CAMARINES SUR POLYTECHNIC COLLEGES
ISO 9001:2015 Certified

CAMARINES SUR POLYTECHNIC COLLEGES
COLLEGE *of* COMPUTER STUDIES

DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

A Thesis Project
presented to the Faculty of
College of Computer Studies
Camarines Sur Polytechnic Colleges

In Partial Fulfillment of the Requirements
for the degree Bachelor of Science in Computer Science

By
Gerald M. Carique
John Mark C. Ruam
Arnold Rie J. Sejera

December 2024

APPROVAL PAGE

In partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science, this research entitled **"DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION"** prepared and submitted by **Gerald M. Carique**, **John Mark C. Ruam** , **Arnold Rie J. Sejera** has been examined and is recommended for approval and acceptance.

IAN P. BENITEZ, DIT
Adviser

This research project entitled, **"DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION"**, in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science has been examined and is recommended for acceptance and approval for ORAL EXAMINATION.

RESEARCH COMMITTEE:

JOSEPH JESSIE S. OÑATE, MSc
Member

TIFFANY LYN O. PANDES, MSc
Member

KAELA MARIE N. FORTUNO, MIT
Chairman

PANEL OF EXAMINERS

APPROVED by the Committee on Oral Examination with a grade of **PASSED** on December 11, 2024.

KAELA MARIE N. FORTUNO, MIT
Chairman

JOSEPH JESSIE S. OÑATE, MSc
Member

TIFFANY LYN O. PANDES, MSc
Member

ACCEPTED and **APPROVED** in partial fulfillment of the requirements in Bachelor of Science in Computer Science with a grade of 2.2.

ROSEL O. ONESA, MIT

OIC Dean, Camarines Sur Polytechnic Colleges

Date: FEB 27 2025

DEDICATION

This research is dedicated to all those who have contributed to its realization, shaping its purpose and outcomes. To **office workers and individuals with mobility disabilities**, whose daily lives can be made easier through the smart trashcan's voice activation and thumbs-up gesture recognition features, enabling them to dispose waste more efficiently and independently. To **researchers** and **innovators**, whose quest for knowledge and development in smart technologies continues to inspire further advancements in machine learning and artificial intelligence, contributing to a better and more connected future.

We also dedicate this study to the **community**, where the smart trashcan serves as a tool for sustainability, promoting an environmentally efficient approach to waste management and encouraging conservation efforts. The potential impact of this research extends to institutions such as **Camarines Sur Polytechnic Colleges** , where the study showcases the role of AI and machine learning in the development of autonomous systems, furthering innovation in the academic realm.

Lastly, this work is dedicated to our **parents and loved ones**. It is their unwavering support, encouragement, and love that have made this journey possible. With their guidance, we have achieved this milestone, and it is to them that we owe our deepest gratitude. This study is a testament to their trust in us, and we are truly thankful for everything they have done to bring us to this point.

ACKNOWLEDGMENTS

First and foremost, we would like to express our heartfelt gratitude to **Camarines Sur Polytechnic Colleges** and the **College of Computer Studies** for providing us with the knowledge, skills, and resources necessary to complete this thesis. To **Mrs. Rosel O. Onesa, OIC**, Dean of CCS, thank you for your leadership and dedication to fostering an environment of academic excellence. Our deepest appreciation goes to our Thesis Adviser, **Dr. Ian P. Benitez** whose expertise, patience, and unwavering support have guided us through the complexities of this study. We are also immensely grateful to **Mr. Allan O. Ibo Jr.** our Thesis Consultant, whose approachable and insightful demeanor made it a pleasure to discuss our work and explore new ideas with him.

Special thanks to our panel members, **Ms. Kaela Marie N. Fortuno**, Panel Chair, and **Mr. Joseph Jessie S. Oñate**, and **Ms. Tiffany Lyn Pandes**, Panel Members, for their invaluable feedback and constructive criticisms that greatly improved the quality of our thesis. To **Mrs. Ivy R. Maraño**, our grammarian, we extend our gratitude for ensuring the clarity and accuracy of our written work.

We deeply appreciate **Mary France S. Maraño**, our class mayor, for her friendliness, helpfulness, and constant willingness to answer our questions whenever we faced uncertainties. To our **classmates**, we give thanks for their cooperation and contributions, especially under the leadership of our class mayor, and a special mention to **Lei I. Parato** and **Shiella R. Dimanarig** for their interactive guidance. Also, we acknowledge **Shiana Mira J. Sejera** and **Joy R. Joven** for their assistance in delivering food and snacks to the panel when time was tight, ensuring that everything ran smoothly.

We would also like to recognize the **ROTC Office**, a familiar place where we often find ourselves working. We owe our **parents and friends** a debt of gratitude for providing us with a supportive workplace, love, and encouragement. Their unwavering support made

this study possible, and their presence helped us relax and find peace during moments of stress. To our **co-researchers**, thank you for the enjoyable and memorable experiences we shared, which made even the challenging moments worthwhile.

Above all, we give our sincerest thanks to our **merciful GOD**, who has guided us every step of the way, blessing us with strength, wisdom, and perseverance to complete this journey. This unforgettable life experience is a testament to His grace and guidance. Thank you to everyone who played a role in making this study a success.

ABSTRACT

Title:	DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION
Authors:	Gerald M. Carique John Mark C. Ruam Arnold Rie J. Sejera
Number of Pages:	124
School:	Camarines Sur Polytechnic Colleges
Degree Conferred:	Bachelor of Science in Computer Science
Keywords:	Smart Trashcan, Autonomous, YOLOv8, Object Detection, Wake Word Detection, Gesture Recognition

Effective waste management is a growing global concern, with an estimated 2.24 billion tons of solid waste generated annually. For individuals with mobility impairments, disposing of waste independently remains a significant challenge. This study addresses this gap by developing “Dolly”, a voice-activated, gesture-recognizing smart trashcan designed to enhance waste disposal efficiency and accessibility. Using the YOLO (You Only Look Once) algorithm, the system detects a thumbs-up gesture to trigger autonomous navigation, allowing the trashcan to move toward the user’s location. This innovation is particularly useful for office workers and individuals with disabilities, promoting inclusivity and sustainability. The study’s objectives include training and evaluating the YOLO algorithm for gesture recognition, integrating the model into a smart trashcan prototype, and testing the prototype’s effectiveness in real-world scenarios. System integration used a Raspberry Pi 4 and Arduino Uno, and the system achieved a mean average precision (mAP@95) of 93%. Voice commands were incorporated through the PICO Voice Porcupine Wake Word engine. Results show that ”Dolly” significantly improves accessibility for users with mobility impairments, promoting independence in waste disposal.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

This research presents the background of the problem which constructed the overview of the researchers, statement of the problem including the objectives. The possibility of the research is set in the scope and limitations. The significance of the study determines the following beneficiaries of this research. The researchers also provide the project dictionary to give ideational and operational definitions of the terms used in research.

Background of the Problem

Waste management has become a global issue due to increased production and use of resources. A World Bank report estimates that 2.24 billion tons of solid waste were generated in 2020, with an average footprint of around 0.79 kilograms per individual daily[4]. This figure is expected to rise significantly due to population growth, urbanization, and changing consumption trends, with annual waste generation projected to increase by 73% by 2050, reaching 3.88 billion tons annually. Effective waste management, which involves sorting, recycling, reusing, and disposing of waste, is crucial for creating sustainable and livable environments.

However, managing waste, especially in densely populated urban areas, poses significant challenges, including space for disposal, landfill management, and reducing greenhouse gases from decomposing waste. There is an increasing need for sustainable waste management approaches that can meet the specific demands of local communities.

Recent research on waste management indicates that, despite initiatives to enhance trash segregation, recycling, and disposal, many individuals encounter challenges that hinder their participation. People with disabilities, especially those with mobility issues, face significant obstacles in engaging in standard garbage disposal activities. Globally, about 1 billion individuals have a disability, according to the World Health Organization (WHO)[7].This number continues to rise due to demographic aging, the growing prevalence of non-communicable illnesses[5], and an increased incidence of mobility-limiting ailments.

In the Philippines, the 2010 Census of Population and Housing (CPH) found that 1.57% of the population, or approximately 1.44 million individuals, have impairments[1]. Tasks requiring physical activity, such as taking out the garbage, pose particular difficulties for these individuals. The unique needs of those with restricted mobility are often not considered in the design of many public and private areas. Trash bins may be positioned in hard-to-access regions or built-in ways that require substantial physical effort to operate, presenting extra challenges for those who already struggle with accessibility and independence.

Recent studies emphasize the need for technology that addresses the requirements of all users. Most current trashcan designs are not user-friendly for those with mobility disabilities, as they generally lack features such as easy-to-open covers, height adjustments, or proximity monitors that would make them easier to reach. Due to their recurring lack of features like height adjustments, proximity sensors, or easy-to-open lids, the majority of trashcan designs now in use are not accessible to those with mobility disabilities.

The absence of accessible trash disposal facilities significantly impacts those with mobility disabilities, often forcing them to rely on others for simple tasks like taking out the garbage. Inaccessible trashcans can make waste disposal difficult, leading to feelings of frustration, powerlessness, and reduced independence[10]. This can result in unhygienic environments and emotional distress. Designing more accessible trashcans and waste management systems is crucial for fostering inclusion and improving the daily lives of people with disabilities. Incorporating hand gestures and voice commands into smart trashcan designs can make waste disposal more accessible and user-friendly. These technologies can help reduce physical barriers, allowing individuals with mobility disabilities to dispose of waste independently and safety.

Statement of the Problem

Traditional waste disposal methods require manual trash handling, which can be challenging for many people, particularly those with disabilities. Current technologies, such as smart trashcans, have helped make waste disposal more accessible and efficient. However, these solutions frequently require the user to approach the trashcan, which could be a barrier for people who cannot walk. The researchers proposed solution, "Dolly," solves this problem by sending the trashcan to the user. Dolly uses object detection technology, particularly the YOLO algorithm, to recognize a thumbs up gesture as an indication to approach the user. This allows those with mobility problems to throw out garbage without moving to the trashcan, making the process more accessible and less difficult. This project intends to create and test Dolly, to contribute to the larger goal of making the environment more inclusive and accessible to people with disabilities. This research can help people with impairments live more independent and productive lives by using technology to aid them with daily tasks.

Objectives of the Study

This section provided the general and specific objectives of the study.

General Objective

The main goal of this study was to develop a prototype of a smart trashcan robot that would utilize the YOLO Algorithm to identify thumbs up hand gesture for autonomous navigation.

Specific Objectives

More Specifically, this study aimed to:

1. Train and evaluate the YOLO algorithm for autonomous navigation of the trashcan;
2. Integrate a trained autonomous smart trashcan model with thumbs up gesture recognition into a prototype;
3. Test the effectiveness of the prototype "DOLLY".

Significance of the Study

The study "DOLLY: A Voice-Activated and Thumbs Up Gesture-Recognizing Smart Trashcan Utilizing the Yolo Algorithm for Autonomous Navigation" is important for several reasons. On the other hand, it addresses a significant waste management gap by creating an advanced technology that transforms ordinary objects like trashcans into functional machines. This also enhances the effectiveness and efficiency of the prototype smart trashcan and contributes to a cleaner environment. The primary beneficiaries of this study are the following:

Individuals with mobility impairments, as the smart trashcan's voice activation and thumbs up gesture recognition features make disposal easier and more efficient for them;

Office workers with mobility disabilities, as the autonomous navigation system allows the trashcan to move to the user's location, reducing the need for physical effort;

Community, as the smart trashcan promotes sustainability and provides an environmentally efficient approach to waste management, encouraging to conserve the environment;

Researchers and innovators, as the study provides insights into the design, development, and implementation of smart machines, inspiring further innovations in the field;

Camarines Sur Polytechnic Colleges (CSPC), as the research can be beneficial for the institution by showcasing the potential of machine learning and artificial intelligence in creating smart, autonomous systems that enhance daily lives and contribute to a more sustainable and inclusive society. It also had a voice activation and thumbs up gesture recognition featured on the said prototype which makes disposal less efficient for persons with mobility impairments.

Scope and Limitation

The study entitled ”DOLLY: A Voice-Activated and Gesture-Recognizing Smart Trashcan Utilizing the YOLO Algorithm for Autonomous Navigation” will concentrate on developing and implementing gesture recognition capabilities in a smart trashcan. The YOLO algorithm would be used for object detection by identifying the thumbs up gestures of a person and determining how the smart trashcan can navigate autonomously in a specific area. The study would also evaluate and test the smart trashcan's efficiency regarding thumbs up gesture recognition and autonomous navigation, which will benefit individuals with mobility impairments.

However, this study had some limitations that are worth noting. Firstly, the findings might not apply to all environment since the testing was performed in a predefined setting. Secondly, the accuracy of voice and gesture recognition might depend on external factors such as background, noise, and light conditions. Thirdly, while the YOLO algorithm is known for its speed and accuracy, it might generate false positives or negatives. Fourthly, the outcomes of the study could be influenced by the capabilities of the devices used, such as the quality of the sensor, camera, and processing capacity of the smart trashcan. Lastly, note that the study did not address collision avoidance with humans or animals.

Project Dictionary

To avoid problems in understanding the terms used, the following technical terms are conceptually and operationally defined to provide a better understanding.

Autonomous Navigation. The robot can explore its surroundings autonomously without human intervention it is an intelligent machine that "can perform tasks and operate in an environment independently, without human control or intervention[8]. In this study, autonomous navigation was used in the actual prototype to locate waste-disposing individual.

DOLLY. Name of the trashcan in this research. In this study researchers named the actual prototype "DOLLY".

Gesture Recognizing. Referring to "DOLLY's" capability to recognize order through human thumbs up gestures as a command. It is also refers to the process of identifying and interpreting hand movements and gestures, often used as an intuitive interface for controlling robots or devices[9]. In this study it allows the smart trashcan to recognize thumbs up gesture.

Object Detection. Is a task in computer vision that involves identifying and locating objects in an image or video. It is an important capability for many applications, including image and video analysis, robotics, and surveillance[2].It is also a process in which "DOLLY" identifies objects within its environment.In this study, object detection was used to detect hand gestures object of individuals.

Smart Trashcan. Is the new high technology that integrated waste containers with smart sensors, which allows you to track through the waste management process[3]. For example, with the smart waste bin system you can control the occupancy ratio of your smart waste bins. A trashcan equipped with hardware, software, and sensors that function independently. In this study researchers created traditional trashcan into more advanced trashcan.

Voice-Activated. Are technological tools that enable users to control their functionality through spoken commands. These devices utilize voice recognition technology to interpret and respond to users input allowing for hands free operation and enhancing accessibility[6]."DOLLY" has the ability to awaken by calling its name. In this study, researchers refer DOLLY's ability to awaken by calling its name "Hey DOLLY".

YOLO Algorithm(You Only Look Once). An algorithm that detects objects in real time by analyzing photos. The algorithm can identify objects in real time as they appear on the screen to determine and compare the predictive performance of different object detection models, we need standard quantitative metrics.The two most common evaluation metrics are Intersection over Union (IoU) and the Average Precision (AP) metrics[10]. In this study researchers used Yolo algorithm to train the model for object detection and recognition.

Notes

[1] AbilityX. 2024. Mobility impairment. Retrieved from: 2024-12-19. https://abilityx.io/disabilities/mobility-impairment.

[2] Encord. 2024. Object detection. Retrieved from: 2024-12-19. https://encord.com/glossary/object-detection-definition/#:~:text=Object%20detection%20is%20a%20task,analysis,%20robotics,%20and%20surveillance.

[3] Evreka. 2024. Ultimate guide to smart bins. Retrieved from: 2024-12-19. (Oct. 2024). https://evreka.co/blog/ultimate-guide-to-smart-bins/#:~:text=Smart%20bin%20is%20the%20new,of%20your%20smart%20waste%20bins.

[4] World Bank Group. 2023. *Solid waste management*. en. (Mar. 2023). https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

[5] InclusionHub. 2024. How to create accessible workplaces for employees with mobility impairments. Retrieved from: 2024-12-19. https://www.inclusionhub.com/articles/how-to-create-accessible-workplaces-for-employees-with-mobility-impairments.

[6] Fiveable Library. 2024. Voice activated devices. Retrieved from: 2024-12-19. https://library.fiveable.me/key-terms/robotics-bioinspired-systems/voice-activated-devices.

[7] World Health Organization. [n. d.] Disability. Retrieved from: Mar. 7, 2023. https://www.who.int/news-room/fact-sheets/detail/disability-and-health.

[8] Waypoint Robotics. 2024. Autonomous robot definition and uses. Retrieved from: 2024-12-19. (Oct. 2024). https://blog.megaventory.com/autonomous-robot-definition-and-uses/#:~:text=According%20to%20Waypoint%20Robotics%2C%20the,without%20human%20control%20or%20intervention%E2%80%9D.

[9] ScienceDirect. 2024. Hand gesture recognition. Retrieved from: 2024-12-19. https://www.sciencedirect.com/topics/computer-science/hand-gesture-recognition#recommended-publications.

[10] Robert Y. Siy. 2022. Persons with disabilities have a right to be mobile. en-US. *The Manila Times*, (Feb. 2022). Accessed: 2024-12-19. https://www.manilatimes.net/2022/02/19/business/top-business/persons-with-disabilities-have-a-right-to-be-mobile/1833450.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents a thorough review of relevant literature and studies sourced from both local and global contexts, accompanied by their respective methodologies. The objective is to provide researchers with an insightful comprehension of this thesis. Furthermore, the incorporation of various perspectives and methodologies enriches the depth and scope of the research inquiry.

Review of Related Literature and Studies

The researchers of this study reviewed a variety of sources, including research articles, academic papers, and websites. These resources provided a solid foundation for this research's successful execution. The researchers were guided of the development of the prototype by referring to the cited literature and related studies.

Evolution of Smart Trash can

Waste management has moved beyond conventional methods in an era of rapid technological advancement. The development of smart trashcans has transformed how people manage waste, offering a new level of ease and efficiency. There's a study in CSPC by Edison A. Villamer et al. that the waste bins are concealed to save space, slow decomposition, and reduce odor[21]. The design is automated to minimize direct contact with garbage. The classifying section uses grippers, servo motors, ultrasonic, capacitive, and photoelectric sensors to collect and separate garbage. Segregated garbage is stored before shredding, and shredded waste is sent to transport bins for collection.

Moreover, another study in the Philippines implemented an Automated Waste Segregator with Smart Compression conducted by John Paul S. Endaya et al.[10]. The concept is that there are two Arduino Unos linked to one another with push buttons to select what kind of trash will be disposed of. LEDs were employed to indicate if the entered data is accurate. The motor stepper is in charge of keeping the garbage cans rotated so that they are fastened to a ring-shaped metal plate. while the ultrasonic sensor will identify if the material is plastic or paper. It is necessary to compress bins. Contraction was enabled by the use of a linear actuator, making the most of the garbage can's area. LEDs are going to further act as a warning that the dumpsters are already full.

While some studies like Smart Garbage System with Garbage Separation Using Object Detection by Vinodha D. et al.[22] utilized IoT. The bins have a Raspberry Pi combined with an ultrasonic sensor to determine the level of rubbish and a Pi camera to segregate the garbage based on object detection using the YOLO algorithm and to automatically open the lid of the corresponding bin using a servo motor. The intelligent bin uses optimum routing to monitor and clear waste by connecting to a mobile application over the cloud. These innovative technologies, which include sensors and other connections, can change the way we live, making it cleaner and more sustainable.

Real-Time Object Detection Using a YOLO Approach

Implementing real-time object detection has been a challenging task in computer vision, but the advent of the YOLO approach has significantly simplified this process. Several studies conducted in the Philippines have utilized the YOLO Algorithm, which shows that this algorithm is not new to the country. Researchers have come up with ideas on how to implement this Algorithm to solve some of the country's problems and create new solutions. Among these studies, some of the researchers focused on Real-Time Object Detection for traffic management. Amie Rosarie Caballo and Chris Jordan Aliac from the College of Computer Studies, Cebu Institute of Technology University[4], address the need for efficient traffic management, especially in urban areas such as Tagbilaran City, Philippines. By employing a YOLO-based model, researchers have successfully detected tricycles, a unique form of public transportation, from traffic videos. The model achieved an average precision of 37.91% for tricycle detection, highlighting its potential for enhancing traffic surveillance systems.

When it comes to traffic here in the Philippines there are a lot of challenges that we cannot deny. In the same way, Jundee Mark G. Molina et al.[16] also focused on creating a solution to solve some of those traffic problems by analyzing traffic. Researchers present a web-based system for real-time traffic monitoring and visualization, incorporating YOLOv5s for object detection and the DeepSort Algorithm for object tracking. The system provides valuable insights for commuters and drivers, aiding in optimal decision-making and enhancing traffic management strategies. In addition, Rowell M Hernandez et al. used Real-Time Object Detection as well by utilizing the YOLO Algorithm for much safer driving[12]. The researchers aimed to create DRIVEMATE, an assistive tool for mobile device users while driving. The application uses computer vision and machine learning to enhance driver awareness and promote safer driving practices. It accurately detects and recognizes traffic signs in real-time scenarios, providing timely alerts and reducing accident risks. The application uses text-to-speech functionality for speech output and live traffic sign detection. Agile scrum development methodology was used, and TensorFlow Lite was used for machine learning models. The Flutter framework and Android Studio Code were used for construction. The application was tested based on ISO 25010:2011, and a survey with 100 respondents confirmed its accuracy and reliability.

Object Detection applies not only to the traffic management system but also can help people with disabilities, especially those mobility-impaired persons who find it difficult to dispose of garbage. Considering “Hand Gesture Recognition for Filipino Sign Language Under Different Backgrounds” by Mark Christian Ang et al.[1], researchers present a hand gesture Filipino Sign Language recognition model using Raspberry Pi, which has shown promise in recognizing letters with gloves and complex backgrounds. The model achieved an average accuracy of 93.29% for differentiating 26 hand gestures representing FSL letters, despite challenges in recognizing Q, J, and Z letters and incorrect interpretation of N and M due to similar hand structures. The system performed well on limited resources and in various environments, demonstrating its dependability and performance. Moreover, Jeloux P. Docto et al. from Electronics and Computer Engineering, Mapua University[9], aims to create a Third Eye Hand Glove for Visually Impaired persons. The study proposes a system using the You Only Look Once (YOLO)v4-tiny algorithm to detect indoor objects for visually challenged individuals. The system uses a camera attached to the Raspberry Pi 4B to capture images, identify object types, and calculate distance. The system has been tested on 40 objects from the Common Objects in Context (COCO) dataset, achieving an overall F1 score, precision, recall, and accuracy of 83.00%.

In addition, when it comes to object detection, robots are considered to be one of the things that use object detection. Especially autonomous robots, Ron Jamin C. Aquino et al.[2] made a robot that uses 360° cameras for the detection, recognition, and tracking of human targets. The system uses YOLO detection and CSRT algorithms and includes a 10-second target recognition method for continuous tracking. These collective efforts highlight the significant impact of Real-Time Object Detection utilizing YOLO-based approaches in addressing real-world challenges and improving quality of life across different domains.

Autonomous Navigation Using the YOLO Algorithm

In the challenging year of 2020, marked by a global pandemic, the focus has shifted towards creating a clean, green, and safe environment. Governments worldwide are emphasizing the development of autonomous and contactless environments to adapt to the new norm. In this context, Autonomous Vehicles (AV) emerge as a promising technology. A critical aspect of Autonomous Navigation is object detection, for which most AVs employ multiple sensors such as cameras, radar, and Light Detection and Ranging sensor (Li-

DAR). The LiDAR sensor, capable of detecting objects using pulsed lasers, is widely used today, especially beneficial in low-light object detection. However, even with advanced technology, the performance of the object detection system can be compromised by poor programming. This study explores the state-of-the-art You Only Look Once (YOLO) algorithms, specifically Tiny-YOLO and Complex-YOLO, for object detection on the KITTI dataset. The algorithms' performances were compared based on accuracy, precision, and recall metrics. The results indicated that Complex-YOLO outperformed Tiny-YOLO in terms of mean average precision when tested with equal parameters[7].

In an era where technology is rapidly advancing, the concept of autonomous and self-driving cars has moved from science fiction to reality. These vehicles rely heavily on accurate object detection, which includes buildings, vehicles, road signs, and pedestrians, to ensure safe navigation. While several object detection techniques have been proposed and are effective under normal weather conditions, their performance significantly deteriorates under adverse weather conditions like heavy snowfall or foggy days. Recognizing this challenge, this paper presents a novel object detection system for Autonomous Vehicles (AVs) that leverages the emerging convolutional neural network (CNN) approach of You Only Look Once (YOLO), in conjunction with a Federated Learning (FL) framework. The primary objective of this system is to enhance detection accuracy in real-time under adverse weather conditions. The proposed system was rigorously tested and validated on the Canadian Adverse Driving Conditions (CADC) dataset. The results of these experiments demonstrated that our solution significantly outperforms traditional solutions such as the Gossip decentralized model and the Centralized model[19].

This paper delves into the role of Global Navigation Satellite Systems (GNSS) in autonomous driving, highlighting recent advancements and their potential impact. Modern GNSS, with four independent global satellite constellations, has led to significant improvements in error correction. The availability of mass-market automotive-grade receiver chipsets has enabled GNSS to deliver better than lane-level accurate localization with high integrity. The emergence of SAE Level 2 partially autonomous vehicles and pilot programs of SAE Level 4 driverless vehicles mark significant progress in autonomous driving. However, challenges remain. GNSS can enhance safety and robustness in autonomous driving, particularly when integrated into vision-based and LiDAR-based systems. Furthermore, GNSS promises interoperability for future Vehicle-to-Everything (V2X) scenarios. This paper aims to shed light on these aspects as the researchers navigate towards a future defined by autonomous driving and advanced GNSS[14].

Artificial Intelligence (AI). This paper expands the discussion by providing a comprehensive overview of the application of AI models and methodologies in transportation engineering, particularly for controlling autonomous vehicles (AVs) in mixed autonomy scenarios. As the researchers navigate towards a future defined by autonomous driving and advanced GNSS, the integration of AI in these systems becomes increasingly significant. From reviewing literature in both transportation engineering and AI, to discussing cutting-edge AI-guided methods and posing open questions, this paper aims to inspire the transportation community and initiate dialogues with other disciplines, especially robotics and machine learning, to collaboratively work towards building a safe and efficient mixed traffic ecosystem[8].

In the realm of autonomous vehicle technology, the development of long-range and short-range navigation systems is crucial for autonomous vehicles due to their complexity and their direct impact on safety. This research aims to create a short-range navigation system specifically designed to detect and avoid humans, which has been implemented on a prototype autonomous vehicle. Techniques such as image processing and deep learning algorithms are utilized for human detection, while an ultrasonic sensor is used to calculate distance. A Fuzzy algorithm, based on the detected human's position and distance, is used for decision-making in the human avoidance system. The system has demonstrated an 85.71 percent, success rate in avoiding humans at an ideal distance of more than 2 meters. The prototype can be adapted for real vehicles with some modifications to the sensor and hardware system, with the expectation that these systems will help reduce traffic accidents caused by human error[18].

The accuracy and performance of an object detection model are paramount for an effective object tracking system. This project aims to examine the performance of machine learning-based object detection using the YOLO v3 technique. Two models were developed for this purpose; one model was trained using only the online Common Objects in Contact (COCO) dataset, while the other model was trained with additional images from several different locations dataset provided by University Malaysia Pahang (UMP). The performance of these trained models was evaluated using mean Average Precision (mAP) and precision techniques. The model with the highest precision was chosen for implementation on an actual road test. The results revealed that the second model had the highest precision and was capable of detecting every class of objects. Each output box displayed the class and the distance to the objects from the RGBD camera of the vehicle. The first model, which was trained to perform, had an mAP value of 90.2 percent and a precision performance of 0.484. However, the second model demonstrated higher accuracy in detections compared to the first model, thereby outperforming it with a precision value of 0.596[13].

So that they introduce the Robobo SmartCity model by Naya-Varela, Martin and Guerreiro-Santalla, Sara and Baamonde, Tamara and Bellas, Francisco (2023), an educational tool designed to expose students to computational intelligence (CI) subjects through the primary use of educational robotics. Robobo SmartCity provides a practical and achievable platform for educators to instruct learners about the basics of artificial intelligence (AI), in line with the guidelines of digital education plans to incorporate AI across all educational stages. The resource is built around the Robobo educational robot and an autonomous driving setup, comprising a city mockup, simulation models, and programming libraries tailored to the students' abilities. Within this setup, students can learn CI subjects that contribute to robot autonomy within the context of autonomous driving. This project is part of the broader field of AI and autonomous systems, serving as an educational tool to learn underlying concepts. Our project, the smart trashcan, is a real-world application of these concepts[17].

YOLO's Evolution and Accuracy

Numerous research works have substantiated that YOLO outperforms CNN. Lee Yong-Hwan et al.[15] conducted an evaluation of a range of algorithms, considering factors such as accuracy, speed, and cost. In comparison to the latest sophisticated solution, YOLO v3 exhibits an optimal trade-off between speed and accuracy. With this understanding, the enhancements in the versions of YOLO (You Only Look Once) are noteworthy. It is crucial to understand the primary motivations behind the development of features, limitations, and the relationships between different versions. This understanding is particularly beneficial and illuminating for researchers, especially those who are new to the field of object detection[6]. Hence different version of YOLO has its own advantages. In a study conducted by Muhammed Enes ATİK et al.[3]. YOLOv2 outperformed in five of the nine classes, but YOLOv3 performed better when it came to small object recognition. In terms of time, YOLOv3 has outperformed YOLOv2, recognizing objects in an average of 2.5 seconds compared to 43 seconds for YOLOv2. Furthermore, there are several factors that must be considered to enhance the precision. M. B. Ullah et al.[20], mentioned that YOLO Algorithm is meant for GPU-based computers, meaning the graphics card needs to be at least 12GB.

Moreover, advancements in similar algorithms also contribute to the field. As per the study[5], the ERF-YOLO algorithm aims to minimize the number of model parameters while maximizing the effective receptive field, striking a balance between detection speed and accuracy. This is not merely achieved by choosing a high-performing network architecture, but also through a more holistic integration and optimization, building upon the ideas proposed by earlier researchers. The detector is broken down into its fundamental components, each of which is carefully designed and examined. The ERF-YOLO algorithm provides superior accuracy benefits compared to its peers. Also, the enhanced YOLO-V4 model has led to improvements in feature extraction, a deeper network structure, and increased detection speed. The comparison of various deep learning algorithms, including YOLO-V3, YOLO-V3-dense, and YOLO-V4, validates the effectiveness of this method. The results show that the Mean Average Precision (mAP), a measure of average accuracy, obtained using the upgraded YOLO-V4 model (YOLO-V4-dense) in this study, is 0.15 higher than that of the standard YOLO-V4. This indicates a significant improvement in detection accuracy[11].

In addition, Yunhua Yin et al.[23] propose a novel method named Faster-YOLO, capable of performing real-time object detection. A joint network, consisting of the Deep Random Kernel Convolutional Extreme Learning Machine (DRKCELM) and Double Hidden Layer Extreme Learning Machine Auto-Encoder (DLELM-AE), is utilized as a feature extractor for object detection. This integrates the benefits of ELM-LRF and ELM-AE. The method directly accepts raw images as input, making it suitable for various datasets. Moreover, most connection weights are randomly generated, resulting in fewer parameter settings and faster training speed. Experimental results on the Pascal VOC dataset demonstrate that Faster-YOLO effectively improves detection accuracy by 1.1 percentage points compared to the original YOLOv2, and offers an average 2X speedup compared to YOLOv3.This continuous evolution and improvement of algorithms are crucial for the progress of object detection research.

Synthesis of the State-of-the-Art

A review of existing literature finds many studies centered on automation throughout various fields, that provides significant insights for the current research. Prior studies have utilized technologies such as Arduino Unos, ultrasonic sensors, and YOLO-based object detection with Raspberry Pi to tackle issues in waste management, mobility, and traffic systems. Muscle activity prediction, smart compression concealed trash containers, automated waste segregators, intelligent garbage monitoring systems, and effective solid waste management systems are a few examples. Many of these systems incorporate advanced features such as odor mitigation and waste compartmentalization, enhancing their functionality. In addition to waste management, YOLO-based technologies have been utilized in traffic systems for the detection of tricycles, monitoring traffic flow, and enhancing visualization. An example is DRIVEMATE, a traffic management system designed to help improve safe driving practices. In a similar way, YOLO has been applied in various fields such as hand gesture recognition for Filipino Sign Language (FSL), outdoor navigation devices like the Third Eye Hand Glove, and indoor object detection systems designed for individuals with visual impairments.

Although the previous studies primarily focused on using YOLO for object detection and classification, this study differentiates itself by applying YOLO for autonomous navigation. This innovative approach addresses real-world object detection challenges, contributing to the development of an autonomous waste collection vehicle. Unlike traditional implementations, this system combines YOLO's robust detection capabilities with autonomous mobility to enhance everyday safety and user experience. Moreover, it corresponds with the technological progress observed in smart trashcans, which incorporate human-object interaction and accurate object detection to enhance waste management for individuals with mobility impairments.

Gap Bridge by the Study

The existing review of the literature discussed above highlights the idea of smart trashcans and the YOLO algorithm as well as YOLO for autonomous navigation. There are similarities present from the existing studies like the Object detection to detect waste and locate its position. The difference is the proposed study used the YOLO algorithm to detect hand gestures to locate the person who wants to throw their trash. Also, this makes it unique since there is a Voice activation process to make it more on human-computer interactions, which is not implemented in the existing study. Furthermore, existing studies utilized the YOLO algorithm for different approaches like real-time object detection to assess traffic and object detection for real-time human tracking. This study has its method that locates the position of the person with the use of the YOLO algorithm.

Notes

[1] Mark Christian Ang, Karl Richmond C Taguibao, and Cyrel O Manlises. 2022. Hand gesture recognition for filipino sign language under different backgrounds. In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*. IEEE, 1–6.

[2] Ron Jamin C Aquino, Charles Kenneth C Beltran, John William A Fajardo, John Loid A Lopez, Nicole E Sambajon, and Roselito E Tolentino. 2020. Image processing based human following cart using 360° camera. In *2020 International Conference on Electronics and Sustainable Communication Systems (ICESC)*. IEEE, 375–380.

[3] Muhammed Enes Atik, Zaide Duran, and Roni ÖZGÜNLÜK. 2022. Comparison of yolo versions for object detection from aerial images. *International Journal of Environment and Geoinformatics*, 9, 2, 87–93.

[4] Amie Rosarie Caballo and Chris Jordan Aliac. 2020. Yolo-based tricycle detection from traffic video. In *Proceedings of the 2020 3rd International Conference on Image and Graphics Processing*, 12–16.

[5] Enhui Chai, Lin Ta, Zhanfei Ma, and Min Zhi. 2021. Erf-yolo: a yolo algorithm compatible with fewer parameters and higher accuracy. *Image and Vision Computing*, 116, 104317.

[6] Richeng Cheng. 2020. A survey: comparison between convolutional neural network and yolo in image identification. In *Journal of Physics: Conference Series* number 1. Vol. 1453. IOP Publishing, 012139.

[7] Nurin Mirza Afiqah Andrie Dazlee, S. Khalil, Shuzlina Abdul-Rahman, and Sofianita Mutalib. 2022. Object detection for autonomous vehicles with sensor-based

technology using yolo. *International Journal of Intelligent Systems and Applications in Engineering*, 10, 1, (Mar. 2022), 129–134. DOI: 10.18201/ijisae.2022.276.

[8] Xuan Di and Rongye Shi. 2021. A survey on autonomous vehicle control in the era of mixed-autonomy: from physics-based to ai-guided driving policy learning. *Transportation Research. Part C, Emerging Technologies*, 125, (Apr. 2021), 103008. DOI: 10.1016/j.trc.2021.103008.

[9] Jeloux P Docto, Angelika Ice Labininay, and Jocelyn F Villaverde. 2022. Third eye hand glove object detection for visually impaired using you only look once (yolo) v4-tiny algorithm. In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*. IEEE, 1–6.

[10] John Paul S Endaya, Ferdinand Jr Mabitasan, and Jonela Cyvel Mae Gonzales. 2020. Design and implementation of automated waste segregator with smart compression. *LPU-Laguna Journal of Engineering and Computer Studies*, 4, 3, 1–1.

[11] Rongli Gai, Na Chen, and Hai Yuan. 2023. A detection algorithm for cherry fruits based on the improved yolo-v4 model. *Neural Computing and Applications*, 35, 19, 13895–13906.

[12] Rowell M Hernandez, Johnrey Manzanal, Joseph Rizalde Guillo, Shiel Marie Garcia, and Melvin Babol. 2023. Drivemate: empowering safe driving through real-time traffic sign detection and speech feedback on mobile devices using yolov5 algorithm and tensorflow lite. In *Proceedings of the 8th International Conference on Sustainable Information Engineering and Technology*, 181–189.

[13] William Chin Wei Hung, Muhammad Aizzat Zakaria, M. I. Ishak, and P. M. Heerwan. 2022. Object tracking for autonomous vehicle using yolo v3. In *Enabling Industry 4.0 through Advances in Mechatronics*. Ismail Mohd. Khairuddin, Muhammad Amirul Abdullah, Ahmad Fakhri Ab. Nasir, Jessnor Arif Mat Jizat, Mohd. Azraai Mohd. Razman, Ahmad Shahrizan Abdul Ghani, Muhammad Aizzat Zakaria, Wan

Hasbullah Mohd. Isa, and Anwar P. P. Abdul Majeed, (Eds.) Springer Nature Singapore, Singapore, 265–273. ISBN: 978-981-19-2095-0.

[14] Niels Joubert, Tyler G. R. Reid, and Fergus Noble. 2020. Developments in modern gnss and its impact on autonomous vehicle architectures. In *2020 IEEE Intelligent Vehicles Symposium (IV)*, 2029–2036. DOI: 10.1109/IV47402.2020.9304840.

[15] Yong-Hwan Lee and Youngseop Kim. 2020. Comparison of cnn and yolo for object detection. *Journal of the semiconductor & display technology*, 19, 1, 85–92.

[16] Jundee Mark G Molina, Angelica S Sotis, Rogamestica C Pascual, James Earl D Cubillas, and Junrie B Matias. 2022. Development of real-time traffic monitoring and visualization system using stationary roadside sensor. In *Proceedings of the 2022 11th International Conference on Networks, Communication and Computing*, 154–160.

[17] Martin Naya-Varela, Sara Guerreiro-Santalla, Tamara Baamonde, and Francisco Bellas. 2023. Robobo smartcity: an autonomous driving model for computational intelligence learning through educational robotics. *IEEE Transactions on Learning Technologies*, 16, 4, 543–559. DOI: 10.1109/TLT.2023.3244604.

[18] Taufiq Nuzwir Nizar, R. W. Tri Hartono, and D. Meidina. 2020. Human detection and avoidance control systems of an autonomous vehicle. *IOP Conference Series: Materials Science and Engineering*, 879, 1, (July 2020), 012103. DOI: 10.1088/1757-899x/879/1/012103.

[19] Gaith Rjoub, Omar Abdel Wahab, Jamal Bentahar, and Ahmed Saleh Bataineh. 2021. Improving autonomous vehicles safety in snow weather using federated yolo cnn learning. In *Mobile Web and Intelligent Information Systems*. Jamal Bentahar, Irfan Awan, Muhammad Younas, and Tor-Morten Grønli, (Eds.) Springer International Publishing, Cham, 121–134. ISBN: 978-3-030-83164-6.

[20] Md Bahar Ullah. 2020. Cpu based yolo: a real time object detection algorithm. In *2020 IEEE Region 10 Symposium (TENSYMP)*. IEEE, 552–555.

[21] Edison A Villamer, Marvin T Agrade, Marlon Jay Delustre, Renato Embestro, Via Claire Mamano, Christopher Pante, Rhoderick Oliveros, Eddie Cabaltera, and Victor Solito Issac. 2022. Concealed automated trash bin with shredder for solid wastes. *Journal of Engineering and Emerging Technologies*, 1, 1, 1–7.

[22] D Vinodha, J Sangeetha, B Cynthia Sherin, and M Renukadevi. 2020. Smart garbage system with garbage separation using object detection. *International Journal of Research in Engineering, Science and Management*, 3, 5, 779–782.

[23] Yunhua Yin, Huifang Li, and Wei Fu. 2020. Faster-yolo: an accurate and faster object detection method. *Digital Signal Processing*, 102, 102756.

CHAPTER 3

METHODOLOGY

This chapter outlines the techniques used to achieve the study's stated objectives. Theorems, methods, and mathematical frameworks for usage during the study will also be evaluated and presented.

Research Design

The study used a constructive research design. This was to formulate the best possible solution for a known problem by constructing a prototype or synthesizing ideas to achieve the desired outcome for a particular problem [2]. This research design also involved iterative testing and refinement of the proposed solution, allowing for adjustments based on feedback and performance metrics. This approach aimed to ensure that the final outcome was both practical and effective in addressing the identified challenges.

In this study, the researchers created a prototype, namely a voice-activated smart trashcan, using the YOLO algorithm for object detection. The algorithm was used to identify thumbs-up interactions for the autonomous navigation of the trash can. The constructive research technique was appropriate for the study as it generated innovative constructions and assisted researchers in identifying various concepts for improving the development of the smart trashcan. This approach allowed the researchers to explore new ideas and refine their designs while ensuring that the resulting smart trashcan meets the practical needs of users. By utilizing the constructive research technique, researchers could iteratively enhance their prototype based on feedback and real-world applications.

Theorems, Algorithm, and Mathematical Model

This section dives thoroughly into theorems, methodologies, and mathematical models relevant to the issue.

YOLO Object Detection

Joseph Redmon's[3], "You Only Look Once," introduced the YOLO algorithm, a real-time object recognition method for image classification. This article introduces object detection, the YOLO algorithm, and its open-source implementation, Darknet, which is a significant advancement in computer vision. Object detection is widely related to self-driving cars and video surveillance that uses computer vision and LIDAR technologies to generate a multidimensional representation of the road, aiding in crowd monitoring, terrorist prevention, and customer experience analysis.

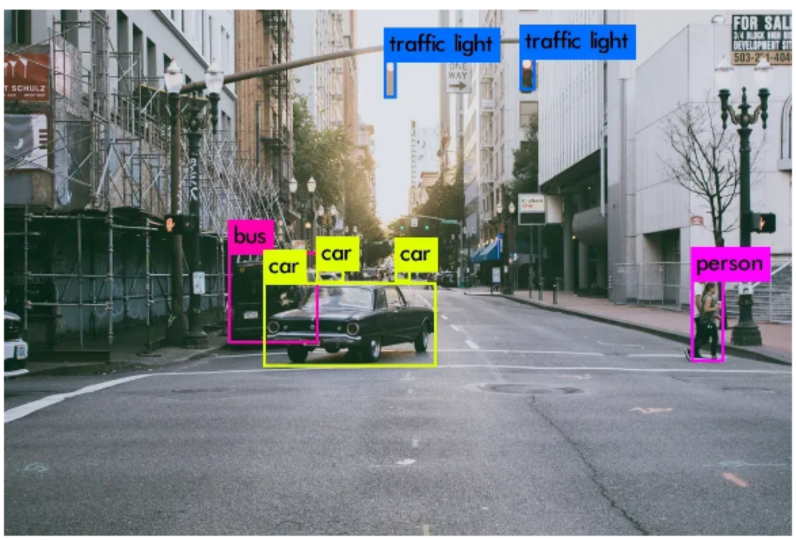


Figure 1: **Annotated Street Scene**

To understand the notion of object detection, start with image classification. Image classification progresses via layers of incremental complexity. First is image classification, which is when researchers assign or label images in different categories[3]. In this study, researchers labeled different images with specific objects before training the model, this is to train the model that a particular image is identified as one object which means, one image has only one category assigned to it. Next, is the classification and localization process, in this part object localization enabled us to locate the object in the image. Based on the different categories that the researchers labeled, the model itself can now identify if that image is in what category. Lastly, with object detection, the model will find all of the objects in an image and draw bounding boxes around them, at this part the model itself can identify multiple objects at the same time in one frame, as seen in Figure 1 for visualization.

Materials and Statistical Tools/Evaluation Methods

This section provides the material and statistical tools used in the study.

Instrument

Researchers employed the following techniques to collect data in a structured way. These methods can efficiently ensured the success of the study.

Data preparation

This section outlined the dataset creation process, data collection techniques, and augmentation strategies used to ensure diversity and balance in the dataset.

Dataset

Researchers manually created the dataset, by collecting necessary data on specific objects and combining them to create an object detection dataset specially designed for indoor research scenarios.

Data Gathering Procedure

The researchers critically analyzed some strategies to gather valuable data to build the prototype DOLLY successfully. Researchers will collected data manually by creating a new dataset with specific classes for object detection.These will served as the base for categorizing classes as objects and successfully identifying the target object.

Software and Hardware tools

This section covered the software and hardware tools utilized by the researchers to build the prototype.

Table 1
Software Specification

Software Tools	Specification
Programming Language	Python, C++
Libraries	Ultralytics
Algorithm	Yolo algorithm
Integrated Development Environment (IDE)	Visual Studio Code, Google Colab, Arduino IDE
PICO Voice	Porcupine Wake Word

Programming language. Python is one of the high-level programming languages that is widely used in robotics for its simplicity and large standard library. It was used to write the software code that eventually controlled Dolly's actions. Algorithms. YOLO Algorithm The YOLO (You Only Look Once) is an algorithm with a real-time object detection system. Integrated Development Environment(IDE). Visual Studio Code is one of the in-demand code editors that supports Python and many other programming languages. It was used to write and debug the Python code for Dolly. Libraries. TensorFlow is one of the powerful open-source software libraries for machine learning and artificial intelligence. It was utilized to train AI model that can recognize voice commands and thumbs up gestures.

Table 2
Hardware and Object Specifications

Hardware Tools/ Object	**Specifications**
Raspberry Pi 4	CPU: Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
Arduino Uno	Microcontroller: ATmega328P Architecture: AVR Operating Voltage: 5V Input Voltage (recommended): 7-12V via barrel jack or VIN pin Input Voltage (limit): 6-20V via barrel jack or VIN pin Digital I/O Pins: 14 (of which six provide PWM output) Analog Input Pins: Six DC Current per I/O Pin: Max. 40mA DC Current for 3V3 pins: Max. 50mA Flash Memory: 32KB ATmega328P (0.5KB used by bootloader) SRAM: 2KB ATmega328P EEPROM: 1KB ATmega328P Clock Speed: 16MHz
Battery/Power Bank	Capacity: 20000mAh 5V 3A
Jumper Wires	Female to Male/Male to Male/Female to Female
Webcam	Full HD 1080p/30fps, HD 720p/60fps
Robot Car Chassis	Material: Acrylic Plate Size: 135mm x 75mm
USB Microphone	Type: Condenser (electret bias) Frequency Response: 50 to 17,000 Hz Signal to Noise Ratio: ¿60dB Frequency Range: 470-952 MHz Connector: 1.2 meter (4ft) cable terminated with a miniature Switchcraft TA4F connector
Wheel	42x19mm
Wheel Tire Set	1 wheel with 2 rubber band tires
Trashcan	Small-size trash can
220 Ohms Resistor	Resistance: 220 ohms
Green LED	Color: Green Forward Voltage: 2.0V Current: 20mA

As shown in Table 2, Raspberry Pi 4 is a small powerful computer with a Quad-core Cortex-A72 (ARM v8) 64-bit SOC running at 1.8GHz. It served as the brain of Dolly, running the Python code that controls Dolly's actions. Arduino Uno. Controls lower-level tasks such as managing the motor movements and responding to sensor data. Battery/Power bank. This will provided the power needed for the autonomous Dolly trashcan to operate. Jumper Wires. These were used to connect the various electronic components of Dolly. Webcam. This device captured video at full HD (1080p/30fps) or HD (720p/60fps), which is then processed by the YOLO algorithm to recognize gestures. Servo MG995 12kg 360 degree. This motor drived Dolly's movements. Its speed and torque can be controlled by the Python code that controls the servo motor to spin the wheels precisely. LED. Provided visual status feedback. DC 5V to 12V USB Cable Step up Boost Converter. Converted USB 5V power to higher voltages required by specific components like servo motors Robot Car Chassis. Served as the base plate of the prototype where main components are mounted. Wheels. This thing allowed Dolly to move around and the Python code controled the DC motor to spin the wheels. Trashcan. This is the main component of Dolly, which collected the trash.

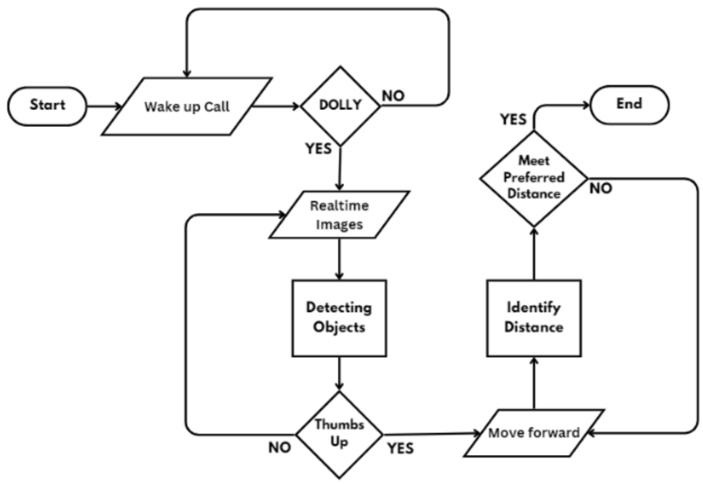


Figure 2: **Flowchart Model**

Flowchart

The autonomous navigation trashcan process is visually represented by the model flowchart depicted in Figure 2. This flowchart serves as a detailed reference to the sequential stages and decision points involved in the system's structure and operation. The method begins with the 'Wake-up Call' process. The model activates and starts the real-time picture input process when it comes across the word "DOLLY". The data that has been input is then tasked with detecting objects. If a thumbs up is identified, the system goes immediately to the Navigation procedure. The algorithm is developed to maintain a process to determine if the Preferred Distance has been met. When this condition is met, the model terminates its operation. This flowchart highlights the complicated logic related to autonomous navigation systems, particularly in scenarios integrating human-robot interaction and gesture detection. The flowchart's methodology highlights the importance of conditional processing and repeated feedback loops in achieving accurate and responsive system performance.

Evaluation Tools

In this section, researchers evaluated DOLLY's object detection model. These metrics convey how this model performs using accuracy, precision, recall, and the F1 score. The following evaluation metrics helped the researchers to examine the model's algorithm performance.

Accuracy.

The researchers utilized this process to measure the proportion of correct predictions made by the model[1]. This identified the accuracy of the model in classifying multiple objects, the formula for calculating accuracy is provided in the image below.

$$\text{Accuracy} = \frac{\text{True Positives (TP)} + \text{True Negatives (TN)}}{\text{Total Predictions}} \tag{3.1}$$

Where:

TP = True Positive

TN = True Negative

Precision.

Researchers utilized this strategy to assess the model's positive prediction accuracy[1]. It was calculated by dividing TP by the sum of TP and FP. The formula for calculating precision is provided below:

$$\text{Precision} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Positives (FP)}} \tag{3.2}$$

Where:

TP = True Positive

FP = False Positive

Recall.

The researchers used this technique because it calculates the number of true positive predictions among all real positive occurrences[1]. It was computed as the ratio of TP to the sum of TP and FN. The formula for calculating recall is provided in the image below.

$$\text{Recall} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Negatives (FN)}} \tag{3.3}$$

Where:

TP = True Positive

FN = False Negative

F-measure.

Researchers utilized the F1 score, which is a measurement that evaluates both precision and recall[1]. This method provided a balance between high precision and high recall. The formula for calculating the F1 score is provided in the image below.

$$F1 = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \tag{3.4}$$

Where:

The harmonic mean of precision and recall = 2 (Precision * Recall) Total number of precision and recall of the model = Precision + Recall

Table 3
Sample Test Case

Test Step	Description	Expected Result
Step 1	Power on the prototype	Dolly in idle state
Step 2	Say wake word: ”Hey DOLLY”	LED lights up for 3 seconds
Step 3	Observe object detection mode	LED blinks
Step 4	Detects thumbs-up gesture	Move forward
Step 5	Remove thumbs-up gesture	Dolly stops and continues detecting
Step 6	New thumbs-up gesture	Dolly moves forward again
Step 7	Meet preferred distance	Dolly immediately terminates the program

Sample Test Case

Researchers prepared a sample test case scenario to assess the operation and usability of the “Dolly” prototype. As shown in Table 3, the main objective is to ensure that wake word detection, gesture recognition, and motor control function consistently to meet expectations. The scenario mimics a real interaction where “Dolly” identifies a wake word, interprets a hand gesture (like a ”thumbs-up”), and reacts by adjusting movements and displaying a visual response via an LED indication. Researchers evaluated the prototype’s performance in various conditions. This process ensured the prototype meets initial design standards and functions as intended when engaging with users. This method helped uncover potential limitations, allowing the team to make necessary adjustments to improve the system for real-world deployment. Each critical function, like wake word detection, gesture recognition, and motor control, was broken down into clear, measurable steps, ensuring all aspects were tested thoroughly. From activating the prototype to responding to specific gestures, the test the system’s performance as it should appear in real-world conditions. The test case affirmed that Dolly is compliant with the initial design requirements, ensuring reliability and usability in practical applications.

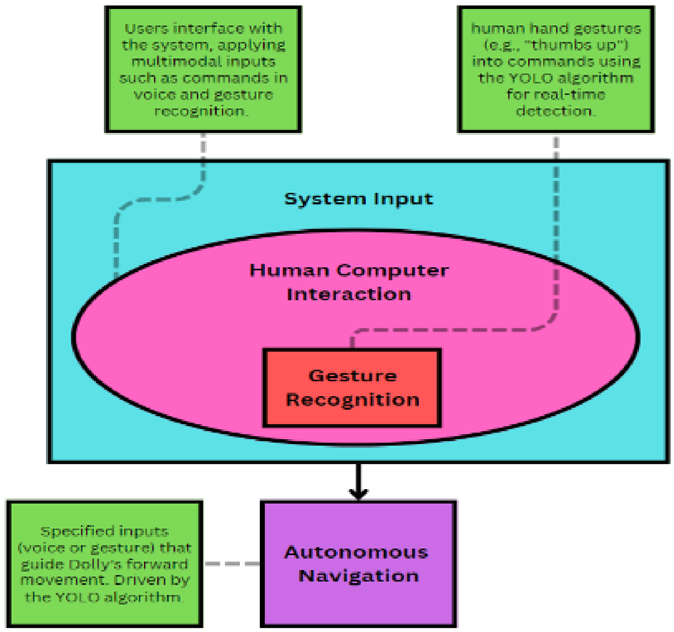


Figure 3: **Theoretical Framework**

Theoretical Framework

As Figure 3 shows this project aimed to create DOLLY, a smart trashcan that can travel independently using voice activation and gesture detection. The YOLO (You Only Look Once) object detection algorithm is used in the project to combine voice-activated technology, gesture-based interface, and autonomous navigation. Human-Computer Interaction (HCI), Gesture Recognition Theory, and Autonomous Robotic Navigation are the three primary fields that define this framework.

Human-Computer Interaction (HCI)

Gesture recognition technology interprets human hand gestures into commands for a computer system. The Sign Language Theory of Gesture Recognition (Mitra and Acharya, 2007) divides gestures into static and dynamic categories. Static gestures feature particular hand position, and dynamic gestures include movement. In the instance of DOLLY, the system used the YOLO algorithm to recognize certain hand motions like “thumbs up” that caused the trashcan to move. Research suggests that implementing gesture recognition into interactive systems may considerably increase user engagement and usability Wachs et al. [2011]. Gesture-based interfaces are intuitive and may be rapidly learnt, minimizing the cognitive strain on users. The use of the YOLO algorithm for real-time gesture detection guarantees high-speed and precise identification, which is vital for a seamless user experience in an autonomous system like DOLLY.

Autonomous Robotic Navigation

Mobile robotics involves robots moving and navigating the surroundings without assistance from humans, therefore, navigation by self is a vital aspect of robotics. Mobile Robot Path Planning (Latombe, 1991) is the basic idea of this research. It emphasizes on the effective and secure planning and movement of robots inside a given area. Through the detection of objects, DOLLY employs the YOLO algorithm to recognize them in real-time, allowing the smart trashcan to move on its own. The YOLO algorithm is especially ideal for this application since it delivers real-time object detection with good accuracy, regardless of small or slightly concealed objects Redmon et al. [2016]. This enabled DOLLY to detect hand gestures with the aim of providing secure and effective movements

Notes

[1] Stephen M. Walker II. 2023. F-score: what are accuracy, precision, recall, and f1 score? Retrieved from: 2024-12-19. (July 2023). https://klu.ai/glossary/accuracy-precision-recall-f1.

[2] Kari Lukka. 2003. The constructive research approach. Retrieved from: 2024-12-19. https://www.researchgate.net/publication/247817908_The_Constructive_Research_Approach?fbclid=IwY2xjawHRFyJleHRuA2FlbQIxMAABHTKgMuQiNsG8tEgNpXFxy0iMBoHhOt_p8ZPx4Iom-rq1oJyLjGTLaqI-KA_aem_4m39pVuyR8ABF7gqaLCl8A.

[3] Jedrzej Świeżewski. 2022. Yolo algorithm and yolo object detection. Retrieved from: 2024-12-19. (Mar. 2022). https://www.appsilon.com/post/object-detection-yolo-algorithm.

CHAPTER 4

RESULTS AND DISCUSSION

This section examines the conclusions and conversations around the conception, creation, and testing of the intelligent trash can Dolly. The gadget combines several hardware and software components to fulfill its intended functions. The chapter describes the results of merging the wake word detection and object identification utilizing YOLO, servo motor control, and ultrasonic sensor modules into a coherent system. The project shows Dolly's ability to react to wake words, identify hand signals with the thumbs up, and move effectively in the user's direction.

Model Training and Evaluation

This section outlines the process of developing and testing the YOLO algorithm for autonomous navigation of the smart trashcan. This involves training the model on a custom dataset of annotated images to recognize specific gestures, such as 'thumbs up,' and evaluating its performance using key metrics, including accuracy, precision, and inference time. The trained model is then validated in real-world scenarios to ensure reliable detection and responsiveness, forming the foundation for the trashcan's autonomous navigation and interaction capabilities.

Data Gathering

Researchers gatherd .jpg images as data for object detection, images were captured using a Tecno Camon 20 Pro 5G Android phone camera. Different lighting conditions, distance and angles were used to simulate realistic scenarios. The researchers captured images in an office environment for better background visualization of the model in its detection process to detect the object even though with some background noise like to enhance the model's robustness in diverse settings. Added by some images online researchers collected enough data to be able to train the model. The dataset consisted of 1699 total images, the team utilized roboflow for annotating captured images and creating dataset. Furthermore, each image was manually annotated using Roboflow's annotation tool to create bounding boxes around gestures. The labels were set as either thumbs up or thumbs down, forming the basis of the object detection model.

Figure 4: **Preprocessing and Augmentation**

Data Preprocessing/Augmentation

As shown in Figure 4, researchers employed cropping and noise augmentation methods in the roboflow, as well as Auto-Orient, Auto-Adjust Contrast utilizing Histogram Equalization, and Resize to expand the picture size to 640 x 640 preprocessing approaches to boost the model's generalization. In Using datasets, 20% was used for validation, 10% for testing, and 70% for training. The group used Roboflow augmentations to gather 4,073 pictures into a dataset; 347 were valid datasets, 3,561 were train datasets, and 165 were test datasets. The dataset had three split ratios: 4% for testing, 9% for validation, and 87% for training.

Training Configuration

Using the free T4 GPU Hardware Accelerator, the researchers trained the YOLOv8 model in the Google Colab. Upon that, the model was converted to PyTorch format for Raspberry Pi use. Additionally, several hyperparameters were used to create the most accurate and efficient model possible. Because Ultralytics is renowned for creating state-of-the-art computer vision technology, it is available via them. Several hyperparameters required for model training are set to their default values.

```
from ultralytics import YOLO
model=YOLO("yolov8n.pt")
results = model.train(data="/content/Hand-gestures-9/data.yaml", epochs=100, imgsz=640)
```

Figure 5: **Training Configuration**

The researcher set the batch size to 16 by default and the learning rate to 0.01 for this particular experiment. For better training with this high number of datasets showed in Figure 5, epochs were set to 100 and assisted the model in becoming more accurate and more broadly applicable. Additionally, since 640×640 is a standard figure for picture size, it was chosen for its efficient computation process. As a result, the model training was quicker and lighter. Moreover, the AdamW optimizer was applied by default for enhanced training performance.

Model Performance Metrics

The performance of the created YOLOv8 model was evaluated using several critical criteria to ascertain how effectively it recognized gestures. The Mean Average Precision (mAP), tested at 95%, calculated by averaging the model's precision across different recall levels at an Intersection over Union(IoU) threshold of 0.50. This high score indicates that the model consistently detected the gesture with minimal false positives and false negatives across different perspectives and lighting conditions.

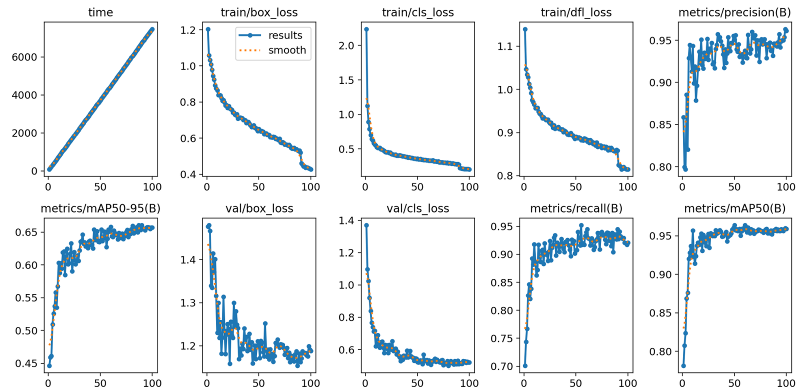


Figure 6: **Model Performance Metrics**

As shown in Figure 6 the model showed a balanced performance between recall and precision by efficiently limiting false positives while identifying the majority of true positives, with a 94% recall rate and a 94% accuracy rate. Moreover, the inference time of the Raspberry Pi ranged from 600 to 800 milliseconds for each frame, suggesting that the model could still perform real-time detections despite the hardware constraints. These results indicated that the model matched the prototype system well since it can reliably identify gestures in various lighting and environmental conditions. Lastly, the modified Yolov8 model was exported using the best.pt format.

Voice Activation

This section showed that Porcupine Wake Word, developed by Picovoice, is an advanced and highly accurate voice activation engine designed for always-listening applications. It enables the detection of custom wake words, such as "Hey Dolly," by utilizing deep neural networks trained in real-world environments. The engine efficiently processes incoming audio, identifying the predefined phrase with minimal latency, even in noisy conditions. Developers can create custom wake words through the Picovoice Console, which employs transfer learning to generate production-ready models without requiring extensive machine learning expertise.

Porcupine achieves over 97% detection accuracy with fewer than one false activation per 10 hours of background speech[1]. Compared to other wake word detection engines, it is significantly more accurate and faster, making it a reliable solution for voice-enabled applications. Its efficiency ensures smooth performance on resource-constrained devices, such as the Raspberry Pi 4, while maintaining responsiveness in various acoustic environments. With these capabilities, Porcupine provides an effective way to implement hands-free voice activation using custom phrases like ”Hey Dolly.”

Model Integration and Prototype Development

This part shows the integration of the learned YOLOv8 model with Dolly's hardware components. The hardware arrangement made exact gesture detection, safe distance interaction, and effortless mobility feasible.

Prototype Mock-Up Design

Figure 7 shows a two-technical view model "MODEL FRONT VIEW" and "MODEL SIDE VIEW. These model mock-up designs respectively represent the conceptual robotics design for the device called "DOLLY "a voice activation and thumbs up gesture autonomous trashcan. The side view includes components like a trash guard, trash bin, Raspberry pi 4B model, servo motor, and rear wheels. The trash guard protects the trash bin, while the trash bin is likely used for collecting trash. The Raspberry Pi 4B model is a microcomputer that is programmable to control the robot. The front view includes power cables, LED lights and a resistor, an arduino board, jumper wires, a webcam, wireless earphones, and front wheels. The power cables supply power to various components such as Raspberry Pi and servo motors, and the LED light and resistor indicate once it has been activated through voice activation.

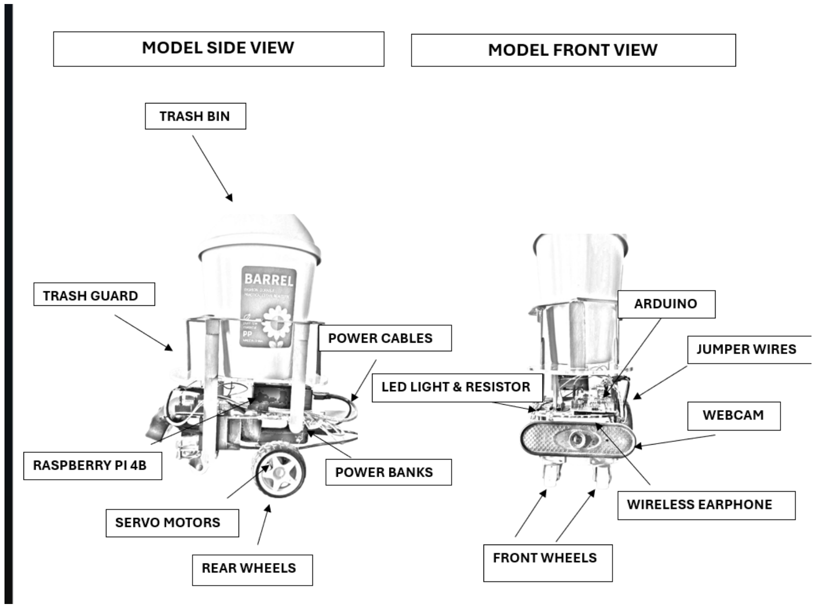


Figure 7: **Prototype Mockup Design l**

The power banks provide a portable power supply, and the Arduino board is another microcomputer for additional functionalities. The jumper wires connect different components, and the webcam is used for capturing and navigating the thumbs-up hand gesture. the wireless earphone the researchers used it as a mic so that it accurately captures the word “HEY DOLLY” to activate the robot and the front wheels assist the rear wheels in movements. The robotics device seems to be designed for waste collection, with remote monitoring and control capabilities.

Schematic Diagram

The schematic design in Figure 8 displays the hardware architecture for the robot’s movement control and gesture recognition, integrating a Raspberry Pi 4, Arduino UNO, voltage converter, ultrasonic sensor, camera, and servo motors. The Raspberry Pi evaluates the video stream from the camera to identify a “thumbs-up” motion using the YOLOv8 model and interacts with the Arduino UNO via serial interface.

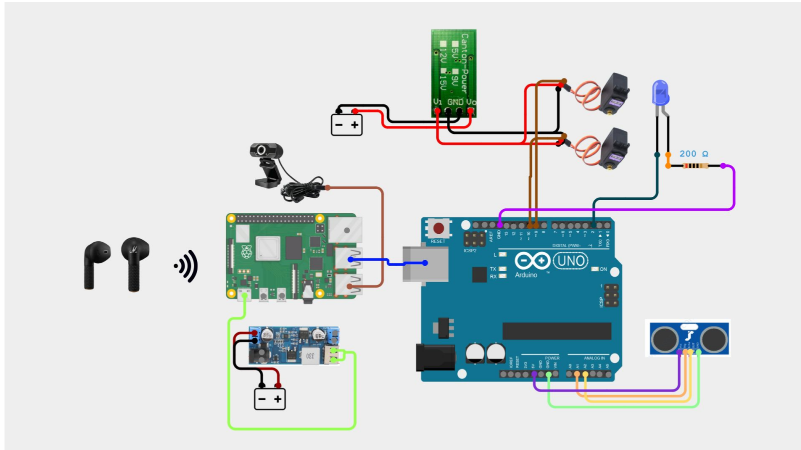


Figure 8: **Prototype Schematic Diagram**

The Arduino controls the servo motors for directional movement, an LED indication for system status, and an ultrasonic sensor for detecting the specified distance. Servo motors are attached to PWM pins on the Arduino to initiate movement, while the ultrasonic sensor continually analyzes the robot's route for blockage. Power for the servos and peripherals is provided by a voltage converter linked to an external power source. The process involves the camera taking live video, the Raspberry Pi recognizing motions, and the Arduino reacting to signals by driving the robot ahead. The ultrasonic sensor assures the specified distance to stop, while an LED offers visual feedback, producing a fully integrated system for real-time robotic movement control based on gesture detection.

Hardware Components

As shown in Figure 9, Dolly trashcan prototype was built with various critical hardware components for real-time gesture detection, navigation, and interaction functionalities. The Raspberry Pi 4 Model B is the system's central controller, and it employs the YOLOv8 object detection model to identify user thumbs-up actions. A USB webcam has been added to take real-time images and detect thumbs-ups. An Arduino Uno is utilized to accept orders from the Raspberry Pi and control the movement of the MG995 Servo Motors. Dolly's wheels are continuous rotation servos, providing fine control over forward and

Figure 9: **Hardware Components**

rotational motions. When the user gets near enough to dispose of waste, Dolly will stop at the specified distance due to the system's HC-SR04 Ultrasonic Sensor, which accurately measures their distance. Furthermore, a small LED Module highlights system parameters like wake word recognition, active scanning, and motion with visual feedback to boost user involvement and transparency. These components work together to create Dolly, an interactive, intelligent trashcan that achieves its objectives.

Software Integration and Control

Dolly's software integration and control consist of several interrelated parts to accomplish intelligent and responsive behavior. The pvporcupine and pyaudio libraries create wake word detection, allowing the system to listen for the keyword "Hey Dolly" and initiate object identification upon recognition. A custom YOLOv8 model is used for Gesture Detection and Navigation to recognize gestures like a "thumbs up." Dolly approaches the user safely and steadily by moving slowly until the distance drops below 50 cm, signifying that the user is ready to dispose of trash. The Distance Reading function further improves Dolly's behavior, which is made possible by integrating an ultrasonic sensor. This feature prohibits the trashcan from moving forward if the user is nearby by stopping its motions within an appropriate distance. Serial communication between the Arduino and Raspberry Pi has been utilized to control all motion-related functions. The Arduino receives commands like F_SLOW (go ahead) and STOP (stop movement) to control the servo motors accurately, enabling seamless navigation and interaction.

Prototype Performance

This section looks at how well the smart trash can works, how reliable it is, and how well it can find its way around on its own. This includes testing whether the system can recognize gestures, react to inputs, and find the object being tested. Key performance measures, including recognition speed and tracking accuracy, are evaluated at to make sure the prototype works well overall and can be used in the real world.

Table 4
Sample Test Case

Test Step	Description	Expected Result	Pass/Fail
Step 1	Power on the prototype	Dolly in idle state	Passed
Step 2	Say wake word: ”Hey DOLLY”	LED lights up for 3 seconds	Passed
Step 3	Observe object detection mode	LED blinks	Passed
Step 4	Detects thumbs-up gesture	Move forward	Passed
Step 5	Remove thumbs-up gesture	Dolly stops and continues detecting	Passed
Step 6	New thumbs-up gesture	Dolly moves forward again	Passed
Step 7	Meet preferred distance	Dolly immediately terminates the program	Passed

System Testing

The system testing phase aimed to evaluate the effectiveness of the prototype, DOLLY, in executing its intended functions based on predefined commands and gestures. A single test run was conducted to evaluate the system’s performance under controlled conditions. Table 4 displays the test results, confirming that the prototype effectively responded to all anticipated inputs and performed the designated actions as intended.

The findings demonstrate that DOLLY effectively recognized the wake word, activating the LED indicator for a duration of three seconds as anticipated. The object detection mode was activated, confirming the system’s capability to recognize objects within its detection range. The YOLO-integrated model successfully recognized the ’thumbs-up’ gesture, leading to DOLLY’s forward movement. The system appropriately stopped operation upon the removal of the gesture, while continuing to remain in detection mode. When the ‘thumbs-up’ gesture was reintroduced, DOLLY resumed movement, demonstrating the reliability of its gesture-based activation. The ultrasonic sensor effectively recognized the specified stopping distance, ensuring that the prototype ended operation to avoid unintended movement.

The results of this preliminary test indicate that DOLLY met expectations across all assessed criteria, satisfying its functional requirements. The results align with the study conducted by Zhou et al. (2024)[2] on smart waste management systems, which demonstrated that integrating object detection technology enhances automation and efficiency in waste disposal. Their research demonstrated that smart bins employing real-time object detection attained high accuracy in identifying waste materials and responding appropriately, akin to DOLLY's successful gesture recognition and execution of predefined actions. The consistency between DOLLY's performance and prior studies supports the validity of its results and confirms its potential applicability in real-world scenarios.

Although the recorded test run demonstrates that DOLLY meets its intended functionality, further testing under diverse conditions is recommended to ensure its robustness and reliability. Conducting additional trials will strengthen the evaluation and provide deeper insights into its effectiveness in different environments.

Notes

[1] Picovoice AI. 2025. Porcupine wake word engine. Accessed: February 22, 2025. (2025). https://picovoice.ai/platform/porcupine/.

[2] Z. Zhang and W. Zhu. 2024. Yolo-mfd: remote sensing image object detection with multi-scale feature distillation. en. *Computers, Materials & Continua*. Accessed from TechScience. https://www.techscience.com/journal/cmc.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter highlights the research's primary results, delivers project-based conclusions, and suggests future development and enhancements to the intelligent trashcan, Dolly.

Summary

The goal of this project is to develop and test "Dolly," a smart, autonomous trashcan prototype that employs safe navigation and gesture recognition to move and communicate with people. During testing, the project's YOLOv8 object detection algorithm achieved a mean average precision (mAP) of 95% and recall of 94% after being trained on a custom dataset of 1,699 annotated images to identify gestures like "thumbs up." The dataset was first processed and optimized to enhance model generalization. With inference durations varying from 600 to 800 milliseconds per frame, the model was optimized for real-time detection on a Raspberry Pi.

The hardware integration consists of an Arduino Uno for motor control, a Raspberry Pi 4 Model B for processing, MG995 servo motors for movement, an HC-SR04 ultrasonic sensor for obstacle detection, and an LED module for user input. By utilizing Porcupine for wake word detection ("Hey Dolly"), gesture recognition initiates, allowing Dolly to approach humans and safely stop within a 50 cm distance. With directives like F_SLOW and STOP offering precise motion control, software integration guarantees efficient interaction between components.

Performance tests showed accurate motion recognition across different lighting and environmental conditions. Dolly achieved 7 out of 7 expected results, proving its fit for application in real life and its capability for future improvement. This project shows the successful mix of machine learning, hardware components, and software integration to build a smart, flexible system for autonomous waste cleanup.

Findings

The main findings and observations from the creation, instruction, and testing of the smart trashcan prototype are presented in this part. In order to validate the efficacy of the YOLOv8 model, hardware integration, and software design in accomplishing the project's goals and guaranteeing dependable operation in real-world scenarios, they highlight the system's performance in gesture recognition, real-time accessibility, navigation accuracy, and overall functionality.

1. This reveals that the YOLOv8 model, trained on a customized and augmented dataset of 1,699 images, achieved a mean average precision (mAP) of 95% with a balanced recall and accuracy rate of 94%. The model demonstrated reliable gesture detection for "thumbs up" and "thumbs down" across varying lighting conditions and perspectives. Additionally, with an inference time of 600–800 milliseconds per frame on the Raspberry Pi, the model proved capable of performing real-time detection despite hardware limitations, confirming its suitability for the prototype's autonomous navigation system.

2. This shows the successful combination of the YOLOv8 model with Dolly's hardware and software components, allowing real-time gesture recognition, navigation, and interaction. The Raspberry Pi 4 Model B, acting as the primary driver, successfully utilized the YOLOv8 model to identify "thumbs up" motions with high accuracy, while the USB webcam provided reliable real-time image capture. The MG995

servo motors and HC-SR04 ultrasonic sensor provided exact movement and safe distance interaction, allowing Dolly to travel easily and stop at suitable distances.

The software sections, including wake word detection through pvporcupine and gesture recognition via the YOLOv8 model, worked smoothly to start detecting objects and react to user interactions. The inclusion of the ultrasonic sensor further improved safety by stopping unexpected forward moves when users were close. Serial contact between the Raspberry Pi and Arduino enabled precise motion control, allowing Dolly to perform its intended jobs consistently. These results support the usefulness of the combined system in achieving innovative, simple, and safe functioning.

3. This demonstrates the responsiveness, dependability, and adaptability of the prototype for practical use. Testing of the system revealed that, under stable settings, the wake word recognition system successfully identified the keyword “hey dolly” and showed resilience to a range of sound sources. With a recognition accuracy of 95% mAP50 for “thumbs up” gestures, the YOLOv8 model demonstrated its versatility in dynamic environments by operating consistently across a range of perspectives and lighting circumstances.

   Furthermore, the ultrasonic sensor prevented Dolly from moving forward unintentionally by precisely recognizing users within 50 cm, ensuring a safe and seamless interaction. The prototype demonstrated its capacity to consistently navigate, identify gestures, and react to user inputs, effectively meeting all seven of the expected outcomes. These outcomes validate the prototype’s efficacy, dependability, and opportunity for future innovation in accomplishing the project’s intended stated objectives.

Conclusion

Based on the findings of the research, the following conclusions can be drawn:

1. The data from the model training and assessment phase indicate the effectiveness of the YOLOv8 model in obtaining excellent performance for gesture recognition in the smart trashcan prototype. Trained on a carefully chosen and supplemented dataset of 1,699 photos, the model obtained a remarkable mean average precision (mAP) of 95%, with a balanced recall and accuracy rate of 94%. This displays the model's ability to consistently distinguish "thumbs up" and "thumbs down" gestures across varied lighting conditions and different points of view, which is crucial for the prototype's real-world process.

   Despite the processing restrictions of the Raspberry Pi, the model maintained an inference time of 600-800 milliseconds per frame, which suggests capable of real-time gesture recognition. These findings demonstrate the model's appropriateness for usage in the autonomous navigation system of the smart trashcan, guaranteeing both accurate gesture detection and responsiveness. Overall, the results suggest that the YOLOv8 model can successfully satisfy the project's objectives, delivering accurate gesture recognition for smooth interaction with the trashcan.

2. The hardware and software components of the Dolly trashcan prototype were successfully integrated with the YOLOv8 concept. The Raspberry Pi 4 Model B, operating as the central controller, employed the YOLOv8 model for real-time gesture recognition, correctly identifying "thumbs-up" movements, which are fundamental to the trashcan's operation. The inclusion of a USB camera for picture capture, MG995 servo motors for motion control, and an HC-SR04 ultrasonic sensor for distance measurement ensured that the Dolly could move successfully and engage securely with persons.

The software components, including wake word detection using the pvporcupine library and gesture recognition via the YOLOv8 model, functioned effectively to trigger object identification and react to user motions. Additionally, the ultrasonic sensor played a crucial part in avoiding unintentionally forward motion by identifying users within a 50 cm range, assuring safe contact. The serial connection between the Raspberry Pi and the Arduino allowed for precise control of Dolly's motions, verifying the system's dependability in real-world situations. Overall, the findings demonstrate that the combined hardware and software system delivers intelligent, responsive, and safe functioning, satisfying the project's aims for a completely autonomous trashcan prototype.

3. The system testing phase proved the prototype's capacity to consistently fulfill its intended functions in real-world settings. The wake word recognition system successfully identified the phrase "Hey Dolly," which shows resilience in varied physic5al settings. The YOLOv8 model also performed well, reaching an identification accuracy of 95% mAP50 for "thumbs up" gestures, even under different lighting conditions and from different points of view. This performance guaranteed that the trashcan could reliably recognize gestures, enabling smooth user engagement.

   Furthermore, the ultrasonic sensor efficiently stopped Dolly from going forward when the user was too near, assuring safety during interactions. The prototype fulfilled all seven portrayed outcomes, indicating that it could understand gestures, react to human inputs, and travel autonomously with dependability and accuracy. These findings suggest that the prototype is not only effective and trustworthy but also adaptable to a number of real-world settings. The successful completion of system testing indicates the prototype's suitability for further development and prospective deployment since it fits the project's aims and sets the platform for future developments.

Recommendations

Based on the findings and conclusions, the following recommendations are proposed for future work and improvements:

1. Optimizing the accuracy of wake word recognition in loud conditions will increase Dolly's applicability in more scenarios. This might be done by experimenting with improved speech recognition models or noise cancellation methods.

2. Since the YOLOv8 model functioned well, additional hyperparameters and dataset variety tuning might lead to greater accuracy. Additionally, studying additional lightweight models or quantified versions of YOLOv8 might minimize inference time and boost performance on the Raspberry Pi.

3. Upgrading the hardware is suggested to achieve more responsive and optimal performance in real-time. Instead of utilizing the Raspberry Pi, more advanced and higher-performance devices such as the NVIDIA Jetson Nano or a mini PC might be considered. These devices give additional computing power, allowing much faster inference times, better functioning, and the capacity to tackle more complicated tasks in future versions of Dolly. A more robust hardware arrangement would enable the system to handle more extensive datasets and complex applications efficiently.

4. Applying Dolly's obstacle avoidance technology to detect and respond to more minor or more complex obstacles could enhance functionality. Additional sensors or camera-based depth perception algorithms might be implemented to increase the perception of the environment.

5. Future studies might examine improving Dolly for more technically advanced functions, such as detecting other motions or considering extra features like automated

waste sorting or disposal. Applying the technology in bigger, more dynamic scenarios, such as public areas, might further determine its durability and flexibility.

6. Strengthening the device's energy economy by optimizing hardware usage, minimizing idle power consumption, and adding sleep modes during inactivity might make Dolly more appropriate for long-term, unsupervised operation.

7. To further improve the functionality and usability of the smart trashcan prototype, it is recommended to integrate a new feature that enables the prototype to return to its original position after completing its tasks. This enhancement will allow the prototype to operate in a continuous cycle, thereby increasing its efficiency and effectiveness in waste management.

BIBLIOGRAPHY

Book Sources

World Bank Group. 2023. *Solid waste management*. en. (Mar. 2023). https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management.

Journal Articles

arpnjournals.org. 2021. Coinic-ph: a philippine new generation series of coin intelligent classification inference approach for visually impaired. *ARPN Journal of Engineering and Applied Sciences*. Accessed: 2024-12-19. http://www.arpnjournals.org/jeas/research_papers/rp_2021/jeas_1021_8713.pdf.

Muhammed Enes Atik, Zaide Duran, and Roni ÖZGÜNLÜK. 2022. Comparison of yolo versions for object detection from aerial images. *International Journal of Environment and Geoinformatics*, 9, 2, 87–93.

Enhui Chai, Lin Ta, Zhanfei Ma, and Min Zhi. 2021. Erf-yolo: a yolo algorithm compatible with fewer parameters and higher accuracy. *Image and Vision Computing*, 116, 104317.

Nurin Mirza Afiqah Andrie Dazlee, S. Khalil, Shuzlina Abdul-Rahman, and Sofianita Mutalib. 2022. Object detection for autonomous vehicles with sensor-based technology using yolo. *International Journal of Intelligent Systems and Applications in Engineering*, 10, 1, (Mar. 2022), 129–134. DOI: 10.18201/ijisae.2022.276.

Xuan Di and Rongye Shi. 2021. A survey on autonomous vehicle control in the era of mixed-autonomy: from physics-based to ai-guided driving policy learning. *Transportation Research. Part C, Emerging Technologies*, 125, (Apr. 2021), 103008. DOI: 10.1016/j.trc.2021.103008.

John Paul S Endaya, Ferdinand Jr Mabitasan, and Jonela Cyvel Mae Gonzales. 2020. Design and implementation of automated waste segregator with smart compression. *LPU-Laguna Journal of Engineering and Computer Studies*, 4, 3, 1–1.

Ximing Fei, Piaopiao He, Haoran Ma, and Yiming Qiu. 2024. Enhancing urban waste management: development and application of smart garbage bin technologies. *Science and Technology of Engineering, Chemistry and Environmental Protection*, 1, 5.

Rongli Gai, Na Chen, and Hai Yuan. 2023. A detection algorithm for cherry fruits based on the improved yolo-v4 model. *Neural Computing and Applications*, 35, 19, 13895–13906.

Muhammad Hussain. 2023. Yolo-v1 to yolo-v8, the rise of yolo and its complementary nature toward digital manufacturing and industrial defect detection. *Machines*, 11, 7. DOI: 10.3390/machines11070677.

Yong-Hwan Lee and Youngseop Kim. 2020. Comparison of cnn and yolo for object detection. *Journal of the semiconductor & display technology*, 19, 1, 85–92.

Martin Naya-Varela, Sara Guerreiro-Santalla, Tamara Baamonde, and Francisco Bellas. 2023. Robobo smartcity: an autonomous driving model for computational intelligence learning through educational robotics. *IEEE Transactions on Learning Technologies*, 16, 4, 543–559. DOI: 10.1109/TLT.2023.3244604.

Taufiq Nuzwir Nizar, R. W. Tri Hartono, and D. Meidina. 2020. Human detection and avoidance control systems of an autonomous vehicle. *IOP Conference Series: Materials Science and Engineering*, 879, 1, (July 2020), 012103. DOI: 10.1088/1757-899x/879/1/012103.

Robert Y. Siy. 2022. Persons with disabilities have a right to be mobile. en-US. *The Manila Times*, (Feb. 2022). Accessed: 2024-12-19. https://www.manilatimes.net/2022/02/19/business/top-business/persons-with-disabilities-have-a-right-to-be-mobile/1833450.

Edison A Villamer, Marvin T Agrade, Marlon Jay Delustre, Renato Embestro, Via Claire Mamano, Christopher Pante, Rhoderick Oliveros, Eddie Cabaltera, and Victor Solito Issac. 2022. Concealed automated trash bin with shredder for solid wastes. *Journal of Engineering and Emerging Technologies*, 1, 1, 1–7.

D Vinodha, J Sangeetha, B Cynthia Sherin, and M Renukadevi. 2020. Smart garbage system with garbage separation using object detection. *International Journal of Research in Engineering, Science and Management*, 3, 5, 779–782.

Yunhua Yin, Huifang Li, and Wei Fu. 2020. Faster-yolo: an accurate and faster object detection method. *Digital Signal Processing*, 102, 102756.

Z. Zhang and W. Zhu. 2024. Yolo-mfd: remote sensing image object detection with multi-scale feature distillation. en. *Computers, Materials & Continua*. Accessed from TechScience. https://www.techscience.com/journal/cmc.

Online Sources

AbilityX. 2024. Mobility impairment. Retrieved from: 2024-12-19. https://abilityx.io/disabilities/mobility-impairment.

BigBelly. [n. d.] Bigbelly. Retrieved Apr. 26, 2023 from https://bigbelly.com/about-us.

Encord. 2024. Object detection. Retrieved from: 2024-12-19. https://encord.com/glossary/object-detection-definition/#:~:text=Object%20detection%20is%20a%20task,analysis,%20robotics,%20and%20surveillance.

Evreka. 2024. Ultimate guide to smart bins. Retrieved from: 2024-12-19. (Oct. 2024). https://evreka.co/blog/ultimate-guide-to-smart-bins/#:~:text=Smart%20bin%20is%20the%20new,of%20your%20smart%20waste%20bins.

Stephen M. Walker II. 2023. F-score: what are accuracy, precision, recall, and f1 score? Retrieved from: 2024-12-19. (July 2023). https://klu.ai/glossary/accuracy-precision-recall-f1.

InclusionHub. 2024. How to create accessible workplaces for employees with mobility impairments. Retrieved from: 2024-12-19. https://www.inclusionhub.com/articles/how-to-create-accessible-workplaces-for-employees-with-mobility-impairments.

Fiveable Library. 2024. Voice activated devices. Retrieved from: 2024-12-19. https://library.fiveable.me/key-terms/robotics-bioinspired-systems/voice-activated-devices.

Kari Lukka. 2003. The constructive research approach. Retrieved from: 2024-12-19. https://www.researchgate.net/publication/247817908_The_Constructive_Research_Approach?fbclid=IwY2xjawHRFyJleHRuA2FlbQIxMAABHTKgMuQiNsG8tEgNpXFxy0iMBoHhOt_p8ZPx4Iom-rq1oJyLjGTLaqI-KA_aem_4m39pVuyR8ABF7gqaLCl8A.

Opengovasia.com. [n. d.] Ai to boost public safety, security in the philippines. Retrieved Aug. 2, 2022 from https://opengovasia.com/ai-to-boost-public-safety-security-in-the-philippines/.

World Health Organization. [n. d.] Disability. Retrieved from: Mar. 7, 2023. https://www.who.int/news-room/fact-sheets/detail/disability-and-health.

Waypoint Robotics. 2024. Autonomous robot definition and uses. Retrieved from: 2024-12-19. (Oct. 2024). https://blog.megaventory.com/autonomous-robot-definition-and-uses/#:~:text=According%20to%20Waypoint%20Robotics%2C%20the,without%20human%20control%20or%20intervention%E2%80%9D.

ScienceDirect. 2024. Hand gesture recognition. Retrieved from: 2024-12-19. https://www.sciencedirect.com/topics/computer-science/hand-gesture-recognition#recommended-publications.

Jedrzej Świeżewski. 2022. Yolo algorithm and yolo object detection. Retrieved from: 2024-12-19. (Mar. 2022). https://www.appsilon.com/post/object-detection-yolo-algorithm.

Other Sources

Picovoice AI. 2025. Porcupine wake word engine. Accessed: February 22, 2025. (2025). https://picovoice.ai/platform/porcupine/.

Mark Christian Ang, Karl Richmond C Taguibao, and Cyrel O Manlises. 2022. Hand gesture recognition for filipino sign language under different backgrounds. In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*. IEEE, 1–6.

Mark Christian Ang, Karl Richmond C. Taguibao, and Cyrel O. Manlises. 2022. Hand gesture recognition for filipino sign language under different backgrounds. In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*, 1–6. DOI: 10.1109/IICAIET55139.2022.9936801.

Ron Jamin C Aquino, Charles Kenneth C Beltran, John William A Fajardo, John Loid A Lopez, Nicole E Sambajon, and Roselito E Tolentino. 2020. Image processing based human following cart using 360° camera. In *2020 International Conference on Electronics and Sustainable Communication Systems (ICESC)*. IEEE, 375–380.

Ron Jamin C. Aquino, Charles Kenneth C. Beltran, John William A. Fajardo, John Loid A. Lopez, Nicole E. Sambajon, and Roselito E. Tolentino. 2020. Image processing based human following cart using 360° camera. In *2020 International Conference on Electronics and Sustainable Communication Systems (ICESC)*, 375–380. DOI: 10.1109/ICESC48915.2020.9155956.

Amie Rosarie Caballo and Chris Jordan Aliac. 2020. Yolo-based tricycle detection from traffic video. In *Proceedings of the 2020 3rd International Conference on Image and Graphics Processing* (ICIGP '20). Association for Computing Machinery, Singapore, Singapore, 12–16. ISBN: 9781450377201. DOI: 10.1145/3383812.3383828.

Amie Rosarie Caballo and Chris Jordan Aliac. 2020. Yolo-based tricycle detection from traffic video. In *Proceedings of the 2020 3rd International Conference on Image and Graphics Processing*, 12–16.

Gene Marck B. Catedrilla. 2022. Mobile-based navigation assistant for visually impaired person with real-time obstacle detection using yolo-based deep learning algorithm. In *2022 5th Asia Conference on Machine Learning and Computing (ACMLC)*, 63–67. DOI: 10.1109/ACMLC58173.2022.00020.

Richeng Cheng. 2020. A survey: comparison between convolutional neural network and yolo in image identification. In *Journal of Physics: Conference Series* number 1. Vol. 1453. IOP Publishing, 012139.

Jeloux P Docto, Angelika Ice Labininay, and Jocelyn F Villaverde. 2022. Third eye hand glove object detection for visually impaired using you only look once (yolo) v4-tiny algorithm. In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*. IEEE, 1–6.

Jeloux P. Docto, Angelika Ice Labininay, and Jocelyn F. Villaverde. 2022. Third eye hand glove object detection for visually impaired using you only look once (yolo)v4-tiny algorithm. In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)*, 1–6. DOI: 10.1109/IICAIET55139.2022.9936740.

Rowell M Hernandez, Johnrey Manzanal, Joseph Rizalde Guillo, Shiel Marie Garcia, and Melvin Babol. 2023. Drivemate: empowering safe driving through real-time traffic sign detection and speech feedback on mobile devices using yolov5 algorithm and tensorflow lite. In *Proceedings of the 8th International Conference on Sustainable Information Engineering and Technology* (SIET '23). Association for Computing Machinery, ¡conf-loc¿, ¡city¿Badung, Bali¡/city¿, ¡country¿Indonesia¡/country¿, ¡/conf-loc¿, 181–189. DOI: 10.1145/3626641.3627610.

Rowell M Hernandez, Johnrey Manzanal, Joseph Rizalde Guillo, Shiel Marie Garcia, and Melvin Babol. 2023. Drivemate: empowering safe driving through real-time traffic sign detection and speech feedback on mobile devices using yolov5 algorithm and tensorflow lite. In *Proceedings of the 8th International Conference on Sustainable Information Engineering and Technology*, 181–189.

William Chin Wei Hung, Muhammad Aizzat Zakaria, M. I. Ishak, and P. M. Heerwan. 2022. Object tracking for autonomous vehicle using yolo v3. In *Enabling Industry 4.0 through Advances in Mechatronics*. Ismail Mohd. Khairuddin, Muhammad Amirul Abdullah, Ahmad Fakhri Ab. Nasir, Jessnor Arif Mat Jizat, Mohd. Azraai Mohd. Razman, Ahmad Shahrizan Abdul Ghani, Muhammad Aizzat Zakaria, Wan Hasbullah Mohd. Isa, and Anwar P. P. Abdul Majeed, (Eds.) Springer Nature Singapore, Singapore, 265–273. ISBN: 978-981-19-2095-0.

Niels Joubert, Tyler G. R. Reid, and Fergus Noble. 2020. Developments in modern gnss and its impact on autonomous vehicle architectures. In *2020 IEEE Intelligent Vehicles Symposium (IV)*, 2029–2036. DOI: 10.1109/IV47402.2020.9304840.

Jundee Mark G Molina, Angelica S Sotis, Rogamestica C Pascual, James Earl D Cubillas, and Junrie B Matias. 2022. Development of real-time traffic monitoring and visualization system using stationary roadside sensor. In *Proceedings of the 2022 11th International Conference on Networks, Communication and Computing*, 154–160.

Jundee Mark G. Molina, Angelica S. Sotis, Rogamestica C. Pascual, James Earl D. Cubillas, and Junrie B. Matias. 2023. Development of real-time traffic monitoring and visualization system using stationary roadside sensor. In *Proceedings of the 2022 11th International Conference on Networks, Communication and Computing* (ICNCC '22). Association for Computing Machinery, ¡conf-loc¿, ¡city¿Beijing¡/city¿, ¡country¿China¡/country¿, ¡/conf-loc¿, 154–160. ISBN: 9781450398039. DOI: 10.1145/3579895.3579919.

Gaith Rjoub, Omar Abdel Wahab, Jamal Bentahar, and Ahmed Saleh Bataineh. 2021. Improving autonomous vehicles safety in snow weather using federated yolo cnn learning. In *Mobile Web and Intelligent Information Systems*. Jamal Bentahar, Irfan Awan, Muhammad Younas, and Tor-Morten Grønli, (Eds.) Springer International Publishing, Cham, 121–134. ISBN: 978-3-030-83164-6.

Md Bahar Ullah. 2020. Cpu based yolo: a real time object detection algorithm. In *2020 IEEE Region 10 Symposium (TENSYMP)*. IEEE, 552–555.

APPENDICES

APPENDIX A

SOURCE CODE

```python
# Raspberry Pi Python Code
import pvporcupine
import pyaudio
import struct
import serial
import cv2
import time
import RPi.GPIO as GPIO  # Import GPIO for the ultrasonic sensor
from ultralytics import YOLO

# Set up the wake word path and model
# Access_key of wake word "Hey Dolly" in PicoVoice Website
ACCESS_KEY = "Ax90xE5Rua3eSzXkxjLbxCNOVlBMUHgSlhrxbz9/QEgvI1FYd+5dOQ=="
WAKE_WORD_PATH = "/home/sintax/dolly/wake_word/Hey-Dolly_en_raspberry-pi_v3_0_0.ppn"
YOLO_MODEL_PATH = "/home/sintax/dolly/models/dolly_model_mAP95.pt"

# Serial communication setup with Arduino
SERIAL_PORT = '/dev/ttyUSB0'
BAUD_RATE = 9600

# Ultrasonic Sensor GPIO Pins
TRIG_PIN = 23
ECHO_PIN = 24

# Setup GPIO pins for ultrasonic sensor
GPIO.setmode(GPIO.BCM)
```

```python
GPIO.setup(TRIG_PIN, GPIO.OUT)
GPIO.setup(ECHO_PIN, GPIO.IN)

# Function to measure distance using the ultrasonic sensor
def measure_distance():
    # Send a pulse to trigger the sensor
    GPIO.output(TRIG_PIN, True)
    time.sleep(0.00001)
    GPIO.output(TRIG_PIN, False)

    # Record the time of start and arrival of the pulse
    start_time = time.time()
    stop_time = time.time()

    # Save the start time
    while GPIO.input(ECHO_PIN) == 0:
        start_time = time.time()

    # Save the arrival time
    while GPIO.input(ECHO_PIN) == 1:
        stop_time = time.time()

    # Calculate the time difference
    elapsed_time = stop_time - start_time
    # Distance in cm (Speed of sound = 34300 cm/s)
    distance = (elapsed_time * 34300) / 2

    return distance

# Setup for wake word detection using Porcupine
def listen_for_wake_word(ser):
```

```
    porcupine = pvporcupine.create(access_key=ACCESS_KEY, keyword_paths
    =[WAKE_WORD_PATH])
    pa = pyaudio.PyAudio()
    audio_stream = pa.open(rate=porcupine.sample_rate, channels=1,
    format=pyaudio.paInt16, input=True, frames_per_buffer=porcupine.
    frame_length)
    print("Listening for wake word...")

    try:
        while True:
            pcm = audio_stream.read(porcupine.frame_length,
    exception_on_overflow=False)
            pcm = struct.unpack_from("h" * porcupine.frame_length, pcm)
            keyword_index = porcupine.process(pcm)
            if keyword_index >= 0:
                print("Wake word detected! Activating Dolly...")
                ser.write(b"LED_WAKE\n")  # Turn on the LED immediately
                ser.flush()
                return True
    except KeyboardInterrupt:
        print("Terminated by user.")
    finally:
        audio_stream.stop_stream()
        audio_stream.close()
        pa.terminate()
        porcupine.delete()
    return False

# Function to perform object detection using YOLO and control Dolly's
    movement
def run_object_detection(ser):
    # Load the YOLO model
```

```
model = YOLO(YOLO_MODEL_PATH)
cap = cv2.VideoCapture(0)  # Open USB webcam

time.sleep(1)  # Shorten the wait time for serial initialization

# Signal the wake word detection and LED activation
print("Wake word detected, LED should be ON for 3 seconds...")
time.sleep(3)  # Keep the LED ON for 3 seconds

# Start blinking the LED to indicate object detection mode
ser.write(b"LED_BLINK\n")
ser.flush()
print("Object detection started, LED is blinking...")

# Variable to keep track of current states
motor_moving = False  # True if the motor is currently moving forward
led_on = False  # True if LED is ON and stable (not blinking)

try:
    while True:
        # Measure distance from the ultrasonic sensor
        distance = measure_distance()
        print(f"Measured Distance = {distance:.2f} cm")

        # Check if Dolly has reached the desired distance (30 cm or less)
        if distance <= 30:
            print("Desired distance reached. Stopping Dolly.")
            ser.write(b"STOP\n")  # Stop the motors
            ser.flush()
```

```
            break  # Terminate the script as the target distance is reached

        ret, frame = cap.read()
        if not ret:
            break

        # Run object detection on the frame
        results = model.predict(source=frame, imgsz=416, conf=0.5, show=True)

        # Check for 'thumbs_up' in the detected results
        detected = False
        for box in results[0].boxes:
            cls = results[0].names[int(box.cls[0])]
            if cls == "thumbs_up":
                detected = True
                break

        # Motor response: Move forward if 'thumbs up' is detected and distance is safe; otherwise, stop
        if detected and not motor_moving:
            print("Thumbs Up Detected! Moving forward...")
            ser.write(b"F_SLOW\n")  # Send the command to move forward
            ser.flush()
            motor_moving = True

            # Update LED state: Turn off LED (steady ON indicates detection)
            if not led_on:
```

```
                    ser.write(b"LED_OFF\n")  # Turn off blinking, indicating detection
                    ser.flush()
                    led_on = True  # Set LED state as OFF (indicating detection)

            elif not detected and motor_moving:
                print("No thumbs up detected, stopping...")
                ser.write(b"STOP\n")  # Send stop command to Arduino
                ser.flush()
                motor_moving = False

                # Resume LED blinking to indicate scanning mode
                if led_on:
                    ser.write(b"LED_BLINK\n")  # Resume blinking LED
                    ser.flush()
                    led_on = False

    except KeyboardInterrupt:
        print("Object detection terminated by user.")
    finally:
        cap.release()
        ser.write(b"LED_OFF\n")  # Turn off the LED when the script is stopped
        ser.flush()
        ser.close()
        GPIO.cleanup()  # Cleanup GPIO pins

if __name__ == "__main__":
    # Setup serial communication with Arduino
    ser = serial.Serial(SERIAL_PORT, BAUD_RATE, timeout=1)
    time.sleep(1)  # Shorten the wait time for serial initialization
```

```
    if listen_for_wake_word(ser):
        # Start the object detection process after the LED indication
        run_object_detection(ser)










########################################################################
// Arduino Uno Code
#include <Servo.h>

// Servo pins
const int leftServoPin = 9;     // Left servo pin
const int rightServoPin = 10;   // Right servo pin
const int ledPin = 2;           // LED pin for visual indicator

// Ultrasonic sensor pins
const int trigPin = A1; // Trigger pin
const int echoPin = A2; // Echo pin

// Create Servo objects
Servo leftServo;
Servo rightServo;

// Variables for LED state management
unsigned long ledTimer = 0;
const unsigned long blinkInterval = 500;  // Interval for LED blinking
    (500 ms)
```

```
bool ledState = false;                    // Keeps track of the LED's on
    /off state
bool isBlinking = false;                  // Keeps track if the LED
    should blink
bool ledWakeActive = false;               // To track if LED is in wake
    state

void setup() {
    Serial.begin(9600);       // Ensure baud rate matches Raspberry Pi
    serial communication
    leftServo.attach(leftServoPin);
    rightServo.attach(rightServoPin);
    pinMode(ledPin, OUTPUT);  // Set LED pin as OUTPUT
    pinMode(trigPin, OUTPUT); // Set trig pin as OUTPUT
    pinMode(echoPin, INPUT);  // Set echo pin as INPUT
    digitalWrite(ledPin, LOW);
    Serial.println("Arduino Ready!");
}

void loop() {
    // Handle incoming serial commands
    if (Serial.available() > 0) {
        String command = Serial.readStringUntil('\n');
        Serial.print("Received command: ");
        Serial.println(command);

        // Handle commands for motor movement
        if (command == "F_SLOW") {
            moveForwardSlow();  // Modified to use the slower movement
    function
        } else if (command == "STOP") {
            stopMovement();
```

```
        }

        // Handle LED commands
        else if (command == "LED_WAKE") {
            digitalWrite(ledPin, HIGH);
            ledWakeActive = true;  // Activate wake LED state
            ledTimer = millis();   // Reset timer for LED wake state
            Serial.println("LED turned ON for wake indication");
        } else if (command == "LED_OFF") {
            digitalWrite(ledPin, LOW);
            isBlinking = false;    // Stop any blinking
            ledWakeActive = false; // Reset wake state
            Serial.println("LED turned OFF");
        } else if (command == "LED_BLINK") {
            isBlinking = true;     // Set flag for blinking
            Serial.println("LED started blinking");
        }
    }

    // Blink the LED if the isBlinking flag is set
    if (isBlinking) {
        if (millis() - ledTimer >= blinkInterval) {
            ledTimer = millis();  // Update the timer
            ledState = !ledState; // Toggle LED state
            digitalWrite(ledPin, ledState ? HIGH : LOW);
        }
    }

    // If LED wake state is active, turn it off after 5 seconds
    if (ledWakeActive && (millis() - ledTimer >= 5000)) {
        digitalWrite(ledPin, LOW); // Turn off LED after 5 seconds
        ledWakeActive = false;     // Deactivate wake state
```

```
        Serial.println("LED turned OFF after wake indication");
    }

    // Continuously read and send ultrasonic sensor data
    long distance = getDistance();
    Serial.println(distance); // Send only the distance value to Raspberry Pi
    delay(500);               // Short delay between readings
}

// Function to move both servos forward at a slower speed
void moveForwardSlow() {
    leftServo.write(95);  // Slow speed forward for left servo
    rightServo.write(85);  // Slow speed forward in opposite direction for right servo
    Serial.println("Moving Forward Slowly...");
}

// Function to stop both servos
void stopMovement() {
    leftServo.write(90);   // Stop (neutral position)
    rightServo.write(90);  // Stop (neutral position)
    Serial.println("Stopping...");
}

// Function to read distance from ultrasonic sensor
long getDistance() {
    digitalWrite(trigPin, LOW);  // Ensure trigPin is LOW
    delayMicroseconds(2);        // Wait for a short time
    digitalWrite(trigPin, HIGH); // Set trigPin HIGH
    delayMicroseconds(10);       // Wait for 10 microseconds
    digitalWrite(trigPin, LOW);  // Set trigPin LOW
```

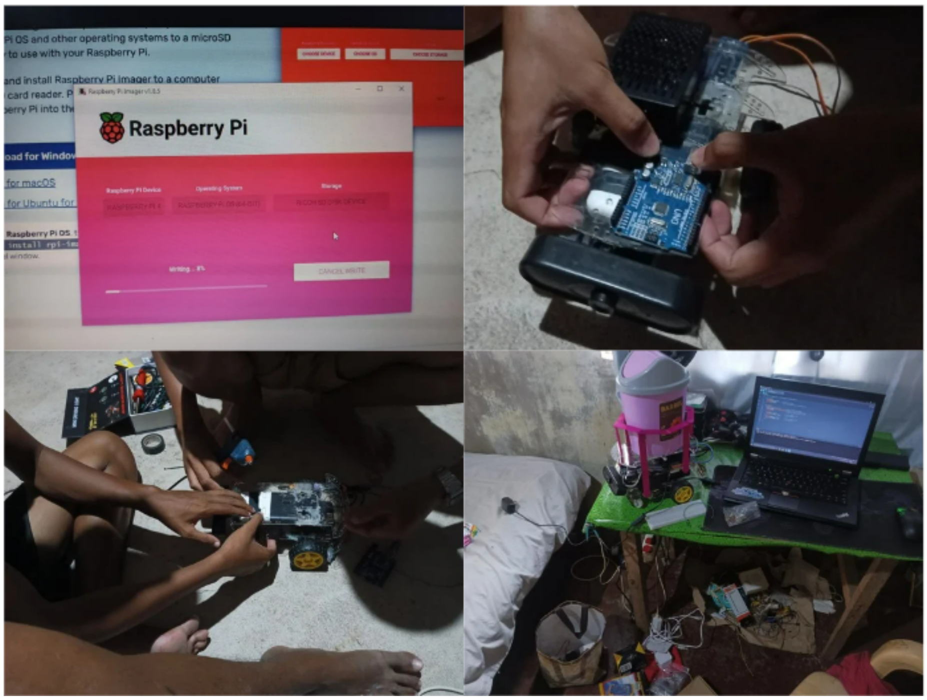
```

    long duration = pulseIn(echoPin, HIGH); // Read the echo pin
    long distance = duration * 0.034 / 2;   // Calculate distance in cm
    return distance;
}
```

Listing A.1: Raspberry Pi python and Arduino Uno source code

APPENDIX B

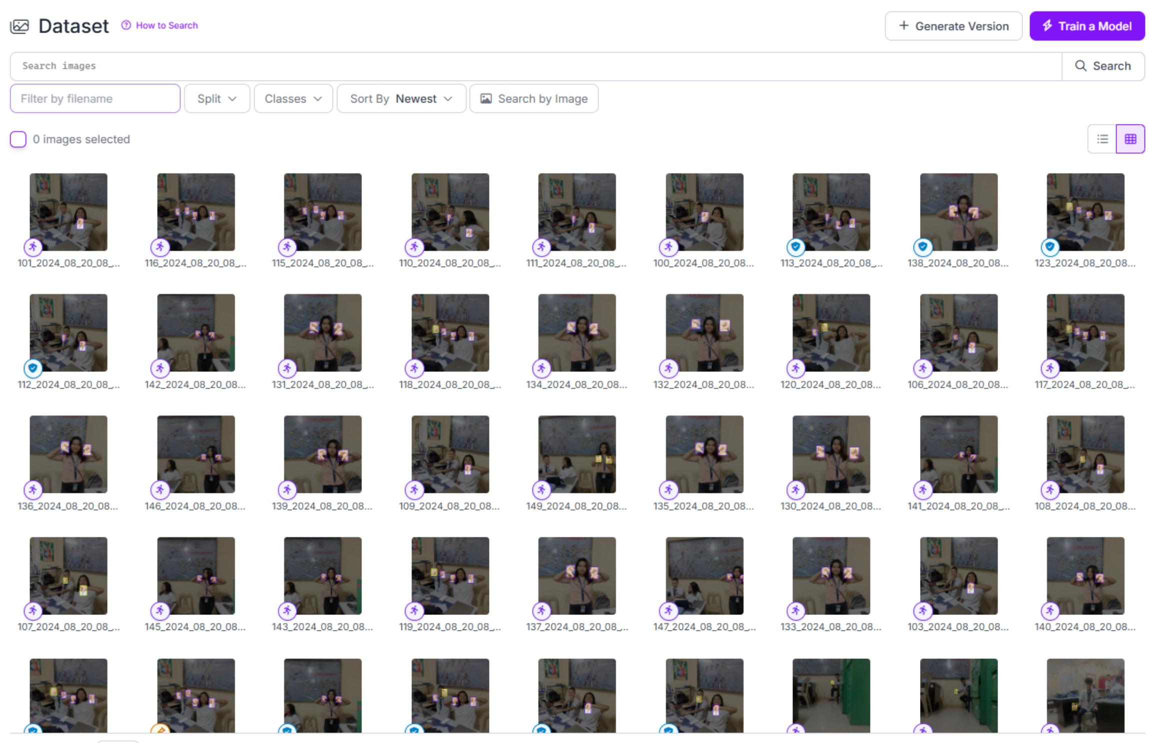
DOCUMENTATION



To bring Dolly, the smart trashcan prototype, to life, we began by installing Raspberry Pi OS on a Raspberry Pi 4 Model B, ensuring compatibility with essential libraries and tools for object detection and motor control. Next, we attached the USB Camera for live image capture, connected MG995 servo motors for mobility via an Arduino Uno, and integrated an ultrasonic sensor for obstacle detection. Throughout development, we tackled challenges such as optimizing model inference times, configuring wake word detection with Porcupine, and troubleshooting hardware connections to ensure seamless communication between components. Finally, we combined all hardware and software elements, including the YOLO-based custom object detection model and voice-activated functionality, to create Dolly—a fully functional smart trashcan capable of recognizing ’thumbs up’ gestures and navigating autonomously.

APPENDIX C

DATASET



APPENDIX D

NON-DISCLOSURE AGREEMENT FORM

Non-Disclosure Agreement Form

EFFECTIVE DATE: April 29, 2024
(*TD submission date*)

This Agreement sets forth the terms and conditions under which confidential, proprietary and other private information shall be disclosed between the College of Computer Studies-Camarines Sur Polytechnic Colleges and Joseph Jessie S. Oñate, MSc hereinafter referred to as "Expert."

By signing below, the parties acknowledge and accept the terms and conditions herein.

1. The Expert authorized to disclose and receive the confidential information is:
   KAELA MARIE N. FORTUNO, MIT – *Panel Chair*
   Name and Title

   On behalf of the College of Computer Studies- Camarines Sur Polytechnic Colleges:
   CHALLIZ D. OMOROG, DIT - Dean
   Name and Title

2. The confidential information disclosed under this Agreement is described as:
   Contents of the TCP by:

   Gerald M. Carique.John Mark C. Ruam, Arnold Rie J. Sejera

   which is entitled:

   "DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION"

3. The confidential information shall be used by the Expert only for the purpose of examination of TCP as part of the requirements of the Bachelor Program in which the student named above is enrolled.
4. This Agreement controls only confidential information, which is disclosed between the effective date and one year following the date of the TCP submission.
5. The obligations imposed upon an Expert hereunder shall apply only to information which at the time of disclosure is:
   a. marked as confidential if such information is disclosed in a physical form as the content of the TCP named above, and the oral defense, if any, of this same TCP, or
   b. if disclosed in some other form or manner is identified as confidential, and which identification is subsequently confirmed in a written notice delivered to the Expert specified in item 1 within thirty (30) days of disclosure.
6. The Expert agrees to take all action reasonably necessary to protect the confidentiality of the confidential information, including without limitation, implementing and enforcing operating procedures to minimize the possibility of unauthorized use or copying of the confidential information. Without limiting the foregoing, the Expert agrees to utilize the same degree of care, to avoid unauthorized disclosure or use of the confidential information of the discloser that the Expert would normally use with respect to its own confidential information.
7. The obligations imposed upon an Expert hereunder do not apply to information:
   a. which is or becomes publicly available without breach of this Agreement;
   b. which is already known to the Recipient prior to its disclosure hereunder;
   c. which is independently developed by the Expert.
8. The parties acknowledge that any technology, product, or other intellectual property

identified as confidential information and provided hereunder is provided on an "as is" basis without warranty of any kind whether express or implied and that the implied warranties of merchantability and fitness for a particular purpose are expressly disclaimed. In particular, the Expert shall not be liable for any direct, indirect, special, or consequential damages in connection with or arising out of the performance or use of any portion of the confidential information.

9. Nothing in this Agreement shall be construed to preclude the Expert from using, marketing, licensing, and/or selling any independently developed technology, product or other intellectual property that is similar or related to the confidential information disclosed hereunder.
10. Neither Party:
    a. acquires any intellectual property rights under this Agreement except the limited right to use the confidential information as specified in Paragraph 3;
    b. has an obligation hereunder to purchase or otherwise acquire any service or item from the other;
    c. has an obligation hereunder to commercially release any products or services using or incorporating the confidential information.
11. Upon the Camarines Sur Polytechnic Colleges written request, the Expert shall immediately return any Confidential Information and the physical media on which it was received or destroy all copies of the Confidential Information and certify in writing to the Camarines Sur Polytechnic Colleges that it has destroyed all copies made of the Confidential Information. Such certification shall be delivered within five (5) days of the Camarines Sur Polytechnic Colleges' request.
12. All modifications or amendments to this Agreement must be in writing and must be signed by both parties.
13. The parties are independent contractors, and this Agreement does not establish any relationship of agency, partnership or joint venture.
14. This Agreement shall be governed by the laws of the Nabua, Camarines Sur and the laws of the Philippines therein.

ACCEPTED BY:

KAELA MARIE N. FORTUNO,MIT
Expert
(Print name and Signature)

DATE: April 24, 2024

CAMARINES SUR POLYTECHNIC COLLEGES

CHALLIZ D. OMOROG, DIT
CSPC Representative
(Print name and Signature)

DATE: April 29, 2024

Non-Disclosure Agreement Form

EFFECTIVE DATE: April 29, 2024
(*TD submission date*)

This Agreement sets forth the terms and conditions under which confidential, proprietary and other private information shall be disclosed between the College of Computer Studies-Camarines Sur Polytechnic Colleges and Joseph Jessie S. Oñate, MSc hereinafter referred to as "Expert."

By signing below, the parties acknowledge and accept the terms and conditions herein.

1. The Expert authorized to disclose and receive the confidential information is:
   JOSEPH JESSIE S. OÑATE, MSc – *Panel Member*
   Name and Title

   On behalf of the College of Computer Studies- Camarines Sur Polytechnic Colleges:
   CHALLIZ D. OMOROG, DIT - Dean
   Name and Title

2. The confidential information disclosed under this Agreement is described as:
   Contents of the TCP by:

   Gerald M. Carique.John Mark C. Ruam, Arnold Rie J. Sejera

   which is entitled:

   "DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION"

3. The confidential information shall be used by the Expert only for the purpose of examination of TCP as part of the requirements of the Bachelor Program in which the student named above is enrolled.
4. This Agreement controls only confidential information, which is disclosed between the effective date and one year following the date of the TCP submission.
5. The obligations imposed upon an Expert hereunder shall apply only to information which at the time of disclosure is:
   a. marked as confidential if such information is disclosed in a physical form as the content of the TCP named above, and the oral defense, if any, of this same TCP, or
   b. if disclosed in some other form or manner is identified as confidential, and which identification is subsequently confirmed in a written notice delivered to the Expert specified in item 1 within thirty (30) days of disclosure.
6. The Expert agrees to take all action reasonably necessary to protect the confidentiality of the confidential information, including without limitation, implementing and enforcing operating procedures to minimize the possibility of unauthorized use or copying of the confidential information. Without limiting the foregoing, the Expert agrees to utilize the same degree of care, to avoid unauthorized disclosure or use of the confidential information of the discloser that the Expert would normally use with respect to its own confidential information.
7. The obligations imposed upon an Expert hereunder do not apply to information:
   a. which is or becomes publicly available without breach of this Agreement;
   b. which is already known to the Recipient prior to its disclosure hereunder;
   c. which is independently developed by the Expert.
8. The parties acknowledge that any technology, product, or other intellectual property

identified as confidential information and provided hereunder is provided on an "as is" basis without warranty of any kind whether express or implied and that the implied warranties of merchantability and fitness for a particular purpose are expressly disclaimed. In particular, the Expert shall not be liable for any direct, indirect, special, or consequential damages in connection with or arising out of the performance or use of any portion of the confidential information.

9. Nothing in this Agreement shall be construed to preclude the Expert from using, marketing, licensing, and/or selling any independently developed technology, product or other intellectual property that is similar or related to the confidential information disclosed hereunder.
10. Neither Party:
    a. acquires any intellectual property rights under this Agreement except the limited right to use the confidential information as specified in Paragraph 3;
    b. has an obligation hereunder to purchase or otherwise acquire any service or item from the other;
    c. has an obligation hereunder to commercially release any products or services using or incorporating the confidential information.
11. Upon the Camarines Sur Polytechnic Colleges written request, the Expert shall immediately return any Confidential Information and the physical media on which it was received or destroy all copies of the Confidential Information and certify in writing to the Camarines Sur Polytechnic Colleges that it has destroyed all copies made of the Confidential Information. Such certification shall be delivered within five (5) days of the Camarines Sur Polytechnic Colleges' request.
12. All modifications or amendments to this Agreement must be in writing and must be signed by both parties.
13. The parties are independent contractors, and this Agreement does not establish any relationship of agency, partnership or joint venture.
14. This Agreement shall be governed by the laws of the Nabua, Camarines Sur and the laws of the Philippines therein.

ACCEPTED BY:

JOSEPH JESSIE S. OÑATE, MSc
Expert
(Print name and Signature)

DATE: April 24, 2024

CAMARINES SUR POLYTECHNIC COLLEGES

CHALLIZ D. OMOROG, DIT
CSPC Representative
(Print name and Signature)

DATE: April 29, 2024

Non-Disclosure Agreement Form

EFFECTIVE DATE: April 29, 2024
(*TD submission date*)

This Agreement sets forth the terms and conditions under which confidential, proprietary and other private information shall be disclosed between the College of Computer Studies-Camarines Sur Polytechnic Colleges and Joseph Jessie S. Oñate, MSc hereinafter referred to as "Expert."

By signing below, the parties acknowledge and accept the terms and conditions herein.

1. The Expert authorized to disclose and receive the confidential information is:
   TIFFANY LYN O. PANDES, MSc – *Panel Member*
   Name and Title

   On behalf of the College of Computer Studies- Camarines Sur Polytechnic Colleges:
   CHALLIZ D. OMOROG, DIT- Dean
   Name and Title

2. The confidential information disclosed under this Agreement is described as:
   Contents of the TCP by:

   Gerald M. Carique.John Mark C. Ruam. Arnold Rie J. Sejera

   which is entitled:

   "DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION"

3. The confidential information shall be used by the Expert only for the purpose of examination of TCP as part of the requirements of the Bachelor Program in which the student named above is enrolled.
4. This Agreement controls only confidential information, which is disclosed between the effective date and one year following the date of the TCP submission.
5. The obligations imposed upon an Expert hereunder shall apply only to information which at the time of disclosure is:
   a. marked as confidential if such information is disclosed in a physical form as the content of the TCP named above, and the oral defense, if any, of this same TCP, or
   b. if disclosed in some other form or manner is identified as confidential, and which identification is subsequently confirmed in a written notice delivered to the Expert specified in item 1 within thirty (30) days of disclosure.
6. The Expert agrees to take all action reasonably necessary to protect the confidentiality of the confidential information, including without limitation, implementing and enforcing operating procedures to minimize the possibility of unauthorized use or copying of the confidential information. Without limiting the foregoing, the Expert agrees to utilize the same degree of care, to avoid unauthorized disclosure or use of the confidential information of the discloser that the Expert would normally use with respect to its own confidential information.
7. The obligations imposed upon an Expert hereunder do not apply to information:
   a. which is or becomes publicly available without breach of this Agreement;
   b. which is already known to the Recipient prior to its disclosure hereunder;
   c. which is independently developed by the Expert.
8. The parties acknowledge that any technology, product, or other intellectual property

identified as confidential information and provided hereunder is provided on an "as is" basis without warranty of any kind whether express or implied and that the implied warranties of merchantability and fitness for a particular purpose are expressly disclaimed. In particular, the Expert shall not be liable for any direct, indirect, special, or consequential damages in connection with or arising out of the performance or use of any portion of the confidential information.

9. Nothing in this Agreement shall be construed to preclude the Expert from using, marketing, licensing, and/or selling any independently developed technology, product or other intellectual property that is similar or related to the confidential information disclosed hereunder.
10. Neither Party:
    a. acquires any intellectual property rights under this Agreement except the limited right to use the confidential information as specified in Paragraph 3;
    b. has an obligation hereunder to purchase or otherwise acquire any service or item from the other;
    c. has an obligation hereunder to commercially release any products or services using or incorporating the confidential information.
11. Upon the Camarines Sur Polytechnic Colleges written request, the Expert shall immediately return any Confidential Information and the physical media on which it was received or destroy all copies of the Confidential Information and certify in writing to the Camarines Sur Polytechnic Colleges that it has destroyed all copies made of the Confidential Information. Such certification shall be delivered within five (5) days of the Camarines Sur Polytechnic Colleges' request.
12. All modifications or amendments to this Agreement must be in writing and must be signed by both parties.
13. The parties are independent contractors, and this Agreement does not establish any relationship of agency, partnership or joint venture.
14. This Agreement shall be governed by the laws of the Nabua, Camarines Sur and the laws of the Philippines therein.

ACCEPTED BY:

TIFFANY LYN O. PANDES, MSc
Expert
(Print name and Signature)

DATE: April 24, 2024

CAMARINES SUR POLYTECHNIC COLLEGES

CHALLIZ D. OMOROG, DIT
CSPC Representative
(Print name and Signature)

DATE: April 29, 2024

APPENDIX E

JOINT AFFIDAVIT OF UNDERTAKING (PLAGIARISM)

JOINT AFFIDAVIT OF UNDERTAKING

We, (1) GERALD M. CARIQUE , of legal age, single/ married and a resident of LA PURISIMA, NABUA CAMARINES SUR, (2) ARNOLD RIE J. SEJERA, of legal age, single/ married and a resident of LA PURISIMA, NABUA, CAMARINES SUR (3) JOHN MARK C. RUAM, of legal age, single/ married and a resident of LA PURISIMA, NABUA, CAMARINES SUR, after having been sworn to in accordance with law, do hereby take oath and state:

(i) That, we are officially enrolled for the thesis/capstone project on the topic titled DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION in the COLLEGE OF COMPUTER STUDIES of CAMARINES SUR POLYTECHNIC COLLEGES.

(ii) That, the contents of our thesis/ capstone project submitted to the Camarines Sur Polytechnic Colleges, for award of BACHELOR OF SCIENCE IN COMPUTER SCIENCE Degree are original and our own work and is not plagiarized.

(iii) That, if, after completing the thesis/ capstone project, are found copied or come under plagiarism, we will be solely responsible for it and College shall have sole right to cancel my research work ab-initio.

(iv) That, this work has not been submitted for the award of any other Degree/Diploma in any other University/Institute.

(v) That, we shall be responsible for any legal dispute/case(s) for violation of any provisions of the Copyright Act relating to our thesis/ capstone project.

IN WITNESS WHEREOF, I have hereunto set my name this ____ day of 28 JAN 2025 202__ in Nabua Camarines Sur, Philippines.

(1) GERALD M. CARIQUE
Affiant
SN: C21101083

(2) ARNOLD RIE J. SEJERA
Affiant
SN: C2110292(?)

(3) JOHN MARK C. RUAM
Affiant
SN: C21101060

SUBSCRIBED AND SWORN TO before me this ___ day of 28 JAN 2025 at Nabua Camarines Sur, Philippines, affiants exhibiting to me their competent proofs of identity above stated.

Atty. Joselito F. Figuracion
Notary Public
Until December 31, 2025
Roll of Atty. No. 52026
PTR No. 2311889 O 1/2/2024 Nabua Camarines Sur
IBP OR No. 363720 10/17/2023
MCLE Compliance No. VII-0028703 valid 4/14/25
San Francisco, Nabua, Camarines Sur

Doc. No. 488;
Page No.: 99;
Book No.: XLX;
Series of 2025

APPENDIX F

PROJECT TEAM ASSIGNMENT FORM

PROJECT TEAM ASSIGNMENTS FORM

Team Alias	PEGASUS
Course Code	CS 3214
Subject adviser/ TSA	ROSEL O. ONESA

Name and Signature	Project Role	Email address/ mobile#(s)
GERALD M. CARIQUE	PROJECT HEAD/PROGRAMMER	gecarique@mycspc.edu.ph 0938 083 5519
JOHN MARK C. RUAM	PROGRAMMER	joruam@mycspc.edu.ph 09387109723
ARNOLD RIE J. SEJERA	QA TESTER/DOCUMENTATION WRITER	arsejera@mycspc.edu.ph 09380087106

*** Accomplished in 2 copies

APPENDIX G

ROLE ACCEPTANCE FORM

ROLE ACCEPTANCE FORM
College of Computer Studies

Date: February 20, 2024

To: **Dr. Ian P. Benitez**

We, the third year students of Camarines Sur Polytechnic Colleges pursuing a degree in BACHELOR OF SCIENCE IN COMPUTER SCIENCE, are currently enrolled in Thesis1.

We are writing to humbly request your service and expertise to serve as our Adviser for our thesis. We believe that your knowledge and experience will be essential to greatly enrich our work. Attached are our thesis tentative title proposals for your kind reference.

Thank you and looking forward to your favorable response of our request.

Respectfully,

Pegasus

To: **DR. CHALLIZ D. OMOROG, DIT**
Dean, CCS

This formally signifies that I ACCEPT/ REJECT the request to serve as Adviser of the team **PEGASUS**.

As Adviser, I agree to perform my duties and responsibilities stipulated in Section 2.6 of the TCP Guidebook from Thesis 1 until Thesis 2.

Furthermore, I agree to set the schedule for advising or consultation to help the students and ensure the success of the thesis.

Conformed:

Dr. Ian P. Benitez, DIT
Name and Signature

Role Acceptance Form

ROLE ACCEPTANCE FORM
College of Computer Studies

Date: February 15, 2024

To: **Mr. Allan O. Ibo Jr.**

We, the third year students of Camarines Sur Polytechnic Colleges pursuing a degree in BACHELOR OF SCIENCE IN COMPUTER SCIENCE, are currently enrolled in Thesis1.

We are writing to humbly request your service and expertise to serve as our Consultant for our thesis. We believe that your knowledge and experience will be essential to greatly enrich our work. Attached are our thesis tentative title proposals for your kind reference.

Thank you and looking forward to your favorable response of our request.

Respectfully,

Pegasus

To: **DR. CHALLIZ D. OMOROG**
Dean, CCS

This formally signifies that I ACCEPT/ REJECT the request to serve as Consultant of the team **PEGASUS**.

As Consultant, I agree to perform my duties and responsibilities stipulated in Section 2.6 of the TCP Guidebook from Thesis 1 until Thesis 2.

Furthermore, I agree to set the schedule for advising or consultation to help the students and ensure the success of the thesis.

Conformed:

Mr. Allan O. Ibo Jr.
Name and Signature

ROLE ACCEPTANCE FORM
College of Computer Studies

Date: December 25, 2024

To: **Ivy R. Maraño**

We, the third year students of Camarines Sur Polytechnic Colleges pursuing a degree in BACHELOR OF SCIENCE IN COMPUTER SCIENCE, are currently enrolled in Thesis1.

We are writing to humbly request your service and expertise to serve as our Grammarian for our thesis. We believe that your knowledge and experience will be essential to greatly enrich our work. Attached are our thesis tentative title proposals for your kind reference.

Thank you and looking forward to your favorable response of our request.

Respectfully,

Pegasus

To: **ROSEL O. ONESA, MIT**
Dean, CCS

This formally signifies that I ACCEPT/ REJECT the request to serve as Grammarian of the team **PEGASUS**.

As Grammarian, I agree to perform my duties and responsibilities stipulated in Section 2.6 of the TCP Guidebook from Thesis 1 until Thesis 2.

Furthermore, I agree to set the schedule for advising or consultation to help the students and ensure the success of the thesis.

Conformed:

Ivy R. Maraño
Name and Signature

APPENDIX H

FINAL PROJECT TITLE FORM

FINAL PROJECT TITLE FORM

Team Alias: PEGASUS
Proponents/Researchers:

1) Carique, Gerald M.
2) Ruam, John Mark C.
3) Sejera, Arnold Rie J.

Proposed Thesis/ Capstone Project Title:

"DOLLY: A Voice-Activated and Gesture-Recognizing Smart Trashcan Utilizing the YOLO Algorithm for Autonomous Navigation"

Submitted by: **GERALD M. CARIQUE** (Signature of Project Head over printed name) Date: ______________	**Noted:** **ROSEL O. ONESA, MIT** (Signature of Subject Adviser over printed name) Date: ______________
Recommending Approval: **IAN P. BENITEZ, DIT** (Signature of Thesis Adviser over printed name) Date: ______________	**Approved:** **CHALLIZ D. OMOROG, DIT** DEAN, CCS Date: MAR 0 5 2024

*** Accomplished in 3 copies

APPENDIX I

HEARING FORMS

THESIS/ CAPSTONE PROJECT HEARING FORM

Date filed: April 29, 2024 [/] Title Proposal [ ] Pre-Oral [ ] Final Oral

Date of Hearing: April 29, 2024 Time: 1:30-3:00 Venue: Aircode, CCS B

Department: COLLEGE OF COMPUTER STUDIES

Research Title:

DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

Proponent/s:

CARIQUE, GERALD M.

RUAM, JOHN MARK C.

SEJERA, ARNOLD RIE J.

Recommended by:

IAN P. BENITEZ, DIT
Thesis/ Capstone Project Adviser

CERTIFICATION

The undersigned members comprising the panel for oral examination hereby agree to the schedule of hearing for the above research. [Please **PRINT NAME** and **SIGN**]

JOSEPH JESSIE S. OÑATE, MSc
PANEL MEMBER 1

TIFFANY LYN PANDES, MSc
PANEL MEMBER 2

KAELA MARIE N. FORTUNO, MIT
PANEL CHAIR

APPROVED:

CHALLIZ D. OMOROG, DIT
DEAN, CCS

NOTED BY:

ROSEL O. ONESA, MIT
Subject Adviser

THESIS/ CAPSTONE PROJECT HEARING FORM

Date filed: December 11, 2024 [ ] Title Proposal [/] Pre-Oral [ ] Final Oral

Date of Hearing: December 13, 2024 Time: 2:00-3:00 Venue: Conference Room.

Department: COLLEGE OF COMPUTER STUDIES

Research Title:

DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

Proponent/s:

CARIQUE, GERALD M. RUAM, JOHN MARK C.

SEJERA, ARNOLD RIE J.

Recommended by:

IAN P. BENITEZ, DIT
Thesis/ Capstone Project Adviser

CERTIFICATION

The undersigned members comprising the panel for oral examination hereby agree to the schedule of hearing for the above research. [Please **PRINT NAME** and **SIGN**]

JOSEPH JESSIE S. OÑATE, MSc
PANEL MEMBER 1

TIFFANY LYN PANDES, MSc
PANEL MEMBER 2

KAELA MARIE N. FORTUNO, MIT
PANEL CHAIR

APPROVED:

ROSEL O. ONESA, MIT
OIC **DEAN, CCS**

NOTED BY:

ROSEL O. ONESA, MIT
Subject Adviser

THESIS/ CAPSTONE PROJECT HEARING FORM

Date filed: October 11, 2024 [ ] Title Proposal [/] Pre-Oral [ ] Final Oral

Date of Hearing: October 11, 2024 Time: 12:00-1:00 Venue: Conference Room.

Department: COLLEGE OF COMPUTER STUDIES

Research Title:

DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

Proponent/s:

CARIQUE, GERALD M. RUAM, JOHN MARK C.
SEJERA, ARNOLD RIE J.

Recommended by:

IAN P. BENITEZ, DIT
Thesis/ Capstone Project Adviser

CERTIFICATION

The undersigned members comprising the panel for oral examination hereby agree to the schedule of hearing for the above research. [Please **PRINT NAME** and **SIGN**]

JOSEPH JESSIE S. OÑATE, MSc
PANEL MEMBER 1

TIFFANY LYN PANDES, MSc
PANEL MEMBER 2

KAELA MARIE N. FORTUNO, MIT
PANEL CHAIR

APPROVED:

ROSEL O. ONESA, MIT
OIC **DEAN, CCS**

NOTED BY:

ROSEL O. ONESA, MIT
Subject Adviser

THESIS/ CAPSTONE PROJECT HEARING FORM

Date filed: December 17, 2024 [ ] Title Proposal [ ] Pre-Oral [/] Final Oral

Date of Hearing: December 18, 2024 Time: 12:00 – 1:00 Venue: Conference Ro

Department: COLLEGE OF COMPUTER STUDIES

Research Title:

DOLLY: A VOICE ACTIVATED AND GESTURE RECOGNIZING SMART TRASHCAN UTLIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

Proponent/s:

CARIQUE, GERALD M
SEJERA, ARNOLD RIE J
RUAM, JOHN MARK C

Recommended by:

IAN P. BENITEZ, DIT
Thesis/ Capstone Project Adviser

CERTIFICATION

The undersigned members comprising the panel for oral examination hereby agree to the schedule of hearing for the above research.

JOSEPH JESSIE S. OÑATE, MSc
PANEL MEMBER 1

TIFFANY LYN PANDES, MSc
PANEL MEMBER 2

KAELA MARIE N FORTUNO, MIT
PANEL CHAIR

APPROVED:

ROSEL O. ONESA, MIT
OIC **DEAN, CCS**

NOTED BY:

ROSEL O. ONESA, MIT
Subject Adviser

APPENDIX J

PANELS RSC (TD, POD, FOD)

Republic of the Philippines
CAMARINES SUR
POLYTECHNIC COLLEGES
ISO 9001:2015 CERTIFIED

COLLEGE of COMPUTER STUDIES

Title : **DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION**

Alias : Team Pegasus

Date : April 29, 2024, 1:30 PM | / | TD | | POD | | FOD

Secretary : Hazel V. Reyes

MANUSCRIPT			
CHAPTER	**PAGE NO.**	**RECOMMENDATIONS, SUGGESTIONS AND COMMENTS (RSC)**	**ACTION TAKEN**
1	1	**Background of the Problem** • Write this section in paragraph form.	**Wrote in paragraph form.**
1	4	**Specific Objectives:** • SO1: To train and evaluate the YOLO algorithm for autonomous navigation of the trashcan. • SO2: To integrate… • SO3: To test the …	**Re-clarified specific objectives.**
1	4	**Significance of the study** • Who will benefit from your study?	**Add beneficiaries**
1	6	**Project Dictionary** • Introduce the project dictionary operationally and conceptually. Alphabetize the terms.	**Alphabetized with introduction.**
2	10	**RRLS** • Justify the paragraphs.	**Justified**
2	19	**Gap Bridged by the Study** • Discuss further the Gap bridged by the study.	**Discussed**
3	28	**Methodology** • Use LaTeX equation and table formatting. • Add figure and table labels.	**Added figure and table labels.**
ALL		**Notes** • Use ACM format.	**Used ACM Format.**
ALL		• Fix hanging pages and add page numbers.	**Added page numbers.**

NOTED BY:

KAELA MARIE N. FORTUNO, MIT
PANEL, CHAIRMAN

JOSEPH JESSIE S. OÑATE, MSc
PANEL, MEMBER 1

TIFFANY LYN O. PANDES, MSc
PANEL, MEMBER 2

Republic of the Philippines
CAMARINES SUR
POLYTECHNIC COLLEGES
ISO 9001:2015 CERTIFIED

COLLEGE of COMPUTER STUDIES

Title : DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

Alias : Team Pegasus

Date : October 13, 2024, 1:30 PM | | TD | / | POD | | FOD

Secretary : Hazel V. Reyes

MANUSCRIPT			
CHAPTER	**PAGE NO.**	**RECOMMENDATIONS, SUGGESTIONS AND COMMENTS (RSC)**	**ACTION TAKEN**
1	1	**Introduction** • Justify your introduction.	**Justified**

	3	**Background of the Problem**
		• Revise by chopping the paragraph.
		  o Waste Management intro
		  o Current studies
		  o Effects
		• Just discuss the specified problem.
			Has been revised & chopped the paragraph

	4	**Significance of the Study** • Add beneficiaries. Who will benefit from your study?	**Beneficiaries have been added**
		Project Dictionary • Add conceptual and operational definition.	**conceptual & operational have been added**
2	10-20	**RRLS** • Add more on Evaluation of Smart Trash Can. Add citation • Remove "Problem ..." • Discuss all the RRL cited and mentioned. • Include the similarities and differences. • Add the gap bridged by the study, "The proposed ...".	**The evolution of smart trashcans has been added information and citations The problem has been removed. Similarities and differences have been included Gap bridged by the study has been added with the proposed solution.**
3	25-38	**Methodology** • Introduce Constructive Research Design first, then Constructive Research in the study. • Remove Research Method and Proposed Solution sections. • Add test cases, minimum of 20. • Results of test cases should be in Chapter 4. • On Theoretical Framework, add a figure and discuss. • The Proposed Solution section is not applicable in this chapter.	**Constructive research design has been introduced with constructive research. The result of test cases has been in chapter 4. The theoretical framework has been discussed with the figure added. The proposed solution has been removed**

Republic of the Philippines
CAMARINES SUR
POLYTECHNIC COLLEGES
ISO 9001:2015 CERTIFIED

COLLEGE of
COMPUTER STUDIES

		• Add mean formula to get the average test case result.	
	24	**Figure 1: Annotated street scene** • No supporting definition and discussion.	**Annotated street scenes have been defined and discussed**
	25	**Table 1 Software Specification** • Use LaTeX Table formatting.	**Latex table formatting has been used**
		Append Table 3 on Table 2 • Combine into one table.	**3 & 2 have been combined**
	28-29	**Revise Figure 2 and 3 Label** • Figure 2: Prototype Mockup design. • Figure 3: Flowchart.	**Revised figures**
4	39-47	**Improve Results and Discussion** • Chapter 4 should contain answers to your objectives. • Follow your objectives. • Introduce Data Preparation in your chapter 3. • Change to actual picture of dolly. • Present the mean result.	**Chapter 4 has been based on the objectives, Data preparation has been introduced An actual picture of the dolly has been used.**
5	49-55	**Summary of Findings, Conclusions, and Recommendations** • Summarize your whole study. • Findings should be based on your objectives. Itemize. • Conclude based on objective findings. Itemize. • Itemize your recommendations.	**The whole study has been summarized and findings, conclusion, and recommendations have been itemized**
ALL		• Avoid first-person pronouns. • Use LaTeX Table formatting.	**First-person pronouns have been removed and the latex table formatting has been used.**

NOTED BY:

KAELA MARIE N. FORTUNO, MIT
PANEL, CHAIRMAN

JOSEPH JESSIE S. OÑATE, MSc
PANEL, MEMBER 1

TIFFANY LYN O. PANDES, MSc
PANEL, MEMBER 2

Republic of the Philippines
CAMARINES SUR
POLYTECHNIC COLLEGES
ISO 9001:2015 CERTIFIED

COLLEGE of
COMPUTER STUDIES

Title : **DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION**

Alias : Team Pegasus

Date : December 13, 2024, 2:00 PM | | TD | / | POD | | FOD

Secretary : Hazel V. Reyes

MANUSCRIPT			
CHAPTER	**PAGE NO.**	**RECOMMENDATIONS, SUGGESTIONS AND COMMENTS (RSC)**	**ACTION TAKEN**
1	3	**Background of the Problem** • Not a subsection. Just follow as flow of discussion. ○ Waste Management intro ○ Current studies ○ Effects	**Removed subsection by just following the discussion.**
	6-7	**Significance of the Study** • Remove.	**Removed unnecessary paragraph.**
	8	**Project Dictionary** • Add operational definition. • Remove bullet points.	**Operational definition has been added and removed the bullet points.**
2	18-19	**Synthesis of the State-of-the-Art** • Ensure you include the similarities and differences.	**Similarities and differences included**
3	26	**Research Design** • Introduce "Constructive Design" in your first paragraph. Then discuss how you will use CD in your study in your second paragraph.	**CD introduced in first paragraph then discussed.**
	30-31	**Prototype Mock-Up Design** • Transfer to Chapter 4.	**Transferred to chapter 4.**
4	ALL	**Subheading** • Do not capitalize.	**Uncapitalized**
	34	**Test Cases** • Add RRL that will support your result.	**Added RRL to support effectiveness.**
	42	• Add prototype model and schematic diagram under Model Integration.	**Prototype schematic and model have been added.**
5	ALL	**Findings, Conclusion, and Recommendations.** • Statements only.	**Removed subtopics and put statements only.**

Republic of the Philippines
CAMARINES SUR
POLYTECHNIC COLLEGES
ISO 9001:2015 CERTIFIED

COLLEGE of COMPUTER STUDIES

ALL		**Tables** • Use LaTeX Table formatting. No left and right borders. **Equations** • Put the proper formula followed by its description. For example: Precision = TP/TP+FP Where: TP = ... FP = ... • Use LaTeX formatting. **Figures** • 1 figure per page.	**Removed the table left and right.** **Used latex equation format with description.**
ALL		• Fix all hanging pages. • Past tense except objectives. • Remove all future tense.	**Removed hanging pages.** **Removed all future tense and made it past tense.**

NOTED BY:

KAELA MARIE N. FORTUNO, MIT
PANEL, CHAIRMAN

JOSEPH JESSIE S. OÑATE, MSc
PANEL, MEMBER 1

TIFFANY LYN O. PANDES, MSc
PANEL, MEMBER 2

Republic of the Philippines
CAMARINES SUR
POLYTECHNIC COLLEGES
ISO 9001:2015 CERTIFIED
COLLEGE of
COMPUTER STUDIES

Title : **DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION**

Alias : Team Pegasus

Date : December 19, 2024, 12:00 PM | | TD | | POD | / | FOD

Secretary : Hazel V. Reyes

MANUSCRIPT			
CHAPTER	**PAGE NO.**	**RECOMMENDATIONS, SUGGESTIONS AND COMMENTS (RSC)**	**ACTION TAKEN**
3	26	**YOLO Object Detection** • Introduction first, then image, then discussion of image/figure.	**Re-arranged Image with discussion.**
	86	**Autonomous Robotic Navigation** • Use ACM citation.	**Used ACM citation.**
4	41	**Model Integration and Prototype Development** • Correct the formatting of the subheading.	**Formatting corrected.**
	42-43	**Figure 7 and 8** • Revise the figure label.	**Revised**
ALL		**Notes** • Add corporate authors. • Use ACM. **Figures** • 1 figure per page. • Ensure that you mention the figure if being discussed.	**Used ACM format with authors.** **All tables and figures are mentioned.**
ALL		• Fix all hanging pages.	**Double check hanging pages.**
		Add ACM, preliminary pages, and appendices.	**Added**

NOTED BY:

KAELA MARIE N. FORTUNO, MIT
PANEL, CHAIRMAN

JOSEPH JESSIE S. OÑATE, MSc
PANEL, MEMBER 1

TIFFANY LYN O. PANDES, MSc
PANEL, MEMBER 2

APPENDIX K

CONSULTATION LOGS FORM (TD, POD, FOD)

CONSULTATION LOGS FORM

Thesis/ Capstone Project Title	"DOLLY: A Voice Activated and Gesture-Recognizing Smart Trashcan Utilizing the YOLO Algorithm for Autonomous Navigation"		
Proponents:	Carique, Gerald M. Sejera, Arnold Ric J. Ruam, John Mark C.		
Alias:	PEGASUS		
Total # of Modules		**as approved by the CAPSA / TSA**	

PROTOTYPE	**DT of Consultation**	**# of Modules Fully Implemented**	**# of Modules Partially Implemented**	**Running Score**	**Percentage**	**Project Manager's Signature**	**TA/TSA/ CAPA/ CAPSA/ Consultant Signature**
	4-19-24						[signature]
	Remarks Add more discussions about chapter 3 start with theories then methodologies.						
Deadline: ________							
	4-26-24						[signature]
	Remarks • Revise the Intro • Enhance the Inline citation						
Deadline:							

*** Must attach with this form your chosen Data and Process Model (IT) or Algorithm Model (CS)

CONSULTATION LOGS FORM

Thesis/ Capstone Project Title		"DOLLY: A Voice Activated and Gesture-Recognition Smart Trashcan Utilizing the YOLO Algorithm for Autonomous Navigation"					
Proponents:		Carique, Gerald M. Sejera, Arnold Rie J. Ruam, John Mark C.					
Alias:		PEGASUS					
Total # of Modules				**as approved by the CAPSA / TSA**			
PROTOTYPE	**DT of Consultation**	**# of Modules Fully Implemented**	**# of Modules Partially Implemented**	**Running Score**	**Percentage**	**Project Manager's Signature**	**TA/TSA/ CAPA/ CAPSA/ Consultant Signature**
(Replace this part about the Activity to be Consulted)							
	Remarks						
	Recommended for blue book.						
						Ivy R. Marano	
Deadline: ________							
(Replace this part about the Activity to be Consulted)							
	Remarks						
Deadline:							

*** Must attach with this form your chosen Data and Process Model (IT) or Algorithm Model (CS)

CONSULTATION LOGS FORM

Thesis/ Capstone Project Title		"DOLLY: A Voice Activated and Gesture-Recognition Smart Trashcan Utilizing the YOLO Algorithm for Autonomous Navigation"					
Proponents:		Carique, Gerald M. Sejera, Arnold Rie J. Ruam, John Mark C.					
Alias:		PEGASUS					
Total # of Modules				**as approved by the CAPSA / TSA**			
PROTOTYPE	**DT of Consultation**	**# of Modules Fully Implemented**	**# of Modules Partially Implemented**	**Running Score**	**Percentage**	**Project Manager's Signature**	**TA/TSA/ CAPA/ CAPSA/ Consultant Signature**
(Replace this part about the Activity to be Consulted)	12-17-24						
	Remarks	Conduct testcases for testing the prototype.					
Deadline: ________							
(Replace this part about the Activity to be Consulted)							
	Remarks						
Deadline:							

*** Must attach with this form your chosen Data and Process Model (IT) or Algorithm Model (CS)

CONSULTATION LOGS FORM

Thesis/ Capstone Project Title	"DOLLY: A Voice Activated and Gesture-Recognizing Smart Trashcan Utilizing the YOLO Algorithm for Autonomous Navigation"	
Proponents:	Carique, Gerald M. Sejera, Arnold Rie J. Ruam, John Mark C.	
Alias:	PEGASUS	
Total # of Modules		**as approved by the CAPSA / TSA**

PROTOTYPE	**DT of Consultation**	**# of Modules Fully Implemented**	**# of Modules Partially Implemented**	**Running Score**	**Percentage**	**Project Manager's Signature**	**TA/TSA/ CAPA/ CAPSA/ Consultant Signature**
	4-19-24						
	Remarks Add more discussions about chapter 3 start with theories then methodologies.						
Deadline: ________							
	4-26-24						
	Remarks • Revise the Intro • Enhance the Inline citation						
Deadline:							

*** Must attach with this form your chosen Data and Process Model (IT) or Algorithm Model (CS)

APPENDIX L

LANGUAGE EDITING CERTIFICATION

This is to certify that the undersigned has reviewed and went through all the pages of the Bachelor of Science in Computer Science thesis manuscript titled

"DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION"

of **Arnold Rie J. Sejera**, **John Mark C. Ruam, Gerald M. Carique**, as against the set of structural rules that govern research writing in accord with the composition of sentences, phrases, and words in the English language.

MRs. IVY R. MARAÑO

Language Editor

Date: 02-07-2025

APPENDIX M

SECRETARY'S CERTIFICATION

This is to certify that the undersigned has provided accurate recommendations, suggestions, and comments unanimously agreed and approved by the panel of examiners during the oral examination of the thesis titled

"DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION"

prepared and submitted by **Arnold Rie J. Sejera**, **John Mark C. Ruam**, **Gerald M. Carique**, and that the same have not been amended, modified or obliterated.

Ms. HAZEL V. REYES

Secretary

Date: 02 - 26 - 2025

APPENDIX N

CERTIFICATE OF ANTI-PLAGIARISM

REPUBLIC OF THE PHILIPPINES
CAMARINES SUR POLYTECHNIC COLLEGES
NABUA, CAMARINES SUR
OFFICE OF THE DIRECTOR
RESEARCH AND DEVELOPMENT SERVICES OFFICE
RESEARCH@CSPC.EDU.PH CSPC.RESEARCHOFFICE

CERTIFICATION

Date of Release:	January 31, 2025
Submission ID:	2575956288
Output Title:	DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION
Author(s):	Gerald M. Carique John Mark C. Ruam Arnold Rie J. Sejera
Program:	Bachelor of Science in Computer Science

Authenticity Report:

Similarity Index Report: **12%**

Internet Sources: 8%
Publications: 7%
Student Papers: 5%

- *Interpretation:* The similarity index report means that **12%** of the output is similar to the sources in Turnitin's (authenticity software) online repository and databases.

AI-Generated Report: ***27%***

AI-generated only: *23%*
AI-generated text that was AI-paraphrased: *4%*

- *Interpretation:* The AI generated report means that **27%** of the output indicates a *likely* AI-generated text and *likely* AI-paraphrased text, which is ***within the acceptable AI usage*** in the field of Engineering (Computer Science).

ENGR. HAROLD JAN R. TERANO, Ph.D.
Director, Research & Development Services Office

Research Office Telefax. No. (054) 288-4519 / Tel. No. (054) 288-4425 loc 152 / e-mail Address: **research@cspc.edu.ph**

12% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Match Groups

- **93** Not Cited or Quoted 10%
  Matches with neither in-text citation nor quotation marks
- **1** Missing Quotations 0%
  Matches that are still very similar to source material
- **20** Missing Citation 2%
  Matches that have quotation marks, but no in-text citation
- **0** Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

8% Internet sources
2% Publications
9% Submitted works (Student Papers)

Integrity Flags

0 Integrity Flags for Review

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

39 Internet
downloads.hindawi.com <1%

40 Internet
eric.ed.gov <1%

41 Internet
www.jameco.com <1%

42 Submitted works
APJ Abdul Kalam Technological University, Thiruvananthapuram on 2024-11-21 <1%

43 Submitted works
Daffodil International University on 2024-03-20 <1%

44 Submitted works
Lebanese International University on 2024-07-02 <1%

45 Publication
Milambiling, Lareina. "Predictive Modelling for Topic Handling of Natural Langua... <1%

46 Submitted works
University of Sheffield on 2021-04-29 <1%

47 Internet
internationalpubls.com <1%

48 Internet
www.ijsrd.com <1%

49 Internet
www.insightsociety.org <1%

50 Submitted works
Camarines Sur Polytechnic Colleges on 2025-01-14 <1%

51 Submitted works
Cranfield University on 2022-08-21 <1%

52 Publication
DiBenedetto, Lukas W.. "Temporary Liver Support Using Artificial Lung Technologi... <1%

11 Internet
evreka.co <1%

12 Internet
arxiv.org <1%

13 Submitted works
Technological Institute of the Philippines on 2024-09-19 <1%

14 Publication
Vivek S. Sharma, Shubham Mahajan, Anand Nayyar, Amit Kant Pandit. "Deep Lear... <1%

15 Submitted works
catsu on 2024-05-21 <1%

16 Internet
open-innovation-projects.org <1%

17 Internet
takas.lk <1%

18 Submitted works
Daffodil International University on 2024-03-19 <1%

19 Submitted works
Angeles University Foundation on 2024-05-03 <1%

20 Submitted works
Boston International School on 2024-03-20 <1%

21 Submitted works
The Hong Kong Polytechnic University on 2016-03-08 <1%

22 Internet
doku.pub <1%

23 Submitted works
Camarines Sur Polytechnic Colleges on 2022-07-03 <1%

24 Submitted works
The University of Manchester on 2024-09-13 <1%

turnitin Page 3 of 61 - Integrity Overview Submission ID trn:oid:::23387:80521701

Match Groups

- 93 Not Cited or Quoted 10%
  Matches with neither in-text citation nor quotation marks
- 1 Missing Quotations 0%
  Matches that are still very similar to source material
- 20 Missing Citation 2%
  Matches that have quotation marks, but no in-text citation
- 0 Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

8% Internet sources
2% Publications
0% Submitted works (Student Papers)

Top Sources

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	Internet	
	www.ijisae.org	<1%
2	Internet	
	www.researchgate.net	<1%
3	Internet	
	eprints.uty.ac.id	<1%
4	Submitted works	
	Staffordshire University on 2024-05-12	<1%
5	Submitted works	
	Camarines Sur Polytechnic Colleges on 2022-05-10	<1%
6	Internet	
	umpir.ump.edu.my	<1%
7	Internet	
	www.v7labs.com	<1%
8	Submitted works	
	Camarines Sur Polytechnic Colleges on 2022-03-30	<1%
9	Internet	
	www.semanticscholar.org	<1%
10	Submitted works	
	Camarines Sur Polytechnic Colleges on 2025-01-18	<1%

25 Internet
knowledgeessaywriting342.blogspot.com <1%

26 Submitted works
Pukyong National University on 2020-01-12 <1%

27 Submitted works
Auburn University College of Engineering on 2024-09-26 <1%

28 Internet
ia802204.us.archive.org <1%

29 Internet
ijsret.com <1%

30 Submitted works
University of Nottingham on 2020-03-14 <1%

31 Publication
S. Prasad Jones Christydass, Nurhayati Nurhayati, S. Kannadhasan. "Hybrid and A... <1%

32 Submitted works
Universiti Teknikal Malaysia Melaka on 2015-12-06 <1%

33 Submitted works
University of Wales, Bangor on 2023-04-27 <1%

34 Internet
shop.vincentmaestro.com <1%

35 Internet
www.coursehero.com <1%

36 Internet
www.e3s-conferences.org <1%

37 Internet
www.ratsoundsales.com <1%

38 Publication
Nilanjan Dey, Bitan Misra, Sayan Chakraborty. "Smart Medical Imaging for Diagn... <1%

53 Submitted works
Edge Hill University on 2021-01-07 <1%

54 Submitted works
Heriot-Watt University on 2023-12-19 <1%

55 Publication
Morales, Erasmo. "Do as I Say - Natural Gesture Control as an Integral Componen... <1%

56 Submitted works
Notre Dame of Marbel University on 2024-12-12 <1%

57 Submitted works
Texas A&M University - Commerce on 2024-12-02 <1%

58 Submitted works
University of Queensland on 2024-05-24 <1%

59 Submitted works
University of Technology, Sydney on 2021-11-07 <1%

60 Internet
mdpi-res.com <1%

61 Submitted works
universititeknologimara on 2025-01-22 <1%

62 Internet
www.digitimes.com <1%

63 Internet
www.researchsquare.com <1%

64 Submitted works
Camarines Sur Polytechnic Colleges on 2023-03-07 <1%

65 Publication
Thangavel Murugan, W. Jai Singh. "Cybersecurity and Data Science Innovations fo... <1%

66 Submitted works
UCL on 2024-09-09 <1%

67 Submitted works

COER University on 2024-12-13 <1%

68 Submitted works

Fakultet elektrotehnike i računarstva / Faculty of Electrical Engineering and Com... <1%

69 Submitted works

Liverpool John Moores University on 2022-03-29 <1%

APPENDIX O

CERTIFICATE OF TRANSFER

Camarines Sur Polytechnic Colleges

CERTIFICATE

OF TRANSFER

THIS IS TO CERTIFY THAT THE

DOLLY: A VOICE-ACTIVATED AND GESTURE RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

developed by Gerald M. Carique, John Mark C. Ruam, and Arnold Rie J. Sejera. Camarines Sur Polytechnic Colleges (CSPC) - College of Computer Studies (CCS) students, as their undergraduate thesis project was transferred to the CCS Dean's Office, Camarines Sur Polytechnic Colleges for further research.

This certification is issued this __ day of February 2025 at CCS Dean's Office for whatever legitimate purpose it may serve.

ROSEL O. ONESA, MIT
OIC Dean, CCS

APPENDIX P

ACM

DOLLY: A VOICE-ACTIVATED AND GESTURE-RECOGNIZING SMART TRASHCAN UTILIZING THE YOLO ALGORITHM FOR AUTONOMOUS NAVIGATION

John Mark C. Ruam
kuyanoy828@gmail.com
Camarines,Sur Polytechnic Colleges
Nabua, Camarines,Sur, Philippines

Gerald M. Carique
gecariqueofficial@gmail.com
Camarines,Sur Polytechnic Colleges
Nabua, Camarines,Sur, Philippines

Arnold Rie J. Sejera
sejeraarnoldrie@gmail.com
Camarines,Sur Polytechnic Colleges
Nabua, Camarines,Sur, Philippines

ABSTRACT

Effective waste management is a growing global concern, with an estimated 2.24 bil- lion tons of solid waste generated annually. For individuals with mobility impairments, disposing of waste independently remains a significant challenge. This study addresses this gap by developing "Dolly," a voice-activated, gesture-recognizing smart trashcan designed to enhance waste disposal efficiency and accessibility. Using the YOLO (You Only Look Once) algorithm, the system detects a thumbs-up gesture to trigger autonomous navigation, allowing the trashcan to move toward the user's location. This innovation is particularly useful for office workers and individuals with disabilities, promoting inclusivity and sus- tainability. The study's objectives include training and evaluating the YOLO algorithm for gesture recognition, integrating the model into a smart trashcan prototype, and testing the prototype's effectiveness in real-world scenarios. System integration used a Raspberry Pi 4 and Arduino Uno, and the system achieved a mean average precision (mAP@95) of 95Voice commands were incorporated through the PICO Voice Porcupine Wake Word engine. Results show that "Dolly" significantly improves accessibility for users with mobility im- pairments, promoting independence in waste disposal.

CCS CONCEPTS

• **Robotics and Autonomous System**; • **Human Comouter Interaction(HCI)**; • **IoT and Smart devices**; • **Artificial intilligence and Machine learning**;

KEYWORDS

Smart Trashcan, Autonomous, YOLOv8, Object Detection, Wake Word Detection, Gesture Recognition

1 INTRODUCTION

Traditional waste disposal methods require manual trash handling, which can be chal- lenging for many people, particularly those with disabilities. Current technologies, such as smart trashcans, have helped make waste disposal more accessible and efficient. However, these solutions frequently require the user to approach the trashcan, which could be a bar- rier for people who cannot walk. The researchers proposed solution, "Dolly," solves this problem by sending the trashcan to the user. Dolly uses object detection technology, partic- ularly the YOLO algorithm, to recognize a thumbs up gesture as an indication to approach the user. This allows those with mobility problems to throw outgarbage without moving to the trashcan, making the process more accessible and less difficult. This project intends to create and test Dolly, to contribute to the larger goal of making the environment more inclusive and accessible to people with disabilities. This research can help people with impairments live more independent and productive lives by using technology to aid them with daily tasks.

1.1 Objectives

(1) To train and evaluate the YOLO algorithm for autonomous navigation of the trashcan
(2) To integrate a trained autonomous smart trashcan model with thumbs up gesture recognition into a prototype.
(3) To test the effectiveness of the prototype "DOLLY".

2 RELATED WORK

2.1 Evolution of Smart Trash can

Waste management has moved beyond conventional methods in an era of rapid technological advancement. The development of smart trashcans has transformed how people manage waste, offering a new level of ease and efficiency. There's a study in CSPC by Edison A. Villamer. that the waste bins are concealed to save space, slow decomposition, and reduce odor[10]. The design is automated to minimize direct contact with garbage. The classifying section uses grippers, servo motors, ultrasonic, capacitive, and photoelectric sensors to collect and separate garbage. Segregated garbage is stored before shredding, and shredded waste is sent to transport bins for collection.

2.2 Real-Time Object Detection Using a YOLO Approach

Implementing real-time object detection has been a challenging task in computer vision, but the advent of the YOLO approach has significantly simplified this process. Several studies conducted in the Philippines have utilized the YOLO Algorithm, which shows that this algorithm is not new to the country. Researchers have come up with ideas on how to implement this Algorithm to solve some of the country's problems and create new solutions. Among these studies, some of the researchers focused on Real-Time Object Detection for traffic management. Amie Rosarie Caballo and Chris Jordan Aliac from the College of Computer Studies, Cebu Institute of Technology University[3], address the need for efficient traffic management, especially in urban areas such as Tagbilaran City, Philippines. By employing a YOLO-based model, researchers have successfully detected tricycles, a unique form of public transportation, from traffic videos. The model achieved an average precision of 37.91% for tricycle detection, highlighting its potential for enhancing traffic surveillance systems.

2.3 Autonomous Navigation Using the YOLO Algorithm

Artificial Intelligence (AI). This paper expands the discussion by providing a comprehensive overview of the application of AI models and methodologies in transportation engineering, particularly for controlling autonomous vehicles (AVs) in mixed autonomy scenarios. As the researchers navigate towards a future defined by autonomous driving and advanced GNSS, the integration of AI in these systems becomes increasingly significant. From reviewing literature in both transportation engineering and AI, to discussing cutting-edge AI-guided methods and posing open questions, this paper aims to inspire the transportation community and initiate dialogues with other disciplines, especially robotics and machine learning, to collaboratively work towards building a safe and efficient mixed traffic ecosystem[5].

2.4 YOLO's Evolution and Accuracy

Numerous research works have substantiated that YOLO outperforms CNN. Lee Yong-Hwan .[7]conducted an evaluation of a range of algorithms, considering factors such as accuracy, speed, and cost. In comparison to the latest sophisticated solution, YOLO v3 exhibits an optimal trade-off between speed and accuracy. With this understanding, The enhancements in the versions of YOLO (You Only Look Once) are noteworthy. It is crucial to understand the primary motivations behind the development of features, limitations, and the relationships between different versions. This understanding is particularly beneficial and illuminating for researchers, especially those who are new to the field of object detec- tion[4]. Hence different version of YOLO has its own advantages. In a study conducted by Muhammed Enes AT˙IK et al[2]. YOLOv2 outperformed in five of the nine classes, but YOLOv3 performed better when it came to small object recognition. In terms of time, YOLOv3 has outperformed YOLOv2, recognizing objects in an average of 2.5 seconds compared to 43 seconds for YOLOv2. Furthermore, there are several factors that must be considered to enhance the precision. M. B. Ullah et al.[9], mentioned that YOLO Algo- rithm is meant for GPU-based computers, meaning the graphics card needs to be at least 12GB.

2.5 Research design

The study used a constructive research design. This was to formulate the best possible solution for a known problem by constructing a prototype or synthesizing ideas to achieve the desired outcome for a particular problem [8]. This research design also involved iterative testing and refinement of the proposed solution, allowing for adjustments based on feedback and performance metrics. This approach aimed to ensure that the final outcome was both practical and effective in addressing the identified challenges.

In this study, the researchers create a prototype, namely a voice-activated smart trashcan, using the YOLO algorithm for object detection. The algorithm is used to identify thumbs-up interactions for the autonomous navigation of the trash can. The constructive research technique is appropriate for the study as it generates innovative constructions and assists researchers in identifying various concepts for improving the development of the smart trashcan. This approach allows the researchers to explore new ideas and refine their designs while ensuring that the resulting smart trashcan meets the practical needs of users. By utilizing the constructive research technique, researchers can iteratively enhance their prototype based on feedback and real-world applications.

Figure 1: Prototype Design

The model shows a three-technical view model "MODEL FRONT VIEW", "BACK VIEW", and "MODEL SIDE VIEW. These model mock-up designs respectively represent the conceptual robotics design for the device called "DOLLY" a voice activation and thumbs up gesture autonomous trashcan. The side view includes components like a trash guard, trash bin, Raspberry pi 4B model, servo motor, and rear wheels. The trash guard protects the trash bin, while the trash bin is likely used for collecting trash. The Raspberry Pi 4B model is a microcomputer that is programmable to control the robot. The front view includes power cables, LED lights and a resistor, an arduino board, jumper wires, a webcam, wireless earphones, and front wheels. The power cables supply power to various components such as Raspberry Pi and servo motors, and the LED light and resistor indicate once it has been activated through voice activation.

2.6 Flow Chart Overview

The autonomous navigation trashcan process is visually represented by the model flowchart depicted in flow chart. This

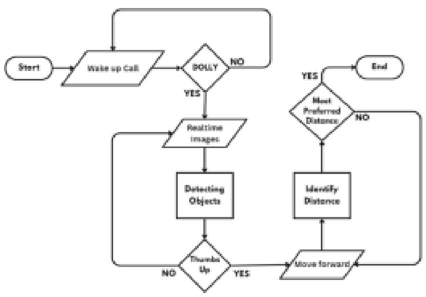


Figure 2: Flow chart Model

flowchart serves as a detailed reference to the sequential stages and decision points involved in the system's structure and operation. The method begins with the 'Wake-up Call' process. The model activates and starts the real-time picture input process when it comes across the word "DOLLY". The data that has been input is then tasked with Detecting objects. If a thumbs up is identified, the system goes immediately to the Navigation procedure. The algorithm is developed to maintain a process to determine if the Preferred Distance has been met. When this condition is met, the model terminates its operation. This flowchart highlights the complicated logic related to autonomous navigation systems, particularly in scenarios integrating human-robot interaction and gesture detection. The flowchart's methodology highlights the importance of conditional processing and repeated feedback loops in achieving accurate and responsive system performance.

2.7 Theorems, Alogrithm and Mathematical frame work

This section dives thoroughly into theorems, methodologies, and mathematical models relevant to the issue.

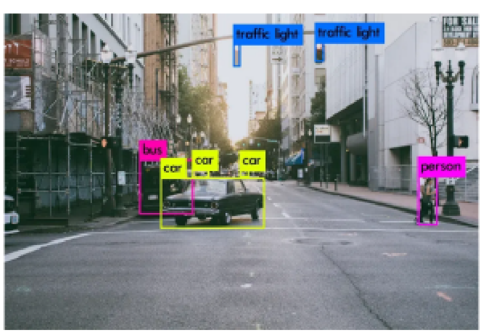


Figure 3: Yolo Object Detection

Joseph Redmon's[11], "You Only Look Once," introduced the YOLO algorithm, a real-time object recognition method for image classification. This article introduces object detection, the YOLO algorithm, and its open-source implementation, Darknet, which is a significant advancement in computer vision. Object detection is widely related to self-driving cars and video surveillance that uses computer vision and LIDAR technologies to generate a multidimensional representation of the road, aiding in crowd monitoring, terrorist prevention, and customer experience analysis.

To understand the notion of object detection, start with image classification. Image classification progresses via layers of incremental complexity. First is image classification, which is when researchers assign or label images in different categories[11]. In this study, researchers labeled different images with specific objects before training the model, this is to train the model that a particular image is identified as one object which means, one image has only one category assigned to it. Next, is the classification and localization process, in this part object localization enables us to locate the object in the image. Based on the different categories that the researchers labeled, the model itself can now identify if that image is in what category. Lastly, with object detection, the model will find all of the objects in an image and draw bounding boxes around them, at this part the model itself can identify multiple objects at the same time in one frame, as seen in 3 for visualization.

2.8 Data Gathering

Figure 4: Processing and Augmentation

Researchers gather .jpg images as data for object detection, images were captured using a Tecno Camon 20 Pro 5G Android phone camera. Different lighting conditions, distance and angles were used to simulate realistic scenarios. The researchers capture images in a office environment for better background visualization of the model in its detection process to detect the object even though with some background noise like to enhance the model's robustness in diverse settings. Added by some images online researchers gather enough data to be able to train the model. The dataset consists of 1699 total images, the team utilized roboflow for annotating captured images and creating dataset. Furthermore, each image was manually annotated using Roboflow's annotation tool to create bounding boxes around gestures. The labels were set as either thumbs up or thumbs down, forming the basis of the object detection model.

Using the free T4 GPU Hardware Accelerator, the researchers trained the YOLOv8 model in the Google Colab. Upon that, the model was converted to PyTorch format for Raspberry Pi use. Additionally, several hyperparameters are used to create the most accurate and efficient model possible. Because Ultralytics is renowned for creating state-of-the-art computer vision technology, it is available via them. Several hyperparameters required for model training are set to their default values. The researcher set the batch size to 16 by default and the learning rate to 0.01 for this particular experiment. For better training with this high number of datasets showed in the trained models, epochs are set to 100 and assist the model in becoming more accurate and more broadly applicable. Additionally, since 640 × 640 is a standard figure for picture size, it is chosen for its efficient computation process. As a result, the model training was quicker and lighter. Moreover, the AdamW optimizer is applied by default for enhanced training performance.

2.9 Model Performance Metrics

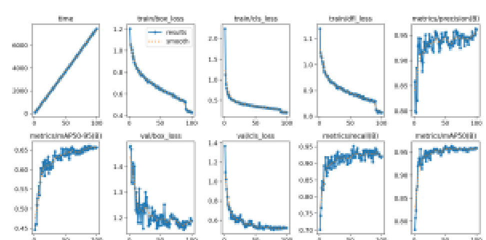


Figure 5: Performance Metrics

The performance of the created YOLOv8 model was evaluated using several critical criteria to ascertain how effectively it recognized gestures. The Mean Average Precision (mAP), tested at 95%, indicated the model's overall accuracy in correctly classifying both "thumbs up" and "thumbs down" gestures across several test scenarios.

As shown in 5 the model showed a balanced performance between recall and precision by efficiently limiting false positives while identifying the majority of true positives, with a 94% recall rate and a 94% accuracy rate. Moreover, the inference time of the Raspberry Pi ranged from 600 to 800 milliseconds for each frame, suggesting that the model could still perform real-time detections despite the hardware constraints. These results indicate that the model matches the prototype system well since it can reliably identify gestures in various lighting and environmental conditions. Lastly, the modified Yolov8 model was exported using the best.pt format.

2.10 Voice Activation

This section showed that Porcupine Wake Word, developed by Picovoice, is an advanced and highly accurate voice activation engine designed for always-listening applications. It enables the detection of custom wake words, such as "Hey Dolly," by utilizing deep neural networks trained in real-world environments. The engine efficiently processes incoming audio, identifying the predefined phrase with minimal latency, even in noisy conditions. Developers can create custom wake words through the Picovoice Console, which employs transfer learning to generate production-ready models without requiring extensive machine learning expertise.

Porcupine achieves over 97% detection accuracy with fewer than one false activation per 10 hours of background speech[1]. Compared to other wake word detection engines, it is significantly more accurate and faster, making it a reliable solution for voice-enabled applications. Its efficiency ensures smooth performance on resource-constrained devices, such as the Raspberry Pi 4, while maintaining responsiveness in various acoustic environments. With these capabilities, Porcupine provides an effective way to implement hands-free voice activation using custom phrases like "Hey Dolly."

2.11 Evaluation Tools

In this section, researchers evaluate DOLLY's object detection model. These metrics convey how this model performs using accuracy, precision, recall, and the F1 score. The following evaluation metrics will help the researchers to examine the model's algorithm performance.

2.12 Accuracy.

The researchers utilize this process to measure the proportion of correct predictions made by the model[6]. This will identify the accuracy of the model in classifying multiple objects, the formula for calculating accuracy is provided in the image below.

$$\text{Accuracy} = \frac{\text{True Positives (TP)} + \text{True Negatives (TN)}}{\text{Total Predictions}} \tag{1}$$

Where: TP = True Positive
TN = True Negative

Precision.

Researchers utilized this strategy to assess the model's positive prediction accuracy[6]. It is calculated by dividing TP by the sum of TP and FP. The formula for calculating precision is provided below:

$$\text{Precision} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Positives (FP)}} \tag{2}$$

Where: TP = True Positive
FP = False Positive

Recall.

The researchers used this technique because it calculates the number of true positive predictions among all real positive occurrences[6]. It is computed as the ratio of TP to the sum of TP and FN. The formula for calculating recall is provided in the image below.

$$\text{Recall} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Negatives (FN)}} \tag{3}$$

Where: TP = True Positive
FN = False Negative
F-measure.
Researchers utilized the F1 score, which is a measurement that evaluates both precision and recall[6]. This method provides a balance between high precision and high recall. The formula for calculating the F1 score is provided in the image below.

$$F1 = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \tag{4}$$

Where: The harmonic mean of precision and recall = 2 (Precision * Recall) Total number of precision and recall of the model = Precision + Recall

2.13 Test Case

Table 3
Test Case

Test Step	Description	Expected Result
Step 1	Power on the prototype	Dolly in idle state
Step 2	Say wake word: "Hey DOLLY"	LED lights up for 3 seconds
Step 3	Observe object detection mode	LED blinks
Step 4	Detects thumbs-up gesture	Move forward
Step 5	Remove thumbs-up gesture	Dolly stops and continues detecting
Step 6	New thumbs-up gesture	Dolly moves forward again
Step 7	Meet preferred distance	Dolly immediately terminates the program

Figure 6: Test Case

Researchers prepared a test case scenario to assess the operation and usability of the "Dolly" prototype. As shown in the 6, the main objective is to ensure that wake word detection, gesture recognition, and motor control function consistently to meet expectations. The scenario mimics a real interaction where " Hey Dolly" identifies a wake word, interprets a hand gesture (like a "thumbs-up"), and reacts by adjusting movements and displaying a visual response via an LED indication. Researchers evaluate the prototype's performance in various conditions. This process ensures the prototype meets initial design standards and functions as intended when engaging with users. This method helps uncover potential limitations, allowing the team to make necessary adjustments to improve the system for real-world deployment. The provided test case table served as a useful methodology for the researchers to check the performance of their Dolly prototype. Each critical function, like wake word detection, gesture recognition, and motor control, was broken down into clear, measurable steps, ensuring all aspects were tested thoroughly. From activating the prototype to responding to specific gestures, the test the system's performance as it should appear in real-world conditions. The test case affirmed that Dolly is compliant with the initial design requirements, ensuring reliability and usability in practical applications.

3 SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION

3.1 Summary

The goal of this project is to develop and test "Dolly," a smart, autonomous trashcan prototype that employs safe navigation and gesture recognition to move and communicate with people. During testing, the project's YOLOv8 object detection algorithm achieved a mean average precision (mAP) of 95% and recall of 94% after being trained on a custom dataset of 1,699 annotated images to identify gestures like "thumbs up." The dataset was first processed and optimized to enhance model generalization. With inference durations varying from 600 to 800 milliseconds per frame, the model was optimized for real-time detection on a Raspberry Pi.

The hardware integration consists of an Arduino Uno for motor control, a Raspberry Pi 4 Model B for processing, MG995 servo motors for movement, an HC-SR04 ultrasonic sensor for obstacle detection, and an LED module for user input. By utilizing Porcupine for wake word detection ("Hey Dolly"), gesture recognition initiates, allowing Dolly to approach humans and safely stop within a 50 cm distance. With directives like F_SLOW and STOP offering precise motion control, software integration guarantees efficient interaction between components.

Performance tests showed accurate motion recognition across different lighting and environmental conditions. Dolly achieved 7 out of 7 expected results, proving its fit for application in real life and its capability for future improvement. This project shows the successful mix of machine learning, hardware components, and software integration to build a smart, flexible system for autonomous waste cleanup.

4 FINDINGS

The main findings and observations from the creation, instruction, and testing of the smart trashcan prototype are presented in this part. In order to validate the efficacy of the YOLOv8 model, hardware integration, and software design in accomplishing the project's goals and guaranteeing dependable operation in real-world scenarios, they highlight the system's performance in gesture recognition, real-time accessibility, navigation accuracy, and overall functionality.

(1) This reveals that the YOLOv8 model, trained on a customized and augmented dataset of 1,699 images, achieved a mean average precision (mAP) of 95% with a balanced recall and accuracy rate of 94%. The model demonstrated reliable gesture detection for "thumbs up" and "thumbs down" across varying lighting conditions and perspectives.
(2) This shows the successful combination of the YOLOv8 model with Dolly's hardware and software components, allowing real-time gesture recognition, navigation, and interaction.
(3) This demonstrates the responsiveness, dependability, and adaptability of the prototype for practical use.

4.1 conclusion

Based on the findings of the research, the following conclusions can be drawn:

(1) The data from the model training and assessment phase indicate the effectiveness of the YOLOv8 model in obtaining excellent performance for gesture recognition in the smart trashcan prototype. Trained on a carefully chosen and supplemented dataset of 1,699 photos, the model obtained a remarkable mean average precision (mAP) of 95%, with a balanced recall and accuracy rate of 94%. This displays the model's ability to consistently distinguish "thumbs-up" and "thumbs-down" gestures across varied lighting conditions and different points of view, which is crucial for the prototype's real-world process.
(2) The hardware and software components of the Dolly trashcan prototype were successfully integrated with the YOLOv8 concept. The Raspberry Pi 4 Model B, operating as the central controller, employed the YOLOv8 model for real-time gesture recognition, correctly identifying "thumbs-up" movements, which are fundamental to the trashcan's operation. The inclusion of a USB camera for picture capture, MG995 servo motors for motion control, and an HC-SR04 ultrasonic sensor for distance measurement ensured that the Dolly could move successfully and engage securely with persons.
(3) The system testing phase proved the prototype's capacity to consistently fulfill its intended functions in real-world settings. The wake word recognition system successfully identified the phrase "Hey Dolly," which shows resilience in varied physical settings. The YOLOv8 model also performed well, reaching an identification accuracy of 93% mAP50 for "thumbs-up" gestures, even under different lighting conditions and from different points of view. This performance guaranteed that the trashcan could reliably recognize gestures, enabling smooth user engagement.

5 RECOMMENDATION

Based on the findings and conclusions, the following recommendations are proposed for future work and improvements:

(1) Optimizing the accuracy of wake word recognition in loud conditions will increase Dolly's applicability in more scenarios. This might be done by experimenting with improved speech recognition models or noise cancellation methods.
(2) Since the YOLOv8 model functioned well, additional hyperparameters and dataset variety tuning might lead to greater accuracy. Additionally, studying additional lightweight models or quantified versions of YOLOv8 might minimize inference time and boost performance on the Raspberry Pi.
(3) Upgrading the hardware is suggested to achieve more responsive and optimal performance in real-time. Instead of utilizing the Raspberry Pi, more advanced and higher-performance devices such as the NVIDIA Jetson Nano or a mini PC might be considered. These devices give additional computing power, allowing much faster inference times, better functioning, and the capacity to tackle more complicated tasks in future versions of Dolly. A more robust hardware arrangement would enable the system to handle more extensive datasets and complex applications efficiently.
(4) Applying Dolly's obstacle avoidance technology to detect and respond to more minor or more complex obstacles could enhance functionality. Additional sensors or camera-based depth perception algorithms might be implemented to increase the perception of the environment.
(5) Future studies might examine improving Dolly for more technically advanced functions, such as detecting other motions or considering extra features like automated waste sorting or disposal. Applying the technology in bigger, more dynamic scenarios, such as public areas, might further determine its durability and flexibility.
(6) Strengthening the device's energy economy by optimizing hardware usage, minimizing idle power consumption, and adding sleep modes during inactivity might make Dolly more appropriate for long-term, unsupervised operation.
(7) To further improve the functionality and usability of the smart trashcan prototype, it is recommended to integrate a new feature that enables the prototype to return to its original position after completing its tasks. This enhancement will allow the prototype to operate in a continuous cycle, thereby increasing its efficiency and effectiveness in waste management.

REFERENCES

[1] Picovoice AI. 2025. Porcupine Wake Word Engine. https://picovoice.ai/platform/porcupine/ Accessed: February 22, 2025.
[2] Muhammed Enes Atik, Zaide Duran, and Roni ÖZGÜNLÜK. 2022. Comparison of YOLO versions for object detection from aerial images. *International Journal of Environment and Geoinformatics* 9, 2 (2022), 87–93.
[3] Amie Rosarie Caballo and Chris Jordan Aliac. 2020. YOLO-based Tricycle Detection from Traffic Video. In *Proceedings of the 2020 3rd International Conference on Image and Graphics Processing* (Singapore, Singapore) *(ICIGP '20)*. Association for Computing Machinery, New York, NY, USA, 12–16. https://doi.org/10.1145/3383812.3383828
[4] Richeng Cheng. 2020. A survey: Comparison between Convolutional Neural Network and YOLO in image identification. In *Journal of Physics: Conference Series*, Vol. 1453. IOP Publishing, 012139.
[5] Xuan Di and Rongye Shi. 2021. A survey on autonomous vehicle control in the era of mixed-autonomy: From physics-based to AI-guided driving policy learning. *Transportation Research. Part C, Emerging Technologies* 125 (4 2021), 103008. https://doi.org/10.1016/j.trc.2021.103008
[6] Stephen M. Walker II. 2023. F-score: what are accuracy, precision, recall, and f1 score? https://klu.ai/glossary/accuracy-precision-recall-f1
[7] Yong-Hwan Lee and Youngseop Kim. 2020. Comparison of CNN and YOLO for Object Detection. *Journal of the semiconductor & display technology* 19, 1 (2020), 85–92.
[8] Kari Lukka. 2003. The Constructive Research Approach. https://www.researchgate.net/publication/247817908_The_Constructive_Research_Approach?fbclid=IwY2xjawHRFyJleHRuA2FlbQIxMAABHTKgMuQiNsG8tEgNpXFxy0iMBoHhOt_p8ZPx4lom-rq1oJyLjGTLaqI-KA_aem_4m39pVuyR8ABF7gqaLCl8A pages: 83-101.
[9] Md Bahar Ullah. 2020. CPU based YOLO: A real time object detection algorithm. In *2020 IEEE Region 10 Symposium (TENSYMP)*. IEEE, 552–555.
[10] Edison A Villamer, Marvin T Agrade, Marlon Jay Delustre, Renato Embestro, Via Claire Mamano, Christopher Pante, Rhoderick Oliveros, Eddie Cabaltera, and Victor Solito Issac. 2022. *Concealed automated trash bin with shredder for solid wastes.* Journal of Engineering and Emerging Technologies, 1(1):1–7.
[11] Jedrzej Świeżewski. 2022. Yolo algorithm and yolo object detection. https://www.appsilon.com/post/object-detection-yolo-algorithm

CURRICULUM VITAE

Gerald M. Carique

Address: Zone 4, La Purisima, Nabua, Camarines Sur

Email Address: gecariqueofficial@gmail.com

Contact Number: 0938 083 5519

PERSONAL INFORMATION

Date of Birth: March 1, 2002

Gender: Male

Citizenship: Filipino

Religion: Roman Catholic

EDUCATIONAL BACKGROUND

Tertiary
A/Y 2021 - 2025

Camarines Sur Polytechnic Colleges
Bachelor of Science in Computer Science
San Miguel, Nabua, Camarines Sur
Honors and Awards:

- Silver Medal - 2024 Philippine National Skills Competition

Secondary
Senior High School
A/Y 2019 - 2021

ACLC College of Iriga Inc.
TVL - CSS - *(Computer System Servicing NCII)*
2nd floor JASACA Center, Highway 1 San Miguel, Iriga City, Camarines Sur
Honors and Awards:

- With Highest Honor

Secondary

Junior High School	**La Purisima National High School**
A/Y 2015 - 2019	La Purisima, Nabua, Camarines Sur

Primary	**Nabua West Central School**
A/Y 2009 - 2015	La Purisima, Nabua, Camarines Sur

SKILLS AND QUALIFICATIONS

- Computer Literate
- Networking Fundamentals
- Cybersecurity Principles
- Software Installation
- Laptop/Computer Troubleshooting

CERTIFICATIONS

COMPUTER SYSTEM SERVICING NC II
TESDA
2020

SEMINARS AND WORKSHOPS ATTENDED

12th Bicol Youth Congress in Information Technology
April 18 - 19, 2024
Nabua Camarines Sur

7th Bicol ICT Research Colloquium
February 6, 2024
Nabua Camarines Sur

11th Bicol Youth Congress in Information Technology
April 20 - 21, 2023
Nabua Camarines Sur

Development, Security, and Operations (DevSecOps)
October 22, 2022
Zoom Conferencing App

CURRICULUM VITAE

John Mark C. Ruam

Address: Zone 3, La Purisima, Nabua, Camarines Sur

Email Address: kuyanoy828@gmail.com

Contact Number: 0938 710 9723

PERSONAL INFORMATION

Date of Birth: January 15, 2000

Gender: Male

Citizenship: Filipino

Religion: Roman Catholic

EDUCATIONAL BACKGROUND

Tertiary
A/Y 2021 - 2025

Camarines Sur Polytechnic Colleges
Bachelor of Science in Computer Science
San Miguel, Nabua, Camarines Sur

Secondary
Senior High School
A/Y 2019 - 2021

ACLC College of Iriga Inc.
TVL - CSS *- (Computer System Servicing NCII)*
2nd floor JASACA Center, Highway 1 San Miguel, Iriga City, Camarines Sur
Honors and Awards:

- With Highest Honor

Secondary
Junior High School
A/Y 2015 - 2019

La Purisima National High School
La Purisima, Nabua, Camarines Sur
Honors and Awards:

- With High Honor

Primary **Nabua West Central School**
A/Y 2009 - 2015 La Purisima, Nabua, Camarines Sur
Honors and Awards:

- 1st Honorable Mention

SKILLS AND QUALIFICATIONS

- Computer Literate
- Knowledgeable in Microsoft Office Applications
- Computer Networking
- Software Installation
- Software and Hardware Troubleshooting

CERTIFICATIONS

COMPUTER SYSTEM SERVICING NC II
TESDA
2020

SEMINARS AND WORKSHOPS ATTENDED

12th Bicol Youth Congress in Information Technology
April 18 - 19, 2024
Nabua Camarines Sur

7th Bicol ICT Research Colloquium
February 6, 2024
Nabua Camarines Sur

11th Bicol Youth Congress in Information Technology
April 20 - 21, 2023
Nabua Camarines Sur

Development, Security, and Operations (DevSecOps)
October 22, 2022
Zoom Conferencing App

CURRICULUM VITAE

Arnold Rie J. Sejera

Address: Zone 5, La Purisima, Nabua, Camarines Sur

Email Address: sejeraarnoldrie@gmail.com

Contact Number: 0938 008 7106

PERSONAL INFORMATION

Date of Birth: October 28, 2001

Gender: Male

Citizenship: Filipino

Religion: Roman Catholic

EDUCATIONAL BACKGROUND

Tertiary A/Y 2021 - 2025	**Camarines Sur Polytechnic Colleges** *Bachelor of Science in Computer Science* San Miguel, Nabua, Camarines Sur
Secondary **Senior High School** A/Y 2019 - 2021	 **La Purisima National High School** ***TVL - CSS*** - *(Computer System Servicing NCII)* La Purisima, Nabua, Camarines Sur
Primary A/Y 2009 - 2015	**Nabua West Central School** La Purisima, Nabua, Camarines Sur

SKILLS AND QUALIFICATIONS

- Computer Literate
- Computer Networking
- Software Installation

- Computer Assembling and Disassembling

CERTIFICATIONS

SEMINARS AND WORKSHOPS ATTENDED

12th Bicol Youth Congress in Information Technology
April 18 - 19, 2024
Nabua Camarines Sur

7th Bicol ICT Research Colloquium
February 6, 2024
Nabua Camarines Sur

11th Bicol Youth Congress in Information Technology
April 20 - 21, 2023
Nabua Camarines Sur

Development, Security, and Operations (DevSecOps)
October 22, 2022
Zoom Conferencing App