SoC Final Project Group 3

Drone-aided Police's Control System

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Chapter 1 Introduction

1.1 Motivation

Fig. 1.1 Itaewon 2022 Halloween

On the night of 29 October 2022, the crowd crush happened in Itaewon, which is in South Korea. At least 156 people were killed and 196 people were injured in this disaster.

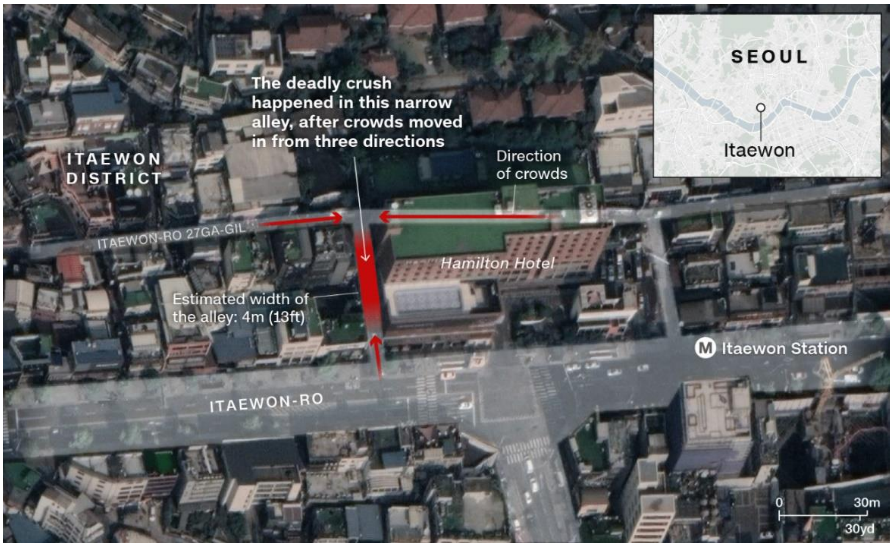


Fig. 1.2 Street Map of Itaewon

At 18:34, police received the first emergency call. Afterwards, as the crowd was growing, there were several emergency calls. Unfortunately, the police had trouble controlling the festivities crowd. The crowd crush occurred at around 22:20. However, eighty-three more ambulances arrived on site as late as 23:45 and the Seoul metropolitan government sent an emergency alert to residents in the Itaewon area at 23:55. Phone and internet reception was temporarily saturated and out of service in the district because of the volume of communications attempted. Finally, by 00:30, the scale of the tragedy was becoming clear.

Fig. 1.3 Aerial View of Itaewon 2022 Halloween

There are several reasons that leaded to this disaster like too many people, traffic flow and so on. We think if the police have more powerful tools, they will control the situations faster and the tragedy might happen less.

1.2 Target applications

Thus, we design drones for the need, including:

(1) Crowd Density Recognition – helping the police understanding situations

(2) Emergency Alert System – helping the police directing crowd

(3) Base station – solving network congestion

(4) Directing Traffic System – helping the police directing traffic

(If drones are not use in large events, it could help other polices' jobs)

Chapter 2 System Architecture

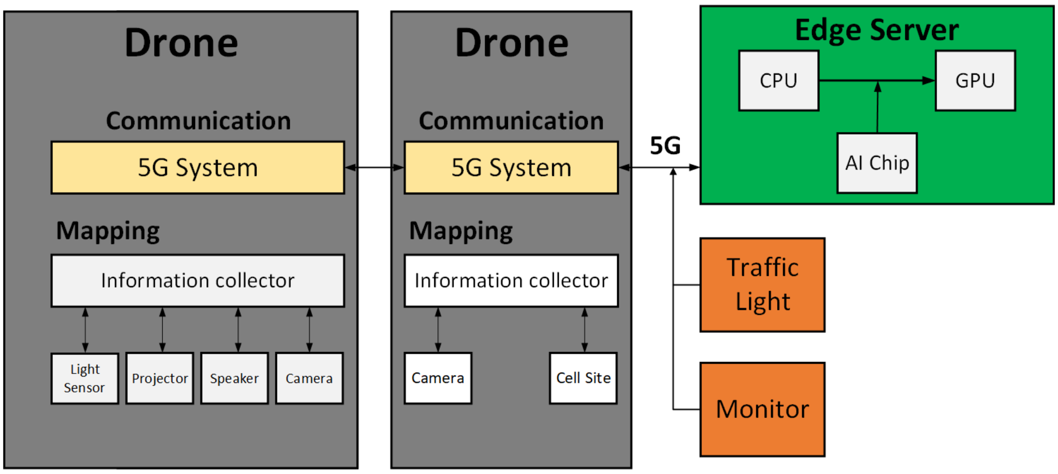


Fig. 2.1 System Architecture

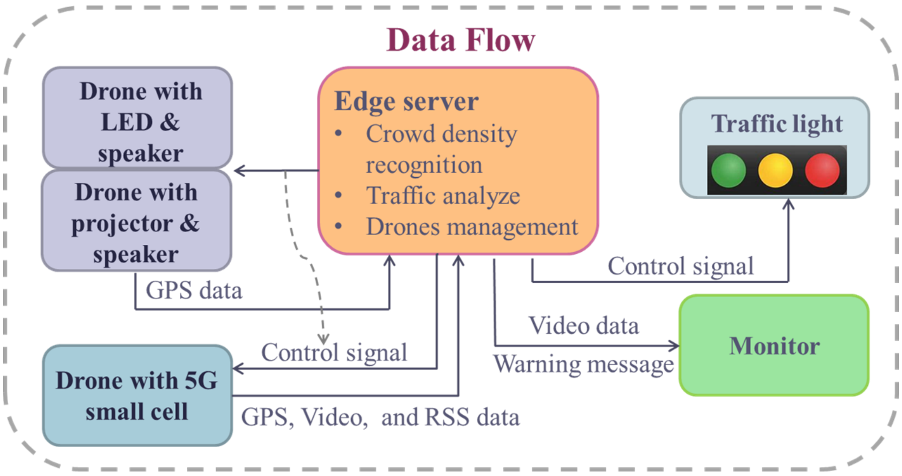


Fig. 2.2 Data Flow

This system architecture consists of two parts, a drone configured with a Soc and an edge server. The edge server includes a CPU, GPU, and AI chip. The GPU has strong computational power and can be used for image processing. We will configure a Soc in the drone, which has a 5G chip that can be responsible for transmitting messages. Specifically, the edge server sends data to the Information Collector through 5G, and the Information Collector sends it to the Monitor, where the police can control traffic through the Monitor. The edge server also controls traffic lights through 5G to facilitate traffic flow.

Chapter 3 Technology Analysis

3.1 Drone

3.1.1 The Main 6 Parts of a Drone

(1) Flying Platform

The size of the flying platform depends on the size of the propellers and the volume of the motors. The longer blade the rotors and the bigger the motors are, the frame will increase accordingly. The frame is generally made of light materials to reduce payload.

(2) Flight control system

The flight control system (Flight Control System) is referred to as "flight control", which generally has built-in controllers, gyroscopes, accelerometers, and barometers. The drone relies on these sensors to stabilize the body, and with the GPS and barometer data, the drone can be locked at the specified position and altitude

(3) Propulsion System

The propulsion system of the drone is mainly composed of propellers and motors. When a propeller rotates, it can generate a reaction force to drive the body to fly. The system is equipped with an electronic speed controller, which is used to adjust the rotating speed of a motor.

(4) Remote Control

This refers to "Remote Controller" or "Ground Station", which allows aerial photography players to control the flight movements of drones through remote control technology.

(5) Remote Control Receiver

The main function is to allow the aircraft to receive the remote control command signal sent by the remote control. A 4-axis drone must have at least 4 channels to transmit signals in order to control each of the 4 sets of rotation axes and motors.

(6) PTZ Camera

At present, the aerial photography cameras used by drones, in addition to the cameras present by drone manufacturers on the aircraft, some models allow users to install third-party cameras by themselves. The aerial camera is mainly installed on the drone through the Gimbal. The gimbal can be said to be the most important part of the entire aerial photography system. Whether the picture of the aerial video is stable or not depends entirely on the performance of the gimbal. The gimbal generally has two sets of built-in motors, which are responsible for the up and down and left and right swings of the gimbal, so that the camera mounted on the gimbal can maintain the same rotation axis, so that the aerial image will not shake due to the vibration of the drone.

3.1.2 Drone Movement Mechanism

(1) Vertical Movement

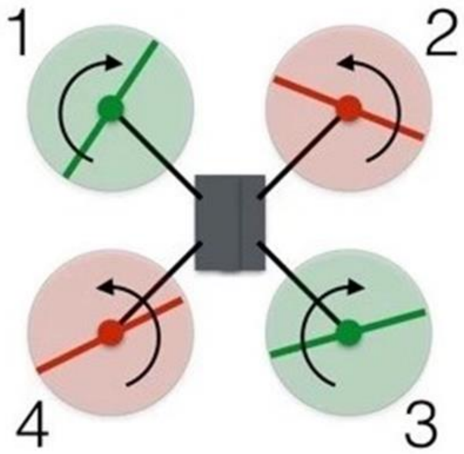


Fig. 3.1 The Rotors of the Drone

Drones use propellers and motors to achieve forward and stop. The reaction force means that when the rotors push the air, the air also pushes the rotor in the opposite direction, this is the basic principle of the drone's ability to go up and down. Therefore, the faster the propellers spin, the greater the lift and vice versa. Nowadays drones can do three things, hover, ascending and descending. About how to achieve these three things, we use the above figure to explain. As shown in the figure, the red rotors rotate counterclockwise, and the green rotors rotate clockwise. When the two sets of rotors rotate in opposite directions, the total angular momentum of the drone is zero. Angular momentum is like momentum, momentum relies on mass and velocity, angular momentum also relies on mass and angular velocity. It means the faster the propellers spin, the higher the angular momentum is:

$$\mathrm{L} = \mathrm{r} \times \mathrm{p} = \mathrm{r} \times (\mathrm{mv}) = r \times \big(\omega \times (mr)\big) = mr^2\omega = I\omega$$

Assuming that the red rotors has positive angular momentum and the green rotors has negative angular momentum, the value of each rotor is divided into -2, +2, -2, +2, Then all the angular forces and forces add up to zero at this point, the drone can thus hover in the air. So how to achieve the ascending and descending? Just increase the thrust of the four rotors to create an upward force greater than gravity. After the action is completed, the thrust of the drone can be relatively reduced, but in order to make it continue to fly upwards, it must be ensured that the upward force is greater than the downward force. The requirement to lower the drone is the opposite, keeping the resultant force downward.

(2) Rotation

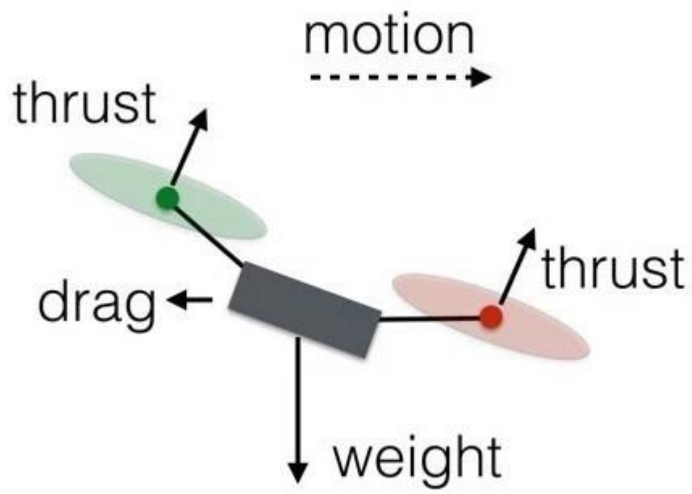


Fig. 3.2 The Rotation of Drones

How to turn the drone to the right? In this case, the angular velocity of rotor 1 and 3 needs to be reduced. While the lack of thrust from rotor 1 and 3 can cause the drone to change direction, at the same time the upward force is not equal to the downward force of gravity, so the drone will descend. In order to maintain the same altitude when changing direction, we need to decrease the rotation speed of rotors 1 and 3 while increasing the rotation speed of rotors 2 and 4, at this time, the angular forces of the rotors are still not zero, so the drone can rotate. And the total forces are still equal to gravity, so the drone can still maintain balance.

(3) Fly Forward and Sideways

What is the difference between the forward and backward movement principles of the drone? Actually not, because drones are symmetrical. This also works for lateral movement. By increasing the speed of rotors 3 and 4 and decrease the speed of rotors 1 and 2. At this point, the total thrust is equal to the weight, so the drone can maintain the same height. Also, since one rotor at the rear spins counterclockwise and the other spins clockwise, the added spin will still be zero, the same is for the rotors in the front. However, the additional force on the rear rotor of the drone will tip it forward, so the thrust on all rotors should be increased slightly to produce a net thrust. So, when you want the drone to move forward, let the front of the body tilt down. The same is true when moving left and right, causing the part of the body in the forward direction to tilt down.

3.1.3 Drone Sensors

(1) Gyroscope

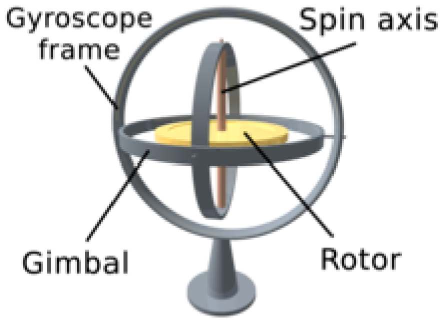


Fig. 3.3 Gyroscope

The gyroscope can calculate the tilt angle of the body and is an indispensable sensor for stabilizing the body. In contrast, an accelerometer, which is very similar to a gyro sensor, is used to detect speed. The combination of the gyro sensor and the acceleration sensor can simultaneously calculate the change of "tilt status" and "speed", and control the body to pull back in the opposite direction of the tilt direction to keep the body balanced and hover in the air. The gyro sensor and the acceleration sensor are the key sensors that can maintain the drone's attitude balance. It can sense the rotational angular velocity of one or more axes, and can accurately sense the complex movement in free space. Therefore, the gyroscope becomes a necessary motion sensor for tracking the moving orientation and rotation of the object. Unlike accelerometers and electronic compasses, gyroscopes can function autonomously without any external forces such as gravity or magnetic fields

(2) Barometer

Fig. 3.4 Barometer

A pressure sensor, also called a barometer, senses the relative and absolute height of an object through changes in air pressure. The higher the altitude, the lower the air pressure will be detected by the air pressure sensor, so the drone can refer to the air pressure number to maintain a specific altitude. But after all, this can only be used to detect air pressure. If the air pressure changes due to gusts or other reasons, it may lose its function. Barometers are sensors used to measure the pressure of liquids and gases. Similar to other sensors, the pressure sensor converts pressure into an electrical signal output during operation. Barometers are used extensively in many monitoring and control applications. In addition to direct pressure measurement, these sensors can also be used to indirectly measure other quantities, such as liquid/gas flow, velocity, water surface height or altitude. Barometers vary greatly in technology used, design, performance, working conditions and price.

(3) Accelerometer

Accelerators can be used to sense linear acceleration and tilt angle, and single or multi-axis accelerometers can sense the magnitude and direction of combined linear and gravitational acceleration. The basic principle of acceleration sensing is quite simple. This type of accelerometer is a movable structure designed using special silicon material properties. Its mechanical structure includes a movable mass and a spring connected to the opposite fixed end of the sensor. as the two poles of the capacitor. When the outside world causes relative displacement between the mass block and the fixed end of the spring due to acceleration, the capacitance between the two poles will change. Through a special circuit, this change can be converted into a corresponding output signal, and then the relative acceleration value can be obtained. However, if there is only one direction of the acceleration sensor, there are relatively few applications. Therefore, in order to apply to the real 3D world, we will further expand it into three directions, that is, the three-axis acceleration sensor , so it can detect the acceleration data of X, Y, and Z, and judge the current motion state according to the three-axis information, and then promote a large number of applications.

(4) GPS

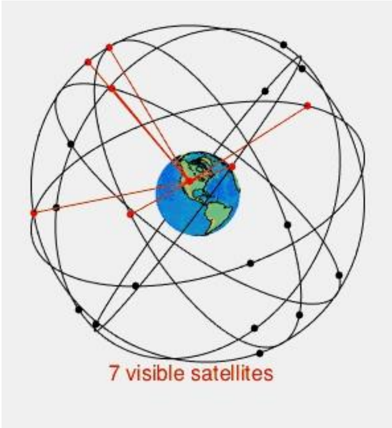


Fig. 3.5 GPS

GPS implements the concept of "time difference of arrival" (delay): using the precise position of each GPS satellite and the navigation information generated by the continuously sent deep space atomic clock to obtain the time difference of arrival from the satellite to the receiver. GPS satellites continuously send radio signals with time and location information in the sky for GPS receivers to receive. Due to the distance factor of transmission, the time when the receiver receives the signal is delayed compared with the time when the satellite sends the signal, which is usually called time delay. Therefore, the distance can also be determined through time delay. The satellite and the receiver generate the same pseudo-random code at the same time. Once the two codes are time-synchronized, the receiver can measure the delay; multiply the delay by the speed of light to get the distance. The figure shows the delay principle of the GPS system. The computers and navigation information generators on each GPS satellite know its orbital position and system time very precisely, and a global network of monitoring stations keeps track of the satellite's orbital position and system time continuously. The master control station at Schriever Air Force Base in Colorado, along with its operations and control section, injects correction data into each GPS satellite at least once a day. The injected data includes: orbital position determination and on-board clock corrections for each satellite in the constellation. These corrections are calculated on the basis of complex models and remain valid for several weeks. The GPS system time is maintained by the cesium and rubidium atomic frequency standards of the atomic clocks on each satellite. These star clocks are generally accurate to within a few nanoseconds of Coordinated Universal Time (UTC), which is maintained by the "master clocks" of the Naval Observatory, each with a stability of several 10-13 seconds. GPS satellites used two cesium frequency standards and two rubidium frequency standards in the early stage, and then gradually changed to more rubidium frequency standards. Typically, only one frequency standard per satellite is active at any given time.

(5) Magnetic Field Orientation Sensor (magnetometer)

The magnetic field orientation sensor is sometimes directly called a compass, which can sense the earth's magnetic field (geomagnetism), so as to know which direction the drone is currently facing, east, west, north, south. However, magnetic north (magnetic north) differs from map north by a certain amount, known as magnetic declination. And with the different time and place, the magnetic declination is not the same. For example, Sapporo's magnetic north is 9° west of the north on the map, but Naha is only 5° off (referenced from the website of the National Geological Institute of Japan). Therefore, if you fly the drone in another place, you need to perform "compass calibration" to reconfirm the difference between the north indicated by the magnetic field sensor and the actual north. About how to calculate the direction angle and make tilt compensation, we must first discuss the calculation of the tilt angle. As the name suggests, the Accelerometer is to detect the magnitude of the g-force and the direction of movement. When the accelerometer is placed horizontally, there will be 1g of gravity on the Z-axis. As the device is changed, the g-value will change in different axes. You can know the transformation of posture. Also because of this characteristic, when the G sensor is stationary, the inclination angle can be calculated by the formula of arcSin/arcCos. Although the G sensor can detect the inclination angle, it has an innate characteristic, that is, the resolution from 0° to 60° Very high (0.1 degree resolution can be achieved in 12bit ADC), but the resolution will drop from 60 degrees to 90 degrees (about 1 to 3 degrees of variation). In the electronic compass, the direction angle can be obtained by reading the output of the X and Y axes and putting them into the formula of arcTan(Y/X).

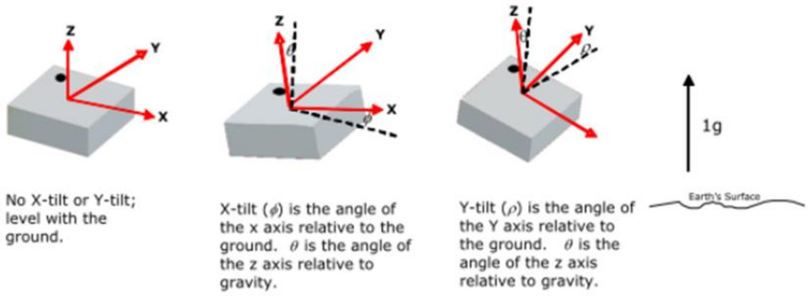


Fig. 3.6 The picture showing X-tilt and Y-tilt

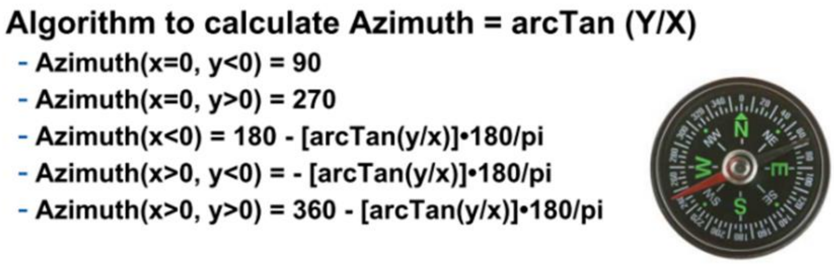


Fig. 3.7 The Algorithm to Calculate Azimuth = arcTan(Y/X))

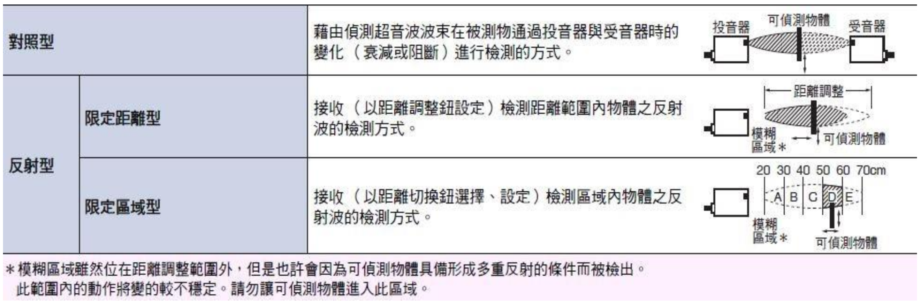
$$X' = X * \cos(\emptyset) + Y * \sin(\theta) * \sin(\emptyset) - Z * \cos(\theta) * \sin(\emptyset)$$

$$Y' = Y * \cos(c) + Z * \sin(\theta)$$

But if you add the variable of the tilt angle, you will need to use the projection theory to do additional calculations on the X and Y obtained by the original compass and the pitch and roll obtained by the G sensor. In this way, X' and Y' can be obtained, and then calculated Bring in the original formula to get the value after inclination compensation. In this way, no matter how the user flips the device on the hand, the direction of the electronic compass pointer will not be erratic and unclear.

(6) Rangefinder (Proximity sensor (ultrasonic sensor))

The ultrasonic sensor can use the echo of ultrasonic waves to sense its own height. When the drone is taking off or landing, if the drone near the ground cannot collect enough altitude information through the air pressure sensor, the ultrasonic sensor will be used. Using a barometric sensor at high altitude and an ultrasonic sensor near the surface, the combination of the two sensors can allow the drone to maintain a certain altitude in each altitude range. Ultrasonic waves will advance in the same medium, and there will be reflection or contrast when they touch different media. This phenomenon will be affected by the type and shape of the medium. Oscillator A component that applies pressure to electrical energy to generate ultrasonic waves, or converts ultrasonic energy into electrical signals. Generally, ultrasonic sensors use piezoelectric barium titanate oscillators, which are shaped like discs or cylinders.



對照型		藉由偵測超音波波束在被測物通過投音器與受音器時的變化（衰減或阻斷）進行檢測的方式。
反射型	限定距離型	接收（以距離調整鈕設定）檢測距離範圍內物體之反射波的檢測方式。
	限定區域型	接收（以距離切換鈕選擇、設定）檢測區域內物體之反射波的檢測方式。

＊模糊區域雖然位在距離調整範圍外，但是也許會因為可偵測物體具備形成多重反射的條件而被檢出。
此範圍內的動作將變的較不穩定。請勿讓可偵測物體進入此區域。

Fig. 3.8 The Different Types of Rangefinders

(7) Limited area (reflective type)

Since the detection distance is adjusted, in addition to the most common detection distance, the shortest detection distance can also be set (or even adjusted separately), this detectable range is called a limited area (area limitation). When adjusting the detection distance, the undetectable area between the sensor head surface and the shortest detection distance is called the non-sensing area. Due to the influence of the structure of the sensor head and the reverberation vibration, the area near the surface of the sensor head that cannot be detected is called the fuzzy area. However, the object to be measured in the blurred area may be detected due to multiple reflections between the sensor and the object.

3.1.4 Drone Specification

Our drones have three different type and the specification is like the following pictures.

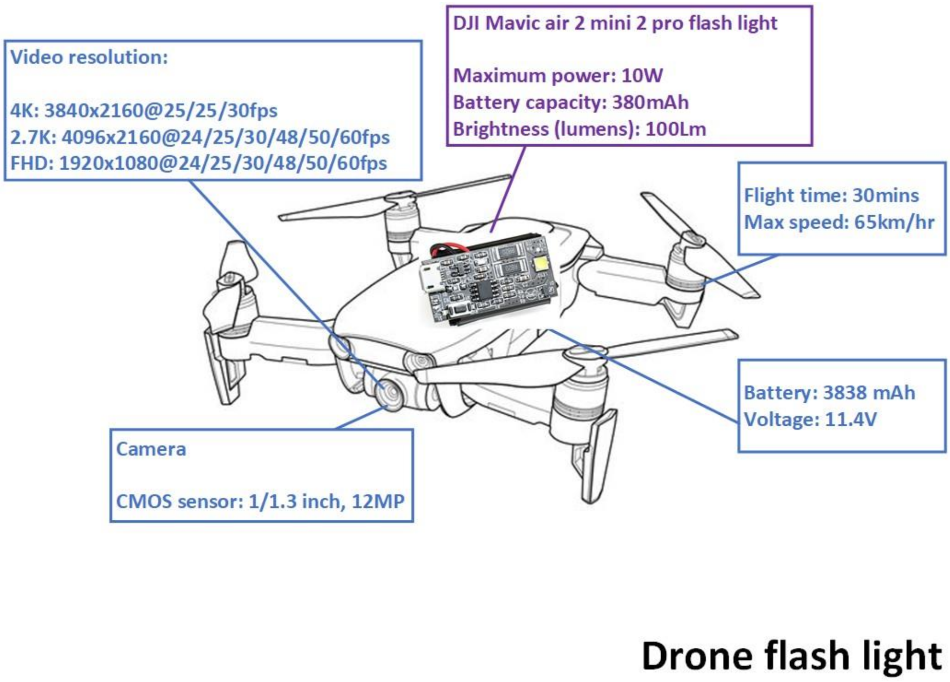


Fig. 3.9 Drone Flash Light

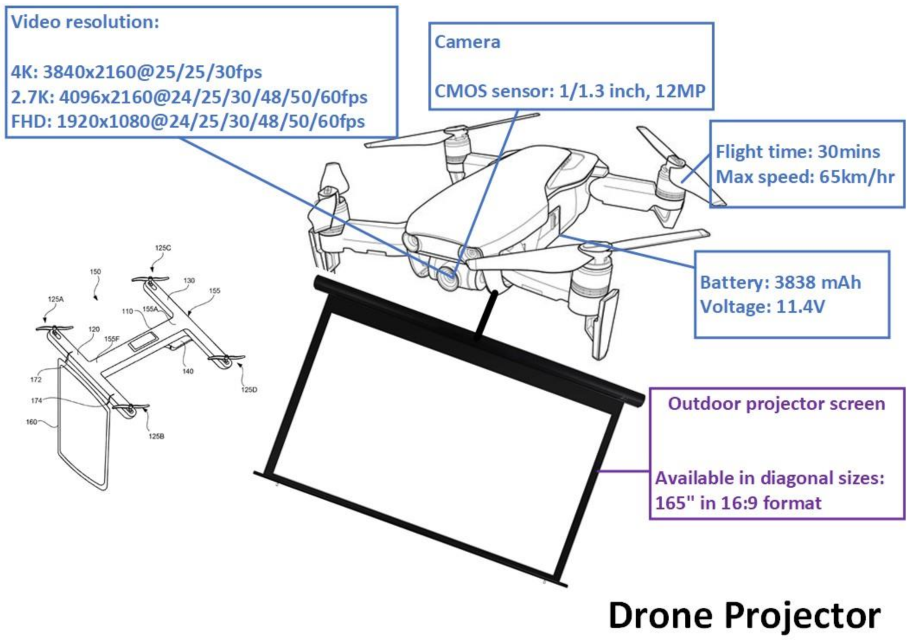


Fig. 3.10 Drone Projector

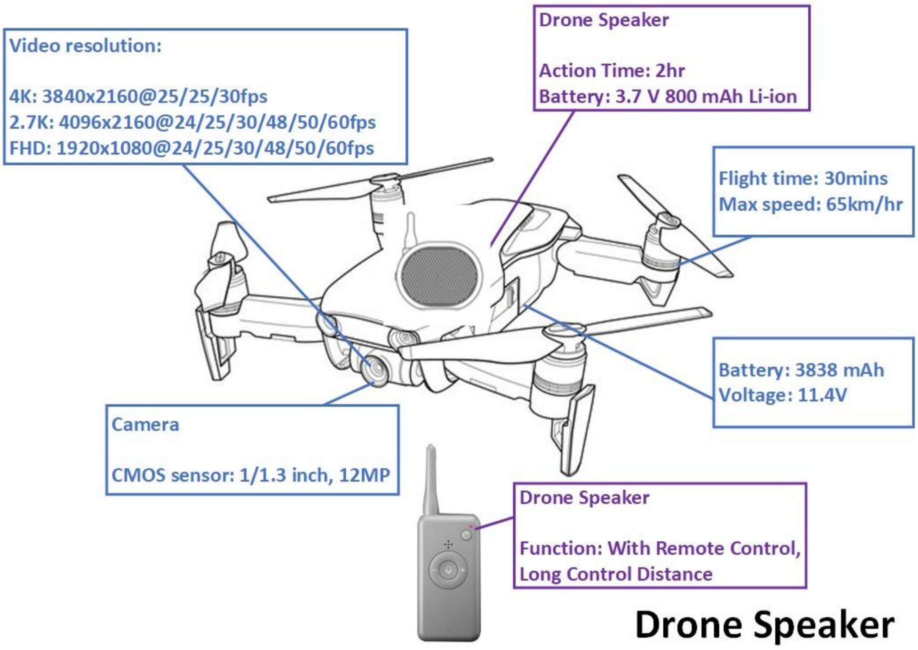


Fig. 3.11 Drone Speaker

3.2 Soc Specification

Our Design focuses on the whole system and algorithms so SoC design is based on Qualcomm® Robotics RB5 Development Platform. The Specification shows in the following table.

SoC Specification	
CPU	MediaTek Dimensity 9200
GPU	Qualcomm® Adreno™ 650 Native 8-bit integer support for efficient GPU DNN OpenGL ES 3.2, Vulkan 1.1, DX12 FL 12_1; OpenCL 2.0 full profile
RAM	8 GB LPDDR5 2750 MHz POP
Storage	Toshiba THGJFCT0T44BAIL (1 Tb NAND FLASH) and1 x MicroSD card slot

Table 3.1 SoC Specification

We will discuss more details about our cameras, 5G system and AI algorithm for drones in Chapter 3.2.1 - 3.2.4. Afterwards, we will introduce our edge server in Chapter 3.3. Finally, we will introduce our target applications in Chapter 3.4 - 3.7, including:

(1) Crowd Density Recognition

(2) Emergency Alert System – Drones Projector and Drone Speaker

(3) Base station – Flying cell site

(4) Directing Traffic System – Traffic Analysis

3.2.1 Camera

3.2.1.1 Camera Specification

Camera Specification	
CMOS sensor	1/1.3 inch, 12MP
Angle of view	82.1 degree
Equivalent focal length	24 mm
Aperture	f/1.7
Focus point	1 meter to infinity
Video resolution	4K: 3840x2160@25/25/30fps
	2.7K: 4096x2160@24/25/30/48/50/60fps
	FHD: 1920x1080@24/25/30/48/50/60fps

Table 3.2 Camera Specification

3.2.1.2 Principle of CMOS image sensor

CMOS image sensor is an active pixel sensor, the basic structure of CMOS image sensor is depicted as follows:

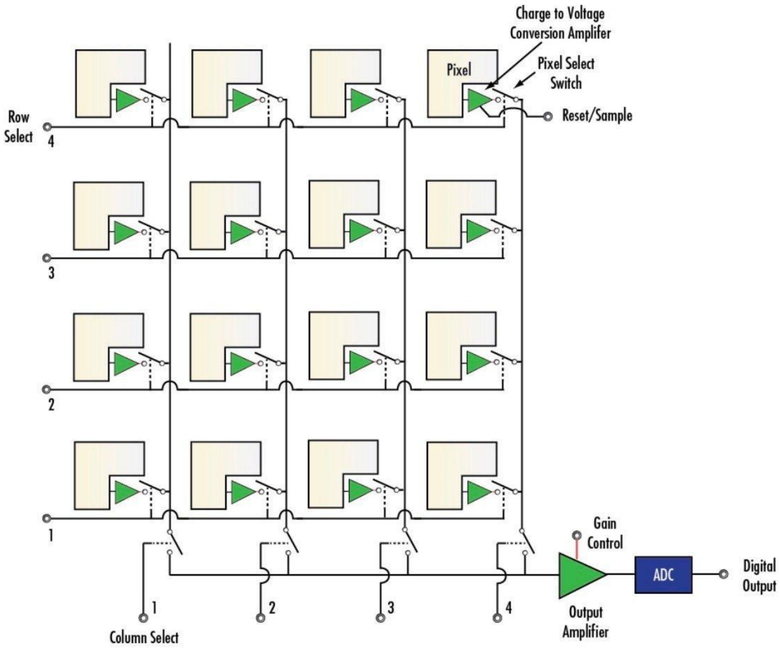


Fig. 3.12 The Basic Structure of CMOS

Each pixel location contains not only the photodiode but also an amplifier. A two-dimensional array of photo-detectors is used to sense the incident light intensity. The charge created by a photo-detector is converted to a voltage signal and passed on the output amplifier through an array of “row select” and “column select” switches. An ADC is used to digitize the amplifier signal. The pixel values of a given row are transferred in parallel to a set of storage capacitors and then, these transferred pixel values are read out sequentially.

The advantage of CMOS image sensors are fabricated in a standard CMOS technology. Therefore, it allows us to integrate the sensor with other analog and digital circuits required for a system. The disadvantage of the CMOS image sensor is that there are several active devices in the readout path that can produce time-varying noise. Moreover, fabrication inconsistencies can lead to mismatch between charge-to-voltage amplifiers of different pixels.

3.2.1.2 Principle of electronic image stabilization (EIS)

Electronic Image Stabilization (EIS) is an image enhancement technique that effectively adjusts and balances the captured image. The system includes a sensor integrated into the camera, reducing jittering and capturing the best stable photos. EIS incorporates two techniques to make the image stable. First, it either digitally zooms in to capture a more prominent image. If the content of the specific part of the image shifts in relation to the next image frame, the section borders also shift. As a result, the pixel that shifted in the image sensor is stored without shifting in the new coordinate system. The system can result in a slight decrease in the camera field of view, which can be observed after the system is enabled. The second method is similar to the first one, it is hardware-based, it corporates a larger sensor to resize the image to fit the available space. After detecting a shake, the coordinates of the center of the region capturing the image move correspondingly. The following figure shows how they work:

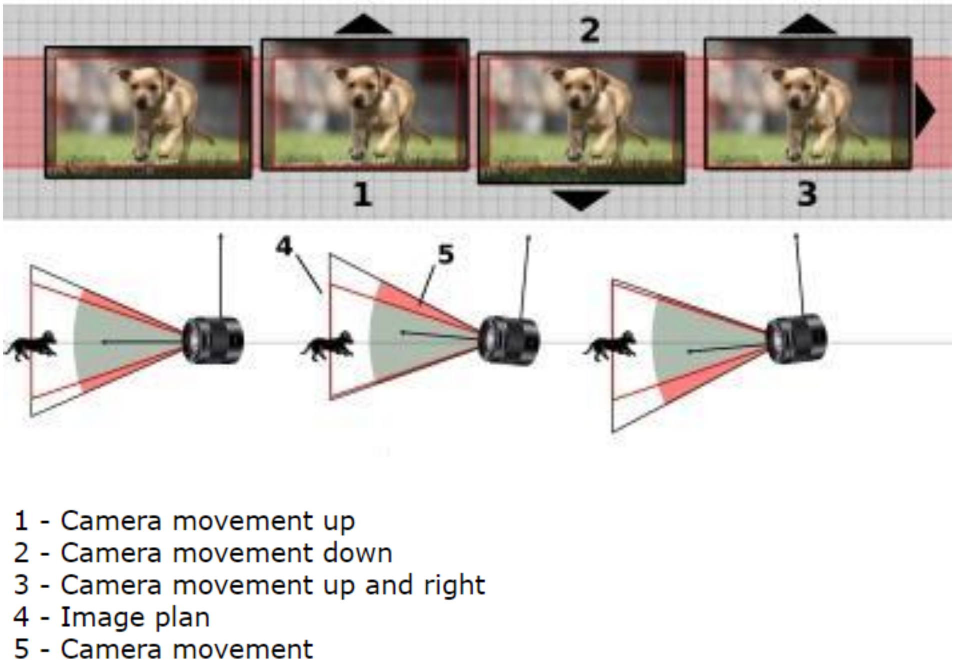


Fig. 3.13 The Figure Showing how EIS works

EIS cannot prevent blur from extreme camera shaking, but it is engineered to minimize blur from normal handheld lens shaking. The bellowing figure is an example of a camera with and without EIS technique.be

Fig. 3.14 Comparison between using EIS and without EIS

Drones fly in the air, the drone’s camera will not adjust to shaking without EIS. EIS is necessary to our drone camera since the image quality is crucial, EIS is the answer to reducing the shakiness and vibration, providing the drone users with their desired quality footage. Compare with another stabilization technique called optical image stabilization which is stabilized by a gimbal stabilizer. The EIS has a better stabilized performance since the EIS keeps improving the appearance through equal shifting, whereas the gimbal stabilizer works only after the drone has shifted.

3.2.2 5G Communication System

3.2.2.1 Overview

Nowadays, in wireless communication, 5G is the best choice. 5G has a lot of benefits like lower latency, higher data rate, wide coverage, etc. If drones use this technology to communicate, they can build more reliable channels with each other. Due to 5G coverage, users can control drones from much further place without worrying about obstacles to interfere signals. Besides, it provides a more efficient way. Therefore, it also improves the power efficiency.

3.2.2.2 5G

In 2019, 5G began developing worldwide. 5G is the fifth-generation technology standard for broadband cellular networks. It is meant to deliver higher multi-Gbps peak data speeds, low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience to more users.

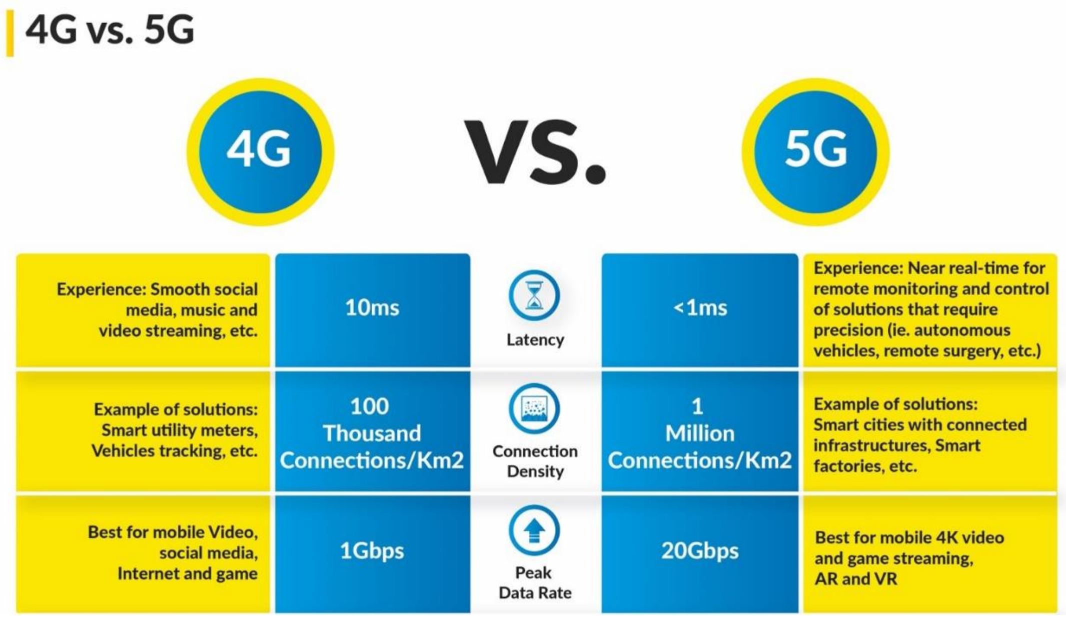


Fig. 3.15 Comparison between 4G vs. 5G

3.2.2.3 The Radio Access Network

5G Marco cell uses MIMO to receive and send more data simultaneously. Thus, it can provide more user to connect and maintain high throughput. Besides, there is another facility called “small cell”. Small cell is a major feature for 5G network. 5G has new millimeter wave frequency but the connection range is short. 5G small cell is as a hybrid between a Wi-Fi router and a macro cell for cellular networks. It enables the network to extend coverage and to deliver lower latency, and also serve more users while maintaining multi-Gbps performance.

Fig. 3.16 Comparison between 4G vs. 5G

3.2.2.4 5G NR (New Radio)

Frequency band for 5G NR are divided in two different ranges. One is Frequency Range 1 (FR1) and it includes sub-6 GHz frequency bands (it might be up to 7.125 GHz) ; the other one is Frequency Range2 (FR2) and it includes frequency bands for 24.25 to 71GHz.

In Taiwan, the carriers used two frequency bands and they are 3.5 GHz and 28 GHz. The range of 3.5GHz is further and the facilities are more complete. 28 GHz frequency band can provide higher peak data speeds but it will be influenced by obstacle and its coverage is shorter. Besides, the facilities are not complete.

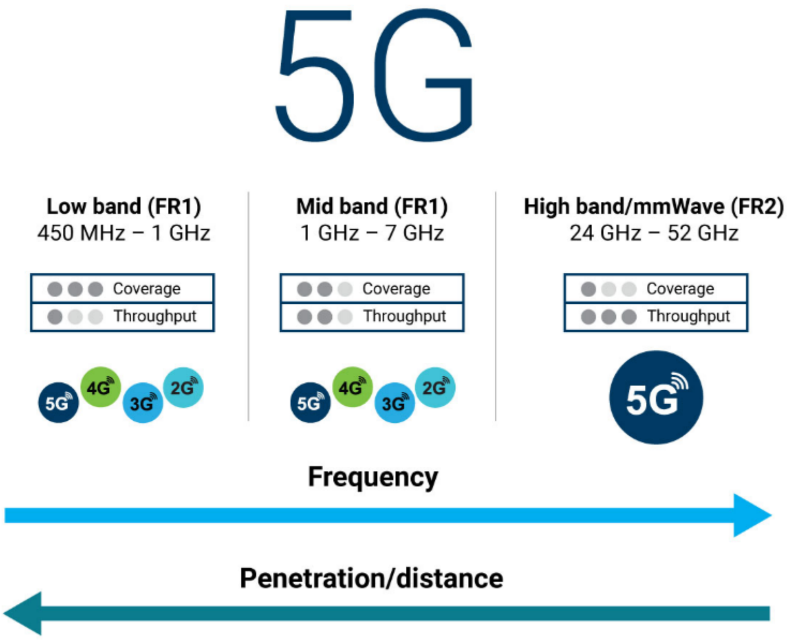


Fig. 3.17 5G Radio Frequency Spectrum

Besides, 5G enables a smart way to segment the network for a particular industry, business or application. For example, emergency services could operate on a network slice independently from other users. In our countries, there are some frequency bands reserving for the police. Using these frequency bands to transmit the video can prevent from interference with other channels. It also provides safer environments and lower latency.

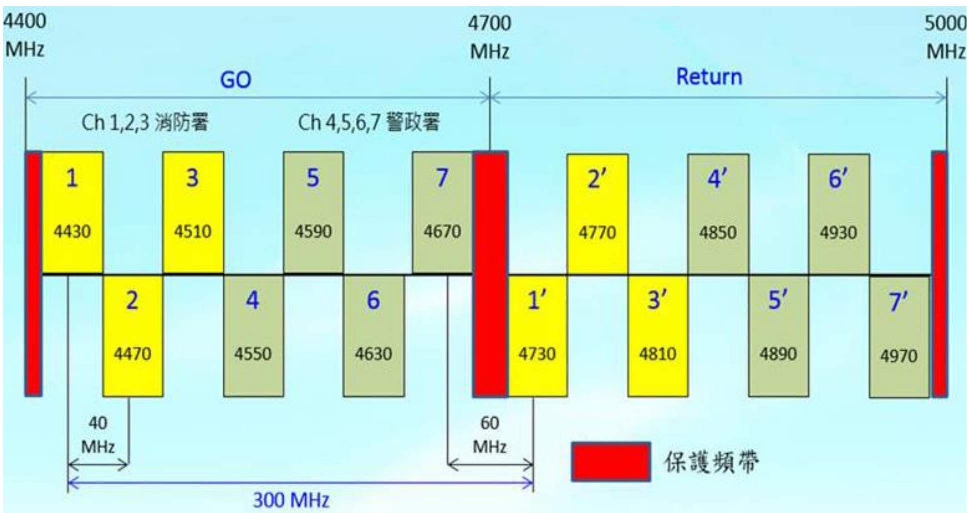


Fig. 3.18 The Frequency Bands for The Police and Nation Fire Agency

3.2.2.5 MediaTek Dimensity 9200

In 2022 November, MediaTek launched their new product, Dimensity 9200. It is with TSMC 4nm process. Dimensity 9200 supports both mmWave 5G and sub-6GHz.

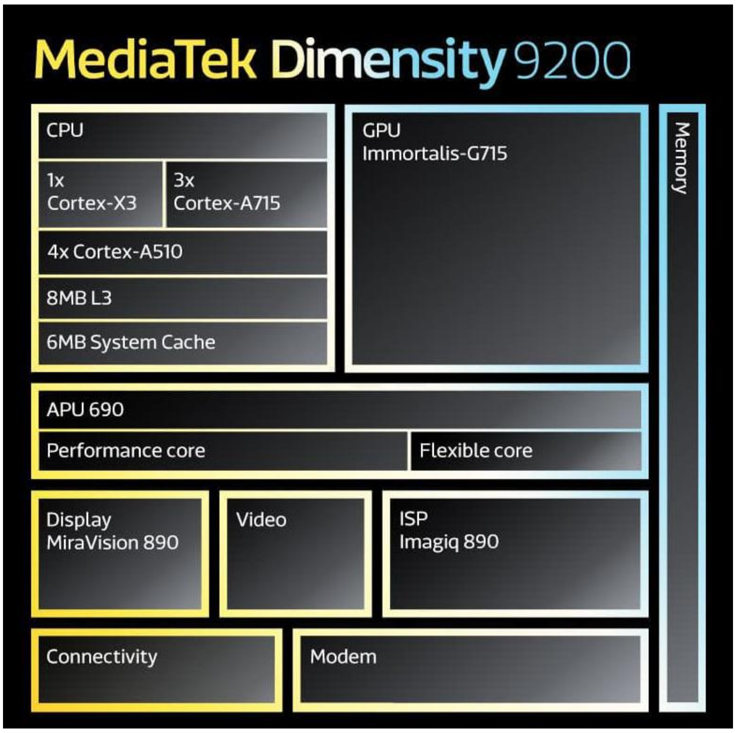


Fig. 3.19 Dimensity 9200 Block Diagram

MediaTek Dimensity 9200 specification

Process	TSMC 4nm (N4P)
Prime core	1 x Cortex-X3 @ 3.0 Ghz
Performance cores	3x Cortex-A715 @ 2.85GHz
Efficiency cores	4x Cortex-A510 cores @ 1.8GHz
GPU	ARM Immortalis-G715
RAM	LPDDR5x at up to 8,533Mbps
Storage	UFS 4.0
Connectivity	5G Sub-6 GHz, mmWave, Wi-Fi 7 and Bluetooth 5.3
Display	5K (2.5Kx2) @ 60Hz, WHQD @ 144Hz, 1080p @ 240Hz

Fig. 3.20 Dimensity 9200 Specification

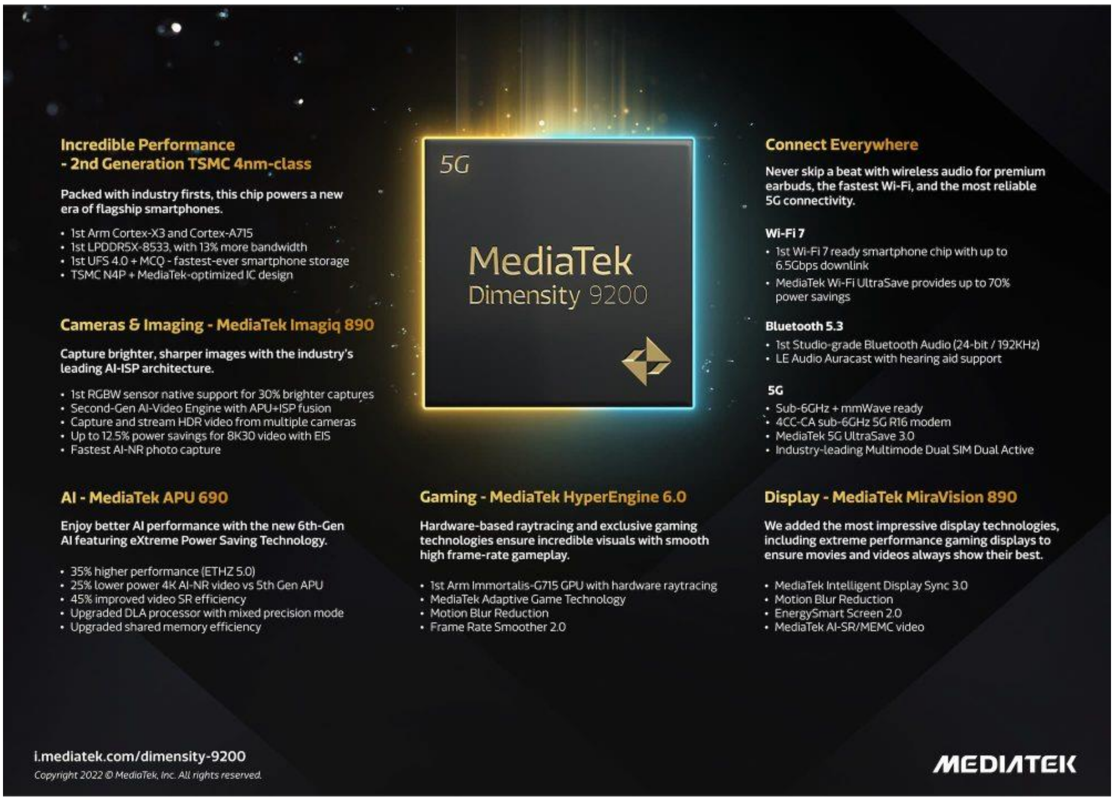


Fig. 3.21 Features of Dimensity 9200

There are other key features of the MediaTek Dimensity 9200 that is suitable for our design. First one is that cutting-edge display technology supports FHD+ up to 240Hz, WHQD up to 144Hz and 5K (2.5K*2) up to 60GHz. Second is that MediaTek AI-SR/MEMC provides best-in-class video streaming. These features ensure the quality of the videos. Otherwise, in comparison to the Dimensity 9000, MediaTek promises a 32% increase in performance and a 41% decrease in power usage. The power consumption is a big problem for the drones. Therefore, to lower the power is also an important target. Last, it also supports Wi-Fi 7. Although our design mainly uses 5G communication, it is convenient in some small areas.

3.2.3 AI Algorithm

3.2.3.1 An AI-based autonomous drone

Our UAV can be put in the category of AI-based autonomous drones. We want it to be this way because it brings several advantages. Autonomous means there is no human operator which can easily translates into a cheaper and safer device since there is no human error. Little to none error ensure consistency and quality, which makes the data more accurate.

Now that we have listed the advantages of our drones being autonomous, the next step will be to explain how we can achieve this. In order to have a self-navigating UAV, as mentioned previously we will need to rely on AI. This is because if we collect data by using sensors or by any other mean, and let an AI interpret it with the objective of training a learning algorithm, that will help the drone in terms of problem-solving and decision-making for various situations.

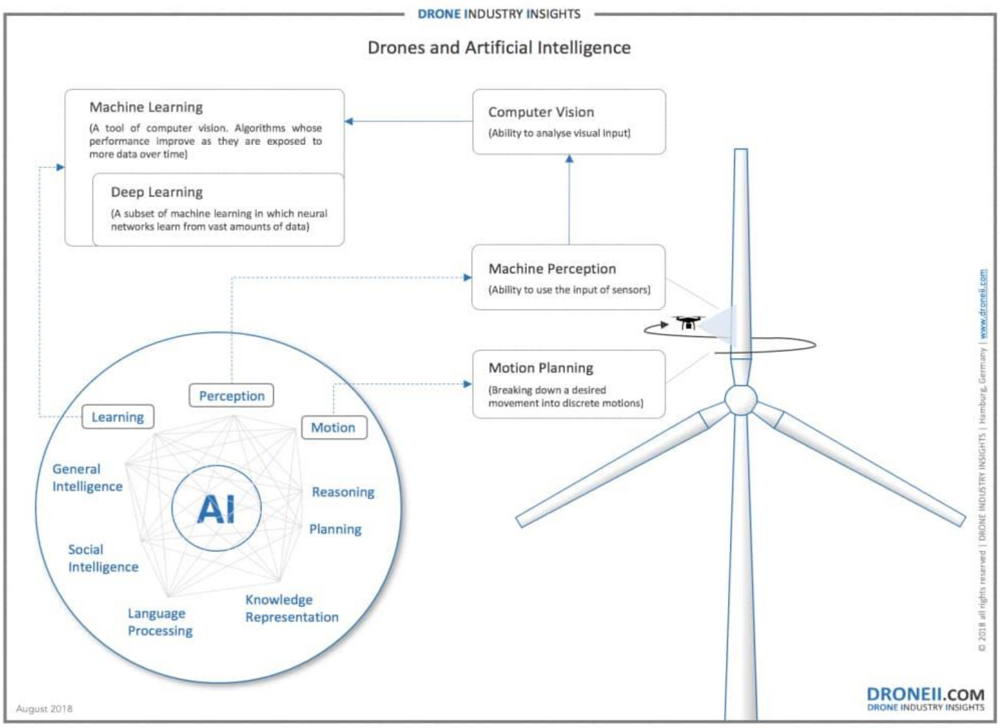


Fig. 3.22 Drones and Artificial Intelligence

One of the biggest applications of AI in drones is computer vision. We have decided that our drones will definitely use computer vision for functions such as obstacle and object detectors. These detectors are key when helping our drone to find the fastest collision free path to reach its destination. More of our computer vision model was be discuss previously when talking about our camera.

Another useful application of AI would be the ability to fly in unstructured environments. This will enable our drones to adapt to new surrounding and changing information. We want this feature because constantly constructing and updating maps or paths is very impractical for any complex environment. Specially because our drones will have pre-programmed flight paths and if there is any small or big change in their surroundings it will be important for them to know how to adjust their flight to complete their mission. Therefore, by giving ours drones the ability to understand their environment we will save ourselves from doing this job.

3.2.3.2 AI powered flight controller

In order to compute all of our AI algorithms we will need an AI-powered flight controller that has the right types of sensors, capable of following a preprogrammed flight path and therefore perfect for autonomous navigation.

3.2.3.3 Positioning system

For a drone to navigate it first should have a good positioning system that is suited for the its specific needs. If our objective was to navigate indoors, we could use WIFI or even Bluetooth positioning systems. But our drone is meant for outdoors so for the localization and mapping system we will depend on our GPS. A second option would be to rely on vision-based methods that are capable of identifying streets or roads for localization. In conclusion, for our design we will need to have a really good GPS system built-in, this will allow us to plot a flight path ahead of time.

3.2.4 Multi-Drone system management

3.2.4.1 Path Planning for multi-drone system

We planned to divide a given area that we wish to monitor into different regions, let's say region A, B and C. Each region will have their own set of drones around it and also have nodes where they should go and stop for some time to monitor or do other task. The drones though from different regions, will have the same launch point and when they finish traveling through all of the nodes in their flight path, they will return to the same launch point and be replace with other set of fully charge drones while this last set will be recharging. In this way we will always have a set of drones in every desired region. Since we have 3 different types of drones, each set of drones will consist of at least one of each kind (one drone speaker, project and flash light)

But how will our drones calculate their flight path? We previously mentioned the use of preprogrammed flight paths. To calculate this preprogrammed flight path, we will take in consideration variables and some constants such as: battery recharge time, battery capacity, arrival time at each node, position, crowd density and objectives of other drones.

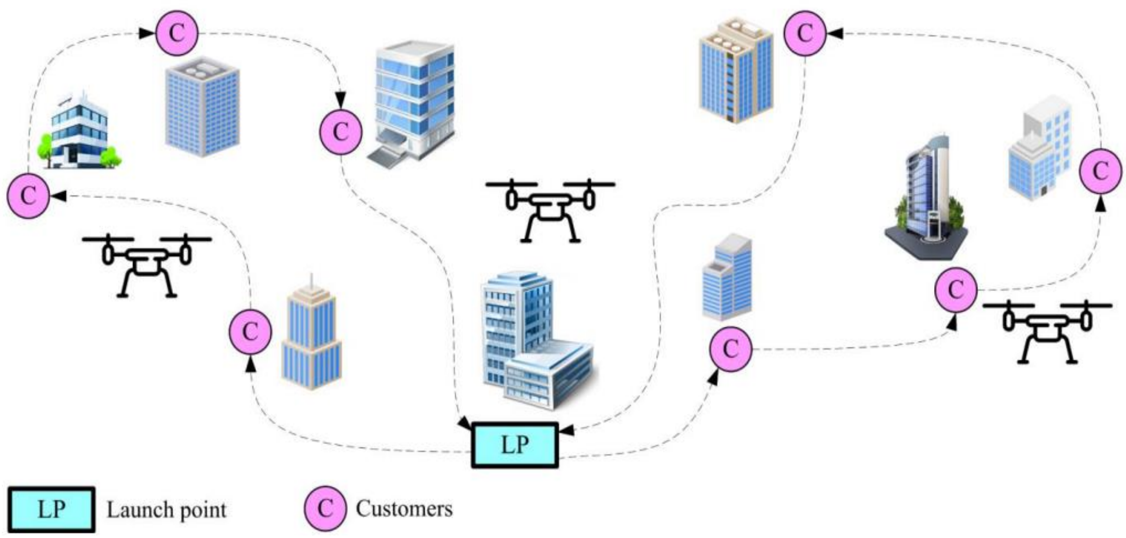


Fig. 3.23 multi-drone system flight path

3.2.4.2 General Drone Scheduling Problem (GDSP)

Drone scheduling is one of the key problems that have received increasing attention over the last decade. Drone scheduling is associated with several features, such as launch points, nodes, objectives, monitoring, and battery capacities. For this problem, set of drones are launch from a launch point to head towards each node. Due to battery capacity limitation, each set of drones will have a time limit before they have to return to base. They are expected finish their flight path and return to the launch point within this limited amount of time. Flying from node to node or completing any mission such as projecting an image or using the speaker, will reduce the battery levels. Therefore, the flight paths of the drones will be optimized, so that the drones can return to the launch point after being able to finish all of their task.

In addition to optimization of flight paths, drone scheduling may be associated with several other features. Each node could be assigned an arrival time window. In this case, the arrival and departure times at different nodes will also be recorded. Based on this information, different types of rules and constraints may be applied.

Clearly the optimization of the flight paths is extremely important. We plan to use GDSP to help with the task of calculating preprogrammed flight paths. GDSP is basically a set of rules and constraints that make sure the path planning for our multi-drone system actually works in the most optimized way possible, with the least number of errors.

General Drone Scheduling Problem (GDSP):

$$\min \sum_{k\in K} p_k \boldsymbol{h}_k \tag{1}$$

Subject to:

$$\sum_{i\in I\cup C}\sum_{k\in K} \boldsymbol{x}_{ijk} = 1 \; \forall j \in I \tag{2}$$

$$\sum_{j\in I\cup C}\sum_{k\in K} \boldsymbol{x}_{ijk} = 1 \; \forall i \in I \tag{3}$$

$$\boldsymbol{x}_{iik} = 0 \; \forall i \in I \cup C, k \in K \tag{4}$$

$$\sum_{j\in I} \boldsymbol{x}_{cjk} = \sum_{i\in I} \boldsymbol{x}_{ick} \; \forall c \in C, k \in K \tag{5}$$

$$\sum_{c\in C}\sum_{j\in I} \boldsymbol{x}_{cjk} = \boldsymbol{h}_k \; \forall k \in K \tag{6}$$

$$\sum_{i\in I}\sum_{c\in C} \boldsymbol{x}_{ick} = \boldsymbol{h}_k \; \forall k \in K \tag{7}$$

$$\sum_{j\in I\cup C} \boldsymbol{x}_{vjk} = \sum_{i\in I\cup C} \boldsymbol{x}_{ivk} \; \forall v \in I, k \in K \tag{8}$$

$$\sum_{i\in I\cup C}\sum_{j\in I\cup C} d_{ij}\boldsymbol{x}_{ijk} \le D_k \; \forall k \in K \tag{9}$$

$$\boldsymbol{t}_{ik} + d_{ij} - M(1-\boldsymbol{x}_{ijk}) \le \boldsymbol{t}_{jk} \; \forall i \in I \cup C, j \in I \cup C, k \in K \tag{10}$$

$$\boldsymbol{x}_{ijk}, \boldsymbol{h}_k \in \{0,1\}, \boldsymbol{t}_{ik} \ge 0 \; \forall i \in I \cup C, j \in I \cup C, k \in K \tag{11}$$

Drone Scheduling Problem for Monitoring (DSPM):

$$\min(\max_{ik} \boldsymbol{t}_{ik}) \; \forall i \in I \cup C, k \in K \tag{15}$$

Subject to:

Constraint sets (2)-(5), (8)-(9), (14)

$$\boldsymbol{t}_{ik} + s_i + d_{ij} - M(1-\boldsymbol{x}_{ijk}) \le \boldsymbol{t}_{jk} \; \forall i \in I \cup C, j \in I \cup C, k \in K \tag{16}$$

(1) minimizes the total drone operating cost.

(2) and (3) guarantee that each customer node is visited once by only one drone.

(4) ensures that a drone cannot travel from one node to the same node directly.

(5) indicates that each drone returns to the launch point where it departed from.

(6) and (7) show the utilization of drones (i.e., how many drones are required to provide a specific service for the existing customer locations).

(8) Flow conservation of the drone flights is guaranteed

(9) ensures that the total flight duration of a drone does not exceed its maximum allowable flight duration.

(10) and (16) functions as a time conservation constraint.

(11) defines the nature of the variables in the GDSP mathematical formulation.

(15) of the DSPM mathematical formulation minimizes the maximum completion time of the monitoring tasks.

Fig. 3.24 The Algorithms of GDSP and DSPM

3.2.4.3 Data transfer

Though our drones will all be able to communicate and transfer data with the ground station, they will not be able to directly share information among each other's. If a drone wants to share data with other drone it will first need to pass through the ground station.

Our drones will transfer data such as: images (video streaming), status information (battery, localization, temperature etc.), objectives (have they performed a certain preprogrammed task).

From the ground station we can also send new tasks to our drones, these tasks can be: to move to a specific address, use speaker to give instruction to people (with the objective of traffic or crowd control)

Also, there will be offboard (first option) and onboard computations depending on the resource's constraints. But the main plan is to leave any heavy computation to be done by the edge server. We believe that since our drones are not meant for onboard heavy computation their price might reduce a bit.

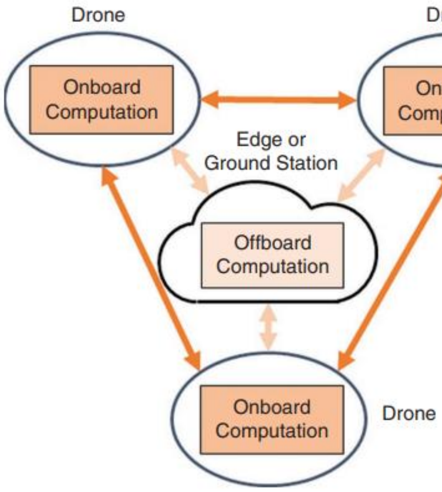


Fig. 3.25 Data transfer between drones

3.3 Edge Server

Edge Server The edge server is an important node device in the edge computing (Edge Computing) infrastructure, also known as the edge computing server. The difference from the traditional server is mainly in the back-end computing architecture and resource utilization mode. Edge computing devices can be mainly divided into two categories: one is a server installed on a network node (that is, an edge server) or a network communication device (such as an edge gateway); the other is a terminal device with an embedded computing chip (such as a sensor detector).

Edge computing is a kind of IT deployment. Different from centralized cloud computing, edge computing is a decentralized network computing architecture. Through external or embedded computing devices, data is processed and analyzed in real time near the data source or terminal, that is, to allow Applications and data are as close to the user as possible. Data does not need to be uploaded to the cloud or a centralized data processing system to reduce transmission delays and network bandwidth usage, and speed up the response speed of user services.

Edge computing and cloud computing are complementary technologies. Edge computing is responsible for the initial processing of data at the edge nodes or terminals, judging whether to respond directly or hand it over to the cloud, which can realize real-time computing; while the cloud is responsible for data storage and more efficient High-performance, low-time-efficiency calculations. Cloud computing uses centralized data centers, while edge computing uses distributed micro-data centers at the edge of the network to use data closer to where it is generated.

Today's Internet of Things (IoT) is booming, driving cloud storage and big data analysis, but with the wave of AI artificial intelligence coming, the new generation of artificial intelligence Internet of Things (AIoT) combined with IoT output or Edge AI (Edge AI) applications, there are more devices that require immediate response, and a greater amount of information needs to be processed. The huge computing demands of AIoT cannot be borne by the cloud computing architecture alone, so edge computing that can share the cloud load has been widely valued. Edge computing features such as low latency in transmission, sharing huge data volumes, reducing transmission costs, lightening cloud load, real-time computing, and local autonomy will be important drivers for the further popularization of AIoT applications.

With the increasing importance of edge computing, edge servers have become one of the popular devices. Edge servers are usually rack-mounted, blade-mounted, or compact industrial computers, and are usually placed close to data sources, terminal devices, or client terminals.

Edge server products focus on high-performance computing (High Performance Computing, HPC), which can complete complex or large-scale calculations at high speed and improve application processing capabilities; in order to achieve this goal, edge server HPC high-performance computing solutions often use cluster computing architecture , connect several nodes in series to form a group, assemble multiple CPUs or GPUs for parallel computing, and concentrate a large amount of computing power in a 1U, 2U or 4U server chassis.

Compact industrial computers, which focus on robust features, have been booming with Industry 4.0 and IoT. After the application of AIoT, edge servers will be scattered everywhere, and the deployment environment will be more diverse or more dangerous. Stronger specifications will inevitably be more popular. Pay attention to, including overcoming strong vibration, sudden impact, high and low temperature changes, etc. Lite Storage provides high-standard wide-temperature SSD products, which have passed the industrial-controlled wide-temperature test before leaving the factory, which meet the requirements of industrial applications; and meet the anti-vibration (Anti-Vibration) standard specified by the US military specification MIL-STD-810G, as well as MIL-STD -Anti-Shock standard regulated by 202G and MIL-STD-883.

3.3.1 Edge Server Specification

Fig. 3.26 W332-Z00 AMD Ryzen™ Tower Entry Workstation

Edge Server Specification	
Motherboard	MZ33-AR0
CPU	AMD EPYC™ 9654
Memory	256GB DDR5
GPU	NVIDIA A100 40/80GB PCIe GPU
Power Supply	Corsair AX1600i

Table 3.3 Edge Server Specification

(1) Motherboard

MZ33-AR0 (rev. 1.x)

AMD EPYC™ 9004 UP Server Board

- AMD EPYC™ 9004 series processor family
- Single processor, 5nm technology
- 12-Channel RDIMM DDR5, 24 x DIMMs
- 2 x 10Gb/s BASE-T LAN ports (Broadcom® BCM57416)
- 1 x Dedicated management port
- 7 x MCIO 8i with NVMe Gen5/Gen4 and SATA ports
- Max. 16 x SATA 6Gb/s devices supported
- Ultra-Fast M.2 with PCIe Gen4 x4 interface
- 4 x PCIe Gen5 x16 expansion slots

Fig. 3.27 Mother Board Specification

(2) CPU

AMD EPYC™ 9654

General Specifications	**Platform:** Server	**Product Family:** AMD EPYC™	**Product Line:** AMD EPYC™ 9004 Series
	# of CPU Cores: 96	**# of Threads:** 192	**Max. Boost Clock:** Up to 3.7GHz
	All Core Boost Speed: 3.55GHz	**Base Clock:** 2.4GHz	**L3 Cache:** 384MB
	1kU Pricing: 11,805 USD	**Default TDP:** 360W	**AMD Configurable TDP (cTDP):** 320-400W
	Socket Count: 1P/2P	**Launch Date:** 11/10/2022	
Connectivity	**PCI Express® Version:** PCIe 5.0 x128	**System Memory Type:** DDR5	**Memory Channels:** 12
	System Memory Specification: Up to 4800MHz	**Per Socket Mem BW:** 460.8 GB/s	

Fig. 3.28 AMD EPYC 9654 Specification

Fig. 3.29 AMD EPYC™ 9654

(3) GPU

NVIDIA A100 PCIe GPU 40GB and 80GB - Specifications

MEMORY

40GB HBM2

- GPU Memory Bandwidth: 1,555GB/s

80GB HBM2e

- GPU Memory Bandwidth: 1,935GB/s

CORES

- Shading Units: 6912
- TMUs: 432
- ROPs: 160
- SM Count: 108
- Tensor Cores: 432
- FP64: 9.7 TFLOPS
- FP64 Tensor Core: 19.5 TFLOPS
- Transistor Count: 54,200 million

INTERCONNECT

- PCIe Gen4: 64GB/s

FORM FACTOR

- PCIe

POWER CONSUMPTION

- 40GB- Max TDP Power: 250W
- 80GB- Max TDP Power: 300W

Fig. 3.30 NVIDIA A100 40/80GB PCIe GPU Specification

Fig. 3.31 NVIDIA A100 40/80GB PCIe GPU

3.4 Crowd Density Recognition (based on RIFNet)

A recent research focus on crowd density estimation, the performance drops dramatically for low-quality images, such as occlusion, or poor light condition. In RIFNet, they leverage both RGB images and received signals (RSS) from UAV to estimate the crowd density.

First, we need to introduce what is RSS, it is a measurement of the power in a received radio signal. Received signal strength (RSS) can be measured from each received packet in the MAC layer. Due to the attention through propagation, the RSS is related to distance between the transmitters (people) and the receivers (UAV), it can be described how far a person is from the UAV according to the RSS. This kind of information can assist the lack of information of RGB images (e.g., if the human is shadowed by a building or tree, the RSS can provide other information of the human).

With combining both RGB images and received signal, the performance and the accuracy of crowd density recognition can be increased. The figures below show the information of RSS, the left-hand figure shows the histogram of the RSS signal, which demonstrates the distance between different people. The right-hand is the transformation of the original RSS signals, the figure depicts the human density map (RDM) which is computed based on the RSS information. The center of the figure denotes the location of the drone, and the color denotes the density of each ring, which a brighter color has a higher density and darker color has a lower density.

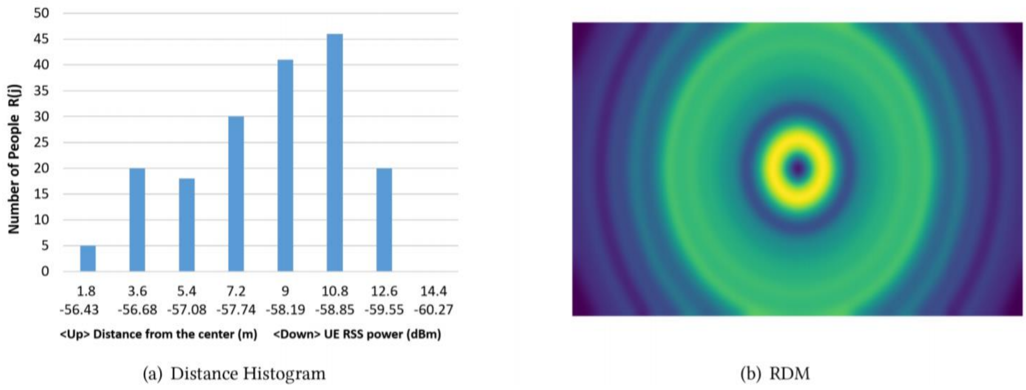


Fig. 3.32 (a) The Histogram of the RSS Signal;
(b) The Transformation of the original RSS signals

The RGB information is capture by the camera, the following figure depicts the scenario:

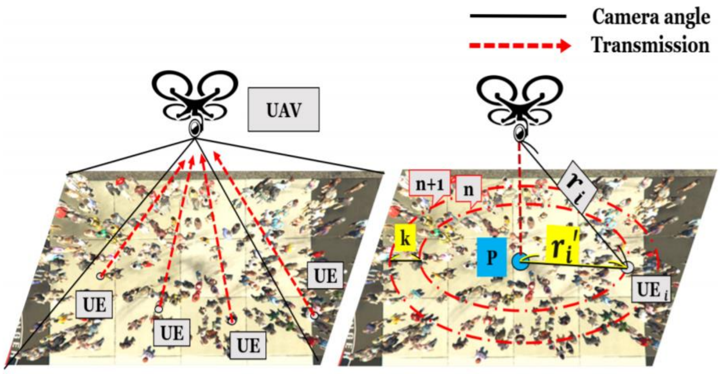


Fig. 3.33 Depicting the Scenario

The overall architecture is as follow:

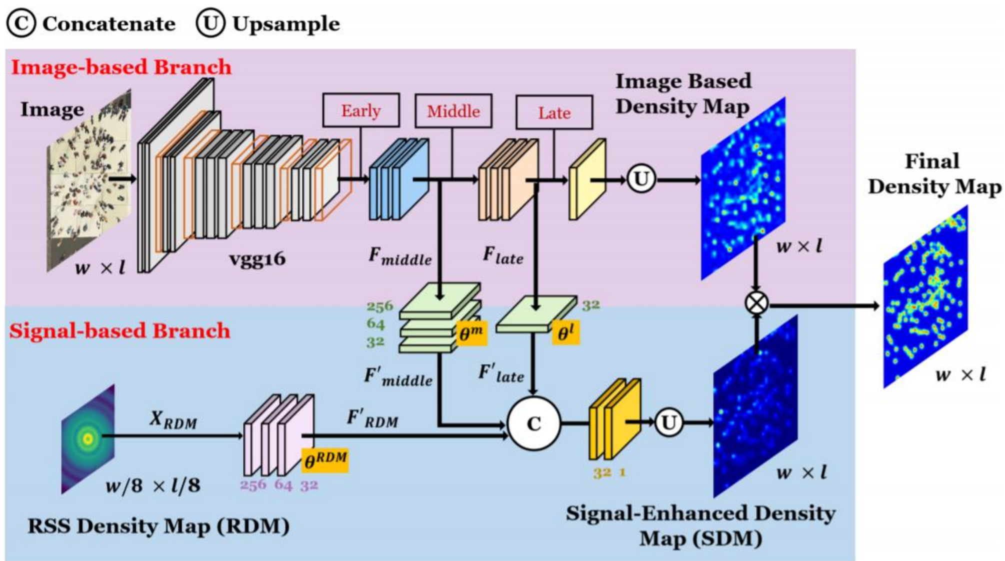
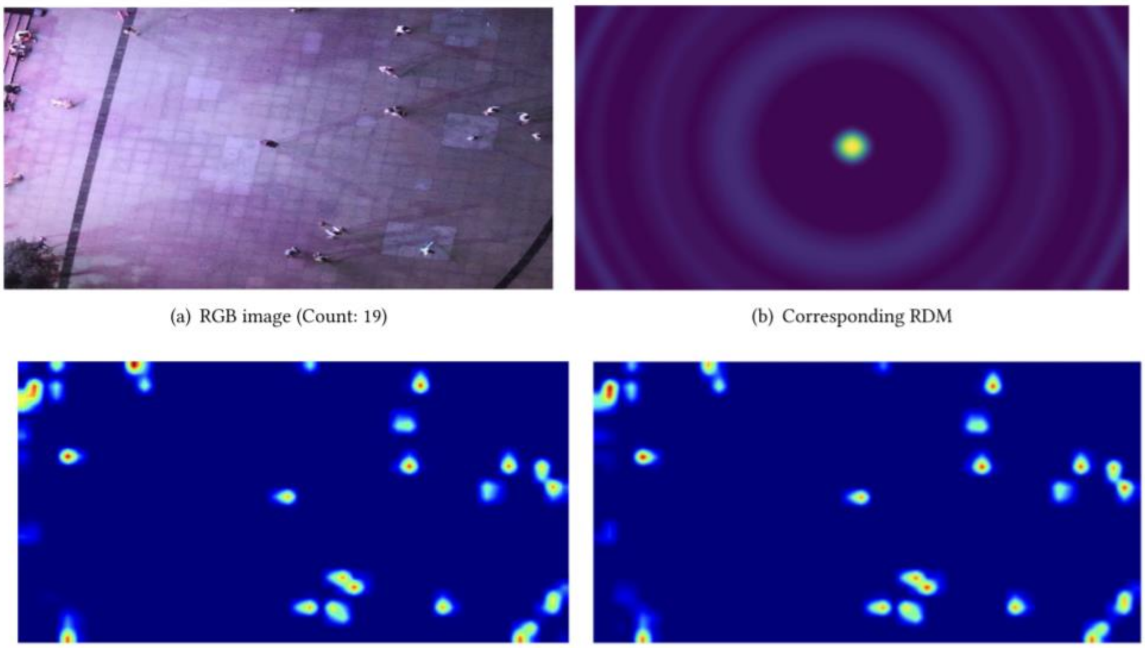


Fig. 3.34 Overall Architecture

We can find that the model has been divided into two branches, the image-based branch and the signal-based branch, both branches extract their features first, and fuse the two different modal features in different levels to exploit information from the signal-based features to complement the RGB features. The output of two branches are the density map, they have been multiplied to obtain the final density map. The density map can demonstrate the human density in heatmap and we can count the amount of people. The following figure shows the original RGB image, the RDM, and the results of the RIFNet.



(a) RGB image (Count: 19)

(b) Corresponding RDM

(c) RIFNet without RDM (Count: 26)

(d) RIFNet with RDM (Count: 24)

Fig. 3.35 The Experiment Result

The performance of RIFNet is better than the state-of-the-art methods, the following table shows the results.

	PMAE	PRMSE	MAE	RMSE
CSRNet	0.6465	0.9576	4.55	6.9686
CSRNet with direct fusion	0.8364	1.2898	5.80	7.6851
CSRNet+RIFNet (ours)	0.5437	0.7939	3.20	4.7457
CAN	0.6286	0.9577	4.85	7.3317
CAN with direct fusion	0.8313	1.2847	7.02	11.9908
CAN+RIFNet (ours)	0.5582	0.8289	3.80	5.6308
MCNN	1.0607	1.5125	9.70	13.0963
MCNN with direct fusion	1.2463	1.8306	10.23	14.0749
MCNN+RIFNet (ours)	0.8669	1.2497	6.66	8.9281
SFCN	0.7430	1.1122	6.12	8.8649
SFCN with direct fusion	1.0905	1.7614	8.07	11.1076
SFCN+RIFNet (ours)	0.5816	0.9089	3.88	6.3093
SCAR	0.6377	0.9020	5.32	6.9174
CAR with direct fusion	1.2618	1.9394	8.70	11.2314
SCAR+RIFNet (ours)	0.5034	0.7407	2.83	4.5372

Table 3.4 The Experimental Results of Each State-of-the-art Image-based Crowd Density Estimation Method Append with the Signal-based Branch, Together with the Baselines (Direct Fusion) of Using Hadamard Product for Fusing the RGB-based and RSS-based Density Maps

Therefore, in our system, we based on the result of RIFNet to estimate the crowd density in real-time and by setting a threshold to detect whether the crowd density is overloaded or not. The police can evacuate the crowd timely to prevent a crowd crush such as Itaewon.

3.5 Emergency Alert System

3.5.1 Drone Projector

3.5.1.1 Simp4Live Records

Simp4live Records is a musical group and also a performance group that uses light and shadow to perform, specializing in light sculpture shows. They are from Taiwan. They install many glowing sensors on drones and the drones fly in the sky to create beautiful pictures. I think we can cooperate with Simp4live Records. This group can train the police so that the police can also write words in the sky through airplanes to disperse traffic.

Fig. 3.36 The Performance of Simp4live Records

Fig. 3.37 The Performance of Simp4live Records

3.5.1.2 DJI Mavic air 2 mini 2 pro flash light

We refer to the specification of DJI Mavic air 2 mini 2 pro flash light. A light sensor is installed on the drone.

Light Sensor Specification	
Maximum Power	**Product Color**
10W	black
Product Weight	**Total Weight (Product + Packaging)**
10.2 g	20.9g
Product Dimensions	**Mode Switching**
36X21X11 mm	long press for 5s
Working Power	**Working Time**
10W	dual flash:3h / single flash:6h
Battery Capacity	**Charge Time**
380mAh	80min
Night Visibility Distance	**Brightness (lumens)**
4~5km	1000Lm

Table 3.5 Light Sensor Specification

Fig. 3.38 Flash Light Sensor

Fig. 3.39 Flash Light Sensor

Fig. 3.40 Flash Light Sensor

3.5.1.3 Google Patents

We have discovered that Google has a new patent for placing a screen on a drone. We think this idea is very interesting and we will reference this patent and improve upon it.

Here is a summary of the patent: A mobile telepresence system may include a frame, a propulsion system operably coupled to the frame to propel the frame through a designated space, a screen movably coupled to the frame, and an image output device coupled to the frame. The frame may include a central body defining a longitudinal axis ofthe frame, a first arm at a first end portion of the central body, and a second arm at a second end portion ofthe central body, opposite the first end portion of the central body. The propulsion system may include rotors at opposite end portions of the first and second arms which propel the frame in response to an external command. The image output device may project an image onto the screen in response to an external command.

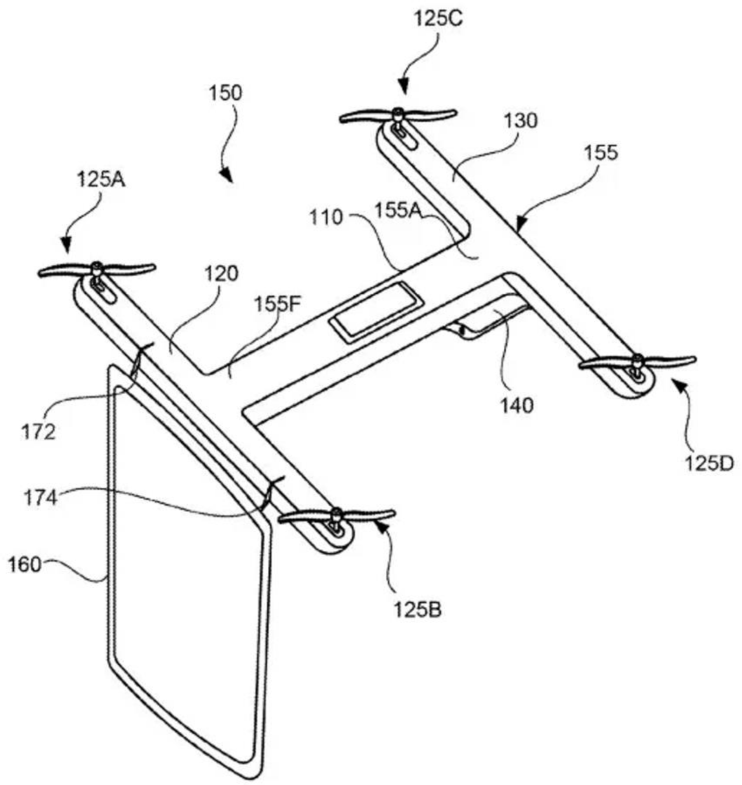


Fig. 3.41 Google Patents

We want to improve the screen part, and we will use an outdoor projector screen instead. This will reduce weight and is suitable for outdoor situations. Our projector screen is from Elite Screens and is designed specifically for outdoor use. It is very lightweight and portable.

The Yard Master Electric is Elite Screens outdoor projector screen for patios and other outdoor spaces. Watch a movie in the convenience of your own backyard, patio, pool deck, or wherever your creative innovation leads. The electric screen is raised and lowered using a Radio Frequency remote control. Additional accessories include a magnetic weight bar bracket and a ground stake kit to keep screen secured against mild wind conditions. Outdoor grade materials enable the product to sustain a long lasting operational lifespan and is IP33 certified for rain/water protection.

Fig. 3.42 Outdoor Projector Screen

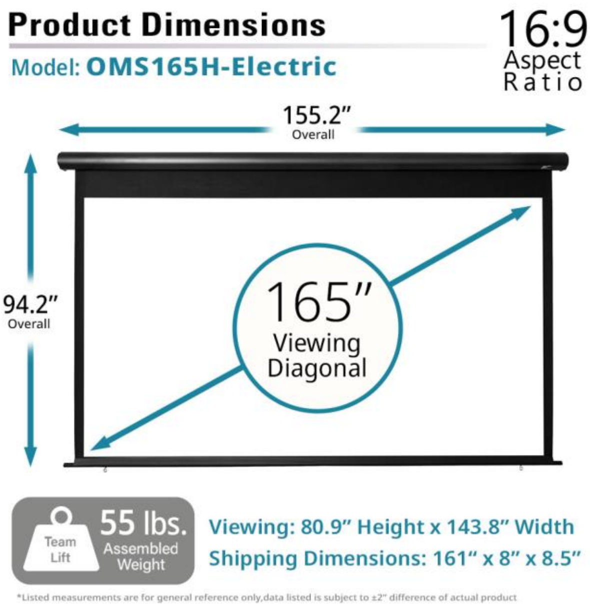


Fig. 3.43 Outdoor Projector Screen

Fig. 3.44 Outdoor Projector Screen

Product Features

- Screen Material
  - - Designed for outdoor use without compromising its home theater visual appeal
  - - MaxWhite® 1.1 gain (matte white) front projection material has superb color temperature
  - - Wide diffusion uniformity allows viewers to enjoy a clear and bright picture from any angle
  - - Not compatible with Ultra/Short-throw Projectors
  - - Black borders absorb projector over scan while enhancing visual contrast
  - - Black material backing eliminates light penetration for enhanced brightness levels
  - - 4K Ultra HD, Active 3D, and HDR Ready
  - - Available in diagonal sizes 100", 120", 150" and 165" in 16:9 format

- Design and Installation
  - - Dynamic indoor home theater quality with outdoor durability
  - - IP33 certified for rain/water protection.
  - - Ideal for backyards, patios, pool decks, and recreation room installations
  - - Floating aluminum anti-rust brackets allow flush wall/ceiling
  - - Capable of suspended ceiling installation
  - - Long distance Radio Frequency remote control included – no line of sight required
  - - Wireless 12-volt projector trigger included to synchronize to projector's power cycle for drop and rise operation of the screen

3.5.2 Drone Speaker

We want to install a speaker on the drone. The speaker can emit an alarm sound, and this device can help the police disperse crowds.

Fig. 3.45 Drone Speaker

Speaker Specification	
Place of Origin	**Brand Name**
Guangdong, China	Global Drone
Model Number	**Material**
Drone Speaker	Plastic
Power	**Function**
Li-on Battery	With Remote Control, Long Control Distance
Drone Speaker Brand Name	**Drone Speaker Material**
Global Drone	Plastic
Drone Speaker Color	**Drone Speaker Battery**
Silver	3.7 V 600 mAh Li-ion
Drone Speaker Remote Battery	**Drone Speaker Control Distance**
3.7 V 800 mAh Li-ion	About 1000m
Drone Speaker Action Time	**Drone Speaker Charging Time**
About 2 Hours	About 50 min
Drone Speaker Size	**Drone Speaker Weight**
13.5 cm*10.2 cm*3.8 cm	95g
Certification	**Type**
FCC, ce, RoHS, Sgs	Remote Control

Table 3.6 Speaker Specification

3.6 Flying Cell Site

3.6.1 Overview

In large events, like New Year's Eve, concerts and so on, there are a lot of people using their mobile at the same moment. Thus, it will cause network congestion. In Taiwan, the carriers might use mobile cell sites to support sudden increases in mobile traffic. However, Cell on Wheels (mobile cell sites) are too big that they might be appropriate in some places. For example, in Itaewon crowd crush, there are a lot of people in the streets and alleys. Therefore, if they can make cell sites in the sky, it will be more convenient and have higher coverage.

3.6.2 Cell on Wheels (COW)

COW is a mobile cell site that includes a tower and transceiver as well as all other necessary equipment. COWs are used to provide expanded cellular network coverage or capacity for short-term demands. They are mainly used in large-scale events, disasters, remote locations and so on. The principle of COWs is like that of cell towers. Cows receive signals by antennas and transport them by (fiber optic) cable. Besides, they need batteries or other power cables for their power supply. Thus, there might be some power generators near by the COWs.

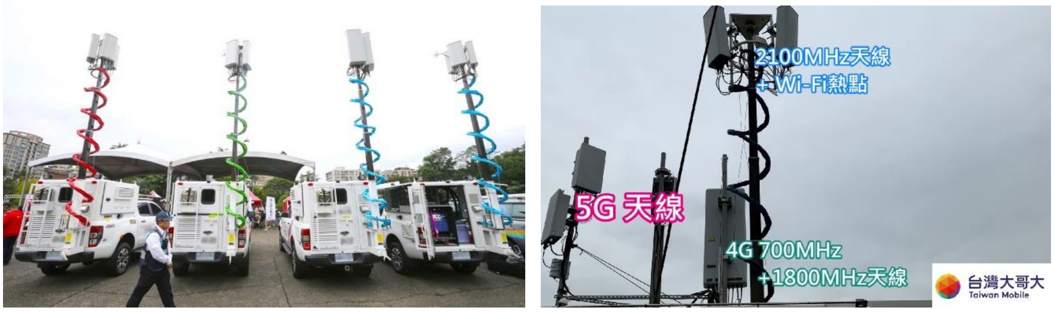


Fig. 3.46 Cell on Wheels in Taiwan

Fig. 3.47 The cables of Cell on Wheels

3.6.3 Cell on Wings (COW) – Flying COW

In 2022, AT&T launched a new technology, 5G Flying COWs. 5G Flying COWs provide 5G network speed. The drones with a tether to the ground and that provides power and fiber optic cable broadcast data to the network. Finally, routers push it through a satellite and link into the cloud.

Fig. 3.48 AT&T Flying COW

In Taiwan, Chunghwa Telecom and THUNDER TIGER have been introduced two kinds of flying COWs, which are also called Flying Mobile Base Station.

Fig. 3.49 Flying COW, ICEMAN

Fig. 3.50 Flying COW, MAVERICK

These Flying COWs also improve the coverage and throughputs. Besides, they can carry heavier equipment so they can help to deliver relief supplies at the same time. Thus, they are much bigger than normal drones.

Fig. 3.51 ICEMAN connected with Satellite Communication Vehicle

The Flying COWs broadcast data with dish antenna of Satellite Communication Vehicle. They use microwave signals to send to satellites. Finally, the signals will be sent by the satellites to ground stations. The Flying COWs also need to connect to the power generators.

3.6.4 Our design

Using microwave to communication might not be suitable for our situations. Optical fiber has higher data capacity than microwave. Therefore, using optical fiber to deal with network congestion is more useful. Besides, large-scale events are usually held in downtown and optical fiber infrastructure is complete. The drones can carriers 5G small cell or Wi-Fi router. As for the power supply for the drones, we think that connecting to transformer boxes or utility poles is more convenient than connecting to the power generators. Besides, our drones need to record the streets view. In conclusion, we will fix our drones on the utility poles. That not only provides the power supply and good views but also constructs a high-density network without obstacles. In addition, the length of the cables might be longer. That makes drones be able to move in a small range.

3.7 Traffic Analysis

Traffic analysis is another issue we are concerned about. Similar to crowd density recognition, the system can analyze whether the traffic is based on the video captured by the drone and deep learning technique. Thanks to the development of artificial intelligence (AI), the emerging AI-based methods improve the performance of object detection.

Real-time analysis of traffic flow is necessary for efficiently managing urban traffic. There have been numerous attempts to tackle this problem with a broad variety of machine learning based algorithms. Two categories can be described. One is to construct a virtual detector with a series of defined bounding boxes. This approach can detect changes in virtual detectors indicating the vehicle's presence. The second is the blob tracking method that is to track vehicles through extracting foreground blobs w.r.t. the vehicles on the scene. However, these conventional methods depend on handcrafted features to track vehicles and therefore suffer issues of poor accuracy and low robustness.

Here we adopt the You Look Only Once version 5 (YOLOv5) to deal with the object detection task, it is an object detection system in real-time that recognizes various objects in a single object. Moreover, it identifies objects more rapidly and more precisely than other recognition systems. The YOLOv5 system can divide into three parts, the backbones, neck, and the head. The backbone is the convolution network that aggregates and forms the image features at different granularities, which adopt the CSPDarknet model.

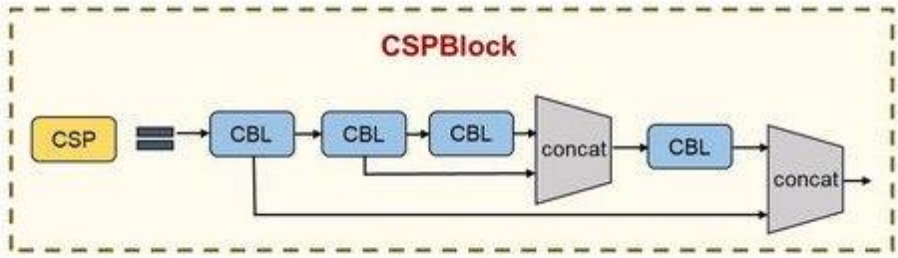


Fig. 3.52 The Architecture of CSPDarknet

The neck is constructed by a series of layers to mix and combine image features to pass them forward to prediction. The head consumes features from the neck and takes box and class prediction steps.

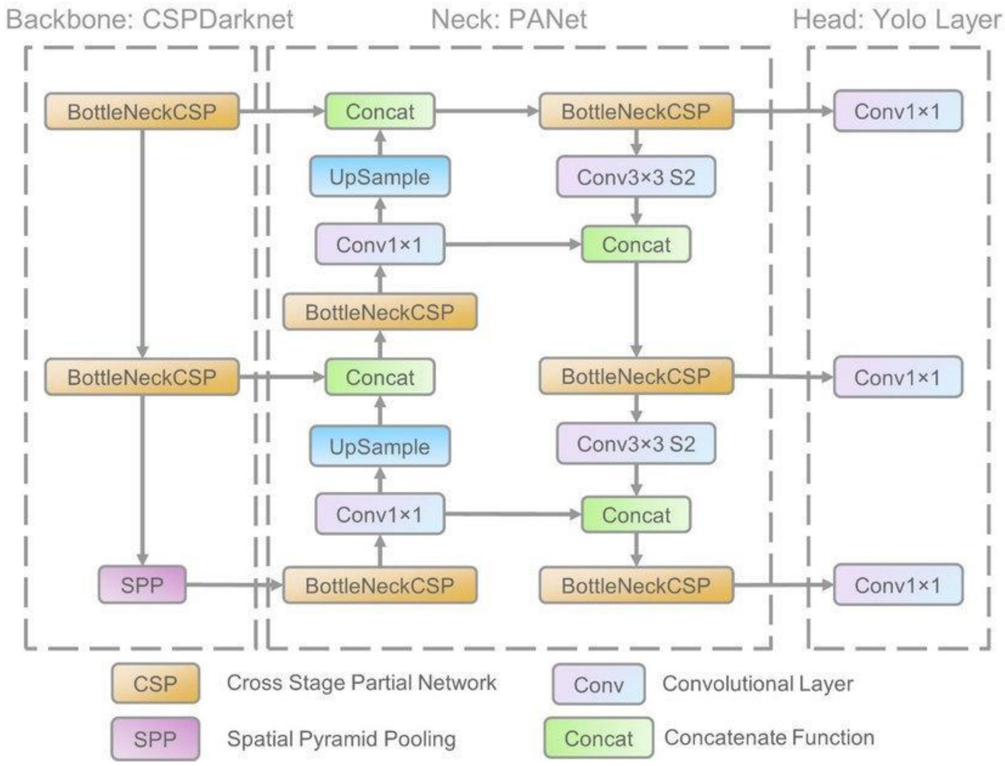


Fig. 3.53 The Overall Model Architecture

Despite there are several versions of YOLO that are newer than the YOLOv5 we adopt, we still choose YOLOv5 since it is powerful enough to deal with our object detection task. If we compare to its previous version, we can find that it has a similar performance compared to YOLOv4 but with a faster computation speed. The following figures show the comparison of the performance (mAP) and the inference time.

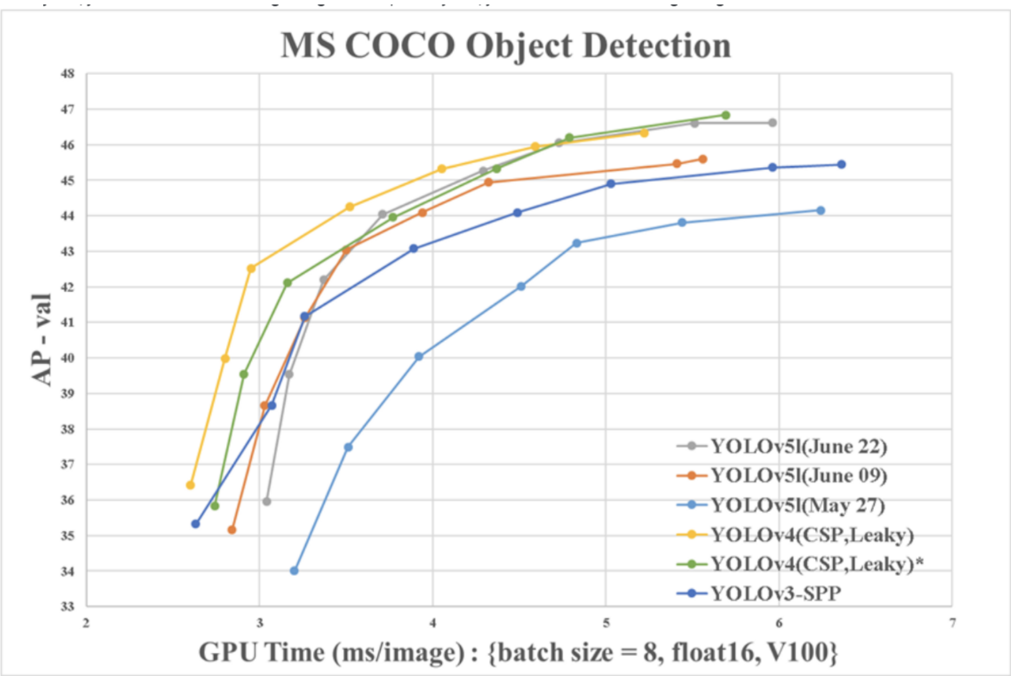


Fig. 3.54 The Comparison of The Performance (mAP)

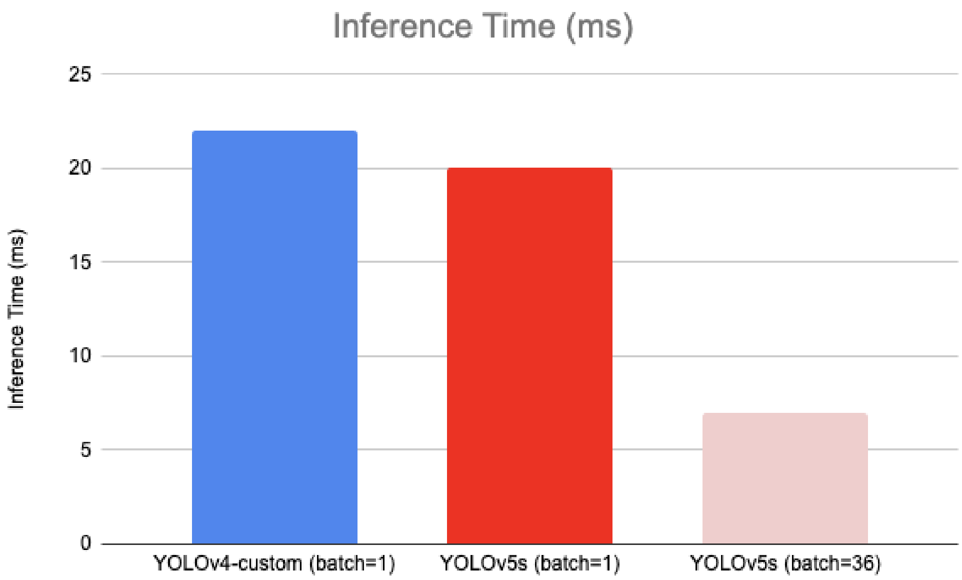


Fig. 3.55 The Comparison of the Inference Time.

The following figures show the detection output of the YOLOv5, which outputs the bounding box of each object with a specific ID.

Fig. 3.56 The Output of the YOLOv5

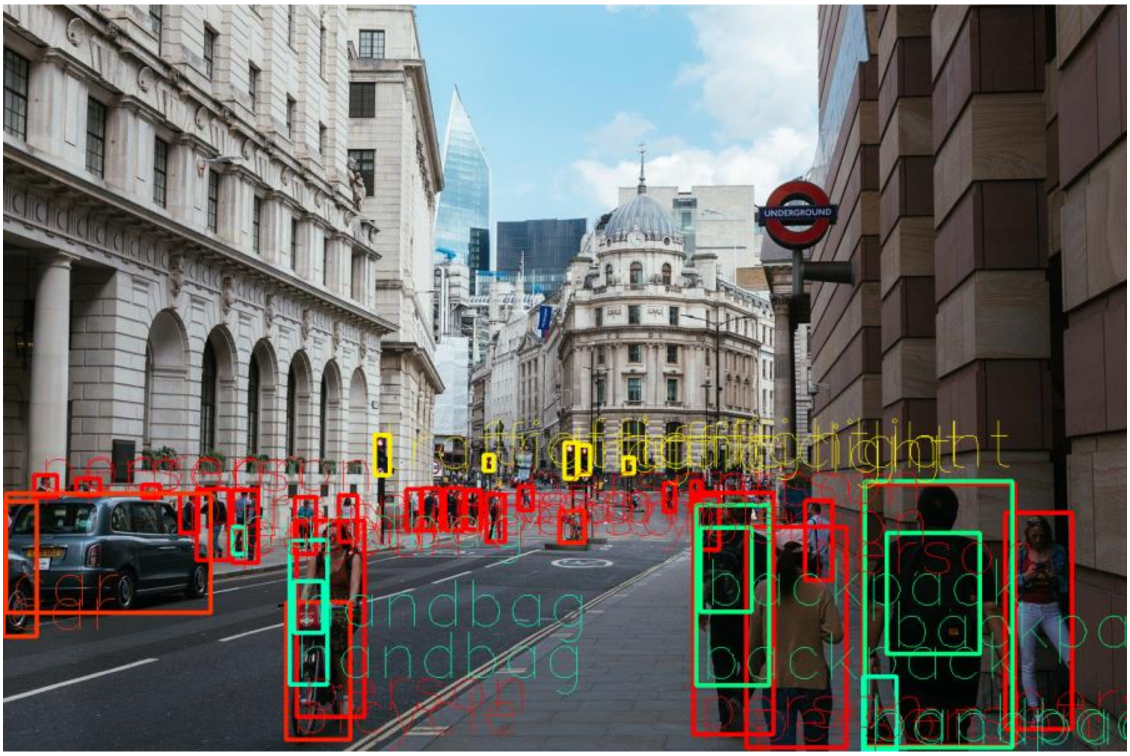


Fig. 3.57 The Output of the YOLOv5

The following table is an experimental result of YOLOv5 object detection in one of our references, we can find that the YOLOv5 can detect different vehicles with a good performance and the miss prediction is low.

Confusion Matrix		True Class									
		Auto	Bicycle	Bus	Car	Mini truck	Person	Truck	Two Wheele	Van	No Class
Predicted Class	Auto	34									
	Bicycle		0								
	Bus			7							
	Car				62						
	MiniTruck					10					
	Person						86				2
	Truck				1			8			
	Two Wheeler								67		
	Van									1	
	No Class	2	1		5	2	9		3		0

Table 3.7 Confusion Matrix

	TP	TN	FP	FN	Sensitivity	Precision	Negative Predicted values	False Positive rate	False discovery rate	False Negative rate	Accuracy	F1-score	MCC
Auto	34	241	0	2	0.9444	1	0.9918	0	0	0.0556	0.9928	0.9714	0.9678
Bicycle		275											
Bus	7	268	0	0	1	1	1	0	0	0	1	1	1
Car	62	213	0	5	0.9254	1	0.9771	0	0	0.0746	0.9821	0.9612	0.9509
Mini truck	10	265	0	3	0.7692	1	0.9888	0	0	0.2308	0.9892	0.8696	0.8721
Person	86	189	2	9	0.9053	0.9773	0.9545	0.0105	0.0227	0.0947	0.9615	0.9399	0.9131
Truck	8	267	1	0	1	0.8889	1	0.0037	0.1111	0	0.9964	0.9412	0.941
Two wheeler	67	208	0	3	0.9571	1	0.9858	0	0	0.0429	0.9892	0.9781	0.9714
Van	1	274	0	0	1	1	1	0	0	0	1	1	1

Table 3.8 The Experimental Result of YOLOv5 Object Detection

With the object detection results, we can estimate the speed of each object. If several objects speed is lower than a threshold, it may have a congestion problem, the system will report to the police center and adjust the time duration of the traffic light to solve the traffic problem.

The processing flow of our system is as follows, including the crowd density and the traffic analysis. First the drone captures the real-time video and RSS signals to update to the server, then the algorithm is implemented and computed at the edge server and transmits the results to the police emergency center for surveillance in real-time.

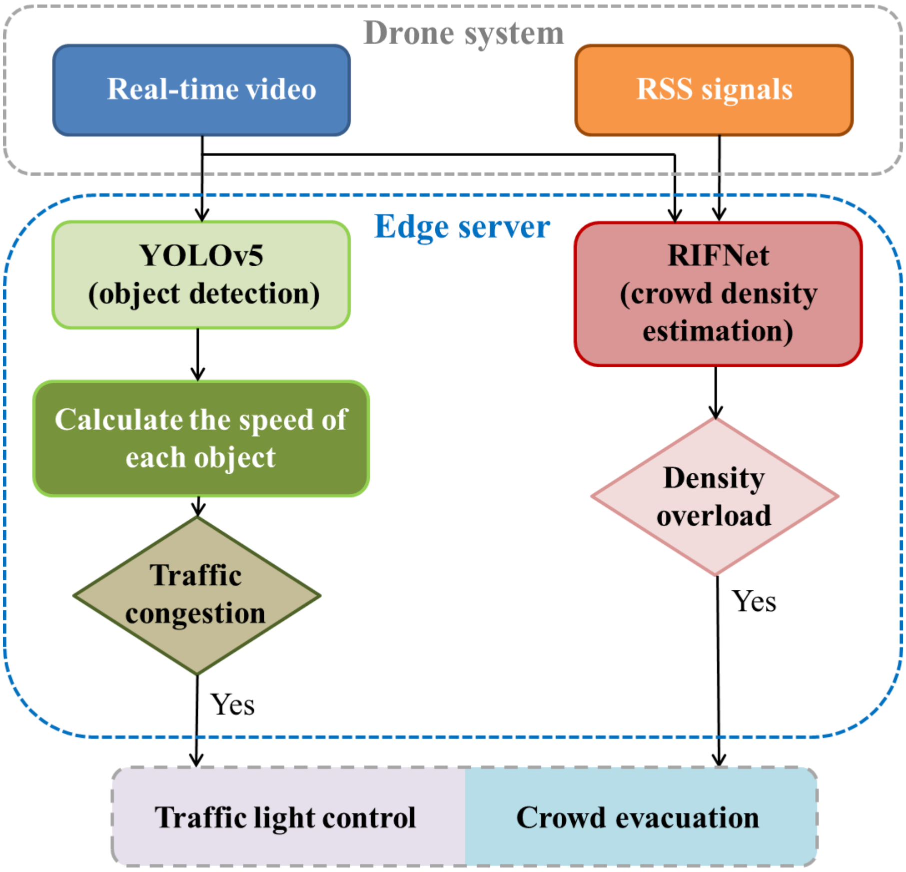


Fig. 3.58 The Diagram showing how the system works

Chapter 4 Global Market Analysis

4.1 Market Analysis

As drone technology advances, many governments are considering the potential of drones. Drones have a wide range of uses, including military, performance, entertainment, and more. Traditionally, drones that we are familiar with are very large and mainly used for war, such as the Bayraktar TB2.

The Bayraktar TB2 is a medium-altitude long-endurance (MALE) unmanned combat aerial vehicle (UCAV) capable of remotely controlled or autonomous flight operations. It is manufactured by the Turkish company Baykar Makina Sanayi ve Ticaret A.Ş., primarily for the Turkish Armed Forces. The aircraft are monitored and controlled by an aircrew in a ground control station, including weapons employment. The development of the UAV has been largely credited to Selçuk Bayraktar, a former MIT graduate student.

Fig. 4.1 The Bayraktar TB2

Fig. 4.2 The Bayraktar TB2

Drones can also be used for performances. According to research, the first drone performance in the world was held in Linz, Austria in September 2012, with 49 drones participating.

In November 2015, semiconductor company Intel held a drone performance in Hamburg, Germany, using 100 drones for the first time and accompanying them with a symphony orchestra, making drone performance an audio-visual performance art for the first time.

Fig. 4.3 The Drone Performance held by Intel in 2015

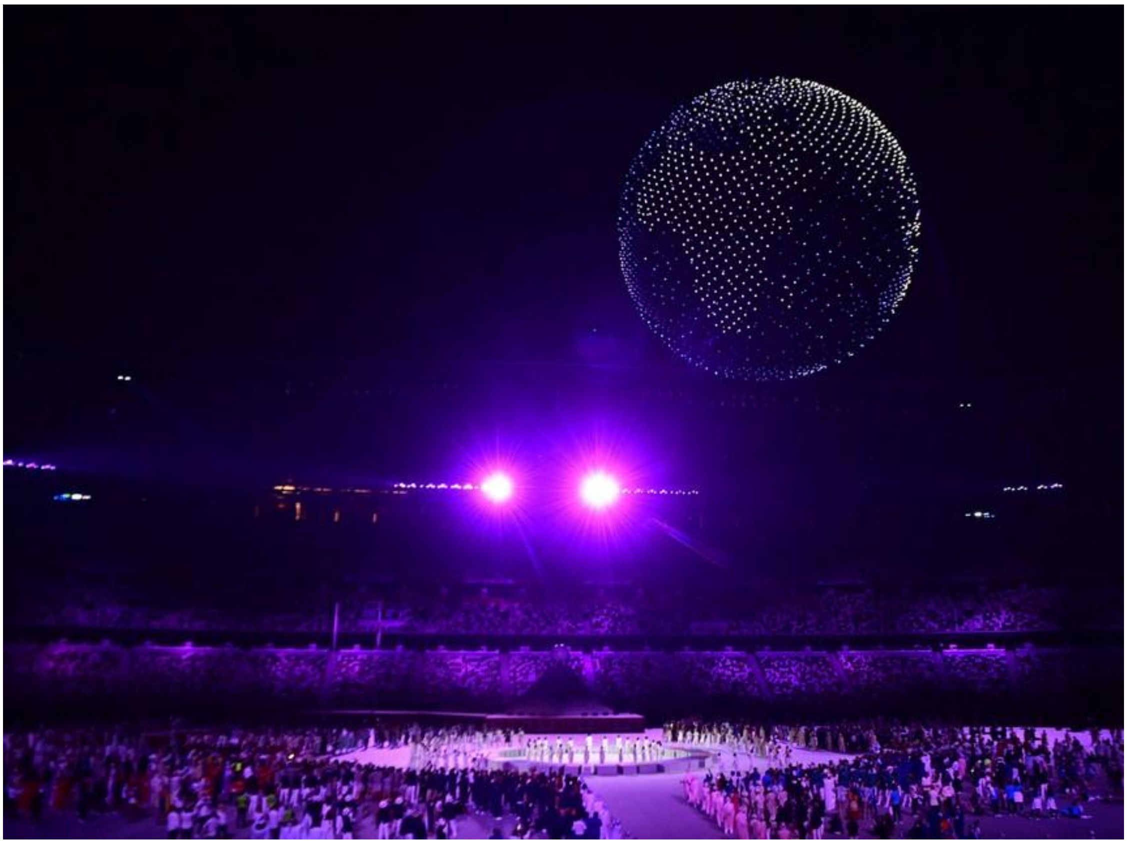


Fig. 4.4 Olympic opening ceremony in 2020

The 2020 Tokyo Olympics was the first Olympic opening ceremony to feature a drone performance, with 1,824 drones participating.

Drones can be used for entertainment, such as aerial photography. People can use drones to take selfies or capture natural landscapes.

(a) (b)

Fig. 4.5 (a)To Take Selfies and (b)natural landscapes

According to reports, the global consumer drone market size was valued at USD 3.42 billion in 2021 and is anticipated to grow at a compound annual growth rate (CAGR) of 13.8% from 2022 to 2030. Consumer drones are becoming increasingly popular among people that want to earn a second income, explore with aerial photography, or fly drones for fun, in addition to traditional flight enthusiasts and hobbyists. Customers are increasingly exploring the benefits of drones in enriching leisure activities and interests, resulting in a significant increase in global consumer drone sales.

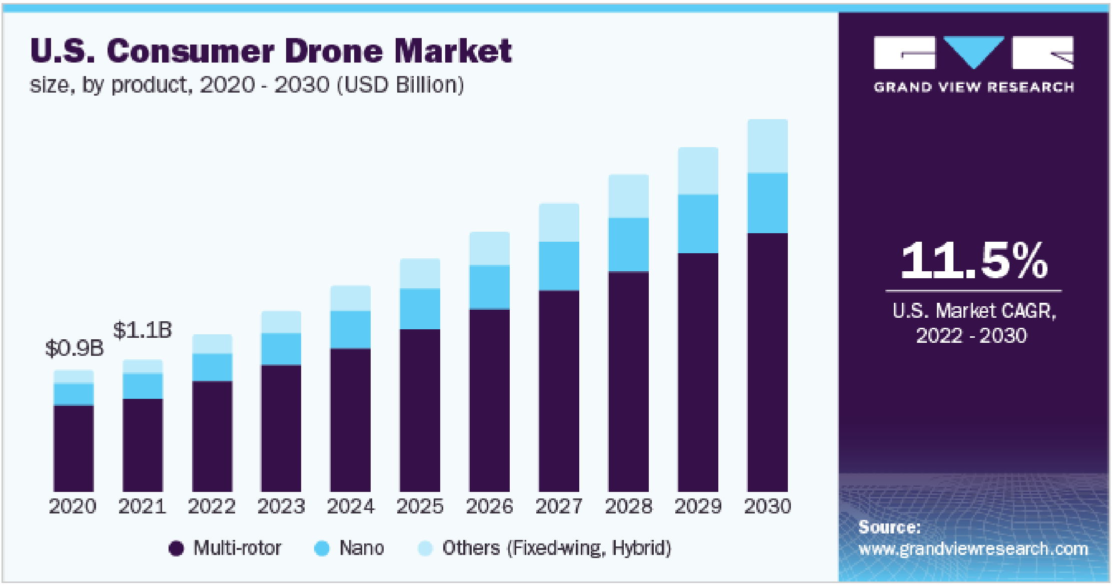


Fig. 4.6 Market Analysis

4.2 S.W.O.T Analysis

- Strength
  1. A product specifically designed for use by the police, which is very unique.
  2. Cooperation with Simp4live Records to maximize the value of drones.
  3. This product is an improvement on the Google patent and may also be eligible for patent registration.
- Weakness
  1. This product is only suitable for the police.
  2. Expensive price.
- Opportunity
  1. The product can be sold to police in other countries.
- Threat
  1. There is a possibility of data theft by hackers.
  2. Public consent is required to disclose user information.

4.3 Porter's 5 Forces analysis

Fig. 4.7 Porter's 5 Forces Analysis

- Bargaining power of customers

Low. Our product is very innovative and is specifically designed for use by the police, so the product needs to be very stable and has a high development cost.

- Bargaining power of suppliers

High. Many patents or technologies are only offered by a single manufacturer.

  - All: Camera
  - DJI: Mavic air 2 mini 2 pro flash light
  - Google: Patent
  - Global Drone: Speaker
  - elite screens: outdoor projector screen
  - Simp4live Records: Drone training

- Threat of new entrants

Low. Our product is mainly designed for the police and is not easily accessible for the general public to purchase.

- Threat of substitutes

Low. Our product is designed by combining the technologies and patents of different manufacturers and is mainly for use by the police.

- Competitive rivalry

None. There are no competitors in the market.

Chapter 5 Conclusion and Future Work

5.1 Conclusion

In this work, we propose a drone-aided police control system to assist the police task. We first propose an emergency alerting system that provides a way to evacuate the crowd when an emergency occurs. Specifically, the drone used for surveillance is equipped with a 5G small cell to enhance the coverage of the mobile signal. The drone used to alert is equipped with a speaker or a projector, the police can select different kinds of equipment depending on the emergency situation. The system can broadcast notifications to the police to prevent emergency situations since the AI algorithm provides real-time monitoring. Moreover, to improve the effectiveness of the traffic control, we implement a traffic analysis to control the traffic light duration, which the drone provides the live screen of the street. The system reduces the loading and improves the efficiency of the police. The industrial analysis results show the novelty of the proposed system, in which the varieties of application scenarios provide the user with multiple choices. In the future, we plan to study the endurance of the drone. We also plan to study the potential market of the system with other suitable scenarios.

5.2 Future Work

We suggest the following future extension to our work:

- Adding Route Planning Algorithm:

Our drones are all over the large-scale events. Thus, if some emergencies happen, the police can directly evacuate the crowd by using drones. However, the police might not be clear about the situations at first moment. Therefore, if we use route planning algorithms with video information, it will make the police to shorten the time to evacuate people.

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TEAM MEMBER TASK PARTITION

Introduction：許芷毓

System Architecture, Data Flow：楊智勝、楊士緯

SoC Specification：許芷毓

Drone: 郭義安、陳俊翰

(1) Communication-5G: 許芷毓

(2) Camera: 楊士緯

(3) Edge Server: 陳俊翰

GPU: 郭義安

(4) AI-obstacle detection and avoidance, path planning strategy: 郭義安

Technology Analysis：

(1) Monitoring system: 楊士緯

(2) Emergency Alert System: 楊智勝

(3) Base station: 許芷毓

(4) Directing Traffic System: 楊士緯

Market Analysis：楊智勝

Conclusion：楊士緯

Organize Report：楊智勝、許芷毓

Presentation: 楊士緯、郭義安、陳俊翰