ParcelGuard: Improving Parcel Tracking and Delivery using GS1 Digital Link

Embedded Operating Systems (2023 CS632)
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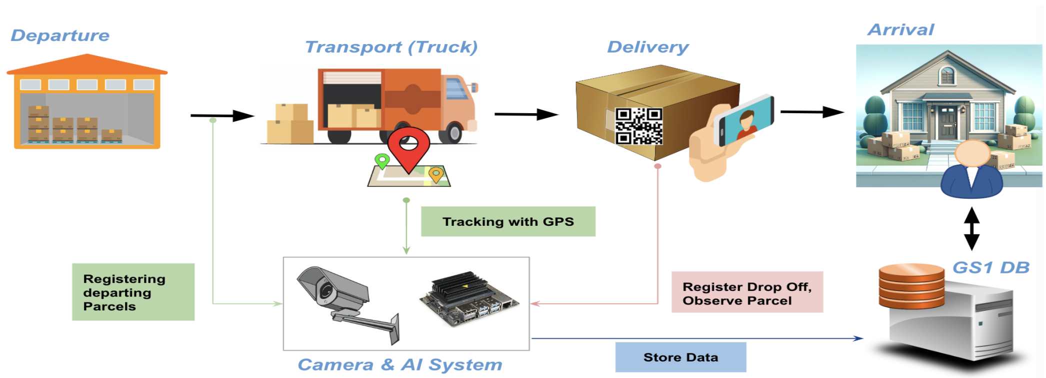

Figure 1. ParcelGaurd pipeline. Green arrows indicate the outdoor parcel tracking system and red arrows indicate the indoor parcel tracking system. GS1 Data are transferred through the Embedded system and stored in the GS1 DB.

Abstract

We present ParcelGaurd, a new parcel-tracking system that combines GPS-based outdoor tracking and Vision AI-based parcel tracking for indoor tracking. We built our system based on embedded devices where Nvidia Jetson was used to implement AI Models and Web interfaces, and LattePanda was used for GS1 Digital Link, FIWARE, and GS1 EPCIS. ParcelGaurd provides real-time tracking that can cover the entire parcel lifecycle, from distribution to the final delivery, which can improve parcel security and management, and offer robust tracking capabilities, and improve user experience.

1. Introduction

Parcel tracking is essential for security, accuracy, data management, and usability. Existing issues include lost parcels, inaccurate tracking, difficulty finding parcels, and non-automated processes. The proposed end-to-end system monitors parcels from shipment to delivery, allowing customers to track them with transparency. This includes: 1) Tracking the parcel's location during the transportation service 2) Tracking the parcel's location after the transportation service. By incorporating cameras and GS1 standards, this system will aid in effective monitoring, security, and accuracy of the process. Furthermore, the customer will have a seamless and easy-to-use experience while accessing parcel details.

Fig. 1 shows the overall ParcelGaurd pipeline. The system uses GPS, cameras, and an AI System for tracking parcel location in real-time and uses GS1 code, Digital Link, and GS1 EPCIS to store and share the data. Our system comprises outdoor tracking and indoor tracking functionalities. In outdoor tracking, we utilize GPS that is attached to the transportation to track the parcel, while in indoor tracking, a vision-based AI system is employed to monitor the parcel's location in conjunction with the camera. The comprehensive process comprises four steps: parcel location, loading, delivery, and receipt, with event management at each step facilitated through the use of GS1 code, Digital Link, and EPCIS.

2. Related Work

GS1 is a global, neutral, non-profit standards organization that brings efficiency and transparency to the supply chain. **EPCIS** is a GS1 standard that enables supply chain partners to share information about the physical movement and status of products, as well as other objects, as they travel throughout the supply chain. **FIWARE** offers a framework of open-source software for developing smart solutions, with its architecture centered around managing digital twin data via the NGSI API. We used GS1 Digital Link, FIWARE, and GS1 EPCIS to capture the parcel's location

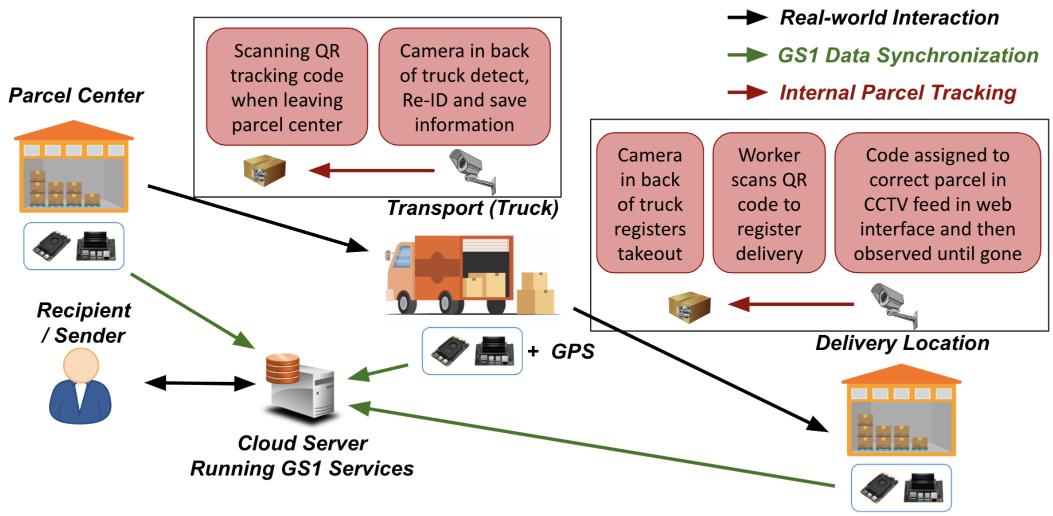

Figure 2. Implementation overview of ParcelGaurd. ParcelGaurd is composed of three major parts 1) Real-world Interaction 2) GS1 Data Synchronization 3) Internal Parcel Tracking.

by tracking the events of the parcel when parcels are moved or taken. [1]

Object Detection and Tracking The YOLO models were first developed by Redmon et al. [6] in 2015 as a revolutionary real-time object detection model. Since then, the model has inspired many different iterations. YOLOv7 is one of the current state-of-the-art YOLO models developed by Wang et. al. [7]. Wojke et al. [8] DeepSORT is used to track the objects by assigning each tracked object a unique ID. DeepSORT is an extension of the SORT algorithm by introduces deep learning. Tracking is made more efficient by adding an appearance descriptor to reduce the identity switches. DeepSORT tracks objects based on their velocity, motion, and appearance. Yang et al. [9] apply YOLOv7 as the object detection part to the DeepSORT, and propose YOLOv7-DeepSORT, which can track multiple objects in a real-time. Our model also uses YOLOv7 to detect parcels from an indoor environment and uses DeepSort to track multiple parcels.

Parcel Tracking System Papers on automated parcel tracking and sorting systems are limited but the existing ones reveal that real-time performance is practical and achievable. Kim et al. [4] use YOLO v5 for parcel detection in public parcel storage for automated positioning. There was a 4.5 % improvement in mean average precision (mAP:0.5) but limited applicability due to high constraints and no matches with other data. Liu et al. [5] use YOLO v5+SE attention mechanism+DeepSORT to track express parcels in sorting facilities. They achieved 2.6% higher in precision. Clausen et al. [2] use a Mask R-CNN siamese network and were able to track about 81% of the parcels correctly in indoor distribution hubs.

3. Methods

In Section 3.1 and 3.2, we will briefly explain the overall structure of our key components and their process. In Section 3.3 $\sim$ 3.7, we will explain in detail the implementation of each parcel tracking system, GS1 Digital Link, FIWARE, GS1 EPCIS, and GUI's'.

3.1. Devices

We used Nvidia Jetson NX and LattePanda as embedded devices. These devices were utilized in the Transport (Truck) and the Parcel Center/Delivery Location. Nvidia Jetson was specifically used for implementing AI Models and Web interfaces, and LattePanda was used for implementing GS1 Digital Link, GS1 EPCIS, and FIWARE.

3.2. Overview

The system can be viewed as three interdependent parts: Real-world Interactions, GS1 Data Synchronization, and Internal Parcel Tracking.

The Real-world Interactions can be seen as the recipient/sender, interacting with the Cloud Server running GS1 Services to track the parcel. The physical movement of the parcel from the Parcel Center and then Transport (Truck) to the Delivery Location is also included in this portion.

GS1 Data Synchronization includes the Nvidia Jetson and LattePanda in the Parcel Center, Transport (Truck), and the Delivery Location all interacting with the Cloud Server that runs GS1 Services.

Internal Parcel Tracking is present in the Transport (Truck) and the Delivery Location. Within the Transport (Truck), the QR tracking code is scanned when leaving the parcel center. The camera in the back of the truck detects

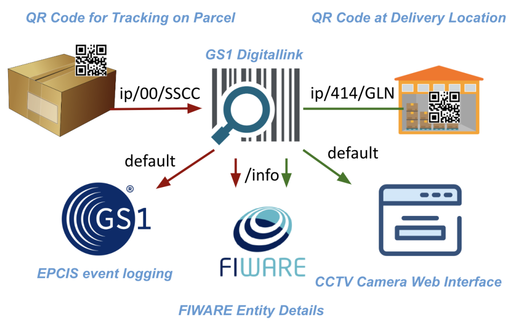

Figure 3. Overview of GS1 Digitallink Implementation

the parcel, Re-IDs, and saves information. At the Delivery Location, the camera in the back of the truck registers takeout, the worker scans the QR code to register the delivery, a code is assigned to a specific parcel in the CCTV feed in the web interface, and the parcel is observed until pickup.

3.3. Object tracking

Yang et al. [9] propose YOLOv7-DeepSORT, an integration of the YOLOv7 object detection network with DeepSORT to leverage the strengths of both systems for improved tracking accuracy. The process involves detecting targets with YOLOv7, extracting distinguishing features via the ReID model, and then using a Kalman filter along with the Hungarian algorithm for target trajectory prediction and matching. However, the existing YOLOv7 that is trained on MS COCO dataset doesn't provide parcel detection, so we fine-tuned YOLOv7 on the Products Couter dataset [3] to detect parcels. Products Couter dataset consists of 25k parcel training images, which have complex and realistic features that contain images such as multiple parcels occluded to each other and damaged boxes. We trained our model with Adam optimizer at a learning rate 10^{-2} for 50 epochs

3.4. GS1 Digitallink

GS1 Digital Link integrates GS1 identifiers with the web, providing information for B2B and B2C transactions. It improves supply chain traceability, brand loyalty, patient safety, and more. A single barcode can provide access to a product's digital information.

Fig. 3 shows the overview of our GS1 Digitallink Impelementation. QR codes are used for tracking parcels, and they offer specific features that facilitate efficient tracking. When the QR code for tracking a parcel is scanned, the IP/00 followed by the Serial Shipping Container Code (SSCC) translates to a GS1 Digital Link, which provides efficient parcel tracking. By default, a GS1 EPCIS event logging is prompted, and crucial event data is captured.

At the delivery location, scanning the QR code will reveal IP/414 accompanied by the Global Location Number

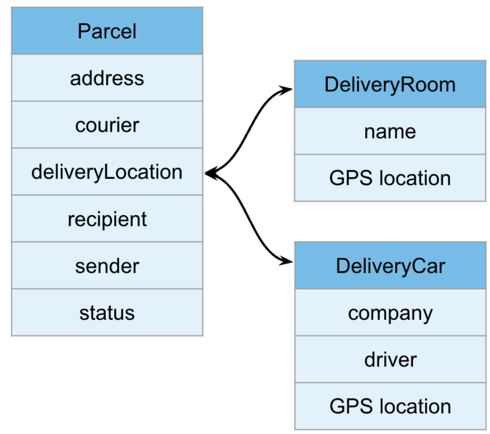

Figure 4. FIWARE Entities created for ParcelGuard. FIWARE Entities is composed of Parcel, DeliveryRoom and DeliveryCar

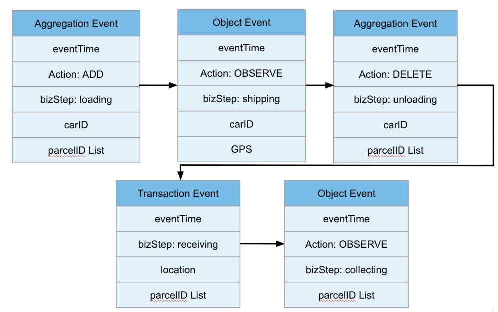

Figure 5. Implemented GS1 EPCIS events in order of occurrence. EPCIS is composed of Aggregation Event, Object Event, and Transaction Events

(GLN), which enables the GS1 Digital Link. By default, it provides access to the CCTV Camera Web Interface, offering real-time visual insights.

In both cases, the "/info" endpoint retrieves FIWARE Entity Details, providing comprehensive information about the entity at the delivery location.

3.5. FIWARE

FIWARE is a software platform standard that helps in the development of Smart Applications. It is implementation-driven, open source, and provides APIs to connect with the Internet of Things (IoTs). With FIWARE, managing context information becomes less complex.

Fig. 4 shows FIWARE entities used on ParcelGaurd. We have created three entities: Parcel, DeliveryRoom, and DeliveryCar. The parcel is associated with either DeliveryCar or DeliveryRoom, and its object fields are updated in real-time based on delivery events.

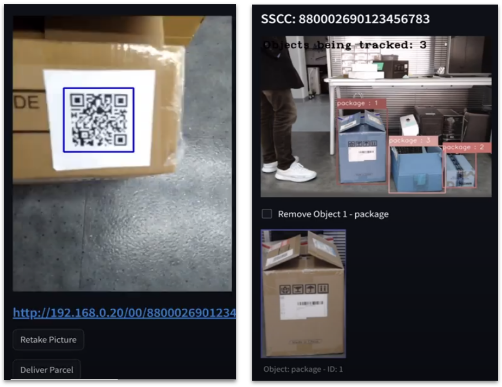

Figure 6. Example of GUI implementation that is developed based on Streamlit.

3.6. GS1 EPCIS

The Electronic Product Code Information Services (EPCIS) is a standard that enables different trading partners to share and exchange information about the status of products as they move through the supply chain globally. EPCIS provides a consistent way to record and communicate data about a product's lifecycle, which in turn enhances visibility and traceability.

Fig. 5 shows implemented GS1 EPCIS events in order of its occurrence. We designed Aggregation events for loading and unloading the parcel from the delivery vehicle. We used Object events for shipping and collecting and Transaction events for the receiving.

3.7. GUI Implementation

Our web-based Streamlit application GUI helps delivery men scan a parcel's QR code. If the QR code is not detected or is found to be blank/corrupted, the delivery man can manually enter it or retake the picture. Once the product number is confirmed, the delivery man can press the Deliver Parcel button, which connects them to the AI system of the parcel delivery room. The webpage then shows pictures of new parcels that have been delivered to the room. Finally, the delivery man can click the dropped-off box to remove it from the newly identified package list. We use a QR-Code Checking system that works through a streamlit picture and checks the validity of the GS1 SSCC Code using its length and validation bit.

4. Results

4.1. GUI implementation and Demo Videos

Fig. 6 shows the result of our GUI implementation that is used to read QR code and assign IDs to the newly delivered parcel for the indoor tracking system. Detailed implementation is shown in our demo video, please refer to the http.

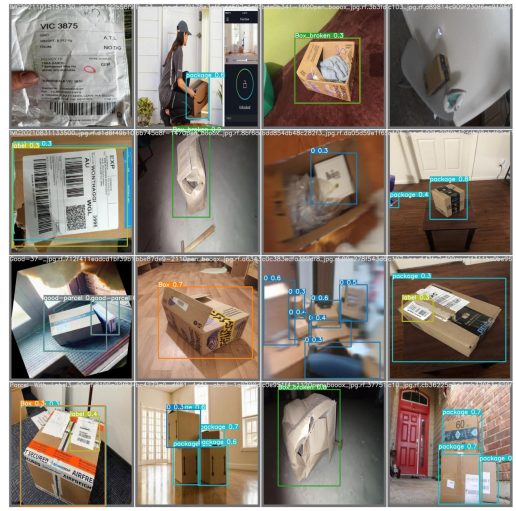

Figure 7. Fine-Tuned YOLOv7 parcel detection result on Products Couter dataset [3] test sets.

4.2. Parcel tracking using YOLOv7 & DeepSort

Fig. 7 shows the result of fine-tuned YOLOv7 that are trained on Products Couter dataset [3]. Although our model occasionally misidentifies non-box-shaped parcels, we can see that our model can detect parcels that are broken or mutually occluded to each other. It has achieved a precision score of 0.611, a recall score of 0.659, and a mean Average Precision (mAP) of 0.656 at an IoU threshold of 0.5 on the test sets. Moreover, it operates efficiently, averaging 10 to 13 frames per second on Nvidia Jetson hardware that can operate on real-time scenario

5. Conclusion

We successfully developed a real-time parcel tracking system using YOLOv7 with DeepSort. However, some limitations need to be addressed. The extended Re-ID of packages needs to be improved to handle longer occlusions. Additionally, accuracy needs to be enhanced, especially in scenes with large numbers of parcels. Currently, only one concurrent user per interface is supported due to performance spikes, and the GUI is not user-friendly for observing parcel delivery. To improve the model's performance in terms of resources and accuracy, further research is required. As our proposed system was only an MVP, full user testing in real-world scenarios is necessary. Lastly, we suggest exploring automatic authentication of users when picking up parcels to prevent theft.

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