

Advanced Research with Autonomous Unmanned Aerial Vehicles

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Extended Abstract

The emerging area of intelligent unmanned aerial vehicle (UAV) research has shown rapid development in recent years and offers a great number of research challenges for artificial intelligence and knowledge representation. Much previous research has focused on low-level control capability with the goal of developing controllers which support the autonomous flight of a UAV from one way-point to another. The most common type of mission scenario involves placing sensor payloads in position for data collection tasks where the data is eventually processed off-line or in real-time by ground personnel. Use of UAVs and mission tasks such as these have become increasingly more important in recent conflict situations and are predicted to play increasingly more important roles in any future conflicts.

Intelligent UAVs will play an equally important role in civil applications. For both military and civil applications, there is a desire to develop more sophisticated UAV platforms where the emphasis is placed on development of intelligent capabilities and on abilities to interact with human operators and additional robotic platforms. Focus in research has moved from low-level control towards a combination of low-level and decision-level control integrated in sophisticated software architectures. These in turn, should also integrate well with larger network-centric based C^4I^2 systems. Such platforms are a prerequisite for supporting the capabilities required for the increasingly more complex mission tasks on the horizon and an ideal testbed for the development and integration of distributed AI technologies.

The WITAS¹ Unmanned Aerial Vehicle Project (Doherty *et al.* 2000) is a basic research project whose main objectives are the development of an integrated hardware/software VTOL (Vertical Take-Off and Landing) platform for fully-autonomous missions and its future deployment in applications such as traffic monitoring and surveillance, emergency services assistance, photogrammetry and surveying. Basic and applied research in the project covers a wide range of topics which include both the development of traditional AI technologies, core functionalities and their pragmatic inte-

gration with other technologies in a prototype experimental UAV system.

The following is a non-exclusive list of some of the activities in the project:

- Development of a generic distributed deliberative/reactive software architecture for (aerial) robotic systems.
- Development of a helicopter control system with flight modes for stable hovering, takeoff and landing, trajectory following, and reactive flight modes for interception and tracking of vehicles.
- Development and integration of numerous AI technologies. These include both path and task-based planning systems, a chronicle recognition system for identifying complex vehicular patterns on the ground, and other high-level services for reasoning about action and change.
- Development and integration of numerous knowledge representation technologies. These include an on-board geographical information system; a dynamic object repository to anchor, manage and reason about dynamic objects such as vehicles discovered during mission execution; a qualitative signal processing framework for dynamic construction of trajectories and histories of world behavior with associated reasoning mechanisms; development of knowledge structures for signal-to-symbol conversion and approximate reasoning in soft real-time; and development of approximate databases using ideas from rough set theory.
- Development of an on-board dynamically programmable image processing system.
- Development of multi-modal interfaces (including dialogue) with software based operator assistants for ground operator/UAV communication with both speech generation and recognition capability.
- Development of simulation environments with hardware-in-the-loop for both testing and visualization of control, reaction and deliberation functionalities.

Development of such a complex system with its many components is a multi-disciplinary effort and is dependent on competences from artificial intelligence, computer science, control theory, and signal processing. One of the most important aspects in the project is the actual development

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¹WITAS (pronounced *vee-tas*) is an acronym for the Wallenberg Information Technology and Autonomous Systems Laboratory at Linköping University, Sweden.

and engineering of an integrated hardware/software architecture with a supporting development environment. The system must be able to support both basic research endeavors and the development and testing of applied research in both the on-board system and in simulation environments on a continual basis.

Much progress has been made in these directions and the majority of technologies listed above have been tested in a prototype VTOL system with segments of actual missions flown in an interesting *urban* environment populated with building and road structures.

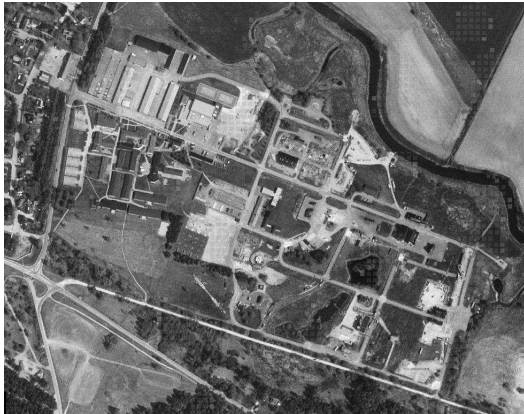


Figure 1: Aerial photo over Revinge, Sweden

Figure 1 shows an aerial photo of our primary testing area located in Revinge, Sweden. An emergency services training school is located in this area and consists of a collection of buildings, roads and even makeshift car and train accidents. This provides an ideal test area for experimenting with traffic surveillance, photogrammetric and surveying scenarios, and scenarios involving emergency services. We have also constructed an accurate 3D model for this area which has proven invaluable in simulation experiments and parts of which have been used in the on-board GIS.

The VTOL platform used in the project is a slightly modified Yamaha RMAX helicopter manufactured by Yamaha Motor Company. It is commercially available in Japan as a radio-controlled platform. The RMAX is approximately 2.7×0.7 meters with a main rotor 3 meters in length. It has an empty weight of 61 kg and a take-off weight of 95 kg. The base system has been extended with a sensor platform which includes GPS and INS systems, and a hardware platform which includes three PC104's (Pentium P5, 700MHz), one each for control, image processing and reactive and deliberative components. Figure 2 shows a picture of one of our RMAXs.

Missions of the following types have been successfully flown in the Revinge flight test area:

- Given a vehicle signature and an initial location for the vehicle, track the vehicle indefinitely as it drives around the Revinge road system.
- Choose n arbitrary building structures in the Revinge area, generate a plan to fly to each and gather video



Figure 2: The WITAS RMAX Helicopter

streams of each of the building's facades.

- Interactively fly to arbitrary positions in the Revinge area by generating collision free paths and then follow these autonomously.
- During interactive missions, while hovering at a particular position, move the camera via voice commands from the ground operator. While flying to a point, speech generated observations about the UAV's state are generated at the ground station.

The invited talk will cover a number of research topics and results related to the UAV project. Focus will be on knowledge representation techniques developed in the project and the support for these techniques provided by the software architecture developed for our UAV platform. Additional focus will be placed on some of the planning and execution monitoring functionality developed for our applications in the areas of traffic monitoring, surveying and photogrammetry and emergency services assistance.

Acknowledgments

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