X4-MaG and RT-MaG: a low-cost open-source micro-quadrotor based on Real-Time Linux and a new Matlab/Simulink toolbox

Manecy A.[1], Vanhoutte E.[2], Mafrica S.[2], Colonnier F.[2], Ruffier F.[2], Marchand N.[3], Viollet S.[2]

[1] *ONERA, DCSD/CT, The French Aerospace Lab, 31055 Toulouse, France*
augustin.manecy@onera.fr
[2] *Aix Marseille Université, CNRS, ISM UMR 7287, 13288, Marseille, France*
{erik.vanhoutte, franck.ruffier, stephane.viollet}@univ-amu.fr
[3] *GIPSA-lab, Control Systems Dept., CNRS-Univ. of Grenoble, 38402 St Martin d'Hères, France*
nicolas.marchand@gipsa-lab.fr

Abstract

The new open-source quadrotor platform called X4-MaG presented here was developed for academic and research applications. X4-MaG is a small, low-cost open quadrotor of only 307-grammes which offers two levels of controllers providing a manual mode and an automatic mode thanks to a powerful Linux-based controller embedded onboard. The controllers and estimators are highly customizable and are designed in the Matlab/Simulink environment and directly implemented onboard the tiny Linux-based autopilot board using a custom made toolbox (RT-MaG toolbox).

The new open-source Matlab/Simulink toolbox called RT-MaG toolbox (see [1]) generates reliable standalone robotic applications running on real-time embedded Linux targets such as tiny Computers On Module (e.g., Gumstix boards). This toolbox gives direct access from Simulink to the main communication drivers classically used in robotics: network interfaces (via UDP), asynchronous and synchronous serial port interfaces (RS232, SPI, I2C), Pulse-width-modulation (PWM), etc.

1 The Linux-based X4-MaG quadrotor

At the hardware level, the quadrotor X4-MaG is composed entirely of low cost off-the-shelf components (see [2] for further details). Its light weight (307 g) and its small frame made of a printed circuit board (PCB) make it highly resistant and robust to crashes. At the software level, the robot is equipped with two different controllers which trigger a rescue mode in case of failure of the main controller. In addition, the high level controller (the main controller) is based on the Gumstix Overo, a powerful low consumption Computer-On-Module providing the robot with huge computational resources at no cost to the payload and the endurance of the quadrotor. Since the Gumstix COM is fully supported by our new open-source Matlab/Simulink toolbox RT-MaG (see the website [3]), the robot is directly piloted via Matlab/Simulink.

The RT-MaG toolbox provides also Simulink blocks for an host computer, in order to monitor in real-time the UAV states thanks to a Matlab/Simulink ground station. This ground station can be used to modify in real-time the high levels setpoints and the different controller's parameters, making it ideal for rapid tuning of control law.

Readers are invited to consult the RT-MaG website (see [3]), which gives all the information needed to assemble and program the X4-MaG quadrotor.

The robot is equipped with the 20-cm span *Nanoframe* (Flyduino [4]), four "5030" propellers, four 3800KV motors, four 6A ESCs (Electronic Speed Controllers for the motors) and a 2200 mAh lithium-polymer battery. The maximum flight time is about 10 to 12 minutes in normal use, the total span (including the propellers) is 30 cm and the weight is about 307g including the battery pack. The X4-MAG is based on the NanoQuad frame (Flyduino), which is a small (20 cm), light (60 g) and genuinely crash-proof platform. This platform, which can be piloted manually via a radio transmitter using the low level controller. An intermediate electronic board was also added in order to finely control each rotor's speed in closed-loop and thus to obtain accurate thrust control. The high level controller (the Gumstix Overo), can be programmed directly using Matlab/Simulink thanks to the RT-MaG toolbox. All the computation of the high level controller are monitored in real-time using a ground station running also Matlab/Simulink; and the controller's parameters can be tune in real-time.

2 A Matlab/Simulink capable quadrotor

The X4-MaG quadrotor is equipped with a Gumstix Overo processor board featuring a Linux operating system patched to ensure real-time capabilities. The RT-MaG toolbox generates reliable real-time applications corresponding to a Simulink model, can run control loop at frequencies up to 1kHz and gives access to the various I/Os classically used in robotic application (UDP, SPI, I2C, RS232, PWM, GPIO and ADC). It also provides efficient debugging modes and feedback information about the real-time performances, giving users several possible metrics for optimizing their applications. This toolbox also makes it possible to perform real-time monitoring via a ground station and tune the parameters of the algorithms in real time. More complete descriptions about the RT-MaG toolbox as the sources can be found on the RT-MaG website: http://www.gipsa-lab.fr/projet/RT-MaG/ ([3]).

As a consequence, the X4-MaG quadrotor can be fully programmed via Matlab/Simulink, and all the control algorithms can be tested in simulation, in processor-in-the-loop mode and implemented on the final hardware using the same environment. This makes the development of new control strategies drastically faster.

Figure 1 gives a classic scheme for the communications between the embedded quadrotor autopilot and the ground station. The autopilot consists in a Simulink model executed in real time on a Computer-On-Module (COM). The real-time host application consists in another Simulink model executed in real time on a host computer (or a ground station). On one hand, the host computer sends high level setpoints and parameters to the embedded application. On the other hand, the host computer monitors all the signals of interest to the user.

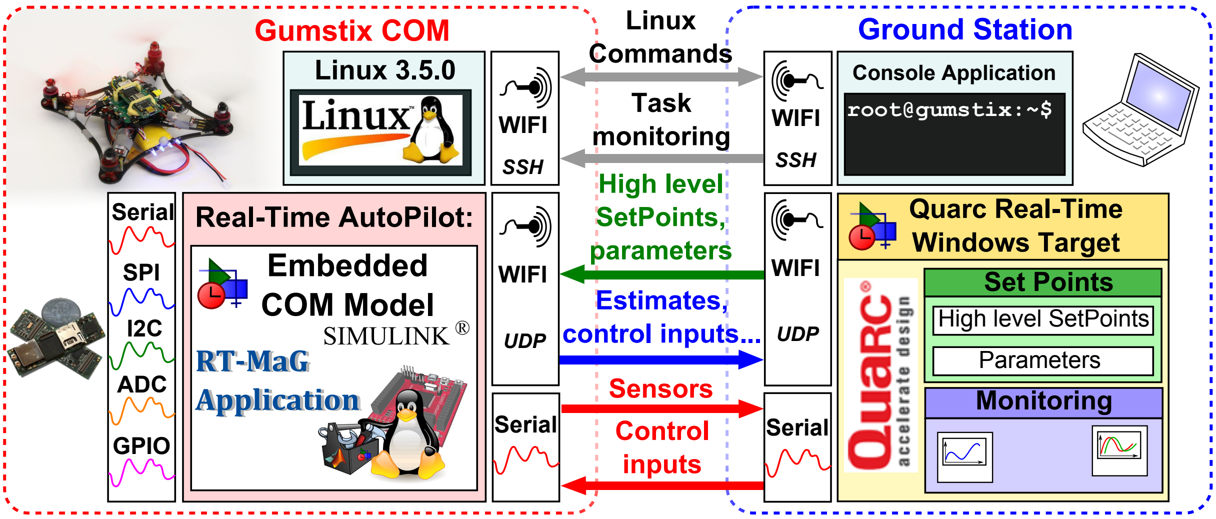

Figure 1: a) A classic communication scheme including the RT-MaG toolbox. The embedded Simulink model working in real-time on the Computer-On-Module uses directly the various I/Os of the quadrotor. The embedded application can be linked to a ground station via a WIFI connection in order to tune the embedded controllers or exchange data in real-time. A Processor-In-the-Loop mode is available if the COM is linked via a RS232 connection to a ground station simulating the dynamics of the X4-MaG quadrotor. Users can start or stop the real-time autopilot wirelessly (via a console) and receive continuously useful information about the embedded application (the CPU load, task execution time, the occurrence of overruns, etc.

References

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