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An International Journal of Multidisciplinary Research

A Real-Time Control and Operating System of UnmannedAerial Vehicles (UAV)

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Abstract:

This article is a study of the research of remotely piloted drones and unmanned aerial vehicles (UAVs). In order to guarantee that activities are done in the allotted amount of time, real-time control systems create more deterministic responses. Drones today have higher expectations for functionality; hence this system characteristic is greatly sought after. The reviewed materials were chosen with the real-time operation of drones and the incorporation of technology utilized in diverse drone applications in mind. The development of highly agile unmanned aerial vehicles (UAVs) has allowed for their use in a variety of fields, including surveillance, aerial navigation, military operations, agriculture, and more. However, there are a number of difficulties associated with the control of these highly agile unmanned vehicles. In an effort to enhance drone efficiency, this article will examine the real-time nature of control and the use of Real-Time Flight Control Systems (RTFCS).

Keywords: Unmanned aerial vehicles, Drones, Real-time operating system, Global positioning system, inertial measurement unit.

Introduction:

A drone, or UAV, is a form of aircraft that does not require a human pilot to fly it [1]. Micro Electro-Mechanically (MEMS) sensors, High-Energy Lithium Polymer (LiPo) batteries, Microprocessors, and more compact and efficient actuators have all contributed to the exponential expansion of unmanned aerial vehicles (drones) during the past few decades [2]. They have a wide range of applications, from monitoring pipelines and power lines to fighting in the military to farming to delivering medicine to remote locations to charting the skies [3]. The literature [4] extensively discusses how the changeable dynamics of the robotic arm add difficulty to the control of UAVs. UAV use is on the rise, and UAV solutions are being developed at a breakneck pace to meet the ever-expanding list of possible applications [5]. The drone's features are determined by the commercial market's level of competition and the UAV's intended use [6]. Recent UAV uses in the cryo-sphere were analyzed. Unlike conventional space-based systems [7].

Controller Mechanism

Drones and other UAVs require an accurate and dependable controller to maintain altitude speed and heading [8]. By isolating the sub-synchronous component of the measured signal's voltage and current, [9] network noise can be reduced. The UAV is controlled by the altitude controller during takeoff and landing so that it maintains a set altitude. Controlling the UAV's heading and velocity can fly between waypoints [10]. Fuzzy logic, sliding mode, proportional integral derivative, linear quadratic regulator, neural network, etc.

[11] is only some of the control systems that can be employed to suit the control needs. Parametric uncertainty and external interference are two of the main challenges that control systems have been developed to address. Uncertainties in propeller rotation, blade flapping, speed changes, and the placement of the center of mass necessitate a dependable nonlinear controller for multi-rotor UAVs [12]. A combination of the Non-Linear Sliding-Mode Control, a robust Back-stepping controller, and a Non-Linear Disturbance Observer (NDO) were used to achieve both robustness and compensation for system non-uniformities. The SMC controls the quad rotor‘s rotation, while the back-stepping controller keeps the translational motion stable [13].

UAV real-time control implementation:

Before real-time control capabilities for UAVs can be implemented, however, tasks must be established. For the purposes of task scheduling, inter-task communication, and resource management (including memory and power consumption), an RTOS is required [14]. The stack in the microprocessor is where the data for each job is stored. The multi-threading functionality in the RTOS kernel is responsible for this. Tasks are scheduled and prioritized, and sensors that provide data for tasks are routinely updated [15] to guarantee that application time limitations are met. We also test the battery cells for fault tolerance in both battery drive and hybrid driving using a GCU battery [16]. Quad-copters use RT-Thread, an embedded real-time operating system, to address problems with latency, heavy processing loads, and command and control. Using a PID control algorithm [17], the RT-Thread control system responded instantly in real-world tests to ensure a stable flight of the quad-copter. Obtaining attitude data, fusing attitude data, and PID control are the application-based tasks in this work. The primary purpose of this program is to manage quad-copters. The RT-Processing Operating System (RT-Thread) serves as its foundation; it is run by a similar type of microprocessor to that found in the quad copter [18]. This CPU has a high-performance ARMC Cortex-M4 core, 1 MB of Flash memory, a Floating-Point Unit (FPU), 168 MHz of maximum system frequency (MHz), and 192 MB of static random-access memory. The Controller-Area Network (CAN) bus and Direct Memory Access (DMA) are among the many peripherals it supports [19]. The quad-copter has a high operating frequency and a large memory, providing it with a high level of computational capability that enables it to do complex calculations. Surplus peripherals can be used to lessen the computational burden on the microprocessor and remove the need for external integrated circuits [20]. The system implementation makes use of a cluster of two

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processors. The bespoke quad-copter used in this experiment is controlled by two processors, one of which handles telemetry. Data collecting from sensors, data transmission to the General Communication System (GCS), and reconfiguration and tracking data transmission via GPS are all software activities performed by the telemetry part of the system [21]. A real-time operating system (RTOS) manages the tasks, and C /OS-IITM makes it happen.

PID Controller:

The control processor, as depicted in Figure 1, runs the PID controller algorithm to stabilize and guide the quad copter. Several jobs were assigned to the control processor, which allowed this to be completed [22]. The following diagrams depict the PID controllers actually put into practice. Implementing the Yaw, Roll, Pitch, and Altitude PID control loops, as well as interpreting data from the GPS, compass, IMU, altitude sensor, and telemetry processor, are all part of the tasks at hand. The CAN bus [23] also relays reconfiguration and monitoring data to the telemetry processor. For the equation describing the relationship between the PID controller's feedback error and the resulting time- domain control signal for the plant, see below.

$$ut = Kpet + Kie \int etdt + Kddedt \qquad (1)$$

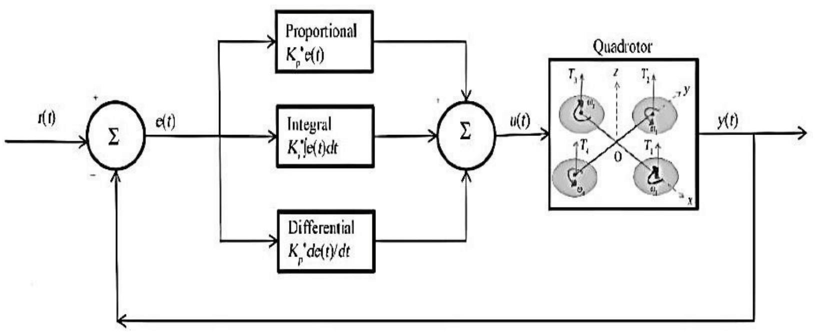

Fig. 1. Block diagram of PID controller for Quad-rotor

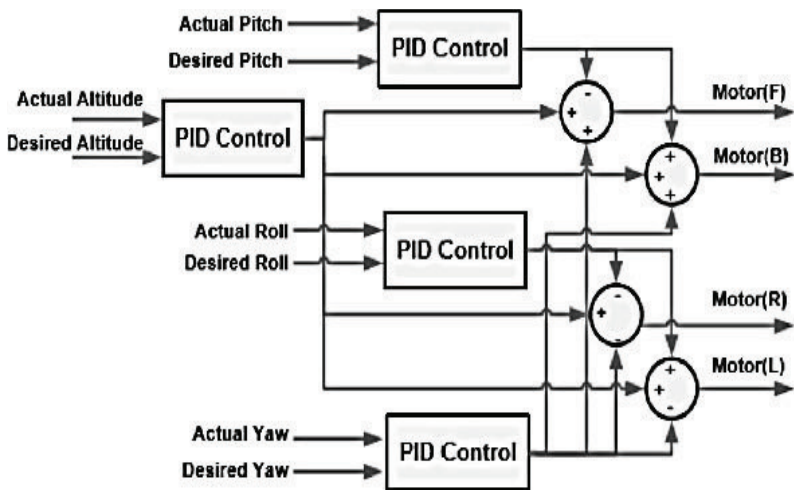

Fig. 2 The control processor loops of PID control

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Linear-Quadratic-Gauge (LQR) Technique

Figure 3 when the linear-quadratic-gauge (LQR) method is combined with the linear-qe and the Kalman filter; it becomes the linear-quadratic-Gaussian method. This method works for systems with both complete and incomplete state information and Gaussian noise. Integral action was used to steady the CA's inclination during hover mode, and the results were good. The integrated LQG controllers have the benefit of not requiring complete state information for implementation [24]. Integrator output, which is the difference between system input and output as a dynamic system, refers to equation (2) [25], and isthe result of adding the integrator and inserting error status (e).

$$x^{\cdot} = Dx+Euy = Gxu = -K'x+kI'ee = r-y = r-Gx (2)$$

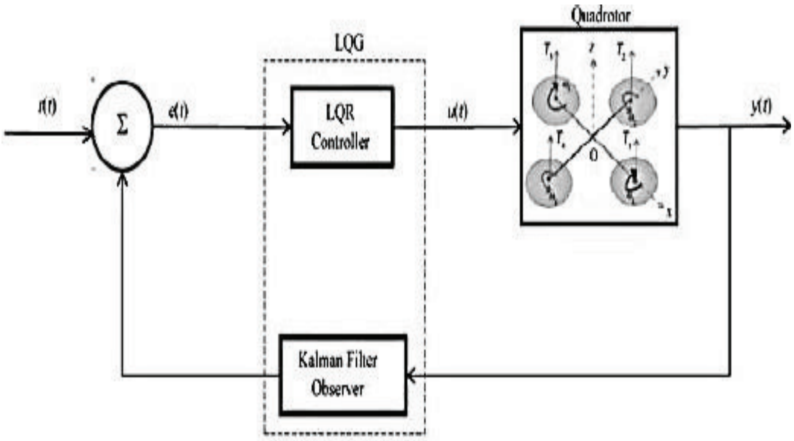

Fig. 3. Block diagram of LQG controller for Quad-rotor

Fuzzy Logic and Artificial Neural Networks controller

Figure 4 demonstrate that in both scenarios, there was convergence in both airspeed and yaw angle [26]. In addition to injecting current and voltage components, sub-synchronized frequency component current is injected into the line to promote network damping. The measured system signal is broken down into the current and voltage components of a sub-synchronized component. [27] Feedback-linearized control was compared to sliding mode control (SMC) with a flexible control mode.

The feedback controller was extremely vulnerable to sensor noise and lacked robustness even when the dynamics were simplified. The SMC worked admirably under harsh environmental circumstances, and its flexibility allowed for precise prediction of uncertainty (including ground effect). A nonlinear, feedback-linearized technique for control offers high tracking but poor disturbance rejection as a result. Good outcomes can be attained when a less noise-sensitive strategy is also used.

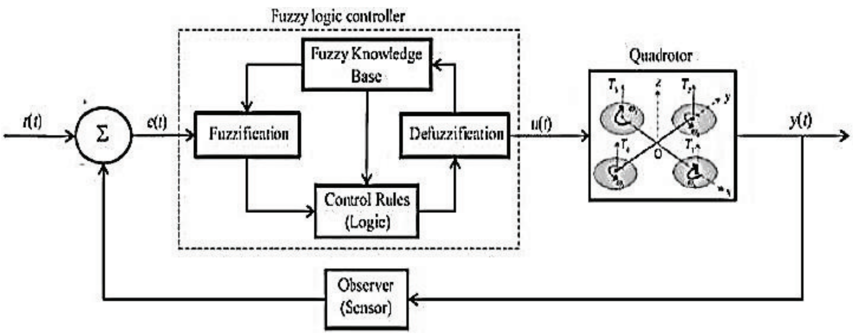

Fig. 4. Block diagram of a Fuzzy Logic Controller for Quad-rotor

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Real-time Operating System

Few studies on the scheduling of UAVs have been published, and even fewer deal with the implementation of real-time drone control systems. An embedded remote-control operating system (RTOS), also known as a UAV operation system (UAS) [28], is necessary for real-time execution in the governor of a drone. Various types of motors, including induction motors, direct current motors, permanent magnet synchronous motors (PMSMs), etc., use FOC and DTC for operation. [29].

The microcontroller's control database is run on a real-time operating system known as an RTOS [29]. The real-time kernel uses the UAV scheduling system to guarantee that application tasks are done on time. Therefore, a UAV must have access to a real-time operating system (RTOS) that can support several duty scenarios. [30]. The Free RTOS is the most extensively used RTMS for UAVs. To assess the functional changes made to the Free RTOS over time, an empirical study was done. The examination of Free RTOS covered 85 different versions, from V2.2.2 all the way up to the current 10.0.0.

As shown in Figure 5, the on-board processing unit of a UAV is the microcontroller, which is responsible for computing and monitoring the state of the UAV. The microcontroller is chosen to meet the application task requirements [31]. It is necessary to take into account factors such as computational speed and communication with the aboard sensors. The reduction in SSR is accomplished by increasing the network damping for frequencies near the Torsional Mode Frequency (TMF) [32]. The Crazy Lie 2.0 Quad Rotor was equipped with hardware and software that enabled it to track objects up to 27 grams in size as part of a commercial COTS Quad Rotor system.

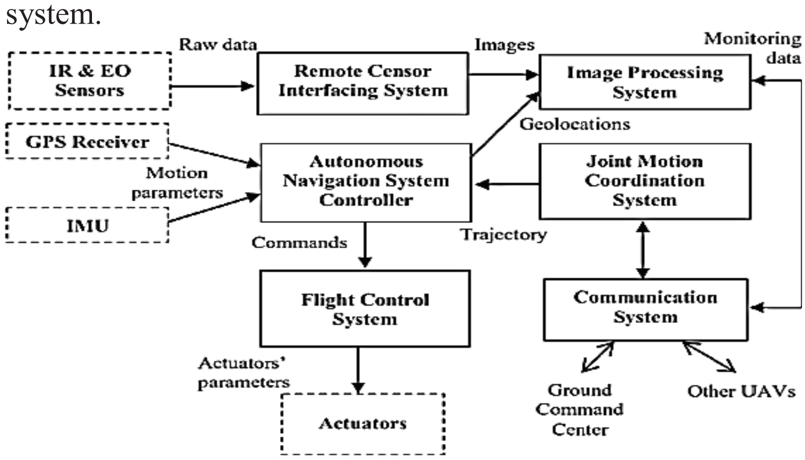

Fig. 5. Sensors with microcontroller

An STM32 F405 microcontroller, which acts as the primary on-board handling unit, and a Nordic NRF51 module, which is used for wireless communication, make up the backbone of the quad rotor platform [33]. The Standard Multithreaded Microcontroller (STM32) runs at 168 MHz [34] and is based on the 64-bit ARM architecture. The vehicle has a 9-axis Integrated Measurement Unit (IMU) in the form of an MPU-9250 that includes an accelerometer, magnetometer, and gyroscope, as well as a pressure sensor, the ST LPS-25H, that is accurate to within around a meter on average.

Conclusion

An embedded Remote-Control Operating System (RTOS) is required for successful real-time control of drones. This real-time operating system (RTOS) has capabilities like multithreading, scheduling, and priority assignment that allow the drone's control system to react instantly to data from sensors like GPS and inertial measurement units (IMUs). The selected drone's motions are then completed via the application of the proper motor speeds by the control system. By performing activities in parallel, like position and alignment guidance, track scheduling, and control execution, multi-threading enables drones to respond in real-time. In addition, some tasks require the use of the results of earlier calculations. As a result of careful planning and prioritization, the microprocessor can allocate its limited processing resources to the most pressing tasks at any given time, such as obstacle avoidance.

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