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AI-Based Smart Delivery System Using Image Processing and Computer Vision

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Abstract

Rapid growth in e-commerce and logistics has created a need for intelligent systems to optimize delivery operations. This paper proposes an AI-based smart delivery system leveraging computer vision to recognize packages and improve efficiency. An ESP32 microcontroller performs real-time object detection using images from an OV7670 camera module. Open-source libraries like OpenCV and TensorFlow enable processing algorithms for detection and classification. Key benefits include accurate labeling, routing, and sorting of packages, reducing human errors and delays. The modular design allows integration with tracking devices and transportation mechanisms for end-to-end automation. Limitations around transparency and lighting conditions are outweighed by the potential for scalability across sectors like food delivery, healthcare logistics, and transportation. With further development, such AI-powered systems can transform traditional supply chains into intelligent, self-regulating delivery ecosystems, providing visibility and reliability. This paper provides practical frameworks to build low-cost solutions using accessible hardware and software tools.

Keywords: Real-time object detection, OV7670 camera module, OpenCV, TensorFlow, Package labeling, Supply chain visibility, Supply chain reliability

INTRODUCTION

The advent of artificial intelligence (AI) has revolutionized various sectors, creating a paradigm shift in how we perceive and interact with the world. One such sector that has greatly benefited from AI is the delivery system industry. The core technologies involved are artificial intelligence, machine learning, computer vision, and image processing for object detection and recognition. Additional technologies include the ESP32 microcontroller, OpenCV, and TensorFlow for implementation. The scope focuses on the software and hardware components required for building a real-time package processing system, including cameras, microcontrollers, storage modules, etc. There is a discussion around modular design and integration capabilities as well. The algorithms explored include object detection, image classification, labeling, routing, and sorting of packages using neural networks and machine learning models. Model training concepts are also covered. Key application areas discussed involve package handling, delivery systems, and logistics across sectors like e-commerce, food delivery, healthcare, transportation, postal services, etc. Business use cases around efficiency, accuracy, and automation are covered. While detailed experimental setup is not covered, the concepts explore viability through modular prototypes with accessible, low-cost hardware and software components.

The paper focuses on operational metrics like reducing human errors, delays, and costs and enhancing reliability. The positive environmental impact of potential transportation optimization is indicated but not quantified. In summary, the scope focuses directly on applying AI and computer vision to automate package processing tasks by building, training, and deploying models on embedded devices. Multiple application scenarios are discussed by keeping the implementation accessible. Let me know if you need any clarification or have additional aspects to include regarding the scope definition. The goal is to create a robust, efficient, and autonomous delivery system that can adapt to the evolving logistical demands and complexities of the modern world. The proposed system exploits the potential of computer vision, a subfield of AI that enables machines to interpret and make sense of visual data. Computer vision, when combined with image processing techniques, can equip the delivery system with capabilities such as object detection, path planning, and obstacle avoidance—critical factors in ensuring timely and successful deliveries. This research paper delves into the intricate aspects of integrating computer vision and image processing into the delivery system, elucidating the application of these technologies for enhanced operational efficiency. The focus here is not just on AI as an overarching technology but specifically on the role and contribution of computer vision and image processing in revolutionizing delivery systems [1,2]. The study provides a comprehensive understanding of the design, implementation, and optimization of these technologies for a smart delivery system, paving the way for future innovations in this realm [3-6]. In the 21st century, the field of AI and smart systems have seen an upward trend of growth and have been increasingly reshaping the service industry by performing several tasks and constituting a major source of innovation [7-9]. AI-based technologies can be put to use in human services to help companies alleviate considerable administrative burdens and free up time for more critical responsibilities by improving decision-making and creating cheaper, more efficient, and faster delivery services. In that extent, Amazon has developed a retail store in Seattle that enables shoppers to take products from shelves and move out directly without checking out to pay. The store is called Amazon Go and relies on computer vision to track the shoppers during the buying process. In the service domain, robots are also encompassing a wider range of advanced technologies that have the potential to overcome the traditional capabilities of industrial robots. The argument is reinforced by Wirtz et al. [10], who state that modern robotics, in combination with rapidly improving technologies like AI, are bringing opportunities to a wide range of innovations that have the potential to dramatically change service industries. A few examples are presented by McKinsey Global Institute, which is now arguing that autonomous drones that use AI technologies as deep learning are completing last-mile deliveries and/or AI-enhanced robots are tracking inventory in warehouses and recognizing empty shelves from a zero-error perspective. Autonomous intelligent robots are robots that can perform desired tasks in unstructured environments without continuous human guidance or intervention. It is an integrated design based on the knowledge of mechanical, electrical, and computer engineering. IR sensors-based autonomous line-follower robot design and fabrication procedure, which always direct along the black mark on the white surface. The robot uses several sensors to identify the plot line, thus assisting the robot to stay on track and reach its destination. The robot is driven by DC motors to control the movements of the wheels. We have gained an understanding of the earlier proposed works in order to increase our collective understanding. It examines the benefits and drawbacks of existing models. Additionally, we have a thorough understanding of how the current system functions as well as the drawbacks of the models already on the market. We've also done studies on numerous developing technologies and their applications in other fields, choosing the one that best fits our needs. As more and more advancements in robotics are made, their role in replacing human labor for tasks such as package delivery and other similar roles seems inevitable. However, the infrastructure and general look and feel of residential areas vary massively. We will develop a system that can help such unmanned robotic devices identify and differentiate such areas and improve efficiency in package delivery with as little human interaction as possible.

PROBLEM DEFINITION

The existing delivery systems lack efficiency and accuracy in package handling, leading to delays and errors in deliveries. This project aims to address these issues by implementing an AI-based smart delivery system that utilizes image processing and computer vision techniques. Our proposed solution involves the development of a smart delivery system that can automatically detect and classify packages using object detection algorithms. By incorporating image processing and computer vision technologies, we aim to improve the accuracy and speed of package handling, ensuring timely deliveries with minimal errors. an AI delivery system that can identify objects such as doors and gates and how to interact with them. This system is meant to complement a mobile robot system equipped with a camera and a manipulator arm that can carry and deliver packages to various locations. The system will use computer vision to identify potential drop-off locations and then run the captures from the footage through a dimensionality reduction algorithm that turns RGB images to grayscale with maximum accuracy but reduces the image to an 8-bit depth image. Then these captures can be run through deep learning techniques to recognize different types of doors and gates, such as sliding, swinging, revolving, or locked ones, as well as their material and locations, such as handles and hinges, and determine the best way to open or unlock them. The system should also be able to handle situations where the door or gate is obstructed. The system should be tested in various scenarios and evaluated based on its accuracy, efficiency, robustness, and safety. The proposed AI-based smart delivery system has potential for further enhancements.

- Integration with GPS tracking systems to provide real-time package location information.
- Implementation of natural language processing (NLP) techniques to extract meaning from package labels or customer instructions.
- Utilizing machine learning algorithms for route optimization and predicting estimated delivery times based on historical data.

By continuously improving and expanding upon these capabilities, our smart delivery system can become more efficient, accurate, and adaptable to evolving industry requirements.

Methodology

Fundamental and testing efforts in a variety of PC applications, such as surveillance, vehicle courses, and independent robot courses, involve object disclosure and the following: A video achievement particle's packaging includes finding objects that are acknowledged in the question. Every subsequent technique needs an inquiry acknowledgment component, either at each edge or when the first sign of disagreement arises in the video. For instance, during the ratio of a planet (as in space science), d is pressing for hang illness in a mammography scan (medical), abs preventing from driving into a barrier (robotics), and recognizing a man's eye concealing or hair color (security). The goal is to create a model that can recognize when something is being concealed and uses open-source technology to utilize the visual design particles obtained from a regular webcam with sensible clarity. Being tracked by an image planning calculation that makes you queasy and that measures your length in the camera's obvious path The PC/compact PC/embedded motor turns the camera, which is mounted on a stepper motor, as the vehicle moves. We utilized OpenCV establishment to do out the suggested computation on the device. It is a forward-thinking dissident method that anticipates future usage.

The ESP32 [11] is a low-cost, low-power microcontroller with integrated Wi-Fi and Bluetooth. It is the successor to the ESP8266, which is also a low-cost Wi-Fi microchip, albeit with limited functionality. When we set our ESP32 board as an access point, it can be connected using any device with WiFi capabilities without connecting to our router. When we set the ESP32 as an access point, we create its own Wi-Fi network, and nearby Wi-Fi devices (stations) can connect to it, like our smartphone or computer. As a result, we can control it without being connected to a router. This can also be helpful if we wish to connect multiple ESP32 devices directly to one another without using a router.

Real-time object detection using the ESP Microcontroller: An ESP microcontroller will be used for this purpose. In order to accurately recognize different types of packages, a deep learning model must be trained on a dataset of package images.

ESP32: Our smart delivery system's primary processing unit will be the potent ESP32 microcontroller. It is energy-efficient and offers the computational power needed for tasks involving the real-time detection of objects.

ESP32 is not the same as NodeMcu. NodeMcu is a development board that is built around the ESP8266 microcontroller platform.

The OV7670 Camera Module Interfaces with the ESP32 Microcontroller, depending on the particular implementation requirements, the ESP32 microcontroller processes the images that the OV7670 camera module captures using either its GPIO pins or dedicated camera interfaces like I2S or SPI.

An SD card module can be interfaced with the ESP32 microcontroller via its SPI bus interface, enabling read/write operations between them efficiently, to store taken pictures or any other delivery-related data.

Power Requirements: Depending on the particular parts utilized in the system, the power requirements will change. Camera modules and ESP32s typically consume little power, which makes them appropriate for battery-powered applications.

Software Interface

OV7670 Camera Module: By utilizing the proper libraries or drivers, the OV7670 camera module can be interfaced with the ESP32 microcontroller, offering an interface for accessing image data from the module.

OpenCV: The Open-Source Computer Vision Library, also known as OpenCV, is a popular computer vision library that offers a number of tools and functions for tasks like object detection and image processing. We will make use of OpenCV's features to perform object detection and improve image quality.

Python: This project's software will be developed using the Python programming language because of its ease of use, abundance of libraries, and superior support for machine learning frameworks such as TensorFlow.

TensorFlow: TensorFlow is a well-known open-source deep learning framework that offers resources and tools for effectively training neural networks. Our object detection model will be trained on extensive datasets of package images using it.

PyWavelets: PyWavelets is a Python library that provides a number of wavelet transforms that are helpful for signal processing tasks like feature extraction from photos taken by the OV7670 camera module or noise reduction.

Another Python library that facilitates optical character recognition (OCR) is called Pytesseract. OCR is useful for extracting text from relevant documents, such as package labels, during delivery processes.

Requirements

We require the following hardware components:

- ESP32 microcontroller board.
- OV7670 camera module.
- SD card module.
- Power supply/battery source.
- For software development:
- Development environment with Python installed.
- Appropriate libraries such as OpenCV, TensorFlow, PyWavelets, etc., installed depending on specific requirements.

ESP8266 and ESP32 are cheap Wi-Fi modules and are mostly used in the internet of things projects. We can easily control and monitor remotely via Wi-Fi. "NodeMcu" is the name of a firmware originally for the ESP8266 microcontroller, with support for the ESP32 microcontroller added more recently, that allows us to program these microcontrollers. ESP32 is the successor to ESP8266. ESP8266 is also known as NodeMcu. This solution includes object detection in an ESP microcontroller, the use of ESP32 and comparing it with ESP8266 (NodeMcu), how the OV7670 camera module and SD card module work with ESP32, and power requirements. The article also discusses the software interface, starting with the OV7670 camera module, followed by OpenCV, Python, Tensorflow, PyWavelets, and PyTesseract. It also talks about custom models like SSD MobileNet V2, FPNLite 320x320, and the binary classification model. The work's requirements section details functional and non-functional requirements, along with user requirements and factors related to software quality. This AI-based smart processing system has various applications. It can provide solutions for unmanned systems in the delivery services sector and be used in industries like package deliveries, food delivery, and federal postal services. It also reduces constant interaction with delivery agents. Furthermore, it improves package security and can function independently of end points. The software can also be used in many forms of robotic systems. The lightweight nature of the system ensures its functionality, even in cost-effective lightweight systems.

Pseudo Code

1. Import necessary libraries and dependencies

2. Define the images to collect

a. Set up folders for collecting images

b. Capture images

c. Perform image labelling

3. Partition images into training and testing sets

4. Download the tf models pretrained models from tensor flow model zoo

5. Install TFOD (TensorFlow Object Detection)

6. Create a label map

7. Update config for transfer learning

8. Update specific parameters in pipeline_config:

a. Set the number of classes to the number of labels

b. Set the batch size to 4

c. Set the fine_tune_checkpoint to the path of checkpoint 'ckpt-0'

d. Set the fine_tune_checkpoint_type to "detection"

e. Set the train_input_reader.label_map_path to the path of 'LABELMAP'

f. Set the train_input_reader.tf_record_input_reader.input_path to the path of 'train.record'

g. Set the eval_input_reader[0].label_map_path to the path of 'LABELMAP'

h. Set the eval_input_reader[0].tf_record_input_reader.input_path to the path of 'test.record'

9. Train the model using the training set

10. Evaluate the model using the evaluation set

11. Train the image classification model using the training set

12. Divide dataset into training, evaluation and testing partitions.

13. Import Keras layers for building the model

14. Fit the model with the dataset for 20 epochs

15. Measure the loss and accuracy of the model to evaluate its performance in real time

An AI-powered system utilizes diagrams is a cutting-edge, novel approach to enabling quicker real-time deliveries. The system uses machine learning (ML) and Computer Vision capabilities to offer the best delivery solutions when the customer places an order. Many companies like have started using AI to enable faster, safer and more efficient deliveries to increase customer satisfaction as well as retaining them. Based on various factors like weather, previous delivery records, number of deliveries, the system predicts the best possible way to complete the task of delivery. Some of the benefits that can be noted as compared to the manual or human based delivery system are:

1. Faster Delivery of Product/Item:

Artificial intelligence allows faster and more efficient planning of the delivery of items or products by applying different AI algorithms and then estimating the average time for reaching the destination. In this way, it helps the companies deliver fresh items or products faster to the customers in a very efficient way and identify the shortest and safest route to the customer's location. Moreover, AI technology today records the previous orders placed by customers and their locations and lists their priorities based on their search. These algorithms also consider other factors such as stages of item or product processing, the distance of the customer's destination, previous orders, etc., which together help ensure improved services to the customer, timely deliveries, and increased revenue.

2. Estimated Time of Arrival (ETA):

AI-enabled systems, unlike traditional delivery models, provide the estimated time of arrival (ETA) of products or items. In this way, customers can reschedule or adjust the time of delivery of their items or products according to their convenience, thus enabling customer satisfaction.

3. Driverless delivery:

An AI-based smart delivery system enables vehicles to manage deliveries automatically without human intervention. Driverless delivery is accomplished through self-driving vehicles powered by LIDAR technology. These vehicles run on electricity, which reduces transportation costs, pollution, and wear and tear on the vehicle, thereby increasing productivity and becoming more environmentally friendly.

4. Threat detection/fraud prevention:

The proposed system can also help businesses detect risks or threats beforehand and prevent fraud. While planning the route for delivery of the item or product, the system checks the records to see if anything unusual might have happened during previous deliveries or not. This greatly reduces the risk and ensures the safe delivery of goods.

5. Increased productivity:

Artificial intelligence can significantly increase the productivity of a business by providing the best logistics solutions that can save time.

DISCUSSION

Our study reveals that, despite the numerous advantages of our AI-based delivery system, there are still some limitations to consider. First, the cost of implementing such an AI model, along with various machine learning algorithms, may be prohibitively expensive for smaller businesses and start-ups. Second, the model's complexity may pose challenges for companies lacking personnel experienced in working with AI and machine learning. Third, the system may be less user-friendly for end-users who are unfamiliar with this advanced technology, especially those in rural areas or older users who are not tech-savvy. Fourth, there are potential security risks associated with storing customer data and product history. Finally, there are technological limitations, as the system's computer vision struggles to identify fully transparent or translucent objects. The prohibitive cost of implementing such technology indicates that it may not be a feasible solution for all businesses, particularly smaller ones or startups with limited capital. The complexity of the system and resulting difficulty in implementation underscore the need for more experienced personnel. This could be addressed through specialized training programs or creating more user-friendly interfaces. The system's lack of user-friendliness for certain demographics, particularly in rural or older populations, suggests that more work needs to be done to ensure accessibility and ease of use for all. Security risks associated with storing customer data and product history are another critical area to address. Future iterations of the system should prioritize strengthening data security to maintain customer trust and ensure smooth operations. The limitations of computer vision in recognizing transparent or translucent objects present a technological challenge that could be overcome by incorporating advanced technologies like LiDAR.

On the other hand, our study also points towards promising future directions. The software part of our project is close to completion, and we aim to make it commercially viable. We also aim to successfully integrate the software with the hardware to create an all-encompassing system. We envisage a variety of business sectors that could benefit from incorporating AI into their delivery and logistics infrastructure, including healthcare, food delivery, government, supply chain management, transportation, waste management, and courier delivery. As AI continues to evolve and become more advanced, it will undoubtedly bring new opportunities for businesses. Further research could provide valuable contributions to strengthen theoretical understanding while continuing to provide practical empirical evidence. Furthermore, the study emphasizes the potential benefits of automation technologies, such as robotics, which can supplement human power and increase efficiency in various operations. Despite the challenges of implementing AI, if addressed efficiently, its advantages could be fully utilized.

CONCLUSION

In conclusion, the proposed AI-Based Smart Delivery System presents a promising solution to enhance and optimize delivery operations in the rapidly evolving landscape of e-commerce and logistics. Leveraging computer vision, the system utilizes an ESP32 microcontroller, an OV7670 camera module, and open-source libraries such as OpenCV and TensorFlow for real-time object detection and classification. The modular design ensures flexibility and seamless integration with tracking devices and transportation mechanisms, paving the way for end-to-end automation. The key benefits of the system include accurate labeling, routing, and sorting of packages, addressing common challenges associated with human errors and delivery delays. While acknowledging limitations related to transparency and lighting conditions, the potential for scalability across various sectors like food delivery, healthcare logistics, and transportation is substantial. As industries continue to embrace technological advancements, the proposed framework provides a practical and cost-effective approach to building intelligent delivery systems. By offering visibility and reliability, these AI-powered systems have the potential to transform traditional supply chains into efficient, self-regulating ecosystems. With further refinement and development, the presented solution can contribute significantly to shaping the future of intelligent and automated delivery services.

CONFLICT OF INTERESTS

The authors confirm that there is no conflict of interests associated with this publication.

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