Autonomous Unmanned Aerial Vehicle using the Atmel AVR

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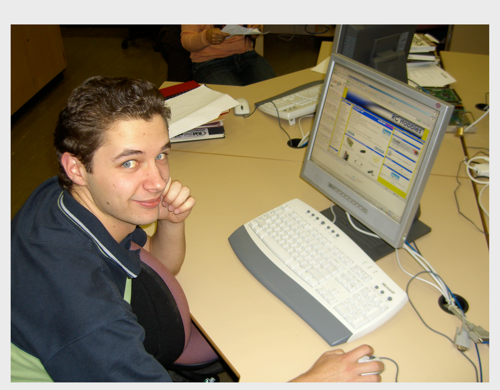
Background

What is an autonomous UAV?

An Unmanned Aerial Vehicle (UAV) is an aircraft that does not carry humans. It may still be controlled by a human, however - via radio, for example. An *autonomous* UAV is one which operates under it's own control, using onboard sensors and electronics. Such aircraft are able to operate in a wider range of environments and scenarios, and on behalf of people who may not have the expertise to control the craft themselves.

Why the need for an autonomous UAV?

- **Safety** - Manned flight carries with it the risk of injury to the pilot. UAVs mitigate this risk by leaving the pilot safely on the ground. Autonomous UAVs remove the pilot all together.
- **Cost** - Manned flight is expensive; aircraft capable of carrying humans are large and expensive to construct, and pilots are expensive to train and employ. UAVs can perform many of the same tasks as a manned aircraft, without the cost of the pilot and at a much lower cost per craft, by virtue of their reduced size.
- **Autonomy** - Autonomous UAVs can be deployed on scales not possible with piloted aircraft; a single operator can supervise concurrent operation of dozens of autonomous UAVs.

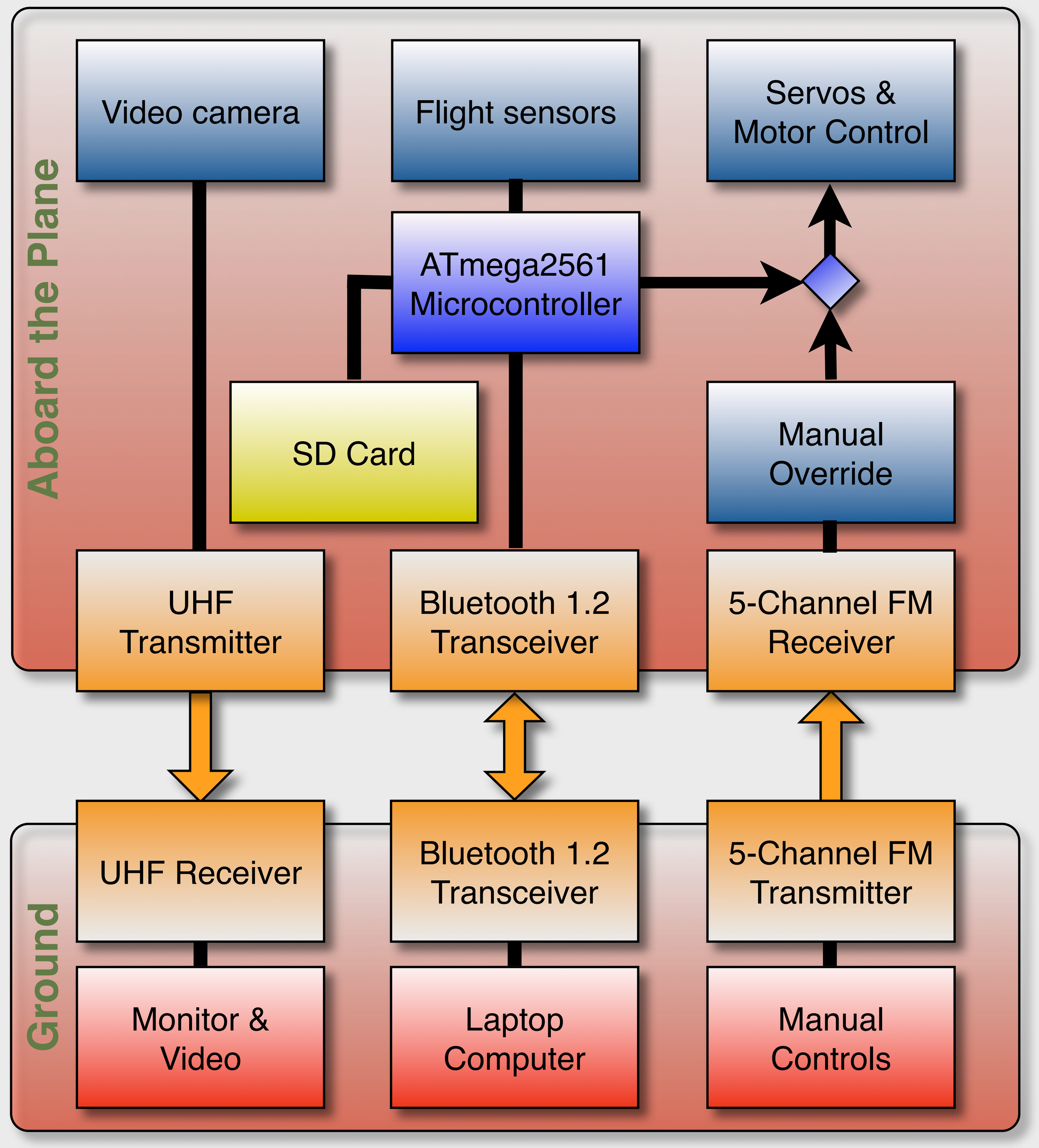


Project Aims

The purpose of the project is to explore numerous aspects of the design and construction of a cheap, general purpose autonomous UAV using COTS (Commercial Off The Shelf) components. In particular, the use of a hobbyist model aircraft as a foundation on which to build the system. Particular intents of the project include:

- development of a **stable flight platform** using an 8-bit AVR microcontroller, GPS receiver and similar widely available sensors.
- investigation of **flight control algorithms**, particularly with regards to unreliable or minimal sensor input. Commercial autopilot systems utilise extensive and expensive sensor networks to perform relatively trivial tasks - e.g. level flight. The hope is that new methods and algorithms can be found to perform these tasks with much more limited inputs.
- experimentation with various **auxiliary sensors and payloads**, such as still and video cameras, atmospheric sensors (pressure, temperature, humidity, etc) and so forth.
- development of **navigation algorithms** and **flight planning software** by which to operate the UAV.

Design Overview



Flight control systems

Microcontroller "brain"

The 8-bit Atmel AVR microcontroller provides the onboard intelligence that navigates and flies the aircraft. Running at 16MHz, the AVR is responsible for observing sensor input - ranging from GPS to accelerometers to payload sensors such as temperature - and using that information to control the aircraft. While not the most powerful microcontroller out there, the AVR is power efficient, easy to program and provides a wide range of I/O capabilities.

Flight sensors

A range of sensors are carried aboard the plane for flight control. One key sensor is the GPS receiver, by which the plane can determine it's absolute position in 3D space, it's velocity and UTC time. The aircraft also carries a dual-axis accelerometer to detect fine changes in pitch and roll.

Manual control & override

The original model plane utilised a simple three-channel radio receiver for direct manual control. For testing purposes and safety, the UAV provides an even more flexible five-channel radio receiver which permits manual override and control on command. This allows the operator to manually position the plane prior to an automated flight, and recover from failures in the onboard control system, should they occur.

Communications

The aircraft utilises three independent radio communication mechanisms, one for each major component:

Bluetooth

Provides bidirectional communication between the onboard microcontroller and the ground controller (a laptop computer). This interface is used for uploading navigational data and commands to the plane, for retrieving stored sensor data, and for monitoring the plane's operation in real time. It is a short range link, primarily intended for use while the plane is on the ground, or in a low-level holding pattern.

UHF

Used to transmit an uncompressed, mid-resolution video stream from the plane to the ground, where it can be processed, viewed and stored. This video stream may also be used for manual control of the plane when it is out of visual range.

FM receiver

Used for manual override and control of the plane. Three channels are utilised for flight control - for the motor, elevator and rudder - while one is used to switch between autonomous and manual control. A hardware mux manages the control paths, providing a reliable recovery mechanism even in the event of catastrophic software or microcontroller failure.

Data logging

In addition to the sensors required for basic flight, other sensors may be carried aboard the plane. These could range from simple transducers for pressure, temperature or humidity, right through to complex devices like cameras.

The radio link, however, provides very limited bandwidth, especially in wide-ranging operation. Indeed, the UAV is designed to be capable of flying beyond radio range (and returning). Thus, the aircraft must be capable of recording all data of interest onboard, for later extraction. This is done by utilising a MMC or SD flash memory card. These are the same memory cards used by digital cameras, and are ideal for this purpose for many reasons:

- they are **rugged, solid-state** memory devices which contain no moving parts and are likely to survive violent movement, hopefully including crashes.
- they are **readily available** in **very high capacities** (up to 4 GB) at very reasonable prices (as little as $40 for 512 MB cards).
- they are **fast** to read and write to, which is important as it minimises the time the AVR must devote to basic I/O, allowing it to perform other tasks such as controlling the plane.

The AVR supports MMC/SD cards formatted as FAT16 or FAT32. Data can be read from and written to multiple files on the card concurrently. When the plane returns to the ground, the MMC/SD card can be removed, placed into a PC and the data retrieved.

Navigation

The aircraft is designed to be capable of following flight paths of arbitrary complexity, within the physical limits of it's operation. Flight paths are laid out on a computer prior to the flight, using specially developed software, and uploaded to the UAV via Bluetooth or the MMC/SD card.

At any point during the flight, the UAV can be switched off manual control to autonomous operation, at which point it begins following the prescribed path. At the end of the path, the UAV returns to radio range (if necessary) and then adopts a holding pattern awaiting further instruction, or a return to manual control.

There are additional failsafe mechanisms built into the design. For example, if during manual control of the plane radio contact is lost for a significant period (several seconds), the UAV automatically switches to autonomous operation. Because the microcontroller is able to operate even under manual control, passively observing sensor inputs, it is able to determine the plane's position where it still had radio contact, and return the plane to that position. It continues retracing the plane's steps until it regains radio contact.