

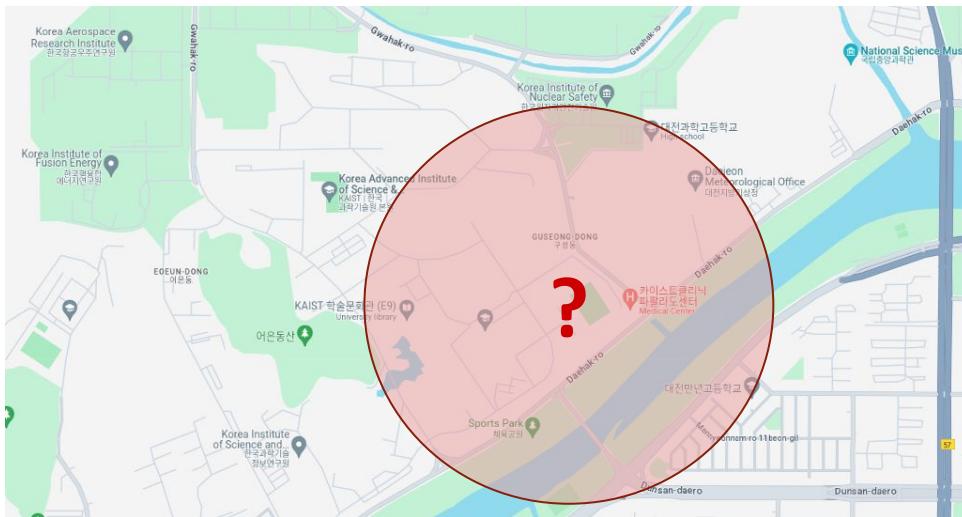
ParcelGuard

Improving Parcel Tracking and Delivery

Dong Hyuk Kim, Lucas Liebe, Min Jae Yi, Eugene Lee

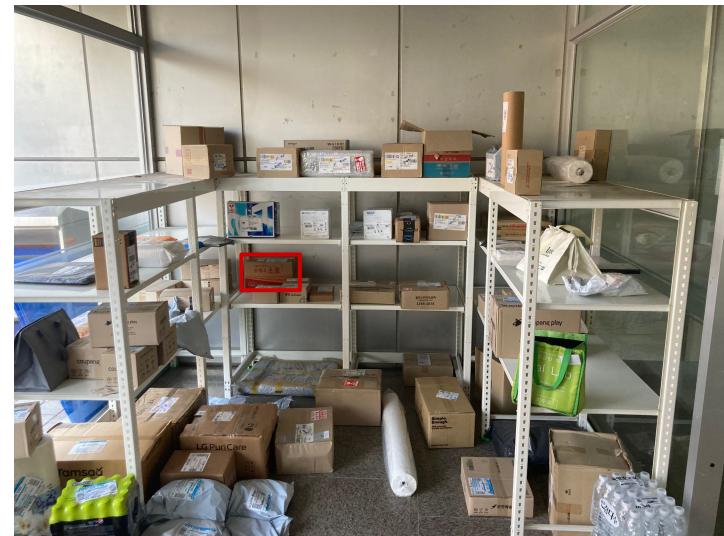
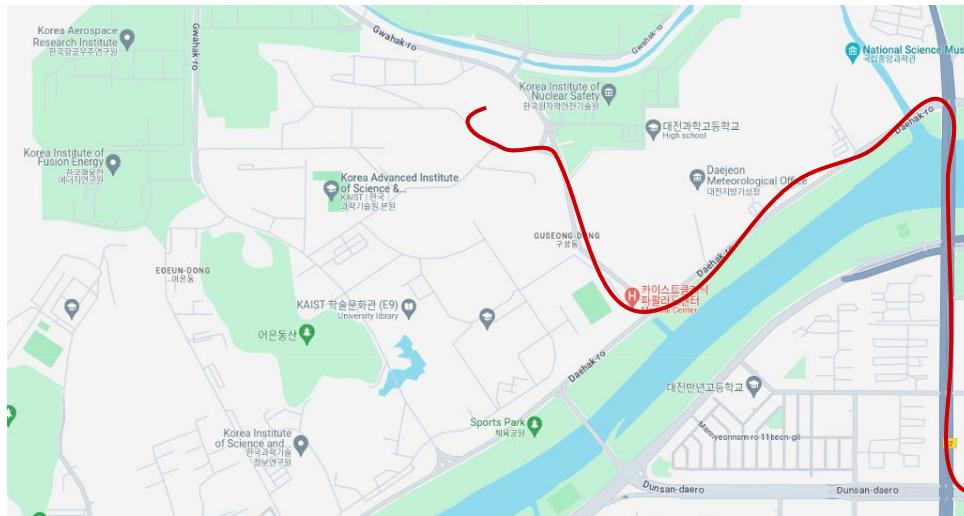
Introduction (Problem Definition)

- Tracking of Parcels should be improved for
 - Security
 - Accuracy
 - Amount of Data
 - Ease of Use



Introduction (Proposed Solution)

- We need parcel tracking system until the parcel is arrived to the end customer.
 - Customers can track its parcel's location during transportation service
 - Customers can track its parcel's location after transportation service
 - Use cameras and GS1 standards



Introduction (Idea Overview)

Departure



Transport (Truck)



Delivery



Arrival

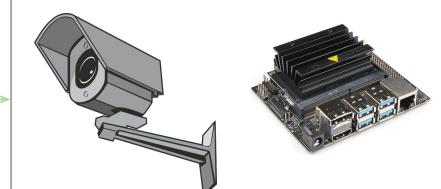


Registering
departing
Parcels

Tracking with GPS

Register Drop Off,
Observe Parcel

GS1 DB

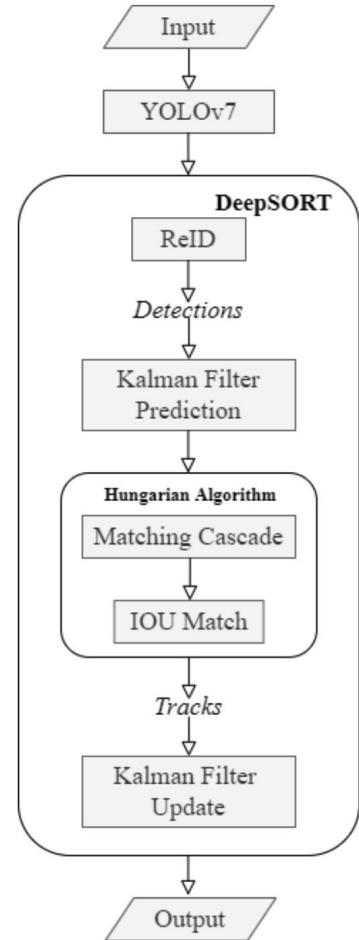
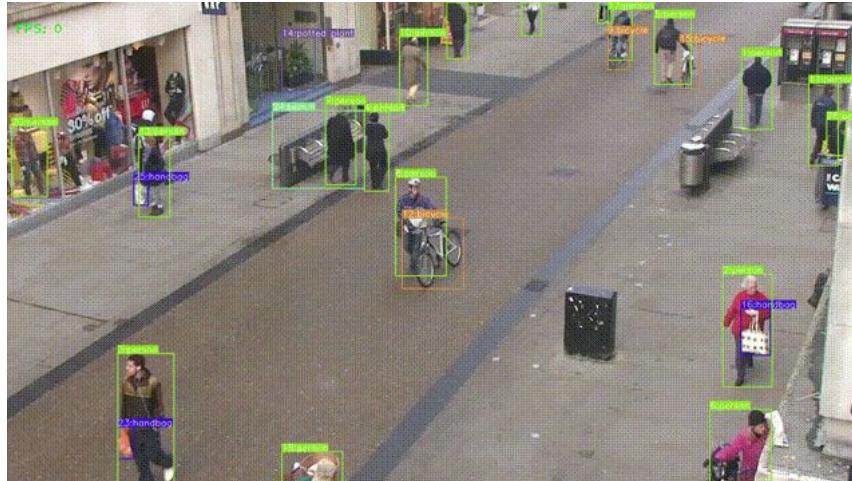


Camera & AI System

Store Data

Related works

AI System using Yolov7 with DeepSort ReID for Parcel Tracking



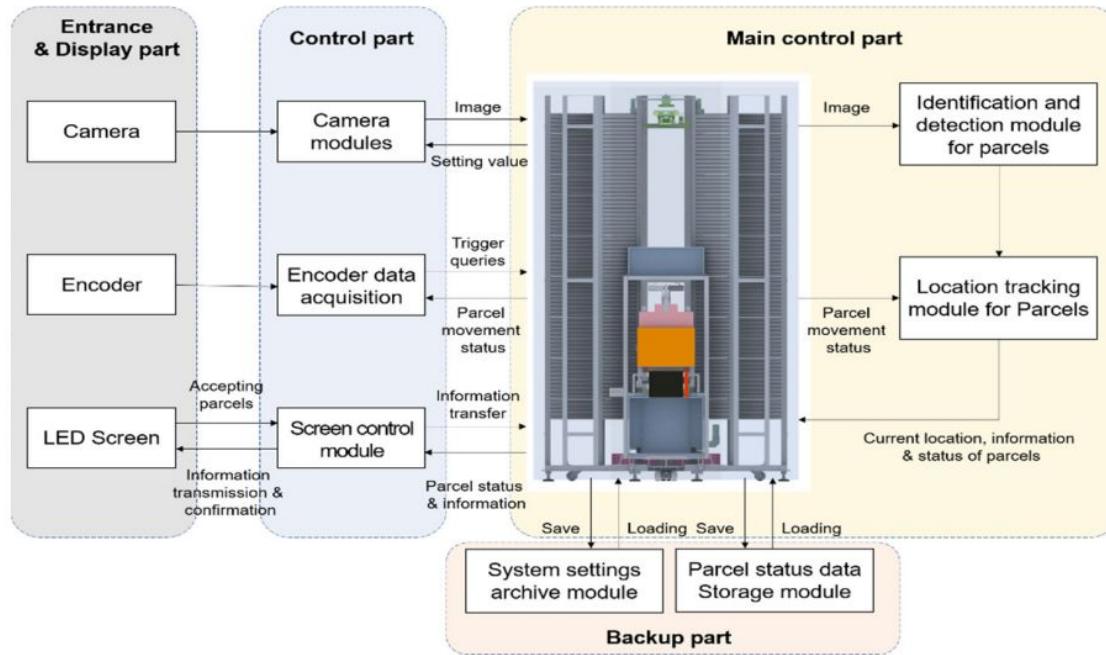
Yang, Feng, Xingle Zhang, and Bo Liu. "Video object tracking based on YOLOv7 and DeepSORT." <https://arxiv.org/pdf/2207.12202.pdf>

Related works

Parcel detection in public storages for automated positioning with Yolo v5

4.5% improvement in mean average precision (mAP_0.5)

[[Kim M; Kim Y, 2023](#)]

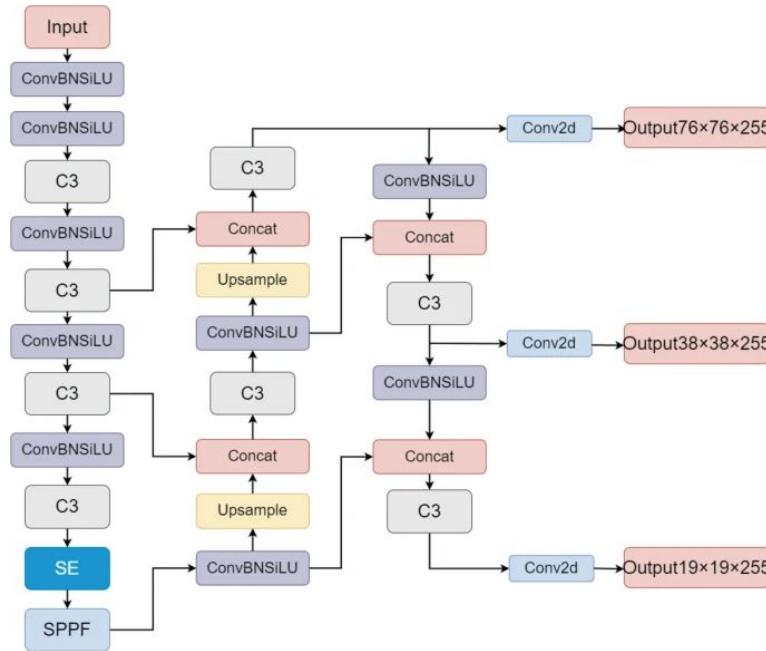


Related works

Real Time Tracking of Express parcels in sorting facilities

Using YOLO v5+SE attention mechanism+DeepSORT to achieve 2.6% higher precision

[Liu et al., 2023]

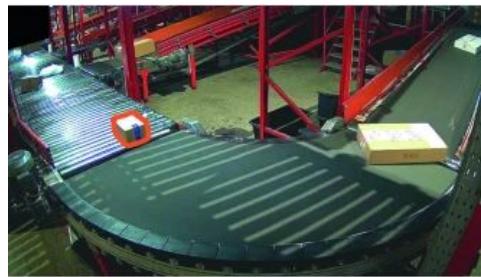


Related works

Parcel Center Tracking multiple cameras and frames with Mask R-CNN siamese network

Able to track about 81% of the parcels correctly in indoor distribution hubs

[\[Clausen et al., 2018\]](#)



(a) Camera 1



(b) Entry camera 2



(c) Exit camera 2



(d) Entry camera 3

Contributions

- **Expanded Related Works to outside Parcel Centers**
 - Usage of embedded devices in mobile environment (delivery car)
 - Established post-delivery parcel traceability
- **Fine tuned YOLOv7 to detect parcels**
 - First use of YOLOv7 for this use-case
 - Added object permanence for parcels
- **Incorporated GS1 standards to parcel delivery pipeline**
 - Usage of webUI and QR codes for GUI

Implementation Devices

Parcel Center / Delivery Location

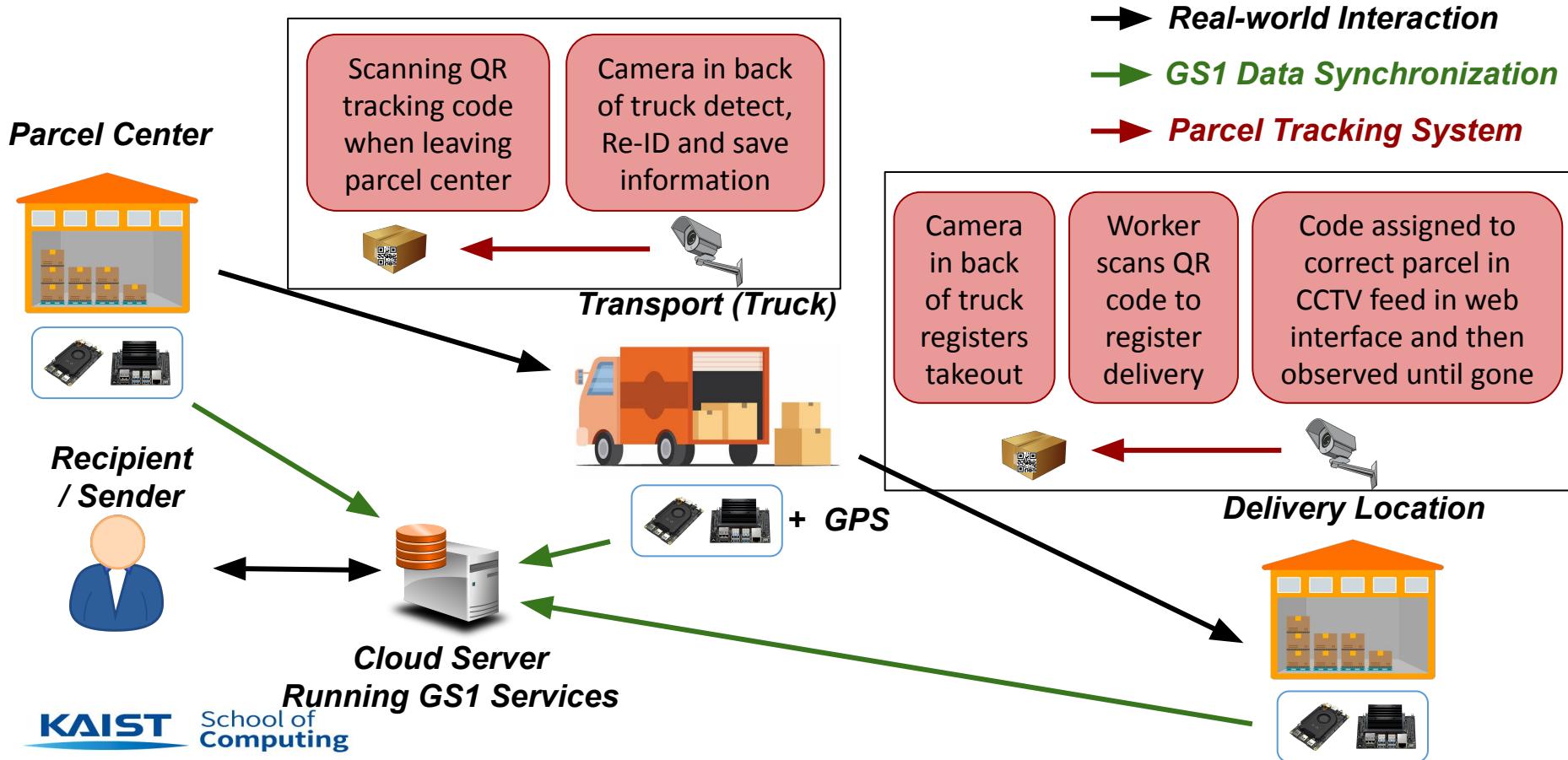
Transport (Truck)



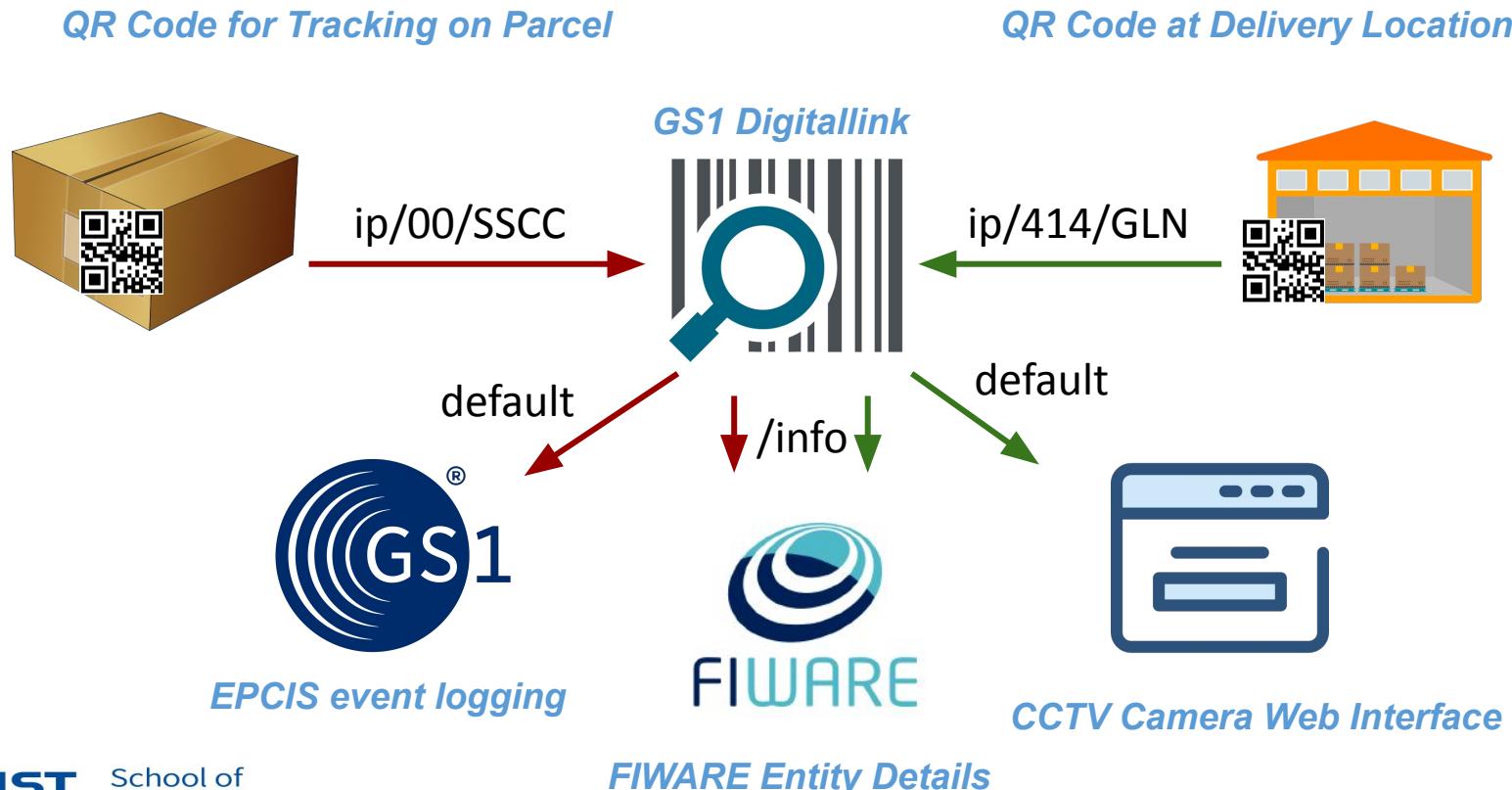
LattePanda:
- Digital Link
- FIWARE
- EPCIS

NVIDIA Jetson:
- AI Model
- Web Interface

Implementation Overview

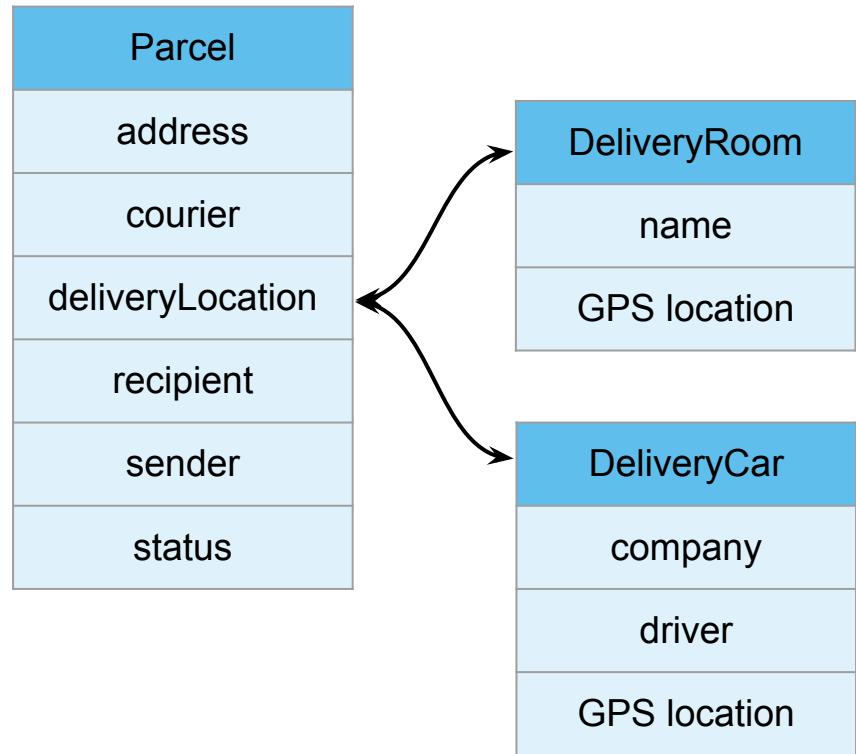


Implementation GS1 Digitallink



Implementation FIWARE

- 3 types of entities created:
Parcel, DeliveryRoom and DeliveryCar
- Parcel has a weak association with
DeliveryCar or DeliveryRoom
- Parcel object fields are updated according
to real-time delivery events



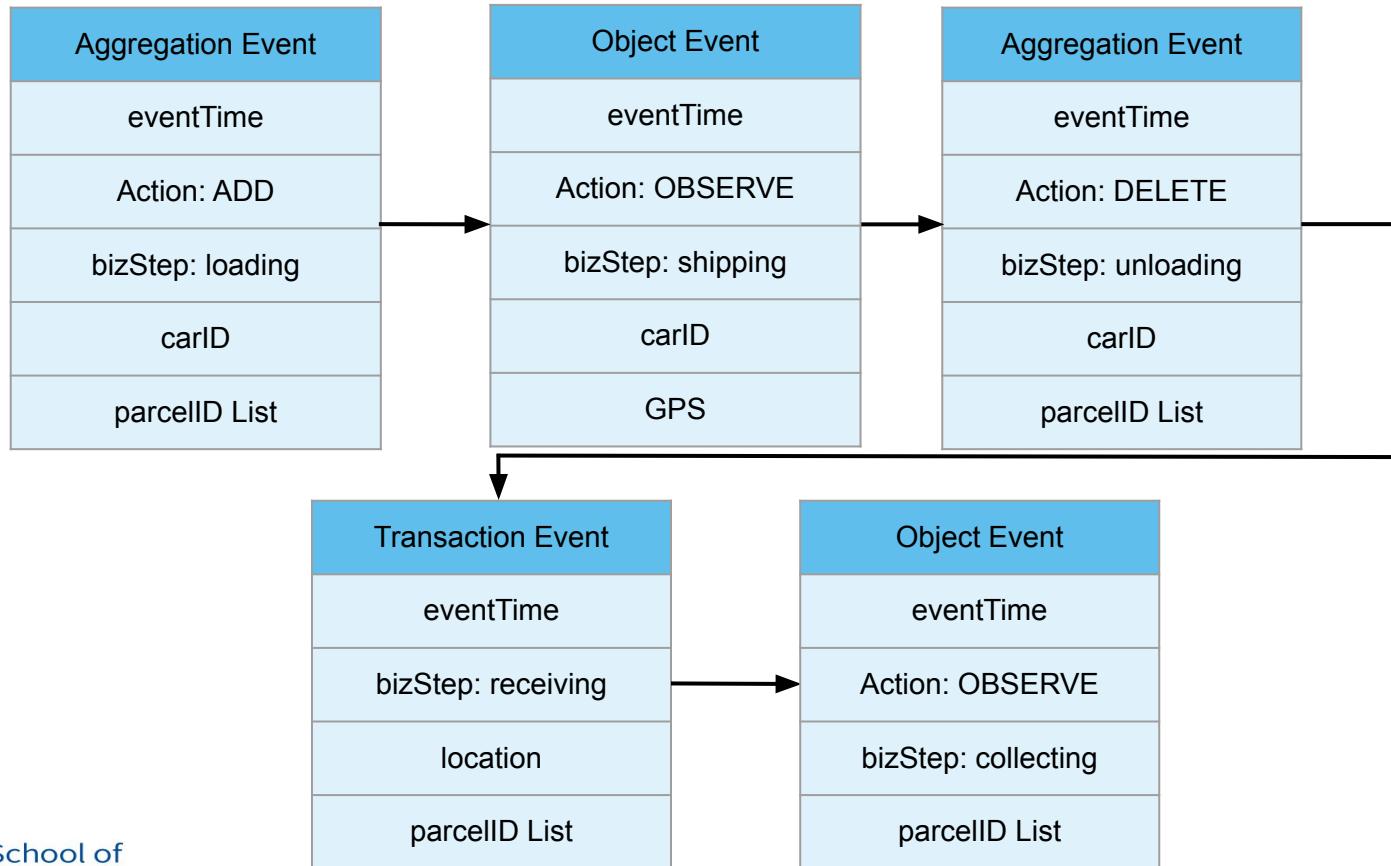
Implementation GS1 EPCIS

- Created Aggregation event for loading/ unloading parcel into/from delivery car, Object events for shipping, collecting and Transaction event for receiving

```
{  
    "eventTime": "2023-11-24T07:59:02.099+09:00",  
    "recordTime": "2023-11-24T00:54:23.115Z",  
    "eventTimeZoneOffset": "+09:00",  
    "type": "AssociationEvent",  
    "certificationInfo": "https://customsauthority.example.gov/certificate/ABC12345",  
    "parentID": "https://id.gs1.org/414/4012345000016",  
    "childPCs": [  
        "https://id.gs1.org/00/106141412345678908"  
    ],  
    "action": "ADD",  
    "childQuantityList": [  
        {  
            "epcClass": "https://id.gs1.org/01/10614141073464/21/2017",  
            "quantity": 1  
        },  
        {  
            "epcClass": "https://id.gs1.org/01/10614141073464/21/2018",  
            "quantity": 1  
        }  
    ],  
    "bizStep": "loading",  
    "__v": 0  
},
```

```
{  
    "eventTime": "2023-11-24T09:46:12.851+09:00",  
    "recordTime": "2023-11-24T00:52:57.235Z",  
    "eventTimeZoneOffset": "+09:00",  
    "type": "TransactionEvent",  
    "bizTransactionList": [  
        {  
            "type": "po",  
            "bizTransaction": "https://id.gs1.org/253/06141410000121618034"  
        }  
    ],  
    "parentID": "https://id.gs1.org/00/106141412345678908",  
    "epclist": [  
        "https://id.gs1.org/01/10614141073464/21/2017",  
        "https://id.gs1.org/01/10614141073464/21/2018"  
    ],  
    "action": "ADD",  
    "bizStep": "unloading",  
    "__v": 0  
},
```

Implementation GS1 EPCIS



Implementation Yolov7

Yolov7 by default does not contain parcel class

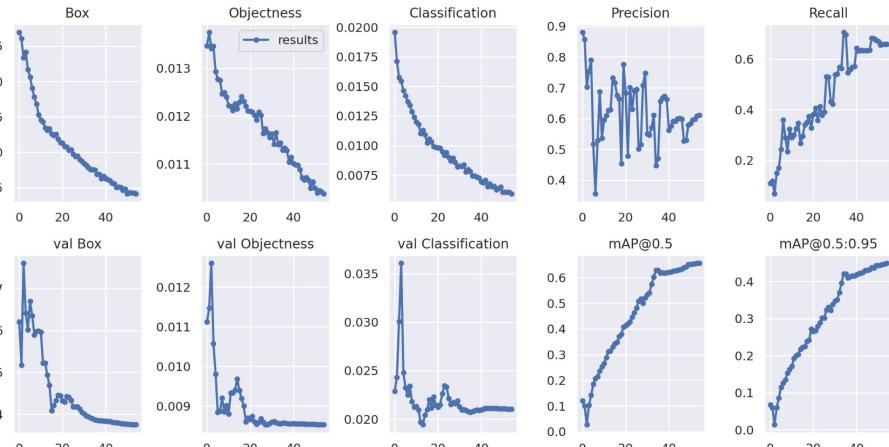
- Fine-Tune Yolov7 on parcel dataset in 50 epochs
 - 26000 parcel images with augmentation

<https://universe.roboflow.com/hamza-dr69s/products-couter-yxfxm>

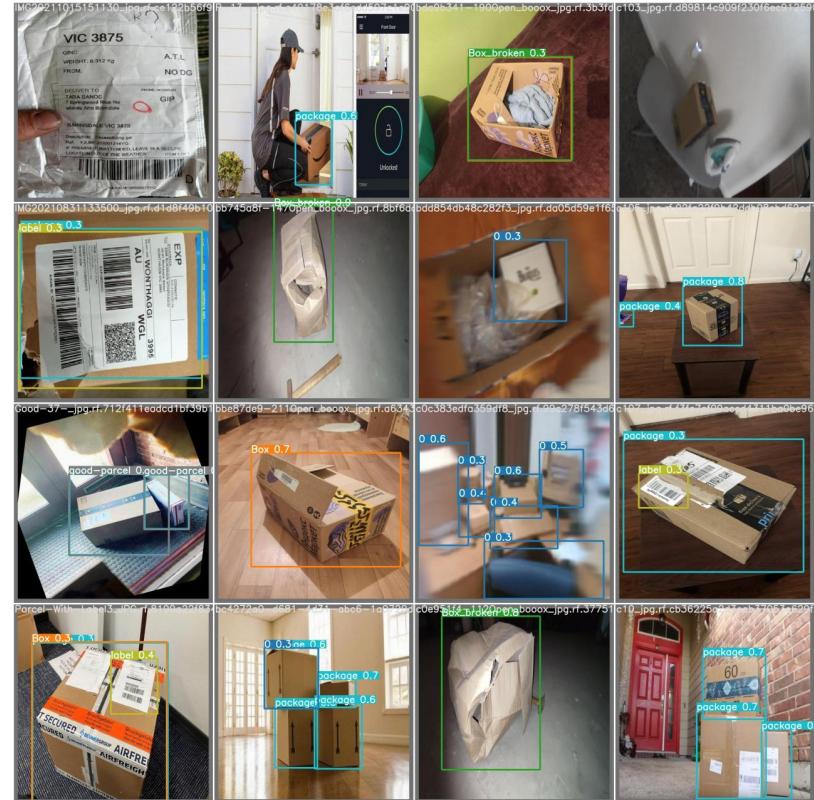


Fintuning Yolov7 Results

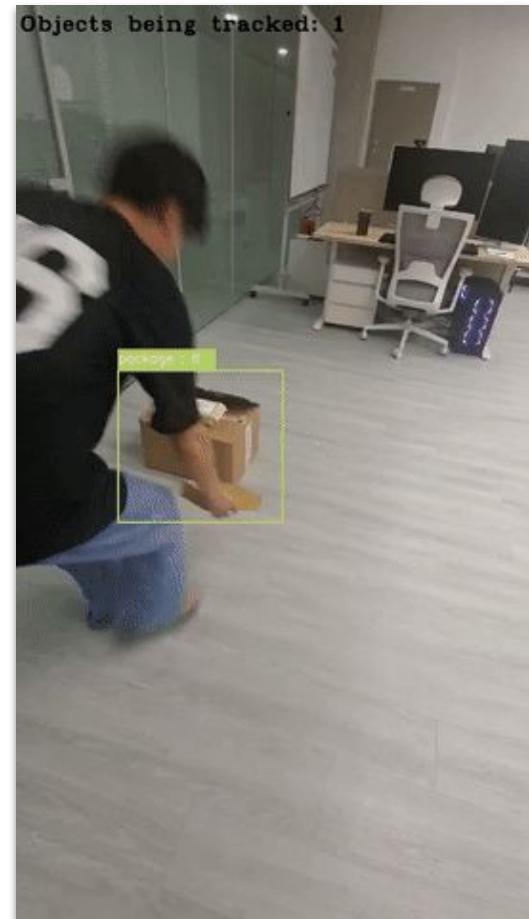
Test Results



Precision	Recall	mAP.5	map.5:.95	val_box	val_obj	val_cls
0.6111	0.6592	0.6565	0.4495	0.03753	0.008535	0.02102



Fintuning Yolov7 Results



Implementation GUI

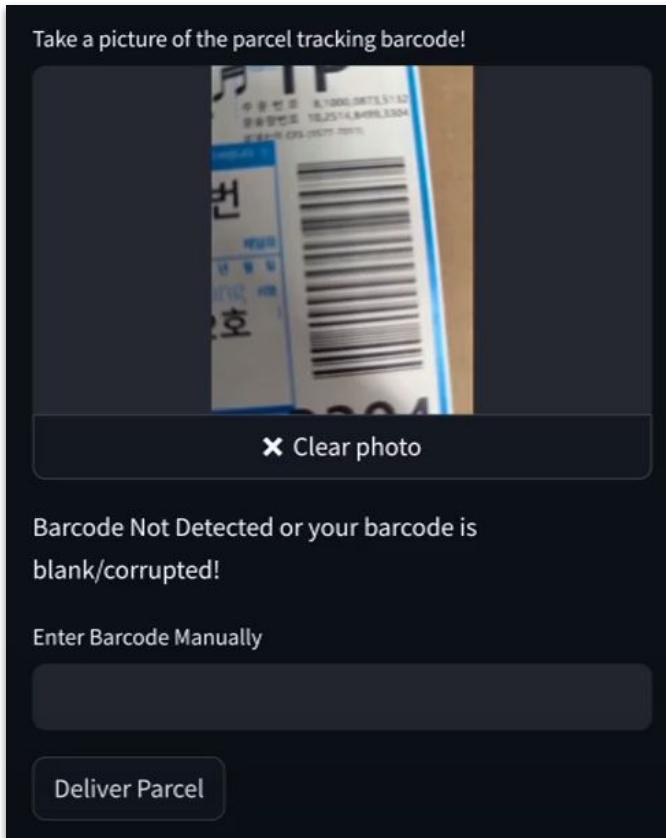
- Streamlit for Web Interface
 - Open-source python framework
 - Create interactive data apps
 - Focus on Machine Learning and Data Science Teams

- `streamlit.session_state` is used to store and interact with data until next refresh
 - No persistence necessary and improved security
- `placeholder = streamlit.empty()` gives us containers that we can fill with different content that can dynamically be displayed
 - Have one page without subpages that handles the whole behavior
 - Minimize data transfer and complexity



Streamlit

Implementation GUI



Screen

placeholder

```
img = streamlit.camera_input(label, key)
```

```
streamlit.write(text)
```

```
code = streamlit.text_input(label)
```

```
streamlit.button(label)
```

Implementation GUI

Take a picture of the parcel tracking barcode!



Clear photo

Barcode Not Detected or your barcode is
blank/corrupted!

Enter Barcode Manually

Deliver Parcel



<http://192.168.0.20/00/8800026901234>

Retake Picture

Deliver Parcel

Screen

placeholder
`streamlit.image(img)`

`streamlit.write(code)`

`streamlit.button(label)`

`streamlit.button(label)`

Implementation GUI

Take a picture of the parcel tracking barcode!



Clear photo

Barcode Not Detected or your barcode is
blank/corrupted!

Enter Barcode Manually

Deliver Parcel

Screen

```
streamlit.subheader(code)
```

placeholder

```
img = streamlit.image(cctv)
```

element

```
streamlit.checkbox(label, key)  
streamlit.image(box, caption)
```

SSCC: 880002690123456783

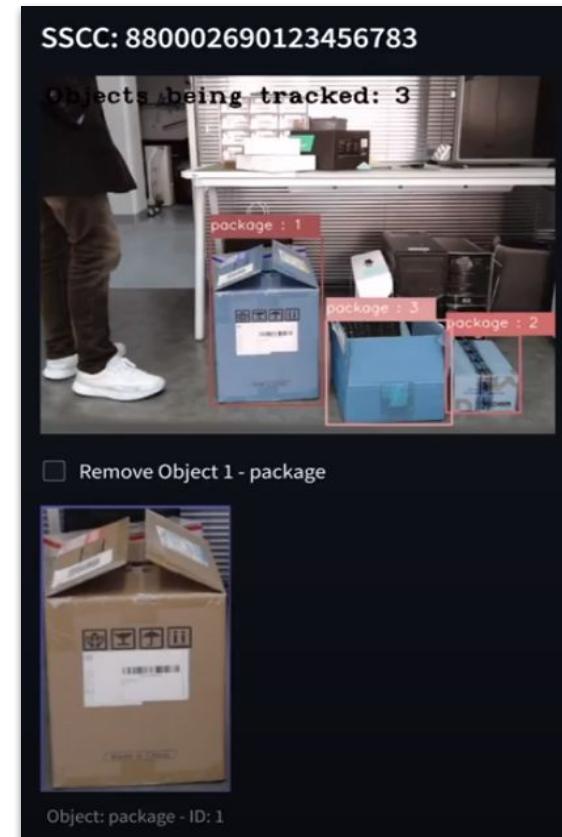
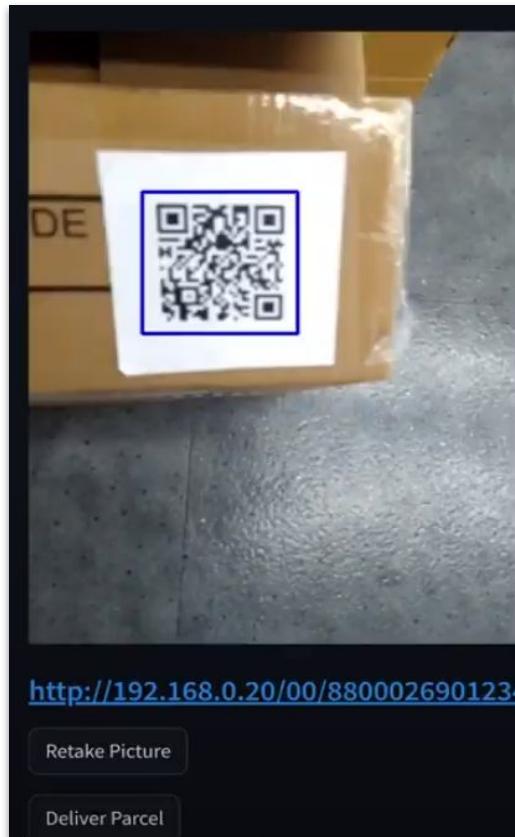
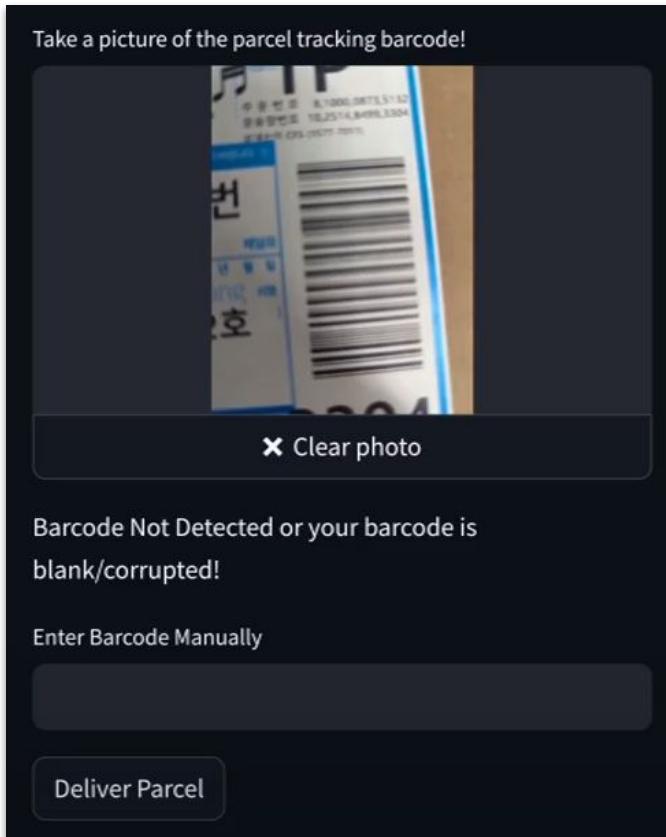


Remove Object 1 - package



Object: package - ID: 1

Implementation GUI



Implementation QR-Code Checking

- Streamlit picture → bytes → OpenCV image in python



- `cv2.barcode.BarcodeDetector()`
- Check validity of GS1 SSCC Code through length and valid bit

Demo

Results

about 10 ~ 13 FPS

→ Real Time Tracking on Jetson NX possible
thanks to lightweight implementation

```
jetson@ubuntu: ~/parceltracking_v2
Processed frame no: 1955 || Current FPS: 12.62 || Objects tracked: 1
Processed frame no: 1956 || Current FPS: 13.14 || Objects tracked: 1
Processed frame no: 1957 || Current FPS: 13.8 || Objects tracked: 1
Processed frame no: 1958 || Current FPS: 12.98 || Objects tracked: 1
Processed frame no: 1959 || Current FPS: 11.87 || Objects tracked: 1
Processed frame no: 1960 || Current FPS: 12.89 || Objects tracked: 1
Processed frame no: 1961 || Current FPS: 12.59 || Objects tracked: 1
Processed frame no: 1962 || Current FPS: 13.02 || Objects tracked: 1
Processed frame no: 1963 || Current FPS: 14.32 || Objects tracked: 1
Processed frame no: 1964 || Current FPS: 14.29 || Objects tracked: 1
Processed frame no: 1965 || Current FPS: 14.48 || Objects tracked: 1
Processed frame no: 1966 || Current FPS: 11.12 || Objects tracked: 2
Processed frame no: 1967 || Current FPS: 12.53 || Objects tracked: 1
Processed frame no: 1968 || Current FPS: 13.01 || Objects tracked: 1
Processed frame no: 1969 || Current FPS: 10.94 || Objects tracked: 2
Processed frame no: 1970 || Current FPS: 11.71 || Objects tracked: 1
Processed frame no: 1971 || Current FPS: 13.06 || Objects tracked: 1
Processed frame no: 1972 || Current FPS: 14.15 || Objects tracked: 1
Processed frame no: 1973 || Current FPS: 10.23 || Objects tracked: 2
Processed frame no: 1974 || Current FPS: 10.82 || Objects tracked: 1
Processed frame no: 1975 || Current FPS: 12.76 || Objects tracked: 1
Processed frame no: 1976 || Current FPS: 10.23 || Objects tracked: 2
Processed frame no: 1977 || Current FPS: 7.73 || Objects tracked: 2
Processed frame no: 1978 || Current FPS: 10.74 || Objects tracked: 2
Processed frame no: 1979 || Current FPS: 11.75 || Objects tracked: 1
Processed frame no: 1980 || Current FPS: 12.82 || Objects tracked: 1
Processed frame no: 1981 || Current FPS: 13.0 || Objects tracked: 1
Processed frame no: 1982 || Current FPS: 13.07 || Objects tracked: 1
Processed frame no: 1983 || Current FPS: 12.87 || Objects tracked: 1
Processed frame no: 1984 || Current FPS: 13.05 || Objects tracked: 1
Processed frame no: 1985 || Current FPS: 14.25 || Objects tracked: 1
Processed frame no: 1986 || Current FPS: 11.21 || Objects tracked: 2
Processed frame no: 1987 || Current FPS: 12.05 || Objects tracked: 1
Processed frame no: 1988 || Current FPS: 12.95 || Objects tracked: 1
Processed frame no: 1989 || Current FPS: 13.13 || Objects tracked: 1
Processed frame no: 1990 || Current FPS: 12.96 || Objects tracked: 1
Processed frame no: 1991 || Current FPS: 14.27 || Objects tracked: 1
Processed frame no: 1992 || Current FPS: 14.07 || Objects tracked: 1
Processed frame no: 1993 || Current FPS: 11.32 || Objects tracked: 2
Processed frame no: 1994 || Current FPS: 12.52 || Objects tracked: 1
Processed frame no: 1995 || Current FPS: 10.73 || Objects tracked: 2
Processed frame no: 1996 || Current FPS: 13.49 || Objects tracked: 1
Processed frame no: 1997 || Current FPS: 11.18 || Objects tracked: 2
Processed frame no: 1998 || Current FPS: 13.53 || Objects tracked: 1
```

<Yolov7 + DeepSort Tracking Result inside GUI>

Results - EPCIS

```
{ "eventTime": "2023-12-01T06:32:11.099+09:00",
  "recordTime": "2023-12-11T05:44:37.070Z",
  "eventTimeZoneOffset": "+09:00",
  "type": "AggregationEvent",
  "parentID": "https://id.gs1.org/00/106141412345678908",
  "childEPCs": [ ],
    "https://id.gs1.org/01/10614141073464/21/2017"
  ],
  "action": "ADD",
  "childQuantityList": [ ]
    {
      "epcClass": "https://id.gs1.org/01/880002690123456783",
      "quantity": 1
    }
  },
  "sensorElementList": [ ]
    {
      "sensorReport": [ ]
        {
          "type": "gs1:Latitude",
          "time": "2023-12-01T06:32:11.099+09:00",
          "deviceID": "https://id.gs1.org/8004/4000001111",
          "deviceMetadata": "https://id.gs1.org/253/0614141123452006847",
          "rawData": "https://id.gs1.org/253/0614141123452006857",
          "dataProcessingMethod": "https://id.gs1.org/253/0614141123452006849",
          "value": 36.373869
        },
        {
          "type": "gs1:Longitude",
          "time": "2023-12-01T06:32:11.099+09:00",
          "deviceID": "https://id.gs1.org/8004/4000001111",
          "deviceMetadata": "https://id.gs1.org/253/0614141123452006847",
          "rawData": "https://id.gs1.org/253/0614141123452006857",
          "dataProcessingMethod": "https://id.gs1.org/253/0614141123452006849",
          "value": 127.359577
        }
      ]
    },
    "bizStep": "loading",
    "__v": 0
  },
  {
    "eventTime": "2023-12-01T10:49:02.099+09:00",
    "recordTime": "2023-12-11T05:46:29.375Z",
    "eventTimeZoneOffset": "+09:00",
    "type": "ObjectEvent",
    "epcList": [ ],
      "https://id.gs1.org/01/10614141073464/21/2018"
    ],
    "action": "OBSERVE",
    "quantityList": [ ]
      {
        "epcClass": "https://id.gs1.org/01/880002690123456783",
        "quantity": 1
      }
    ],
    "sensorElementList": [ ]
      {
        "sensorReport": [ ]
          {
            "type": "gs1:Latitude",
            "time": "2023-12-01T10:49:02.099+09:00",
            "deviceID": "https://id.gs1.org/8004/4000001111",
            "deviceMetadata": "https://id.gs1.org/253/0614141123452006847",
            "rawData": "https://id.gs1.org/253/0614141123452006857",
            "dataProcessingMethod": "https://id.gs1.org/253/0614141123452006849",
            "value": 36.373869
          },
          {
            "type": "gs1:Longitude",
            "time": "2023-12-01T10:49:02.099+09:00",
            "deviceID": "https://id.gs1.org/8004/4000001111",
            "deviceMetadata": "https://id.gs1.org/253/0614141123452006847",
            "rawData": "https://id.gs1.org/253/0614141123452006857",
            "dataProcessingMethod": "https://id.gs1.org/253/0614141123452006849",
            "value": 127.359577
          }
        ]
      },
      "bizStep": "shipping",
      "__v": 0
    }
```

Results - EPCIS

```
{ □
  "eventTime": "2023-12-01T12:15:42.099+09:00",
  "recordTime": "2023-12-11T05:49:29.334Z",
  "eventTimeZoneOffset": "+09:00",
  "type": "AggregationEvent",
  "parentID": "https://id.gs1.org/00/106141412345678908",
  "childEPCs": [ □
    "https://id.gs1.org/01/10614141073464/21/2017"
  ],
  "action": "DELETE",
  "childQuantityList": [ □
    { □
      "epcClass": "https://id.gs1.org/01/880002690123456783",
      "quantity": 1
    }
  ],
  "sensorElementList": [ □
    { □
      "sensorReport": [ □
        { □
          "type": "gs1:Latitude",
          "time": "2023-12-01T12:15:42.099+09:00",
          "deviceID": "https://id.gs1.org/8004/4000001111",
          "deviceMetadata": "https://id.gs1.org/253/0614141123452006847",
          "rawData": "https://id.gs1.org/253/0614141123452006857",
          "dataProcessingMethod": "https://id.gs1.org/253/0614141123452006849",
          "value": 36.374109
        },
        { □
          "type": "gs1:Longitude",
          "time": "2023-12-01T12:15:42.099+09:00",
          "deviceID": "https://id.gs1.org/8004/4000001111",
          "deviceMetadata": "https://id.gs1.org/253/0614141123452006847",
          "rawData": "https://id.gs1.org/253/0614141123452006857",
          "dataProcessingMethod": "https://id.gs1.org/253/0614141123452006849",
          "value": 127.36501
        }
      ]
    }
  ],
  "bizStep": "unloading",
  "__v": 0
}, { □
  "eventTime": "2023-12-01T12:17:22.099+09:00",
  "recordTime": "2023-12-03T05:40:24.641Z",
  "eventTimeZoneOffset": "+09:00",
  "type": "TransactionEvent",
  "bizTransactionList": [ □
    { □
      "type": "po",
      "bizTransaction": "https://id.gs1.org/253/0614141000121618034"
    }
  ],
  "parentID": "https://id.gs1.org/00/106141412345678908",
  "epcList": [ □
    "https://id.gs1.org/01/880002690123456783"
  ],
  "action": "OBSERVE",
  "bizStep": "receiving",
  "__v": 0
},
```

Conclusion

Current Limitations

- Extended Re-ID of packages is needed to handle longer occlusions
- Improve accuracy on scenes with large amounts of parcels
- Only one concurrent user per interface supported due to performance spikes
- No easy GUI for users to observe parcel delivery

Future Work

- Improve model performance in terms of resources and accuracy
- Implement and user test a full system in real world use
- Automatic authentication of user when picking up parcel to prevent theft

ParcelGuard

Improving Parcel Tracking and Delivery

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