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Parking Tag Detection Report

CS440 – CS Seminar: Drones

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The Tag Detection project was developed to enhance parking enforcement and safety by detecting parking passes automatically using computer vision. The motivation behind this project stems from the need to ensure that vehicles are parked in designated areas and to reduce manual monitoring. This technology has significant potential applications in smart city surveillance, access control, and public safety, where identifying authorized vehicles quickly and accurately is crucial.

The team aimed to design a system that could detect parking tags under varying real-world conditions and be integrated into automated surveillance or gate control systems. The overarching goal was to train an image detection model capable of identifying parking tags with high accuracy across a variety of scenarios.

The main objectives of the project were as follows:

Accurate Tag Detection: Develop a model that can reliably identify parking passes on vehicles.

Diverse Data Collection: Capture images from multiple angles and lighting conditions to make the model robust.

Model Generalization: Train a machine learning model that could be deployed in real-world applications for automated tag recognition.

To train the detection model, the team collected a dataset consisting of 202 images—152 captured with a phone and 50 using a drone. The data was deliberately taken under various conditions, including different brightness levels, viewing angles, and degrees of obstruction. However, challenges such as window reflections, sun glare, and occluded tags affected some images.

Annotation was performed using Roboflow, a platform that allows collaborative labeling of images. Each team member annotated a subset of images, identifying the tag regions manually. Once annotated, the images were combined into a unified dataset and exported for model training.

The team employed YOLOv11 (You Only Look Once, Version 11) as the detection algorithm, known for its real-time object detection capabilities. The following preprocessing and training procedures were implemented:

Preprocessing Steps:
Images were auto-oriented, resized to 512×512 pixels, and converted to grayscale to simplify input data.

Augmentation Techniques:
Blur and exposure adjustments were applied to expand the dataset and help the model generalize across lighting conditions.

Training Configuration:

Epochs: 50

Batch Size: 16

Image Size: 640

This setup was chosen to balance computational efficiency with sufficient model convergence.

5. Results and Evaluation

The trained YOLOv11 model achieved strong performance metrics:

Mean Precision (mP): 0.970

Mean Recall (mR): 0.949

mAP 0.5: 0.971

mAP@0.5:0.95: 0.686

These results indicate that the model correctly identifies most parking passes with high precision and recall. The visualization outputs demonstrated consistent bounding box predictions around the tags, confirming the model's effectiveness in controlled conditions.

Despite the strong results, several sources of error were identified:

Most images were taken at similar times of day, limiting lighting diversity.

Sunny conditions caused glare and window reflections that occasionally obscured tags.

Some tags occupied small portions of the images, making detection more difficult.

These factors likely explain the drop in performance at higher Intersection-over-Union thresholds (e.g., mAP@0.5:0.95).

To further enhance the model's robustness, the team proposed the following improvements:

Capture more images across different weather and lighting conditions.

Move the camera closer to the parking passes to improve feature visibility.

Experiment with additional preprocessing and augmentation filters in Roboflow.

Expand the dataset to include a wider variety of vehicle and tag types.

These adjustments would allow the model to perform better under less controlled, real-world environments.

The Tag Detection project successfully demonstrated a high-performing object detection system using YOLOv11, achieving a mean precision of 97%. Through careful data collection, annotation, and model tuning, the system proved effective at recognizing parking tags from varied angles. However, improvements in environmental diversity and dataset size would further increase robustness.

Overall, the project highlights the practical potential of computer vision in parking enforcement and smart infrastructure systems. With further refinement, this model could serve as a foundation for automated parking validation and real-time surveillance solutions.