Smart Highway Traffic Prediction and Management System

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Research Outline

01 Motivation

02 Related Works

03 Proposed Method

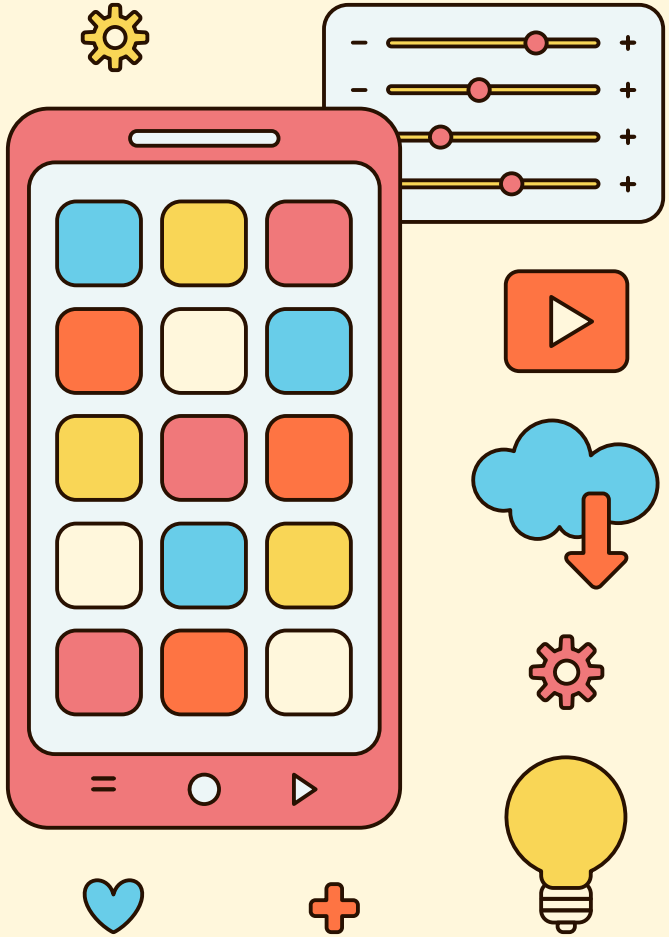
04 Detail Implementation

05 Conclusion

01

INTRODUCTION

Introducing the Current Status and Challenges



Introduction

1. Nearly every modern family owns a car, which has led to a subsequent increase in the number of vehicles on the road. Consequently, the problem of traffic congestion has become increasingly severe.
2. Most roads frequently experience congestion issues, especially national highways which become jammed during every festival or holiday, resulting in wasted travel time for drivers.

平日					假日				
國道	路段	時段	方向	壅塞機率%	國道	路段	時段	方向	壅塞機率%
國1	五股_圓山	8-10	北上	93.9	國1	新竹_竹北	16-18	北上	42.2
國1	湖口_新竹	8-9	南下	87.9	國5	宜蘭_坪林	15-18	北上	37.5
國1	五股_楊梅	8-9	北上	74.1	國1	圓山_汐止系統	21-22	北上	31.3
國1	林口_五股	18-19	北上	65.5	國1	北斗_埔鹽系統	18-19	北上	31.2
國1	汐止_內湖	8-9	南下	53.5	國3	關西_龍潭	17-19	北上	29.7
國1	台中系統_大雅	18-19	南下	37.9	國1	彰化系統_埔鹽系統	11-12	南下	28.1
國1	高科_楊梅	18-19	南下	31.0	國5	南港_坪林	11-12	南下	28.1
國3	新店_中和	18-19	南下	22.4	國1	台中系統_大雅	17-18	南下	25.0

Introduction

1. The current real-time highway system only displays present congestion, hindering drivers from predicting when delays will end and wasting travel time. This is a core problem smart roads intend to solve.
2. Traffic congestion also further contributes to air pollution problems in cities. Reducing air pollution is one of the goals modern smart cities aim to achieve.

Introduction Solution

By processing the images from the national highway image monitoring system, we can dynamically display the congestion status for the next 15, 30, 45, and 60 minutes on drivers' mobile applications. This provides drivers with immediate information, allowing them to make better-informed decisions for planning their driving times.

Developing a user application (app) to display real-time national highway information.

SYSTEM

Providing Real-time National Highway Future Congestion Prediction for Every Section.

PREDICT

Analyzing Real-time National Highway Footage using YOLOv7 and DeepSORT

ANALYSIS

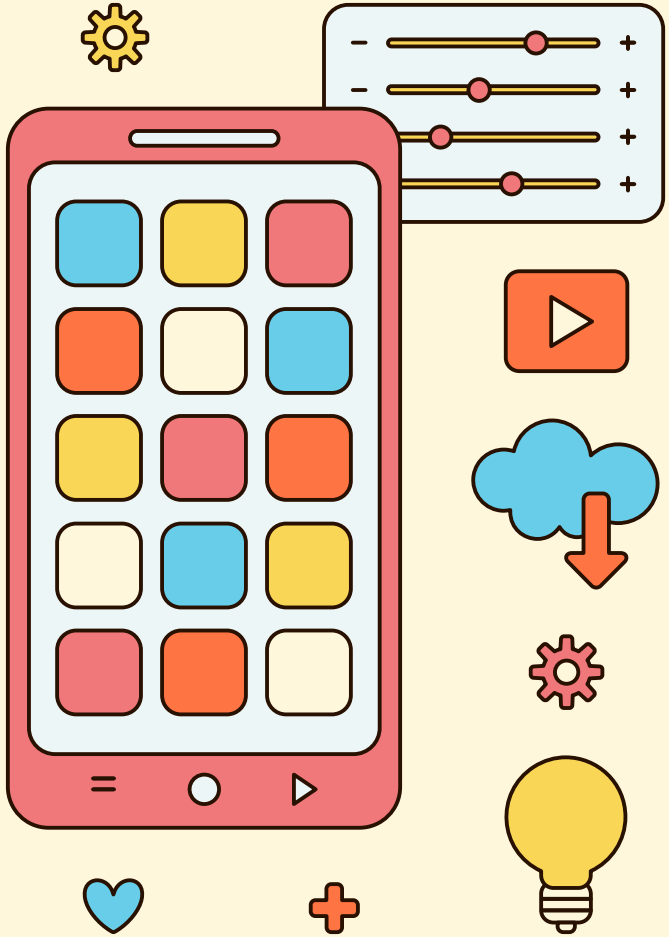
Employing machine learning models to leverage historical data.

MODEL

02

Related work

Related Technologies and References



Related work(1/7)

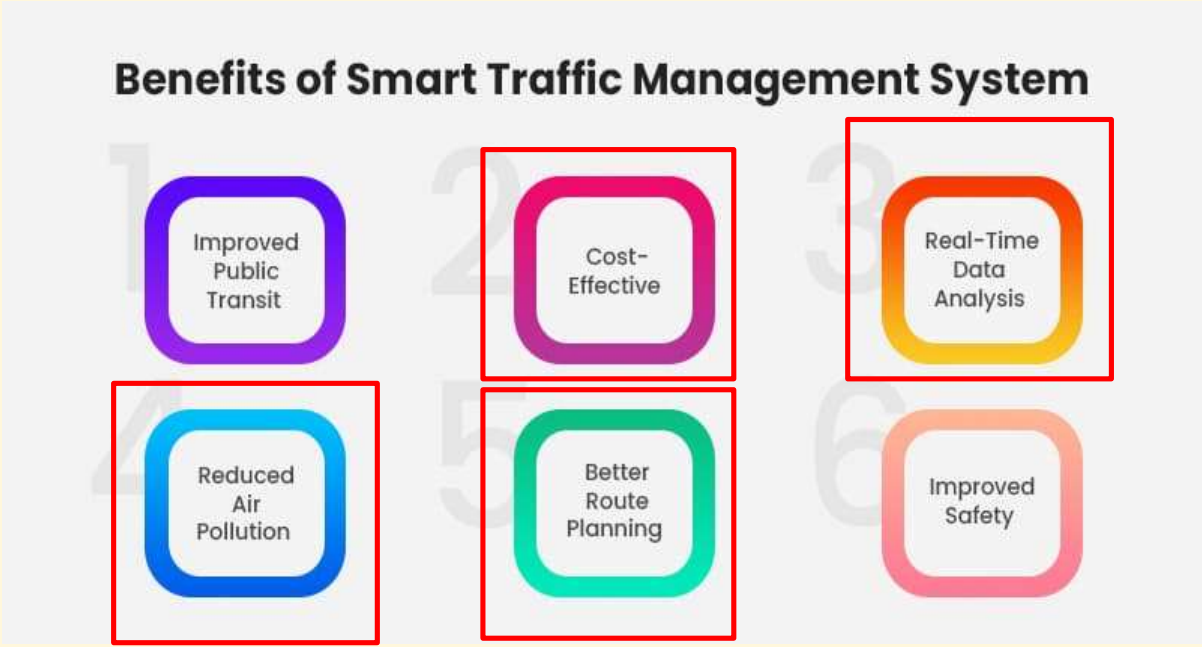
In smart cities, environmental concerns include high-density traffic issues and air pollution problems.

Smart City Applications

Environmental issue addressed	Mitigation strategies	Innovation Mechanism	Role of ICTs	Outcome
- high traffic density - high amount of waste - increasing air pollution - increasing energy consumption/sinking resources - loss of biodiversity and natural habitat - sinking water resources.	- efficient transportation systems - compact city design - waste management and recycling - increasing green space - CO_2 capture - reduction of atmospheric pollution - renewable sources - low energy buildings - increasing efficiency of devices and processes - developing animal and/or plant protection areas - maximizing water use efficiency.	- technological innovation - process innovation - Citizen engagement and participation	- information and knowledge sharing - forecasts - integration	- sharing information and resources - identifying problems and underlying issues - actually solving problems - support or influence decision making and policy making

Related work(2/7)

In smart transportation within smart cities, the goals for improvement include addressing air pollution issues and analyzing real-time traffic information, which can further influence route planning and the efficiency of travel time.



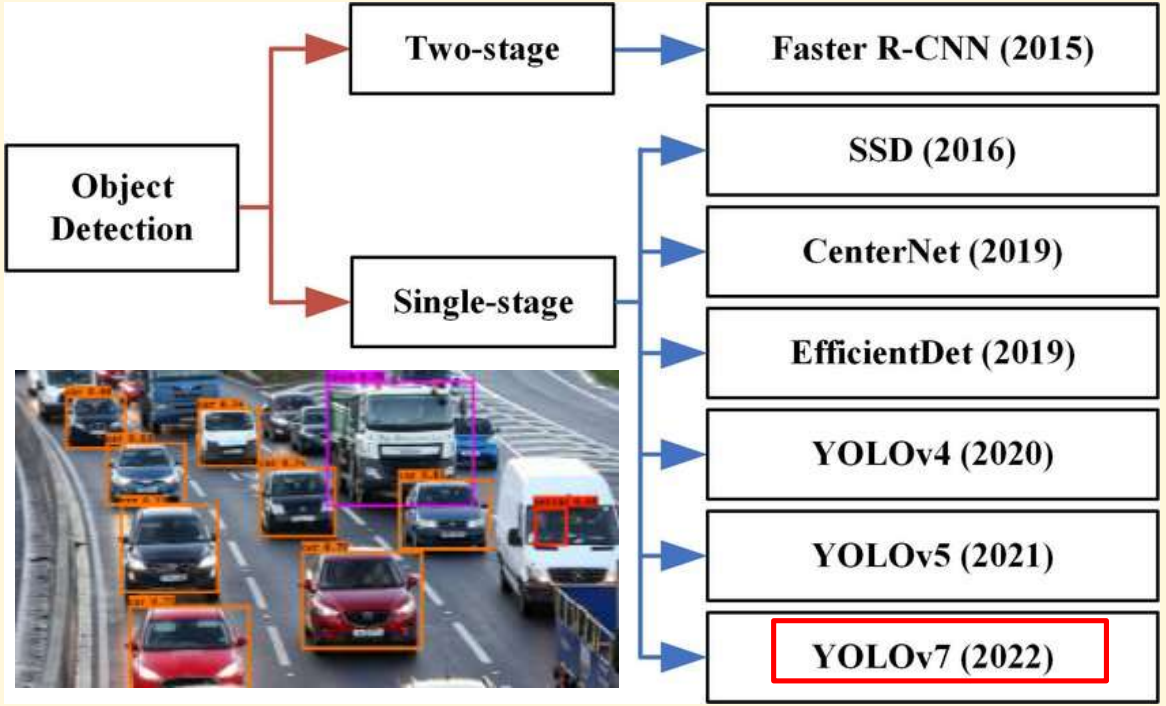
Related work(3/7)

We selected the one-stage object detection algorithm, YOLOv7, to detect vehicles in the lane view of the road.

Pros: One-stage object detection algorithms are faster for real-time video processing than two-stage methods, making them ideal for real-time tasks while retaining high accuracy.

Cons: Two-stage algorithms are not fast enough to handle this real-time detection task

Additionally, YOLOv7 offers stable performance, making it suitable for various scenarios, including rainy conditions or nighttime.



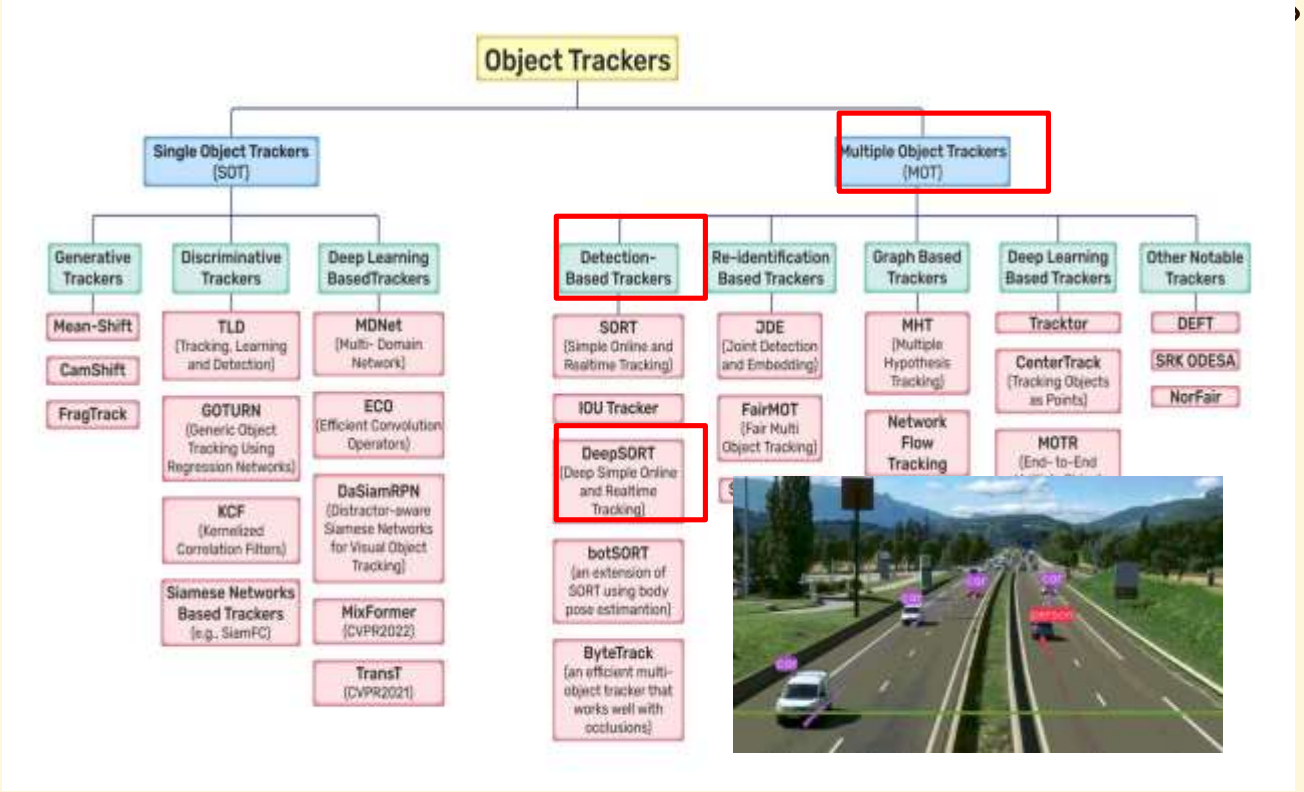
Related work(4/7)

For the object tracking algorithm, Multi-Object Tracking is used to identify different classes of vehicles, hence the DeepSORT algorithm is employed.

The reasons we chose the DeepSORT algorithm are:

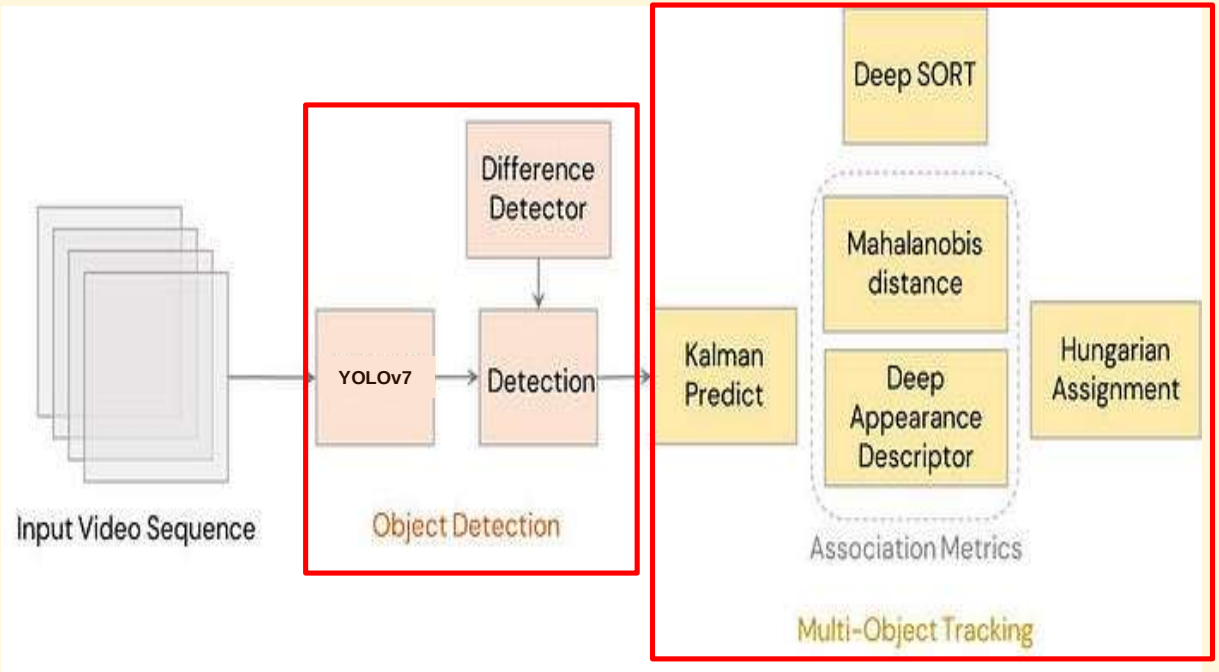
1. DeepSORT can handle issues related to visual occlusion and folding.

2. DeepSORT is a real-time tracking technique.



Related work(4/7)

The process of combining the two algorithms involves first processing the real-time webcam footage using YOLOv7, and then applying the multi-object tracking DeepSORT algorithm to count the number of vehicles in the frame.



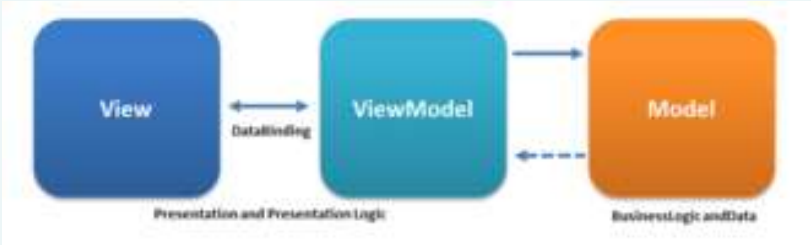
Related work(5/7)

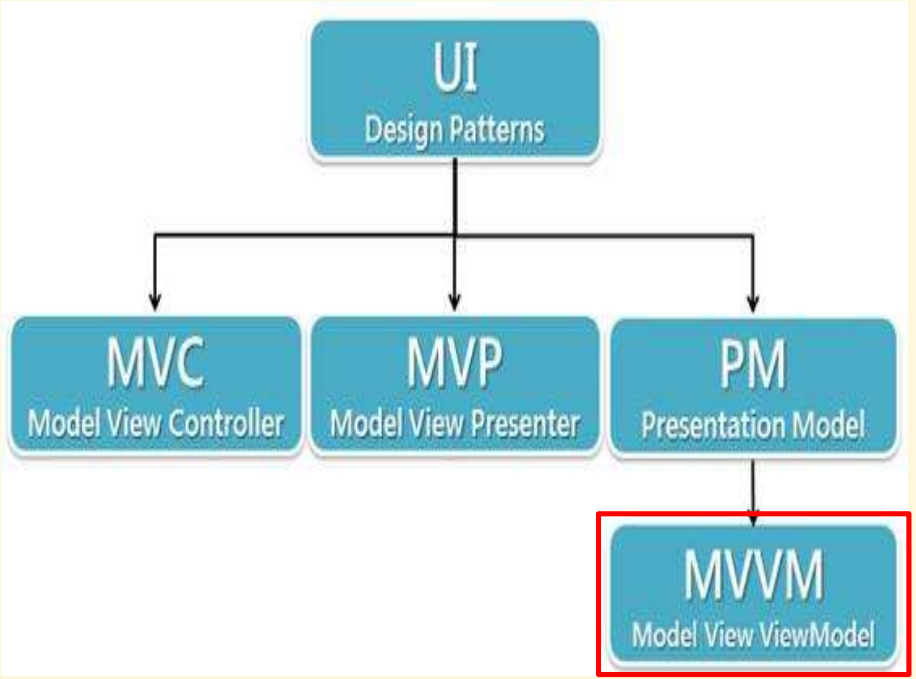
We used the CART algorithm for model training because our continuous data limits the choices to C4.5 and CART. Given the large sample size required for this vehicle recognition data, CART is the more suitable choice, even though C4.5 offers slightly higher accuracy.

Features	*ID3*	*C4.5*	*CART*
Type of data	Categorical	Continuous and Categorical	continuous and nominal attributes data
Speed	Low	Faster than ID3	Average
Boosting	Not supported	Not supported	Supported
Pruning	No	Pre-pruning	Post pruning
Missing Values	Can't deal with	Can't deal with	Can deal with
Formula	Use information entropy and information Gain	Use split info and gain ratio	Use Gini diversity index

Related work(6/7)

We adopted the MVVM architecture to implement the driver application because the separation of business logic and user interface (UI) design minimizes the "Massive View Controller" problem often seen in traditional MVC architecture. Furthermore, MVVM makes writing tests significantly easier.





Related work(7/7)

Currently, Taiwan's Ministry of Transportation and Communications (MOTC) 1968 real-time highway system uses big data to predict highway travel times, but it does not predict travel times based on actual congestion status.

各旅行時間預測

起點 預計出發時間	15:00	15:30	16:00	16:30	17:00	17:30	18:00
預測旅行時間	約15分	約13分	約13分	約13分	約15分	約23分	約28分
終點 預測到達時間	15:15	15:43	16:13	16:43	17:15	17:53	18:28

Related work(7/7)

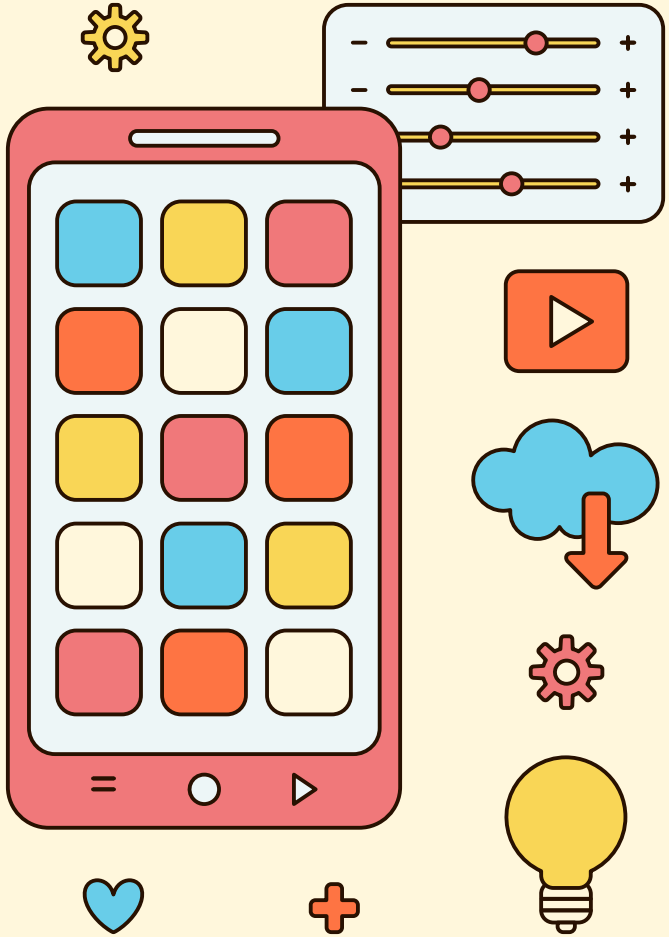
Feature Comparison of Relevant Systems

	Predicting Congestion Clearance Time	Real-time Information per Section	Route Planning Time Prediction	User
1968 National Freeway Surveillance System		✓	✓	Driver
Our Proposed System	✓	✓	✓	Driver

03

Proposed Method

Current Situation, Design Philosophy, System Architecture, and Flowchart



Aim

1. To solve the problem of highway traffic congestion in smart cities, which leads to urban traffic jams and further causes air pollution problems.

2. Drivers need real-time information on when congestion will clear to make informed decisions about when to access the national highway.

Data Collection

Data Analysis

Congestion is indicated when the traffic volume exceeds 50 vehicles per minute.

A traffic volume less than or equal to 50 vehicles per minute indicates not congestion.

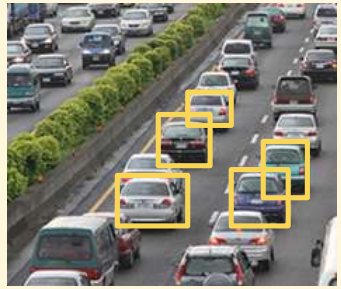
Method(1/5)

Object Detection and Tracking

We use a combination of the image recognition algorithms, YOLOv7 and DeepSORT, to complete the vehicle flow detection. The vehicle flow and timestamps are then transmitted to and stored in the MySQL database to serve as training data.

Historical Video Footage

Yolov7 with Deepsort



The frame captured N vehicles.

Store the traffic volume (N vehicles) and the timestamp.

Method(2/5)

Training Model

Next, the data is transmitted to the ML model, and the training data is pre-processed into a suitable training format. During training, the CART algorithm from Decision Trees is utilized, and the trained weights are then stored.

Vehicle Count (N) and Timestamp

Data pre-processing

Add data label

Training Decision Tree Model

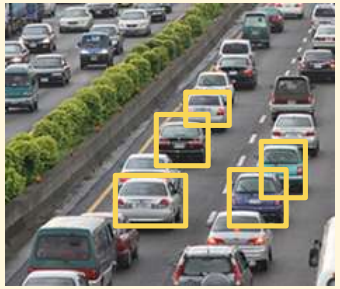
Method(3/5)

Real Time Object Detection and Tracking

Through the combination of real-time image recognition using YOLOv7 and the DeepSORT algorithm, the vehicle flow detection is completed. The vehicle count and timestamp are then transmitted to and stored in the MySQL database to serve as data for real-time prediction.

Real-time WebCam Footage

Yolov7 with Deepsort



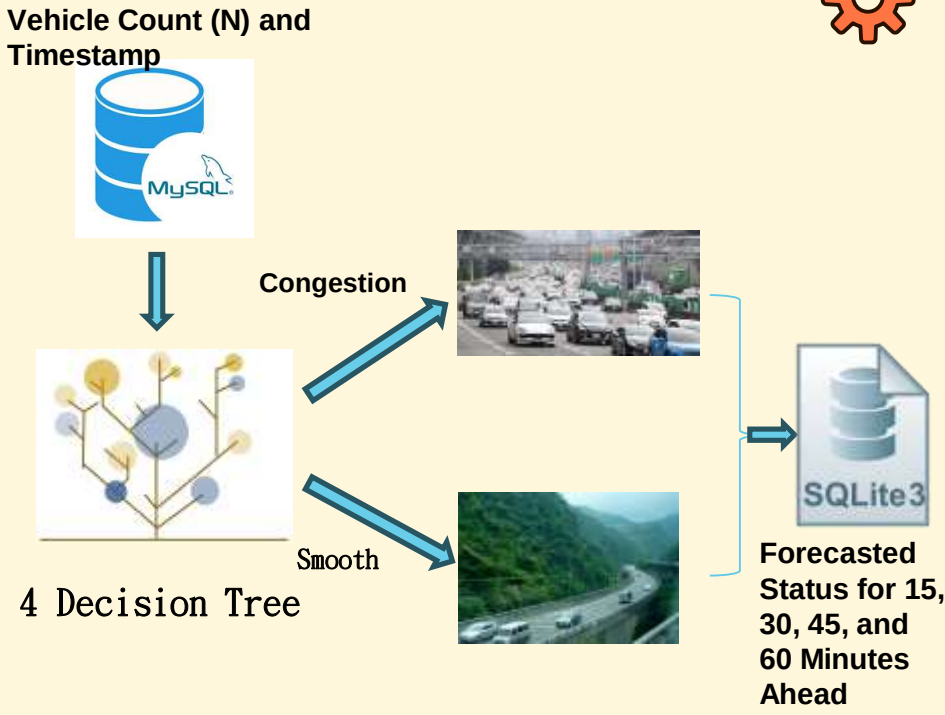
N vehicles were detected in the frame.

Store the vehicle count (N) and the timestamp.

Method(4/5)

Model Prediction

Next, the trained Model is used to make decisions based on the real-time data received. Four separate prediction models are employed to forecast the future status for the next 15, 30, 45, and 60 minutes, respectively. Each model yields one of two results: "National Highway Congestion" or "National Highway Flowing Smoothly." These results and their corresponding time points are then stored in the SQLite3 database.



Method(5/5)

Driver App

Next, the data from the database is provided to the user's mobile application for access. The user's frontend will display the predicted congestion status for the next 15, 30, 45, and 60 minutes. Drivers can then use this information to decide when to travel on this national highway, thereby avoiding unnecessary waiting and mitigating the problem of highway congestion.

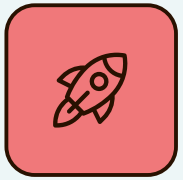
Forecasted Status for 15, 30, 45, and 60 Minutes Ahead

Displaying Real-time Information to Drivers

Overall System Functions

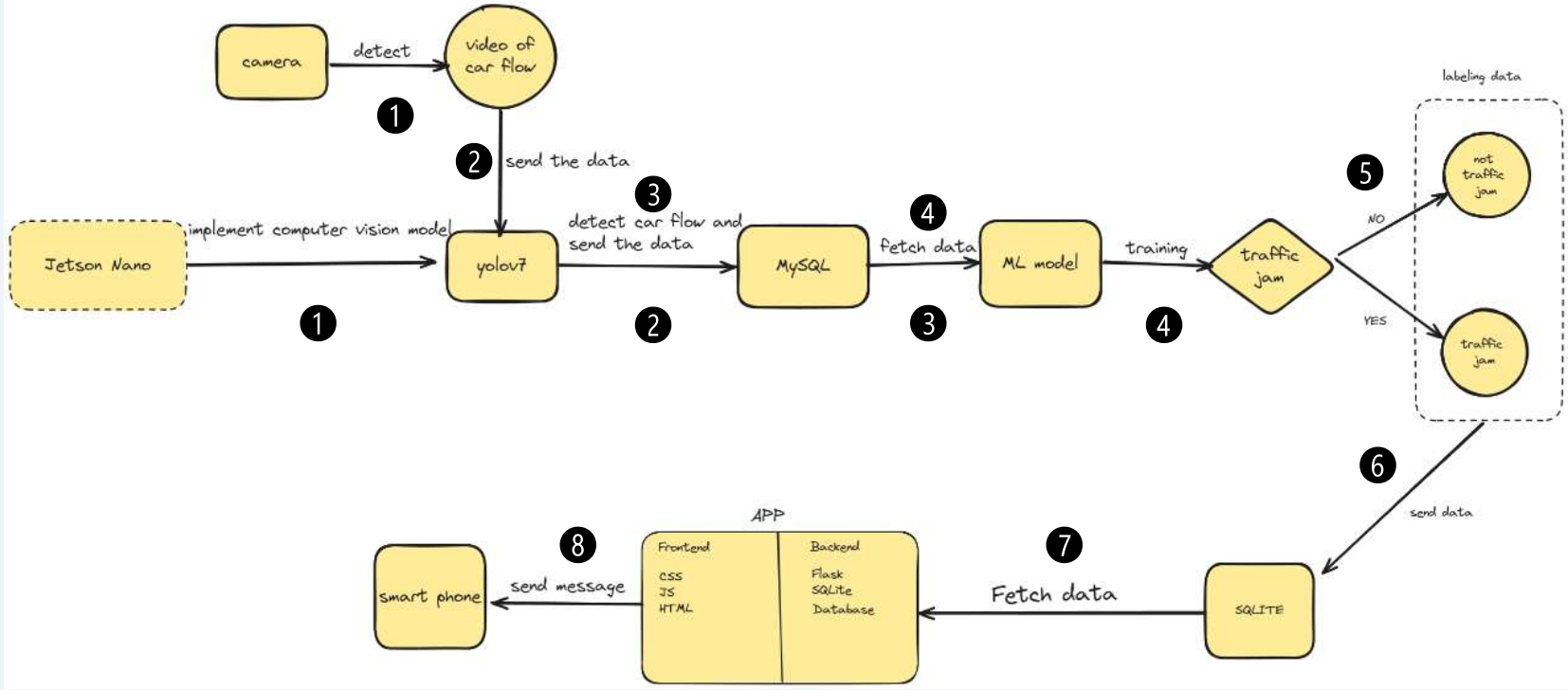
Real-time National Highway Congestion Information for Users

Preventing the Continuation of National Highway Congestion

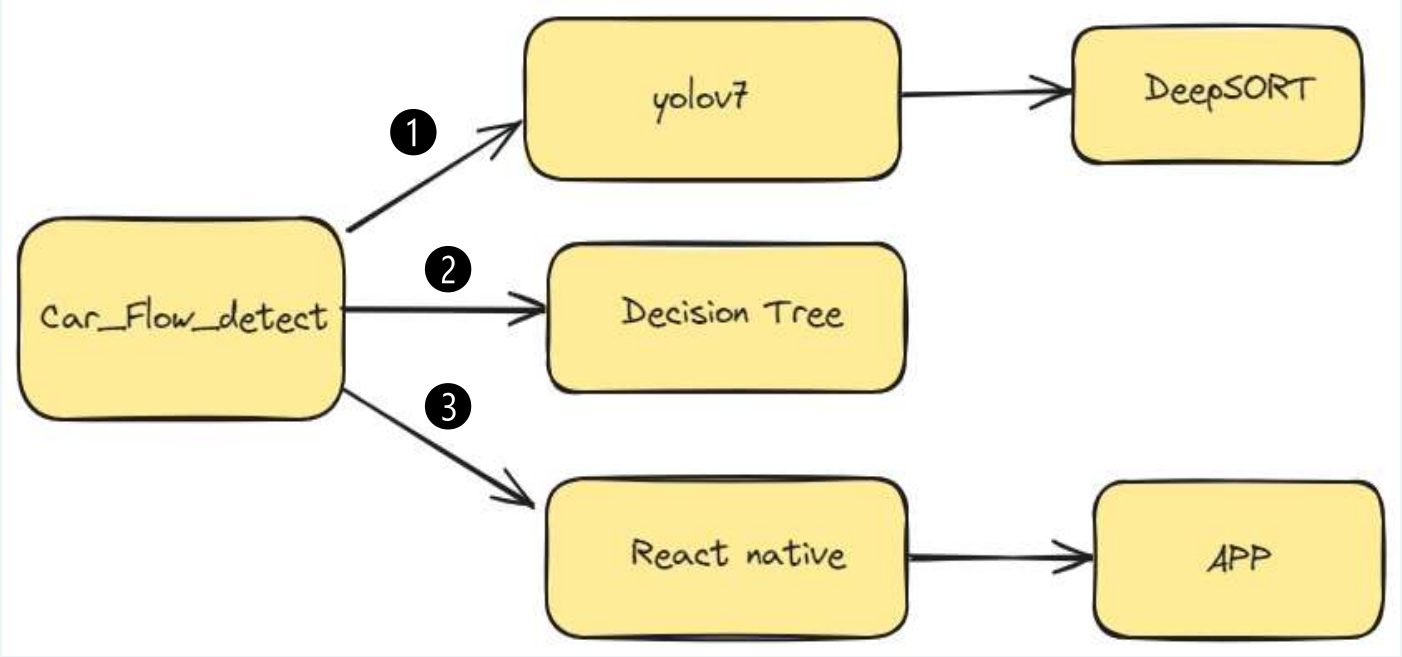


Reducing further carbon emission problems

System Design Flowchart



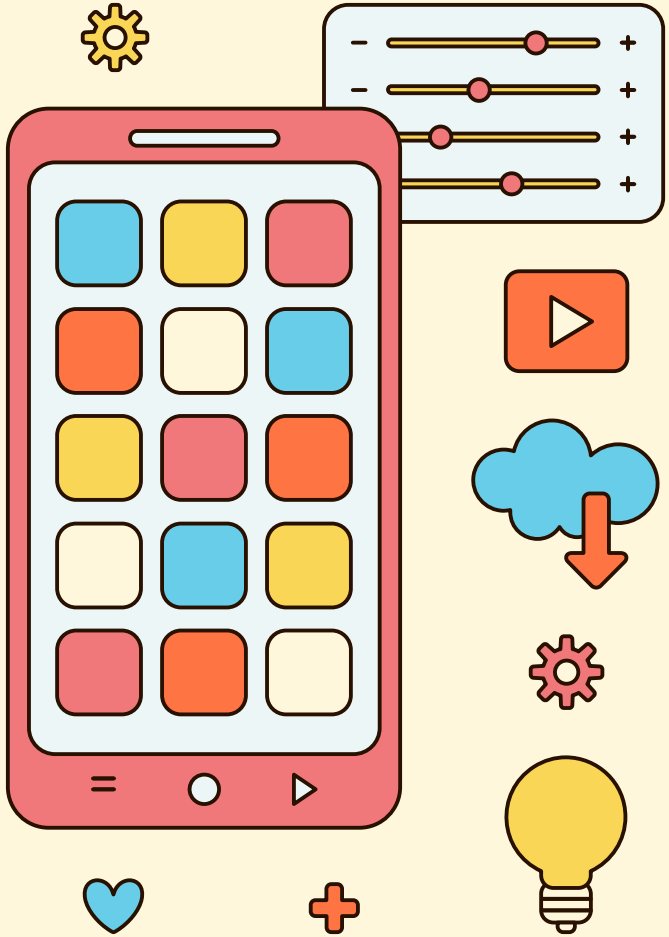
System Design Architecture Diagram



04

Detail Implementation

Implementation Process and Final System Presentation



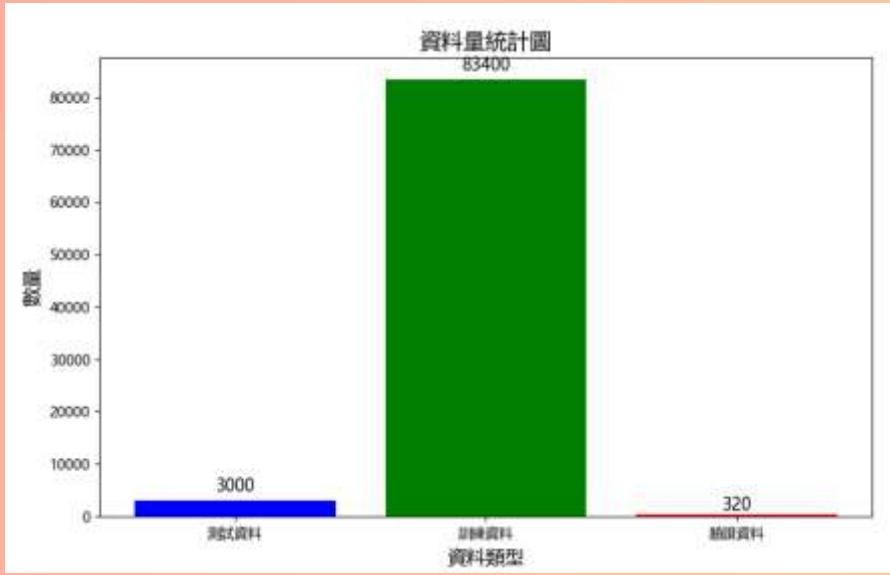
Detail Implementation(1/7)

For a specific road segment's video footage, perform data collection using YOLOv7 and DeepSORT, and generate a dataset to be stored in the database.

Detail Implementation(2/7)

Training dataset、Testing dataset、Validation dataset

We used the webcam to capture data, collecting a full day's worth of data (86,400 minutes) to perform dataset splitting into three subsets: training, testing, and validation datasets.



Detail Implementation(3/7)

Display of Prediction Results from the Testing Dataset on the User's App

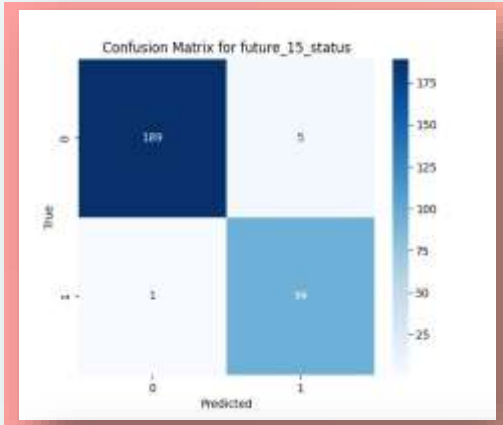
The trained model provides accurate predictions for a specific road segment, informing drivers of both the current status and the status forecasted within the next 60 minutes.

中和隧道即時預測結果

ID	車流量	時間	未來15分鐘	未來30分鐘	未來45分鐘	未來60分鐘
637	46	38160	不壅塞	不壅塞	不壅塞	不壅塞

Detail Implementation(4/7)

Testing Dataset Accuracy and Confusion Matrix

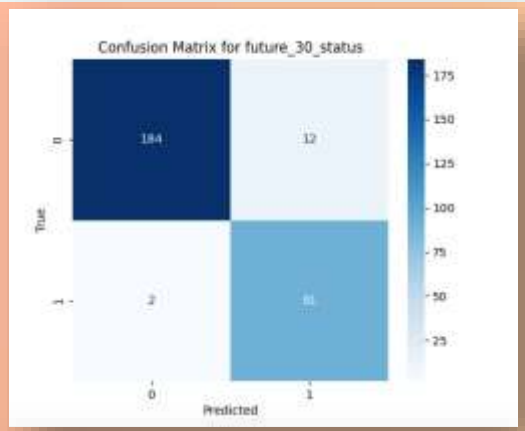



```
Results for future_15_status:
Accuracy: 0.9792387543252595
Classification Report:
              precision    recall  f1-score   support

           0       0.99      0.97      0.98       194
           1       0.95      0.99      0.97        95

    accuracy                           0.98       289
   macro avg       0.97      0.98      0.98       289
weighted avg       0.98      0.98      0.98       289
```

With a sufficient dataset covering at least an entire day, high accuracy can be achieved, but when the dataset is too small, the accuracy will be very low.



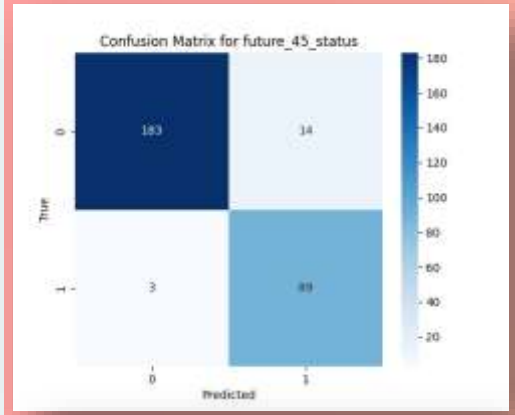

```
Results for future_30_status:
Accuracy: 0.9515570934256056
Classification Report:
              precision    recall  f1-score   support

           0       0.99      0.94      0.96       196
           1       0.88      0.98      0.93        93

    accuracy                           0.95       289
   macro avg       0.94      0.96      0.95       289
weighted avg       0.96      0.95      0.95       289
```

Detail Implementation(5/7)

Testing Dataset Accuracy and Confusion Matrix

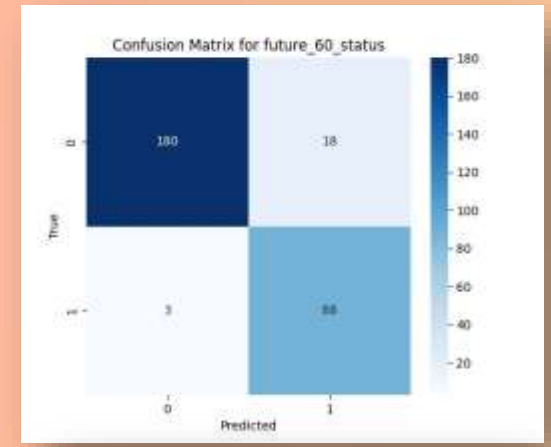



```
Results for future_45_status:
Accuracy: 0.9411764705882353
Classification Report:
              precision    recall  f1-score   support

           0       0.98      0.93      0.96       197
           1       0.86      0.97      0.91        92

    accuracy                           0.94       289
   macro avg       0.92      0.95      0.93       289
weighted avg       0.95      0.94      0.94       289
```

The prediction accuracy tends to decrease slightly for longer forecasting horizons.




```
Results for future_60_status:
Accuracy: 0.9273356401384083
Classification Report:
              precision    recall  f1-score   support

           0       0.98      0.91      0.94       198
           1       0.83      0.97      0.89        91

    accuracy                           0.93       289
   macro avg       0.91      0.94      0.92       289
weighted avg       0.94      0.93      0.93       289
```

Detail Implementation(6/7)

The real-time update frequency is to fetch the latest prediction data every minute.

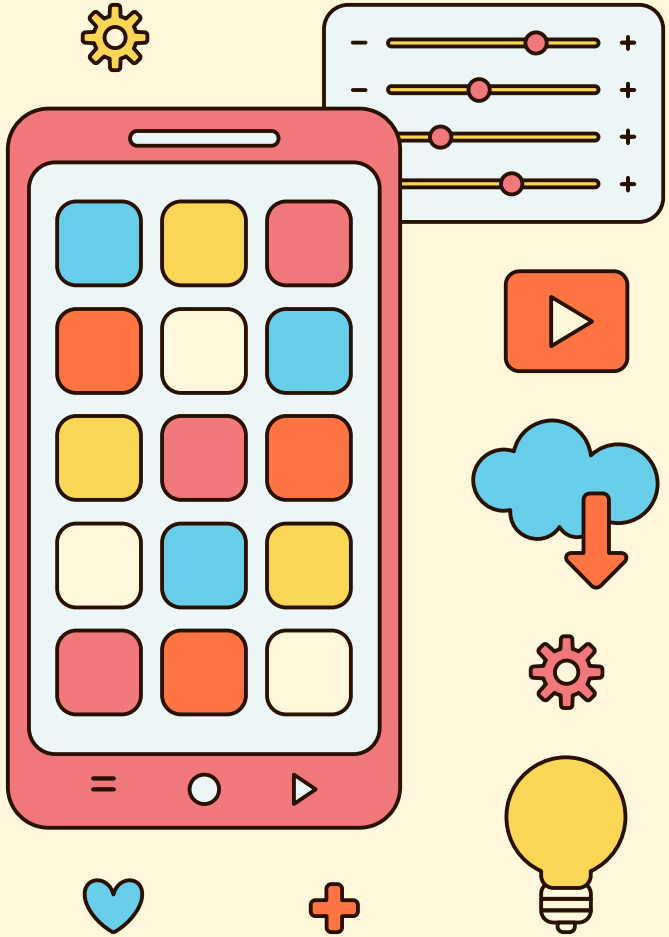
Detail Implementation(7/7)

Road Segment Selection System

05

Conclusion

Conclusion, Areas for Improvement, and Future Outlook



Conclusion(1/2)

Contributions:

1. Through AIoT-enabled intelligent prediction, we can help improve the decisions currently made by national highway drivers.

2. The new system we proposed can currently process real-time footage with high efficiency, enabling the monitoring of multiple surveillance feeds.

Conclusion(2/2)

Research limitations:

1. The accuracy of the future prediction model is currently constrained because the dataset is incomplete, meaning it cannot yet be extended for use on any arbitrary road segment.

Feature works:

1. This can serve as a method for improving future national highway traffic conditions.

THANKS!