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Title: Autonomous Multirotor UAV Flight Control System based on GPS and INS data fusion

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ABSTRACT

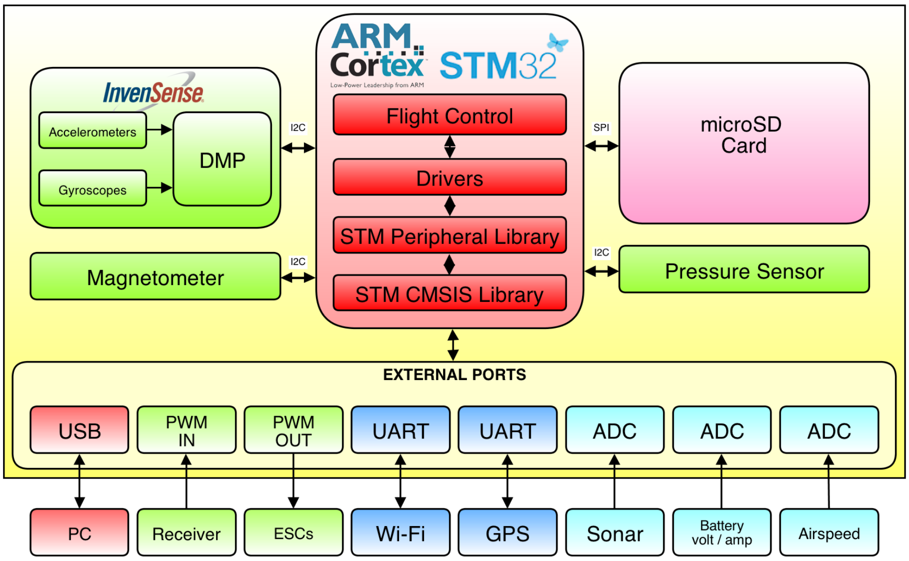
Autonomous Multirotor UAV Flight Control System based on GPS and INS data fusion

Multirotor Unmanned Aerial Vehicles (UAV) are known as good flying platforms for high-quality aerial photography, videography, monitoring and other terrain explorations due to their ability of low-speed flight, hovering and vertical take off and landing, which makes them easy to use in space limited conditions.

Obviously, the behavior of such vehicles is unstable. Therefore, Flight Control System (FCS) is required which must be responsible for both stabilization and navigation functions. Key feature of such device is capability of fully autonomous flight. Rapid development of contemporary electronics makes possible to create low-cost and compact FCS, which can be integrated in small UAVs. However, accuracy of implemented measurement units is not high. Multi-sensor data fusion is one of the methods for its increasing.
Present paper describes the requirements and general concepts to be guided in the development of FCS as well as results obtained in flight tests and their comparison. Special attention is paid to multi-sensor data fusion methods, which allow increasing flight precision and reliability. Moreover, the description of hardware and software architectures is provided.

FCS's hardware consists of main board and peripheral devices. General element of main board is 32-bit 72MHz STM32 microcontroller (CPU) based on ARM Cortex M3 core. Main board includes Micro Electro-Mechanical System (MEMS) sensors for attitude and position determination. For higher accuracy all implemented MEMS sensors are digital. The key feature of FCS is implementation of InvenSense MPU-6050 Inertial Measurement Unit (IMU), which includes 3-axis accelerometer, 3-axis gyroscope and Digital Motion Processor (DMP) in single Integrated Circuit (IC) package. DMP performs calculations (angular rates integration, gyroscope drift correction, extended Kalman filtering) in order to get orientation in space in quaternion representation at the frequency of 200Hz, which significantly helps to reduce general CPU load.

Moreover, the board has a magnetometer for heading determination and Z-gyroscope drift correction as well as a pressure sensor for altitude measurement. In addition, there is microSD card slot for configuration storage and in-flight data logging. The board is very compact and light (60x40mm, 14g) which makes application in small UAVs possible.
GPS receiver, wireless module for Ground Control Station (GCS) communication and ultrasonic range finder (sonar) can be connected externally. Sonar helps to increase altitude measurement accuracy up to 1cm (below the level of 6m).



The software architecture consists of several levels: from the lowest - STM microcontroller libraries to the highest – flight control logic. CMSIS Library from STM makes possible to create higher software hardware-independent. The second level is STM Library which provides high-level functions for microcontroller peripheral communications. Next level includes drivers for sensors readings and actuators control. The highest level consists of functions responsible for stabilization, navigation, flight control and digital signal filtering where it's necessary. Additionally, the highest level includes GCS interface functions based on MAVLink communication protocol library. The entire software is run by FreeRTOS (Real Time Operating System) developed especially for embedded applications which provide functionality for effective tasks and resources control being crucial for such devices. For safety guidelines every function belongs to its priority group corresponding to its importance.

By the moment, FCS described above allows multicopter UAV to fly autonomously (including auto take off and landing) based on GPS navigation with real-time flight observation and control via GCS. The results obtained during flight tests being analyzed showed that only GPS navigation is not enough for high-precision UAV positioning. Several methods of increasing positioning accuracy are available, among which is GPS and INS (Inertial Navigation System) data fusion. One knows that the acceleration being integrated twice returns displacement. The advantage of GPS is position determination on a global scale, but precision in a certain point is poor. In contrast, INS is unable to provide global location, however relative displacement can be calculated quite accurately. One knows that MEMS sensors measurement accuracy is not high, therefore special filtration, integration and error compensation methods should be applied. Different methods and various combinations will be considered and compared in the full paper. Furthermore, pressure sensor and Z-accelerometer data fusion methods for precise altitude hold are covered. To sum up, the key idea of the method is calculation of true flight parameters having inaccurate measurements from sensors achieved by multi-sensor data fusion.

It is worth mentioning that the research is conducted with presented FCS which provides opportunities for flight tests as well as parameters logging and their subsequent analysis.