CATCHING SPEEDERS VIA MOBILE PHONES & MACHINE LEARNING: AN OPPORTUNITY TO IMPROVE SPEED ENFORCEMENT

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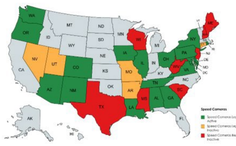
WHAT STARTS HERE CHANGES THE WORLD

Motivation

- **Speeding** is a major contributor to crashes: **28%** of US fatal crashes + **13%** injury crashes were speed-related in 2021.
- More speed cameras & **automated enforcement** will help, but public agency **cameras** cost approx **$120,000** for hardware + **$170,00** for 5 years of operation & maintenance = cost ineffective in many sites.
- **Cellphone cameras permit** anyone to report dangerous driving. Suddenly, **all locations are open** for reporting violators.



Methods Used

Speed Estimation Approach

Speed = Distance travelled per frame * FPS (frames/sec)

- Distance travelled = Distance travelled in video * Scale factor
- Video distances (between frames) come from Vanishing Point (VP) associated with each moving vehicle's bounding box.

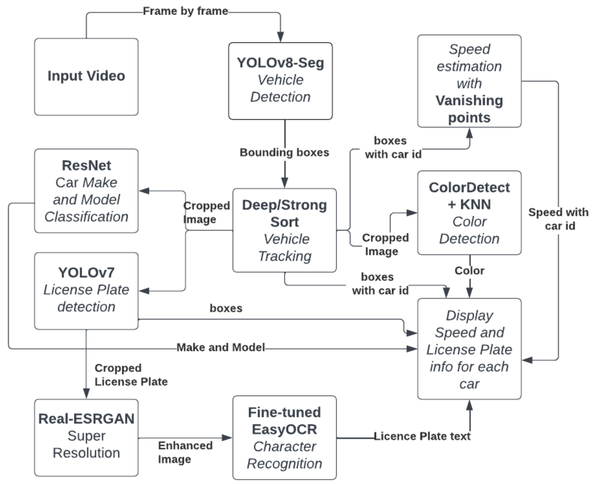
Vehicle Identification & Tracking Model

- **YOLO**v7 used here to **detect license plates (LPs)**.
- **YOLO**v8-Seg algorithm lowers system complexity for **vehicle detection**.
- EasyOCR & Tesseract algorithms **recognize license plate characters** (using segmentation + classification).
- **Vehicle Colors** recognized using Histogram + KNN techniques & ColorDetect library.
- Fine-tuned **Make & Model recognition** via CNNs trained on **>15,000 images** of U.S.'s **100 most popular** passenger vehicles.

Example Model Predictions

- License Plate = **PSL??J8** & no state predicted (confidence = 0.64)
- Make + Model = **Toyota RAV4** (confidence = 0.39)
- Color = **Dim gray** (21% of image in box is Gainsboro)
- Speed = **25.3 mi/hr**

Program Code Flowchart



Web-based User-interface for Video Submission

- **Users report** traffic violations via video, location, & other estimates.
- **Program extracts** speed limits for that location & sends estimated speeds & other details to associated law enforcement agencies.

Overall Results

Test 1: Vehicle Make & Model Identification

#Correct images (from 3 images/model)	Number of models (Top-1)	Number of models (Top-2)	Number of models (Top-3)
0	16	7	5
1	41	22	11
2	30	43	44
3	13	28	40
Overall accuracy	46.7%	64.0%	73.0%

Note: Top-k accuracy: the actual information is included in the top-k predictions.

Test 2: Speed Estimates

Actual (Ground-truth Speed) (km/h)	Computer Vison-estimated Speed (km/h)	User-estimated Speed (user-input Vanishing Points) (km/h)	% Relative Error for Automatically Estimated Vanishing Points	% Relative Error for User-input Vanishing Points
30 km/h	29.30 km/h	28.04 km/h	-2.3%	-6.5%
40	39.28	42.30	-1.8%	5.8%
50	50.11	56.16	0.22%	12.3%
60	73.87	81.47	23.1%	35.8%
70	22.07	77.97	-68.5%	11.4%
81	81.47	85.32	-0.58%	5.3%
90	86.33	100.30	-4.1%	-11.4%

Test 3: License Plate Model Test

- Tested License Plate model on 1800 images in UFPR-ALPR dataset (for Brazilian vehicles).
- **License Plate detection accuracy = 78%**
- **Character recognition** accuracy = **only 47%**

Model	# Correct OCR	% Correct OCR
OCR	252/1800	14.2%
Super Resolution + OCR	407/1800	22.6%
Super Resolution + Fine-tuned OCR	847/1800	47.0%

Test 4: Overall Test

- Tested on smart-phone videos in Austin

Predicted Tables	# Correct Predictions	% Correct Predictions
Speed (within 20% of actual)	26/147	17.7%
Color	90/148	60.8%
Make & Model	71/148	48.0%
License Plate	32/101	31.7%

- License Plate predictions are **accurate for speeds under 40 mph** & when the vehicle is in the nearest lane, but quality declines for distant or fast-moving (>40 mph) vehicles.
- Color prediction **predicts Gray & Black accurately** but confuses other
- **Lower speed-estimation accuracy with moving phones**, & we need to eliminate noise from parked vehicles.
- Make & model predictions are improving but are not enough, the algorithm identified makes better than the model of the vehicles.
- Different states have their jurisdiction agencies for reporting traffic violations (Police district jurisdiction, Highway patrol, etc), while some states don't accept individual recordings (like NY & Wisconsin).

Conclusions

- **Best predictions** (lowest error) when filming **lower-speed vehicles,** using **landscape view** (horizontal), & **3-camera phones.**
- **Make + Speed + User-interface** estimates are **good.**
- **License Plate** text character recognition improves when using **fine-tuned** model & **super-resolution** techniques.
- Algorithms **not yet** predicting US **state**, but can be combined with the **user estimates** & location in US.
- **Color** is **well-estimated** for **Gray & Black** vehicles.
- **Speed estimates** are currently **variable/unstable with moving phones** & easily disturbed by **parked & overlapping vehicles**.
- Still need comprehensive U.S. map for relevant enforcement agencies.
- Improvements needed: train for **moving cameras** (dashcams & hand-held), **extend to night-time** videos, extend to **red-light running**, dangerous weaving, etc.