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Implementation of Deep Learning and Motion Control Using Drone

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Abstract: In current times, drones have widely used in many sectors such as transportation, photography, army and agriculture. However, the control system of the drone remains the same. Leap is a motion sensor using infrared and a camera to detect a hand signal and hand gesture. A leap motion sensor has been applied to this project as a controller to replace the variation of the control system of the drones. DJI Tello Edu drone has been chosen as Unmanned Aerial Vehicles (UAVs) for this project. A computer has been used as the main system that helps connect the leap sensor and drones via WIFI. This project use python language as the system of the program to control the drones. The main purpose of this project is to control the drones using leap motion and implement all possible gesture to control the drone at any movement. To evaluate the system performance of the drones in retrieving the video from the drone with object detection. There are three methods of object detection applied to this project which is Haar cascade face detection and YOLO V3 tiny object detection. The purpose of a computer visioning system is used to determine the output of video quality by comparing the frame rate for each detection method. The result shows that the leap sensor is successful to control the drones more stable and most all of the hand gesture and movement are applied to control the drone. For object detection, it shows that edge detection produces a higher frame rate compared with YOLO and Haar cascade detection. Overall, the frame rate shows the drone produces a static frame rate when in idle condition. However, when the drones are in flying condition, the frame rate decrease. The overall system still has pros and cons. Some suggestion are given to make sure the project can still improve.

Keywords: Hand Recognition, Deep Learning, Convolution Neural Network

1. Introduction

Transportation is divided into several classes like land transport, off-road, space transport. The land transport is the most used in most of the country where the process of import and export takes part. Meanwhile, the huge amount of land transport can lead into an accident, traffic jammed and road destruction. The total of accident per year increases as the amount of transportation increase. To reduce

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this problem, the delivering transportation could be decrease by replace it using space transportation by using drones.

Drones or know as unmanned aerial vehicles (UAVs) are the automated pilot that does not required human control in it. Drones nowadays have successfully applied in many areas such as military [1], small range transportation, filming [2], delivery services and education purposes. Drones is a small flying vehicle that can be used to reach in the small areas, high places, and more difficult places for human to reach. It also can perform a difficult task such as carrying an item, act as radar, surveying an area and even in rescuing area and much more. However, the weakness of the drone remains unsolvable where the battery and energy consumption of the drones are still limited due to the weight carried over time [3]. Drones average can operate around 10-15 minutes due to the battery capacity and the total weight carried. Drones are using radio frequency (RF), Bluetooth and wireless fidelity (Wi-Fi). Which the drones can only communicate within the certain area [4]. However, the disadvantages of the drones will be solved and reduce as the time move forward.

As the technology rising for advances, the complexity of the drones has been developed to make it easier to control. The leap motion application has been widely used in 3D gaming [5], medical training [6], vehicle control [7] and much more. Leap Motion Application Program Interface offers an array of protocols and schedule for developing using application. Lead motion sense the human body gesture by depending on the program itself. Most of the project are using hand and arm gesture to give a signal to an application of the system.

This project aims are to develop the full control drone with a camera which control it using Leap Motion sensor with an instruction by using hand gesture. In addition, solving the performance of the system and use full control system of the drone itself.

The motivation for this project is drones nowadays are designed with a variety of functions that help to serve a critical task. They are variety of control that has been developed to fulfill the performance of drones. However, the variable technique of controls needs to apply to find the most suitable and best performance for the drones. The leap motion sensor required human gesture motion in order to give a signal. Every motion required a program to do its specific task. Based on research the leap motion sensor has a bit lack of sensing the hand gesture due to the performance of the system and the speed of detect.

The aim of this project is to develop a drone that fully control with hand gesture which replace with normal controller to perform a specific task. However, there are additional objectives which is to implement all possible hand gesture and hand movement that can be detect by leap motion sensor and apply to the drone, to provide more stable controlling system using leap motion sensor that interact with drone directly and to evaluate the system performance of the drone in term of frame rate in receiving the images with object detection.

Every project require limitation which is this project limitation only consist the area of the project only available where the drone can be control through Wi-Fi coverage. The drone will control by using leap sensor which only hand gesture is included to give an instruction. The image processing applied to the drone only to test the video output and resolution based on the drone performance and condition. Several test will be conducted in order to evaluate the performance of the developed system.

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

2.1 Material

i. Leap motion sensor

Leap motion sensor is a device with a capability to detect the movement of hand gestures. The device provides with two infrared cameras and three IR LED with a limited Field of View (FOV). The camera stereoscopy of the sensor can minimize error from tools, fingers and hand features and its built on a unique mathematical model to maximize speed and precision. as the device is working, the frames of data will update frequently. Each frame has list of tracking data such as hands, fingers, tools, recognized gestures and factor describing the overall motion of the scene. Figure 1 shows a leap motion sensor.

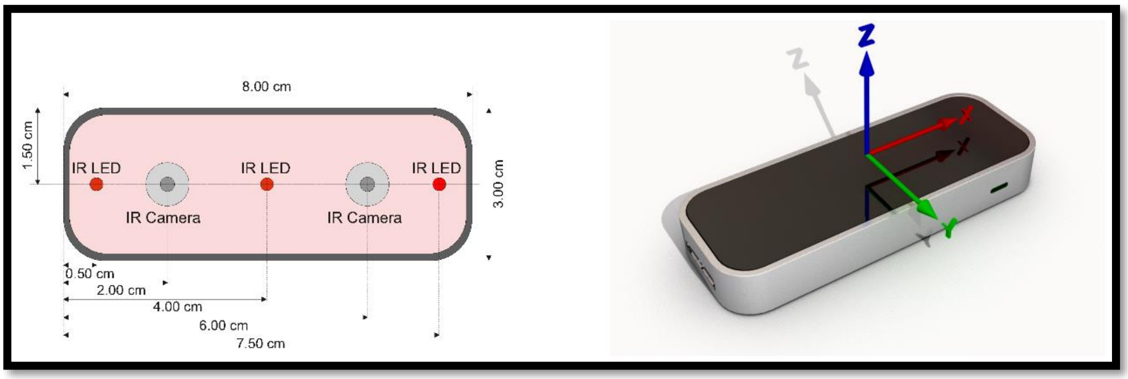


Figure 1: Leap Motion Sensor

All the list tracking allows leap motion to recognize the hand features such as hand palm orientation, fingers length, width and orientation, hand opening and other non-hand features including tools and computer screen location. Furthermore, the leap motion development provides the Software Development Kit (SDK) where the overall program of the leap motion and libraries for reprogramming the software are available. SDK provide with two programming languages which is in C++ and Python.

ii. DJI Tello Edu Drone

Tello Edu drone is a small quadcopter or known as mini drone and it produce by DJI company. The drones provided with extra features such as Vision Positioning System and an onboard camera. The combination of advance controller and extra features makes the drones are able to hover in place and suitable for flying indoors. Tello Edu also provide an advance feature compared to other drones which is bounce mode, 8d flips and EZ shots. Figure 2 shows the Tello Edu Drone.

Tello Edu captures 5-megapixel photos and stream 720p live video to the Tello app on mobile device. Its maximum flight time is approximately 13 minutes and its maximum flight distance is 328 ft (100m). Failsafe protection enables Tello Edu to land safely even if you lose connection and its propeller guards give more reliability to the drones.

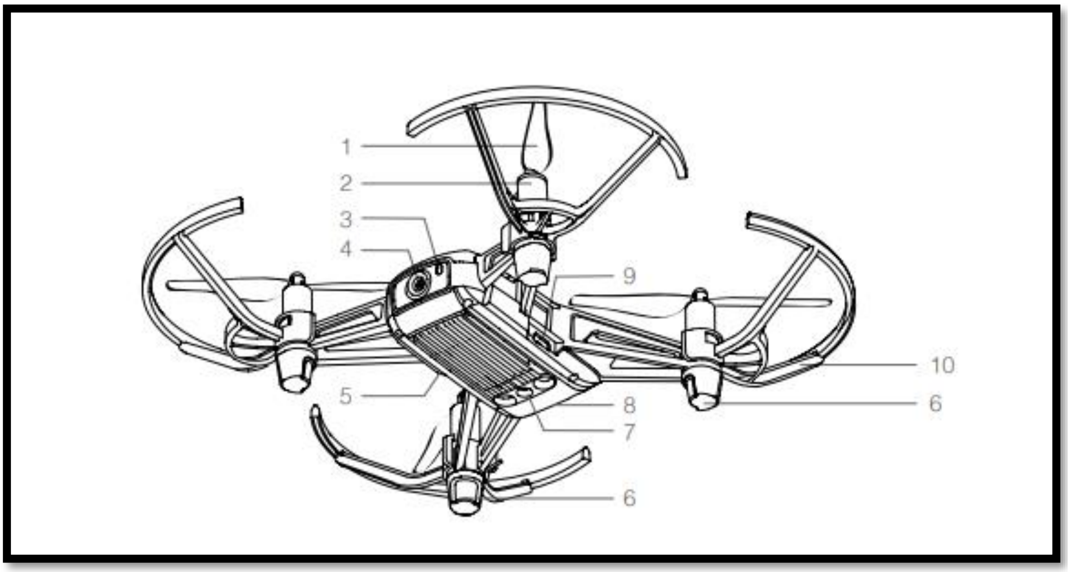


Figure 2: Tello Edu Drone

iii. Computer

The computer used for this project using intel i5-7200, 480GB SSD internal storage and 12GB RAM with 64-bit operating system. The operating system is windows 10 home single language.

iv. Visual studio 2019

Visual studio is an Integrated Development Environment (IDE) software produce by Microsoft. It serves a purpose by develop computer programs, as well as websites, web apps, web services and mobile apps. Visual studio uses Microsoft software development platforms such as windows Application Program Interface (API), windows Presentation foundation, windows store and Microsoft Silverlight. Visual studio also can produce in both native code and managed code.

Visual studio support most of the programming language and allow code editor and debugger to support any programming language specific service exist. Total of 36 different programming language such as C, C++/CLI, C#, F#, JavaScript, Typescript, XML, XSLT, HTML, CSS, Java, Java# and more language is included in the software. Side programming language software that requires plug ins includes python, Ruby, Node.js and M. It's also provided other built-in tools such as code profiler, GUI application designer, web designer, class designer and database schema designer. Visual studio provides a supporting IntelliSense as well as code refactoring. Visual studio debugger can be performed as a source level debugger and machine level debugger. Almost every level of plug-ins that can be supported its functionality for source control systems and adding new toolsets like editors and visual designers for domain specific languages or toolset.

In this project, python language has been chosen as medium between leap and drones communication. Python 2.7 and python 3.7 have been applied to this project. Some external library such as OpenCV, Leap SDK and DjiTello has been use to make sure this project running smoothly. OpenCV helps in retrieve the video from the drones and help in image processing. DjiTello library help in connect the drones to the computer and instruct the variable movement of the drones. It's also help in show the status of the drones such as battery, temperature and more. Leap SDK helps in hands detection and recognition properties and makes easier to program.

2.2 Methods

Figure 3 shows the system architecture needed for this project. The project consists of three division which is input, process and output. For the input division, the hand gesture is use as a controller signal. Where the Leap motion sensor is used to detect the hand gesture movement. Then the leap motion then transferring the recognition images to the computer for next process. The computer or a laptop will process the data using visual studio 2019. Visual studio 2019 provided with the python language where the overall program for the drone is take place.

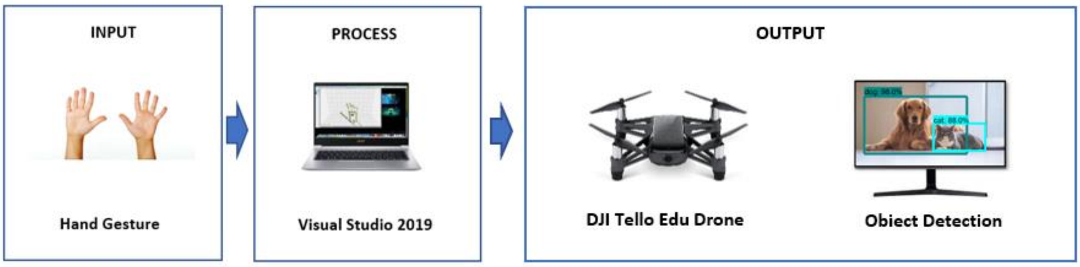


Figure 3: System architecture

The program is combined with the LEAP motion SDK program where it will be use as GUI to guide the position and condition of the hand gesture. The main program also will connect to another library for DJI Tello Edu drone. The program will be syncing the data from hand recognition to the drone by transferring the data to the drone via WIFI connection.

The drones will receive the instruction from the laptop and execute the moves depending on the program. The drones will move around the coverage of the WIFI where it can only be reach by the computer communication performance. The Wi-Fi is provided from the drones where its only cover the area of 100m radius. While controlling the drone, several test of object detections, face detection and object detection will be applied to the drone. This test is to identify the maximum performance of the drone in retrieving the video while flying.

3. Results and Discussion

The result contains of two outcome which is the control of leap motion sensor and the application of the object detection using Haar cascade and YOLO V3. Figure 4 shows the system overview of the project. The item used are leap sensor, a computer and Tello Edu drone. The screen of the computer show the streaming video from the drone.

Figure 4: System overview

For the result, the circle gesture has been used to control the drone for takeoff instruction and landing instruction. It will detect as a circle gesture when an index fingers rotate clockwise or counter clockwise as the Table 1.

Table 1: Take off and land instruction

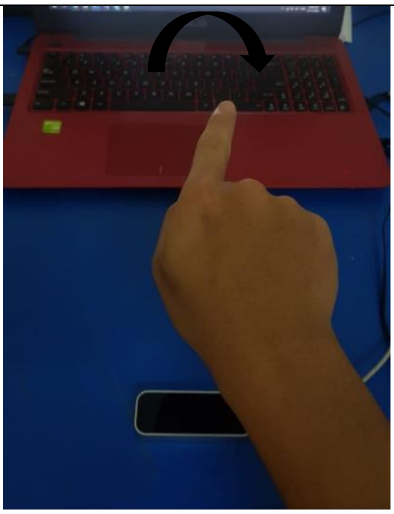
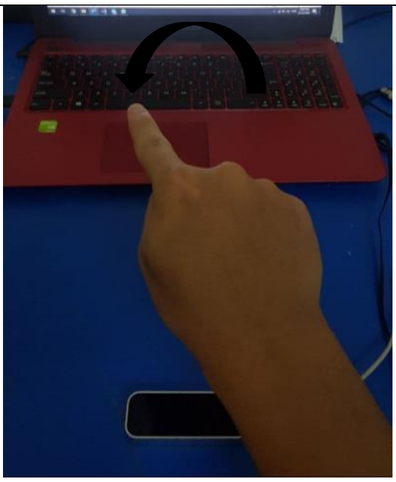
Rotation	Hand gesture	Drone movement
Clockwise		
Counterclockwise		

Table 2: Hand movement instruction

Hand direction	Hand orientation	Tello command
Yaw	Yaw >= 30°	Rotate right
	Yaw <= -30°	Rotate left
Pitch	Pitch >= 30°	Move forward
	Pitch <= -30°	Move backward
Roll	Roll >= 30°	Move left
	Roll <= -30°	Move right

For other movement of drones are replaced by yaw pitch and roll hand movement. Table 2 shows the hand movement instruction. Every instruction require 30° and above to trigger the drone to move. The pitch and yaw require the hand direction to detect the movement either it is yaw or pitch using the tolerance of x and y axis movement of the palm. For roll, it requires the rotation of the palm either it is in normal degree rotation or vice versa. Table 3, 4 and 5 show the result for drone movement based on the hand movement. The command windows show the result after drone receive the command and display the result instruction.

Table 3: Yaw gesture result

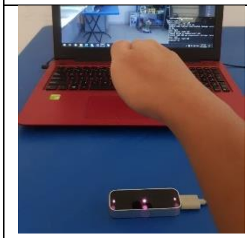
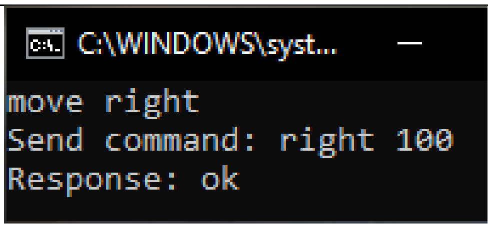
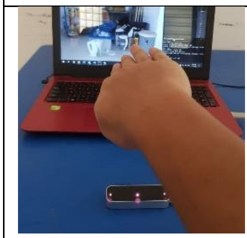
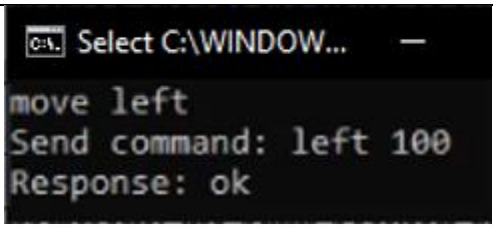
Yaw Gesture	Command Output	Drone movement
		
		

Table 4: Pitch gesture result

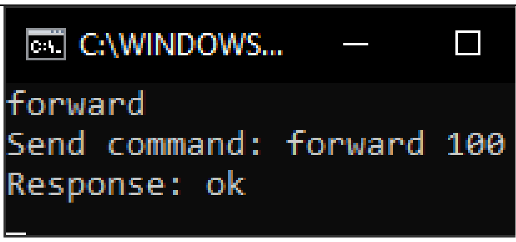
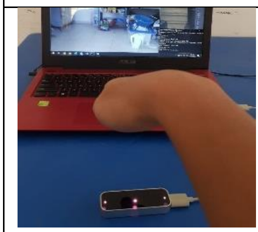
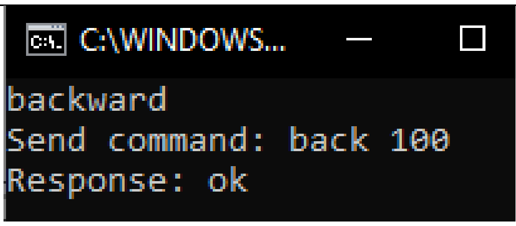
Pitch Gesture	Command Output	Drone movement
		
		

Table 5: Roll gesture result

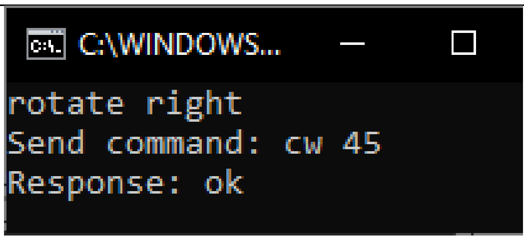
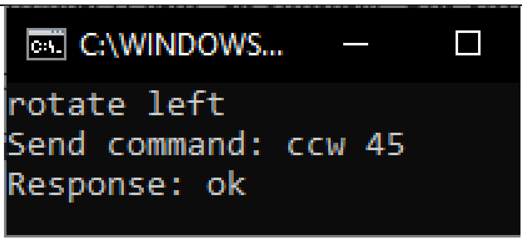
Roll Gesture	Command Output	Drone Movement
		
		

Figure 5 shows the result of the object detection applied to the drone. The drone performance are able to use object detection with low fps produce. The original video can produce around 80 fps, this shows that the use of object detection reduces the performance of the drone in term of frame rate however the drone still able to applied object detection. There are three motorcycle, however YOLO tiny can only detect one motorcycle. YOLO tiny only have lowest Mean Average Precision (MAP) among all the YOLO v3 model.

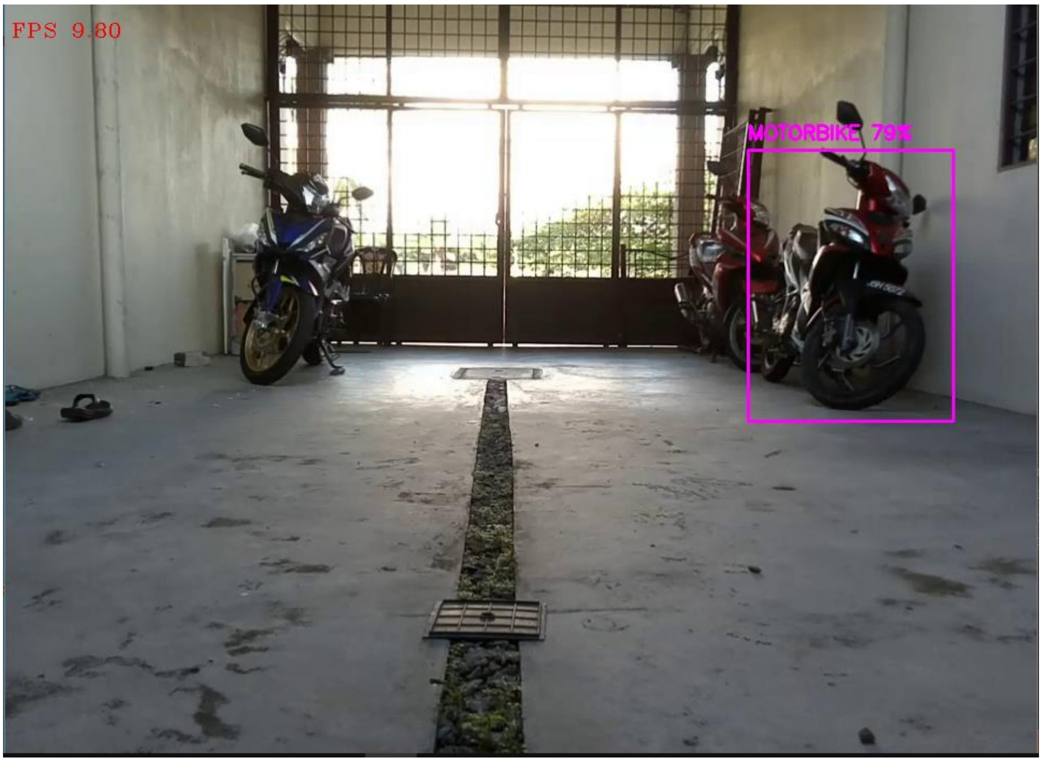


Figure 5: YOLO V3 object detection result

Table 6 and Figure 6 show the comparison of frame rate for two try and two condition which are drone in idle condition and drone in flying condition. Both method will reach the static condition either in idle or flying but the flying condition will reach slowly then the idle condition since the drone in moving condition makes the video correction a bit slow. Both try produce different scale of fps. However both try still can perform object detection.

Table 6: FPS comparison suing YOLO

Time (s)	YOLO tiny with flying drone		YOLO tiny drone idle	
	1st test	2nd test	1st test	2nd test
1	3.70	7.70	3.50	6.33
2	3.90	8.18	4.00	7.25
3	4.20	8.64	4.50	7.80
4	4.56	8.25	5.20	9.00
5	4.58	8.62	5.50	8.70
6	4.69	8.50	5.70	8.55
7	4.87	8.87	6.10	8.17
8	4.60	8.62	6.20	8.50
9	5.12	8.94	6.50	8.00
10	6.50	8.42	6.40	8.12
average	4.672	8.474	6.4	8.12

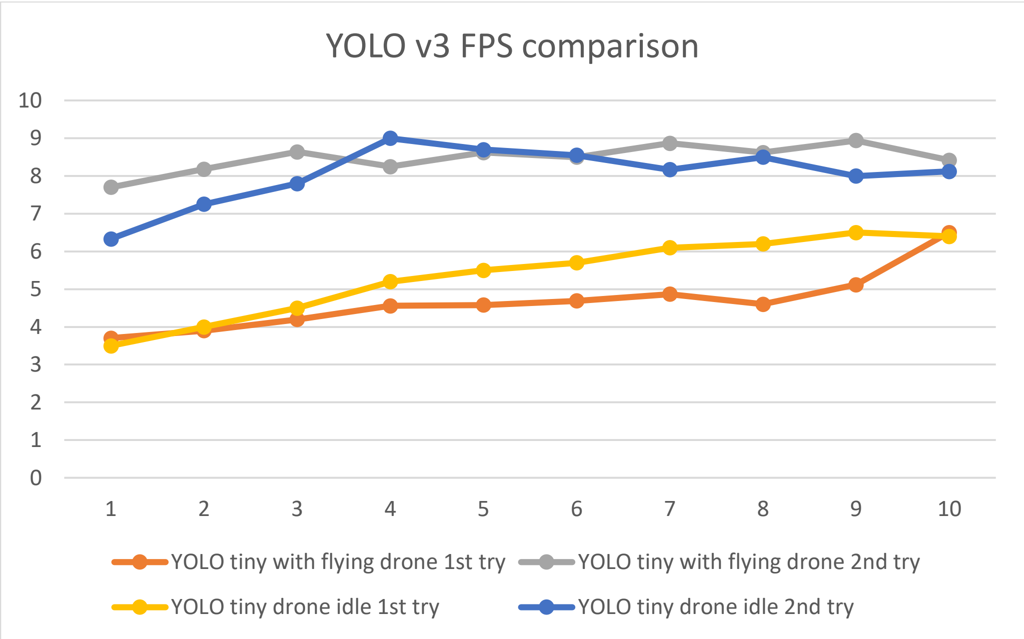


Figure 6: YOLO v3 Tiny FPS Comparison

Figure 7 shows the result for greyscale and the result for face detection after the greyscale. Left image shows the output of cascaded method where the image that contain the blue rectangle are shown as detected face.

Figure 7: Greyscale and cascade image face detection

Table 7 and Figure 8 shows the fps comparison of two test video capture using harr cascade face detection with and without leap motion. The minimum and maximum fps reach by two test are 8.1 and 11 fps. For the first try, we can see that the average value with drone being control are 8.1 the fps hard to reach 10 fps since its moving during flying. However, during idle of first test, which drone are not moving, the FPS are reach average of 9.9 fps. The second test are made to make sure the fps are same as the previous test. For the second test, the fps reach with leap control is 9.2 and without leap control which the drone are in idle condition the fps are 10.3.

Table 7: FPS Haar cascade face detection comparison

Time (s)	Haar Cascade with leap sensor (fps)		Haar cascade without leap(fps)	
	1st test	2nd test	1st test	2nd test
1	10	10	10	11
2	9	10	10	11
3	9	9	9	11
4	8	9	10	10
5	8	9	10	10
6	8	9	10	10
7	8	9	10	10
8	7	9	10	10
9	7	9	10	10
10	7	9	10	10
Average	8.1	9.2	9.9	10.3

From observation, the first test and second test reach different value and mostly have 1 fps different for with and without control for first tests and second test. Similar result can be seen which the movement drone produces less fps for first and second test and idle condition produce higher fps.

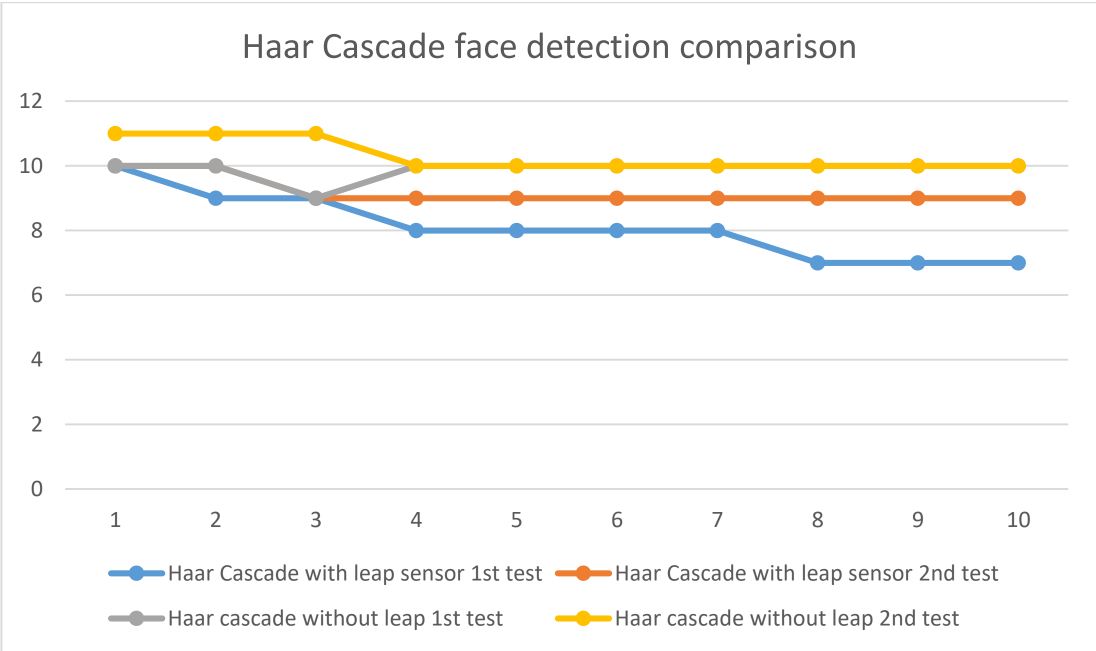


Figure 8: Haar cascade comparison face detection

4. Conclusion

The In conclusion, leap motion sensor has been successfully able to control the drone with stability and good performance detection. Moreover, the system helps in process the data between the leap and drone makes the interconnection between them strong and hard to interrupt. However, there are certain movement that are unable to use such as moving upward and downward for drones. This is happened because the leap motion sensor is unable to combine the gesture and the palm condition at the same time which make the movement limited for a drone that have a lot of movement. The other movement of the drone are successfully applied and perform well.

In addition, some computer vision has been applied to this project to maximize the performance of the drones. There are three method applied to the drones which is object detection using YOLO v3 tiny and Haar cascade detection. The purpose to check either the drones can process the video smoothly without any interference and distortion during retrieving the video. The frame rate or frame per second has been used to determine the performance of detection. YOLO v3 tiny can perform well due to object detection. However, there are slight issue where the yolo tiny have a bit of data set and hard to recognize the object clearly. In addition, the frame rate produce by YOLO are low which reach below 6 fps compared with the original video are around 50 fps. Haar cascade face detection successfully applied to detect face detection and the frame rate are around 10 fps which only 25% from the normal video fps. The object detection causes a heating of the drone drastically rise and makes the drone are unable to use in short period of time. The battery drains drastically due to computer vision addition applied to the drone.

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