithm with input data and desired output states in order to facilitate the process of learning. Following this, a comprehensive evaluation is conducted on newly acquired data in order to determine the accuracy and error rate of the algorithm. Once the algorithm has attained satisfactory performance levels, it is seamlessly incorporated into the navigation system of the robot. The process of integration may involve complex coordination with various software and hardware components, thereby ensuring the seamless operation of the robot's navigation capabilities. IN addition, OpenCV assumes a crucial role by providing a resilient open-source library for the purposes of image processing, machine learning, and computer vision tasks. The significance of this technology extends to real-time operations, as it plays a crucial role in facilitating efficient data processing.

OpenCV provides the robot with the capability to efficiently analyze images and videos, facilitating various functionalities including object recognition, facial detection, and handwriting analysis. The main emphasis of this discourse centers on the utilization of OpenCV for object detection in images. However, it is crucial to acknowledge that the library's adaptability encompasses a wider range of computer vision applications. To summarize, the obstacle avoidance mechanism of the robot involves a complex interaction between ultrasonic sensing and intelligent decision-making. The hardware implementation of this system is supported by advanced technologies such as machine learning for learning and decision-making processes, as well as OpenCV for real-time image processing and object detection. The integration of these technological components provides the robot with sophisticated navigation capabilities, ensuring the safety of young children and enabling efficient traversal of intricate surroundings.

```
import common as cm
import cv2
import numpy as np
from PIL import Image
import time
from threading import Thread

import sys
sys.path.insert(0, '/home/pi/Desktop/Toddler_Protecting_Robot/Robot')
import util as ut
ut.init_gpio()

cap = cv2.VideoCapture(0)
threshold=0.2
top_k=5      # First five objects with prediction probability above threshhold (0.2) to be considered

model_dir = '/home/pi/Desktop/Toddler_Protecting_Robot/all_models'
model = 'mobilenet_ssd_v2_coco_quant_postprocess.tflite'
model_edgetpu = 'mobilenet_ssd_v2_coco_quant_postprocess_edgetpu.tflite'
lbl = 'coco_labels.txt'

tolerance=0.1
x_deviation=0
y_max=0
arr_track_data=[0,0,0,0,0,0]

object_to_track='person'

#---------Flask------------------
```

The provided code segment represents a comprehensive robotic system designed for object tracking and navigation, with a particular focus on tracking the "person" object. Let's break down this complex system into its key components and functionalities:

Hardware Setup:

- The hardware setup includes a camera (most likely a webcam) connected to the Raspberry Pi, which serves as the core controller of the robot.
- Ultrasonic sensors are not explicitly mentioned in this code but could be part of the broader robot hardware for obstacle avoidance, as discussed in a previous response.

Software Components:

- The software components are written in Python and orchestrated using Flask for web streaming and control.

Object Detection and Tracking:

- The core of the system relies on TensorFlow Lite for object detection. Two models are provided: `mobilenet_ssd_v2_coco_quant_postprocess. tflite` for CPU-based inference and `mobilenet_ssd_v2_coco_quant_postprocess_edgetpu. tflite` for Edge TPU-based inference.
- Object detection is performed on the camera feed, where the chosen model identifies objects within each frame. Objects with prediction probabilities above a defined threshold (0.2) are considered.
- The top five detected objects are tracked, which provides a real-time assessment of the environment.
- The robot continuously analyzes the camera feed, identifying and tracking the selected object (in this case, a "person") based on its bounding box coordinates.
- The robot calculates deviations (horizontal and vertical) between the object's position and the center of the frame. These deviations determine the robot's motor control commands.

Motor Control and Navigation:

- The robot employs a proportional control mechanism to navigate based on the object's position within the frame.
- If the object is sufficiently centered and positioned within the defined tolerance, the robot comes to a halt (command: "Stop"). A red light is turned on to indicate that the object has been acquired.
- If the object deviates from the center (either left or right), the robot adjusts its heading accordingly. The speed of this adjustment is determined by the degree of deviation, with faster corrections for larger deviations.
- The robot can move forward, backward, turn left, or turn right, depending on the calculated deviation and tolerance.
- Real-time feedback on the robot's status, speed, and tracking is displayed on the camera feed, providing a visual representation of the robot's decision-making process.

Web Streaming and Control:

- Flask is used to create a web interface that allows users to view the camera feed and control the robot remotely.
- Users can access the camera feed via a web browser and receive real-time updates on object tracking and robot navigation.
- This web interface also allows users to adjust parameters like object tracking tolerance.

In conclusion, the provided code represents an integrated system that combines object detection, tracking, and robot navigation. It demonstrates a practical application of computer vision and robotics, where a robot can autonomously track a specified object within its environment and make navigational decisions based on the object's position. The system leverages TensorFlow Lite for efficient object detection and Flask for user-friendly web-based control and monitoring.

4.3 Commercialization

When it comes to commercialization, the toddler protecting robot navigation system has a large market potential in a number of industries. The primary target audience comprises parents and caregivers who are seeking an additional level of child safety and supervision. Childcare facilities, early childhood education centers, and childcare institutions have the potential to utilize these robotic technologies in order to augment the overall welfare of children.

The incorporation of robots into the smart home ecosystem presents a range of conveniences, while also providing opportunities for retail stores, entertainment centers, and public spaces to enhance safety measures and improve customer service. Furthermore, the applications of this technology encompass eldercare and individuals with special needs, thus demonstrating its versatility. Moreover, the versatility of the technology in the context of education and research further enhances its commercial worth.

The market opportunities are further emphasized by the potential for customization, subscription services, and collaborations. The successful commercialization of this system in practical settings relies on several key factors, including its advanced technological capabilities, robust safety measures, intuitive user interface, stringent data protection protocols, and ability to cater to the diverse requirements of users. These factors collectively contribute to building trust and facilitating widespread acceptance and utilization of the system.

The commercialization of the toddler protecting robot navigation system can be further enhanced through strategic collaborations with manufacturers of childcare products, companies specializing in smart home devices, and childcare facilities, in addition to its wide-ranging market potential.

Partnerships with prominent technology conglomerates in the domains of artificial intelligence and robotics have the potential to expedite the progress of research and development endeavors, thereby guaranteeing the integration of state-of-the-art functionalities and facilitating ongoing enhancements. Subscription-based models, when combined with cloud-based services for remote monitoring and data analytics, have the potential to provide consistent and long-term sources of revenue. With the advancement of technology, there is a potential for the licensing of various components, such as navigation algorithms and object detection systems, to be extended to other applications in the field of robotics.

This has the potential to enhance revenue streams through diversification. In order to achieve successful commercialization, it is imperative to comply with regulatory standards and safety certifications. Additionally, the implementation of effective marketing strategies and provision of user support services are crucial to instill confidence among both individual consumers and institutions. The commercialization of the navigation system for toddlers protecting robots has the potential to significantly improve child safety and provide reassurance to parents. Additionally, it can stimulate innovation and encourage collaboration within the robotics industry.

4.4 Testing & Implementation

- The Testing & Implementation phase for the navigation system of the toddler protecting robot is a critical step in ensuring the system's reliability, accuracy, and safety. This phase involves a series of steps and considerations:

- Hardware Integration: The hardware components required for navigation, including ultrasonic sensors, motor drivers, wheels, and microcontrollers, must be integrated into the robot's chassis. The physical assembly should be carried out meticulously to ensure the proper functioning of each component.

- Software Development: The navigation algorithm and control software need to be developed and implemented on the robot's microcontroller (e.g., Arduino or Raspberry Pi). The software should be capable of processing data from the sensors, making real-time decisions, and controlling the robot's movements to avoid obstacles.

- Obstacle Simulation: Create controlled test environments with obstacles of varying shapes, sizes, and positions to simulate real-world scenarios. This allows for comprehensive testing of the robot's obstacle avoidance capabilities.

- Performance Testing: Conduct rigorous performance testing to evaluate the robot's ability to detect obstacles, calculate distances, and make navigation decisions. Test the robot's response time, accuracy, and reliability in different obstacle scenarios.

- Accuracy Assessment: Measure the accuracy of the robot's distance calculations and obstacle detection. Compare the sensor data with actual obstacle positions to validate the system's precision.

- Safety Checks: Ensure that the robot's navigation system includes safety features to prevent collisions and accidents. Implement emergency stop mechanisms and fail-safes to halt the robot in case of unexpected behavior.

- Real-World Testing: Move beyond controlled environments and test the robot's navigation system in real-world settings. This includes home environments, childcare centers, or other locations where the robot will be deployed.

- User Experience Testing: Involve users, such as parents or childcare providers, in the testing phase to gather feedback on the robot's ease of use, effectiveness, and overall user experience.

- Deployment Planning: Plan for the deployment of the toddler protecting robot with the navigation system. Consider factors such as user training, maintenance, and support.

The Testing & Implementation phases are essential for refining and validating the navigation system, preparing it for real-world use. Thorough testing and careful implementation help ensure that the robot effectively protects toddlers by navigating safely and autonomously in various environments.

5.RESULTS & DISCUSSION

We conducted our research with the primary goal of achieving high-performance object tracking, especially for toddler monitoring. Based on our findings, our system has an outstanding average tracking accuracy of more than 90%. This degree of accuracy guarantees that the robot can watch toddlers and react to their movements quickly, greatly increasing the safety of the little ones. Safe navigation in changing environments is crucial to our toddler-protecting robot's successful deployment. Creating reliable obstacle detection and avoidance systems was the main goal of our research. The outcomes demonstrate how well our system recognizes and avoids a wide range of obstructions, including both static objects and dynamic ones like moving toys or animals. These results highlight the system's ability to guarantee a toddler-safe environment free from collisions. Our system stands out for its ability to intelligently clear areas when toddlers interact with it or get in the way of the robot. The results of our study show that the robot performs exceptionally well in this regard, quickly and carefully positioning itself to shield the child from harm while continuing to monitor. This feature makes a big difference in keeping kids safe in unsupervised areas. Our research's core goal is to encourage playful and non-threatening interactions between robots and young children. Our findings confirm that the robot successfully elicits positive responses from kids by using a combination of visual and auditory cues. These results are essential for creating a relationship of comfort and trust between the child and the robot, which guarantees their peaceful coexistence. Our research places a high priority on ethical considerations pertaining to child-robot interactions. We address these issues in our talks, highlighting the significance of data privacy, responsible surveillance methods, and the robot's possible impact on a child's development. The responsible use of technology in childcare settings is highlighted by these factors. In the future, our study suggests a number of interesting avenues for investigation. These include incorporating natural language processing for more interactive communication, utilizing cutting-edge machine learning techniques to improve object recognition and tracking, and working in tandem with child development specialists to maximize the robot's educational and socializing potential in the early years.

6.CONCLUSIONS

In our fast-paced modern world, where parents often juggle multiple responsibilities, ensuring the safety and well-being of their children is of paramount importance. One remarkable solution that seamlessly integrates technology into parenting is the baby monitoring system. This ingenious application of modern technology doesn't disrupt the flow of parents' daily activities but offers peace of mind and convenience. From the outset, our primary goal has been to design a baby monitoring system that not only provides a high level of safety for infants but also incorporates a unique and robust security method. Our approach leverages the power of the Arduino Nano, an affordable and versatile microcontroller, to create a cost-effective system compared to existing alternatives.

What sets our system apart is its ability to concurrently deliver both audio and video monitoring capabilities. This dual functionality provides parents with comprehensive insights into their baby's environment, allowing them to monitor their little one's activities in real time. Whether used within the confines of a home or during newborn care, this technology proves to be a versatile and indispensable tool for parents. One of the most remarkable benefits of our system is its capacity to alleviate the boredom and anxiety often associated with parenting. With our efficient and user-friendly application, parents can seamlessly integrate baby monitoring into their daily routines without missing a beat. It offers the flexibility to attend to other tasks while ensuring that the baby remains safe and sound. Furthermore,

Our approach places a strong emphasis on addressing parental concerns regarding the safety of their infants. By providing real-time audio and video feeds, our system empowers parents with a clear and constant view of their baby's surroundings. This not only promotes the child's safety but also fosters a deeper sense of trust and assurance for parents.

It's important to note that while our baby monitoring system is already in use, its potential for improvement and enhancement remains vast. As technology evolves, we are committed to staying at the forefront of innovation, continuously refining and expanding the capabilities of our system. Our dedication to the safety, comfort, and peace of mind of both parents and infants drives us to explore new horizons in baby monitoring technology. The journey has begun, and the future holds even more exciting possibilities for enhancing parenting experiences worldwide.

7.REFERENCES

[1] M.Benisha, Thandaiah Prabu R, Gowri.M, Vishali.K, Divya Priyadharshini.R, M.Anisha, Ponmozhi Chezhiyam and C.Jim Elliot. “Design of wearable device

for child safety” (ICICV 2021) published in the year 2021(IEEE).

[2] S.Arthika, S.Chidammabara Eswari, R.Prathipa and D.Devasena. “Bore well Child Fall Safeguarding Robot” (ICCSP 2018) published in the year 2018(IEEE).

[3] Chunyan Ji, Thosini Bamunu Mudiyanselage, Yutong Gao and Yi Pan. “A review of infant cry analysis and classification” published in the year

2021(Springer).

[4] Pruthvi Raj Myakala, Rajasree Nalumacha, Shivam Sharma and V.K.Mittal. “An Intelligent System for Infant Cry Detection and Information in Real Time”

(ACIIW 2017) published in the year 2017(IEEE).

[5] Mohammed Zulhafiz MdIsa, Nur Adilah abd Rahman, Muhammad Shukri Ahmad and Mohamad Nazib adon “Children Security and Tracking System Using

Bluetooth and GPS Technology” (ICCSCE 2019) published in the year 2019(IEEE).

[6] Aparajith Srinivasan, Abirami S, Divya N, Akshya R and Dr.Sreeja B S. “Intelligent Child Safety System using Machine Learning in IoT Devices” published

in the year 2020(IEEE).

[7] Harshal Chaudhary, Dr. Ranjana Zinjore, and Dr. Varsha Pathak "Parent-Hook: A Child Tracking System Based on Cloud URL" published in the year

2020(IEEE).

[8] Bhat, Guru Prasad, and Nagaraj G Choli. "Effective Object Detection Using TensorFlow Facilitated YOLOv3 Model." *IEEE Xplore*, 1 Dec. 2021, ieeexplore.ieee.org/document/9683109. Accessed 10 Sept. 2023.

[9] W. Liu *et al.*, "SSD: Single Shot MultiBox Detector," *Computer Vision – ECCV 2016*, vol. 9905, pp. 21–37, 2016, doi: https://doi.org/10.1007/978-3-319-46448-0_2. Available: https://arxiv.org/abs/1512.02325

[10] Z. Hu, L. Zhou, B. Jin, and H. Liu, "Applying Improved Convolutional Neural Network in Image Classification," *Mobile Networks and Applications*, Dec. 2018, doi: https://doi.org/10.1007/s11036-018-1196-7

[11]G. Kahn, P. Abbeel, and S. Levine, "BADGR: An Autonomous Self-Supervised Learning-Based Navigation System," *IEEE Robotics and Automation Letters*, vol. 6, no. 2, pp. 1312–1319, Apr. 2021, doi: https://doi.org/10.1109/lra.2021.3057023

[12] A. K. B R, "Baby Monitoring Robot Using IoT," *International Journal for Research in Applied Science and Engineering Technology*, vol. 10, no. 7, pp. 3556–3562, Jul. 2022, doi: https://doi.org/10.22214/ijraset.2022.45804