International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume –05, Issue – 10, October 2020, PP – 17-24

Design of Pre-Emptive Virtual Framework Support for Individual Piloting (PROPILOT)

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Abstract: PRO PILOT is an IoT based exigency support system model that assist the pilot facing quandary situations or overburden of work load due to onboard emergencies such as pilot incapacitation(s) or system faults like autopilot failure. Internet of Things (IoT) is a network of physical devices are that are interconnected with each other and communicate with one another through the access of internet. In the aerospace industry, IoT is revolutionizing operations on the ground and in the air and extends a multitude of lateral automation windows for the airplanes. PRO PILOT is an IoT based automation concept which make use of the internet for manipulating the flight controls from the ground station via a remote pilot assistance. An Adruino Uno board with ESP8266 Wi-Fi module to enable internet connectivity is integrated with the RC circuit installed onboard of the RC aircraft. The authenticator controls the RC aircraft using a smart phone by commanding it over the internet through an applet. The project demonstrates the aircraft control ed by the pilots (control using RF controller) when encounter emergency issues like pilot incapacitation(s) or other system errors like autopilot failure, a deterministic takeover of the aircraft control (controlling RC over internet) using IOT is effectuated. This real time procedure is hoped to be helpful for coping with the situation. The paper focuses on developing the PRO PILOT system and improve the demand of implementation by solving for the associated problems.

Keywords: PROPILOT; Internet of Things (IoT); Autopilot ; Remote Pilot ; RC Aircraft ; Adruino Uno; ESP8266 WiFi module.

I. INTRODUCTION

Aviation is one of the main drivers behind globalization, driving the development of the modern world. A network of airlines, airports and air traffic management organizations link the major cities and small communities of the world 24 hours a day with increasingly advanced aircraft. Aviation has continued to expand. It has weathered crises and demonstrated long-term resilience, becoming an indispensable means of transport. Historically, air transport has doubled in size every 15 years and has grown faster than most other industries. In 2019, airlines worldwide carried around 4.6 billion passengers annually with 7.1 trillion Revenue Passenger Kilometers (RPKs). Fifty-three million tons of freight were transported by air, reaching 205 billion Freight Tons Kilometers (FTKs). Every day, around 100,000 flights transport over 10 million passengers and around USD 18 billion worth of goods. Commercial aviation is the world’s safest mode of transportation, with a record that continues to improve even as the enterprise steadily grows. Demand for air travel is growing so fast that IATA expects it to double in the next 20 years. With over 100,000 flights made daily, serving over 2 million people, safety is still a major concern. Accidents related to air transport average to about 265 yearly, mainly due to human error.

Statistically speaking, general aviation aircraft are both more common and risky than commercial planes. Despite the inherent risks associated with flying in any type of aircraft, the National Transportation Safety Board (NTSB) reported in 2015 that general aviation accidents had been steadily declining for years, and associated fatalities had also declined. Commercial airline crash statistics may be even more encouraging: During the seven-year period from 2010 through 2016, not one US based commercial airline crash resulted in a fatality. In 2017, there were two commercial airline crashes that resulted in fatalities. Even with these positive trends, fatal crashes continue to occur in general aviation.

In recent years, a sharp rise is observed that automation has started to be used in aviation as well as in many different areas. Especially in-flight decks, there has been a swift movement to the usage of digital systems instead of mechanical systems. Currently airplanes have flight deck automation systems that change the task, re-distribute workload for the crew, and present situations that induce an error. The change in role from active, manual control to one of system management has left pilots less proficient in manual skills but still required, on occasions, to take control in time critical situations. The whole world is talking about Industry 4.0 or the fourth industrial revolution. That is the current trend of higher levels of automation, digitalization and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of Things and cloud computing among others technological assets. With more than 5000 sensors, which generate up to 10 GB of data per second, new modern aircraft engines are a clearly exponent of what digitalization and the internet of aircraft things could furnish, as part of the upcoming Industry 4.0 revolution, in the aviation industry called Aviation 4.0. This new era has the potential to help to improve all key performance areas of air transport.

PRO PILOT is an exigency support system model based on Internet of Things (IoT) that assist the pilot facing quandary situations or overburden of work load due to onboard emergencies such as pilot incapacitation(s) or system faults like autopilot failure. The PRO PILOT is developed based on numerous case studies of several aircraft incidents that have dealt with the abovementioned perplexity hard and others which culminated into fatal crash. This framework would be adoptable for both commercial airlines and private jets. The private jets are mostly single pilot operated and some having autopilot installed (e.g. Falcon 7X), making the PRO PILOT an essential back up support for averting dangerous situations in airborne flight.

II. MATERIALS AND METHODS

A. 2.1 RC Components and electronics

This framework is about the procedure for the design of PROPILOT. Here we use RC aircraft components and other electronic components for developing the PROPILOT system integrated with the conventional RC aircraft circuit for interchangeable control of the whole aircraft. The components are readily available in the market as a ready-to-install set. These components are explained further as follows:

2.1.1 Coro Polypropylene Sheet: Referred to, in the industry, as "Corex" or "Coro", this material is predominately used for making hobbyist RC airplanes. Originally developed to protect electronics, these materials have applications in many industries. Permanently neutralizes corrosive gases, using no oils. Protects silver, copper, brass, bronze and ferrous metals.

2.1.2Fly Sky FS-TH9X 9CH Transmitter: The 2.4 GHz 9Channel transmitter model FS-TH9X from the manufacture of Corona and Assan is used in the system for transmission of control signals. This transmitter offers 9 channels of which only 5 channels are used.

2.1.3FS-IA6B Receiver: The features on this radio are amazing for the price and is specified it out especially for the customers with the FS-iA6B Telemetry receiver, which has a hard case, coated antennae and includes data ports for extra telemetry modules. The 6 channels 2.4Ghz radio FS-iA6B receiver supports heli/standard wing/elevon/V-tail models.

2.1.4Scorpion SII-2208-1100 V2 Brushless Motor: The new SII-22 series motors are an updated and improved version of the popular S22 motors that have been so successful. This V2 motor replaces the V1 S-2208-34. Max Continuous Power 130 Watts. Max Continuous Current 12 Amps, 1100 kV.

2.1.5HITEC HS-55 Micro Servo: The HS-55 set the standard for affordable performance, offering precision components that have been engineered to provide long lasting trouble-free service. Featured in a hundred model aircraft reviews worldwide, the HS-55 is the best choice when it comes to controlling Park Flyers.

2.1.6RC Lithium Polymer Battery: A Lithium Polymer Battery is a rechargeable battery commonly used in RC planes and drones with a capacity of 2650 mAh and nominal voltage of 11.1V.

2.1.7Grayson Hobby Brushless Speed Controller [GH30A]: This brushless speed controller controls and regulates the speed of the electric motor. It has a BEC of 3 amps and an auto shut down feature when signal is lost.

2.1.8Arduino UNO R3: The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case.

2.1.9ESP8266 Wi-Fi Module: The ESP8266 Arduino compatible module is a low-cost Wi-Fi chip with full TCP/IP capability, that has a MCU (Micro Controller Unit) integrated which gives the possibility to control I/O digital pins via simple and almost pseudo-code like programming language. ESP8266 Arduino module comes with PCB trace antenna which seems to have a very good coverage.

2.2 Procedure

We choose a stick fuselage model and an already available scale down model plan is adapted for guidance and the flight is built over it. The model plans are shown in the latter figures. The weight of the flight is given importance and the whole flight is built using choro sheet, the properties of which are discussed former in the report. The main frame, wing and stabilizers are constructed and surfaced with the choro sheet. The high resistivity and toughness of the sheet helps in withstanding the air forces encountered on the flight course.

The materials are to be cut with precision and the uncut edges, corner chips and sanding problems are to be eliminated by filing smooth, laser cut and the adhesive bonding. To keep sanding minimum, try to cut all parts as accurate as possible including spars, longerons, wing leading edge sheeting etc. This will save time of replacing broken parts. It is advised not to cut the plan over as it will lead to formation of ribbons and hence reducing the aero properties of the structure. The modelling is done in two phases. In phase 1, the construction of RC aircraft is carried out. In phase 2, assembling of RC electronics is done. The detailed procedure is explained below,

Phase 1: The planform shape of the fuselage was drawn onto a sheet of coroplast sheet. The foam was cut on the lines with a manual retractable craft knife to produce four sets of fuselage sections. The profile of the fuselages is such that the front section is a curved tapering contour and the rear section is extended trapezium which is later glued onto each other using cyanoacrylate. Rectangular formers with square cut-outs are placed at each interval spanning throughout the fuselage supported with stingers to establish shape of the fuselage. Aluminium rod is inserted forcefully through the square cut-outs to produce the aft section and glued. Slots are made on the top and middle areas at the rear end of the rod to accommodate stabilizers. The planform shape of the horizontal stabilizer and vertical stabilizer was drawn onto the sheet and cut on the lines to produce the stabilizers sections The horizontal stabilizer was partially cut to obtain normally flexible elevators at the rear end and inserted into the middle slot of the rod and glued. The vertical stabilizer was partially cut to obtain laterally flexible rudder at the rear end and inserted into the top slot of the rod and glued. The planform shape of the wing was drawn onto a sheet of coroplast sheet. The foam was cut on the lines with a manual retractable craft knife to produce single set of whole wing which is double the dimension with suitable margin. The flat base Clark Y airfoil is cut out and duplicated into more and glued at equal intervals in the one section the wing span wise which corresponds to ribs of the wing. Slot for the spars can be cut with a small hacksaw and finished with a square edged fine file. The components of the wing are to be checked for accuracy before wrapping it around with the choro sheet. It needs to be ensured that all parts fits together precisely without deviation from each position and the symmetry is maintained at all costs. We choose the centerline of the tail plane as the datum line as this is normally set as 0-degree incidence. The other section is folded onto the latter compensating the margin to obtain the whole wing structure. The ailerons are cut at each side of the wing at rear end. The whole wing assembly is placed over the cabin part of the fuselage centrally and glued. A strong square motor mount made of depron foam is placed at the forward end of the fuselage. The landing gear mount is placed below the fuselage to install the bracket which is later bolted with landing strut. On the back side attach the gear with a washer and a nylon lock nut. Glue the nylon control horns one each at elevator, rudder and both ailerons. Glue the servos one each at horizontal stabilizer, vertical stabilizer and rear end of wing. The Z type push/pull rod is connected between the servo metal gear and control horn at each section. The brushless motor was bolted centrally on the mount and the plastic propeller is attached at fore section of the rotor. The receiver, ESC and battery pack are installed in the fuselage volume.

Phase 2: It comprises a smart phone control station at transmitter end and an Arduino-based integrated RC circuit at the receiver's end establishing a four-channel wireless control. The receiver end connection is explained below,

The Arduino board at receiver's side is driven by an 11.1V LiPo battery, which is used to power the brushless DC motor through the ESC module. Pin 11 of board 2 is connected with data pins 6 and 7 of the receiver. The pins 12 of the board is connected with the signal pin of servo motor M1 driving the elevator. The pin 10 of the board is connected with the signal pin of servo motor M2 driving the rudder. The pin 8 of the board is connected with the signal pin of servo motor M3 driving the aileron. The pin 9 of the board is connected to the ESC module. The Tx and Rx pins of the ESP8266 WIFI module is connected to the Rx and Tx pins of the adruino board respectively. The power pins of the same is connected to the 3.3V and GND pins. The Binding between transmitter and receiver, programming adruino to control servo motor, programming adruino to control brushless dc motor, programming ESP8266 to deep sleep mode, setting up ESP8266 Wi-Fi module on adruino are completed before the integration.

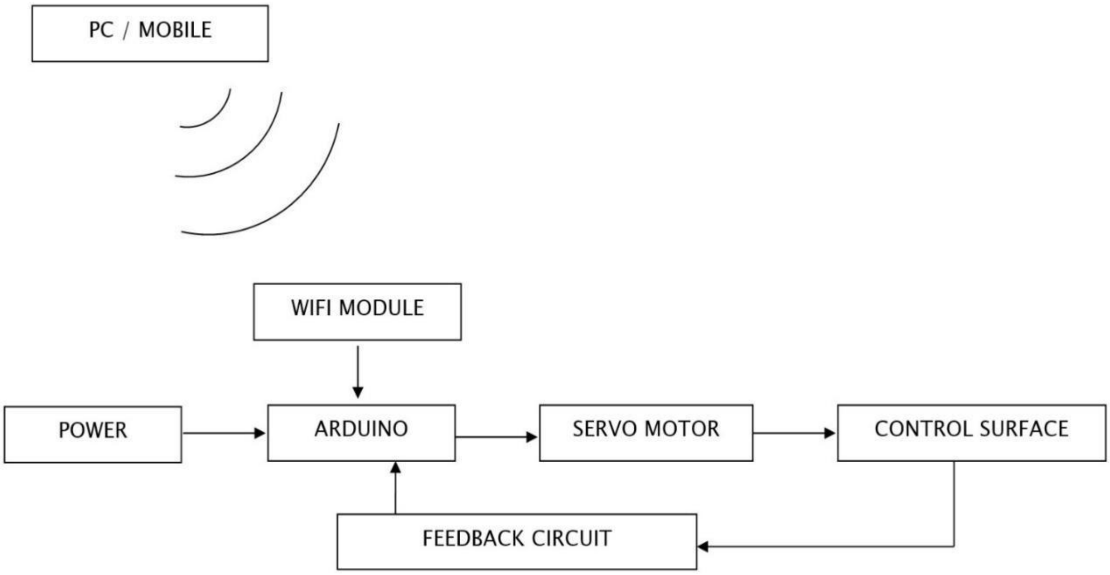

Figure 1: PRO PILOT basic working block diagram

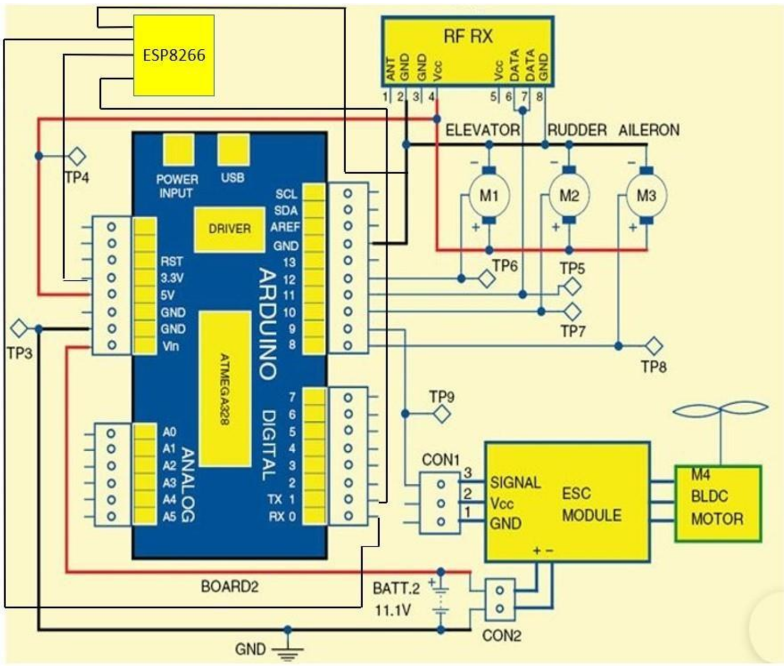

Figure 2: Circuit diagram of integrated Arduino Uno in RC circuit

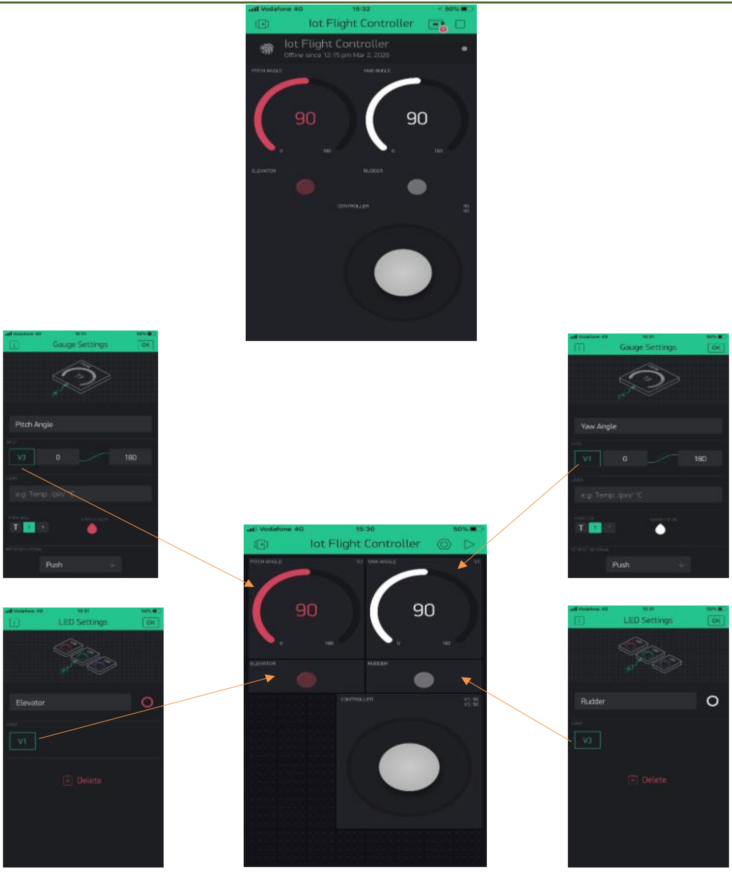

Figure 3: Basic Blynk app settings

III. WORKING PRINCIPLE

The working of the prototype is done in two phases. In phase 1, we control the RC aircraft using the radio transmitter any flying the aircraft solely on RF transmission. In phase 2, the aircraft is now controlled with Wi-Fi with a PC console. The detailed description of how the entire prototype works is explained below,

3.1 Phase 1: Controlling The Airplane Using Radio Frequency

Since the binding of the transmitter and receiver is completed, the aircraft is now fit to fly. The brushless motor is throttled up using the fore motion of the transmitter left stick. The linear motion causes the transmitter to transmit a set sequence of electrical pulses in which each sequence contains a short group of synchronization pulses. The synchronization segment alerts the receiver to incoming information is four pulses that are 2.1 milliseconds long with 700 microseconds intervals. The pulse segments tell the antenna to throttle up the motor uses 700 microsecond pulses with 700 microsecond intervals. The number of pulses for each motion is as, for forward: 16 pulses, forward/left: 28 pulses, forward/right: 34 pulses. The transmitter sends bursts of radio waves that oscillate with a frequency of 72,000,000 cycles per second (pulse modulation).

The aircraft is constantly monitoring the assigned frequency (72 MHz) for a signal. When the receiver receives the radio bursts from the transmitter, it sends the signal to a filter that blocks out any signals picked up by the antenna other than 72 MHz. The remaining signal is converted back into an electric pulse sequence. The PWM output from the receiver is sent to the adruino. The ATMEG processor processes the signal and sends an appropriate output through pin 9 to the ESC. The PWM output from the receiver is sent to the ESC in which the input is converted to voltage proportional to the duty cycle using the low pass filter embedded in the Integrated Circuit. The Field Effect Transistor in the ESC acts as a switch to regulate the power to the motor. Current speed controllers differ the power to the motor by fast switching the power ON and OFF. Here, MOSFET Transistor is used as a switch instead of a mechanical device, and the amount at which it is switched is about 2000 times a second. So, the power to the motor is diverse by changing the amount of ON time, against off time in a specified cycle. When the MOSFET is switched ON, the current rises as the magnetic field in the windings of the motor increases. When the MOSFET is switched OFF, magnetic energy stored in the windings has to be absorbed by the ESC. By cabling a diode across the motor, we return the energy into the motor as current, which rises down as the magnetic field failures.

For other maneuverability of the aircraft pre-set sticks in the transmitter is moved. The receiver picks the transmitted signal for a particular manoeuvre, say pitch up. The PWM output from the receiver for pitch up is sent to the adruino. The ATMEG processor processes the signal and sends an appropriate output through pin 12 to the servo motor M1. The servo will move based on the pulses sent over the control wire, which set the angle of the servo horn. The servo expects a pulse every 20ms in order to gain correct information of the angle. A servo pulse of 1.5ms set the servo to neutral position, a servo pulse of 1.75ms set the servo to 180 degrees. Thus, pitch up manoeuvre is accomplished.

3.2 Phase 2: Controlling the Aircraft Using Wi-Fi

The ESP module is programmed to function deep sleep for a period of 180000ms (3 minutes) during the phase 1 operation to prevent the interference of RF and Wi-Fi signals. Soon as the module wakes up, the board is ready to accept the Wi-Fi signals. Now the RF transmitter is no longer needed. The smartphone interface has been developed to access control at the receiver end. The Wi-Fi connection is adopted since it can save the battery onboard of the aircraft. An ESP8266 Wi-Fi module has been connected to appropriate pins of the adruino board and programmed. The phase 2 requires the complete inactivity of the radio frequency influence because it can influence the interference between the two signals.

The web based PROPILOT smartphone application has several options listed such as throttle up/down, elevator up/down, aileron left/right, rudder left/right and finally exit option. To access the control of the receiver end, the smartphone has to establish a Wi-Fi connection between the module and the latter. After the ESP module is connected to Wi-Fi, it will assign the static IP and also creates the server. Once the server is created, the module is waiting for connecting with the client. Now the ground controller can swipe up the application to grant command for the airplane. To throttle up the brushless motor slide the throttle option from the application. The inbuilt antenna of the smartphone transmits the data and pings with the ESP module. The TensilicaXtensa LX106 CPU of the module processes the data and convert into proportional PWM. The output of the module is connected to the respective pins on the adruino board. The ATMEG processor of the board processes the signal and transmits the output to the ESC to throttle up the airplane.

Also, to accomplish certain manoeuvre of the aircraft, say pitch up, slide the elevator up option and rest of the operating principle is same as explained above. The deep sleep of the ESP module saves the battery power.

IV. CONCLUSION

It has been demonstrated that the practical approach to analyzing how the RC plane function by internet shed light on how the system works effectively and its practicality in modern air transportation. The study on various assistive technologies, rules and regulations, and required components has been done. The methodology has been developed for the project. The project team has acquired significant knowledge on the concepts and how the components work and has a clear idea on how to move forward with the proposed project.

Opportunities exist today for the deployment of IoT technologies to the commercial aviation industry. These opportunities span both operational efficiencies in commercial aircraft flight as well as opportunities to exploit real-time device data to provide integrated predictive maintenance and intelligence linked into advanced flight management and MRO systems. Future autonomous systems will also provide an excellent opportunity for new market segments as regulations are released to provide for safe operation alongside passenger-carrying aircraft. The deeming requirement of automation in aviation has inspired this project and the PROPILOT can be an apt application of IoT in the aircraft.

V. APPLICATION

With the inclusion of digital technologies, the airline industry has now been able to deliver unique customer experiences, simplified underlying processes, and most importantly enhancing the productivity of the workforce. The next stride in leveraging IoT can lead to the exploration of newer dimensions in the aviation industry. Combining IoT with other technologies like AI and robotics would generate a number of opportunities related to service delivery improvement. Further, a smart IoT ecosystem can bring in all the required entities and assets together in the industry value chain and make it look like the new normal. Though the PROPILOT is a small scale practical demonstration on RC airplane, its applicability in most modern air transportation is much attention seeking. In light of various aviation incidents happened in past decade, the concept of PROPILOT is necessary. The additional setup for incorporating IIoT in aviation avionics is required to develop a full scale practical PROPILOT. The availability and feasibility of such industrial IoT Machines have to be yet researched.

One concept involves integrating the airplane avionics and IoT machine is similar and analogous to our PROPILOT concept.

In case of pilot incapacitation or autopilot failure, the current pilot in charge can attempt or proceed with a procedural way of engaging the PROPILOT. The pilot switches the power supply to the internet module, making the aircraft controllability dual mode. The module is connected to internet provider. For effective communication higher bandwidth is required. The reason is related with the need for higher bandwidth.

VI. FUTURE SCOPE

The future scope of this project relies on the development of Artificial Intelligence. The project works describe the manual interpretation of controlling the aspects of flight using single board computers that support machine codes. That human pilots are trained to handle flight uncertainties or emergency situations such as severe weather conditions or system failure so they can provide better results than the current autopilot system. Manually designing and developing all the necessary controllers to handle the complete spectrum of flight scenarios and uncertainties ranging from normal to emergency situations might not be the ideal method due to feasibility limitations such as the difficulty in covering all possible eventualities. Also, the autopilot is not desirable during emergency conditions because it cannot take independent decisions based on the emergency situation.

To solve this issue, a proposed Intelligent Autopilot System (IAS) can be utilized. This system can collect the data based on how the pilot control the aircraft in emergency situations and based on this data the autopilot system can control the aircraft.

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