A Computer Vision Based Approach for Automated Traffic Management as a Smart City Solution

BY

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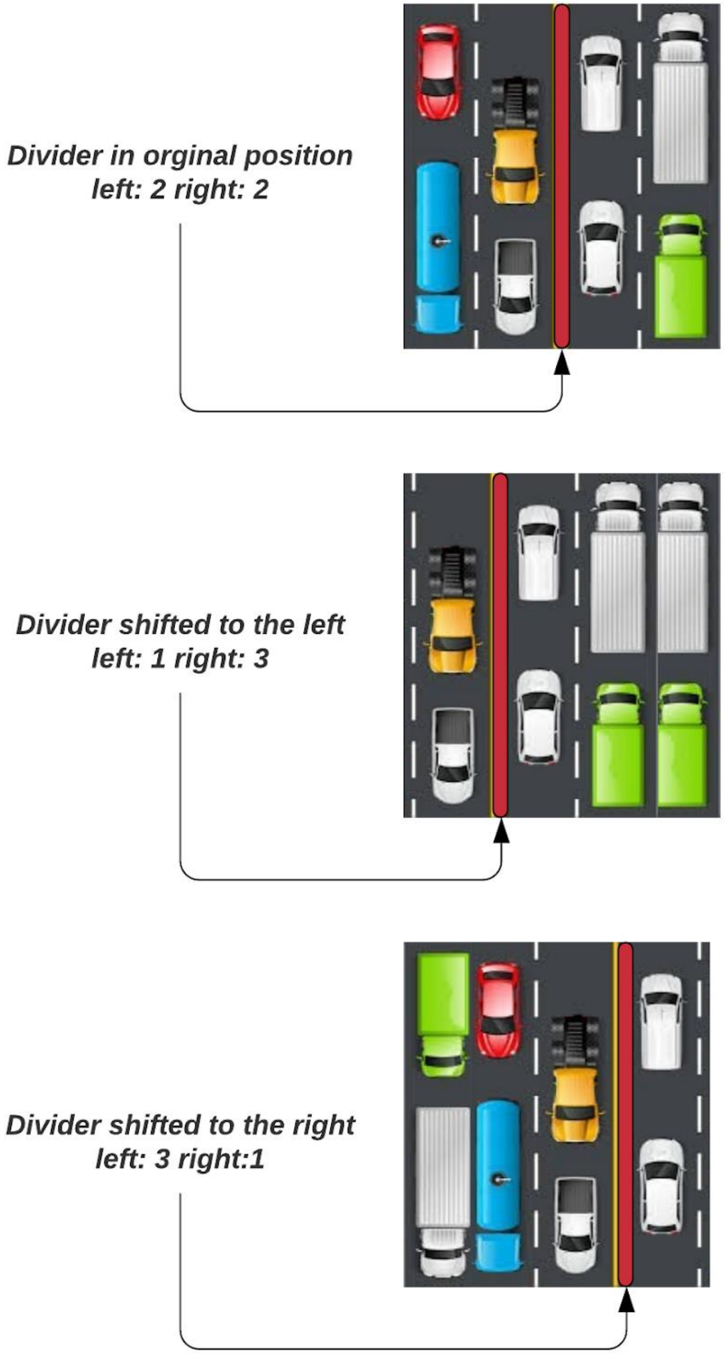
Problem Statement: *Land Acquisition due to Highway Expansion*

- With increasing automobile production and consumption, highway lanes are constantly expanding to surmount congestion.
- The booming population bears it's costs as lesser land is available for residential and recreational purposes.
- Constant highway expansion also reduces prospects of Green Space.
- Current applications of AI in traffic management only help analyze and organize traffic shifts and patterns but do not offer solid solutions to the problem.

Solution: *Adaptable Traffic Lane Dividers*

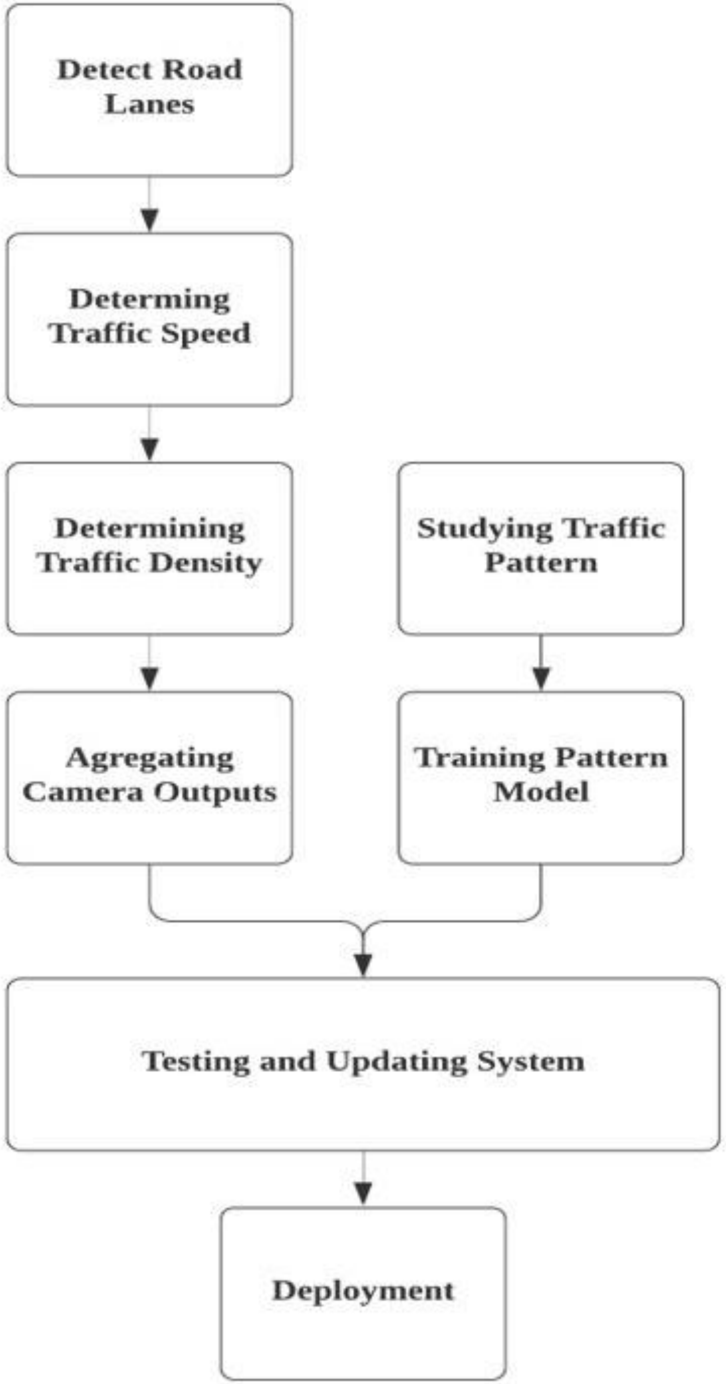
- Previous studies in traffic patterns have shown that during rush hours both directions of the roads are not completely occupied.
- Smart Cities and future constructions can therefore reduce the speed of lane expansion by introducing adaptable lane dividers.
- Based on the real-time video analysis and pattern recognition, dividers can be trained to move in order to make virtual space for the direction of traffic that requires it.
- Therefore 8 lane highways (4/4) could be converted to (6/2) or (3/5).



System Architecture

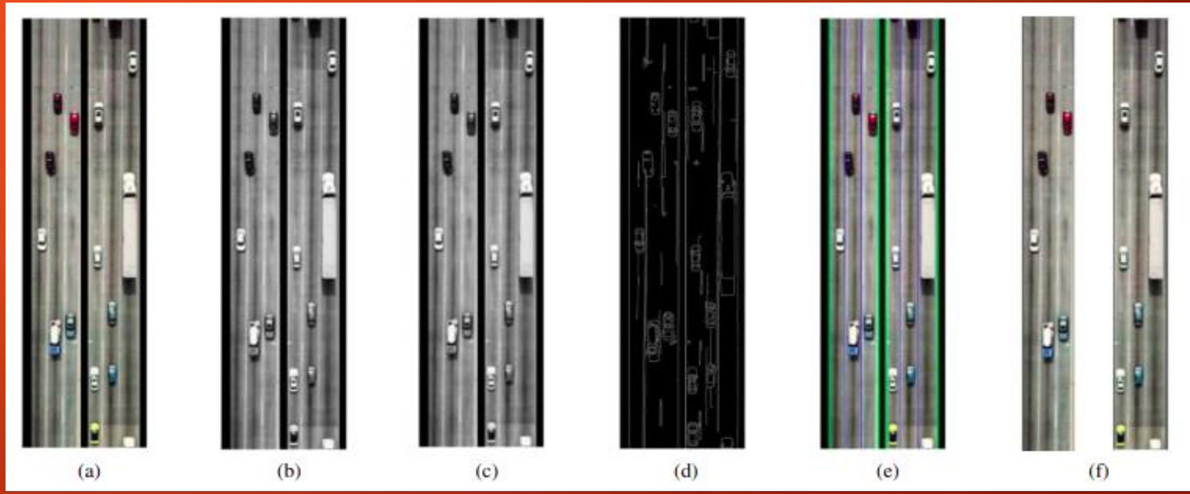
- A fixed number of N cameras along a single stretch of the highway, repeating across multiple stretches.
- The decision across the N cameras will be aggregated to make a collective decision for one stretch.
- In default state, when divider is in the middles there are equal number of lanes on both sides. When divider shifts to the left, it add lanes to the right side and vice versa.
- The number of lanes to be shifted will be provided by the system as an output as well. If there are N lanes the shift will can be only by a maximum of N-1 lanes.

System Design

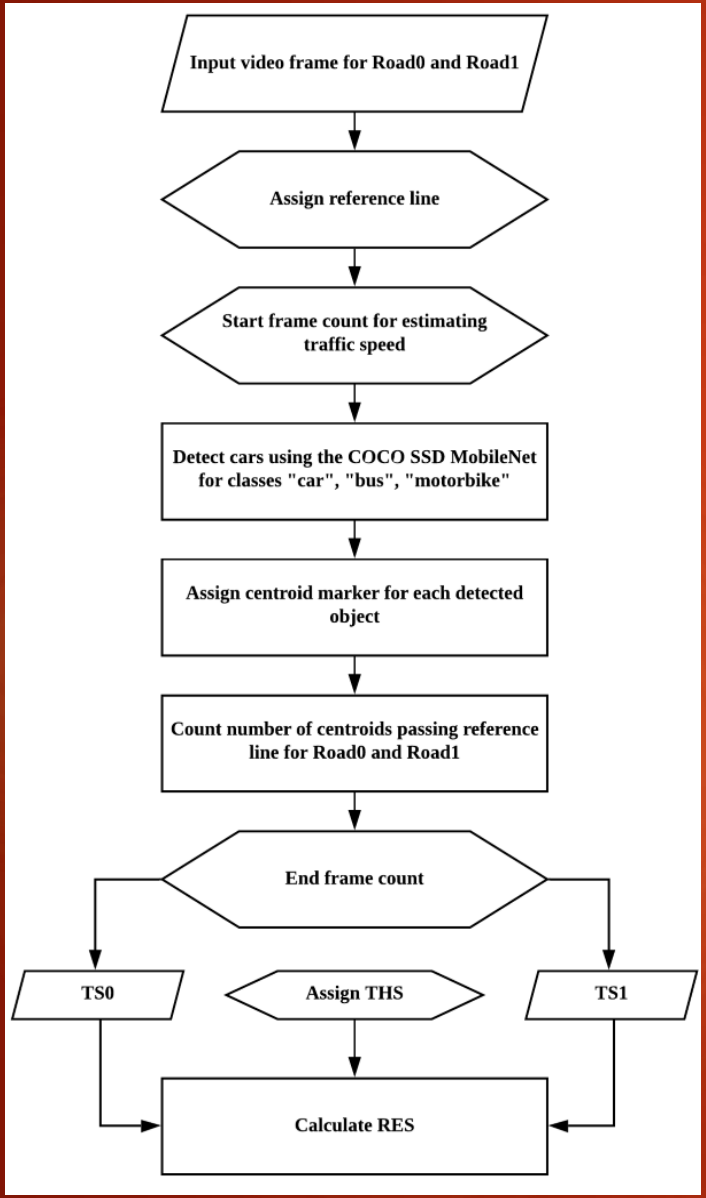


Detecting and Classifying Road Lanes

- To detect and classify road lanes, a Probabilistic Hough Transform model is used employing steps involved in Canny Edge Detection.
- Finally the input videos are split to work on the roads separately as represented in Fig. (f).



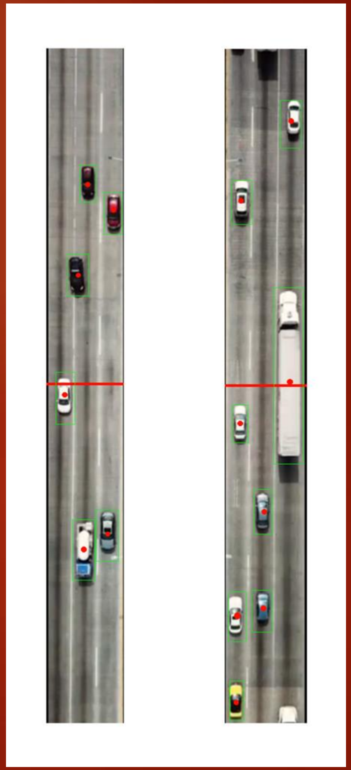
Determining Traffic Speed



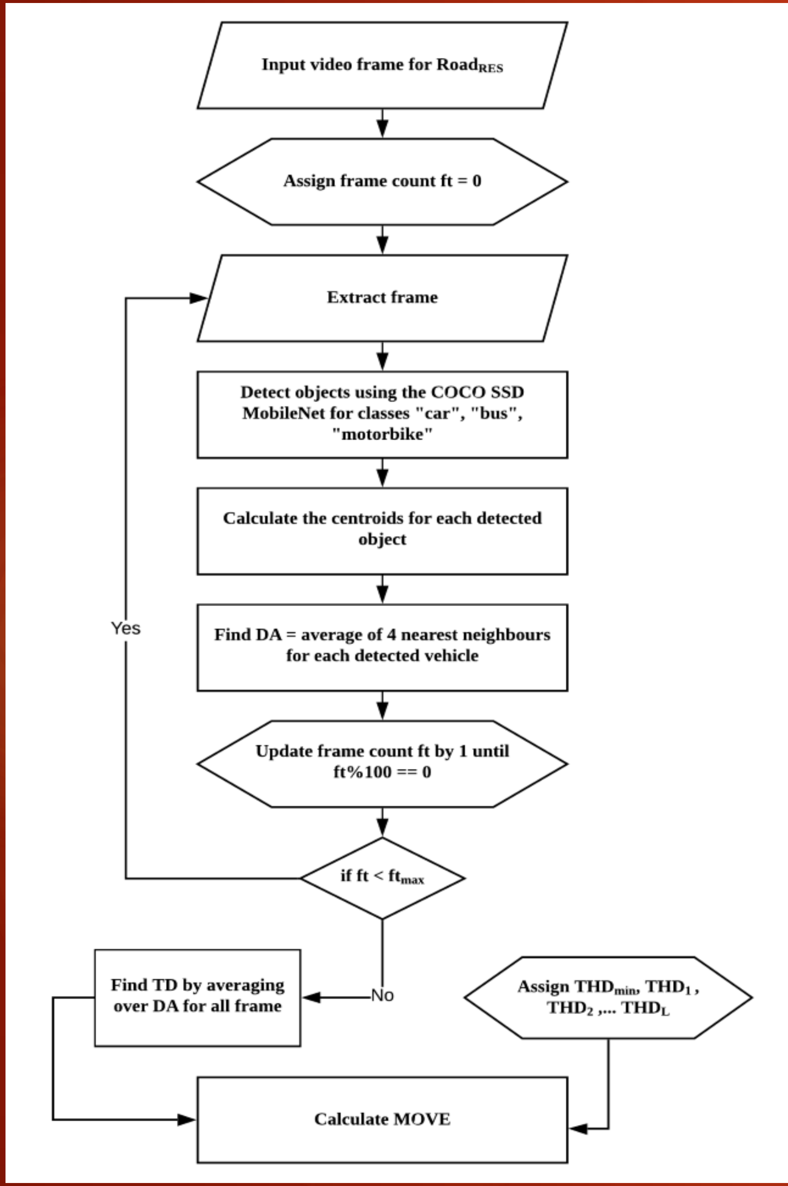
- Using the COCO SSD MobileNet for classes "car", "bus" and "motorbike", the vehicles are detected with bounding box coordinates.
- The same are used for centroid tracking. Based on the number of centroids passing a reference line in a given span of time, "Traffic speed" i.e TSX for each road is calculated. Using a defined threshold value TH, RES is found,

$$RES = \begin{cases} 0, & \text{for } TS0 - TS1 > TH \\ 1, & \text{for } TS1 - TS0 > TH \\ E, & \text{for } TS1 - TS0 < TH \end{cases}$$

- The value of RES is related to the relative difference between the "traffic speed" for both lanes, making up extreme cases when the divider has no need to move, as in when both roads are completely occupied or when both roads are empty enough to not require any movement.
- Here 0 represents left, 1 represents right and represents "no movement".



Determining Traffic Density



- Similar to the steps involved in determining "traffic speed", the detected centroids are used to find how far the vehicles are from each other. This value is then averaged over a set of frames over a time period to determine the value of TD.
- Comparing against different threshold values, the number of lanes to be moved, i.e MOVE can determined by:

$$MOVE = \begin{cases} 0, & \text{for } TD < THD_{min} \\ 1, & \text{for } TD < THD_1 \\ 2, & \text{for } TD < THD_2 \\ ..., & \text{for } TD < THD_K \\ L, & \text{for } TD < THD_L \end{cases}$$

- Here the different values refer to how many lanes the divider should shift. When the density is lower than the minimum threshold, MOVE value will be zero. The largest move being L that is one less than the total number of lanes.

Aggregating Camera Outputs

- Traffic at the start of a road has greater effect on the divider decision than at the end. Thus the decision from each camera is not considered equally and are instead assigned priorities.

$$a = \frac{1}{C}$$

$$aC + \frac{C(C-1)}{2}b = C$$

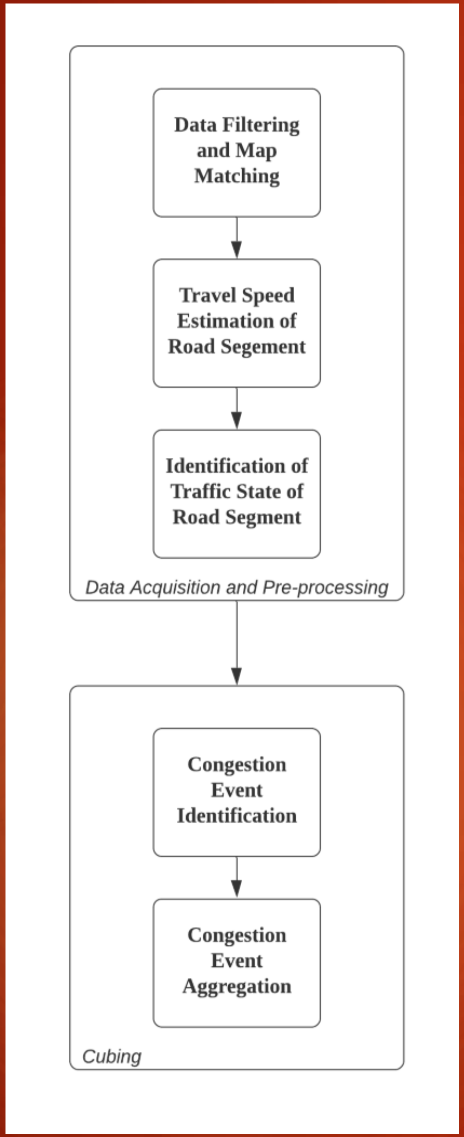
$$\Rightarrow a + \frac{C-1}{2}b = 1$$

$$\Rightarrow b = \frac{2(1-a)}{C-1}$$

Camera ID	**Status**	**Priority**
I_1	X_n	a
I_2	X_n	a+b
I_3	X_n	a+2b
...	X_n	...
I_K	X_n	a+Kb
...	X_n	...
I_C	X_n	a+(C−1)b

Determining Traffic Pattern

Based on research by: **Xu, Lin & Yue, Yang & Li, Qingquan. (2013). Identifying Urban Traffic Congestion Pattern from Historical Floating Car Data.**

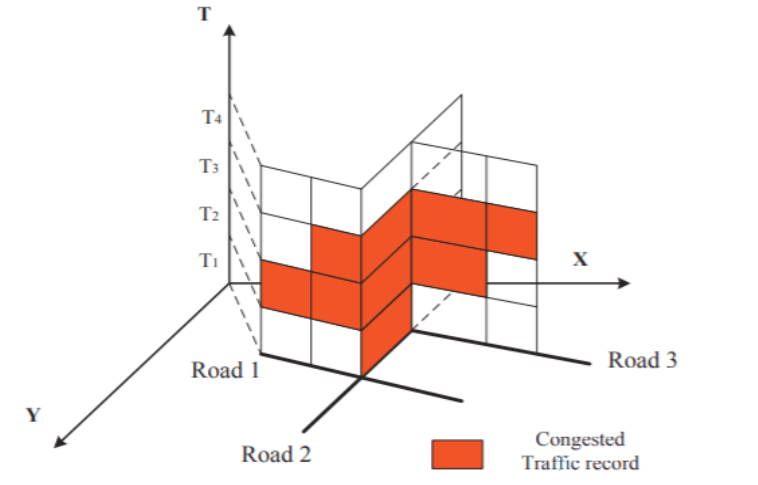


- Traffic congestion is a dynamic spatial-temporal process
- System analyzes divider movement output from a defined number of cameras across a stretch for the divider.
- Traffic congestion progress is identified as a 'congestion event' which consists of spatially and temporally congested road segments
- The traffic data acquisition and the preprocessing module is in charge of collecting floating car data from the cameras fixed on the divider lanes, map matching these data to the road network and then getting the divider movement state on each road segment by aggregation of sample data.

Determining Traffic Pattern

Based on research by: **Xu, Lin & Yue, Yang & Li, Qingquan. (2013). Identifying Urban Traffic Congestion Pattern from Historical Floating Car Data.**

- Data-cubing module takes abnormal or congested traffic data record from the data pre-processing layer and then identifies the congestion event based on spatial-temporal connected relationship.
- The identification is performed by randomly picking a traffic record from the data that has been collected by the cameras employed along the dividers
- Once the event identification is performed by identifying and aggregating the data collected, summarized information as shown can be obtained. Thus if the road segment is marked and identified as a congestion event, the divider moves.



RID	DAY	TIME	STATUS
2	12-03-2020	7:00 AM	Divider Moves
2	12-03-2020	7:30 AM	Divider does not move
2	12-03-2020	8:00 AM	Divider does not move
...	12-03-2020	...	...
2	12-03-2020	12:00 PM	Divider Moves
2	12-03-2020	12:30 AM	Divider Moves
...	12-03-2020	...	...
2	12-03-2020	7:00 PM	Divider does not move

Challenges

- **Integration with Navigational Services**

Our proposed model implements an adaptive lane divider mechanism, integrating it with navigational services like google maps can prove to be challenging. In any case, the divider shall only move a maximum of L−1 lanes, where L is the total number of LANES. Thus, not completely eliminating the path directed to by the mapping service.

- **Efficiency**

Although covering all edge cases is nearly impossible, we aim to develop this model to provide maximum safety

- **Cost and Hardware Aspects**

Our current research focuses specifically on developing a proof of concept of the system. Such a system is expected to be implemented from scratch in smart cities as part of their default transportation infrastructure.

Conclusion

- The employed use of Computer Vision and Pattern Recognition helps us in developing an artificially intelligent system which when supported with adequate hardware can help avoid land acquisition for road expansion.
- Proposed future work:
  - accident recognition
  - crime recognition
  - flexible mobility of emergency and rescue vehicles.

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Thank You!