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A UAV Skydog as a Platform for a Research and a Development of Advanced Control Systems

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Introduction

To create and implement advanced control systems in the unmanned aerial vehicle (UAV), it is first necessary to create simulation model, which will be used to verify correct operation of systems.

Simulation model was created in simulation environment Matlab/Simulink based on the parameters of a UAV Skydog.

The Skydog mathematical model has the same dynamic coefficients as the real UAV, so it is suitable for testing advanced algorithms and control systems.

Only after successful simulations, it is possible to implement algorithms in the real UAV.

Overview of a UAV Skydog

The main control unit of the UAV is an autopilot unit Pixhawk PX-4, which is connected to the power source, motor, radio telemetry and all electronics including servos and antennas.

The autopilot is equipped with its own inertial measurement unit (IMU) with accelerometer, gyroscope, magnetometer (compass), barometer.

It is also possible to connect global positioning system module, power system and other interfaces to the Pixhawk.

Attitude is controlled by an operator from a ground station via RC controller.

Figure 1 The UAV Skydog

6DoF mathematical model

The mathematical model can provide valuable simulation data, which can be used for further improvement of the real UAV.

The main part of mathematical model is the 6-degrees-of-freedom (6DoF) model itself.

Block scheme also includes feedback that is used for the output monitoring and adjusting the input commands.

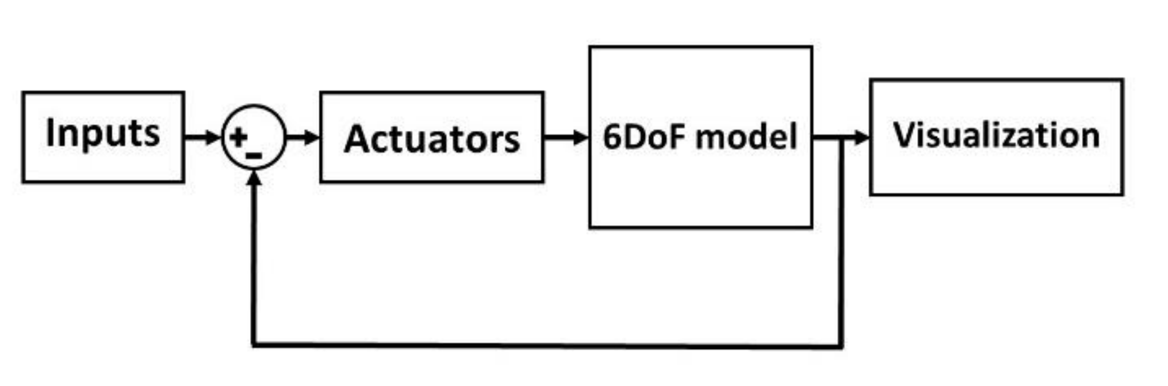

Figure 2 Block scheme of the UAV‘s mathematical Model

Flight phase classification and diagnostic system

This system can classify flight phase based on the aircraft's velocity, altitude and thrust.

Three different approaches were used – decision table (DT), fuzzy inference logic (FIS), time-delay neural network (TDNN).

Flight phase classification and diagnostic system is one of the systems in the aircraft's advanced control.

Based on the flight phase, the regulators can change their regulating gains, therefore the stability and controlability can be enhanced.

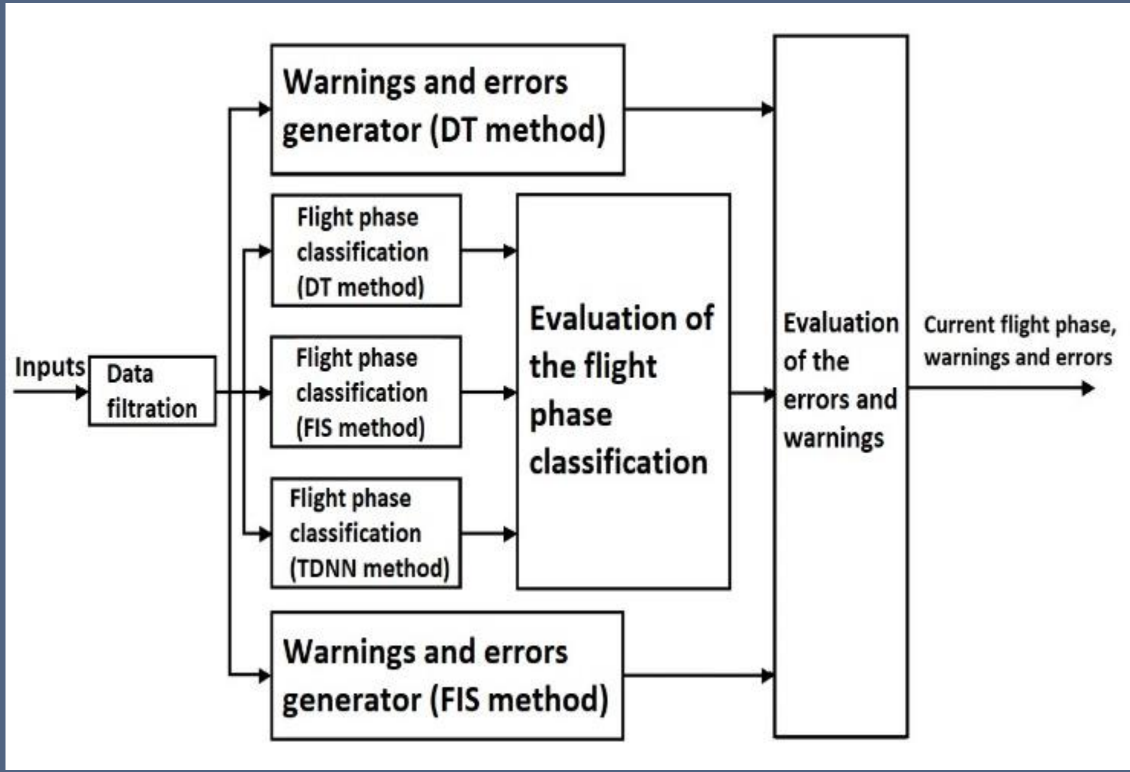

Figure 3 Flight phase classification and diagnostic system

PID and robust controller comparison

Another approach to enhance stability of the aircraft was to create controllers that would help in improving of the aircraft’s control.

Two types of controllers were used – PID and robust controller.

The principle of comparing the PID controller with a robust controller was to define properties of controllers and their impact on flight dynamics.

The properties were estimated based on the system’s roots, transition, phase and frequency characteristics and time responses of the transition characteristics.

Inertial sensors analysis and modeling

A static measurement over a long period of time is required for a reliable analysis of inertial sensors.

Allan variance was used for analysis of the Pixhawk‘s IMU unit.

By creating Allan variance graphs for individual sensor axes, the development of noise mechanisms over time can be observed.

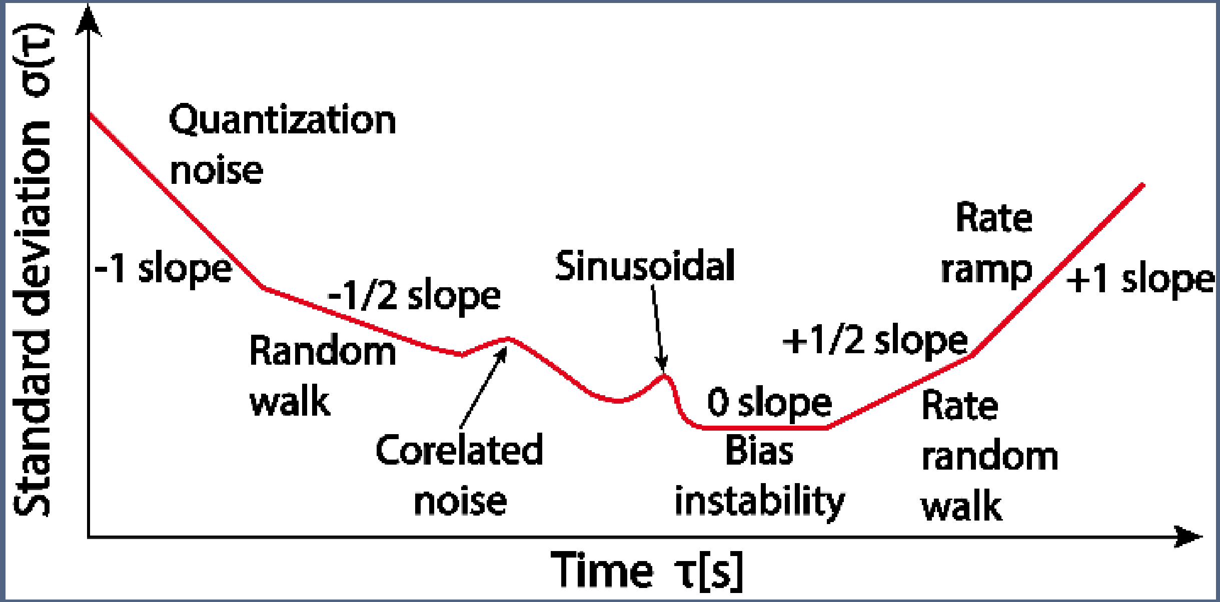

Figure 4 Sensor noises identified by allan variance

Sensor‘s error model

With the help of the Allan variance graph, it is possible to determine the parameters of individual noise mechanisms and thus construct an error model of the sensor.

Stochastic as well as deterministic sensor‘s errors were included in our simulated sensor‘s error model – Angle Random Walk, Bias Drift, Misalignment and Nonorthogonality error.

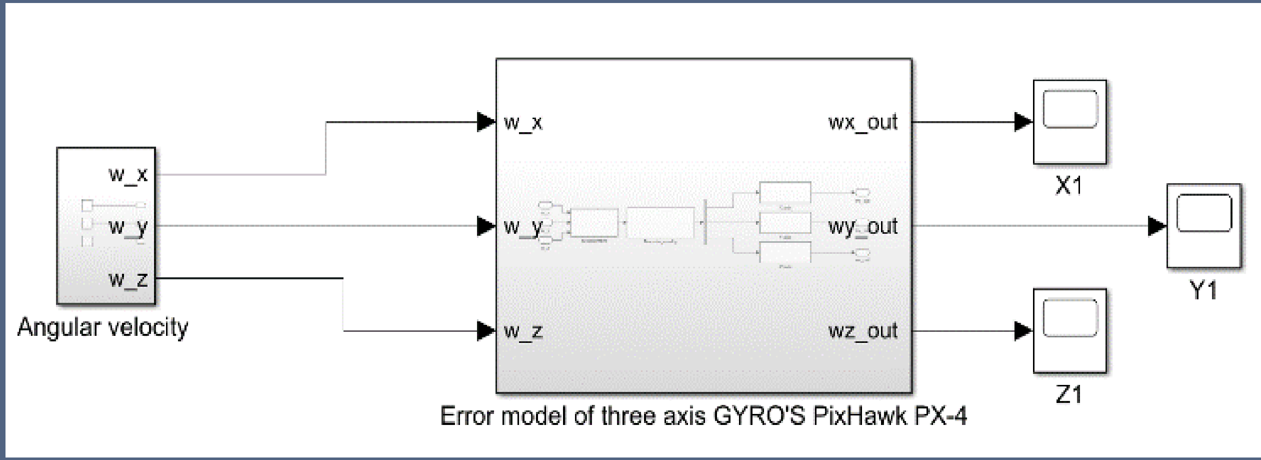

Figure 5 Errors Model of Angular Velocity Sensor

Integration model of advanced control systems

The inputs for the flight phase classification are altitude, velocity, and electric current.

After diagnostic, the specified flight phase and pilot commands for UAV control enter the controller block.

The control signal proceeds to the 6DoF block of the model, which causes a change in the aircraft‘s dynamics.

A created model of sensor‘s errors is involved in the negative feedback, which simulate random errors in the sensors.

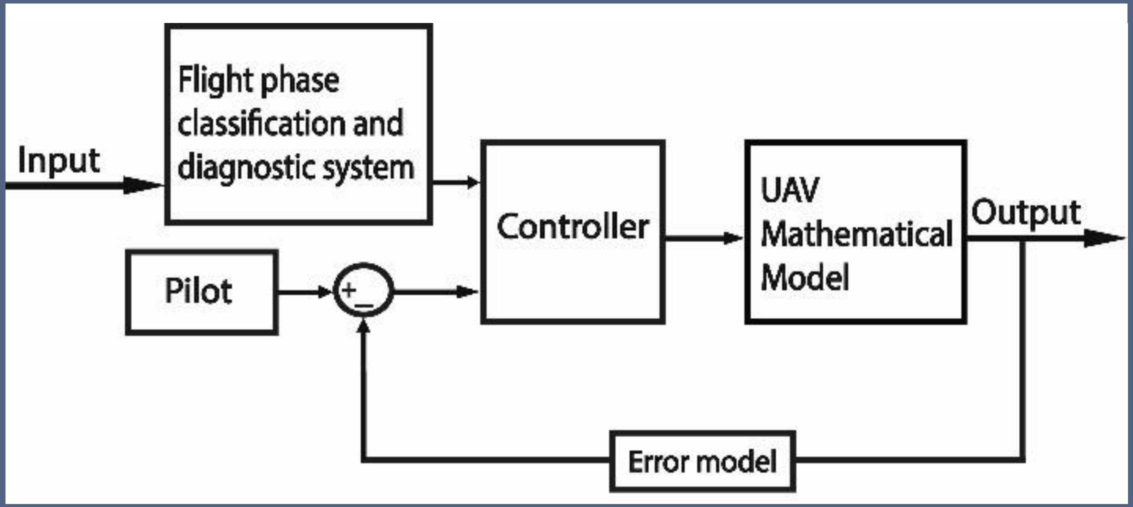

Figure 6 Integrated advanced control system

Integrated advanced control system can improve the stability and controllability of the UAV model.

Conclusion

This work aims to describe advanced control systems, which were made with focus on flight phase classification, diagnostics, errors, operator‘s inputs and UAV control.

The project Skydog is used as a platform for development of the advanced control system.

Based on the results shown in the paper, the integration of advanced algorithms will improve aircraft‘s stabiblity and controlability of the real UAV.

Thank you for your attention.