The WITAS UAV System Demonstration

Mariusz Wzorek and **Patrick Doherty**
Department of Computer and Information Science
Linköping University, SE-58183 Linköping, Sweden
{marwz,patdo}@ida.liu.se

The Autonomous UAV Technologies Laboratory [1] at Linköping University, Sweden, has been developing fully autonomous rotor-based UAV systems in the mini- and micro-UAV class. Our current system design is the result of an evolutionary process based on many years of developing, testing and maintaining sophisticated UAV systems. In particular, we have used the Yamaha RMAX helicopter platform (Fig. 1) and developed a number of micro air vehicles from scratch.

Figure 1: The WITAS UAV platform.

Integrating both high- and low-end functionality seamlessly in autonomous architectures is currently one of the major open problems in robotics research. UAV platforms offer an especially difficult challenge in comparison with ground robotic systems due to the often tight time constraints present in the plan generation, execution and reconfiguration stages in many complex mission scenarios. The WITAS [2] UAV system built at our Lab is fully intergrated with the Yamaha RMAX platform. It is highly distributed system that includes components ranging from control to deliberation. Its backbone is implemented using CORBA (Common Object Request Broker Architecture). The integration between control and deliberative components have been the driving force of the WITAS UAV system design.

Much effort has also gone into the development of useful ground control station interfaces which encourage the idea of push-button missions, letting the system itself plan and execute complex missions with as little effort as possible required from the ground operator other than stating mission goals at a high-level of abstraction and monitoring the execution of the ensuing mission. The mission scenarios we use are generic in nature and may be instantiated relative to different applications. For example, the functionality required for the monitoring/surveillance mission described below can be modified slightly and used in mission scenarios such as power line inspection.

An example of such a push-button mission that has been used as an application scenario in our research is a combined monitoring/surveillance and photogrammetry mission out in the field in an urban area with the goal of investigating facades of building structures and gathering both video sequences and photographs of building facades. Let us assume the operational environment is in an urban area with a complex configuration of building and road structures. A number of these physical structures are of interest since one has previously observed suspicious behavior and suspects the possibility of terrorist activity. The goal of the mission is to investigate a number of these buildings and acquire video and photos from each of the building's facades. It is assumed the UAV has a 3D model of the area and a Geographical Information System (GIS) with building and road structure information on-line.

The only ground operator's task is to simply choose building structures of interest on the map and press a button.The multi-segment mission is automatically generated to fly to each building, move to waypoints to view each facade, position the camera accordingly and gather and/or relay video sequence. The motion plans generated are also guaranteed to be collision-free from static obstacles. If the ground operator is satisfied with the generated mission, he or she simply clicks a confirm button and the mission begins. During the mission, the ground operator has the possibility of suspending the mission to take a closer look at interesting facades of buildings, perhaps taking a closer look into windows or openings and then continuing the mission. This mission has been successfully executed robustly and repeatedly from take-off to landing using the RMAX.

---

[1] www.ida.liu.se/ patdo/auttek/

[2] WITAS is an acronym for the Wallenberg Information Technology and Autonomous Systems Lab which hosted a long term UAV research project (1997-2004).

This research is partially founded by the Wallenberg Foundation under the WITAS Project and an NFFP4-S4203 grant.

Other mission scenario includes gathering video footage of an arbitrary polygonal area using multiple UAV platforms. The ground operator would simply mark the area to be scanned and the algorithm would calculate multiple multi-segment paths for each UAV. The algorithm takes into account the maximum velocity of each UAV and its camera aparture. The collision-free motion plans are distributed to each UAV platform and executed. Such a mission has been executed using two RMAX platforms from take-off to landing.

A hybrid deliberative/reactive software architecture (Doherty *et al.* 2004) has been developed for the WITAS UAV system. Conceptually, it is a layered, hierarchical system with deliberative, reactive and control components, although the system can easily support both vertical and horizontal data and control flow. The main execution component is a reactive Task Procedure (TP). The TP is a high-level procedural execution component which provides a computational mechanism for achieving different robotic behaviors. TPs can call both deliberative and flight control services concurrently.

We have developed and tested several autonomous flight control modes: take-off, landing via visual navigation (Merz, Duranti, & Conte 2004), hovering, dynamic path following (Conte, Duranti, & Merz 2004), and reactive flight modes for tracking and interception.

There are currently two motion planners used in the system which are based on two sampling techniqes, namely Probabilistic Roadmaps (PRM) and Rapidly Exploring Random Trees (RRT) (Pettersson 2006; Wzorek & Doherty 2006). The planners use a GIS database available onboard, that provides a 3D map of the evironment, to produce collision-free paths. The paths are represented as a set of cubic splines. The path planners ensure continuity of the first-order derivative (i.e. velocity) at the waypoints between segments. Different contraints can be added dynamically during run-time which are taken into account while planning. Constraints include e.g. no-fly zones, bounds on minimum and maximum altitude etc.

The WITAS system also includes an execution monitoring component which uses the linear temporal logic (LTL), with extensions to handle intervals, to express safety constraints of the execution (Heintz & Doherty 2006). The LTL formulas are evaluated on-line, as the execution takes place, over a sequence of states by a method called progression. This state sequence is created by a component called the dynamic object repository (DOR), which takes streams of sensor data and extracts a sequence of coherent states as a stream of “current” states, taking different delays and sampling rates into account. If a formula is evaluated to false, then the UAV knows that a safety contraint has been violated and can execute an appropriate recovery action.

To operate our UAVs we have devoloped a number of graphical user interfaces ranging from low-level control/flight test interface to high-level mission specification interface. The latter has been implemented on the standard PC machine and a mobile phone.

The control interface is more a traditional user interface used mainly for development of different control modes and image processing algorithms. It displays telemetry data (i.e. position, altitude etc.) transmitted by the UAV during the flight. It also provides a set of indicators showing the status of the UAV and its sensors (e.g. GPS sensor). The ground operator can view debug messages that are sent by UAV’s control modes and image processing components. The interface can display the video stream with overlayed image processing results from the on-board camera.

The high-level graphical user interface is used to specify missions were deliberative services are used. Such missions include basic flying to a coordinate with use of the GIS and the path planners and more sofisticated missions as the one descibed earlier.

Our simulation environment includes 3D vizualization tool that can display arbitrary environment models. It can display many objects with real-time update e.g. helicopters, simulated cars, planned trajectories, flown trajectories, view from the helicopter’s camera etc. The visualizer is used during simulation and real flight tests.

We use two simulators of the WITAS RMAX platform. First one, is a simple non-real-time simulator which does not include the helicopter dynamics. Second one, includes dynamic model of the helicopter and it is strictly used on the helicopter computers during hardware in the loop simulation. The sensor noise is not modeled. The model of the RMAX helicopter was created by using model identification techniques.

Demonstaration of the system includes running both mission scenarios described earlier i.e. building survey and scanning of the area. If the quality of the Internet connection allows, we will give a live demonstration of our system with the hardware in the loop. The low-level part of our system will be running on the RMAX helicopters’ computers at Linköping University in Sweden.

References

Conte, G.; Duranti, S.; and Merz, T. 2004. Dynamic 3D Path Following for an Autonomous Helicopter. In *Proc. of the IFAC Symp. on Intelligent Autonomous Vehicles*.

Doherty, P.; Haslum, P.; Heintz, F.; Merz, T.; Persson, T.; and Wingman, B. 2004. A Distributed Architecture for Autonomous Unmanned Aerial Vehicle Experimentation. In *Proc. of the Int. Symp. on Distributed Autonomous Robotic Systems*, 221–230.

Heintz, F., and Doherty, P. 2006. A Knowledge Processing Middleware Framework and its Relation to the JDL Data Fusion Model. *Journal of Intelligent and Fuzzy Systems*. To appear.

Merz, T.; Duranti, S.; and Conte, G. 2004. Autonomous Landing of an Unmanned Helicopter based on Vision and Inertial Sensing. In *Proc. of the 9th International Symposium on Experimental Robotics*.

Pettersson, P.-O. 2006. Using Randomized Algorithms for Helicopter Path Planning. *Lic. Thesis Linköping University.*

Wzorek, M., and Doherty, P. 2006. Reconfigurable Path Planning for an Autonomous Unmanned Aerial Vehicle. In *Proceedings of the ICAPS-06*. To Appear.