DEEP LEARNING IN RAILWAY APPLICATIONS

STATE OF ART AND POTENTIAL FUTURE VISION

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28th/May/2020

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Presentation Outline

- DEEP LEARNING: QUICK INTRODUCTION.
- COMPUTER VISION.
- OBJECT DETECTION.
- RAILWAY APPLICATIONS.
- DATA
- NLP
- A LEAP TO THE FUTURE, CONCLUSION
- COLLABORATION. **(GREAT!!)**

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DEEP LEARNING 1/4

- **Deep learning** (also known as deep structured learning) is part of a broader family of **machine learning methods** based on artificial neural networks with representation learning. Learning can be **supervised, semi-supervised** or **unsupervised.** (Wikipedia)

DEEP LEARNING 2/4

- Deep learning architectures such as **deep neural networks**, deep belief networks**, recurrent neural networks** and **convolutional neural networks.** (Wikipedia)

DEEP LEARNING 3/4

- Deep Learning have been applied to fields including
  - Computer vision.
  - Speech and audio recognition.
  - Natural language processing
  - Bioinformatics, drug design and medical image analysis.
  - Material inspection and
  - Board game programs.

It has produced results comparable to and in some cases surpassing human expert performance.

DEEP LEARNING 4/4

DEEP LEARNING APPLICATIONS

COMPUTER VISION

NATURAL LANGUAGE PROCESSING (NLP)

Bioinformatics, Drug Design and Medical Imaging

Many Other Applications

Presentation Focus

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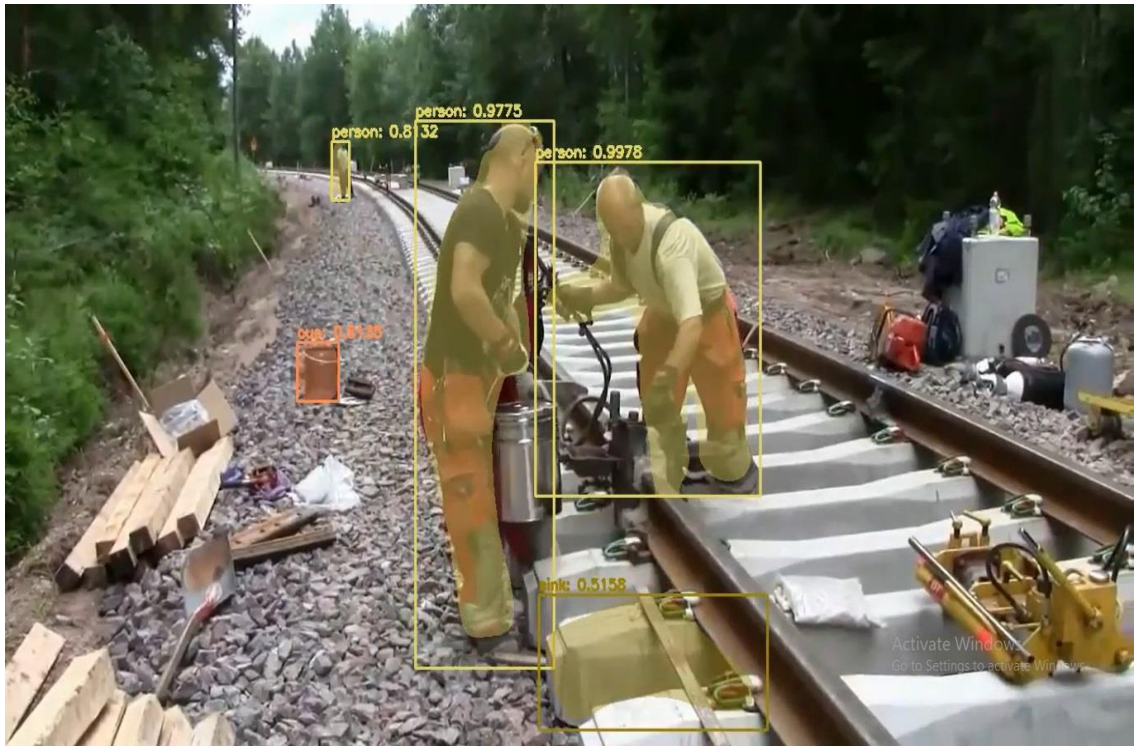
COMPUTER VISION 1/10

- **Object Detection** is one of the fundamental problems in computer vision.
- Deep Learning have emerged as **powerful strategy for learning feature representation** directly from data.
- Remarkable breakthrough in the field of **Generic Object Detection**.



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COMPUTER VISION 2/10

- **Objective of object detection** can be stated as “For Any instance of any object for given categories – to return the spatial location”

- Understanding computer vision and object detection High Level Vision tasks such as **Segmentation**, **scene understanding**, **object tracking**, **image captioning**, **event detection** and activity recognition.

*****_DeepLearningforGenericObjectDetection:A Survey (Li Liu, et al)._

COMPUTER VISION 3/10

- Many Applications including:
  - **Robot Vision** related to have a fully automated maintenance.
  - Consumer electronics
  - **Security.**
  - **Autonomous driving.** –Highly relevant to transport and railways, specially maintenance equipment's.
  - Human Computer interaction
  - Content based image retrieval.
  - **Intelligence video surveillance**
  - Augmented Reality.

COMPUTER VISION 4/10

- **Object Detection can be either**
  - Detection of specific instance.
  - Detection of broad categories – Generic object dete

- **The detection can happen through**
  - A bounding box
  - Segmentation mask

*Deep Learning for Generic Object Detection: A Survey (Li Liu, et al).

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COMPUTER VISION 5/10

- **The research community is moving from**
  - Image Level Object Classification
  - Single Object Localization
  - Generic Object Detection
  - Pixelwise object segmentation.

- **The Focus is on the following:-**
  - Classification (There is a dog)
  - Detection (Where is the dog)

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COMPUTER VISION 6/10

- **High Quality**/Accuracy VS **High Efficiency**. (Algorithm Trade offs)

- **Accuracy** related challenges
  - Vast Range of intra-class variations
    - 1- intrinsic factors.
    - 2- image conditions.

VS

- **Efficiency**
  - The need to localize and recognize, computational complexity growing with (possibly large) number of objects categories.

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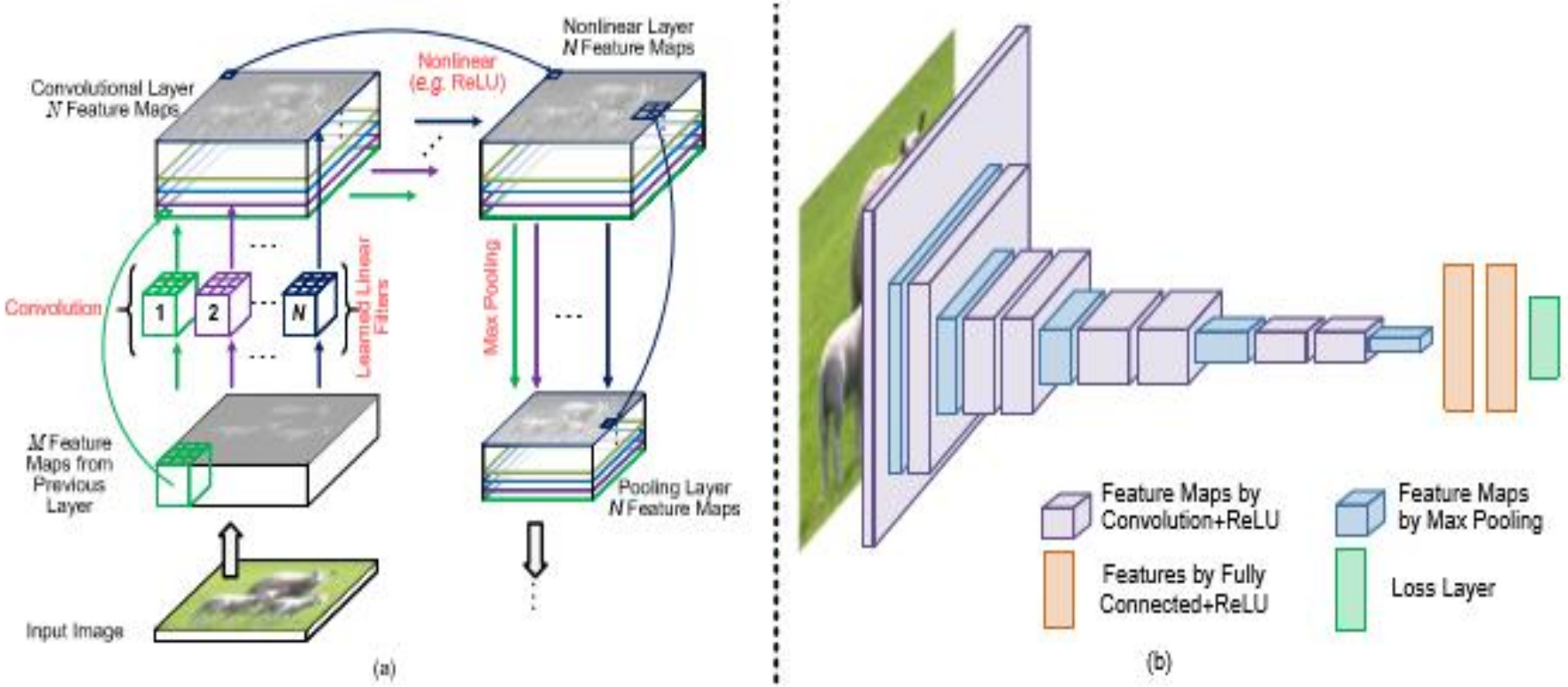
COMPUTER VISION 8/10

- A typical **CNN** has a **hierarchical structure** and is composed of a **number of layers** to learn **representation data**.
-
- Between an **input feature map** convolved with a **2D convolutional Kernel**.
- Finally Pooling corresponds to the down sampling/upsampling of feature maps.

COMPUTER VISION 9/10



*Deep Learning for Generic Object Detection: A Survey (Li Liu, et al).

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COMPUTER VISION 10/10

- DCNNs have number of outstanding advantages
  - The capacity to **learn very complex functions** and **learning feature** representation. With **minimum domain knowledge**.
- Deficiencies:
    - There is an extreme need for **labeled training data** and requirement of expensive computing resources.
    - Considerable skill and experience are still needed to select appropriate learning parameters. **(This is getting less important with AUTOML and Hyper parameters)**
    - Explainbility is till an issue.

OBJECT DETECTION 1/7

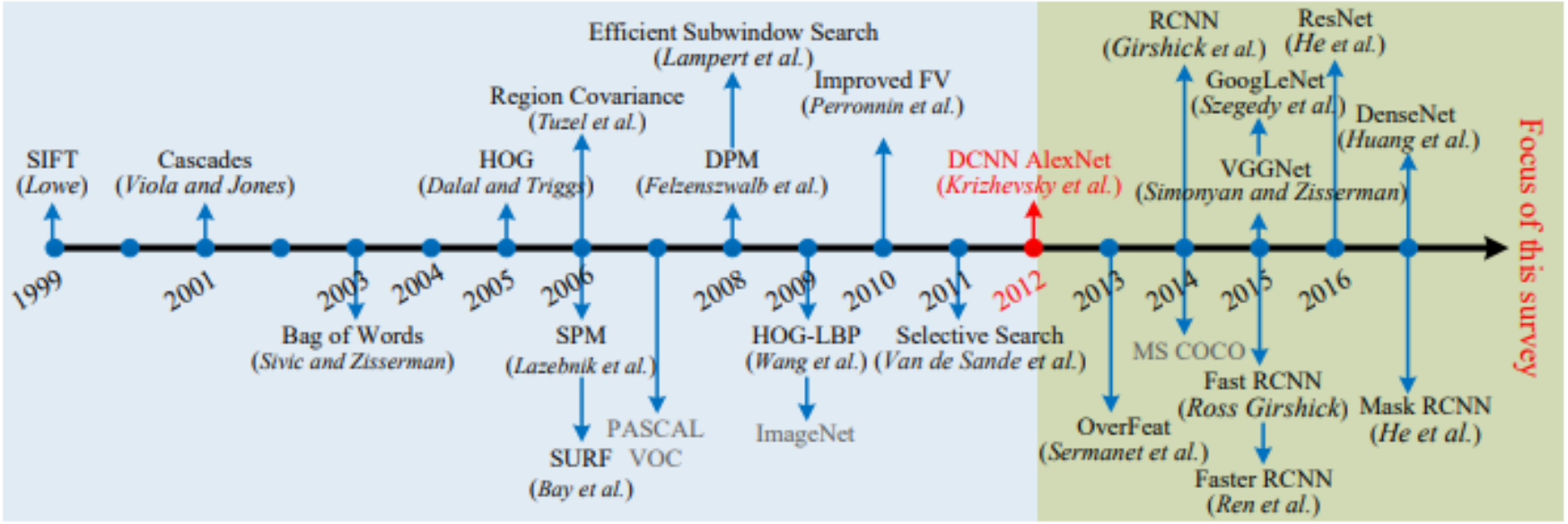


Fig. 4 Milestones of object detection and recognition, including feature representations [47, 52, 101, 140, 147, 178, 179, 212, 248, 252, 263, 276, 279], detection frameworks [74, 85, 239, 271, 276], and datasets [68, 166, 234]. The time period up to 2012 is dominated by handcrafted features, a transition took place in 2012 with the development of DCNNs for image classification by Krizhevsky *et al.* [140], with methods after 2012 dominated by related deep networks. Mostof the listed methods are highly cited and won a major ICCV or CVPR prize. See Section 2.3 for details.

*Deep Learning for Generic Object Detection: A Survey (Li Liu, et al).

OBJECT DETECTION 2/7

- The aim is to **design efficient** and **effective detector**, with small computational cost.

- There are Two categories of detectors:
  - **Two Stage Detection Frameworks**. (Including a prepossessing step)
  - **One Stage Detection Framework.**

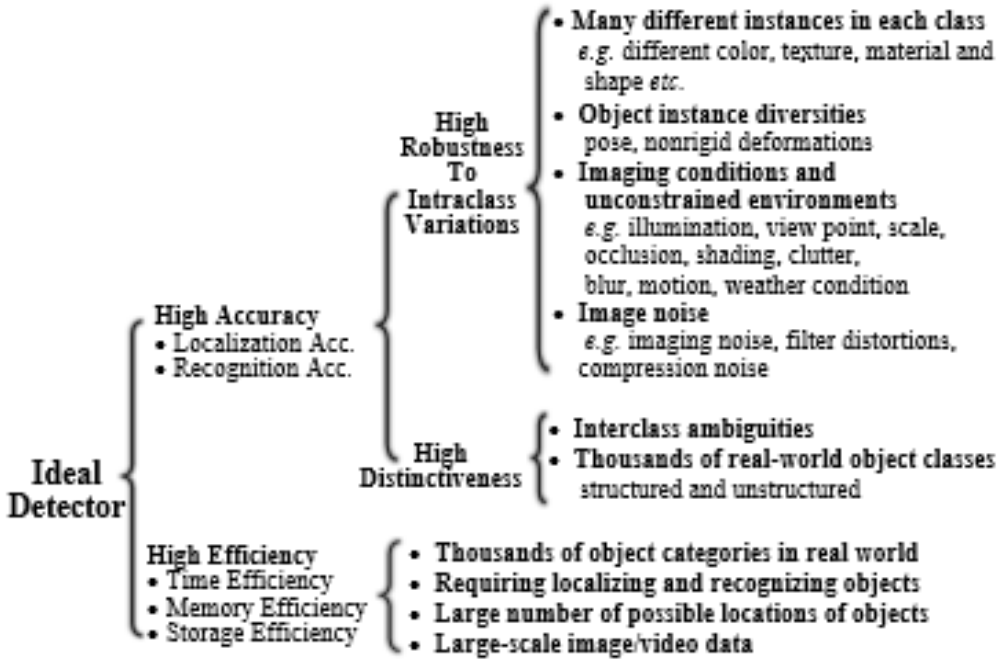


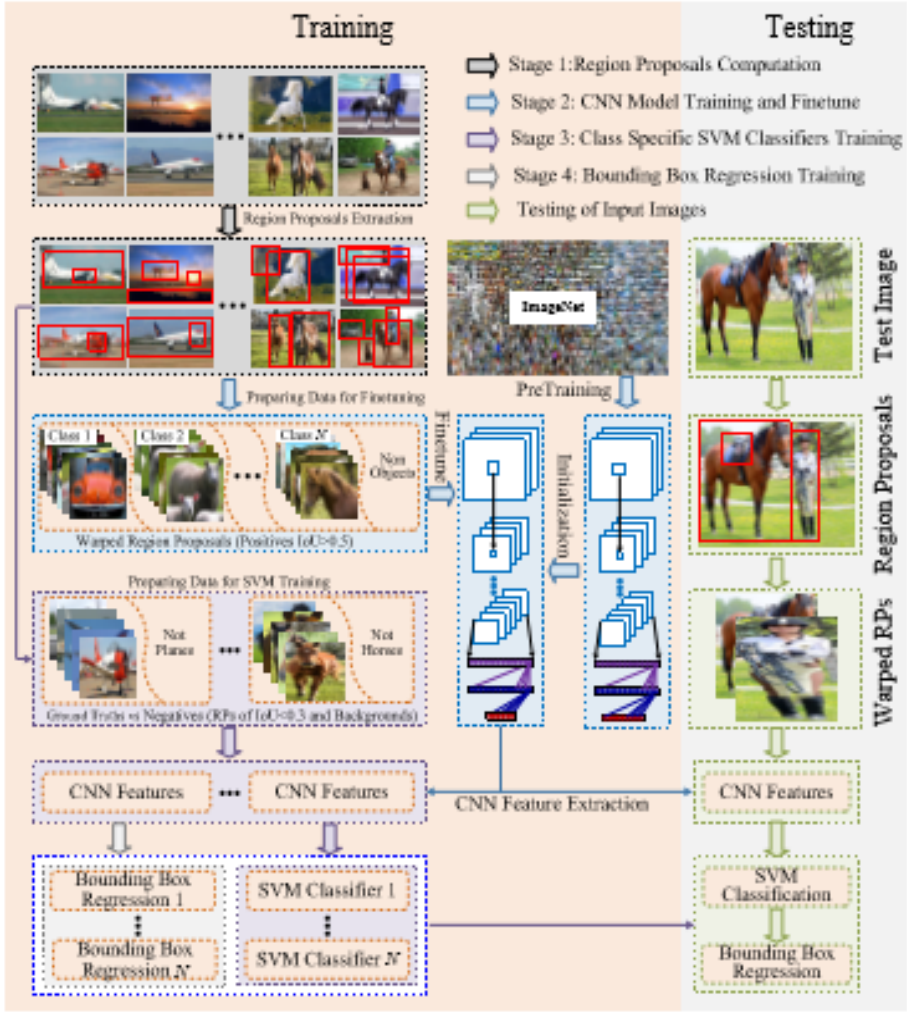
Fig. 6 Taxonomy of challenges in generic object detection.

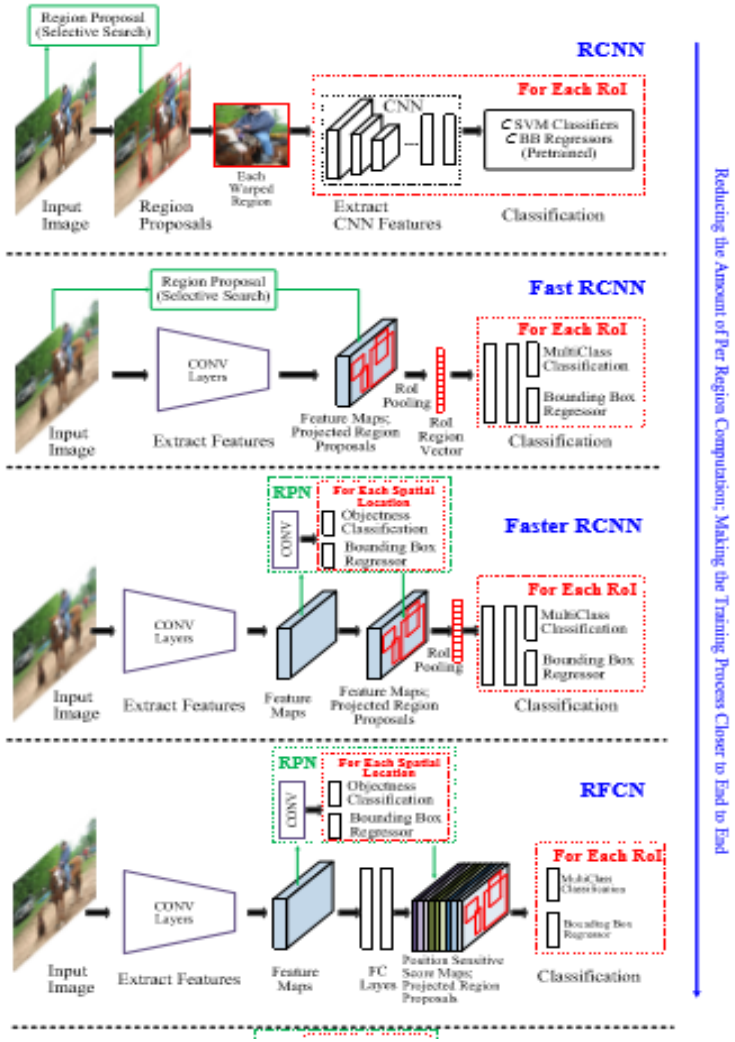
*Deep Learning for Generic Object Detection: A Survey (Li Liu, et al).

OBJECT DETECTION 3/7

- **<u>TWO/MULTI STAGE DETECTORS:-</u>**
- It has started with RCNN
- Further Development
  - SPPNet.
  - Fast RCNN – has managed to speed up the detection process
  - Faster RCNNs –
- There was a challenge for **region based fully convolutional Neural Networks)**
  - Mask RCNN was developed to tackle object instance segmentation.

OBJECT DETECTION 4/7





*Deep Learning for Generic Object Detection: A Survey (Li Liu, et al).

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OBJECT DETECTION 5/7

- **SINGLE STAGE DETECTORS:-**
- It has all started with a model called overfeat
- Further models were developed including
  - **Yolo.**
    - Small sets of candidate regions.
    - Fast by Design running at 45 FPS.
    - Fast Yolo has achieved 155 FPS.
  - **SSD.**
    - Achieves 74.3% mAP at 59 FPS.
      - Please note Yolo45 achieves 63.4 mAP at 45 FPS. (VOC2007 dataset)
      - Please note RCNN achieves 73.2% mAP at 7 FPS. (VOC2007 dataset)
  - **Croner Net**

OBJECT DETECTION 6/7

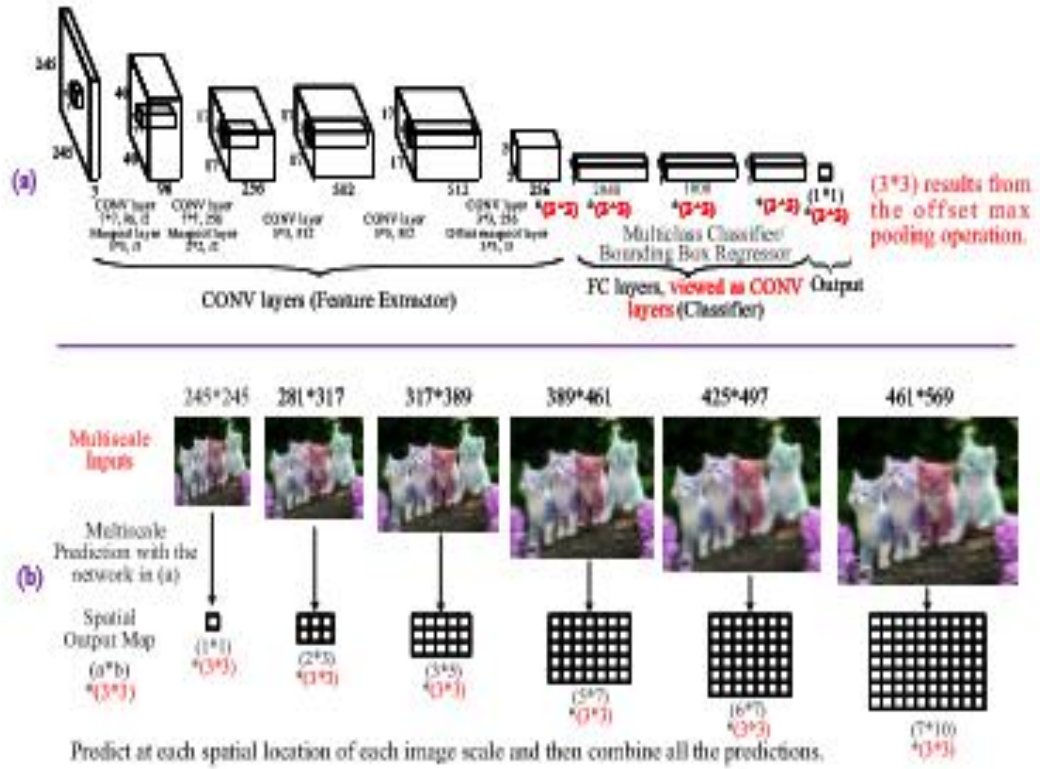

Fig. 14 Illustration of the OverFeat [239] detection framework.

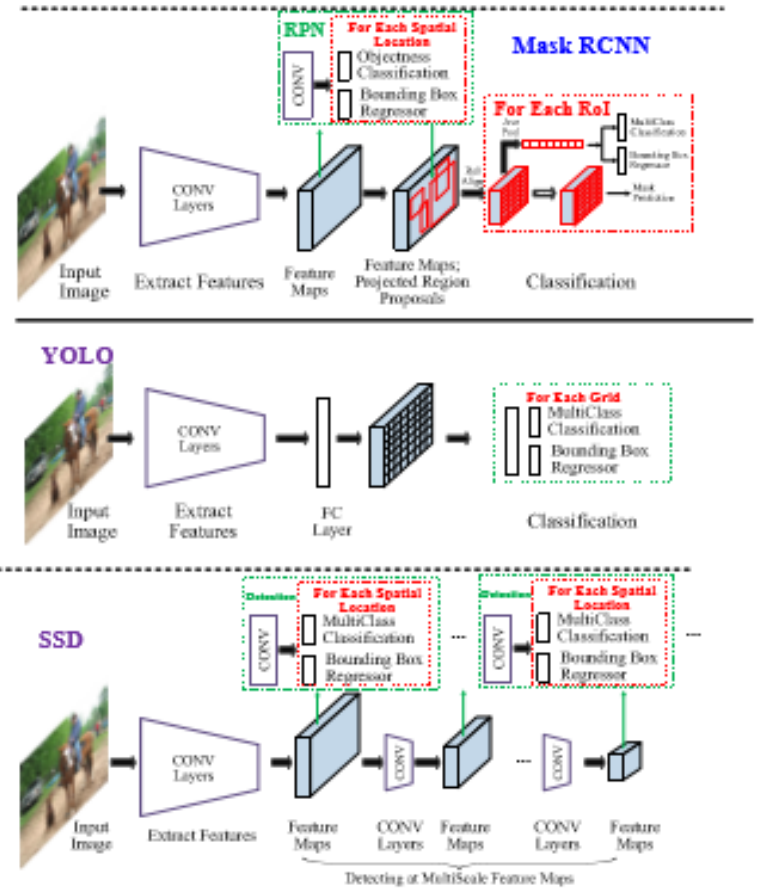

Fig. 13 High level diagrams of the leading frameworks for generic object detection. The properties of these methods are summarized in Table 11.

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OBJECT DETECTION 7/7

- **<u>Performance Mertics:-</u>**
- Three Evaluating Criteria
  - **Detection Speed** - Frames Per Second (FPS)
  - **Precision** - Average Precision (AP)
  - **Recall** – Avery Precision (AP)

- Average precision is computed separately for each object class based on Precision and Recall.

RAILWAY APPLICATIONS 1/15

- Railway Applications Using Computer Vision has focused on the followings aspects:-
  - Fastners inspection. (High Quality Camera).
  - Obstacle detection.
  - Daily Entrance and Exit Passenger Flow of Rail.
  - Rail Surface Defects.
  - Satellite and UAV images detection.

I wanted to have a feeling on what does **a generic object detection algorithms** see in **different railway environments**. I applied (YOLO, SSD and MASK RCNN).

- YOUTUBE LINK

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RAILWAY APPLICATIONS 2/15

https://youtu.be/qHmFcuurv0o

SSD

YOLO

MASK RCNN

VARIOUS MODELS

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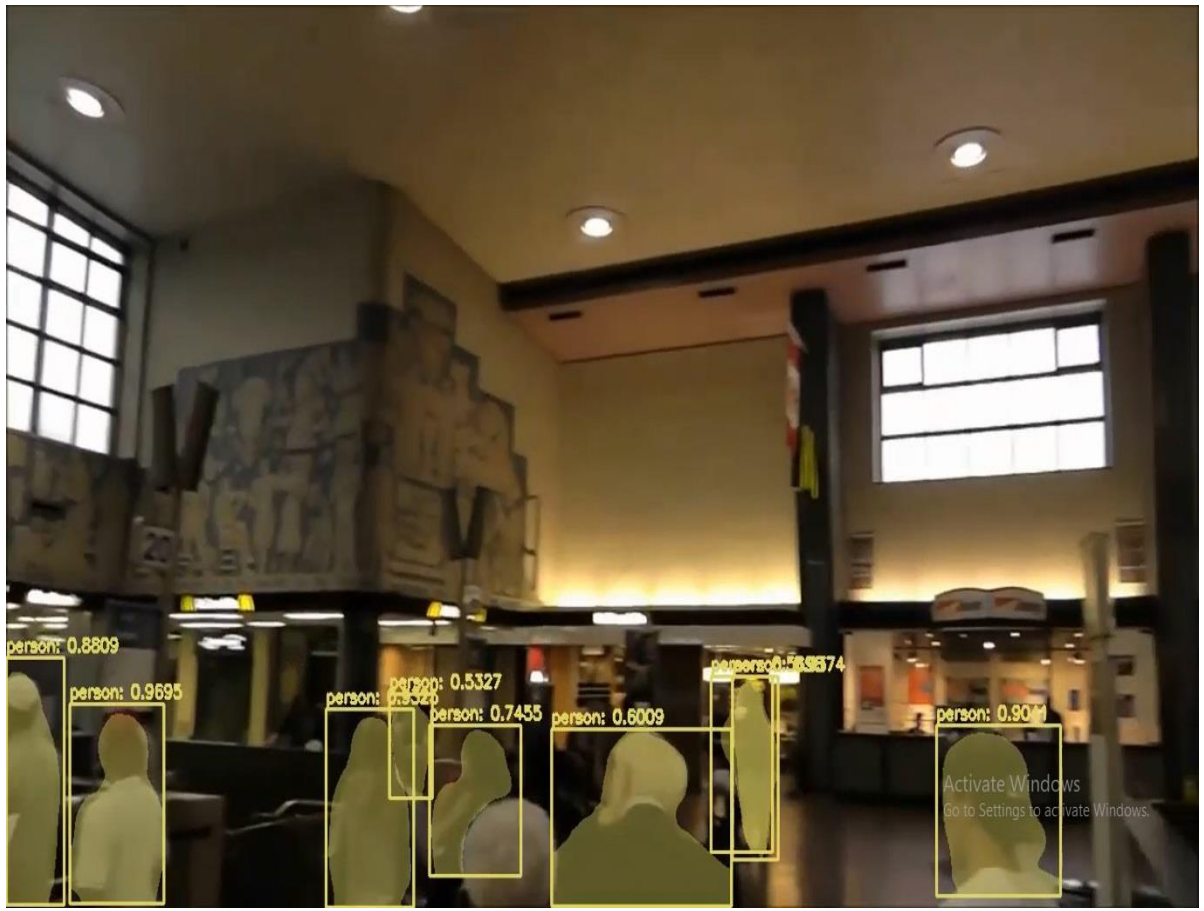
RAILWAY APPLICATIONS 3/15

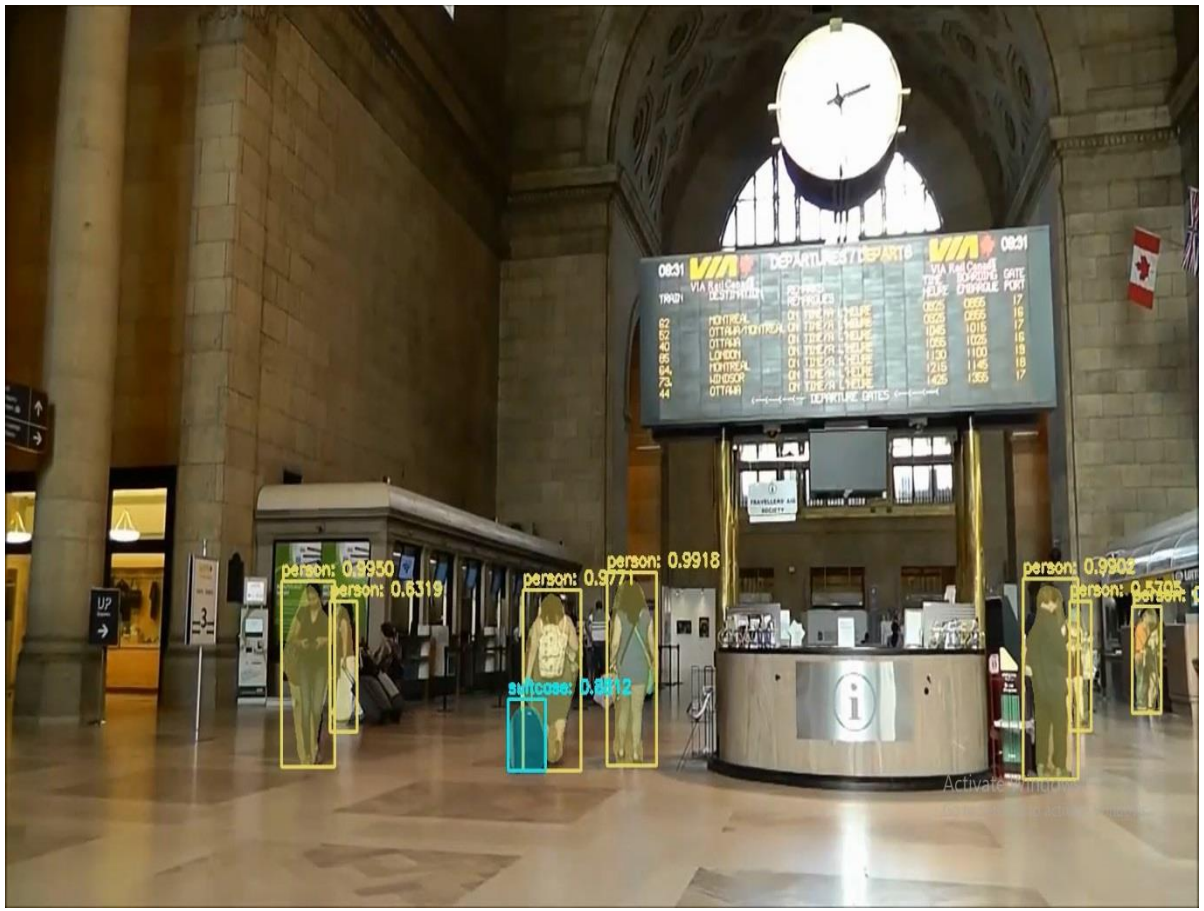
https://youtu.be/qHmFcuurv0o

LEVEL CROSSINGS

RAILWAY APPLICATIONS 4/15

https://youtu.be/qHmFcuurv0o

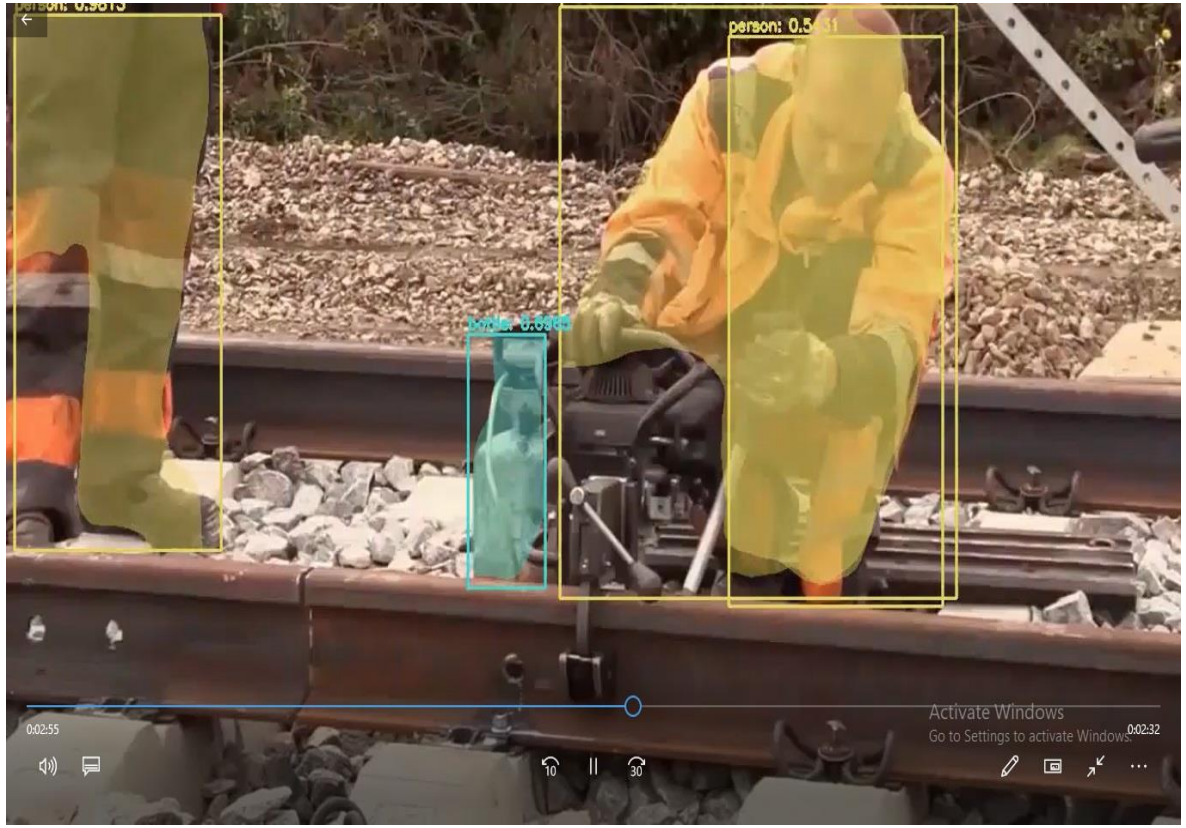


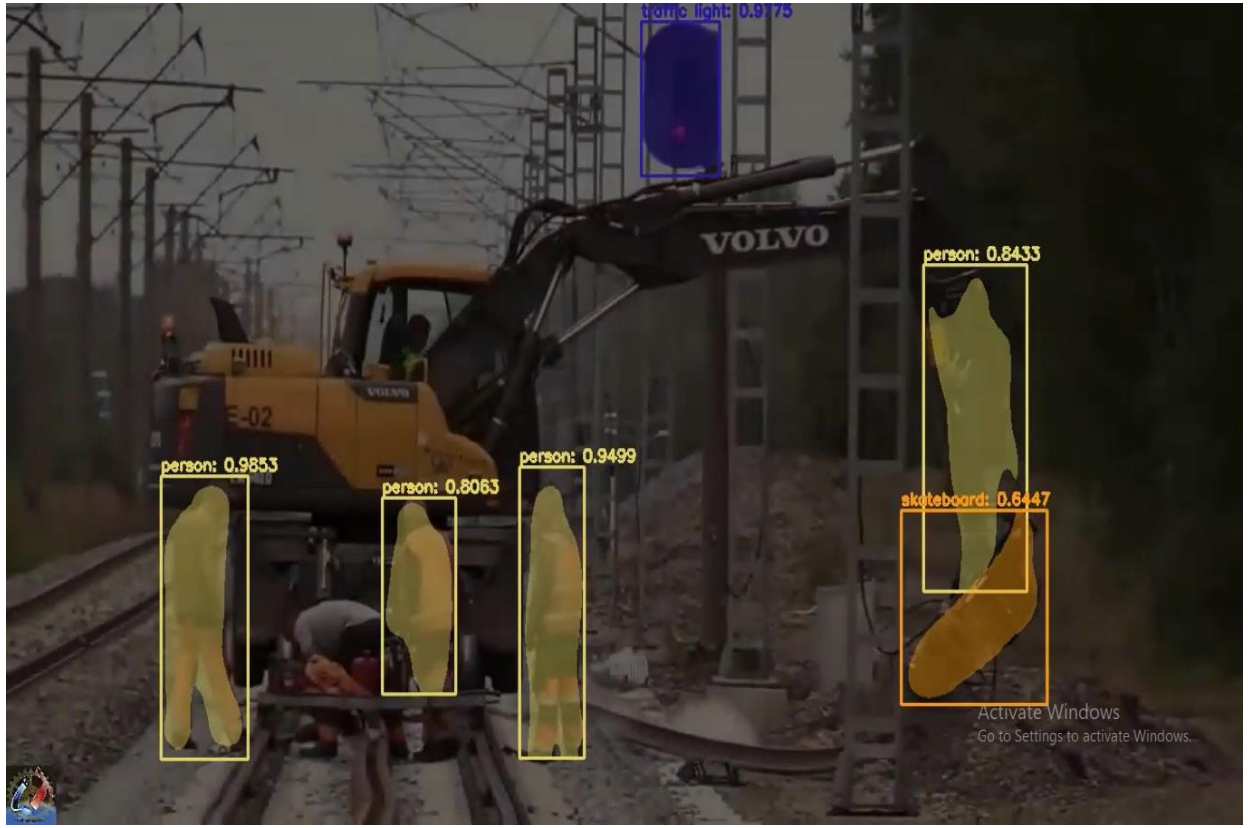


STATION OPERATION

RAILWAY APPLICATIONS 5/15

https://youtu.be/qHmFcuurv0o





MAINTENANCE OPERATION

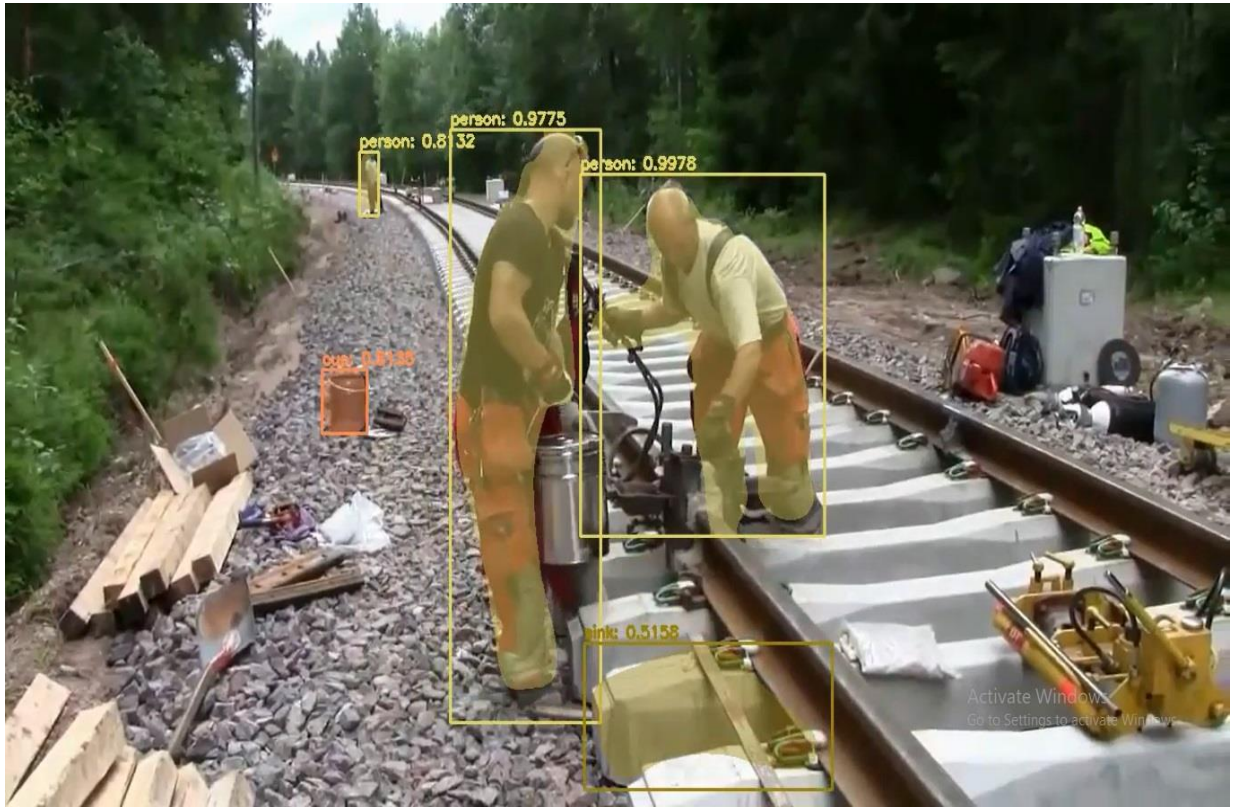
RAILWAY APPLICATIONS 6/15

https://youtu.be/qHmFcuurv0o

S&Cs + INSIDE TUNNELS

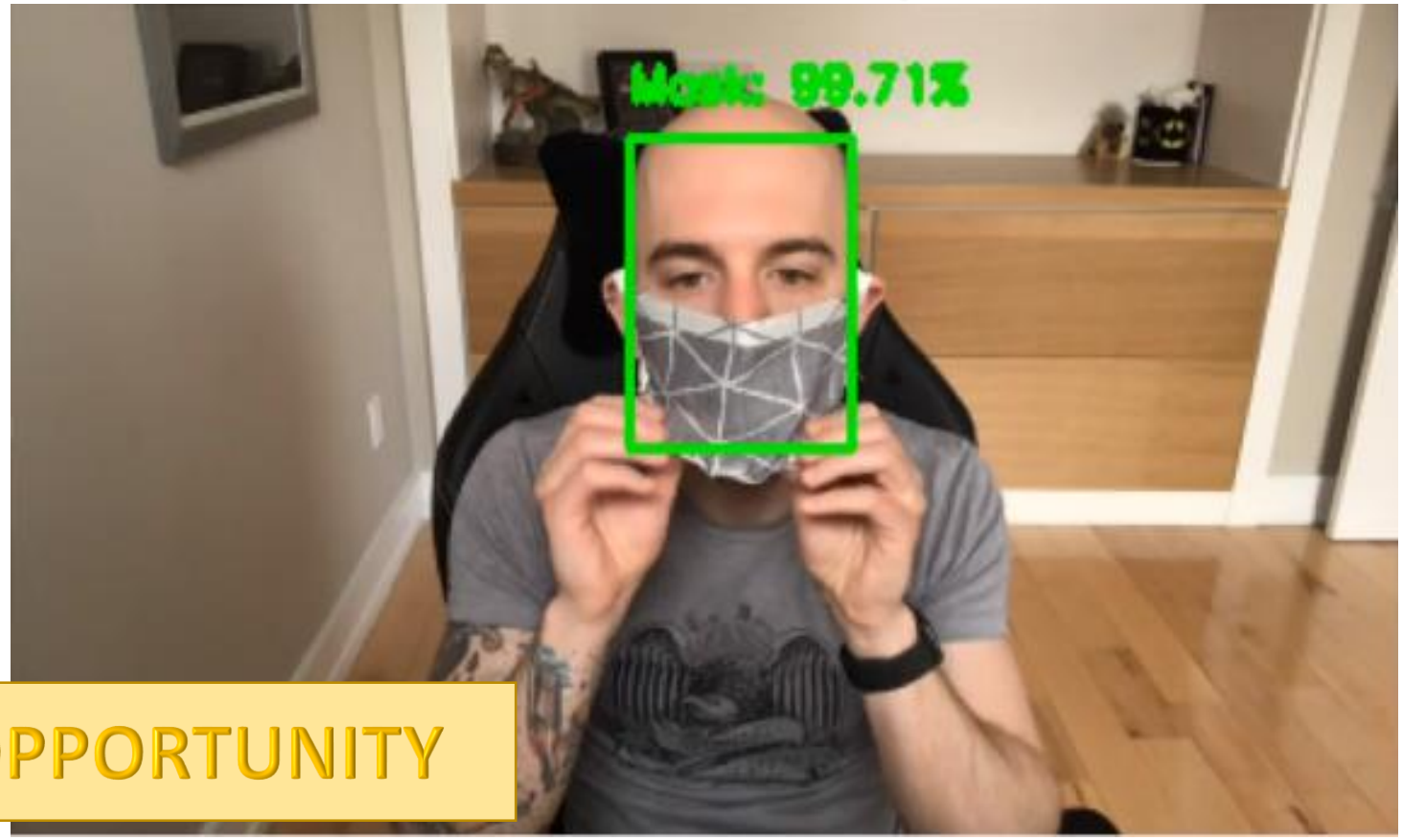
RAILWAY APPLICATIONS 7/15

https://youtu.be/qHmFcuurv0o



WELDING OPERATION

RAILWAY APPLICATIONS 8/15

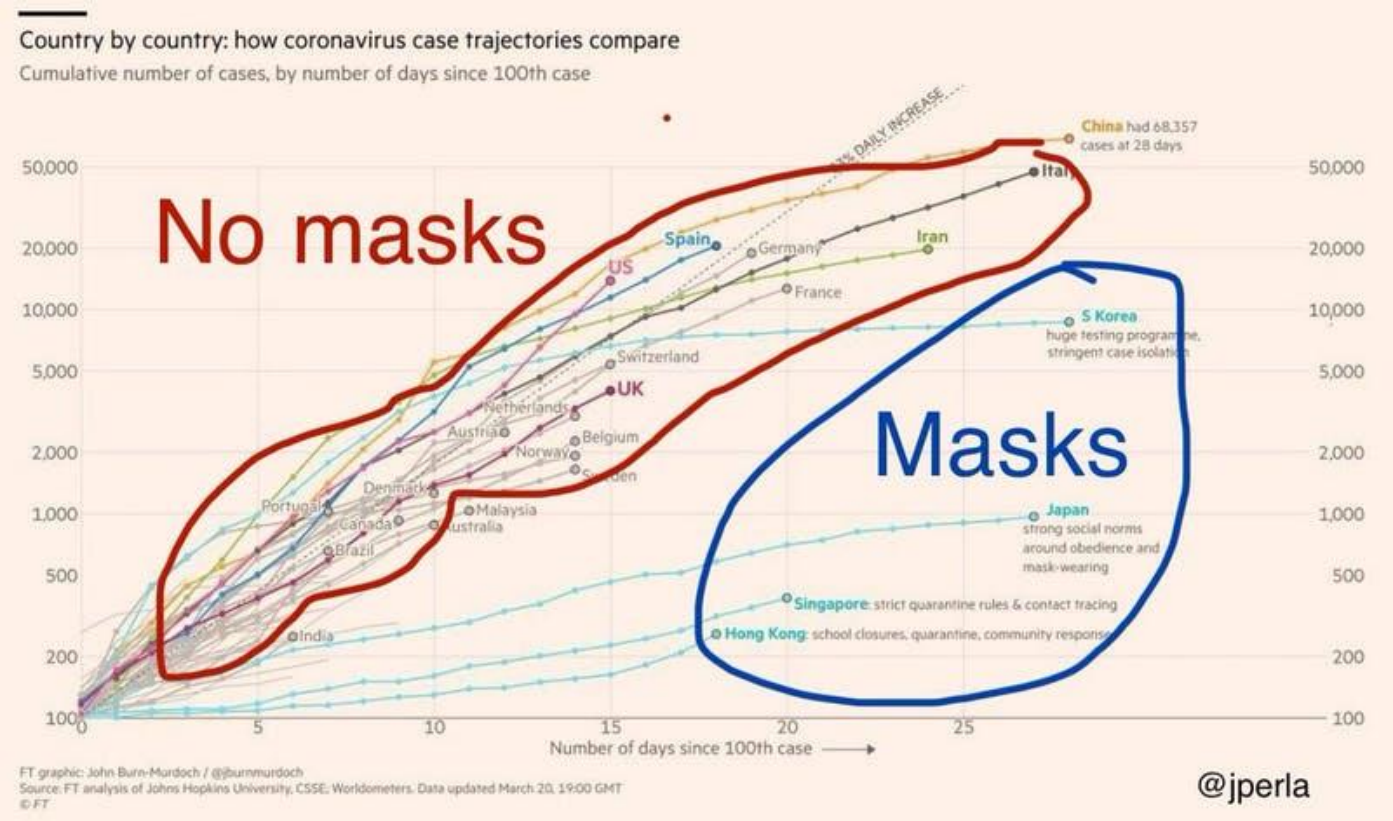


GOLDEN OPPORTUNITY

- Compulsory Masks and Gloves while using Public Transport!! **(OPPORTUNITY)**

**Adrian of Pyimage Research.*

RAILWAY APPLICATIONS 8/15



- Compulsory Masks and Gloves while using Public Transport!!

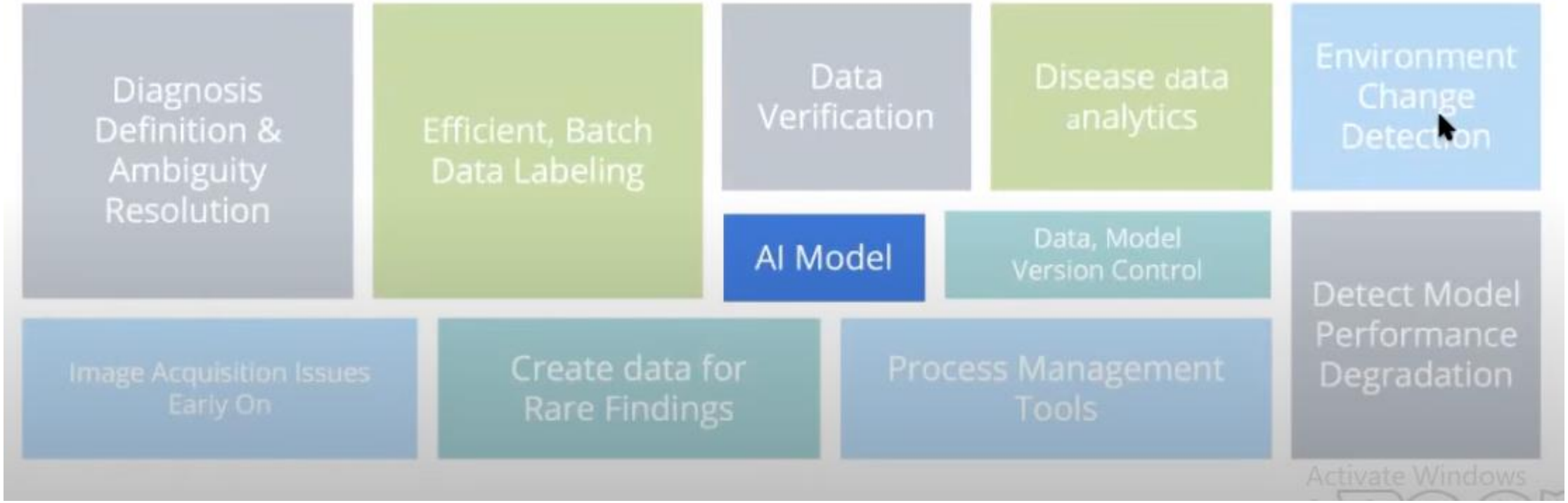
**Google Images.*

RAILWAY APPLICATIONS 9/15

- **Machine Learning Challenges:-**
  - **Small Data**
    - Data Distribution.
  - **Generalization and Robustness - Production Systems.**
    - A Model that works well according to a published paper often does not work in a production setting.
    - Human in the Loop
    - Technical Solutions.
  - There is a huge gap between ML Model and ML System.
  - **Change Management.**

**Andrew Ng, Video conferencing Presentation.*

RAILWAY APPLICATIONS 10/15

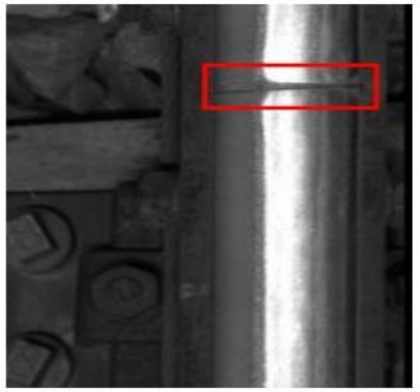


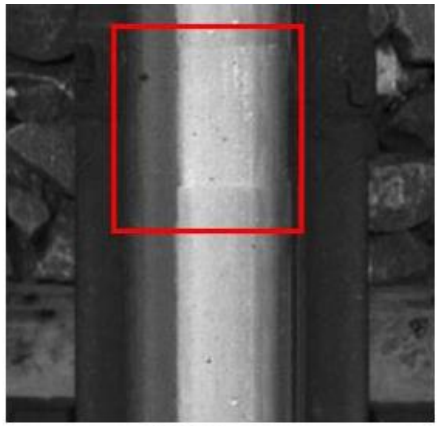
- Requirements for a Production ML SYSTEM. (Andrew Ng)

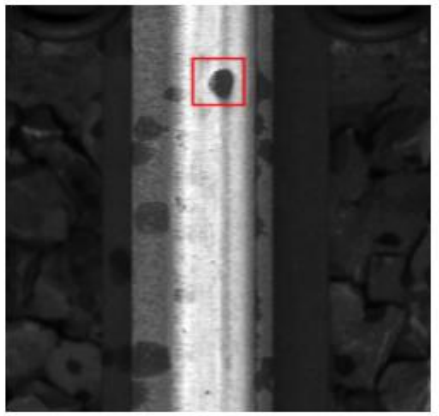
**Andrew Ng, Video conferencing Presentation.*

RAILWAY APPLICATIONS 11/15

- **Railway Surface Defects:-**
  - This is a project that was done in collaboration between **SBB and CSEM**. (All Images in this section are from this project).
    - **Railway Surface Defect Fault Classification**
    - **This is not a generic railway environment object detection!!**
  - They have faced the following problems in Fault Classification:-
    - Very little training data
    - Fault Categories: Reduced from 20 to 4
    - Expert Opinion can vary.


Joint

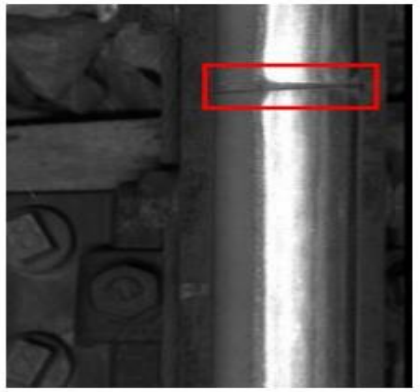

Welding


Surface Defect

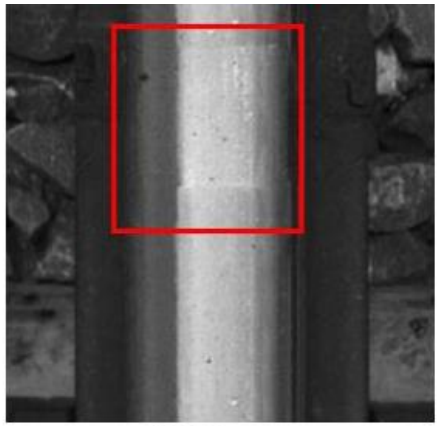
*SBB and CSEM.

RAILWAY APPLICATIONS 12/15

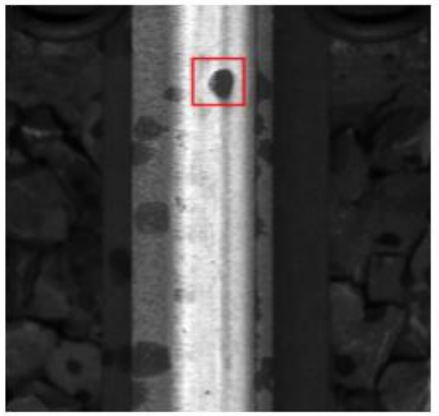
- **<u>Detection Results were:-</u>**
  - Joint 99%.
  - Weld 57%
  - Surface Defect 65%.
  - No Training Data was for Squat and Wheel Slip, so it was not detected!!.



Joint



Welding



Surface Defect

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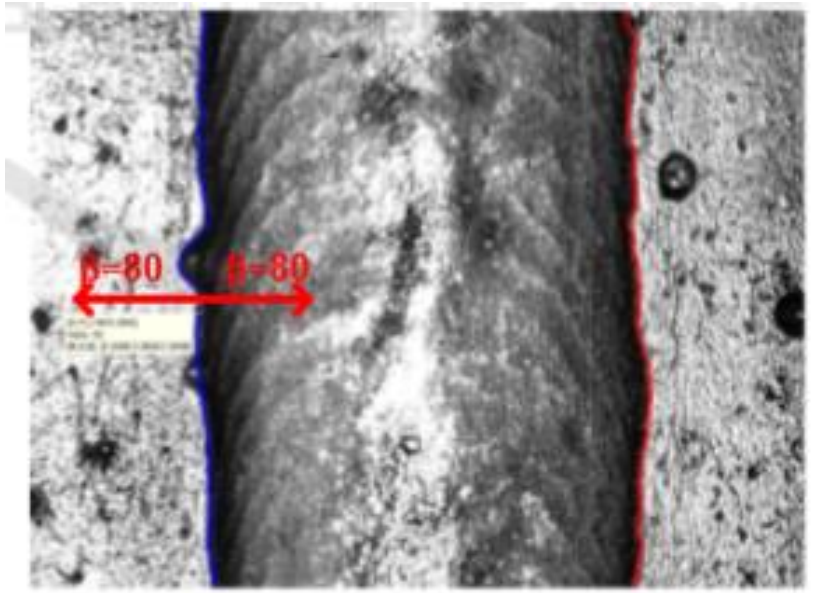
RAILWAY APPLICATIONS 13/15

- In Another Study that was focused on Rolling Contact Fatigue:
  - It was concluded “The investigation of MPI images of the rolling surface on a crossing nose during a frog’s lifecycle has shown that they have a significant statistical relation to the frog’s lifetime.”
  - **This why I think a generic object detection will help in identifying relationships between different objects in the image. (Future)**

**Prediction of Rail Contact Fatigue on Crossings Using Image Processing and Machine Learning Method (Sysyn, et al).*

RAILWAY APPLICATIONS 14/15

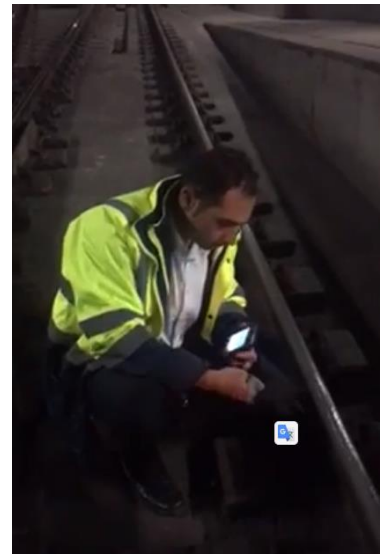
- **<u>Another study was focusing on welding:-</u>**
  - "The proposed method successfully identified the weld bead edges with maximum errors of 10.96 pixels"
  - Again , **This is not a generic object detection and this why I think generic object detection will help in various aspects. (Future)**



*Computer Vision System for Weld Bead Analysis. (Soares, et al)

RAILWAY APPLICATIONS 15/15

- **In Conclusion:-**
  - Generic Object detection in railway environment research is still in it is early stages.
  - Deep Learning development is accelerating in unprecedented way.
  - Data is there but more data is needed.
  - If Railways will move to the world of AI, they have to invest in deep learning, computer vision and object detection.
- ***Our Contribution:-***
  - Introduction of several **generic object detection models** in the **railway environment.**
  - We have also developed **inspectro** a hand held inspection device that can be utilized as a **data collection platform across many sectors**.
  - We have identified a **golden opportunity during COVID19**. – MASK detection. (This will push both privacy and machine learning research).



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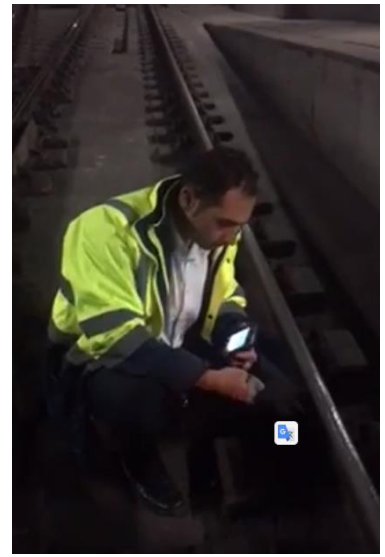
DATA 1/2

- Deep Learning have shown the need for **labeled data** in order for models to work to an acceptable level of accuracy.
- The great breakthroughs that have happened in deep learning creates new areas of research including:-
  - *Privacy, ethics and policy.*
  - *New Deep Learning Models.*
  - *Production Machine Learning systems.*



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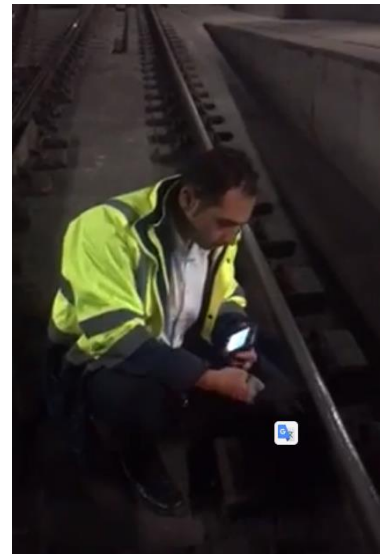
DATA 2/2

- It was fundamentally believed that *railways **have enough data** , that is hanging in their and waiting to be analyzed.*

- *I believe there is great development in Deep Learning that can help in the analysis of old data.*

- *But also I think there is an emergent need for more comprehensive, smart innovative and labeled data collection tools that people will find intrinsic value in those tools*



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NLP 1/10

- **Natural language processing (NLP)** is a subfield of linguistics, computer science, information engineering, and artificial intelligence concerned with the interactions between computers and human (natural) languages, in particular how to program computers to process and analyze large amounts of natural language data (Wikipedia).

- We did not do a comprehensive literature review of the progress of NLP, but we are excited about some of the recent Development specifically **BERT.**

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NLP 2/10

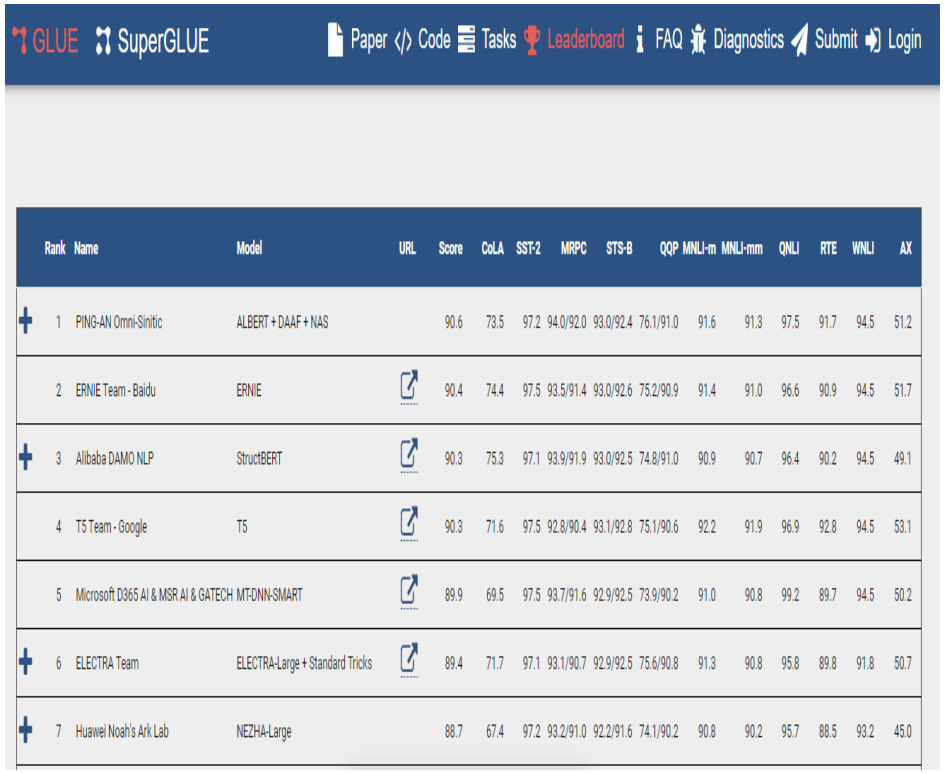
- **Bidirectional Encoder Representations from Transformers (BERT)** is a technique for NLP (Natural Language Processing) pre-training developed by Google. BERT was created and published in 2018 by Jacob Devlin and his colleagues from Google. Google is leveraging BERT to better understand user searches.

- The original **English-language BERT model** used two corpora in pre-training: **BookCorpus** (800 Million Words) and **English Wikipedia** (2.5 Billion Words).

NLP 3/10

- When BERT was published, it achieved state-of-the-art performance on a number of natural language understanding tasks:

- **GLUE** (General Language Understanding Evaluation) task set (consisting of 9 tasks)
- **SQuAD** (Stanford Question Answering Dataset) v1.1 and v2.0.
- **SWAG** (Situations With Adversarial Generations)



Rank	Name	Model	URL	Score	CoLA	SST-2	MRPC	STS-B	QQP	MNLI-m	MNLI-mm	QNLI	RTE	WNLI	AX
1	PING-AN Omni-Sinitic	ALBERT + DAAF + NAS		90.6	73.5	97.2	94.0/92.0	93.0/92.4	76.1/91.0	91.6	91.3	97.5	91.7	94.5	51.2
2	ERNIE Team - Baidu	ERNIE		90.4	74.4	97.5	93.5/91.4	93.0/92.6	75.2/90.9	91.4	91.0	96.6	90.9	94.5	51.7
3	Alibaba DAMO NLP	StructBERT		90.3	75.3	97.1	93.9/91.9	93.0/92.5	74.8/91.0	90.9	90.7	96.4	90.2	94.5	49.1
4	T5 Team - Google	T5		90.3	71.6	97.5	92.8/90.4	93.1/92.8	75.1/90.6	92.2	91.9	96.9	92.8	94.5	53.1
5	Microsoft D365 AI & MSR AI & GATECH	MT-DNN-SMART		89.9	69.5	97.5	93.7/91.6	92.9/92.5	73.9/90.2	91.0	90.8	99.2	89.7	94.5	50.2
6	ELECTRA Team	ELECTRA-Large + Standard Tricks		89.4	71.7	97.1	93.1/90.7	92.9/92.5	75.6/90.8	91.3	90.8	95.8	89.8	91.8	50.7
7	Huawei Noah's Ark Lab	NEZHA-Large		88.7	67.4	97.2	93.2/91.0	92.2/91.6	74.1/90.2	90.8	90.2	95.7	88.5	93.2	45.0

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NLP 4/10

Computational_complexity_theory

The Stanford Question Answering Dataset

Computational complexity theory is a branch of the theory of computation in theoretical computer science that focuses on classifying computational problems according to their inherent difficulty, and relating those classes to each other. A computational problem is understood to be a task that is in principle amenable to being solved by a computer, which is equivalent to stating that the problem may be solved by mechanical application of mathematical steps, such as an algorithm.

GOLDEN OPPORTUNITY

What branch of theoretical computer science deals with broadly classifying computational problems by difficulty and class of relationship?

Ground Truth Answers: Computational complexity theory | Computational complexity theory | Computational complexity theory

Prediction: Computational complexity theory

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NLP 5/10

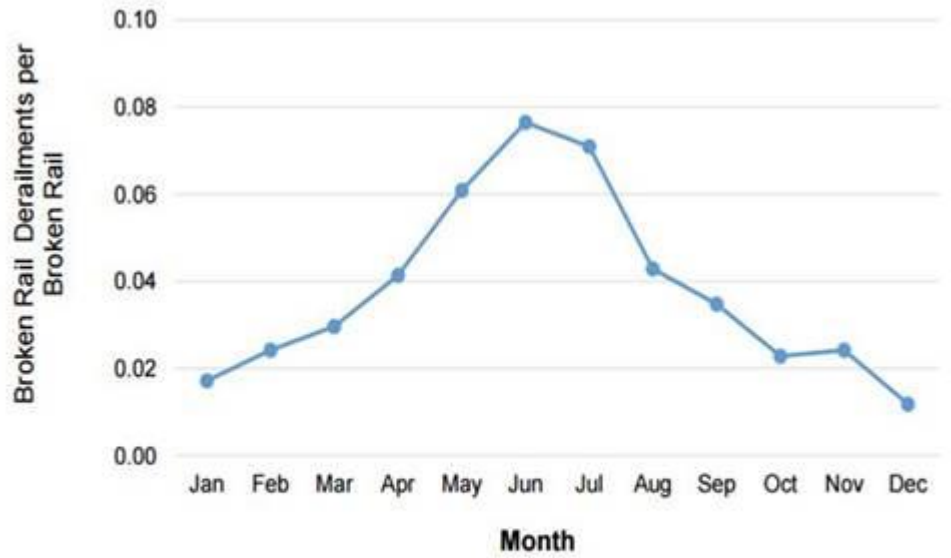
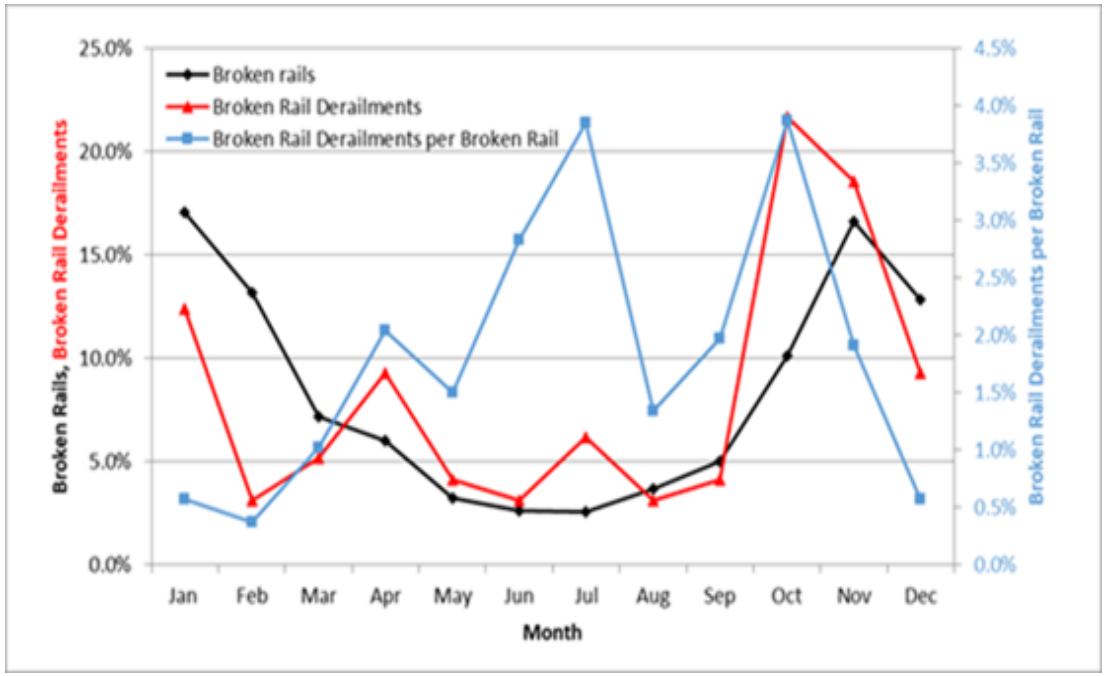


Figure 3 Average number of broken-rail-caused derailments per broken rail by month, adapted from Dick (2001) Table A-6 [2]



"Q1) I would be grateful to receive any hypotheses to help explain why the **ratio of broken rail derailments** to **broken rails** is generally greatest in summer?

! and why the same ratio, but for

Q2) **contact stress** related **breaks** and **derailments** gives **summer and fall peaks?"**

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- An **Email Thread** Started for around a month, a group of experts, consultants, professors started t give their answers? The answers varied from different perspectives.
  - Vehicle dynamics and Wheel Rail Forces
    - Temperature Rail, critical crack size, rolling contact fatigue loading, tensile stress
  - Wheel Rail interface
    - Adhesion.
  - Operations
    - Signaling failures, signaling system did not detect the broken rail.
  - Many Many others…..

NLP 7/10

- An Answer came:-
  "There may be certain types of fracture, the formation of which and growth are less temperature sensitive. We know that defects in the transverse plane are negatively impacted by falling temperatures. But those don't comprise all of the fractures.
-
- *Ideally, we should look at the broken rail derailment data for the summer months and see what type of fracture was involved and the circumstances surrounding its occurrence. What we learn could then guide inspection policy"*

NLP 8/10

Conclusion was belt on the following Inputs:-

1- This is based on a wide swath of freight railroad data from North America and is believed to include all rail breaks – including those at welds and base-breaks.

Conclusions was based on the following inputs:

1- Class 1 (large NA freight) railroad one in the summer and one in the fall.
2- Derailments due to transverse defects (transverse fissure and detail fractures) are included.

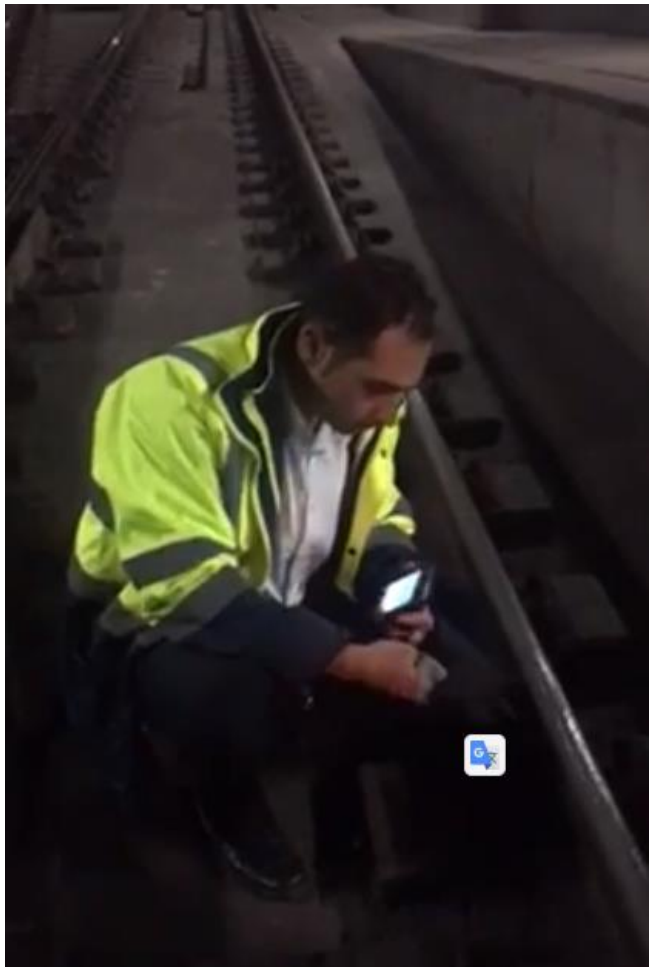
ANSWERS

Person	Answer Focus	Opinion / Answer	Right / Wong / Source	Key Parameters
Anonymous	**Introductory Fact**	In general multiple rail breaks or a massive part of the rail detaching is required to cause derailments		Number of Rail Breaks Number of Derailments
	Introductory Fact	In winter there is tension, thus the critical crack size is small.		**Temperature and Tension**

NLP 9/10

- **Opportunity: Expert Opinion Search**
  - Bert might be able to find the answer of specific questions in very long text.
    - Examples: The rail-Breaks **Email Threads** – ICRI- Rail Breaks.
    - **Surveys.**
    - **Inspectro. (Our Work)**

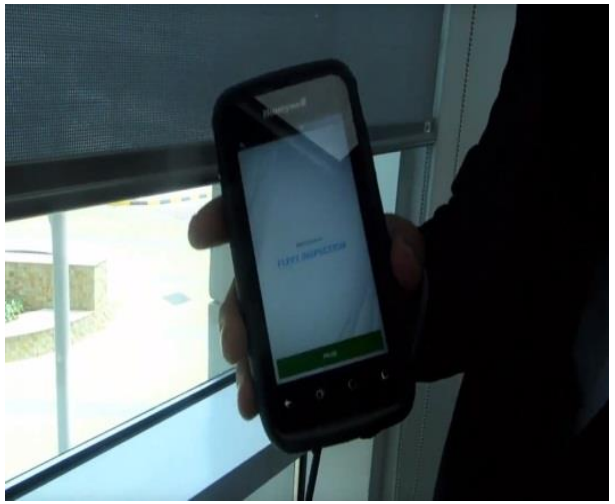
NLP 9/10

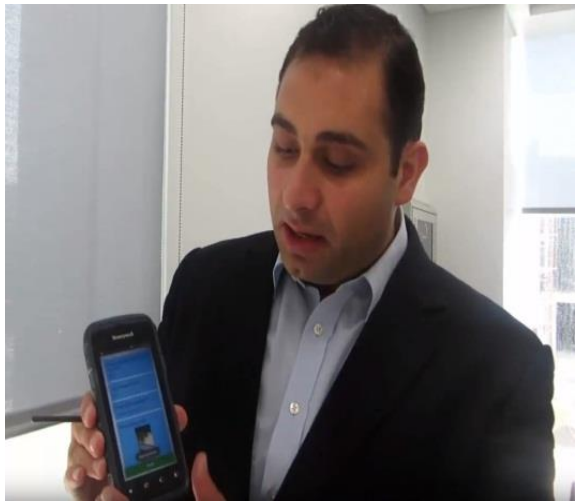


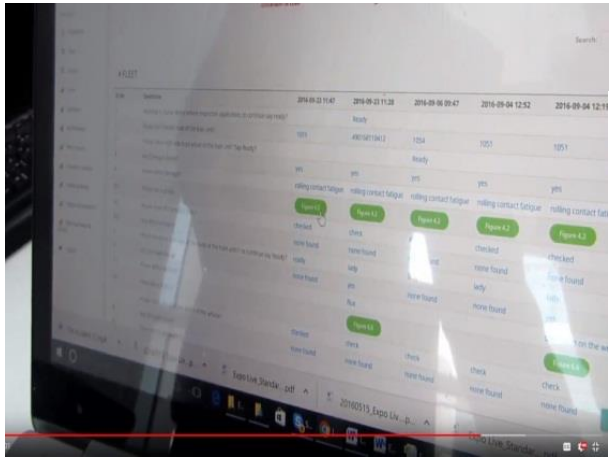
Inspectro is handheld voice enabled device that was aimed at helping in visual inspection.

provide a cross-sector platform for data collection across construction, transport, Energy, retail, health and other industries.

NLP 10/10







The original software platform was designed to ease report making and to make visual inspections reports or field reports as easy as taking a picture.

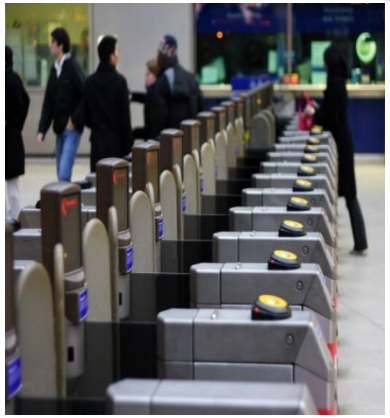
REVIEW : THE POTENTIAL USE OF BLOCKCHAIN TECHNOLOGY IN RAILWAY APPLICATIONS : AN INTRODUCTION OF A MOBILITY AND SPEECH RECOGNITION PROTOTYPE

Publisher: IEEE | Cite This | PDF

1 Author(s) Feras Naser All Authors

THE FUTURE OF RAILWAYS 1/8

- In **2018** in JEA, I have made a presentation saying that **Railway stations** can be the next **Facebook**. What I meant by that there are many data collection devices in the station that can be seen as a new DATA ENGINE.
- In **2018**, in USA, I have also proposed the usage of **trust services** as a new service that is offered by public infrastructure Agencies as a way to fund new projects.



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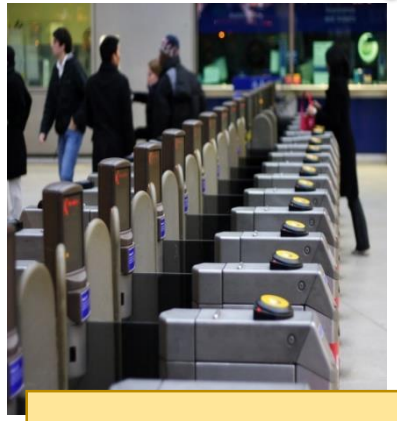
THE FUTURE OF RAILWAYS 2/8

- Utilizing the data that is available about people in **railway station** and in **railway trains**, specially during long journeys. Can help in the following:-
  - Building a better understanding of the concept of **TRUST.**
  - Offering **TRUST SERVICES** which can facilitate social and economical interactions.
  - People will have a difficulty in objecting the use of data because it happens in the **public space**.
  - This can facilitate many other areas of research in social science, engineering and more.. **TRUST were in crisis during COVID19.**



GOLDEN OPPORTUNITY

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THE FUTURE OF RAILWAYS 3/8

- **FEW REMAINING ADVANTAGES FOR THE RAIL MODE.**
  - **FRICTION** is one of they key advantages for railways.
  - **Environmental Impact** is another key advantage.
  - **SPEED** is another advantage.
  - **SPACE** requirement is another Advantage.

- The Development of **Electric Autonomous Cars** will lead to the development of electric autonomous busses and many rail advantages **will fade.**

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THE FUTURE OF RAILWAYS 4/8

From Whom we can Learn and Why?!

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Google

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THE FUTURE OF RAILWAYS 5/8

- TESLA is one of the pioneers of
  - **Production Machine Learning systems in real transport scenarios.**
    - TESLA Autopilot Model
      - Approximate object detector
      - Algorithm and Sensor Health Monitoring.
      - Data Engine
      - Label the Images
      - Evaluation Metrics (How did the model performed in several scenarios).
  - **Hydra Net**
    - Shared Backbone with (more than 1000 detectors)
    - 1000 Distinct Detectors, 48 Networks and 70,000 GPU hours (This is a lot!!)

THE FUTURE OF RAILWAYS 6/8

- Google is one of the pioneers of
  - Making **Machine Learning** as accessible as possible.
    - Automation of Machine Learning.
    - Providing Tensor Flow for Mobile and the JavaScript the browser
  - Developing Personalized and on device training
    - Privacy, privacy preserving Machine Learning Systems
    - Federated Learning
    - Recently, MIT published about Split Learning. (More efficient federated learning)

THE FUTURE OF RAILWAYS 7/8

- If the railway industry want to move to the AI world, they should have their own data engines.
  - Facebook has it social media network and applications – powerful data engine
  - Google – has youtube, gmail and the search engine as powerful data engine.
  - Tesla – has their own cars as a very powerful data engine (1 million tesla's are on the road today!!)

- *What is the railway data engine*:-
  - Onboard Train Sensors.
  - Stations and Trains CCTV Cameras.
  - Handheld Devices – Personal Helmets and Cameras.

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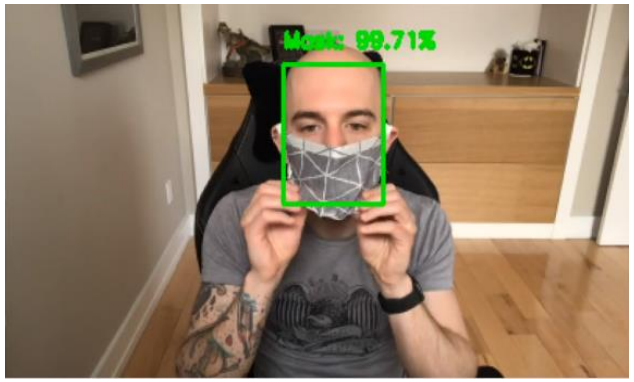
THE FUTURE OF RAILWAYS 8/8

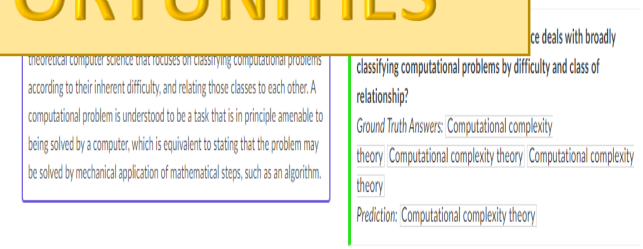
- **DAQRI** is a company that provide augmented reality helmets. we wanted to implement **Inspectro** on their helmets in 2016.

COLLABORATION 1/4

- **Presentation Brief:-**
  - We have presented an introduction to deep learning, computer vision and object detection.
  - We have made a video testing three generic object detection models (YOLO, SSD and Mask RCNN to provide a feeling of what can these models detect in a railway context. **(my work)**
  - We talked briefly about the Data challenge. We made a quick introduction to NLP and BERT.
  - We have identified **three key opportunities (quick wins)** for the rail industry based on the available technology. **(my work)**



GOLDEN OPPORTUNITIES



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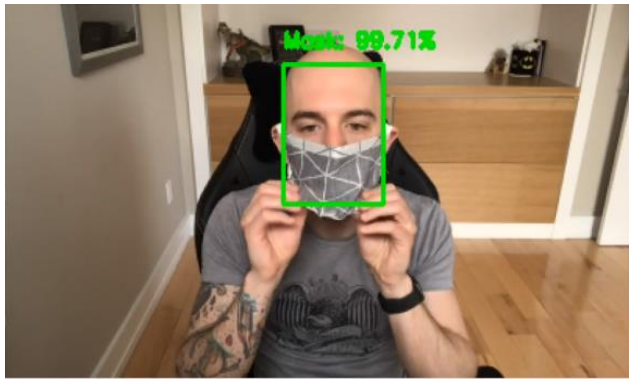
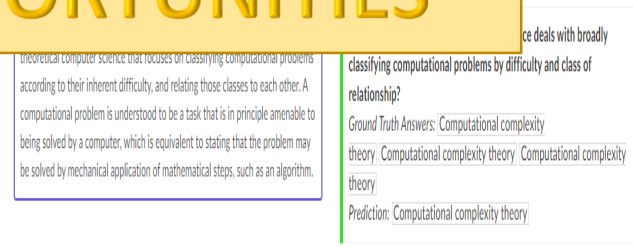
COLLABORATION 2/4

- **Presentation Brief:-**
  - We have introduced our work inspectro. **(My work)**
    - As a new data collection tool and the possibility of applying such a solution on augmented reality helmets.
  - We have talked about my opinion about the future of railways and a railway data engine.
  - The Video can be found on
    - https://youtu.be/qHmFcuurv0o
  - The presentation can be found on TRANSPORT MEN.com



GOLDEN OPPORTUNITIES



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COLLABORATION 3/4

- COLLABORATION OPPORTUNITIES
  - I am very happy to write a **specific proposal for an R&D grant** based on the previous golden opportunities. But we would like to apply for grants with high possibility of success.
  - We do welcome offers for **early market representation** or technical follow up as part of our transportmen.com startup.
  - We also consider dislocation to become **nearer to ASIA**
    - We do have a scholarship offer from SPJAIN to do a GMBA (Singapore, Sydney and Asia)
    - We welcome offers to co-sponsor the scholarship to cover additional fees.
    - We will provide new rail related business models and systems as an exchange for this sponsorship.

COLLABORATION 4/4

- Our group **FerasNaser.com** is an innovation based startup group and we have many projects that require talent and investment.
  - We do have limited budget for innovation and R&D.
  - But also we do have limited access to innovation funding due to our location.
  - So we can consider new ways of collaboration.

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Thank You!!

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