PALLET DETECTION, TRACKING AND COUNTING USING COMPUTER VISION TECHNIQUES TO ACHIEVE THE WAREHOUSE AUTOMATION

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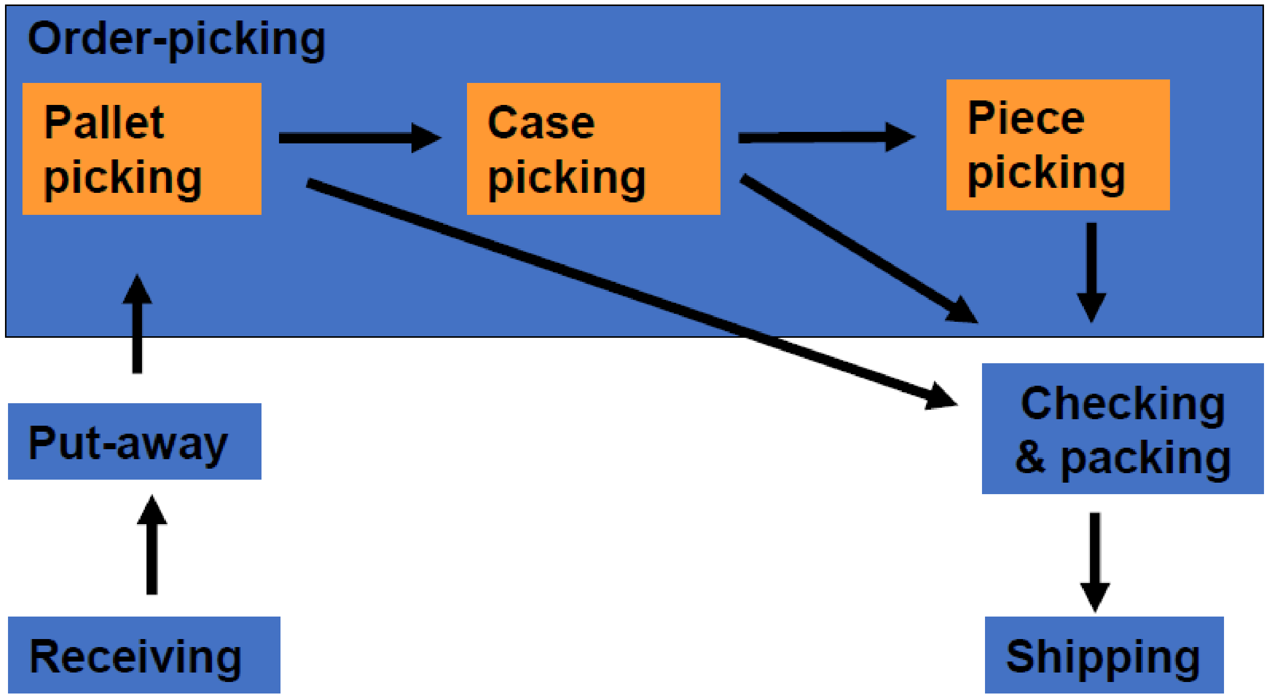
INTRODUCTION



- Warehouse management is a key component in the supply chain, that deals with the movement and storage of material within a warehouse.
- A typical warehouse management system consists of different processes as shown in the figure.

Image source: ValueQwest Pte. Ltd.

Background of the study

- Due to the rapid increase of the volatile demand and the availability of highly customized products and services, warehouses today are not just the storerooms to store the goods, but they are becoming more robust to satisfy the customers.
- The advent of industry 4.0, which aims to integrate both the cyber and physical systems, has contributed a lot to warehouse automation and yielded fruitful results.

  Example: Internet of things, Implementation of RFID technology.

  But this also has enabled the generation of a large amount of data.
- In this data-driven world, and with the continuous rise of Data science applications across all domains, researchers started exploring its application in Supply chain management as well. And as a result, many companies also started utilizing Data science methodologies.
- Demand and sales forecasting, Warehouse management, supplier identification and evaluation, risk management, production planning, prediction of the optimum delivery route and sentiment analysis of customers are some use cases, where Data Science finds its applications.

Literature review

- The literature review follows a funnel-down approach, and here is the overview.
- A study proposed an object detection framework using a light weight model, developed using YOLOv3,along with the application of robotics in sorting the parcels quickly and accurately (Han et al., 2020).

S No.	Study Reference	Topic
1	(Mabert and Venkataramanan, n.d.), (Janat Shah, 2016), (Li et al., 2011), (Huan et al., 2004), (APICS Supply Chain Operations Reference Model SCOR Version 12.0, 2017)	Evolution of Supply chain management & SCOR model
2	(Kumar et al., 2021a), (Cormier and Gunn, 1992), (Dewa et al., 2017), (Boysen et al., 2019), (Christoph Jan Bartodziej, 2017), (Tjahjono et al., 2017), (Lee et al., 2018), (Ding et al., 2021), (Zhao et al., 2020), (Ghaouta et al., 2018), (Tirkolaee et al., 2021), (Toorajipour et al., 2021), (Hoque et al., 2021), (Chen et al., 2021)	Evolution of Warehousing and the role of Industry 4.0
3	(Wiley and Lucas, 2018), (Feng et al., 2019), (O'Shea and Nash, 2015), (Girshick et al., n.d.), (Ren et al., n.d.), (He et al., 2017), (Redmon et al., 2015), (Liu et al., 2015), (Luo et al., 2021), (Bewley et al., 2016), (Wojke et al., 2017)	A review on Computer vision techniques
4	(Gray et al., 2021), (Kalinov et al., 2020), (Patel and Chowdhury, 2020), (Han et al., 2020), (Kumar et al., 2021b)	Applications of Computer vision in Warehouse management

Identification of research gap.

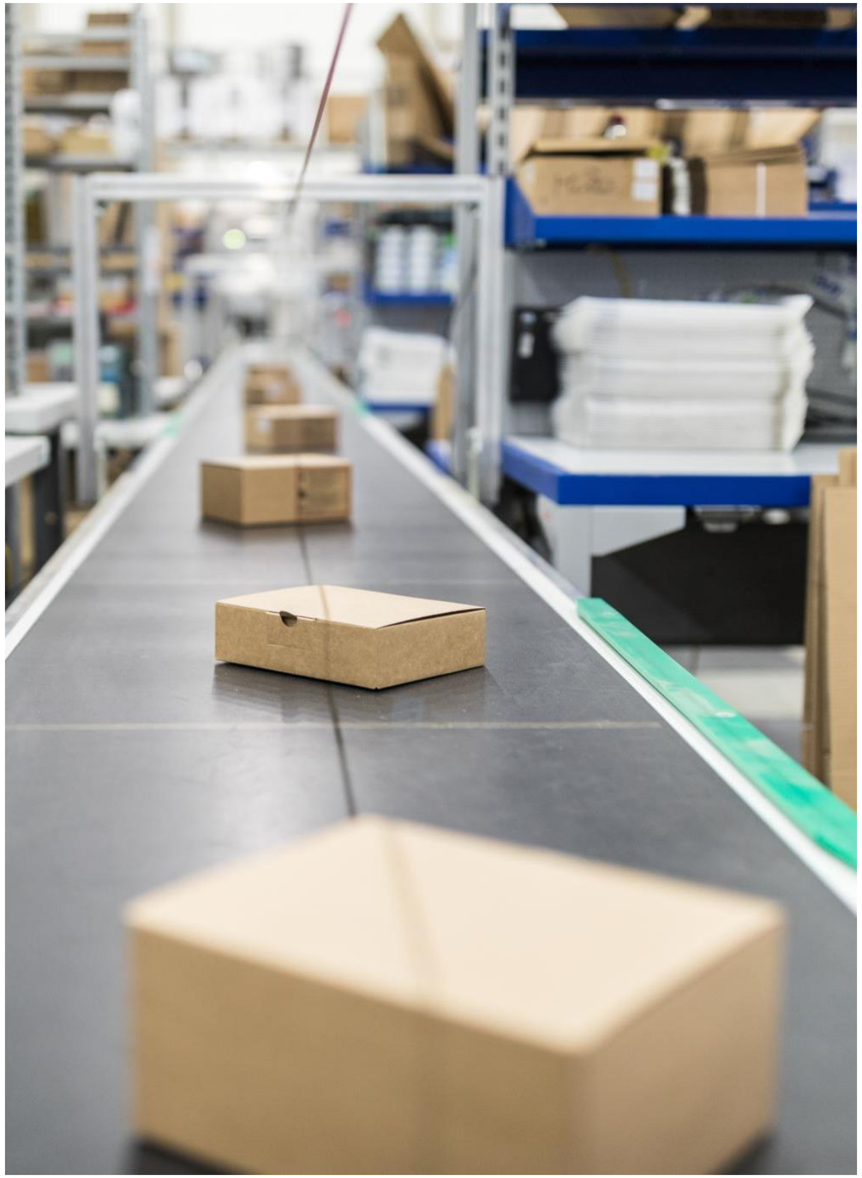
Object detection and tracking methodologies are finding applications in many use cases, such as driverless cars and surveillance. These methodologies may also be implemented in the warehouses to accurately detect, track and count the pallet boxes or parcels. Implementing them has the potential to improve the efficiency of warehouse management and reduce human efforts.

PROBLEM STATEMENT

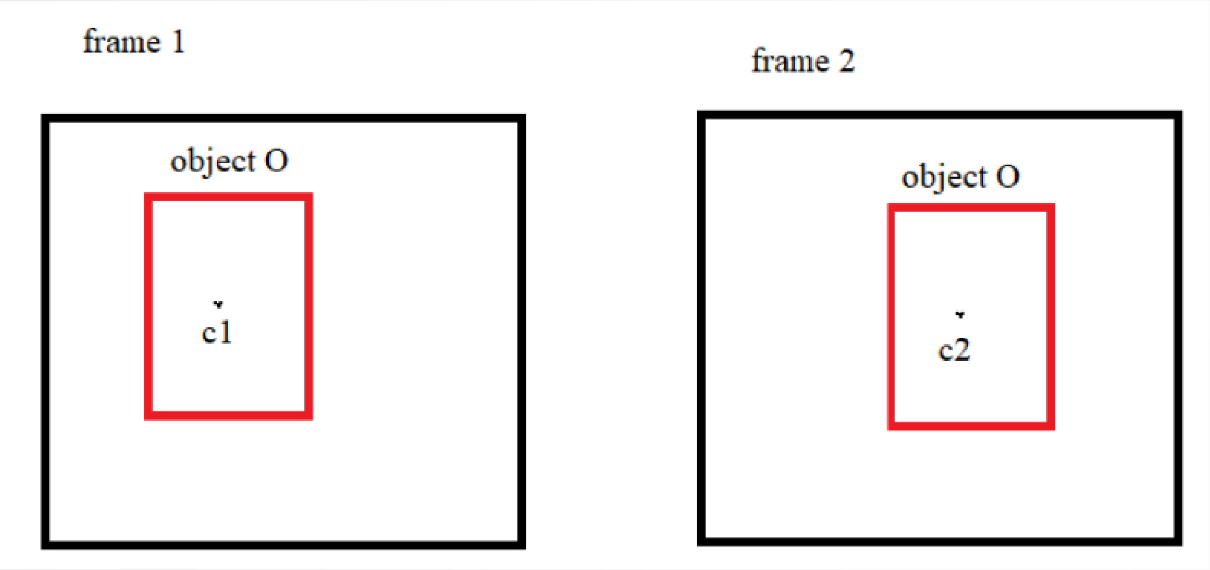
Some of the challenges often occur in the warehouse management are:

- Performing redundant tasks.
- Improper inventory management.
- Occurrence of human errors.

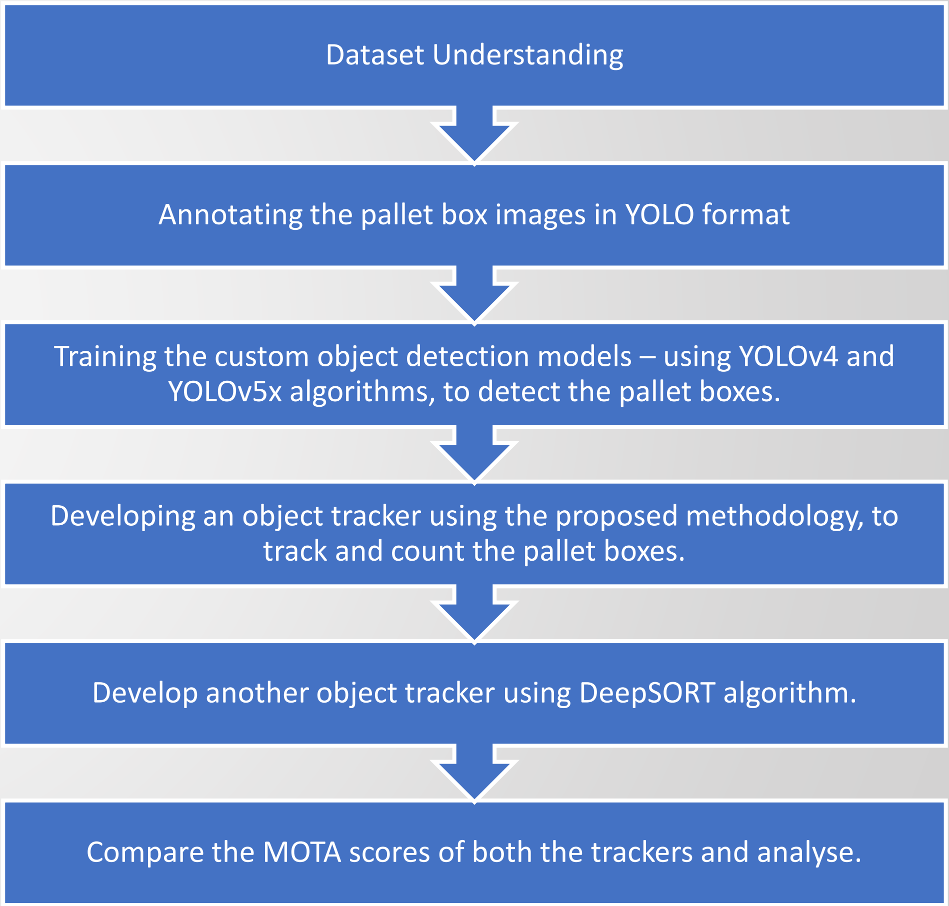
- To solve these challenges, a computer-vision-based methodology has been proposed and implemented in this thesis work, which detects, tracks and counts the pallet boxes moving on a conveyor belt, thereby providing accurate real-time data and reducing the human efforts to a large extent.
- Here is the link to the dataset: https://drive.google.com/drive/folders/1Zwn249gVJhNL0ABIND6UBRsXXtZ6Ek8K.



Methodology



Custom object tracking methodology

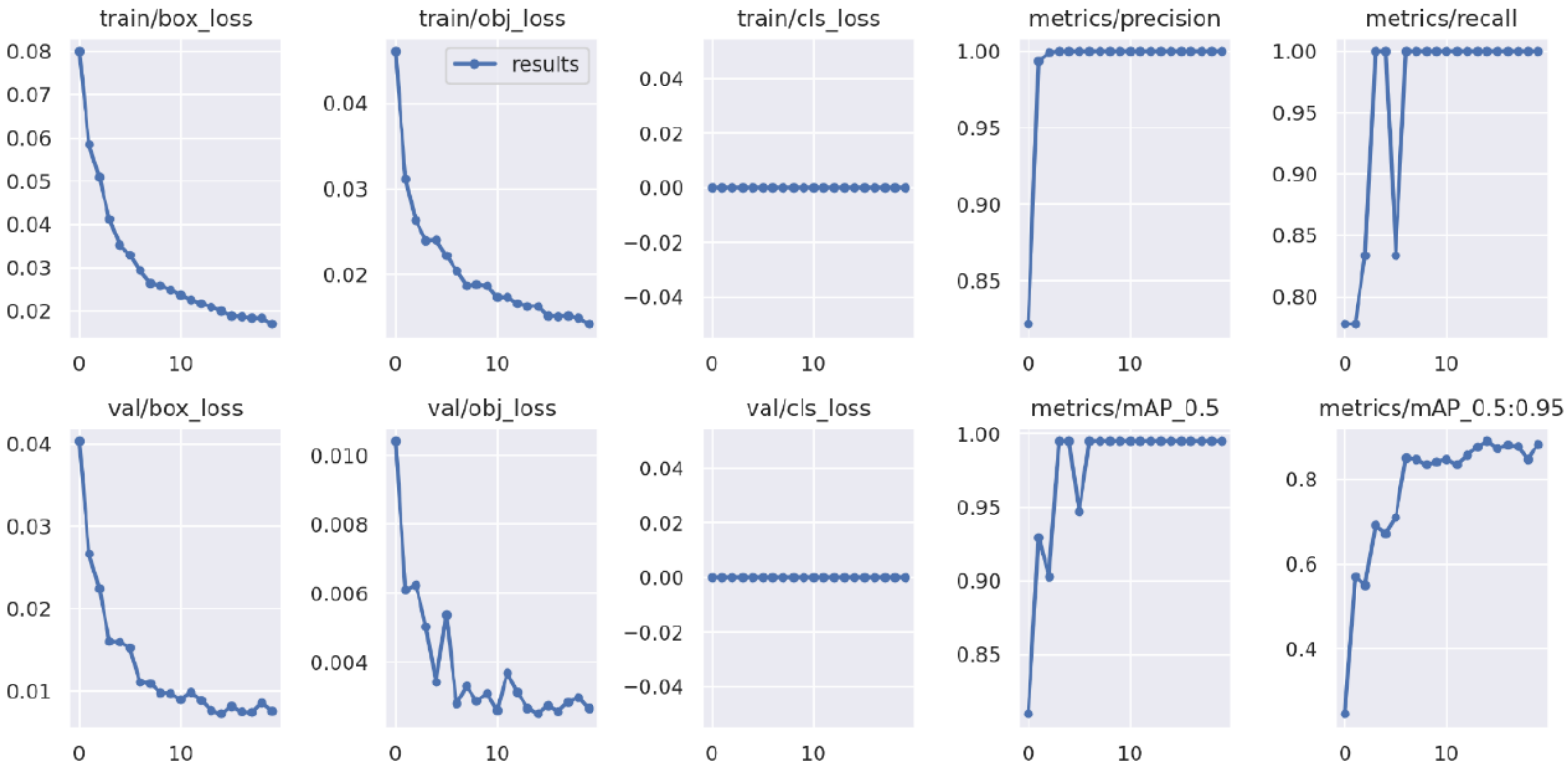


Object detection by YOLOv5x model

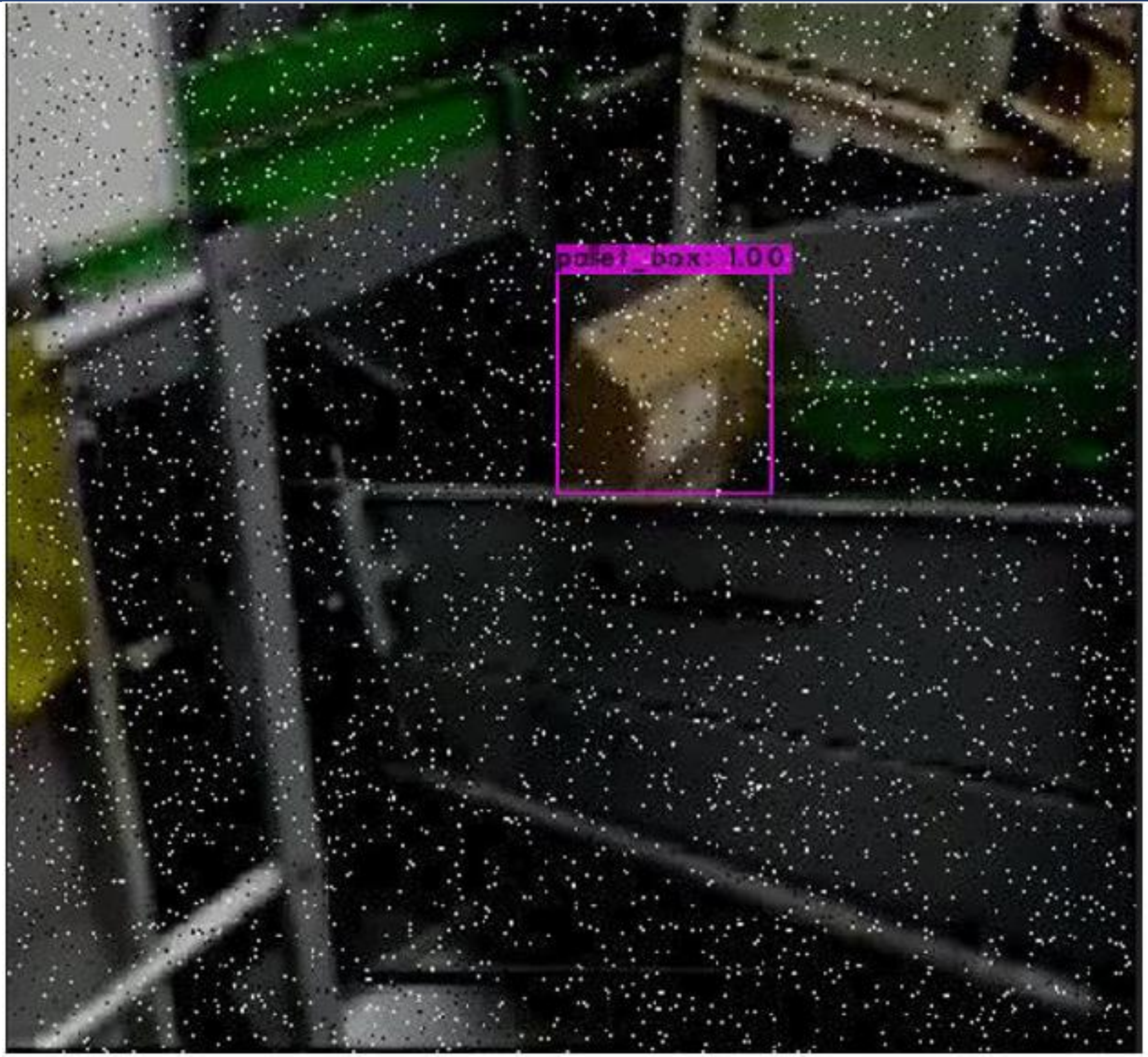
Results: YOLOv5x model evaluation

We trained our model with the following hyperparameters:

- batch size = 12
- no. of epochs = 20
- learning rate = 0.01
- IOU training threshold = 0.2
- box loss gain = 0.05
- class loss gain = 0.5
- fliplr = 0.5
- flipud = 0



Object Detection By Yolov4 Model



Results: YOLOv4 model evaluation

- The mAP score achieved is 96% at 0.5 IOU threshold.
- The hyper parameters for this model are set in the “custom_yolov4.cfg” file, present inside the cfg folder in the darknet directory.

  image width = 416

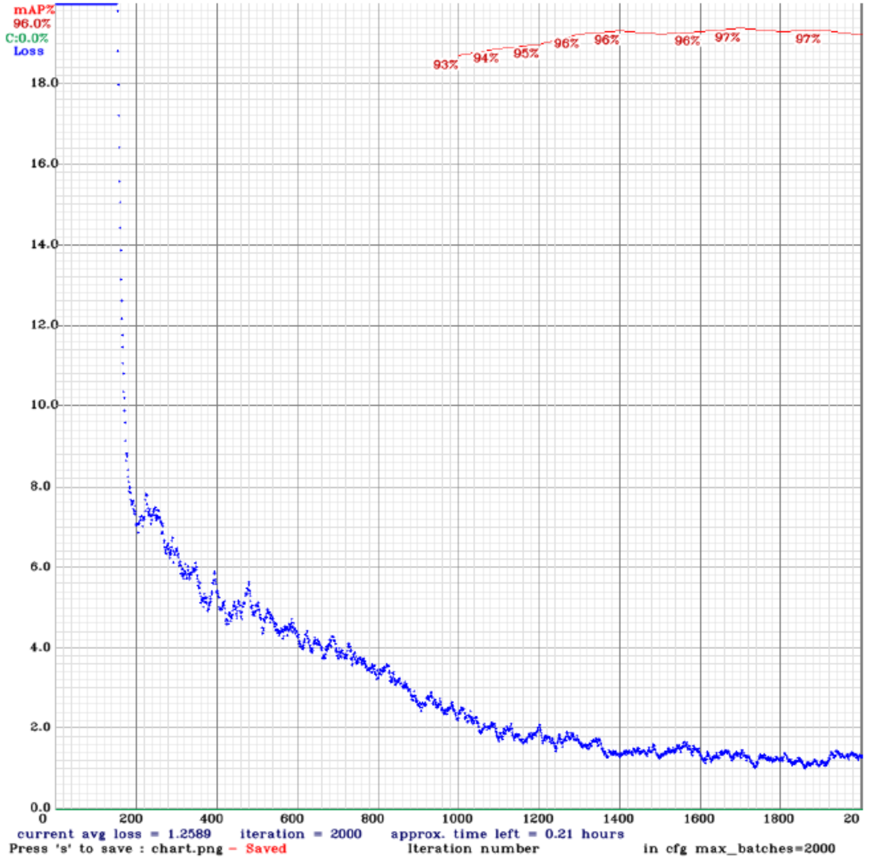
  image height = 416

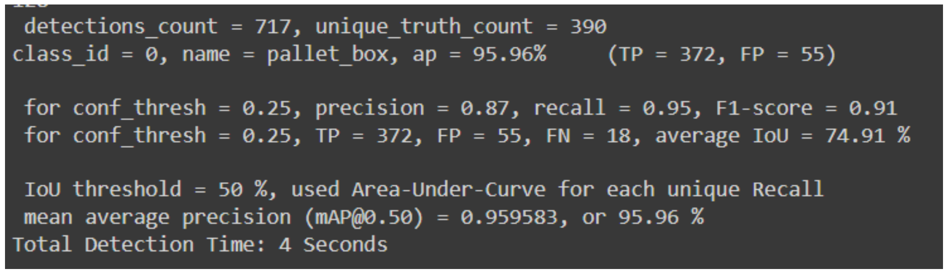
  learning rate = 0.001

  batch size = 64

  subdivisions = 16

  max batches to 2000.
- Since we are dealing with the single class object detection problem, we set the classes to 1 in all the 3 yolo layers and set the number of filters to 18 in every convolution layer before each yolo layer. This was calculated using the formula (classes + 5) × 3.





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 detections_count = 717, unique_truth_count = 390
class_id = 0, name = pallet_box, ap = 95.96%     (TP = 372, FP = 55)

 for conf_thresh = 0.25, precision = 0.87, recall = 0.95, F1-score = 0.91
 for conf_thresh = 0.25, TP = 372, FP = 55, FN = 18, average IoU = 74.91 %

 IoU threshold = 50 %, used Area-Under-Curve for each unique Recall
 mean average precision (mAP@0.50) = 0.959583, or 95.96 %
Total Detection Time: 4 Seconds
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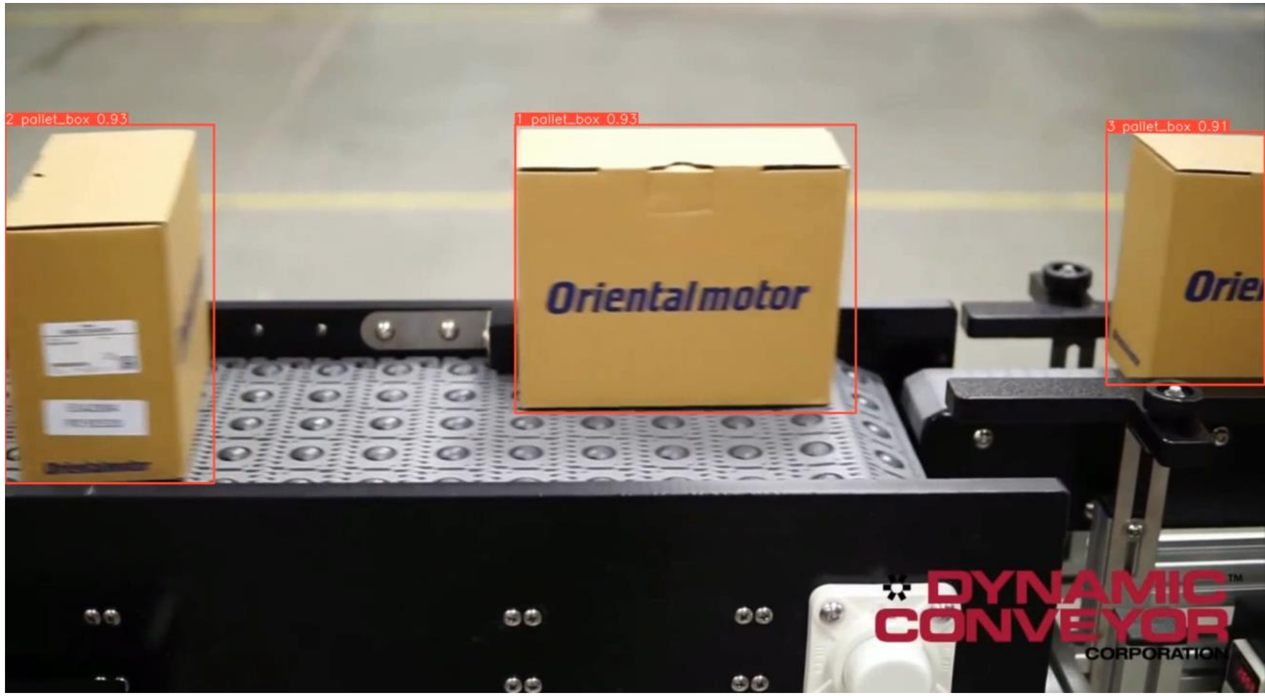
Comparing the mAP of YOLOv5x and YOLOv4 models

Model	**mAP at 0.5 IOU**
YOLOv5x	99.5%
YOLOv4	96.0%

Comparison of two object trackers

Custom object tracker developed using the proposed centroid methodology. This also counts the pallet boxes in a frame.

Custom object tracker developed using the DeepSORT methodology. This was developed just to compare its performance with the former one.



Both these algorithms use, custom trained YOLOv5x model to make detections

Comparing the MOTA scores of the object trackers

Object Tracker	Total ID Switches	Total False positives	Total False Negatives	Total Ground Truth objects	MOTA Score
Custom Object tracker	7	24	36	873	92%
Object tracker developed using Deep SORT	5	2	0	873	99%

$$MOTA = 1 - \frac{\sum_t FN_t + FP_t + IDS_t}{\sum_t GT_t}$$

MOTA equation image source: https://visailabs.com/evaluating-multiple-object-tracking-accuracy-and-performance-metrics-in-a-real-time-setting/

Conclusion

- This study has discussed the application of computer vision techniques to achieve warehouse automation.
- Trained the object detection models using yolov4 and yolov5 algorithms on the dataset, and the best model has been chosen.
- Developed object tracking algorithm, with the proposed centroid based tracking methodology, and compared its performance with the state of the art DeepSORT based object tracking algorithm.

Future works

- Apart from the pallet boxes, this Computer vision methodology can also be applied on other storage containers like barrels and cable drums.
- With the availability of high-performance faster GPUs, the availability of the high-speed internet, and the cloud technologies, the proposed Computer vision methodology can be augmented with the Internet of things, to achieve more accurate results and the machines can share data among themselves without human intervention. The data generated can be stored in the cloud and can be utilized to draw the business-driven insights.

THANK YOU