UAV interface development for countering dangerous drones

Midterm Presentation

Team: BTT

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PURDUE UNIVERSITY | Polytechnic Institute

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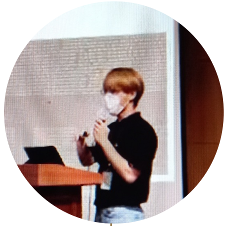
INTRODUCTION

[redacted]

- Team members
- The reason why we choose this project
- Subject

Introduction

Team members



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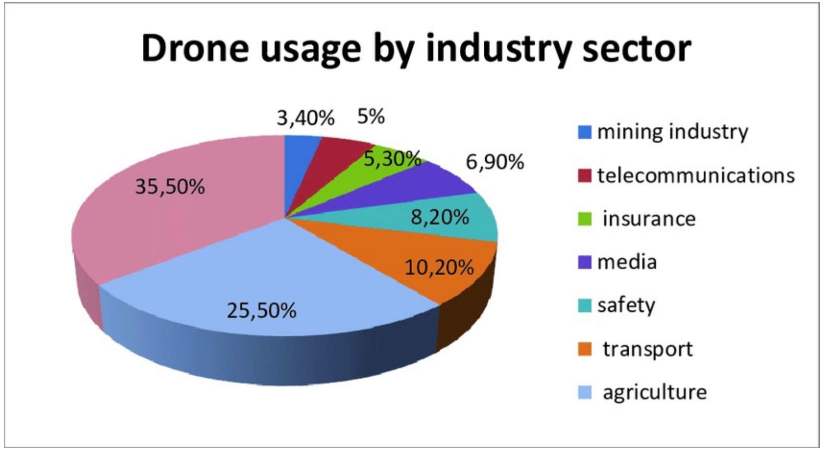
Introduction

The reason why we choose this subject

[1]



- UAVs are now more easily accessible to the public with reduced cost and device miniaturization.
- UAVs are used in various fields with new services.

[1] Zaychenko, Irina & Smirnova, Anna & Borremans, Alexandra. (2018). Digital transformation: the case of the application of drones in construction. MATEC Web of Conferences. 193. 05066. 10.1051/matecconf/201819305066.

Introduction

The reason why we choose this subject

[2]

Russia launches 'kamikaze' drone attack on Kyiv, killing 4 and hitting civilian infrastructure

By Victoria Butenko, Olga Voitovych and Yulia Kesaieva, CNN

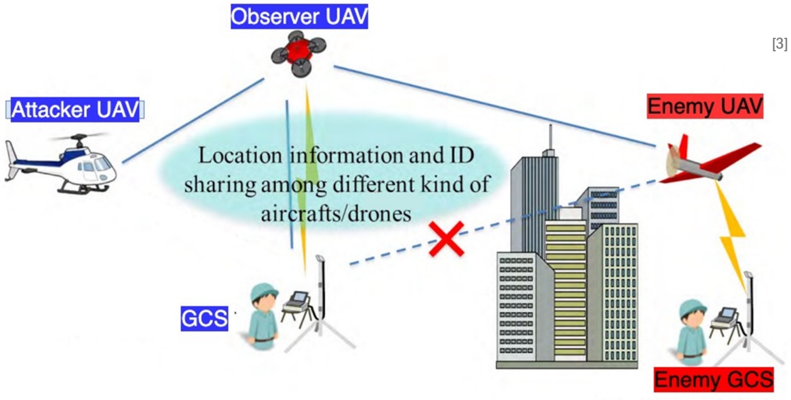
Updated 3:09 PM EDT, Mon October 17, 2022

- A lot of issues about safety of UAVs, which accelerate the development of anti-drone technology.
- Anti-drone is a system designed to protect us from drone accidents or terrorism.

[2] Victoria Butenko, Olga Voitovych and Yulia Kesaieva. "Russia launches 'kamikaze' drone attack on Kyiv, killing 4 and hitting civilian infrastructure," CNN: October 17, 2022.

Introduction

Subject



[3]

Developing the UAV interface for countering dangerous drones

[3] L. Shan, R. Miura, T. Kagawa, F. Ono, H. -B. Li and F. Kojima, "Machine Learning-Based Field Data Analysis and Modeling for Drone Communications," in IEEE Access, vol. 7, pp. 79127-79135, 2019, doi: 10.1109/ACCESS.2019.2922544.

RELATED WORKS

- Existing projects
- Challenge
- Solution

Related works

Existing projects

To increase the accuracy of drone detection -> detection model in GCS -> video streaming

"Wi-Fi mesh networking"

high bandwidth
Propose Wi-Fi mesh network for military situation.
Transmit images in real time at a distance of 60m.

[4] Chand, G.S.L.K., Lee, M. and Shin, S.Y. (2018) Drone Based Wireless Mesh Network for Disaster/Military Environment. Journal of Computer and Communications, 6, 44-52

Related works

Challenge

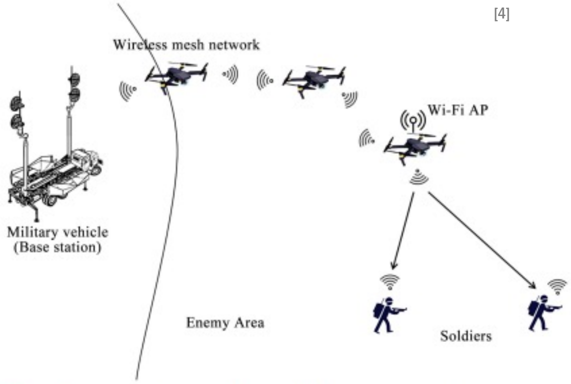


Figure 1. Secnario of the proposed system. (Military environment).

Wi-Fi mesh

- high power consumption
- Limited on-board energy is major limitation of UAV systems.

➡ **can be a problem in a situation where both networking and detection are needed.**

[4] Chand, G.S.L.K., Lee, M. and Shin, S.Y. (2018) Drone Based Wireless Mesh Network for Disaster/Military Environment. Journal of Computer and Communications, 6, 44-52

Related works

Solution

[5]

LoRa

- Low power consumption
- Long range communication
- Low bandwidth

[5] Maker.io Staff. "Introduction to LoRa Technology - The Game Changer" Maker.io. Accessed: October. 8, 2016. [Online]. Available: https://www.digikey.com/en/maker/blogs/introduction-to-lora-technology

Related works

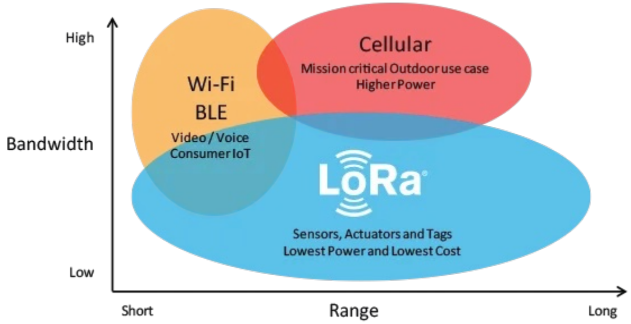
Solution

Low bandwidth

- It doesn't provide video streaming.
- Detecting drones in GCS is impossible.

→ **On-device detection**

[6]



[6] "What are LoRa and LoRaWAN?" thethingsnetwork. [Online]. Available: https://www.thethingsnetwork.org/docs/lorawan/what-is-lorawan/

METHODOLOGY

[redacted]

- Novelty
- How to implement network part
- How to implement detection part

Methodology

Novelty

- Our project‘s novelties

  Low Power & Long Range

- Networking

  Mesh Network and **LoRa**

- Detection

  Tiny Machine Learning (Tiny ML)

Methodology

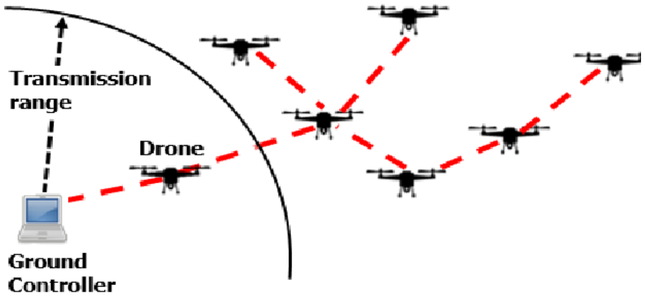
How to implement network part

Mesh Network

- A type of communication in radio networks
- Equipped with a wireless communication system each drone
- Communicated with each other using a suitable protocol

Flow of Mesh Network

[7]



[7] Anay Deshpande. "SMURF: RELIABLE MULTIPATH ROUTING IN FLYING AD-HOC NETWORKS" Windmil. Accessed: January. 21, 2022. [Online]. Available: https://ksp-windmill-itn.eu/research/smurf-reliable-multipath-routing-in-flying-ad-hoc-networks/

Methodology

How to implement network part

Advantages of Mesh Network

- Enables drones to cover larger areas
- Operates in environments where direct communication is not possible

" Our first task is to construct long range network between UAVs for sending detection result. "

Methodology

How to implement network part

LoRa Mesh Network

- Sends small amount of data reliably over very long distance
- Uses digital modulation technology called CSS(Chirp Spread Spectrum)
- Has advantage of low power and long range
- Operate in the range of 5~15km at data rates between 0.3kbps to 50kbps [8]

Other Protocols

- Wi-Fi is usually used in U2U communication, but it has limited ranges.

[8] Sharma V, You I, Pau G, Collotta M, Lim JD, Kim JN. LoRaWAN-Based Energy Efficient Surveillance by Drones for Intelligent Transportation Systems. *Energies*. 2018; 11(3):573. https://doi.org/10.3390/en11030573

Methodology

How to implement detection part

"Our second task is to develop an on-board detection method, which consumes low power by using TinyML"

[9] "Tiny ML" Tech in 3. [Online]. Available: https://medium.com/geekculture/tiny-ml-ca0dd5ca8dd2
[10] N. N. Alajlan and D. M. Ibrahim, "TinyML: Enabling of Inference Deep Learning Models on Ultra-Low-Power IoT Edge Devices for AI Applications," *Micromachines*, vol. 13, no. 6, p. 851, May 2022, doi: 10.3390/mi13060851.

Methodology

How to implement detection part

Tiny ML Frameworks and Platforms

TensorFlow Lite
for Microcontrollers (TFLM)

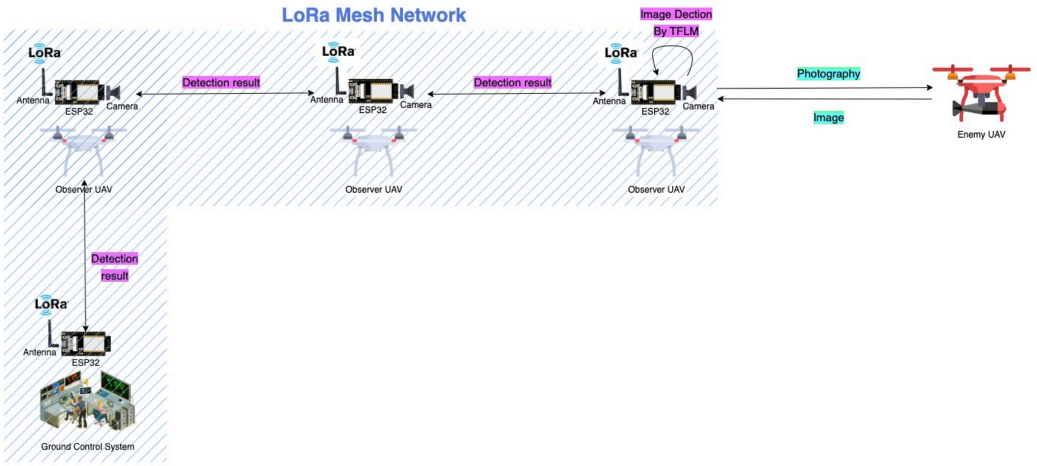
MLX

X-Cube-AI

- Provides a broad set of tools and libraries

Methodology

Project goal



- Some observer UAVs connected by LoRa Mesh Network
- Observer UAVs detect unidentified UAV using TFLM with live streaming.
- If detection result is YES (Drone detected), the result is sent to other UAVs through LoRa mesh network.

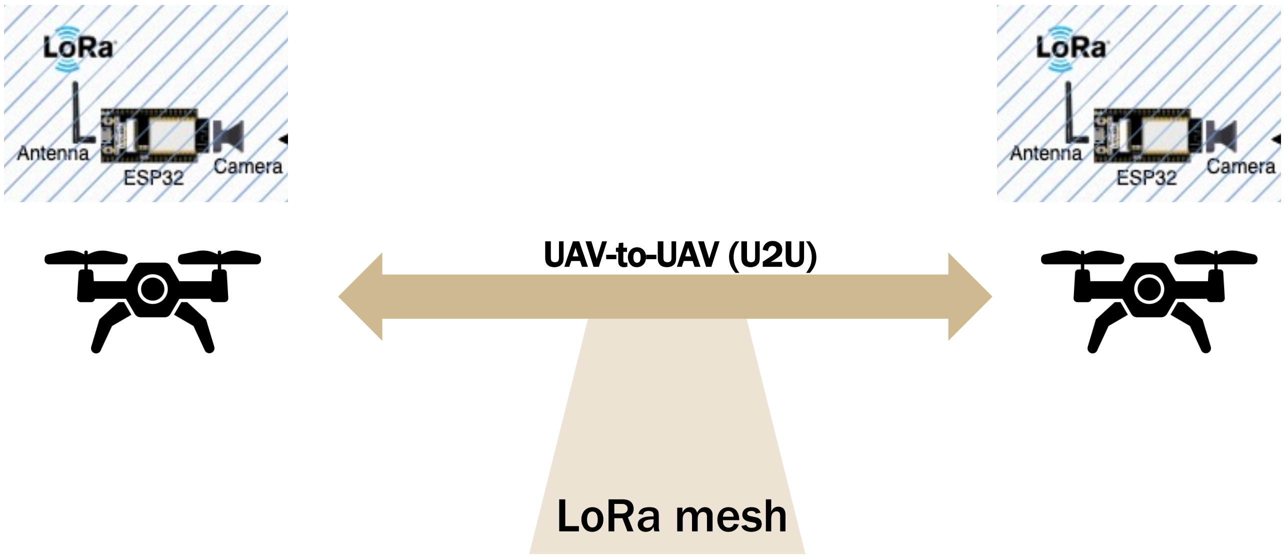
PROGRESS

[redacted]

- Networking
- Drone detection

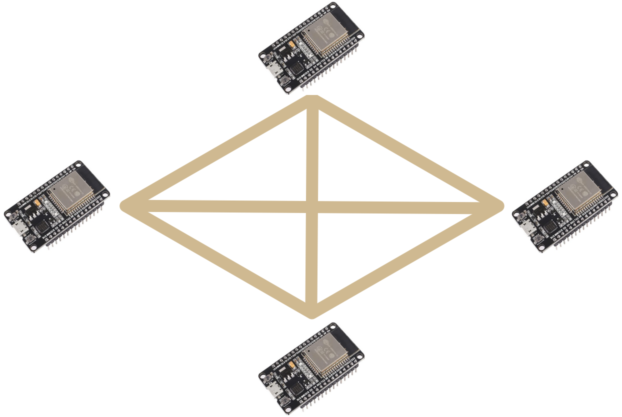
Progress

Networking



Progress

Networking



- Implemented LoRa mesh network
  with open-source library based on Arduino

- Each board is a node of network.

Progress

Networking

Progress

Drone detection

Application TFLM on ESP32 board

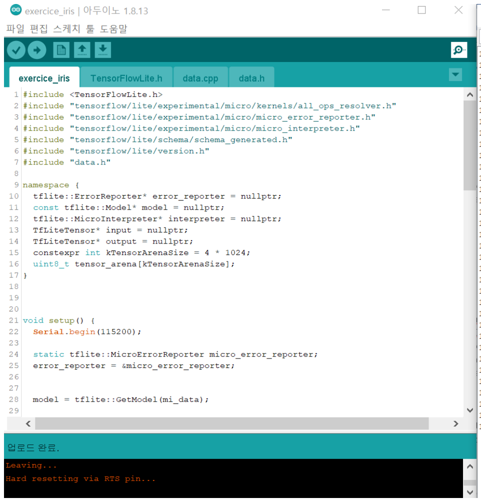
1. Train prediction model with IRIS dataset in Colab
2. Convert the model to the TensorFlow Lite format
3. Save model in HEX file format to move into Arduino
4. Connect ESP32 board with Arduino and run source code

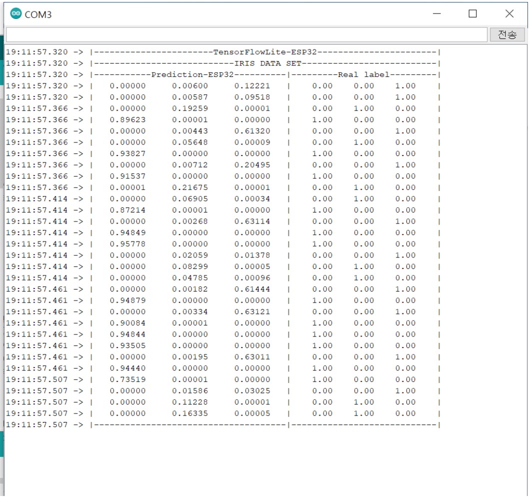
[11] sandroormeno (2021) exercice_iris [Source code]. https://github.com/sandroormeno/TensorFlow-LITE-ESP32-ARDUINO/tree/master/exercice_iris.

Progress

Drone detection

Application TFLM on ESP32 board





FUTURN PLANS

[redacted]

- Finding deep learning model
- Field experiment – networking
- Field experiment – detection

Future plans

Finding deep learning model

1. Find pre-trained deep learning model that is suitable for our project
2. Run our model on ESP32 board
3. Send the result of detection using LoRa mesh network

Future plans

Field experiment - networking

- **Maximum distance**
  - How many kilometers of communication can be made when three drones are arranged?
- **Optimal route**
  - Verify that our system routes the optimal route when drones are arranged in complex form
- **Power consumption**
  - Attach the power quality analyzer to the power supply

Future plans

Field experiment - detection

- **Accuracy**
  - Concentrate on verifying it is possible to detect enemy drones
- **Memory usage**
  - Check how much of the memory is used by both parts (networking, detection)
- **Inference time**
  - Measure the inference time which means the time taken to determine drones

Q&A

[redacted]

Thank You

Team. BTT

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