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Android Application to Control Commercial UAV

Vishva P[1], Nivethitha P V[2], Sowndarya Lakshmi V[3], Vithun S S[4]and Manavaalan G[5]

[1]Electrical and Electronics Engineering, Coimbatore Institute of Technology, Anna University, Coimbatore, India

[5]Associate Professor, Electrical and Electronics Engineering, Coimbatore Institute of Technology, Anna University, Coimbatore, India

E-mail: [1]vishvavichu13@gmail.com, [2]nivethithasarathi@gmail.com, [3]sowndaryalakshmi2002@gmail.com,[4]vithunsathyanarayanan@gmail.com,[5]manavaalan.g@cit.edu.in

Abstract

Unmanned Aerial Vehicles (UAVs) have been used in many industries because they can fly out of sight, maximize production, reduce costs and risks, while ensuring visual security and safety for human workers during pandemics. A commercial drone is typically controlled and navigated using a remote control and a mobile application. Mobile apps are used to visualize the drone's coordinates on a map. There is no direct mobile app for controlling a developer drone like the DJI Matrice 100. This research presents a mobile application for controlling a DJI drone as well as a sensor system for providing information about obstacles encountered during the flight.

Keywords: UAV, DJI Matrice 100, Flight control app, Sensor system

1. Introduction

The DJI Matrice 100 is a professional-grade drone intended for industrial and commercial applications, which is shown in Figure 1. It is a highly customizable platform that can fit a variety of applications, such as aerial photography, inspection, surveying and mapping, and search and rescue operations. Majority of the developer drones by DJI are controlled by a remote controller, along with a mobile phone used to track the flight parameters, camera output and other data. Some advanced commercial drones in the DJI drone series have specific app meant for both control and monitoring. Such an app control method has various advantages over the conventional method. This is not available in developer drones like DJI

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Matrice 100. The DJI Matrice 100 is controlled by the remote controller. The DJI GO app is used to control the external device connected such as Gimbal, camera and other connected devices of the drone. The app does not provide a joystick feature for easier control. Hence, this work brings forward an android application to control the DJI Matrice 100 developer drone using the DJI Mobile Software Development Kit (SDK). The app has features like take off, land, virtual joystick, etc. The ultrasonic sensor system provides the distance of the object from the drone. This data can be used by the user to make decisions for safe flight.

Figure 1. DJI Matrice 100

The DJI Matrice 100 drone specifications are shown in Table 1 [1].

Table 1. DJI Matrice 100 Specifications

Weight with TB47D Battery	2.355 kg
Maximum Takeoff weight	3.600 kg
Diagonal Wheel base	650 mm
Hovering time with TB47D Battery	No payload: 22 min; 500g payload: 17 min; 1kg payload: 13 min
Operating Temperature	-10°C to 40°C
Operating Frequency	5.725 ~ 5.825 GHz 2.400 ~ 2.483 GHz

2. Related Works

The difficulty of operating a drone in a cluttered environment is solved by path planning. The reference for the real-time path planning and some references are given in [2]. The article gives a study of algorithms for improving the tracking performance of quad-copters. Package delivery services by drones are revolutionized by automated landing systems. A camera-based automated landing system was proposed in [3]. The control is aided by the Raspberry Pi 3B+ and PID controller. For navigating the drones in difficult terrains such as forests, path planning technique by image processing was proposed in [4]. Semi-autonomous flight control of forestry-use drones to realize the stability of the flight was proposed in [5]. DJI SDK aids the drone to be used in different applications. UAV based automated vehicle license plate recognition system built using DJI Windows SDK was proposed in [6]. Drones find increasing applications in disaster management. They are used in aerial searches, mapping, analyzing terrains and delivering supplies during pandemics. The search operations are performed using a combination of sensing techniques such as camera, thermal sensing and LiDAR [7][8]. Swarm drones are increasingly implemented for searching operations and delivery of various services [9]. A drone based gas sensing system was implemented in [10]. The drone has autonomous control and a gas sensing system using thermal cameras and gas sensors. The study [11] presented an algorithm for protecting the drone in complex situations.

3. Quad-copter Dynamics

Two frames of reference, the inertial frame and the body frame are considered. The inertial frame or the earth frame is where the x, y and z axes are with reference to the ground. The body frame is with reference to the quad-copter where the x and y axes points are in the direction of the arms, assuming the quad-copter has a symmetrical frame and the z-axis points up in the direction of the motor axes. Figure 2 and Figure 3 show the Euler angles and coordinates of the quad-copter.

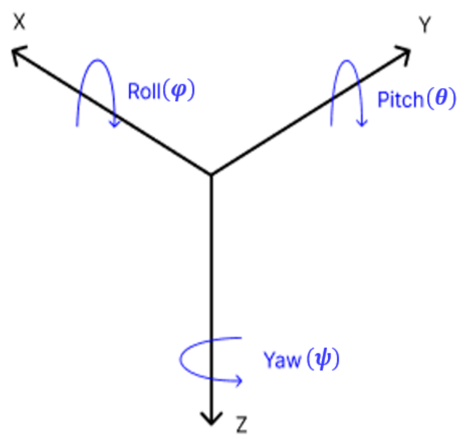


Figure 2. Quad-copter Euler Angles

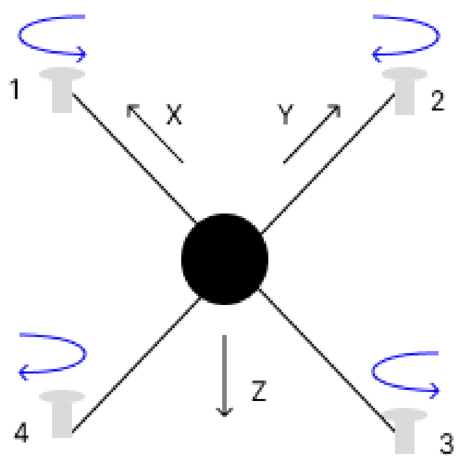


Figure 3. Quad-copter Coordinates

ϕ, θ, and ψ are the rotation along the x, y, and z axes, and the rotational matrix R to convert body frame parameters to the reference frame is given by (1).

$$R_{(\psi,\phi,\theta)} = \begin{bmatrix} c_\theta c_\psi - s_\phi s_\psi s_\theta & -c_\phi s_\psi & c_\psi s_\theta + c_\theta s_\phi s_\psi \\ c_\theta s_\psi + s_\phi c_\psi s_\theta & c_\phi c_\psi & s_\psi s_\theta - c_\theta s_\phi c_\psi \\ -c_\phi s_\theta & s_\phi & c_\phi c_\theta \end{bmatrix} \quad (1)$$

where $s_\theta = \sin(\theta)$, $c_\theta = \cos(\theta)$

If F_1, F_2, F_3 and F_4 are the forces generated by the four motors of the quadcopter and m is the mass of the quadcopter, the relation between the forces of the motor and the acceleration of the drone is given by (2).

$$m \begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ -mg \end{bmatrix} + R \begin{bmatrix} 0 \\ 0 \\ F_1 + F_2 + F_3 + F_4 \end{bmatrix} \quad (2)$$

4. Proposed work

This section presents the necessary features required for the app to control the flight and the control logic used to control the flight.

4.1. Basic Requirements of Flight Control

A) Remote Controller: The DJI Matrice 100 uses DJI C1 remote controller. It has a range of up to 5km. It supports transmission frequencies of 2.4 GHz and 5.8 GHz. The C1 controller supports real time video and data transmission. It supports the DJI SDK for customization. Figure 4 shows the remote controller of the DJI Matrice 100.

Figure 4. DJI Remote Controller for Matrice 100

B) Flight Controller: The DJI Matrice 100 consists of the DJI N1 flight controller. The high performance DJI N1 flight controller is designed for commercial drones such as DJI Matrice 100 and Matrice 600 to support various flight modes and manual control. The flight controller is capable of streaming high quality video data and flight parameters.

C) Electronic Speed Controller (ESC): The DJI Matrice 100 has an inbuilt ESC E SERIES 620D speed controller. The purpose of the ESC is to regulate the power to the motors and support two-way communication between the rotor and the onboard flight controller.

D) Mobile and Remote Controller linking: For controlling the DJI Matrice 100, the pairing must be done between the drone and the C1 remote controller. While using mobile application, the DJI developer account must be logged in the app after connecting with the remote controller.

4.2 Block Diagram

The block diagram in Figure 5 consists of two main parts: Ground station and DJI Matrice 100. In the ground station, there is a C1 remote controller that is connected to the mobile which has the drone control application installed in it. The C1 remote control sends appropriate signals to DJI Matrice 100 based on the input control action received from the mobile application.

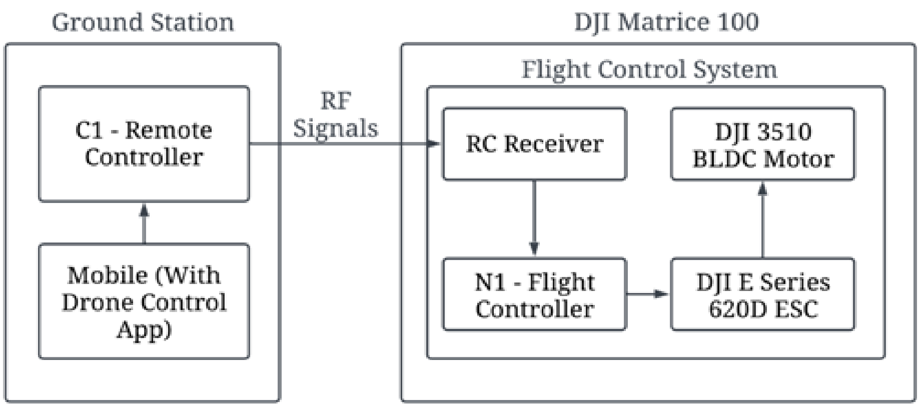


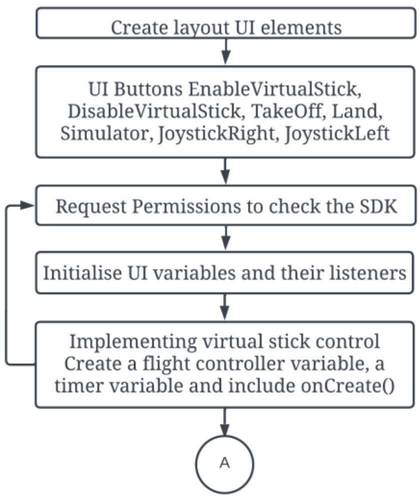
Figure 5. Block Diagram

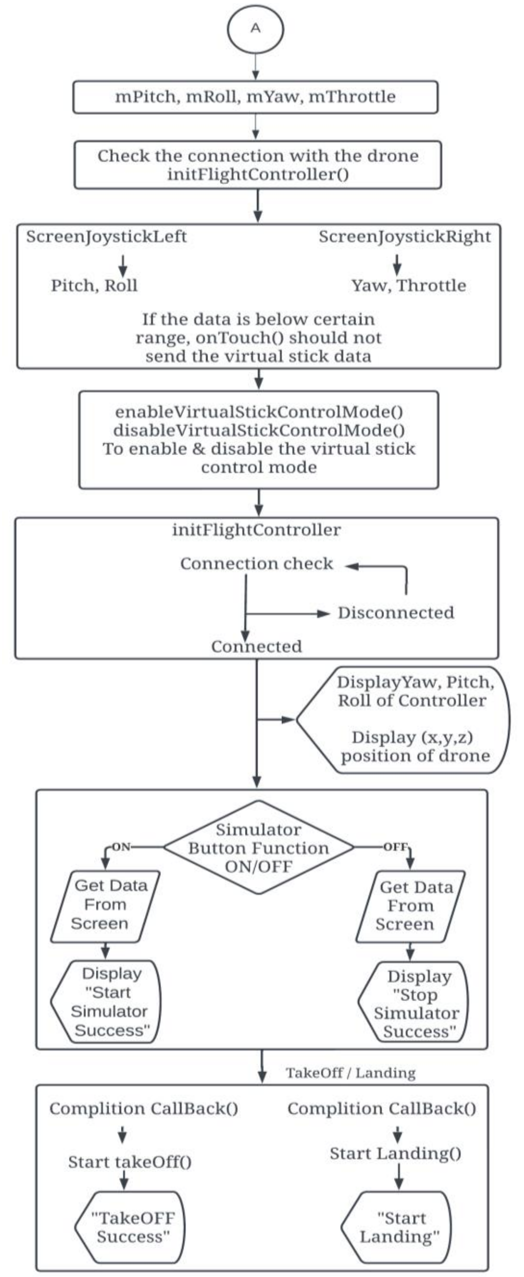
The signals sent from the C1 remote controller are received by the RC receiver on the drone. The signals are then sent to the N1 onboard controller for processing. Control action signals are sent to the ESC which then controls the propellers.

4.3 Control Method

The mode of communication between the C1 remote controller and DJI Matrice 100 is Radio Frequency (RF) signals. The other modes of communication use Wi-Fi and Lightbridge. The DJI Lightbridge is a high-definition video transmitter. For DJI Matrice 100, only RF signals are being used. The control data from the remote controller is converted into physical parameters by combining sensors and software algorithms. The remote controller sends digital data to the onboard flight controller of the drone. The flight controller processes the data and converts it to physical parameters such as orientation, speed and altitude.

The User Interface (UI) and entire application were developed using Android Studio. Figure 6 shows the flow chart of the program. Initially, in the program, the variables have been declared as mentioned in Figure 6. Next, the program seeks SDK permissions and initializes the variables and their functions. Then it implements a virtual joystick where Yaw, Pitch, Roll and Throttle control are available. Then the program checks for the connectivity between the drone controller and ground station controller. If the connection status is positive, the program looks for control signals from virtual joysticks on both sides and other controls in the mobile app like Take Off and Land Buttons. Once the application receives input from the user, accordingly it transmits an appropriate signal to the remote controller. This remote controller sends the appropriate control signal to the flight controller. Once the 'Start Simulator' button is turned 'ON', the virtual simulator turns 'ON' in the application, in which the yaw, pitch, roll and throttle values get displayed on the screen. When the 'Stop Simulator' button is turned 'ON', the virtual simulation is turned 'OFF'.





Figures 6a and 6b. Flow Chart of the Control Application

4.4 Sensor System

The sensor system shown in Figure 7 consists of six ultrasonic sensors to give an angle coverage of 120°.The sensors are interfaced with ESP32 module which sends the real-time data to the firebase. Firebase provides services for various applications in which real-time database is also one of the services. The mobile application gets that real-time data output from the firebase. Based on the sensor data, the location of the obstacle with respect to the drone is obtained.

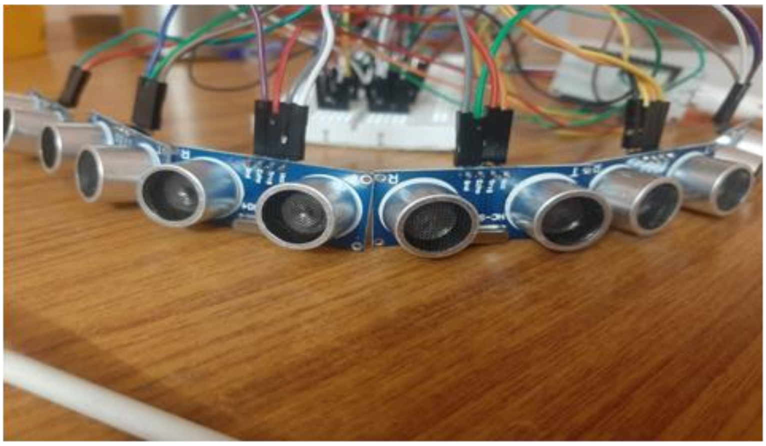


Figure 7. Ultrasonic Sensor Array

4.5 Tools Used

A. Android Studio

Android studio is a mobile application development environment in Google's Android operating system. Android studio aids in building and debugging tools to build Android apps. After coding the Java and xml files, the system is built and the final APK can be tested on either emulator which is a virtual mobile phone or an externally connected mobile phone.

B. Node MCU – ESP 32

ESP 32 is a System on Chip microcontroller that has an inbuilt Wi-Fi and Bluetooth modules. It runs on a 32-bit dual-core processor with a clock speed of 160 MHz to 240 MHz.

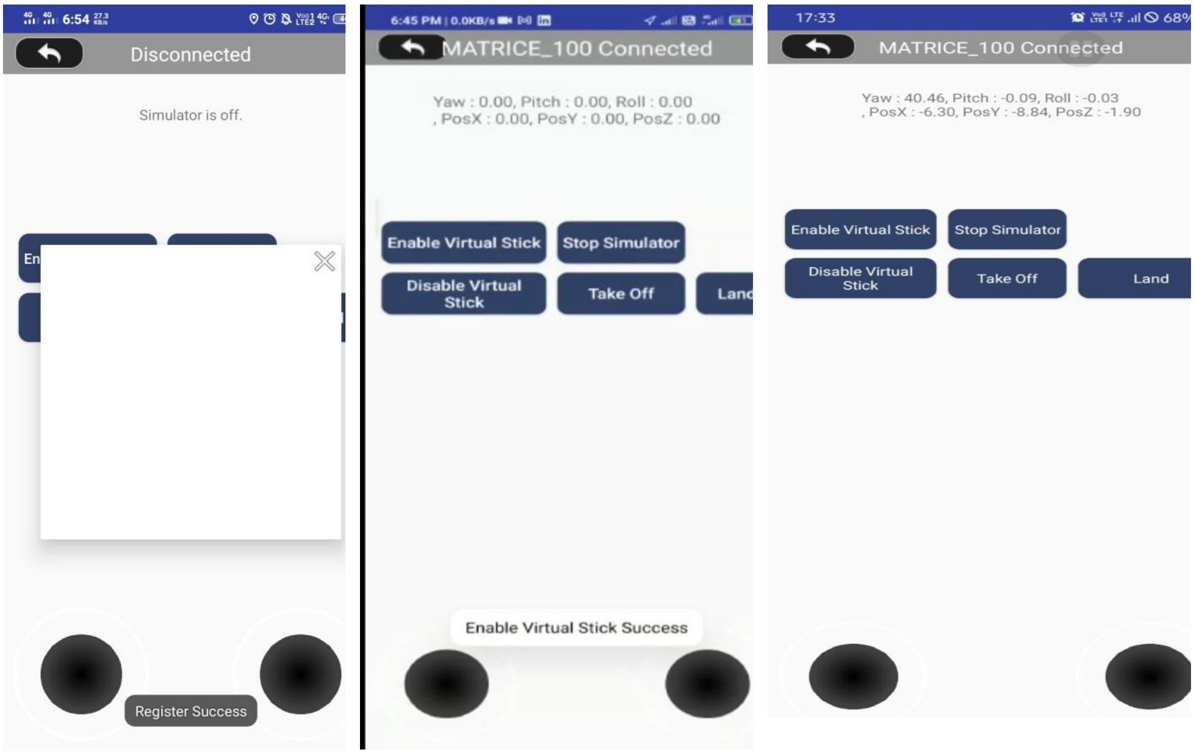
C. Ultrasonic sensor (HC-SR04)

Ultrasonic sensor (HC-SR04) detects the distance of an object using sonar. The maximum range is 4m and the minimum range is 2cm. The operating frequency is 4 kHz. The measuring angle is 15°. The trigger input signal is 10µS TTL pulse.

5. Results and Discussion

The application is tested on DJI MATRICE 100. It is tested in both indoor and outdoor environments.

5.1 Control Application User Interface



(a) (b) ©

Figures 8a,8b and 8c. Screenshots of the Control Application

The User Interface of the control application for controlling the drone is given in Figure 8. Figure 8(a) shows the DJI registration page of the application. The app has to be registered at DJI before connecting the DJI MATRICE 100 to it. Once the registration is successful, the DJI MATRICE 100 gets automatically connected to the application. The remote controller of the DJI MATRICE 100 is connected to the android mobile phone containing the application via a USB cable. Fig. 8(b) shows the application page after connection with DJI MATRICE 100. The connection establishment can be confirmed by the “MATRICE 100 connected” display in the application. After connection with DJI MATRICE 100, the virtual joystick is enabled to the quad-copter from the application. To enable the virtual joystick, the “Enable virtual joystick” button is clicked on the application. Fig. 8(c) shows the page of the application after enabling the virtual joystick.

5.2 Control Application Testing

The connectivity of the Mobile App to the Drone via the Remote Controller and the TAKEOFF and LAND features of the App is tested.

Figure 9. Indoor Testing

Figure 10. Outdoor Testing

The control application has been tested in indoor and outdoor environments. Figure 9 shows the indoor testing of the control application, being successfully connected with the DJI Matrice 100 drone. Figure 10 shows the application being tested in outdoor by flying the drone using the mobile application developed.

5.3 Sensor Data Display

The data from the ultrasonic sensors which are mounted on the drone are collected and sent to the Firebase database with the help of Node MCU - ESP 32 through the internet. Then the data from the Firebase is retrieved and displayed on the mobile application via the internet as in Figure 11. This app is developed using android studio. It shows the distance of the obstacle from each of the six ultrasonic sensors.

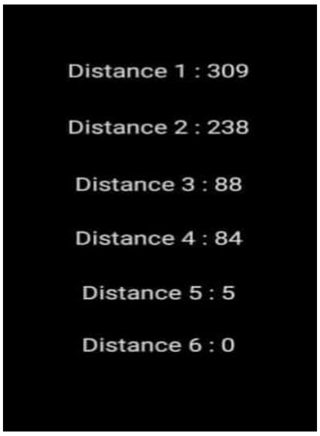


Figure 11. Application displaying the sensor data

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6. Conclusion and future work

The application built has features such as take-off, land and a virtual joystick for the control of flight and navigation. The sensor system gives real-time data about the obstacle if any, during the flight of the drone. By using the sensor data, a control algorithm is to be developed for the flight control of the quad-copter, thus aiming for autonomous control of the drone.

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Author's biography

Vishva P is pursuing the bachelor's degree in Electrical and Electronics Engineering from the Coimbatore Institute of Technology, Coimbatore, India. His interests include LabVIEW and power electronics.

Nivethitha P V is pursuing the bachelor's degree in Electrical and Electronics Engineering from the Coimbatore Institute of Technology, Coimbatore, India. Her interests include Electric Vehicles, Drone technology and Power Electronics.

Sowndarya Lakshmi V is pursuing the bachelor's degree in Electrical and Electronics Engineering from the Coimbatore Institute of Technology, Coimbatore, India. Her interests include Embedded systems, Power electronics and Drone technology.

Vithun S S is pursuing the bachelor's degree in Electrical and Electronics Engineering from the Coimbatore Institute of Technology, Coimbatore, India. His interests include EV and Electrical Machines.

Manavaalan Gunasekaren received the bachelor's degree in Electrical Engineering from the University of Madras, Chennai, India, in 2002, the master's degree in Applied Electronics from the Coimbatore Institute of Technology, Coimbatore, India, in 2005, and the Ph.D. degree in Electrical Engineering from the Indian Institute of Technology at Kanpur, Kanpur, India, in 2015. In 2017, he joined the Coimbatore Institute of Technology, India, as a Faculty Member. His research interests include applications of control systems, smart electrical vehicles, robotics, and automation and soft computing techniques.