Implementation of real-time functionalities in the hardware of an intelligent ultra-light camera specialized for aerial photography.

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Highlights: The growing popularity of UAVs[1] has brought the OEMI laboratory[2] of IGN[3] to design and produce an ultra-light smart camera better fitted for photogrammetric works than consumer digital camera. This camera, based on a SoC/FPGA[4], makes it possible to implement in hardware some image processing algorithms, making them real-time compliant. For example, and as a first step, we work on an image stacking algorithm adapted to the UAV surveys.

Keywords: *UAV, image processing, photogrammetry, Hardware/Software co-design, real-time*

Introduction:

The main topic of this work is to benefit in the implementation in the hardware of a part of a processing image algorithm. The main difficulty resides obviously in the choice of architecture, i.e. the partitioning of tasks between hardware and software, and then the optimization of soft algorithms to fit the hardware requirements. We chose the images stacking with registration algorithm as a test application to validate our work in the context of UAV surveys.

Used platform:

The platform will typically include:

Figure 1: The UAV DJI F550 with CamLight

Figure 2: IGN's CamLight Camera

[1] UAV: Unmanned Aerial Vehicule
[2] LOEMI: Laboratoire d'Opto-Electronique, de Métrologie et d'Instrumentation
[3] IGN: Institut National de L'information Géographique – The French Mapping Agency
[4] SoC/FPGA: System On Chip / Field Programmable Gate Array

- a UAV (Hexacopter for example)
- a photogrammetric quality lightweight smart camera : IGN CamLight [1]

This camera was developed at the French Mapping Agency (IGN) by the OEMI Laboratory and is based on the CMOS 20MP sensor (CMOSIS CMV20000) and the Zynq 7030 SoC/FPGA from Xilinx. It has both an embedded intelligence, in the form of two ARM cortex A9 CPUs running a Linux OS and the exploitation software, and a programmable logic portion used first to acquire image data from the sensor, and then possibly to do the real-time image processing. CamLight camera also has inertial sensors and in the future a GPS receiver that will provide position and attitude of the camera during shooting.

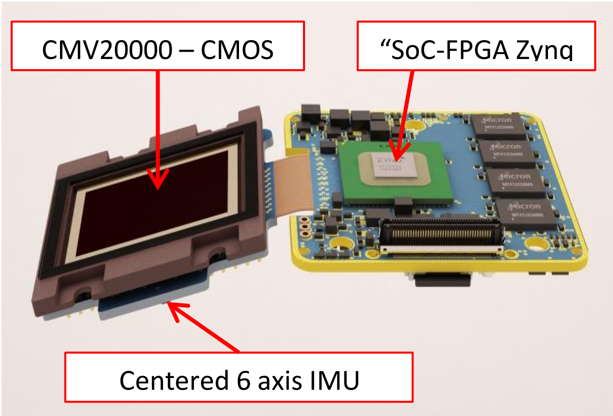

Figure 3: the CMOS Sensor with the inertial sensors and the embedded intelligence

Choice of the test application:

The images stacking with registration will produce a blur free composite image with an equivalent long time exposure with better dynamics. The necessary resampling of the individual images must be processed in real time in the camera as we want to save only the resulting image to save bandwidth on the storage device, leading to a better overall frame rate.

To obtain the correct orientation parameters for the resampling, we need to accurately measure the deformation in image pairs with template matching on interest features, which in software is very time consuming, and will profit greatly to be done in hardware. For example, extraction of interest features has already been done on hardware by Aydogdu M.F [2], Svab J. [3] and Beau Tippetts [4]; commercial solutions for image stabilization on FPGA exist for video sized image streams.

We will suppose in a first approach that the UAV is quasi stationary: we will neglect the variation of the camera position, considering only the attitude variation, thus alleviating the need of a DSM for the image resampling.

Image and data processing algorithm:

- Attitude and position of the camera are computed continuously by a Kalman filter using measurements from the inertial sensors and GPS.
- The camera acquires a burst of several (5-10) images into its RAM.
- Stack the first image

- Detect a determined number of interest features in the first image. This part should be implemented on the hardware
- For the next sequential images:
    - In this image, initial estimated positions of interest features are computed using position and angles obtained from the Kalman filter to speed up the next step
    - By template matching determine the accurate homologous position of these features
    - Estimate the 3D rotation-translation between the two shots by using the least squares method and the RANSAC [5] algorithm.
    - Possibly use this information as feedback in the Kalman filter to improve the determination of calibration of sensors (drifts) and the overall quality of the result of the filter
    - Resample the image in the geometry of the first image taking into account the accurate attitude of the camera
    - Stack it
- Store the stacked image

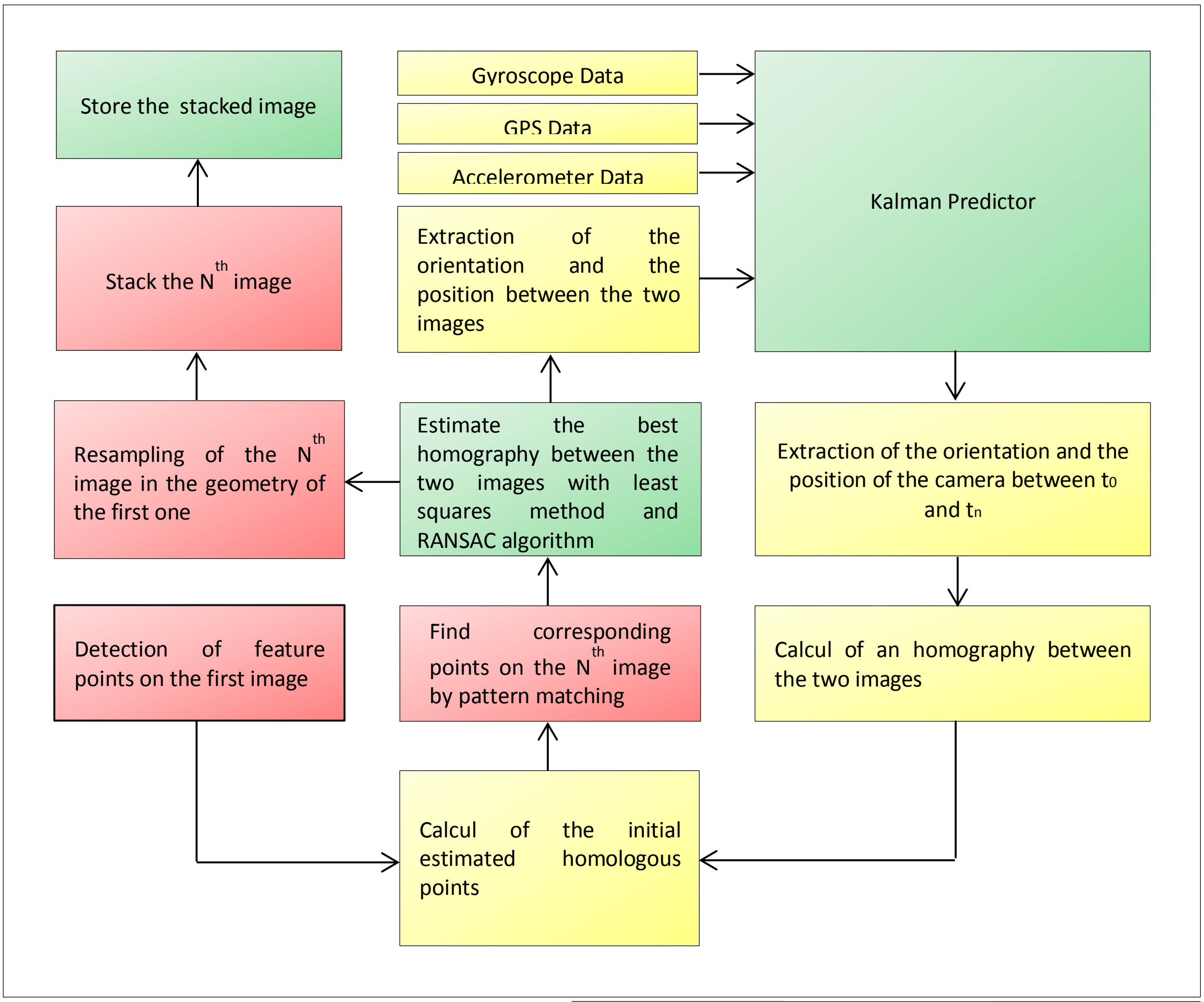

Figure 4: architecture of the algorithm

Current work:

We are now implementing the algorithm in software, we do detection of interest features with a Harris Detector [6], we estimate the parameters of homography between two shots by using the least squares method and the RANSAC algorithm; on the other hand we calculate the orientation of the camera by using inertial sensors data and the quaternion representation. With these tools, we validate that attitude changes between shots computed from image data are coherent with IMU data, in a laboratory context.

Further work:

Once the algorithm validated in software, we will distribute the tasks between hardware and software and then optimize the code. In other terms, we will begin the implementation of some tasks in hardware step by step. Also, we will implement the Kalman filter in order to eliminate the drift and noise of the inertial sensors, with optionally the GPS data to improve the overall positioning accuracy and robustness. Finally, we will test the system in laboratory and in real conditions on the UAV.

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