Drone controlled real live flight simulator

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Abstract. Flight simulator has been used to train pilots for more than 80 years, whether to fly military aircrafts, passenger aircrafts, or even private aircrafts. A flight simulator is a flying cockpit installed on the ground to help training pilots in flying real aircrafts in a low risk and cost-effective way. Nevertheless, all the previous simulators are dependent on a program being installed in combination with special hardware. Therefore, the purpose of this paper is to design a ground-based flight training simulator. This simulator depends on a drone to transfer the flying environment in real-time to the trainee. A prototype of the project has been implemented based on a small drone equipped with a MPU6050 piezoelectric gyroscope, laptop, and Arduino since the building of the final shape of the simulator is relatively expensive. Satisfying results are gained and the prototype can transfer the drone movement to the ground simulator giving the trainee the feeling as in a real aircraft, improving the trainee’s capabilities of having real-time decisions over the flying environment. The main contribution of this study is the improvement of the current flight simulators by cloning the real environmental effects to the highest possible levels especially for the training purpose of the new pilots or the rehabilitation of pilots with long out-of-service periods.

1. Introduction
Most of cabinet flight simulators works based on a software programed in their control unit, this software simulates the environment of a flying aircraft by converting it to a mechanical effect which can be felt by the trainee using the simulator. However, in most ground-based simulators, the artificial environment produced by mechanical effects does not exactly match the environment of a real flying aircraft. Unmanned Aerial Vehicles (UAV), or Remotely Piloted Aircraft Systems (RPAS) or simply Drones are being used in a large variety uses in commercial, military, scientific, agricultural, recreational, as well as many other applications, e.g., product deliveries, policing and surveillance, smuggling, aerial photography, and drone racing [1].

Drone Controlled Real Live Flight Simulator (DCRLFS) are simulators considers the idea of using drone’s movement and vision by a pilot sitting in a training cabinet on the ground. Special mechanism transfers the drone’s movement to the cabinet to provide the needed environmental effects to the pilot. A DCRLFS consists of two major parts, the training cabinet and the simulation drone. The trainee can use the controlling dashboard in the cabinet to control the drone, in return, the drone returns back the flight effects in a form of data that moves the mechanical motors of the cabinet’s base.

Any aircrafts can fly in three-dimensions or angles pitch (i.e., nose up or down about an axis running from wing to wing), yaw (i.e., nose left or right about an axis running up and down) and roll (rotation about an axis running from nose to tail) [2]. The axes are alternatively designated as vertical, lateral, and longitudinal. These axes move and rotate relative to the Earth along with the aircraft (see Figure1).
The simulation cabinet provides these effects by depending on mechanical motors that provide it with the possibility to move in the three axes mentioned above.

2. Background and Related Works
Flight simulators have been effectively used for training, procedure checking, navigation and system knowledge since 1950s. In 1929 the very first flight simulator was created. Naming it the Pilot-Maker/that had a complete cockpit and controls that simulated the sounds, motions, and sensations of flying. Many researches have been done to improve flight simulators performance by making the pilot feel the real flying aircraft environmental effects [3]. In 1998 Rosenkopf, and Tushman, M [4] shown the interact between the networks coevolve and technology and develop a set of propositions on the emergence, growth and reformation of (cooperative technical organizations) CTO networks, and explore how the evolution of these networks can help flight simulation industry by present some theoretical guidance for industries with products to reduce the complex.

More environmental effects must be considering in pilots training, J. Arthur at el, mentioned a number of these effects in studying the Evaluation of Flight Simulator and shows that the most effecting factor is the limited visibility and its impact on both the capacity and safety for the whole world aviation. Over 30 percent of fatal accidents in the commercial aviation only are classified as Controlled Flight Into Terrain (CFIT), since there are number of airplanes without any mechanical problem crashed by accidentally hitting the ground, water or any other obstacle according to the narrow of outside vision. Thinking that using synthetic terrain with PFD (Primary Flight Display) will enhance pilots’ efficiency to reveal and avoid expected CFIT in compared with the traditional equipment [5]. NASA Aviation Safety Program’s Synthetic Vision Systems (SVS) Project improves a practical applications technologies to remove low visibility situation as it is one of most important factor causing the civil aviation accidents as well as imitate the operational benefits of flight operations in boundless ceiling and visibility-day conditions, in any case of the real exterior climate or lighting condition. Getting a flight simulator close to reality has become the primary goal of flight instructors, many researches works hard to obtain this goal. While in 2014 the researchers Chittaro, Buttussi, Fabio Zangrando, and Nicola [6] proposed a 3D interactive simulation of an emergency situation aimed at the general public, They used the virtual reality technology in order to be very close to the real situation. Even-though and with all of these tries to let the pilot feel as he is leading a real aircraft it still cannot expect any new emergency event that may happen.

3. Research Problem and Objective
Since aircraft has been used in different fields like military, industry, agricultural, civil flight and many other areas which is direct in contact with human life and any small error can cause huge accidents and loss of lives and money [7][8]. Aircraft safety organizations have identified accidents as
events that lead to material losses in equipment, aircraft, and disasters as they cause damage to crew and passengers. The events of airline planes fall into the category of air disasters because they are often accompanied by human casualties. These disasters can be classified in several ways:

- Crash the machine by hitting the ground.
- Crash the machine in the air.
- An accident on the ground.

To avoid such disaster from happening during flying, a need of fully training pilot who can be confident in his choices to face any emergency accident. As mentioned above flight simulator comes with a programmable software that didn’t allow the pilot to feel that he is in real aircraft even if the cockpit panels, the instruments and most of the avionics are the same as the real aircraft, however, when the aircraft is in the air, it is facing a new danger that cannot be not programmed in the simulator’s cabinet.

4. Proposed Model

Usually new pilots are not exposed to the environment of a real flight as software-based simulators are not reliable in providing the actual environmental flights effects, on the other hand, using real aircrafts is risky and expensive. Due to all of what previously mentioned in this section, the use of drones can be much cost effective and more reliable solution. The conceptual model of our simulator is shown in the below diagram, started by connecting the control system of the drone with the control panel of the training cabinet so the trainee can have full control to fly the drone, and a camera which is connected to the drone in order to provide the needed visibility for the trainee (see Figure 2) [9][10].

![Figure 2. Training Cabinet Connecting with Drone](image)

The aircraft flies in the desired route by means of navigation. The navigation method used depends on on-board navigation equipment, which keeps the aircraft in the desired route. The route has many parameters such as aircraft position (attitude), distance, directions to the airports, speed etc. The devices that offer most of these parameters are gyroscope and radio compass also called Automatic Direction Finder (ADF).

4.1. Gyroscope

The gyroscope gives the attitude (pitch, roll and yaw) of aircraft in the sky on the attitude indicator. The attitude indicator also known as an artificial horizon (see Figure 3) shows the aircraft's relation to the horizon. From this the pilot can tell whether the wings are level (roll) and if the aircraft nose is pointing above or below the horizon (pitch). Gyroscopes comes in different types like mechanical, MEMS, optic fiber and ring laser.
4.2 Automatic Direction Finder

ADF (Automatic Direction Finder) [11] is a radio-navigation instrument for finding the direction or bearing to ground transmitter or radio station generally based in the airport. The bearing angle is indicated on ADF indicator as shown in Figure 4.

5. Implementation

Nowadays, so many kinds of drones are available in the market. The drone which was chosen in this experiment is equipped with MPU6050 piezoelectric gyroscope as shown in Figure 5.
The Piezoelectric Gyroscope is a gyroscope that uses a vibrating structure of piezoelectric material to determine the rate of rotation. Fig. 6 illustrates the piezoelectric gyroscope. To simulate the operation of the gyroscope and indicate the changes in the position of the aircraft we use the Arduino board with the laptop.

![Piezoelectric gyroscope MPU-6050](image)

**Figure 6.** Piezoelectric gyroscope MPU-6050

5.1. *Arduino*

Arduino board designs have used a set of controllers and microprocessors [12]. It equipped with groups of analog and digital Input/Output pins that may be linked with different circuits and boards. The boards have serial communication linked, including Universal Serial Bus (USB) on some models that could be utilized for loading programs from personal equipment. The microcontrollers are typically programmed using languages C and C++.

![Illustrates of Arduino Board](image)

**Figure 7.** Illustrates of Arduino Board

5.2. *Interfacing Gyroscope to Arduino*

In this section, the interfacing of the gyroscope to the Arduino will be shown. A gyroscope is a component used to measure the three axes of angular velocity. It is applied to define the direction of the object depending on the concept of the angular momentum. Gyroscopes are being used in many applications in smartphones, flight controlling, gaming and missile guidance. Different types of gyroscopes are available like MEMS (Micro Electro-Mechanical Systems) gyroscopes, mechanical gyroscopes, optical fiber gyroscopes and ring laser gyroscopes. In this project, MEMS gyroscopes were chosen due to their compact design and cost-effective component that widely being used in smartphones and RC toys. MEMS are relying on Foucault pendulum in sensing the orientation by depending on their vibrating electro-mechanical element. An embedded module that consists of an accelerometer and a 3-axis gyroscope has been used in this project, coded as GY521.
5.3. GY521 module (MCU6050)
This module is based on MCU6050 MEMS IC that contains six built-in ADC channels, three of them for the accelerometer and the other are being used for the gyroscope. The 12C protocol is the protocol used to communicate between the module and the microcontroller. MCU6050 is operating with voltage range from 2.37V to 3.46V. User programmable full-scale ranges of the gyroscope and the accelerometer, which they are +/- 2g, 4g, 8g and 16g, while for the accelerometer are +/- 250 °/S, 500 °/S, 1000 °/S and 2000 °/S.

5.4. The GY-521 Pins Out Diagram
The GY-521 board has 8 pins, which are the VCC with 3.3 voltage or 5 voltage; the ground pin GVD and 2 pins for the primary 12C Communication that is Serial Clock Line and Serial Data Line (SCL and SDA); also, it has 2 auxiliary pins (XCA Auxiliary Clock Line and ADL Auxiliary data line) for Auxiliary 12C communication. There is also another pin for master or salve interface which it is the ADO pin and the Interrupt pin (INT). The is a voltage regulator on the board to control the voltage from 3.3-5 volts and an Invernesses chip of MPU6050 in order to grasps the gyro meter sensors and accelerometer (see Figure 9).

6. Applying the Model
Depending on MPU6050 datasheet [13], it can convert the three-directions of the raw gyroscope output values to control speed in the three-directions applying the equations as follows:

\[ V_{\text{pitch}} = \frac{GyX}{131} \]
\[ V_{\text{roll}} = \frac{GyY}{131} \]
\[ V_{\text{yaw}} = \frac{GyZ}{131} \]

Figure 10 is also illustrated pitch roll and yaw in three-dimensional space of an object.

Figure 8. Piezo Electric Gyroscope

Figure 9. Three-Dimensional Space of an Object
Connecting the GY-521 with the Arduino is shown in the Table 1 below:

| MIPU6050/ GY-521 | Arduino UNO Pin |
|------------------|-----------------|
| VCC              | 5v (the GY-521 has a voltage regulator) |
| GND              | GND             |
| SDA              | A4 (12C SDA)    |
| SCL              | A5 (12C SLC)    |
| INT              | D2 (interrupt #0) |

The SCL pin and SDA pin of the GY-521 must be connected to the SCL pin and SDA pin in Arduino since these pins are used for I2C communication. The SCL and SDA pins on Arduino Uno are the A4 and A5 pins correspondingly. Hence, the SCL pin and SDA pin of GY-521 are connected to A4 and A5 pins in Arduino Uno (see Figure 11). The two auxiliary pins (SDA and SCL) which the GY-521 MPU6050 is an additional I2C controller, to let the GY-521 MPU6050 act as a master for the second I2C bus. These additional pins can be used if there is another sensor that needs to be added.

![Arduino Uno connections](image)

**Figure 10.** The Pins Connections diagrams of Arduino with GY-521

The two auxiliary pins (SDA and SCL) which the GY-521 MPU6050 is an additional I2C controller, to let the GY-521 MPU6050 act as a master for the second I2C bus. These additional pins can be used if there is another sensor that needs to be added.

![Designing conceptual model](image)

**Figure 11.** Main Steps in this Research
7. Result and Discussion
After the implementation of the proposed model, satisfying results were obtained and as showing in the picture below (see Figures 12-16).

- **Figure 12.** Connecting Arduino with GY-521
- **Figure 13.** Connecting the Circuit with Laptop
- **Figure 14.** Testing Connection
- **Figure 15.** Testing Movement
- **Figure 16.** Aircraft Movement Transferred to the Laptop

8. Conclusion
In conclusion and according to the experiments’ results, the movement of the drone can be transferred to the training cabinet on the ground which let the beginner pilot to face a real air situation while he is on the earth and to support his ability in taking real time decisions in controlling the aircraft since the situations are different and cannot be predicted by the pilot. The limitation of this research appears in
getting component with specific characteristics, according to its higher cost. Future work can include more environmental effects like sound, wind, and other effects.

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