INGENIA SE | COURSE 2022-2023

System Design Document V1.0

Hell-ix Team

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Contents

1. Introduction

1.1 Purpose

This document describes the model designed with MATLAB/Simulink System Composer tool of the autonomous drone racing competition system.

1.2 Overview

In the first place, the system architecture will be explained in a global manner. Afterwards, each of the subsystems composing the system will be detailed. The design rationale will be commented during the description of each subsystem.

2. System overview

The system consists of a competition of autonomous drones in the context of the INGENIA SE 2022-2023. In order to design the system, MATLAB/Simulink System Composer tool has been used, taking into account the requirements that were defined in the SyRS document. The design procedure is up-to-down, meaning that the design is more generic in the first steps and as the design process advances, the design of each subsystem is further detailed.

3. System architecture

3.1 Architectural design

The model for this system has been divided in three subsystems that interact with each other: the drone itself, the ground central station and the competition environment where the drone will have to perform better than the rival team's drone.

They are connected by the following signals as shown in Figure 3.1:

- **Test:** This signal specifies which test is being performed by the drone.
- **Environment:** Represents all the elements around the drone, including the track, obstacles and detection targets. Wind speed is also considered as the environment because even though the drone is meant to fly indoors, there may be air currents or other perturbations.

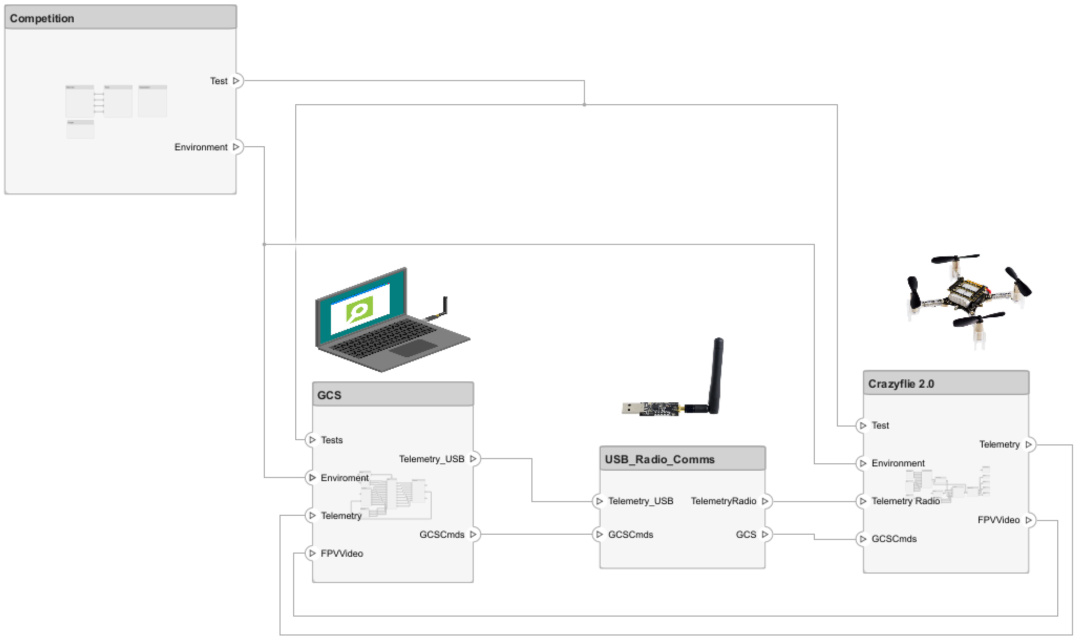

Figure 3.1: Overview of the whole system

- **Telemetry_USB Telemetry Radio:** Messages sent from the ground station to the drone, consisting of the next desired state of the drone. This state being defined by position and velocity.
- **Telemetry:** Similar in format to the previous, but sent from the drone to the GCS. Its purpose is to provide feedback and mantain both systems properly coordinated.
- **GCSCmds:** Other messages sent from the ground station to the drone with objectives other than control of movement. These include lift-off and landing, and starting and stopping mounted devices.
- **FPVVideo:** This signal is sent from the drone to GCS, where the pictures taken by the drone are analyzed. This kind of signal has a specific format which is BMP.

3.2 Decomposition description

3.2.1 Ground Central Station

Since the decision to use a Ground Central Station (GCS) was made, it is important to set the information flow.

It is considered that the GCS will receive two main data from the Competition component and another two from the Drone component. Component is how MATLAB calls the system subdivisions. "Tests" and "Environment" are received from Competition and "Telemetry" and "FPVVideo" from Drone.

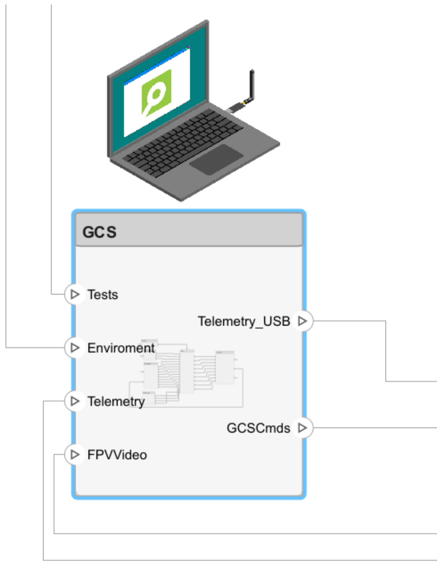

Figure 3.2: GCS inputs and outputs

With the information of these inputs, it is possible to know the drone position, speed and angle as well as the detected obstacles images. This is sent to the CPU which with this information and the competition rules defined is able to obtain the output parameters: position, angles and speed of the drone.

After this, the controller is in charge of sending the telemetry and the commands to the drone by using the USB Radio Antenna. It also feeds back the drone state.

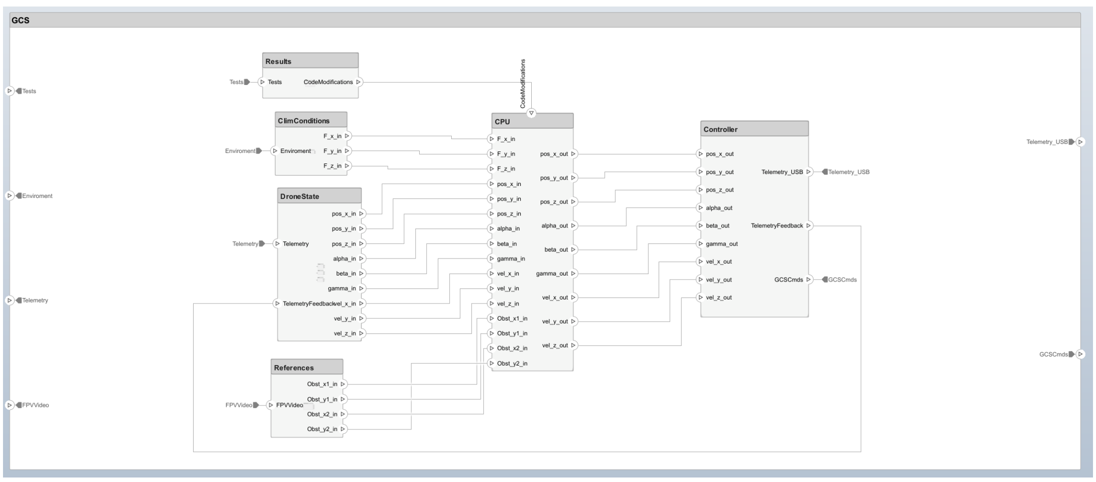

Figure 3.3: GCS Components

3.2.2 Crazyflie 2.0 Quadcopter

The drone used is already designed and all the components needed are present. The design is centred around the software involved in controlling the drone, and sending and receiving information from the ground station.

The model of the system is depicted in Figures 3.4 and 3.5.

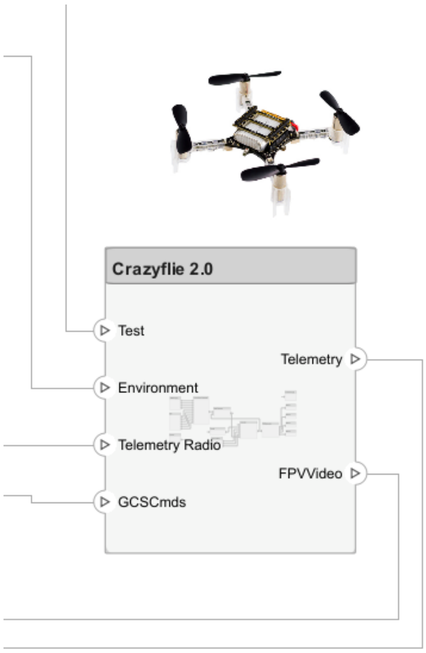

Figure 3.4: Crazyflie inputs and outputs

The following list describes the components present in Figure 3.5:

- **STEM Ranging:** Autonomous drone that can be controlled to explore and operate a robot in 3 dimensions. It has the ability to detect obstacles around it.
- **IMU:** The IMU consists of an accelerometer and a gyroscope for obtaining the acceleration and the rate of change of the rotation of the drone. It is the main orientation device alongside STEM Ranging and its information is fed to the State Estimator.
- **Camera:**This drone mounts a camera which film the environment that surrounds the drone. The information from the camera is sent directly to the ground control station, where all these images are evaluated.
- **Current State Calculation:** Calculation of the current drone states: acceleration (in 3 dimensions), distance to obstacles and finally the drone movements(pitch, yaw and roll).

- **State Estimator:** Consists of an observer such as the Kalman Filter or a Particle Filter. The estimator receives information from the IMU and STEM Ranging, as well as the previous actuation signal to produce an estimation of the current state of the drone (position, orientation, etc.).
- **Results:** This block changes the parameters of the drone in the different types of tests that it has to complete. This test could be passed through windows or point on a dartboard.
- **Controller:** It takes the estimated state and the reference and produces an actuation signal for each of the motors. The control method is yet to be determined but it can range from multiple PIDs or LQRs to Sliding-Mode controllers if required.
- **Clime conditions:** Receives from the Environment signal information about wind speed and feeds it to the controller as disturbances to consider.
- **PWM Generator:** In this module, the actuation signal is translated into PWM, which is sent to the motors in the drone.
- **Functional Logic:** Responsible for managing all the systems that are not directly related to the control pipeline.
- **Motors:** Drone motors, each one receives a PWM signal for varying their voltage.

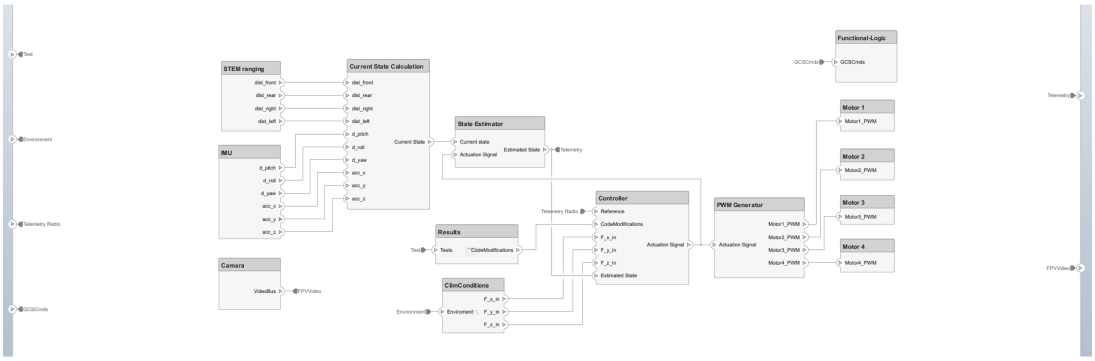

Figure 3.5: Crazyflie components

3.2.3 Competition

The competition has 4 main elements: the trials, the materials, the people and the organization.

- **Trials:** has 6 subcomponents that represent the 6 trials of the competition.

- **Materials:** represents the materials needed for the competition and its organization.
- **People:** represents the contestants, the public and a third group that will help to make sure that the rules of the competition are being respected.
- **Organization:** represents organizational details like the place, date and publicity of the competition.

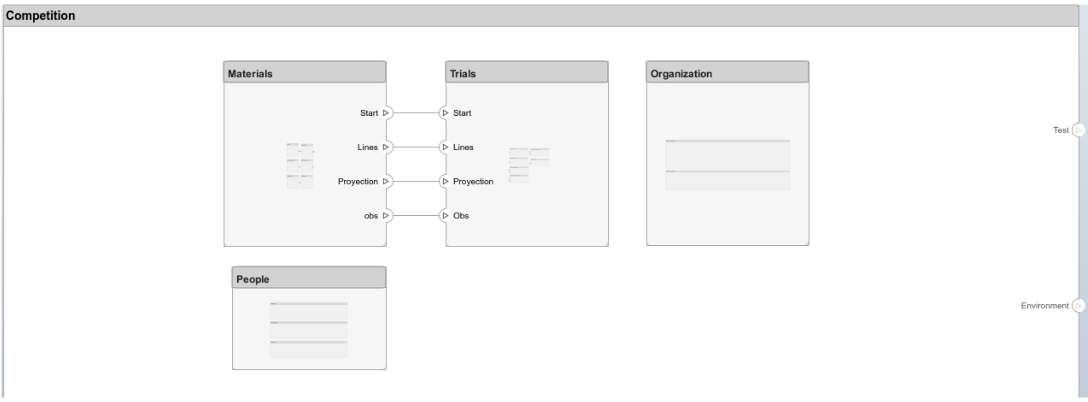

Figure 3.6: Competition