Efficient Video Object Detection for EV Charging Plug Type Identification in Real-World Scenarios

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Introduction

- **Problem**: Rapid EV adoption requires efficient charging systems, but varied plug types create challenges.
- **Objective**: Develop a video object detection system for identifying EV plug types using YOLO models (V5-V8) on a custom dataset.
- **Application**: User-friendly website for real-time EV plug detection.

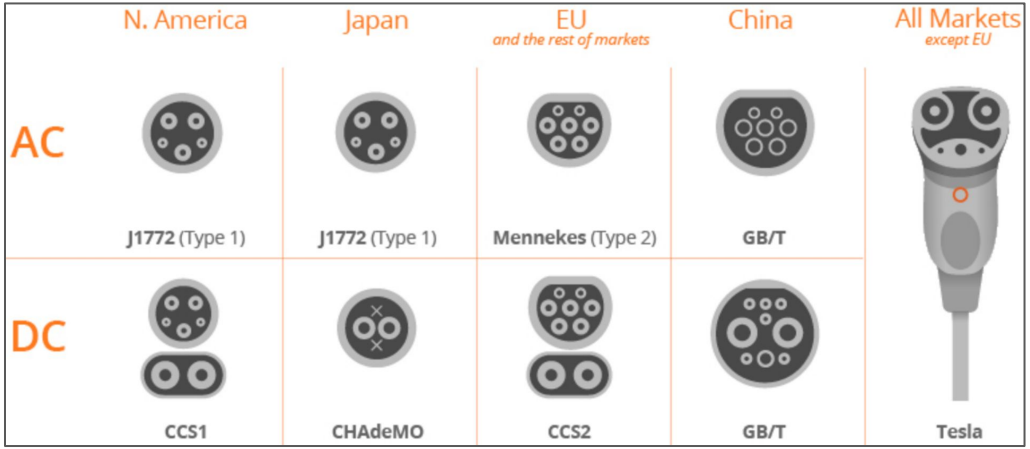


Figure 1 shows electric car charging plugs around the world.

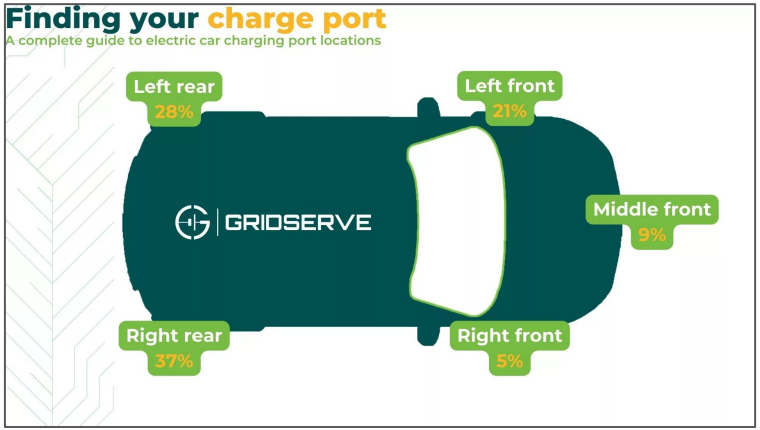


Figure 2 shows the location of EV charging plugs in Various plug locations.

Literature Review

- **YOLO Architecture**
  - **YOLO** (You Only Look Once) is a fast, single-stage object detection model that identifies multiple objects in a scene using bounding boxes via a CNN.

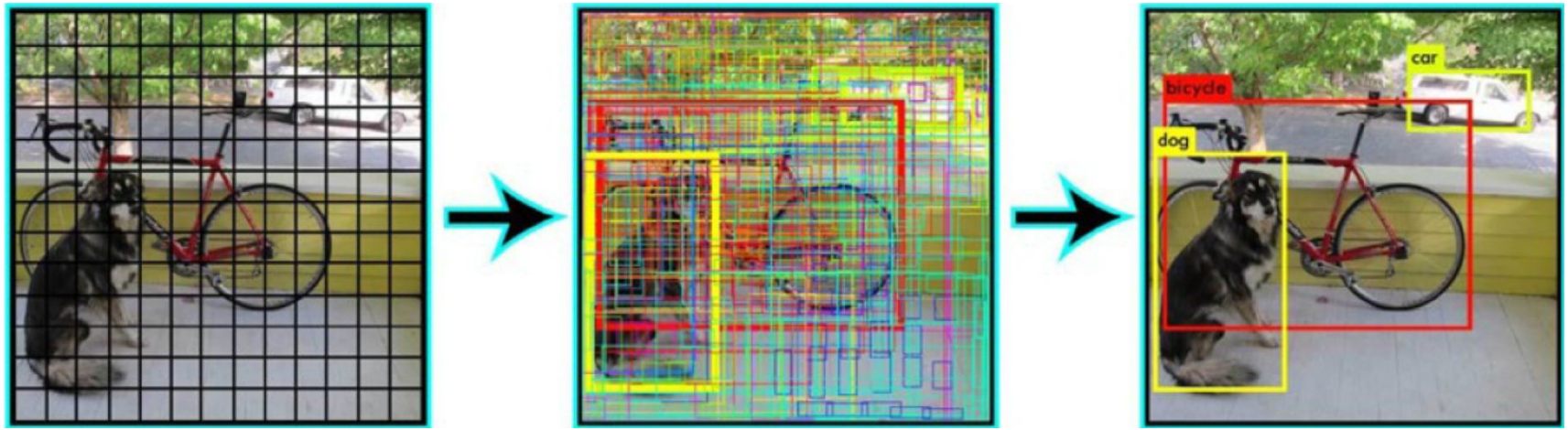


Figure 3 shows the Operating procedure of the YOLO algorithm with the NMS function.

Literature Review

- **YOLO Version Comparisons**

Version	Key Features
YOLOv5	- Introduced CSPDarknet backbone. - Utilized Feature Pyramid Network (FPN) for improved feature extraction.
YOLOv6	- Focused on efficiency with EfficientRep. - Implemented Rep-PAN for enhanced feature aggregation.
YOLOv7	- Enhanced accuracy through Efficient Layer Aggregation Network (ELAN).
YOLOv8	- Introduced C2f module for improved feature flow. - Employed anchor-free detection for simplicity. - Utilized smaller kernel sizes for faster inference.

Dataset

- **Total Images:** 109,902 images.
- **Classes:** Five classes of EV sockets.
- **Augmentation:** Using Albumentations for rotation, scaling, blur, and noise.
- **Split:** Training, validation, and testing in an 8:1:1 ratio.
- **Sources:** Public sites like Roboflow, Google, YouTube.

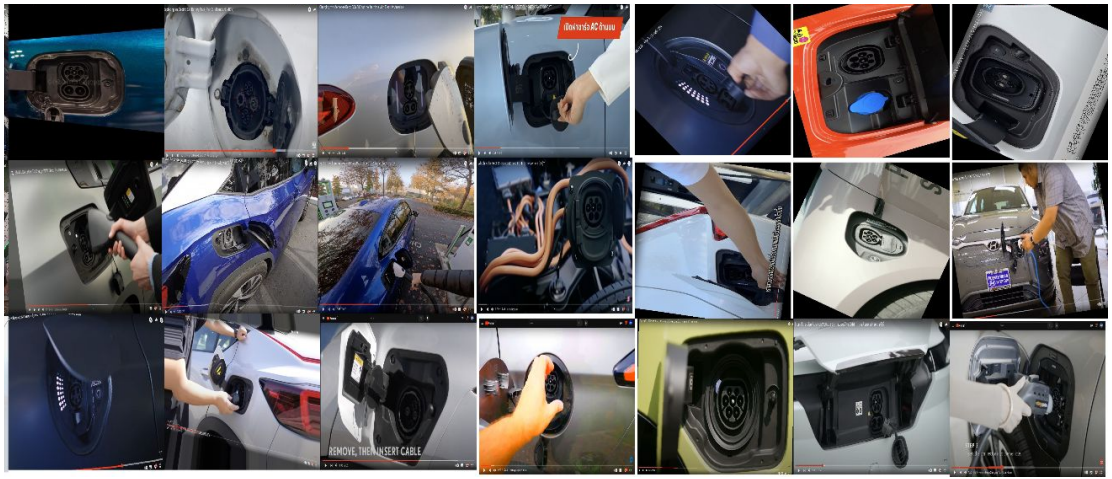


Figure 4 shows an overview of the dataset showing different sockets.

Dataset and Classes for EV Plug Types

- **Total Classes:** 5
- **Plug Types:**
  1. CHAdeMO
  2. AC Type 1
  3. AC Type 2
  4. DC CCS Type 1
  5. DC CCS Type 2

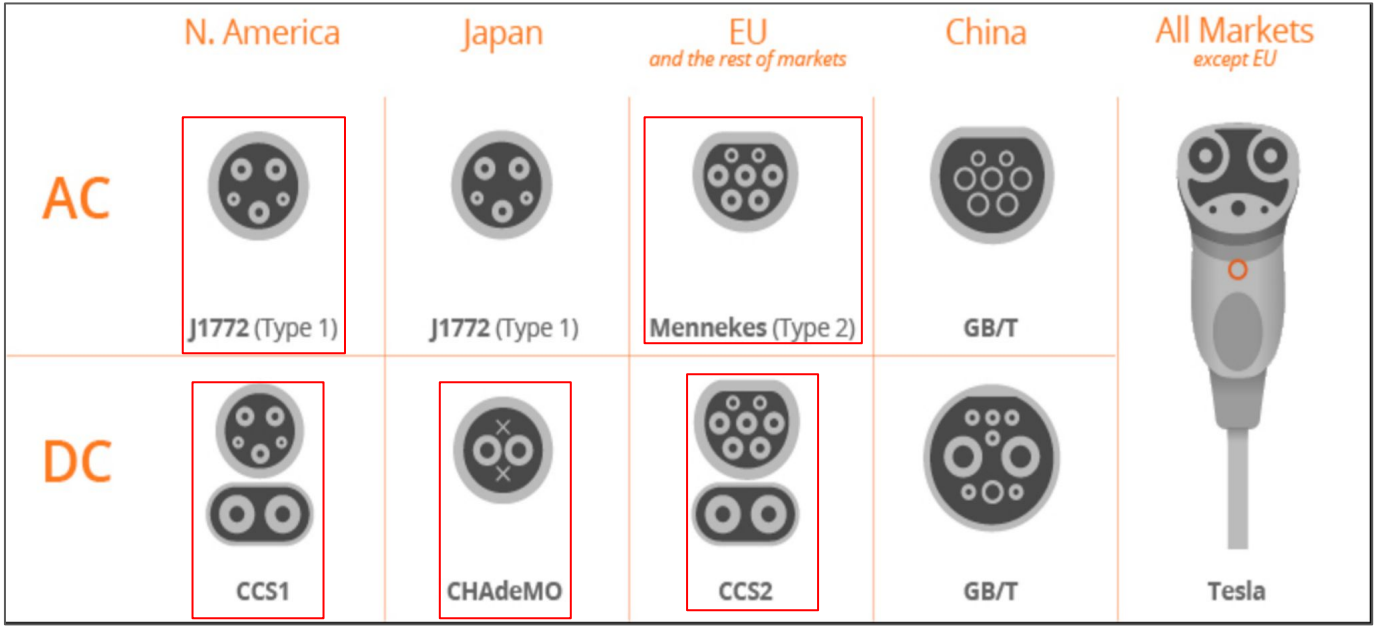


Figure 5 shows electric car charging plugs in Thailand.

Real-world test video

- **Data collection locations:**
  - **Events:** EV Expo and Motor Show in Thailand.
  - **Locations:** Gas stations, shopping malls, hotels.
- **Conditions:**
  - **Lighting:** Daylight, night, rain.
  - **Settings:** Outdoor and indoor environments.

Figure 6 Video clips taken at actual locations at various charging stations.

Experimental setting

- **Model training setup:** Epochs =100 , batch size =32, image size =640, optional use default.
- **Training dataset:** The same dataset is used for training four models.
- **Experimental environment:** Refer to Figure 7 for visual representation.

Component	Environment A	Environment B	Environment C
Hardware/Cloud	https://www.runpod.io/	MacBook Pro M2 Max 2022	iPhone 12 Promax
Environment used for	training, validation, and prediction	prediction	prediction
Python	3.10.12	3.10.12	n/a
PyTorch	2.10+cu118	2.10+cu118	n/a
GPU	NVIDIA RTX A5000	Apple M2 max	Apple A14 Bionic
CPU	AMD EPYC 7302P	Apple M2 max	Apple A14 Bionic
RAM	31.3 GB	32 GB	6 GB
Operating system	Ubuntu 22.04	macOS Sonoma 14.1.1	IOS 18.0

Figure 7 show Enviroment used experimental

Results - YOLO Performance

- **Metrics Used:**
  - mAP@0.5, mAP@0.5:0.95, precision, recall, F1 Score, Gigaflops.
- **Best Model:**
  - YOLOv5s has the lowest Gigaflops and Parameters value among all YOLO
  - YOLOv6s has the lowest Training time value among all YOLO.
  - YOLOv7 has the highest mAP@0.5 of 0.997.
  - YOLOv8s had the highest mAP@0.5-0.95 of 0.95, precision of 0.998, and recall of 0.996.
  - YOLOv8s delivers the best balance of accuracy and efficiency.

Model	Precisions	Recall	mAP@0.5	mAP@0.5-95	F1 Score	Training time (hours)	Gigaflops	Parameters
YOLO V5s	0.996	**0.996**	0.995	0.912	0.996	15.092	**16.0 Gigaflops**	**7,033,114**
YOLO V6s	0.993	0.994	0.994	0.933	0.993	**14.966**	44.9 Gigaflops	16,452,192
YOLO V7	0.995	0.997	**0.997**	0.921	0.996	36.479	105.2 Gigaflops	37,218,132
YOLO V8s	**0.998**	**0.996**	0.995	**0.95**	**0.997**	15.595	28.7 Gigaflops	11,137,535

Figure 8 shows the results of the experiments.

Performance Comparison of YOLO Models

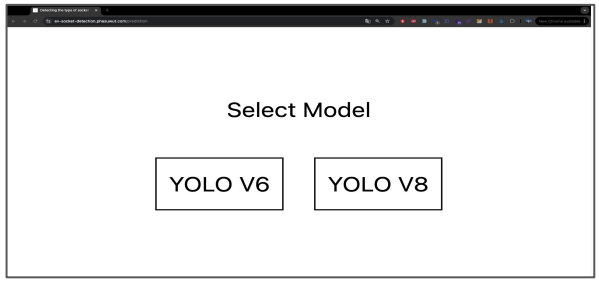
- **Metric Summary:**
  - **Gigaflops & Parameters:**
    - **Lightest Model:** YOLOv5s
    - **Heaviest Model:** YOLOv7
  - **Precision & Recall:**
    - **Best Performance:** YOLOv8s (highest precision and recall)
  - **Conclusion:** YOLOv8s is ideal for accuracy-intensive tasks.

Detection EV Socket on website

- **Website Development Overview**
  - Framework: Next.js (version 14.2.7)
  - Prediction Library: "@tensorflow/tfjs" (version 4.21.0)
  - Rendering Method: Client-Side Rendering (CSR)
  - Predictions are processed directly on the client side
- The website have YOLO V6s and YOLO V8s models used for prediction

Detection EV Socket on website

- **Homepage** (Figure 11):
  - Users can select between two models for prediction: YOLOv6 and YOLOv8.
- **Detection Modes** (Figure 12):
  - Four buttons for user interaction: “Change Model”, “Open Image”, “Open Video”, and “Open Webcam”.
- **Detection Results** (Figure 13):
  - Displays the results of the EV socket detection.



Figures 11 shows a button that can select a model

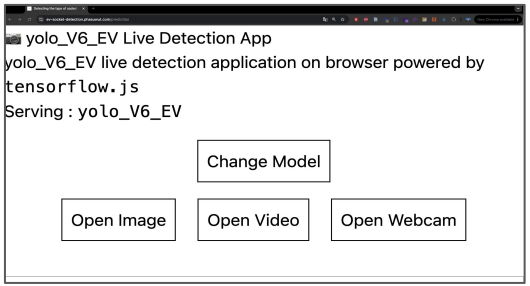
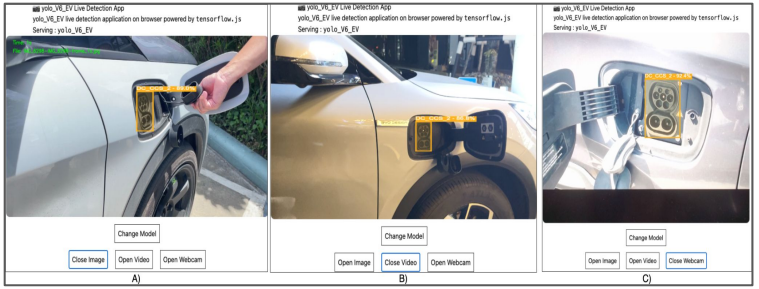


Figure 12 shows the menu



Figures 13 show the experimental results.

Detection EV Socket on website

- Video and image test for ev-socket-detection
  - URL : https://kaggle.com/datasets/9d1ccb2f90198091526f5986311ffeb4e0de1fb6f672b49af2f50264f06584ee
- Website Ddemo
  - URL : https://ev-socket-detection.phasuwut.com/prediction

Figure 9 shows the QR code of the Website.

Figure 10 shows the QR code of the Video and image test for ev-socket-detection

Video 1 shows a demo detection socket EV on the website.

Results of detection EV Socket on website

- **Accuracy Improvement:**
  - YOLOv8s outperforms YOLOv6s by:
    - 3.49% in Environment B
    - 3.31% in Environment C
- **Prediction Variability:**
  - Environment B: Difference of 0.54%
  - Environment C: Difference of 0.37%
- **Model Stability:** Demonstrates consistent performance across varying environments.

TABLE 4. Detection results of Environment B and Environment C

File name	Second	Environment B		Environment C	
		YOLO V6s	YOLO V8s	YOLO V6s	YOLO V8s
IMG_6279	0	85.1	90.1	86.1	90.9
IMG_6283	7	85.8	90.6	86.1	91
IMG_6283	8	86.7	91.8	87.2	91.6
IMG_6292	21	86.9	90.3	87.7	90.9
IMG_6292	20	87.1	89.7	88	90
IMG_6292	35	90.8	93.1	90.9	93.7
IMG_6292	33	92.1	93.3	92.3	93.4
AVG		87.79	91.27	88.33	91.64

Figure 14 shows the Results of the detection EV Socket on the website.

Conclusions

- **Study Focus:** YOLO-based models for video object detection in automatic EV charger robots.
- **Key Findings:**
  - **YOLOv5s:** Most efficient; suitable for low-resource devices; comparable metrics to YOLOv7.
  - **YOLOv6s:** boasts the fastest training time.
  - **YOLOv7:** Strong mAP@0.5 (0.997); resource-intensive.
  - **YOLOv8s:** Highest mAP@0.5:0.95 (0.95), Precision (0.998), F1 Score (0.997).
- **Real-World Testing:**
  - 85.08% accuracy in detecting EV sockets in real time.
  - Web implementation allows cross-device predictions.
- **Recommendation:** Use YOLOv5s for resource-constrained environments.

Thank you

ref : [x]