Onboard Object Recognition on the PIXHAWK Micro Air Vehicle

Computer Vision and Geometry Lab

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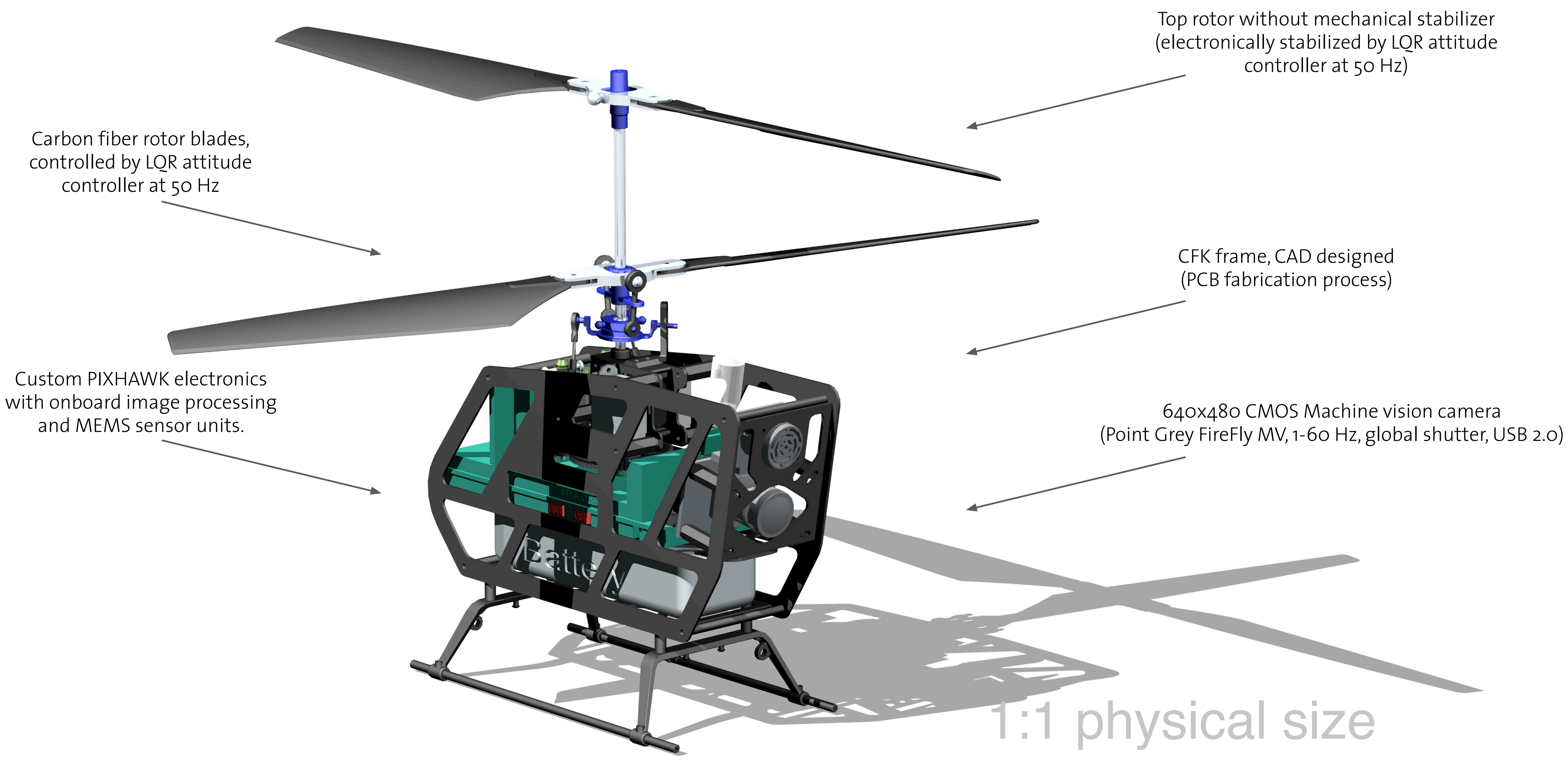

Figure 1: CAD model of the PIXHAWK Pioneer system (1:1, actual size of the helicopter)

Abstract

The PIXHAWK Pioneer is a computer vision research platform using a coaxial helicopter airframe at the Computer Vision and Geometry Lab of ETH Zurich.
The attitude is fully electronically controlled without the help of any mechanical aids (e.g. a flybar). The stabilization is achieved using micro-electro-mechanical sensors (MEMS) as input for a LQR attitude controller. The system is designed for computer vision applications and can use up to two OMAP 3530 single board computers for onboard vision processing at 10-30 Hz. The real-time onboard pattern recognition can detect 10 or more arbitrary patterns printed on paper. The feasability of pure onboard processing was demonstrated at the EMAV 2009 conference, where the PIXHAWK team won the Indoor Autonomy Competition. The system was one of the smallest micro air vehicles to enter the competition (34 cm rotor diameter) and was the only system which could automatically identify the A4 photograph on the walls of the competition building.
This poster introduces three selected key aspects of the system: The fully electronic stabilization, the onboard pattern recognition and the efficient and scalable real-time onboard and swarm communication infrastructure.

Coaxial helicopter with fully electronic attitude stabilization

In order to control the position the helicopter must control and stabilize it's attitude. The custom electronics module offers gyroscopes and accelerometers in all three dimensions. This allows to always estimate the attitude of the vehicle without any additional sensors. The vehicle is stabilized by actuating the swash plate. In contrast to common coaxial helicopter designs with mechanical stabilization aids ("flybar"), the attitude control is purely electronic (LQR attitude controller). A LQG position controller for X,Y,Z at 50 Hz has been implemented as well, and will be used for future work.
Estimation and control:

Sensor readout

- (X, Y, Z) accelerometer: *FTI SCA-3300 (± 2g, SPI)*
- (phi θ, theta ϕ, psi Ψ) gyroscopes: *Invense IDG-500 (±500 deg./s, ADC)*

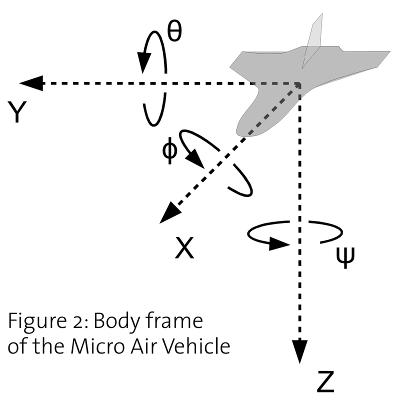

Figure 2: Body frame of the Micro Air Vehicle

Complimentary filter

The attitude is estimated by using the gravity vector as a long-term estimate. As these measurements are inprecise and therefore low-pass filtered, the vehicle dynamics are lost. The higher frequencies are re-introduced by adding the the high-pass filtered and integrated signals from the gyroscopes. The output of the filter are the three euler angles.

LQR attitude control at 50 Hz update rate

A model of the helicopter has been derived by measurering the rotor dynamics with a 6DOF force and torque sensor. This linearized rotor model has then been augmented with an analytical model of the complete system, which allowed to derive the LQR/LQG controllers with standard techniques.

Onboard Pattern Recognition

The main goal of the onboard pattern recognition is real-time execution speed and high detection probability. We are using the OMAP3530 processor (500 MHz, 256 MB RAM) on the Gumstix Overo Fire [2] (cell phone-class processor, used e.g. in IPhone 3 GS.)

Figure 3: Pattern recognition pipeline

1. Detection of regions of interest (ROI): The greyscale image is thresholded and quadrangles are fitted in these regions [1].

2. Extraction and rectification: All ROIs are extracted and transformed to a 32x32 pixel square with a perspective warp using the four corner points of the quadrangle.

3. Matching against patterns: The extracted candidate set is matched against the stored patterns in all four possible orientations of the quadrangles. Several approaches have been tested, best performance provided SSD template matching and calculating SIFT descriptors on the stored patterns and candidates.

Examples from the EMAV 2009 competition:

B D P R S

Figure 4: Recognition targets from the EMAV 2009 competition

Swarm and Onboard Communication

The system has been carefully designed to offer the required flexibility and real-time speed on limited hardware ressources. As can be seen in Figure 6, the vehicle has a UDP based onboard network [3].

Sharing images across processes

Multiple processes share the same camera, e.g. one process for pattern recognition and one for localization. This is necessary on a small scale platform which cannot carry one camera/sensor per mission task. Real-time performance is made possible by using shared memory for image data. Images are not streamed back to the groundstation, as this would already consume most processing ressources.

Onboard and swarm / groundstation communication

The MAVLINK broadcast message format has been developed for action, status and command messages, which can be used both onboard and for the communication with the groundstation/other MAVs in swarm setups. Messages are identified by content instead of recipient addresses. Routing nodes (e.g. the onboard-offboard bridge) filter messages that belong only to a subnet.

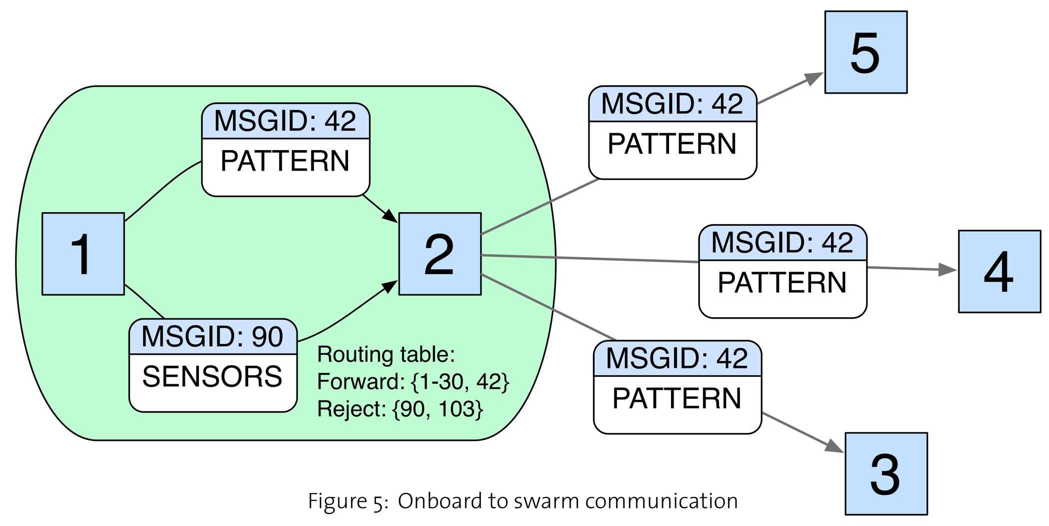

Figure 5: Onboard to swarm communication

References and Acknowledgements

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References

[1] Wagner and Schmalstieg. Artoolkitplus for pose tracking on mobile devices. Proceedings of 12th Computer Vision Winter Workshop St. Lambrecht, 2007.

[2] Gumstix Overo Fire Computer-on-Module. http://www.gumstix.com

[3] Huang, Olson and Moore. Lightweight Communications and Marshalling for Low-latency Interprocess Communication. MIT CSAIL Technical Report, 2009.

pixhawk

http://pixhawk.ethz.ch

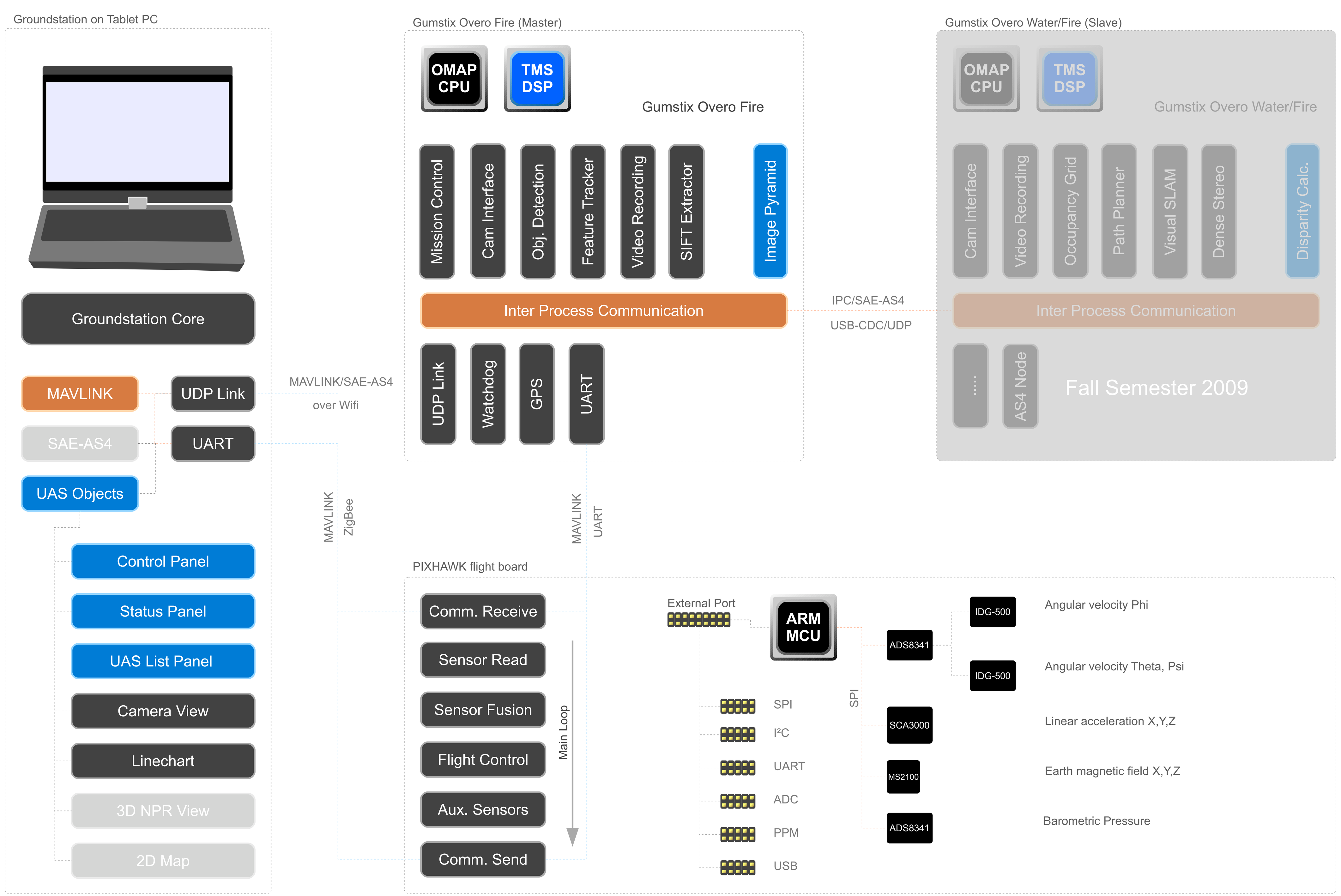

Figure 6: Complete system architecture with 2 single board computers and ground control station (GCS)

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