FSD Multicopter Simulation

Minimal User-Guide for Protected Release 1.1,

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1. Prerequisites

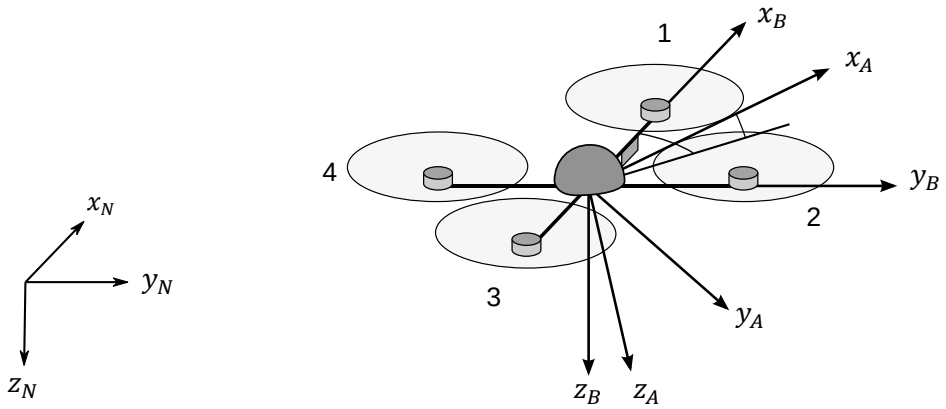
- Mathworks Matlab & Simulink 2012b with appropriately set up compiler (*mex -setup*)
  Additional Toolboxes: Simulink 3D Visualization, Simulink Coder
- Recommended: Joystick with 6 or more analog axes, preferably Futaba 7C Remote Control with appropriate USB-Interface

2. Quick Start

This is usually all you need to get started:

1. Change Matlab working directory to the simulation base directory (*Multicopter_r1.1*)
2. Open *Multicopter_Testbed.slx*
3. Choose Simulation Mode (*Normal* or *Accelerator*)
4. Configure joystick mapping block to match your model (see Assignment) or replace by included test signals in the case of no connected joystick.
5. Open 3D View (> Visualization > VR_View) or Sensor Scopes (> Visualization > Sensors)
6. Press the Start button

3. Coordinate Frames and Notation



Subscript	Description
B	Body-fixed Frame
A	Aerodynamic Frame
O	NED Frame
N	Navigation Frame
WGS84	WGS84 Frame

4. Files

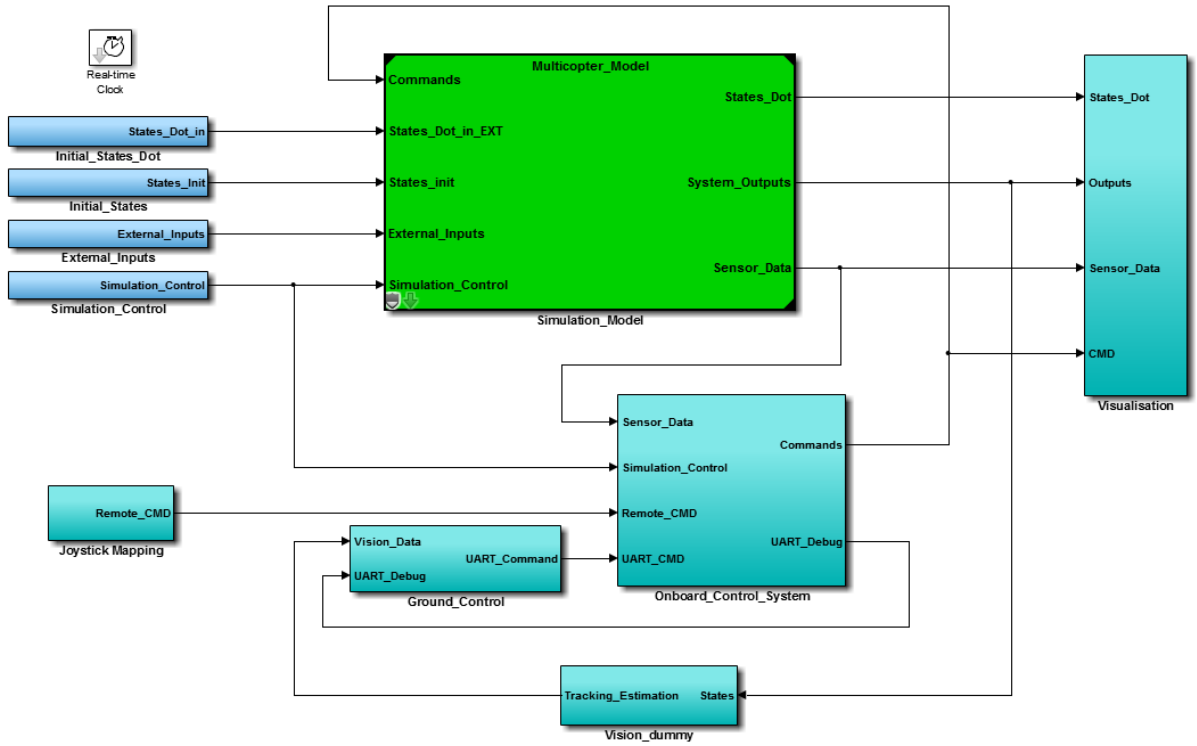
The following files and subfolders are provided in a zip-archive.

Item	Description
Multicopter_Testbed.slx (Main File)	Control Testbed for the Multicopter Simulation Model
Multicopter_Simulation_Data (Subfolder)	Contains the simulation model referenced in the testbed (*Multicopter_Model.slxp*) and necessary init and data files. It will be added to the Matlab Search Path after loading the testbed. These files are provided in protected mode currently.

5. Testbed

5.1. Overview

The Main file contains a testbed which references the simulation model and can be used to test own control algorithms. It is meant to be a template which should be adapted to the users needs.



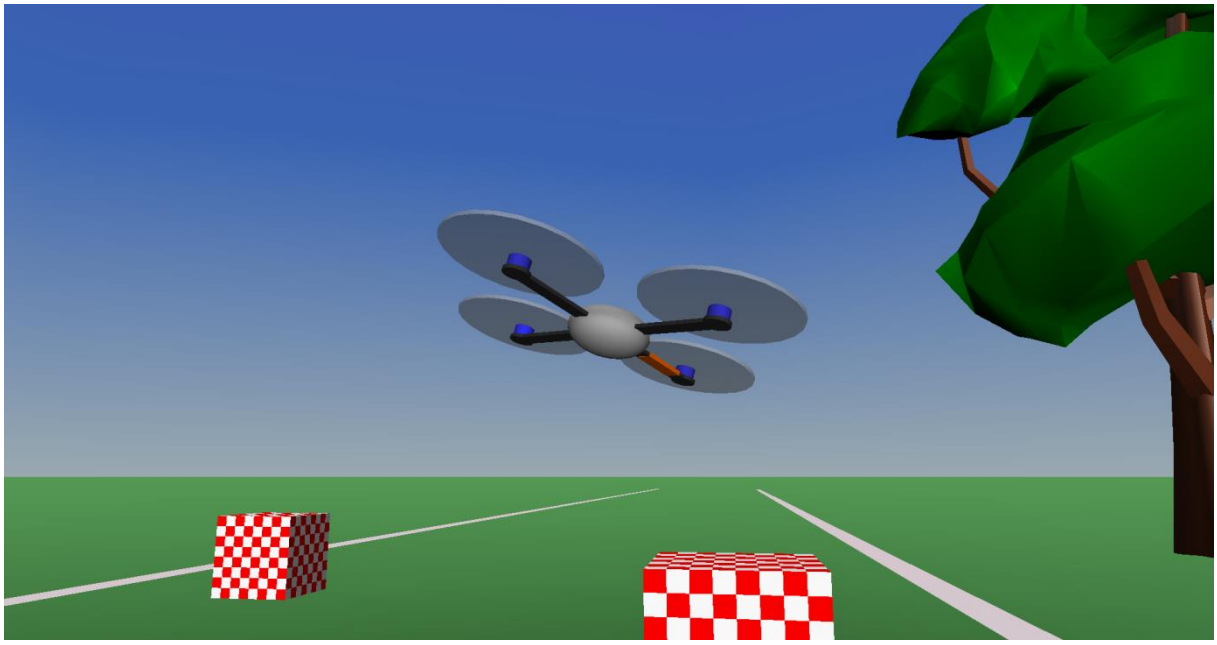
Block Name	Description
Initial_States_Dot	Not used
Initial_States	Initial Simulation States (Position, Velocity, Attitude, Rate, …)
External_Inputs	External Inputs (Temperature, Wind, Magnetic Disturbance, Drive Condition)
Simulation_Control	Inputs to stop or reset the simulation, Switches to disable sensor errors or to restrict degrees of freedom
Simulation_Model	Referenced simulation model. Available Airframe Configurations (double-click): • Airframe_Hummingbird • Airframe_Firefly

	• Airframe_Pelican
Visualization	A place to connect scopes and displays. A simple 3D visualization is prepared in the subsystem VR_View.
Onboard_Control_System	Contains signal processing, a custom high level control (template) and the AscTec low level control
Ground_Control	Replaces the ground control station which sends and receives a signal vector.
Vision_Dummy	A place to add additional sensors like external tracking systems or optical estimates

Some of the mentioned components are described in more detail below.

5.2. Visualization

There are two 3D-Visualization blocks, one for the Hummingbird and one for the Firefly. Open the appropriate one. It is possible to switch between ground view and onboard view.



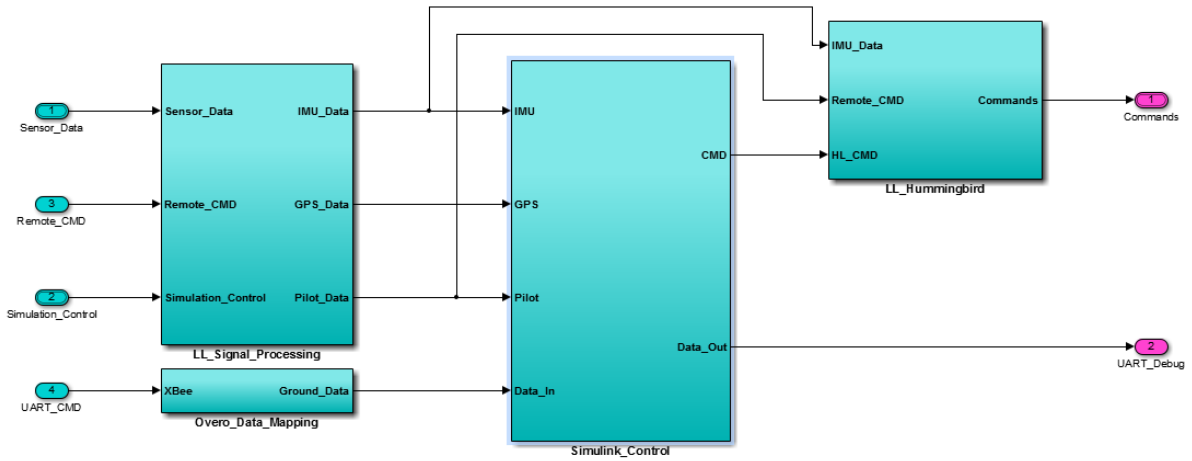
5.3. System Outputs

For some applications it is useful to analyze the real system states without sensor models. The corresponding bus is routed to *System_Outputs*. A selection of commonly used signals is shown below.

Name	Unit	Description
States.Rigid_Body.Rotation.ROT_IB_B	rad/s	Rigid body rotation rate
States.Rigid_Body.Attitude.ATT_quat_OB	[1]	Attitude quaternion
Motion_Kinematics.ATT_euler_OB	rad	Attitude in Euler-Angle format
Motion_Kinematics.VEL_K_R_E_O	m/s	Inertial velocity in NED-System
States.Rigid_Body.Position.POS_NR_N	m	Position relative to local navigation frame
States.Airframe.Motor1.ROT_x_PRot_P	rad/s	Relative rotation rate of motor 1
…	…	…

5.4. Onboard Control System

5.4.1. Overview



The simulated flight control system consists of signal processing and two flight control laws. The Low-Level Signal Processing block produces outputs similar to the real onboard signal processing. The Low-Level Control Law (here: LL_Hummingbird) imitates the preprogrammed flight control law by Ascending Technologies, but has only a small subset of features. It lacks e.g. the height and position control mode. The empty simulink control template can be filled with the experimental flight control laws which are to be implemented later on the real High-Level Processor. As for the real system, the pilot can switch between Low-Level and High-Level Control anytime (see Pilot Input Assignment).

5.4.2. Control Inputs

The simulation implements direct individual motor control (range: 1..200 = 0..100 %). Other control modes (e.g. attitude control) are not used by our institute and therefore currently not implemented. If needed, they can be added to the LL_Hummingbird block.

5.4.3. Pilot Input Assignment

The joystick block mapping as well as the pilot control input vector have the following content and are available in the simulation as well as in the FCC.

Signal No.	Name	Range	Description
1	Roll	[-1;1]	Pilot Roll Command
2	Nick	[-1;1]	Pilot Nick/Pitch Command
3	Yaw	[-1;1]	Pilot Yaw Command
4	Thrust	[-1;1]	Pilot Thrust Command between idle (-1) and maximum (1)
5	SW_HL	[-1;1]	Pilot Switch between user defined High-Level (1) and AscTec Low-Level Control (-1)
6	SW_Mode	[-1;1]	Selected Low-Level Control Mode: Attitude (-1), Height-Control (0), Position-Control (1) Only attitude mode is available in the simulation
7	Gain	[-1;1]	Rotary button can be used for in-flight adjustments

5.4.4. IMU Data Bus

The following signals are part of the IMU Data Bus as provided to the custom high level control. The signal availability in the simulation and on the real flight control computer (FCC) is noted, but subject to change.

Name	Unit	Description	Availability
w_x_K_IB_B_radDs	rad/s	Rigid body rotation rate in x-axis	Sim, FCC
w_y_K_IB_B_radDs	rad/s	Rigid body rotation rate in y-axis	Sim, FCC
w_z_K_IB_B_radDs	rad/s	Rigid body rotation rate in z-axis	Sim, FCC
f_x_R_B_mDs2	m/s²	Specific force in x-axis	Sim, FCC
f_y_R_B_mDs2	m/s²	Specific force in y-axis	Sim, FCC
f_z_R_B_mDs2	m/s²	Specific force in z-axis	Sim, FCC
B_x_R_B_T	Tesla	Magnetic field strength in x-axis	Sim, FCC
B_y_R_B_T	Tesla	Magnetic field strength in y-axis	Sim, FCC
B_z_R_B_T	Tesla	Magnetic field strength in z-axis	Sim, FCC
Phi_est_rad	rad	Estimated bank angle	Sim, FCC
Theta_est_rad	rad	Estimated pitch angle	Sim, FCC
Psi_est_rad	rad	Estimated azimuth angle	Sim, FCC
lambda_R_WGS84_est_rad	rad	Estimated longitude	(FCC)
phi_R_WGS84_est_rad	rad	Estimated latitude	(FCC)
z_R_N_est_m	m	Estimated height above ground	Sim, FCC
u_K_R_E_O_est_mDs	m/s	Estimated velocity in north direction	(FCC)
v_K_R_E_O_est_mDs	m/s	Estimated velocity in east direction	(FCC)
w_K_R_E_O_est_mDs	m/s	Estimated velocity in down direction	Sim, FCC
voltage_battery_V	Volt	Battery voltage	FCC
motor1_rpm	[1]	Motor RPM mapped to 1-200	FCC
motor2_rpm	[1]	Motor RPM mapped to 1-200	FCC
motor3_rpm	[1]	Motor RPM mapped to 1-200	FCC
motor4_rpm	[1]	Motor RPM mapped to 1-200	FCC
motor5_rpm	[1]	Motor RPM mapped to 1-200	FCC
motor6_rpm	[1]	Motor RPM mapped to 1-200	FCC
motor7_rpm	[1]	Motor RPM mapped to 1-200	FCC
motor8_rpm	[1]	Motor RPM mapped to 1-200	FCC

5.4.5. GPS Data Bus as provided to the custom high level control

The following signals are part of the GPS Data Bus as provided to the custom high level control. The signal availability in the simulation and on the real flight control computer (FCC) is noted, but subject to change.

Name	Unit	Description	Availability
lambda_R_WGS84_rad	rad	Longitude	Sim, FCC
phi_R_WGS84_rad	rad	Latitude	Sim, FCC
h_R_MSL_m	m	Height	Sim, FCC
u_K_R_E_O_mDs	m/s	Velocity in north direction	Sim, FCC
v_K_R_E_O_mDs	m/s	Velocity in east direction	Sim, FCC
w_K_R_E_O_mDs	m/s	Velocity in down direction	FCC
chi_K_rad	rad	Ground bearing	FCC
accuracy_horizontal_m	m	Horizontal accuracy	FCC
accuracy_vertical_m	m	Vertical accuracy	FCC
accuracy_speed_mDs	m/s	Speed accuracy	FCC
week_1	[1]	GPS week	FCC
time_of_week_ms	ms	GPS time of week	FCC

num_sv	[1]	Number of satellite vehicles in view	FCC
fixtype	[1]	Type of GPS fix	FCC
flags	[1]	GPS status flags	FCC
diffS	[1]	Differential system status	FCC