

國立臺北大學資訊工程學系114學年度專題 衛星物聯網-智慧鳥類監測與驅趕系統

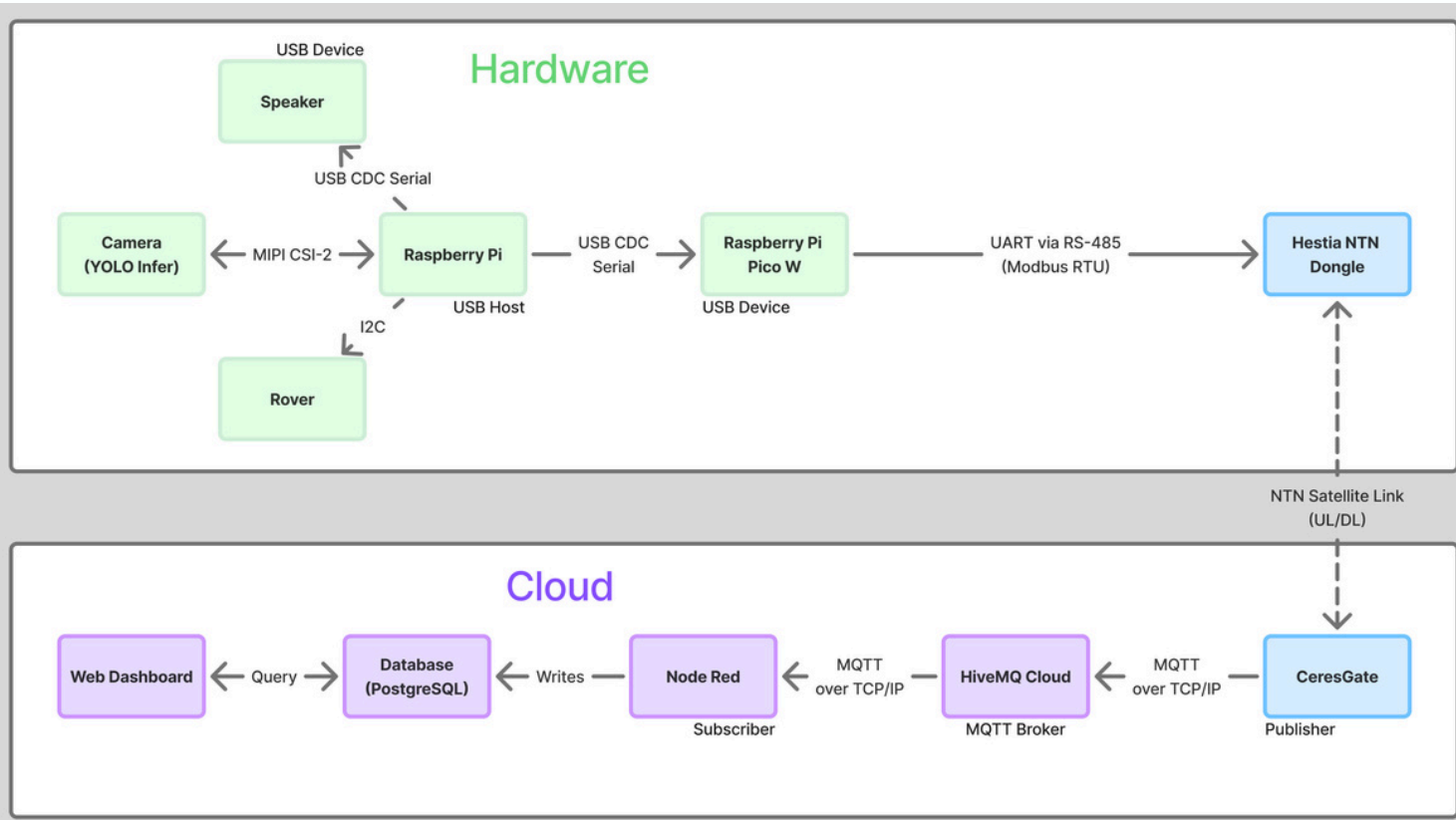
專題學生：應添利、馮寶妍、尹基明、曾冠綸

1. INTRODUCTION & MOTIVATION

With the growth of urbanization and campus ecology, bird monitoring and pest-bird management have become increasingly important. However, traditional manual observation is time-consuming and often incomplete, while fixed deterrence methods may become less effective as birds gradually adapt. In addition, unstable network coverage in some areas limits real-time data transmission.

This study focuses on the Mind Lake area of National Taipei University's Sanxia campus and develops a smart bird monitoring system integrating edge AI, satellite IoT, a mobile deterrence rover, and a web-based visualization platform. The system can detect bird species in real time, record bird activity events, and selectively deter target bird species.

2. SYSTEM ARCHITECTURE

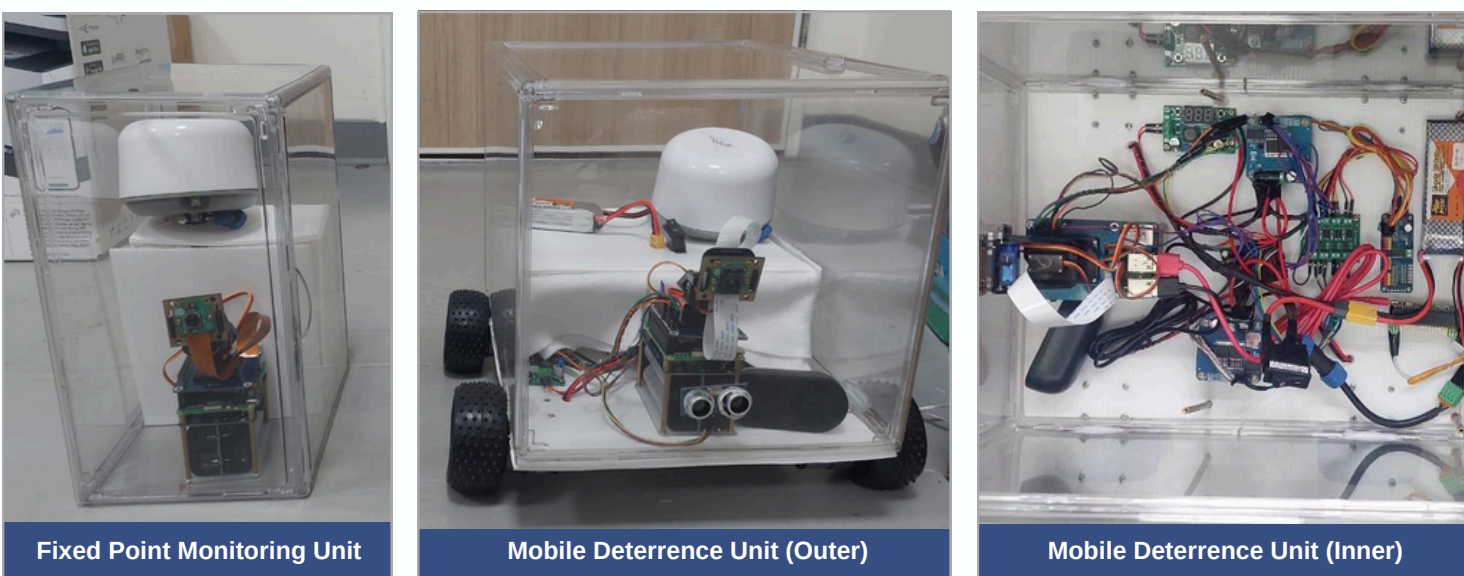


The system is divided into three layers: hardware, satellite and cloud.

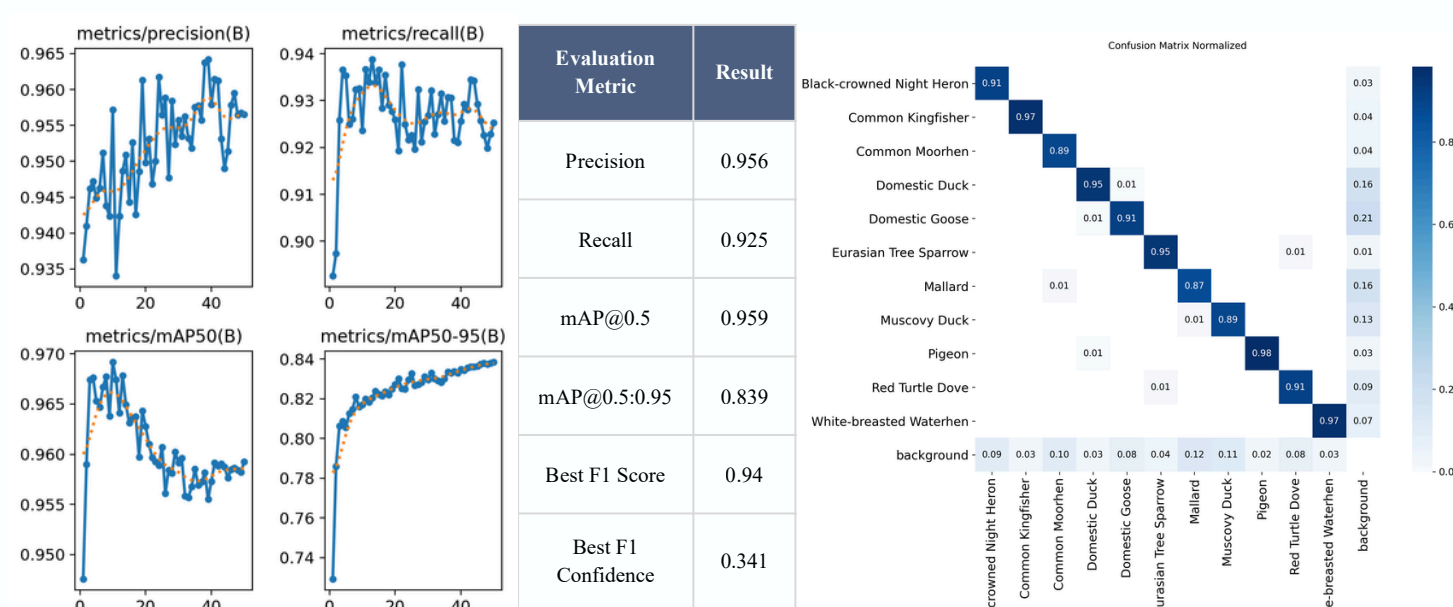
- The hardware layer uses a camera and Raspberry Pi to detect birds with YOLO, then activates deterrence through a speaker or rover. Detection data is sent through Pico W and the Hestia NTN Dongle via satellite.
- The cloud layer receives the data through CeresGate, transfers it using MQTT and HiveMQ Cloud, stores it in PostgreSQL through Node-RED, and displays the results on a web dashboard.

3. HARDWARE PROTOTYPE

The system includes both a fixed point monitoring unit and a mobile deterrence unit.

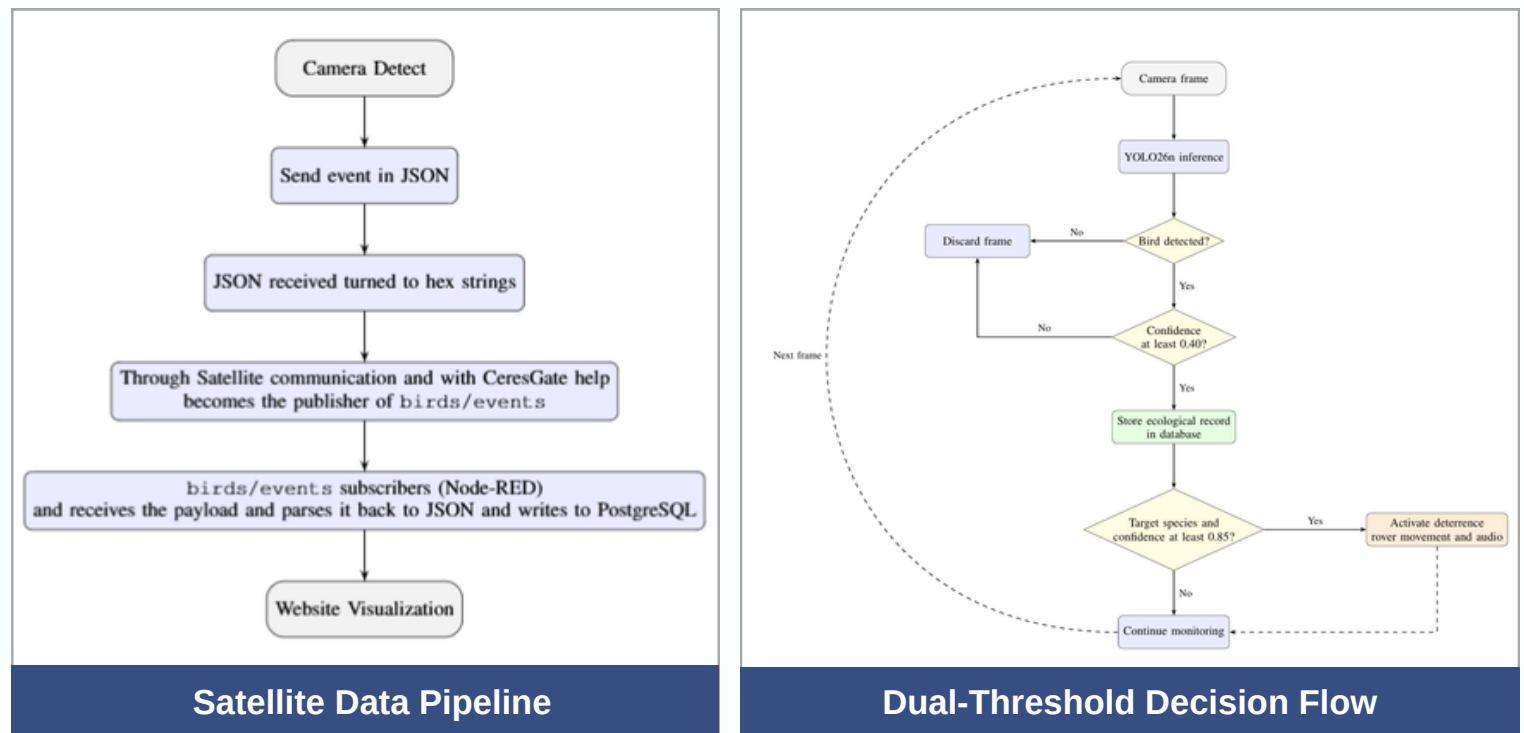


4. YOLO MODEL



YOLO26n is used in this project because of its small model size and lower computation requirement make it suitable for running on Raspberry Pi 5 with faster inference and lower power usage. In this project, we trained our model for around 50 epochs and The YOLO26n model achieved strong overall performance, with 0.956 precision, 0.925 recall, 0.959 mAP@0.5, and a best F1 score of 0.94 at a confidence threshold of 0.341.

5. EVENT DECISION & SATELLITE TRANSMISSION



Sample Compact JSON

After YOLO detects a target bird, the system creates a compact JSON event. For example, a pigeon detection event can be written as:

```
{"t":0,"id":"a1b2c3d4e5f6","ts":1717850000,"b":8,"c":0.88}
```

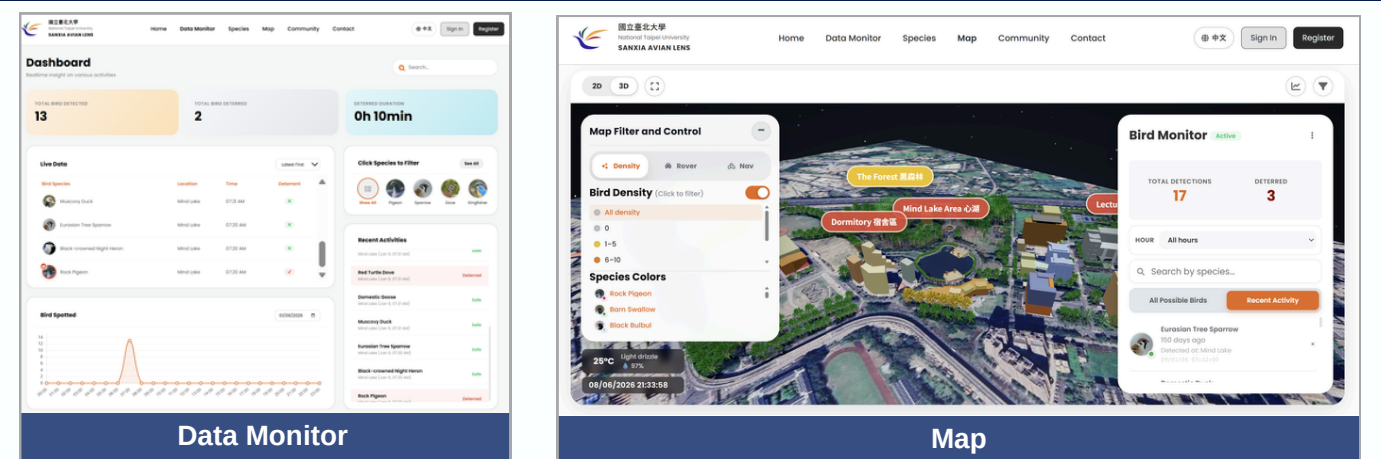
where t=0 means detection, b=8 represents pigeon, and c=0.88 is the confidence score.

Before satellite transmission, this JSON string is encoded into hexadecimal format:

```
7b2274223a302c226964223a22613162326333643465356636222c2274  
73223a313731373835303030302c2262223a382c2263223a302e38387d
```

After the payload is received through CeresGate and MQTT, the subscriber (Node-RED in this context) converts the hexadecimal data back into the original JSON string, parses the fields, and writes the structured event data into PostgreSQL for website visualization.

6. FRONTEND VISUALIZATION



The frontend requests bird event data through RESTful API endpoints, which query PostgreSQL, return the required records in JSON format, and allow the web dashboard to visualize detection events, timestamps, bird classes, and system status.

7. EXPERIMENTAL RESULTS



In the experimental results, our model successfully detected the target species, pigeons, and triggered the deterrence mechanism based on the system's detection output.

The detection records and deterrence results were also displayed on the frontend dashboard, showing that the proposed system can support real-time bird monitoring and selective deterrence in the test environment.

8. CONTRIBUTIONS AND CONCLUSION

Contributions

- Mind Lake-specific YOLO26n model (11 species)
- Dual-threshold ecological/deterrence strategy
- End-to-end NTN satellite-IoT pipeline
- Autonomous mobile deterrence rover
- Sanxia Avian Lens 2D+3D visualization

Conclusion

- The system successfully detected 11 Mind Lake bird classes.
- The model achieved 0.959 mAP@0.5, showing reliable recognition performance.
- The full pipeline from edge detection → satellite transmission → database → web visualization was verified.
- Future work includes weather-resistant hardware, GPS tracking, solar power, aerial deterrence, and more bird species.