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Detection of Data Matrix Encoded Landmarks in Unstructured Environments using Deep Learning

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Presentation Outline

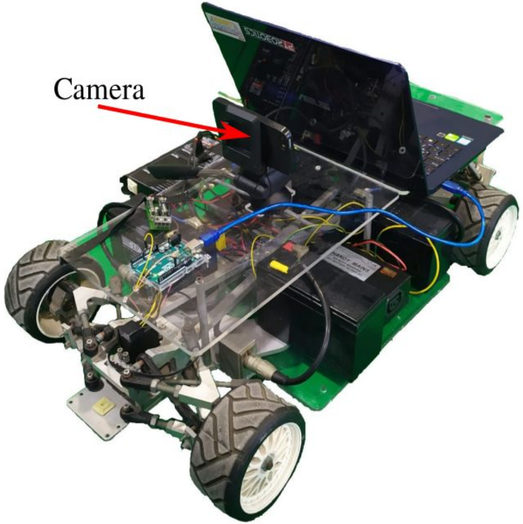
1. Introduction

Produtech Project

- Development of a flexible and low-cost localization and navigation system
- Mobile robot capable of computing its own location in real-time
- Robust system to perform in complex and unstructured environments such as production facilities
- Detect encoded landmarks (with its own location) and then apply triangulation/trilateration techniques

1. Introduction

How do we do that?



2. Related Work

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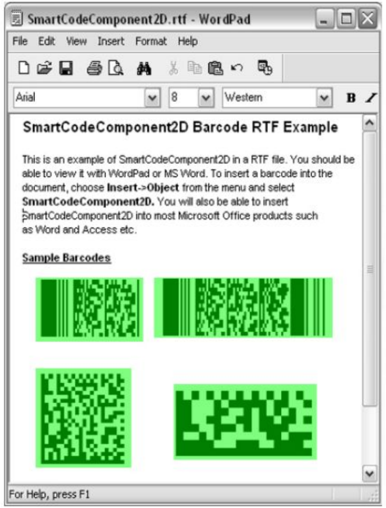
Object Detection DL Approaches

- Faster RCNN
- YOLO (all versions)
- SSD (Single Shot Detection)

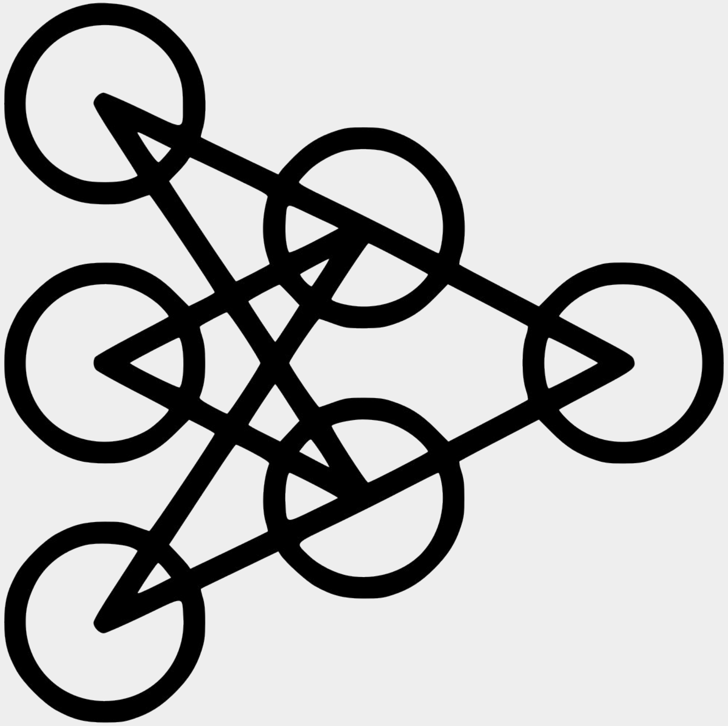
Data Matrix Detection

- 

  from: A.Zharkov and I. Zagaynov, “Universal barcode detector via semantic segmentation”, Available: http://arxiv.org/abs/1906.06281

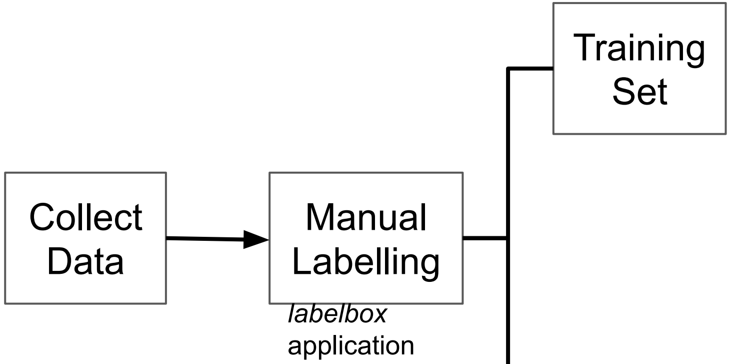
- Classic algorithm from libdmtx (Python library)

3. Proposed Approach



3. Proposed Approach

a. A dataset of Data Matrix Images



Lab (78 frames)

Workshop I (78 frames)

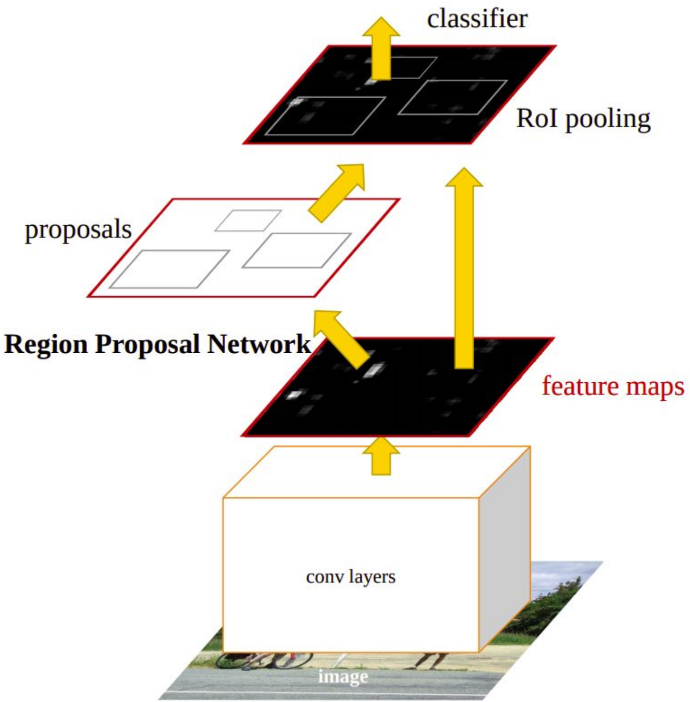
Hallway (158 frames)

Workshop II (66 frames)

3. Proposed Approach

b. Faster RCNN Architecture

- 2 modules(deep fully convolutional network and classifier)
- Region Proposal Network (RPN)
- Faster R-CNN detector
- Non-Maximum Suppression (NMS)



3. Proposed Approach

c. DNN Training Details

- Detectron2 research platform (Pytorch)
- Training images size: 8000×6000
- Data Augmentation: image resizing and random flip
- Learning rate: 0.00025 during 4000 iterations
- NVidia RTX2080ti GPU
- NMS threshold: 0.7

4. Experiments and Results

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Evaluate the trained model on the test set

- COCO dataset metrics:
  - Average Precision (AP): $$P = \frac{T_P}{T_P + F_P}$$
  - Average Recall (AR): $$R = \frac{T_P}{T_P + F_N}$$

T_P (True Positive)

F_N (False Positive)

4. Experiments and Results

Experiments and Results

AR>AP

- Both metrics averaged over multiple IoU thresholds (threshold $\epsilon[0.50; 0.95]$ in steps of 0.05 $\longrightarrow [0.50 : 0.05 : 0.95]$)

- For AP, a constant IoU thresholds of 0.5 ($AP@0.5$), 0.75 and 0.95 are also computed

- Small objects: $area < 32^2$, medium objects: $32^2 < area < 92^2$ and large objects: $area > 92^2$

- For AR, maximum number of detections ($maxDets \ \epsilon\{1, 10, 100\}$)

	IoU Thresholds	Scales	maxDets	AP/AR values
AP	[0.50 : 0.05 : 0.95]	all	100	0.619
	0.50	all	100	0.876
	0.75	all	100	0.730
	0.95	small	100	0.364
	[0.50 : 0.05 : 0.95]	medium	100	0.565
	[0.50 : 0.05 : 0.95]	large	100	0.737
AR	[0.50 : 0.05 : 0.95]	all	1	0.288
	[0.50 : 0.05 : 0.95]	all	10	0.669
	[0.50 : 0.05 : 0.95]	all	100	0.670
	[0.50 : 0.05 : 0.95]	small	100	0.438
	[0.50 : 0.05 : 0.95]	medium	100	0.611
	[0.50 : 0.05 : 0.95]	large	100	0.786

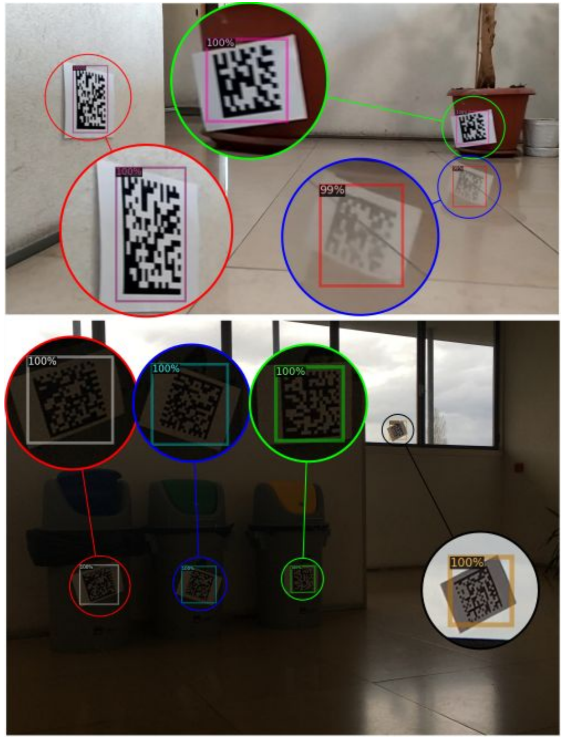
4. Experiments and Results

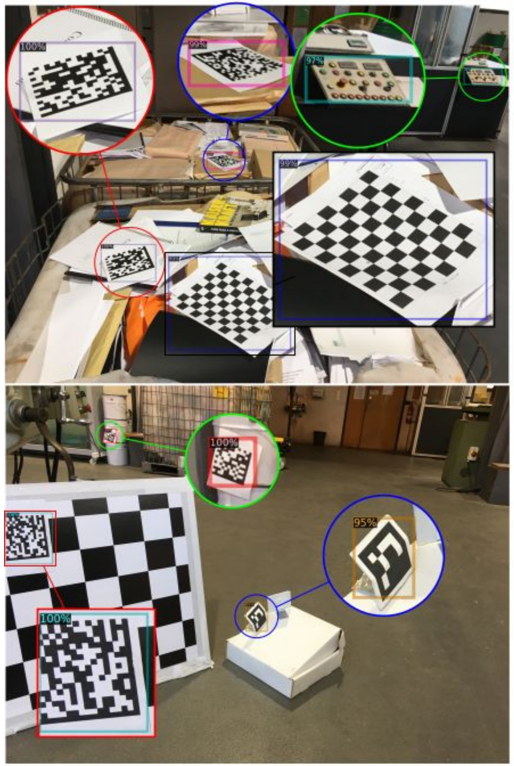
Running Time Results and Comparisons

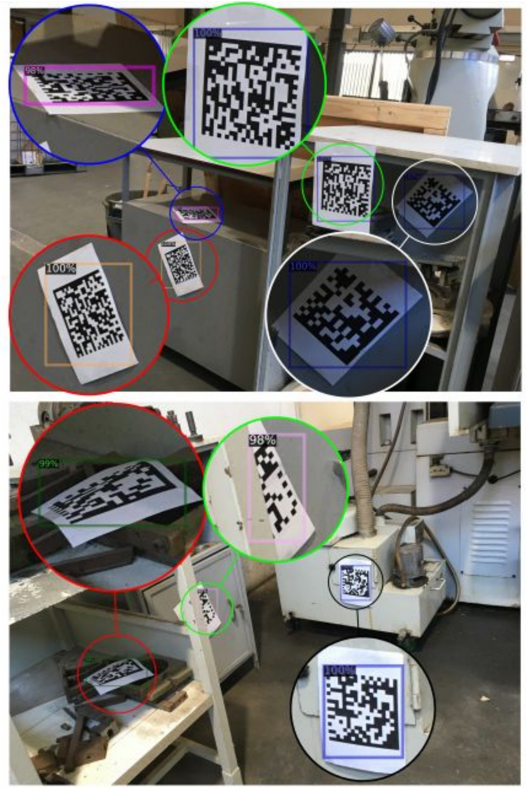
- 144 ms per image (7 fps)
- Only 45% of the test set frames were accurately processed by the classic algorithm
- The running time for the classic algorithm was 4.97 s per image (40 times slower than the model that we use in this paper)

4. Experiments and Results

Qualitative Results







5. Conclusions and Future Work

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- The model performs accurately and it is consistent by detecting almost all the landmarks in the test set;
- Overcomes by far, in performance and frame rate, the traditional algorithms;
- This implies a self-localization system more robust and performant;
- Future work; the development of a DNN whose outputs are parallelograms instead of simple rectangular bounding boxes; this would provide a novel technique for finding the transformation robot-marker with only one necessary landmark.

https://github.com/tmralmeida/faster-rcnn-data-matrix

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