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# Challenges in Vision-Based Adaptive Traffic Control Systems

Venkatesh Wadawadagi
Solution Consultant - Cognitive Solutions
Sahaj Software Solutions (sahaj.ai)

Sahaj software

Background and Need for ATCS

What is ATCS (Adaptive Traffic Control System)?

- ATCS adjusts the signal timing parameters in real time according to the seasonal changes and short-term fluctuation of traffic demand

- ATCS algorithm determines optimized red-green phases of traffic signals in order to achieve junctions green-green synchronization across the entire region of deployment

- ATCS into consideration here is the one based on Deep Learning based object detection
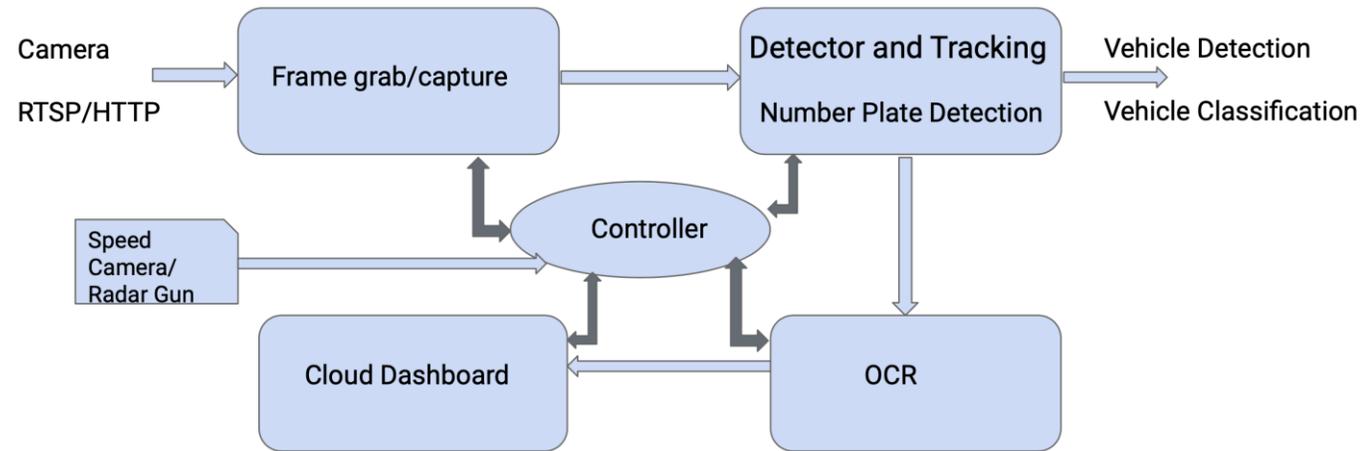
Block diagram of Vehicle Analytics System where-in ATCS is part of it

Need for ATCS

- The existing systems widely used are traffic signals with pre-set timers which operate under fixed time operation

- Current traffic signal control systems rely heavily on oversimplified information and rule-based methods

- Real-world traffic conditions evolve in a complicated way, affected by many factors such as driver's preference, interactions with vulnerable road users (e.g., pedestrians, cyclists, etc.), weather and road conditions

- In 2014, traffic congestion cost Americans over $160 billion in lost productivity and wasted over 3.1 billion gallons of fuel [Economist 2014]

Benefits of ATCS

- Increase travel speeds

- Reduce accident rates

- Improvement of the efficiency of traffic operations on urban road networks

- Suggestions to future infra requirements based on the real time traffic density

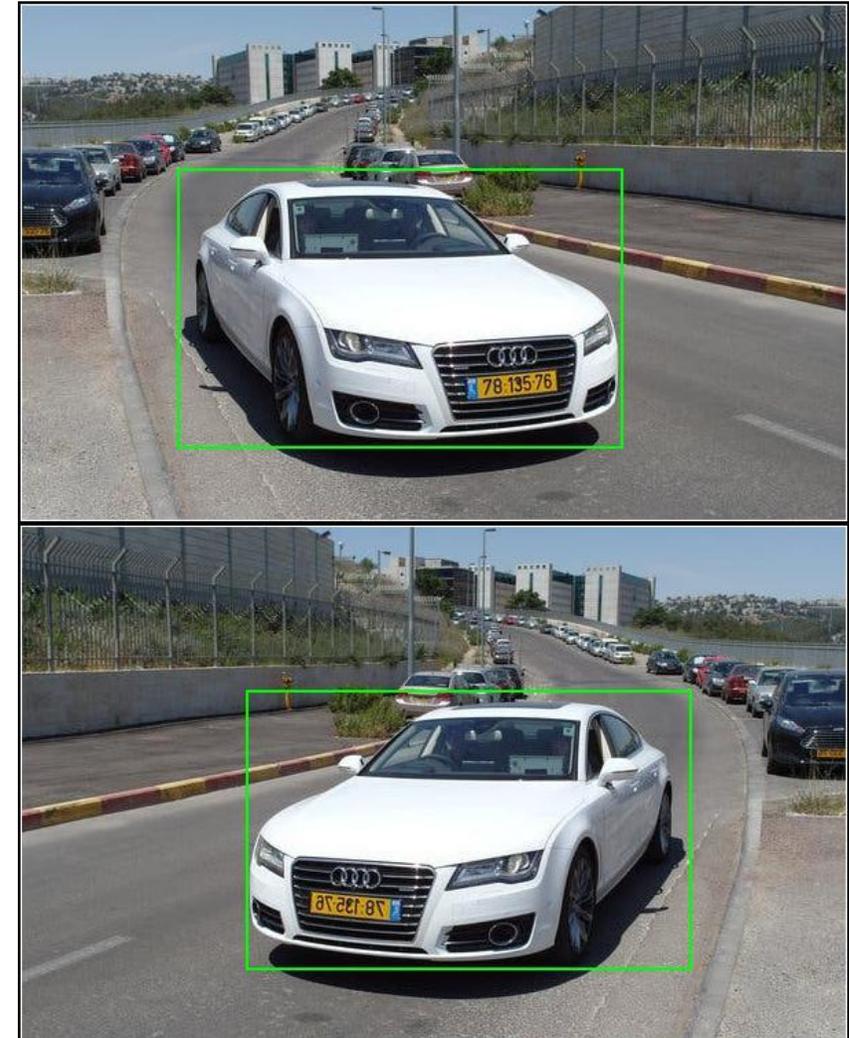# Variety Associated with Vehicles

- Challenge: Missing/wrong detections and/or wrong classifications of vehicles, because of the variety associated with them

- Why important to solve?

  - Wrong bounding box, leading to lot of complications

  - Wrong signal timing

  - Less efficient traffic operations

Variety Associated with Vehicles

- Difficulties:

  - A given junction will have variety of vehicles passing through, depending on the geographical location

  - Various categories and sub-categories of vehicles

    - 2 wheelers, 3 wheelers, 4 wheelers & 6 wheelers etc.

    - Various types of cars

    - Various sizes of buses and trucks

Variety Associated with Vehicles

- Techniques to Solve:

 - Include images/videos with variety of vehicle classes in training dataset and validation dataset

  - Include images/videos with all possible view profiles of vehicles

    - Front view, back view, side view, diagonal and top view

    - Leverage horizontal flipping

  - Data augmentation

    - Random sampling to make final model more robust to various vehicle sizes and shapes

    - Re-scaling, zoom based transformation and translation

Horizontal Flipping
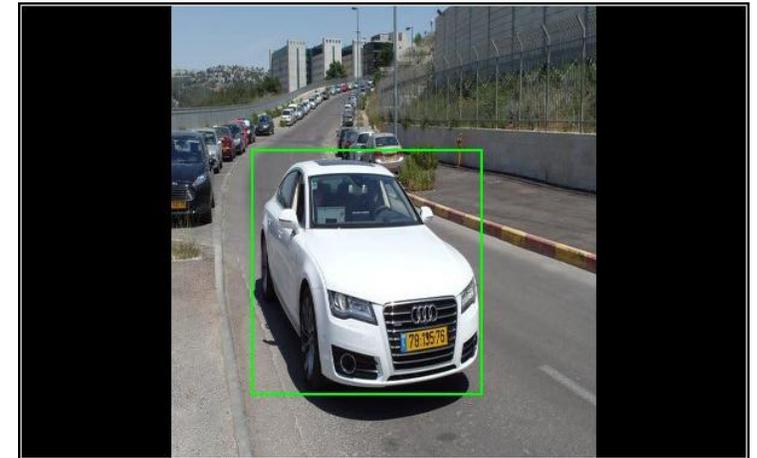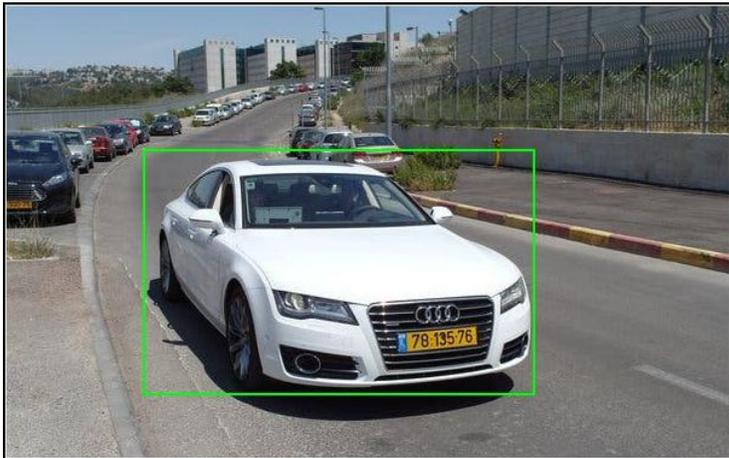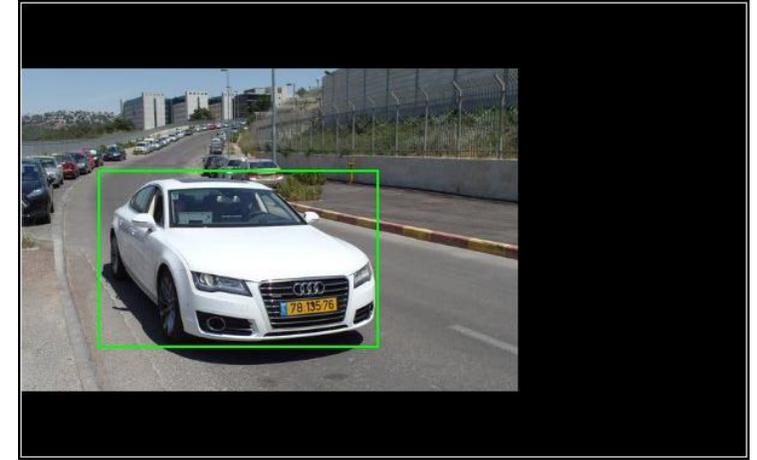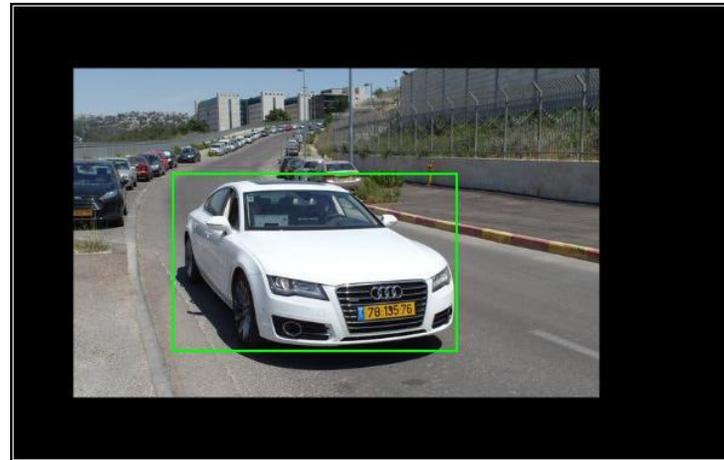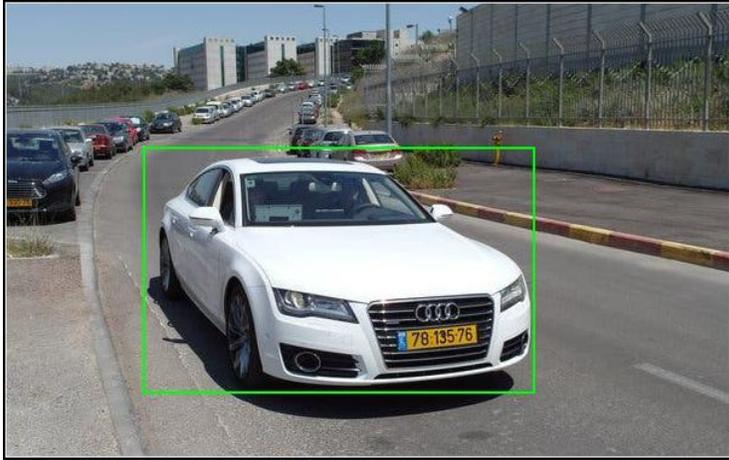
- Techniques to Solve:

  - Ensure precise bounding boxes while annotating the images

  - Split vehicle classes as per their categories and sizes

    - Categories - Motorcycles, LMVs(Light Motor Vehicles), MGVs(Medium Goods Vehicles), HGMVs(Heavy Goods Motor Vehicles) and HPMVs (Heavy Passenger Motor Vehicles)

    - Apart from main model that detects and classifies the type of the vehicle such as hatchback car, sedan car etc, we can have one more model to detect it's category

    - Detection and classification of category helps in preventing wrong classification mistake made by main model to an extent and additionally helps to approximate the size of the vehicle

Effect of Lighting and Weather Conditions

- Challenge: Missing/wrong vehicle detections due to the effects of lighting and weather conditions

  - Bad lighting, darkness, rain, fog/mist etc.

- Why important to solve?

  - Wrong signal timing

  - Less efficient traffic operations

Effect of Lighting and Weather Conditions

- Difficulties:

  - Bad lighting, darkness & fog/mist might result in bad quality images for ATCS processing

  - Vehicles with headlamps (especially high beam ones) might obstruct the ATCS view of their own or other vehicles night

  - Rain/winds can potentially alter the view of vehicles for the roads with trees

  - Snow can alter/obstruct the view of the vehicles

- Techniques to Solve:

  - Include images/videos captured across the weeks/months at various times in training dataset and validation dataset

    - Early morning, morning, evening, night & mid-night

    - Rainy day, windy day & snowy day

  - Data Augmentation

    - Gaussian noise, Laplace noise, Poisson noise, Impulse noise and salt & pepper noise to mimic/tackle bad light and rain

    - Adjustments like brightness, contrast, hue and saturation etc. to enable that vehicles
      with blurry edges can be detected as precisely as possible

    - Make use of weather based augmenters to mimic/tackle clouds, fog, rain, snow and snow flakes
      (*imgaug.augmenters.weather*)

Addition of Gaussian Noise
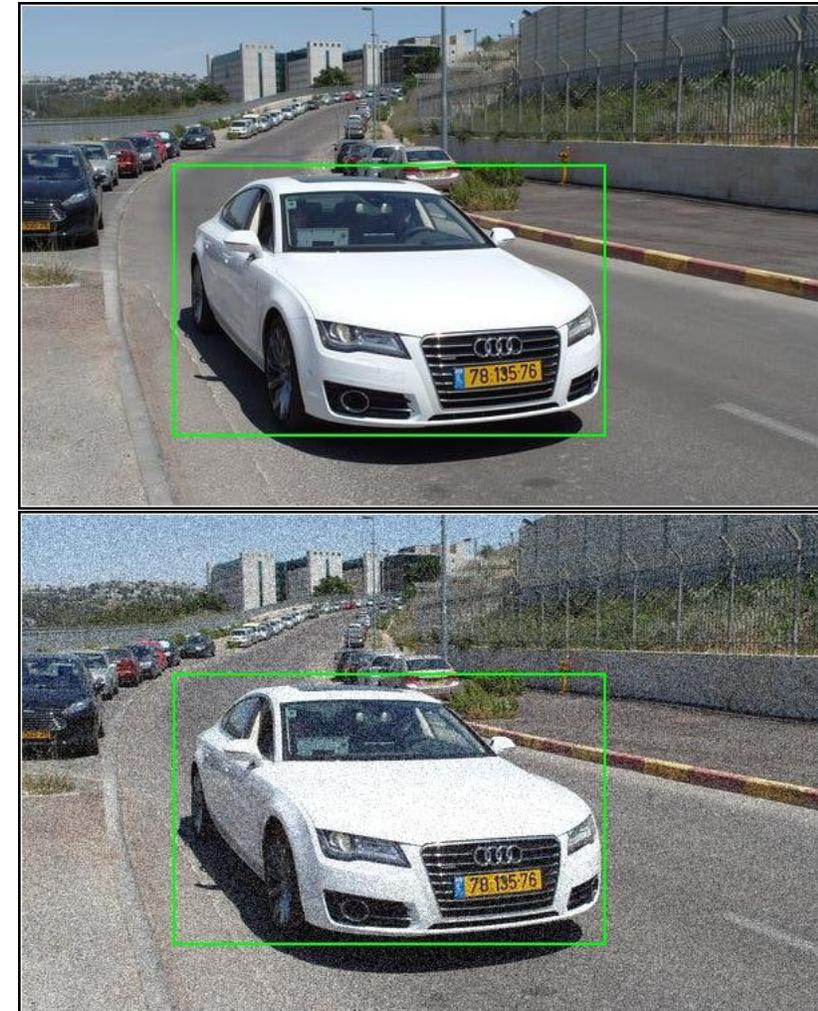
Effect of Lighting and Weather Conditions
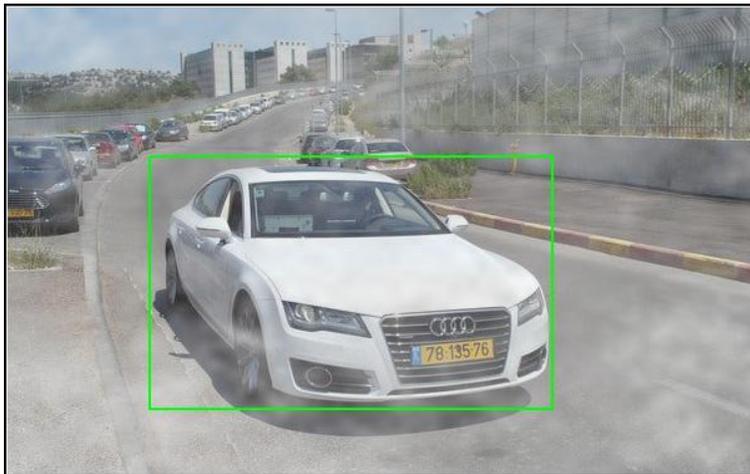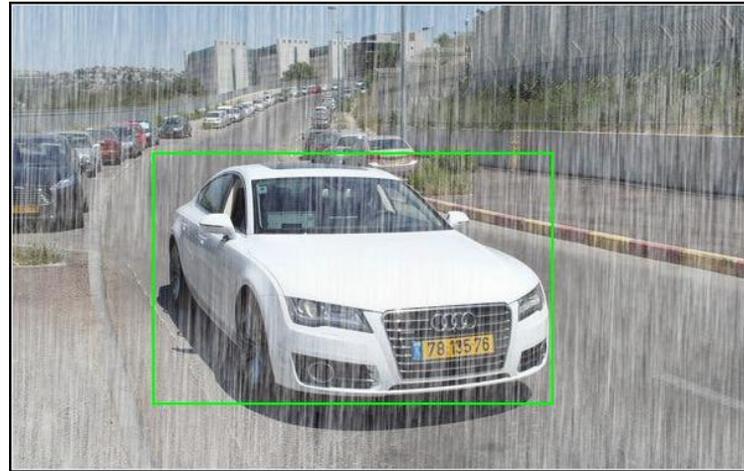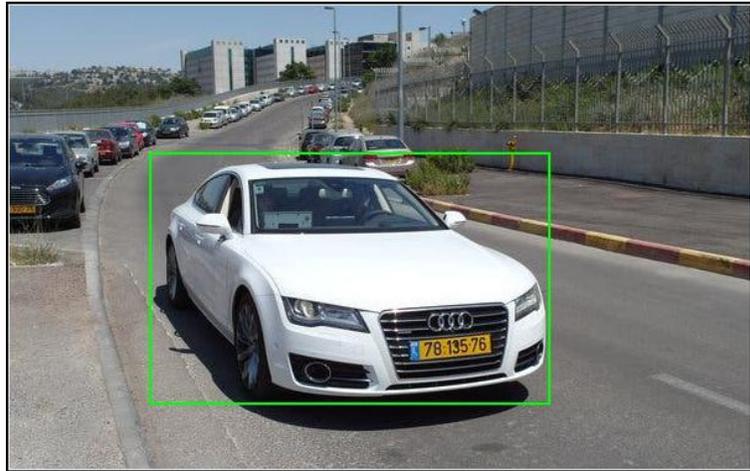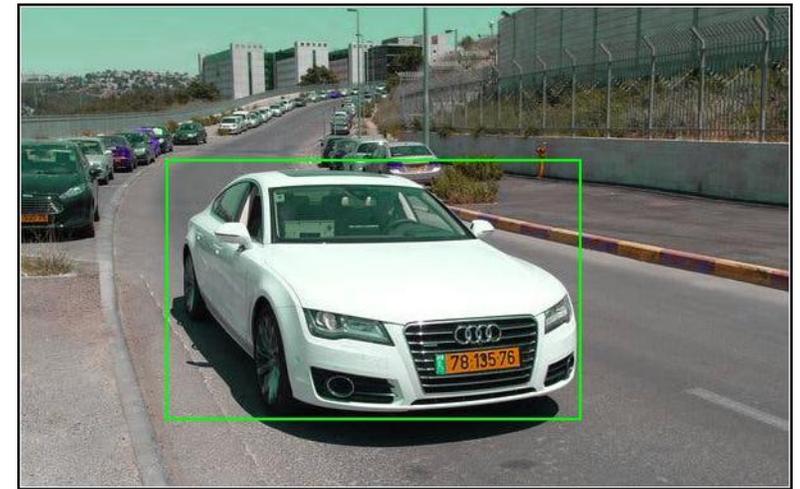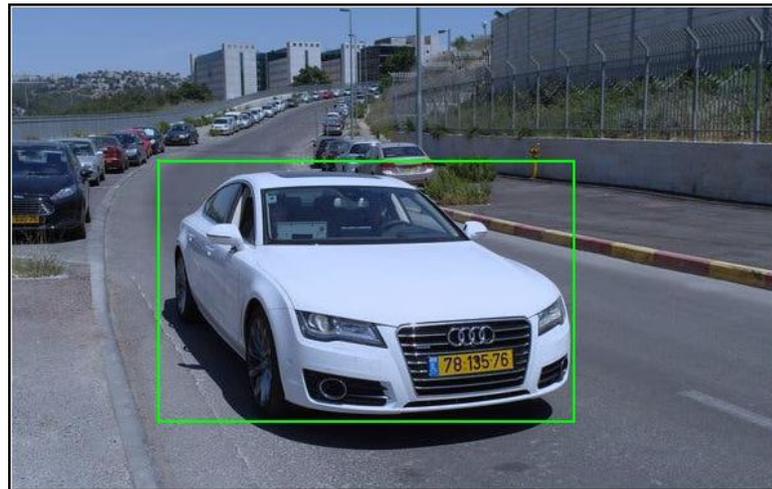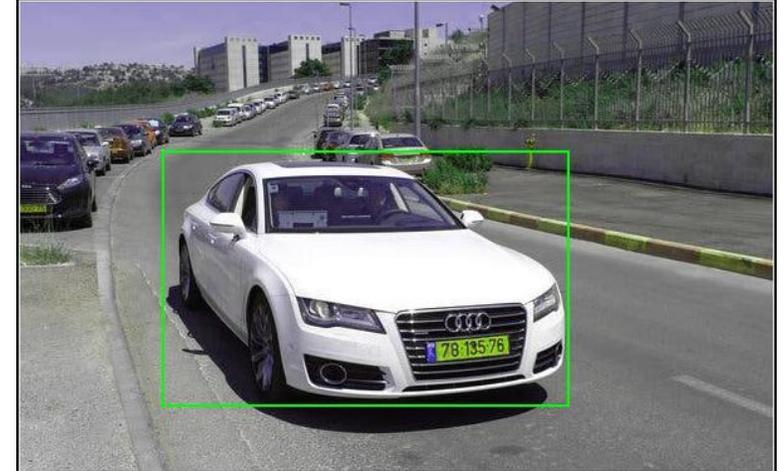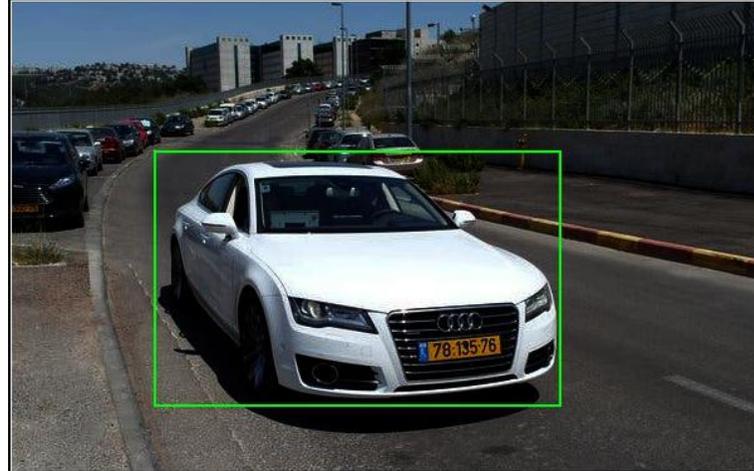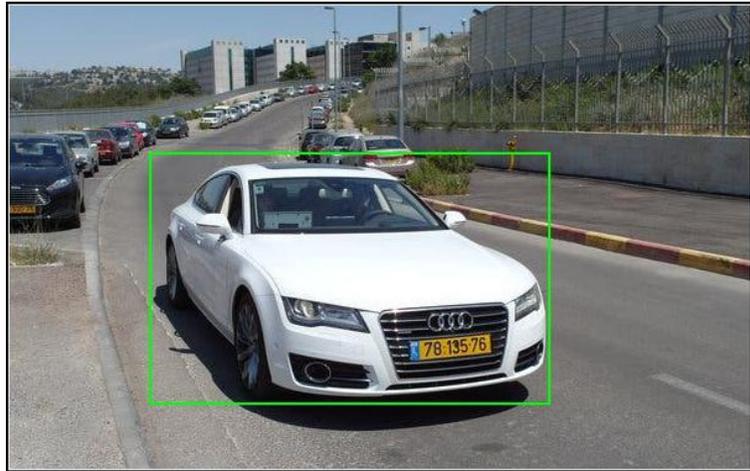
- Techniques to Solve:

  - Train the models with headlamp as separate class so that it won't be confused with other vehicle classes

  - Use ensemble of vehicle detector models to improve the accuracy at night, foggy mornings and snowy days

- Challenge: Wrong classification of person as two wheeler or other way around

  - Pedestrian crossing the road, person walking on the side etc.

- Why important to solve?

  - Wrong vehicle density calculation

  - Less efficient traffic operations

  - It can lead to safety issue as well as ATCS will not allow extra time for pedestrian to cross when mis-classified as two-wheeler

- Difficulties:

  - Especially in the evening and at night, we may not have clear view of the pedestrian

  - Width and height of person bounding box can be similar to that of two wheeler
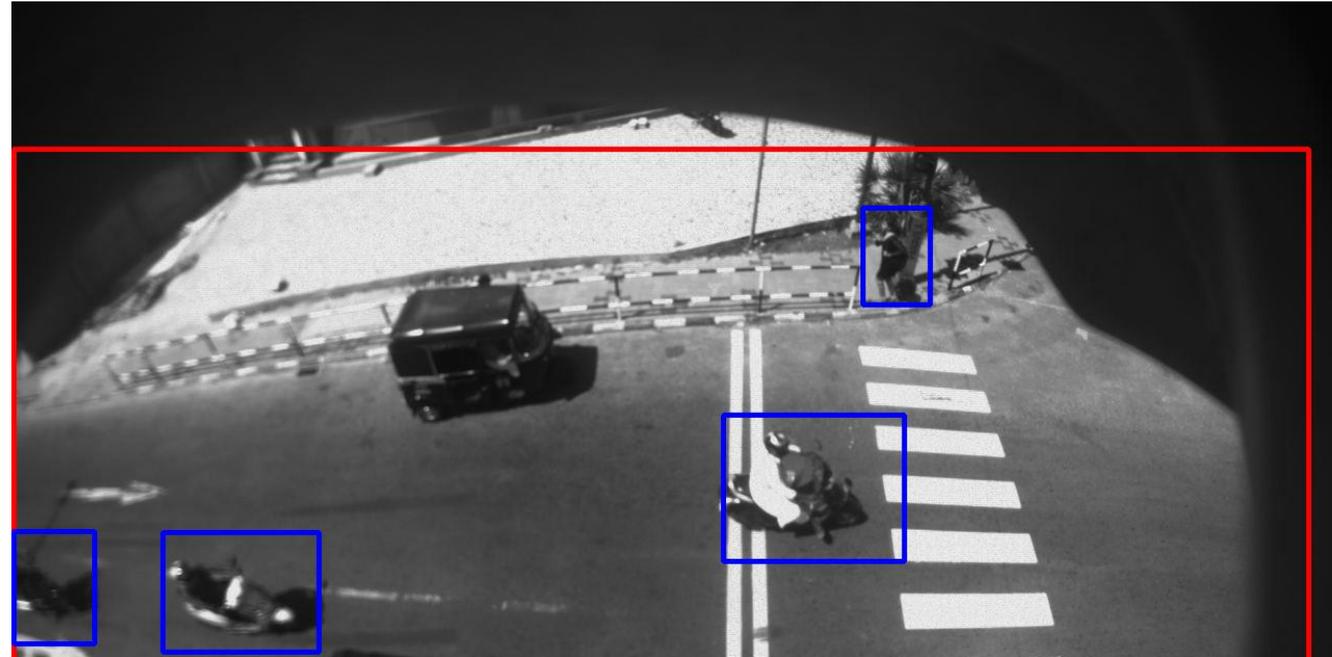
Handling Person Detection and Mis-classification

- Techniques to Solve:

  - When vehicle detector classifies the entity as two wheeler use separate person detector to differentiate person from two wheeler

  - Use object tracker across the frames so that person can be filtered out based on the direction of motion

    - Direction of motion for pedestrian crossing the road would be different from direction of motion for vehicles passing through

  - Error associated with person walking on the side of the road can be avoided with the help of precise ROI (Region of Interest) for ATCS operation

    - Draw/configure very tight ROI so that footpaths are excluded

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- Challenge: Missing/wrong vehicle detections due to the occlusion caused by various reasons

- Why important to solve?

  - Wrong vehicle density calculation

  - Wrong queue length and wait time

- Difficulties:

  - Occlusion can be caused by bigger vehicles present next to the vehicle of interest

    - It's very easy for smaller vehicles such as two wheelers, three wheelers and small cars to get occluded by bigger buses, goods trucks and trailers, etc.

  - Occlusions can be caused by trees on the roads (especially during windy days)

- Techniques to Solve:

  - Use random cropping as the one of the image augmentation methods while creating the training data set to train the vehicle detector model

  - Use ensemble of vehicle detector models to improve the accuracy against the partial occlusions

  - Ensure surveillance cameras have the better view of the all the vehicles at the junction

    - Prefer top view and diagonal top view

  - Make the decisions based on the images from multiple cameras rather than preferring single camera

Random Cropping

Summary
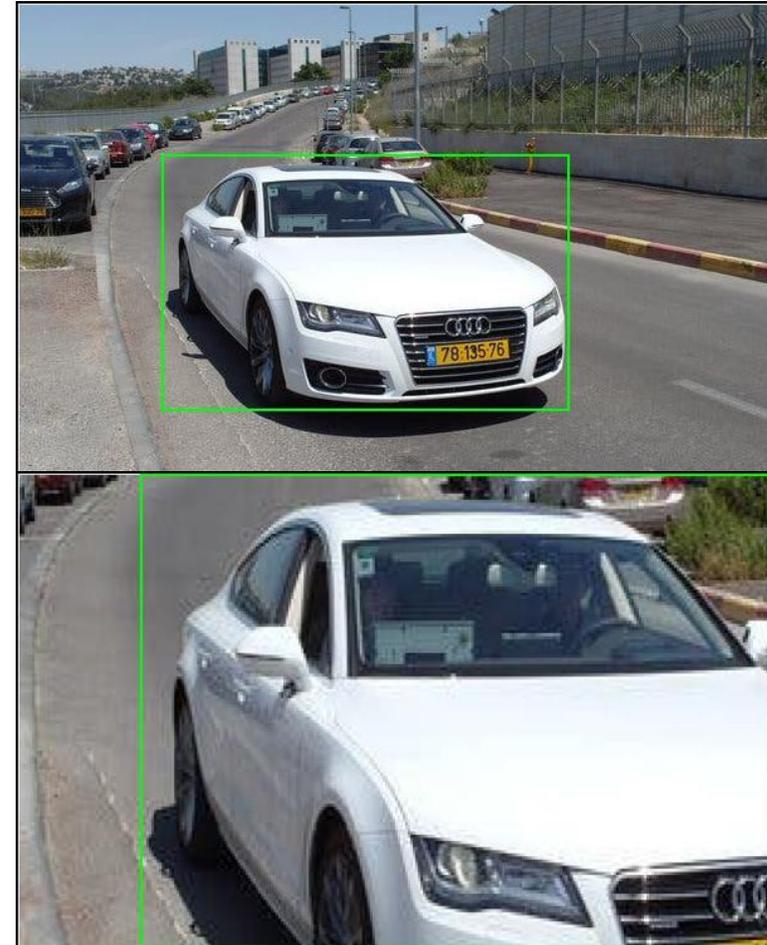
- Image augmentation techniques play a major role in creating various possibilities within the image for the object of interest (vehicle here) thereby helping in

  - Creating well defined, diverse and dynamic dataset

  - To mimic real world scenarios

  - To build generalised vehicle detector for ATCS

- Since it is important to get the best possible accuracy for ATCS, ensemble of models helps more often than not (ensure that models aren't alike)

- Configuration and adjustment of camera is always an important step to give best possible view and ROI (Region of Interest) for efficient ATCS

- Apart from looking at spatial features, it's necessary to look at temporal features as well to be able to solve some of the tricky problems associated with ATCS (usage of vehicle tracker)

Future of ATCS - Thoughts

- Under multimode vehicle traffic flow, system can more abundantly and accurately collect information such as the position and speed of the vehicle and can directly guide the connected vehicles and control the autonomous vehicles

- The use of a digital twin for the urban traffic system within the correct framework may enable to find limitations, bottlenecks and mistakes w.r.t traffic operations earlier leading to optimal and efficient ATCS

- System can operate with four control modes

  - Traffic signal control

  - Connected vehicles guidance

  - Automated vehicles control

  - Indirect control of conventional vehicles through connected vehicles and automated vehicles

AI based Vehicle Analytics for smart cities

https://medium.com/inspiredbrilliance/ai-based-vehicle-analytics-for-smart-cities-2c795681d077

Weather based augmenters

https://imgaug.readthedocs.io/en/latest/source/overview/weather.html

Backup Material

Sahaj is a technology consulting company specialised in developing purpose-built AI and data-led solutions

Sahaj/

adjective

With its origin in Sanskrit, stands for "simplicity"
Meaning: natural; original; innate; spontaneous.

Founded In	With	And
2014	**100+ Clients**	**120 Consultants**

San Francisco

London

Bengaluru Chennai
Pune

Melbourne

Sahaj software

What we do ?

Services Focus

Advisory

Identify the potential to create or enhance value

Build

Grow value with new intellectual property

Design

Explore ideas and solutions to add new value

Enable

Coach client teams so they can create ongoing value

Technology and Solution Focus

Distributed Systems | Data Platforms | Intelligent Data Products

CAPABILITY OVERVIEW

Purpose-Built Data Platforms and Products

Bringing together expertise in data engineering and machine learning with the discipline of agile product creation.
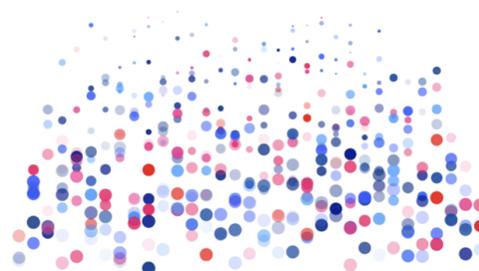
AI Solutions and Data Products

Product Creation

- Data-driven solution discovery
- Accelerated upfront discovery
- Emphasis on early feedback
- Regular release cadence

Data Science / Machine Learning:

- Statistical Learning
- Computer Vision
- Natural Language Processing
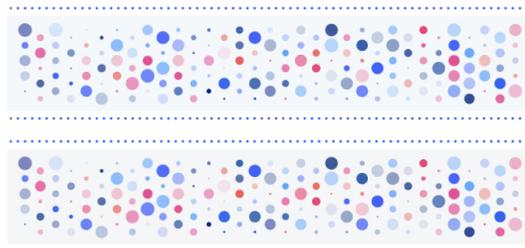
Data Platforms

Big Data Infrastructure & Data Engineering

- Large scale data management
- Real-time and batch processing
- Data lake design and deployment
- Query (OLAP, OLTP) handling
- Analytics/BI solution engineering
- Visualization tools and capabilities

Data Platforms and Products

RECENT WORK
Purpose-Built Data Platforms and Products

Small Teams

Cohesive team of 5 or less

Go Live

In a short span of 4 - 12 weeks

3x Faster

Pace that's faster than a role-based team

SERVICE FOCUS
New Product Build

SOLUTION FOCUS
Geo-location Modeling

Behavior-based OOH campaign planning product for a specialist outdoor media and creative agency.

SERVICE FOCUS
Product Enhancement

SOLUTION FOCUS
Natural Language Processing

Content discovery product for a global content digitization and aggregation company.

SERVICE FOCUS
Product Innovation

SOLUTION FOCUS
Computer Vision

Intelligent automation of creative reviews and approval starting with compliance to specific guidelines.

SERVICE FOCUS
Platform Design and Build

SOLUTION FOCUS
IoT Infrastructure

Custom-designed data stack for an emerging market connected vehicle platform.

SERVICE FOCUS
Platform Design and Build

SOLUTION FOCUS
Core Infrastructure

Core infrastructure stack including data, connectivity, and content SDKs for nation-wide ed-tech platform in India.

SERVICE FOCUS
Technology Advisory

SOLUTION FOCUS
Cloud Data Infrastructure

Scale the data platform for a computer-vision startup focused on manufacturing shop floor operations.

- It helps to create purpose-built visual-ai solutions that enables you to monetise and monitor visual content

- Use cases/Applications

  - Automated Ad-creative Approvals

  - Brand Monitoring

  - Sponsorship Monitoring

  - Adoption across industries - retail, e-commerce, marketing, automotive etc.
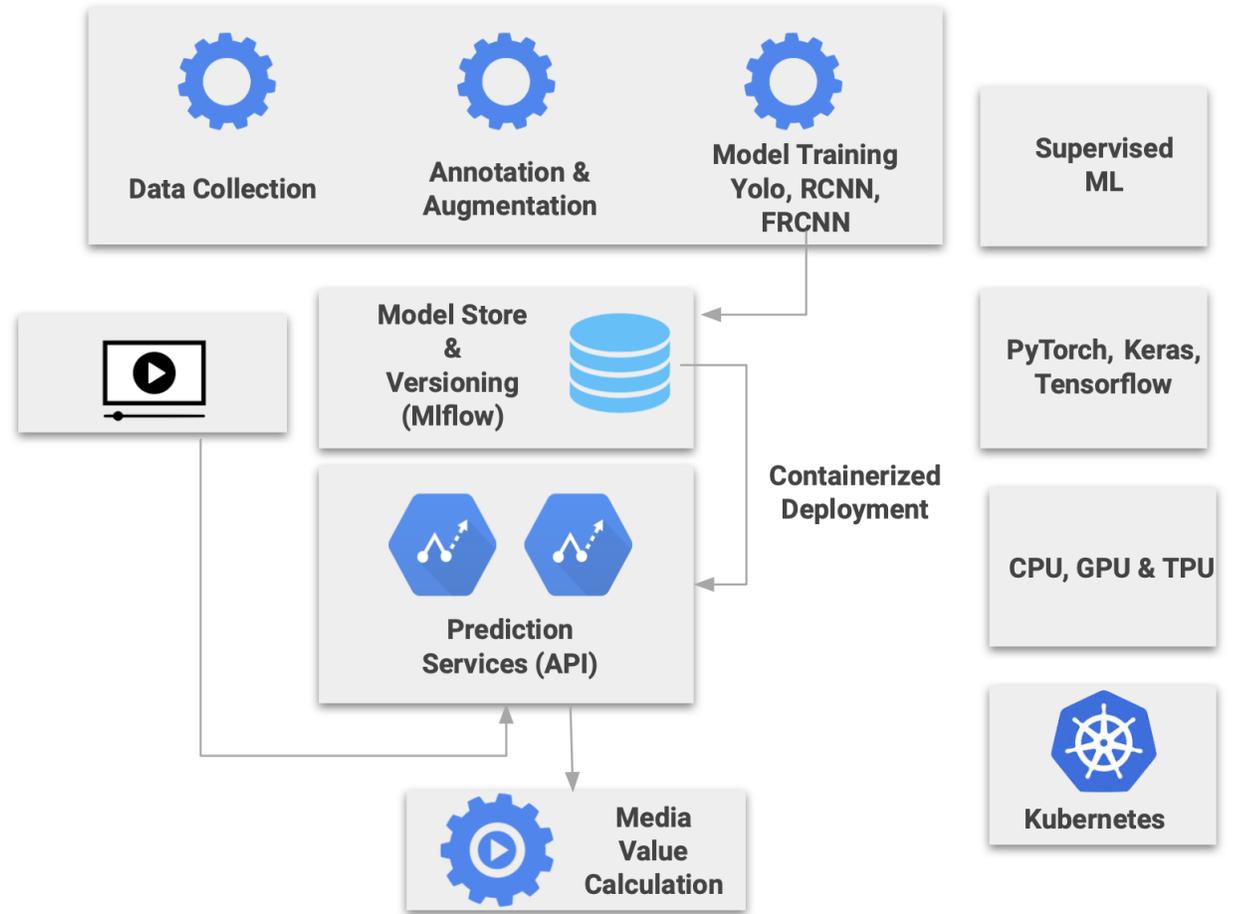
Conversation Understanding Intelligent System (CUIS)

Language Conversion (*If needed*)

Plug -in

Domain Specific Key Concept Definition

• Training

Large Query Response data set (Amazon Q/A dataset) Model Accuracy: 90%

• Training

Information Extraction

Conversation ┄┄┄> **Entity Classification** ┄┄┄> **Q/A classification** ┄┄┄> **Dialogue linking** ┄┄┄> **Integration Module & Value Extraction**

Content
• Human-Human dialogue
• Human-bot chat
• Chat Transcript from call

AI/ML- NLP
• Text classification : key concepts
• Seq2Seq Language model
• Semantic embedding

AI/ML- NLP
• Sentence classification : Question/ Statement
• Seq2Seq Language model
• Semantic embedding

AI/ML- NLP
• Establish Dialogue flow→ Query response linking
• Context mapping For multi thread Conversation

NLP
• Integrate output from previous modules
• Morphological analysis : extract exact value of key concepts in chat