MANNED-UNMANNED-TEAMING BETWEEN HELICOPTER AND UAV

Stefan Haisch, Torsten Butter, Dr. Kreitmair-Steck,
Eurocopter Deutschland GmbH ,Ottobrunn , Germany
Wolfgang Ensinger
EADS Deutschland GmbH, Military Air Systems, Germany

Abstract

UAVs nowadays can take over more and more - mainly military - missions, which were performed by manned air vehicles. The Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology and the Bavarian police helicopter squad requested UAVs could support police missions as well. Between July 2007 and June 2009 therefore the industry was funded by the Bavarian Ministry of Interior, to investigate in a possible use of different types of UAVs for typical police missions. The project was called "Demonstration project for UAV-operations at the Bavarian Police" (DEMUEBP). Target of this research project was a concluding demonstration campaign, showing two scenarios in a flight demo at the end of the project. The first scenario was the search for a missing person, the second one a covert mission, where a high-jacked car had to be followed. This paper focuses mainly on scenario 2, where the helicopter teamed with an UAV.

1. INTRODUCTION

The Bavarian police helicopter squadron is one of the technically most progressive helicopter police units in Europe. They started the consequent use of infrared cameras, night vision goggles and infrared illuminators for helicopter police operations. In 2007 questions came up, whether the use of unmanned aerial vehicles (UAV) could be interesting in future. The Bavarian Ministry of Economy therefore funded a research project for the Bavarian industry and research institutes called "DEMUEBP". Eight partners teamed under the lead of EADS Military Air Systems for the project, which was running from end of 2007 to summer of 2009.

Figure 1: Bavarian police helicopter EC135

DEMUEBP means "Demonstration project for UAV-operations at the Bavarian Police". The main intent of the project was a demonstration with flying UAVs providing sensor data to a ground station. Eurocopter contributed the helicopter part and demonstrated manned - unmanned teaming.

2. TWO TYPICAL POLICE SCENARIOS

The first task of DEMUEBP was the definition of possible useful applications of UAVs for the police. After some exchange between Eurocopter and the Bavarian police helicopter squad two missions were selected out. The mission scenario, which happens most often in reality, is the search for missing persons. Here an UAV could be less expensive, when flying search patterns over the respective area. Another advantage of an UAV is its ability, to fly and observe being undetected by persons on ground. Therefore the second mission scenario was the chase and observation of a high-jacked car. The UAV had to follow autonomously a high-jacked car assisted by a helicopter chasing the UAV in some distance.

2.1. Scenario 1: Searching a missed person

Depending on the available UAVs from the joined partners in the project scenario 1 was performed by two UAVs, one rotary wing UAV acting as sensor platform and one fixed-wing relay UAV. The rotary wing UAV was assigned to fly a search pattern over the mission area. Therefore it should be equipped with a visual sensor (IR and/or daylight video) and a data-link, to provide the sensor data to the user, i.e. a ground control station (GCS). As the scenario defined a rough terrain for the searching area, the need for a flying relay station was decided. This task was taken over by a fixed wing UAV flying holding patterns close to the search area. Both UAVs should be transported to the search area and should be started there. The ground control station for both UAVs should be located close to the mission area.

Once the missing person was detected a helicopter could fly and rescue the person. The intention behind taking a UAV for the search mission is the lower cost and lower noise level at ground. In the DEMUEBP demonstration of scenario 1 the helicopter did not participate.

2.2. Scenario 2: Observing a high-jacked car

In the second scenario the UAV was selected in order to perform a covert mission. The persons in the high-jacked car should not recognize that they are followed. With a helicopter this would not be easy due to the noise. So the helicopter took the sensor UAV as stand-off sensor. The helicopter followed the UAV in some distance. The UAV should be equipped with a daylight video camera. With the information from the UAV the crew in the helicopter and the officers on ground could decide, how to proceed with the high-jackers and to possibly use the helicopter, to stop the car.

3. SYSTEM ARCHITECTURE AND DATA FLOW

The system architectures and especially the flow of data between UAVs, GCS and helicopter had to follow restrictions given by the certification aspects of the UAVs. Especially the command and control (C^2) data-links between the UAVs and their dedicated GCS had to remain unchanged. All UAV operations in the frame of the project had been performed in temporarily closed airspaces in Germany as there is no other possible rule up to now which could be applied for UAVs.

3.1. Teaming of Sensor UAV and Relay UAV

The sensor UAV in scenario 1 was controlled by its GCS. In the GCS a search pattern was calculated and sent via C^2 data link to the automatic flight control system (AFCS) of the UAV. As the UAV was partly stabilized, it was possible, to fly the search pattern autonomously. On the ground a safety pilot was prepared to take over control in case of failures.

The sensor UAV was equipped with an IR camera. The IR-video-stream was sent via a line of sight data-link to a fixed wing UAV, which was flying holding patterns close to the search area and was acting as relay UAV between the sensor UAV and the ground station. The relay UAV was manually controlled during the flight tests.

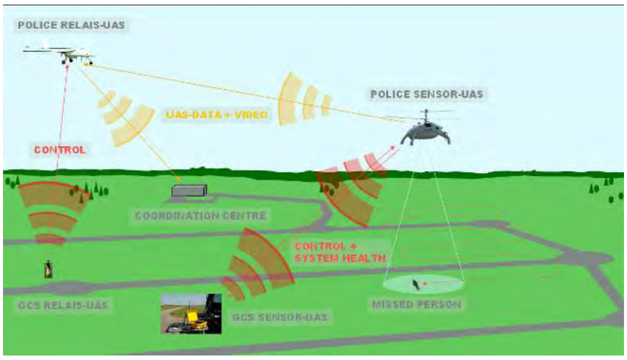

Figure 2: Data flow in scenario 1

Inside the ground station, which demonstrated the search and rescue coordination centre, the video stream was captured by a computer. This computer was hosting ATR (Automatic Target Recognition) software, developed by the partner EADS MAS (see chapter 5). This ATR software was specialized to find hot spots looking like lying persons in the video. Once the person was detected, the position of the missed person could be provided to the search and rescue team.

3.2. Manned – Unmanned Teaming between Sensor UAV and Helicopter

In scenario 2 the fixed-wing sensor UAV was controlled by its GCS via proprietary data-link. It could fly stabilized and follow autonomously pre-planned routes, which could be planned in the GCS. The video stream of the sensor was linked via GCS to the helicopter and there processed and analyzed by the automatic target recognition software (see chapter 5). The ATR software was able to follow a car, which was pointed out by the operator before. By tracking the car, the software provided offset data, which were sent to the UAV's GCS. There the offset was used to calculate the best flight path in order to follow the car. The helicopter in the meantime was flying slowly in a safe distance from the UAV.

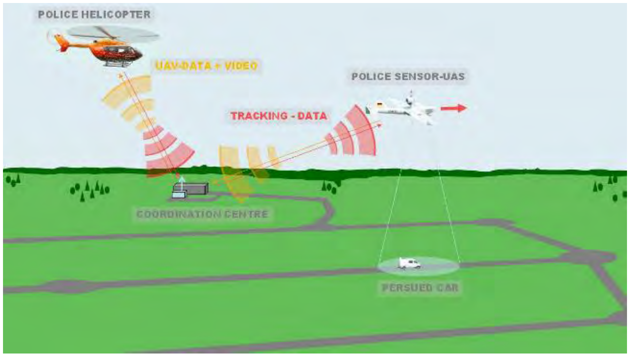

Figure 3: Data flow in scenario 2

The system architecture is physically divided in three main blocks: the UAV, the UAV GCS and the helicopter. The following data are transmitted on the UAV's proprietary data link:

- UAV control data (upwards)
- Sensor platform control (upwards)
- Sensor data/video stream (downwards)
- UAV flight/health data (downwards)

Between the GCS and the helicopter the following data are transmitted:

- Sensor data/video stream (upwards)
- UAV flight data (upwards)
- Target offset coordinates (downwards)
- Helicopter flight data (downwards)

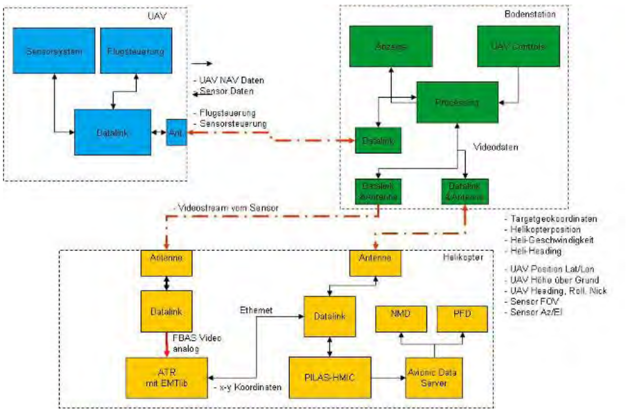

Figure 4: System architecture in scenario 2 between UAV (blue), GCS (green) and helicopter (yellow)

Onboard the helicopter an existing experimental avionic system named "PILAS" was used as basis for add-ons for DEMUEBP. PILAS is a pilot assistance system providing various assistance functions for route planning, safe flight, in-flight re-planning, synthetic vision system and 2D map presentation. For more details see respective articles from reference list.

One data link was connected to the PILAS system by Ethernet. Inside PILAS a computer called "Human Machine Interface Computer" (HMIC) collected all information to/from data link. Additionally there was an operator station dedicated to DEMUEBP with its own computer and a separate data link, to receive the video stream from the UAV. This computer was the platform for the ATR software.

The data link system was built-up through a WLAN system. Each computer inside the DEMUEBP project got its own unambiguous IP-address. Two connections from H/C to the GCS were established via WLAN. The first one was used to provide an analog video signal to the police operator place and ATR-software in the H/C. The second connection was realized by a WLAN-bridge to connect a PC located at GCS directly to the H/C onboard network providing the exchange of position and status information (H/C and UAV).

4. DESCRIPTION OF THE TEST VEHICLES

In the research project three UAVs and one manned helicopter participated. The selection of aerial vehicles was driven by the selection of partners. The following vehicles flew in the demonstration for DEMUEBP:

- ULLTRA Evo (Technical University of Munich)
- KOAX X-240 (Swiss UAV/EADS IW)
- LUNA (EMT GmbH)
- EC 145 (Eurocopter)

The ULLTRA Evo and the KOAX X-240 demonstrated scenario 1, while the LUNA and the EC145 did scenario 2.

4.1. EC145 Research helicopter

The EC145 helicopter used for DEMUEBP is a special research test bed. The cockpit of this helicopter is equipped with two large format non-serial displays. One is presenting a synthetic vision based on a digital elevation model and overlaid by a high resolution aerial view, the other is displaying a 2D digital map.

Figure 5: EC145 experimental helicopter

In the cargo room of this helicopter there are installed two 19-inch racks, which are carrying the experimental computer system. Behind the cockpit two operator places had been installed for the DEMUEBP flight tests. The operator place at right hand side behind the pilot is necessary, to start and monitor the experimental computer system (PILAS), which also drives the both displays of the pilot.

Figure 6: Operator station with ATR software in the helicopter (left)

At the left hand side a police operator place was built-in together with a powerful computer for the ATR-software. A joystick was additionally mounted as cursor control device.

4.2. LUNA – a fixed wing UAV

LUNA is an all-weather, easy to operate unmanned air vehicle (UAV) system for real-time surveillance, reconnaissance and target location at ranges exceeding 100 km with an endurance exceeding 6 (optional 8) hours. The LUNA system is in service with the German Army since March 2000 and is successfully performing reconnaissance missions in Kosovo, Macedonia and Afghanistan under severe weather conditions and in difficult terrain.

Figure 7: LUNA on the start catapult

As the system is strongly supported by automated processes, the handling of the LUNA system is easy and does not require personnel with aeronautical skills. Full crew training is accomplished within a few weeks. Still the performance of LUNA is superior to that of many conventional reconnaissance and surveillance drone systems. All system components can be transported in and operated from small vehicles or portable shelters by a small crew, allowing rapid deployment by medium transport helicopters.

Figure 8: LUNA GCS

LUNA is providing a modular payload concept. For DEMUEBP a daylight camera system was installed on a movable and remote controllable platform. The video stream from the camera was integrated into the LUNA proprietary data link.

The LUNA GCS was installed in trailer. The catapult start, the whole mission and the parachute landing – everything was controlled from this GCS. The two pilots inside the GCS had no direct view to the UAV. But on the monitors they could see the flight data of the UAV and the sensor video. The sensor video was transmitted via extra data link to the helicopter.

5. AUTOMATIC TARGET TRACKING SOFTWARE

Image exploitation systems are key mission systems for current and future military surveillance and reconnaissance platforms. As civil law enforcement operations like search and rescue or pursuit missions need similar capabilities as military systems to perform target detection and tracking functions, algorithms could be reused for civil applications. For the DEMUEBP project an already existing target classification and tracking software should be reused to show the potential of such functions for law enforcement operations.

The available automatic target recognition (ATR) and tracking software was developed at EADS Military Air System (MAS) and is designed primarily for onboard use to provide higher autonomy levels to unmanned air vehicles. Due to lack of onboard computing capacity within DEMUEBP this capability was shifted towards the ground station for demonstration purposes including some slight modification. For an operator the look and feel of this implementation is quite similar compared to the embedded onboard solution.

The key features of the provided ATR system are:

- Software library which is capable of running on COTS and mission computer environment.
- Capable of real time processing[1]
- Detection and Tracking capability
- Object classes are defined via parameter sets
- Multiclass capable[1]

The algorithmic core of the software is founded on a learning based automatic target detection (ATD) algorithm which has been patent-registered by EADS MAS.

5.1. Performed Development Tasks

A key characteristic of learning based algorithms is the adaptation prior to the mission. For the EADS

[1] Depending on available computer hardware and defined mission scenario

MAS component this is done by generating object class depending parameter sets. To train these parameter sets a image generation phase to record mission typical image sequences is required. The following figure shows three sample images taken from the pre-recorded scenario 2 video sequences, which have been used to generate the appropriate parameter sets.

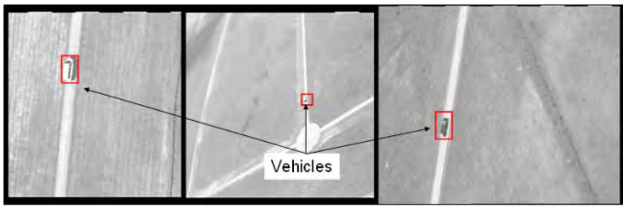

Figure 9: Sensor image samples from scenario 2

Additionally to the parameter generation the detection and tracking software has to be incorporated within the existing mobile exploitation station. Figure 10 illustrates the graphical user interface of the mobile exploitation station. The sensor image is displayed in the centre part of the GUI, flanked by a user interface on the right side of the image.

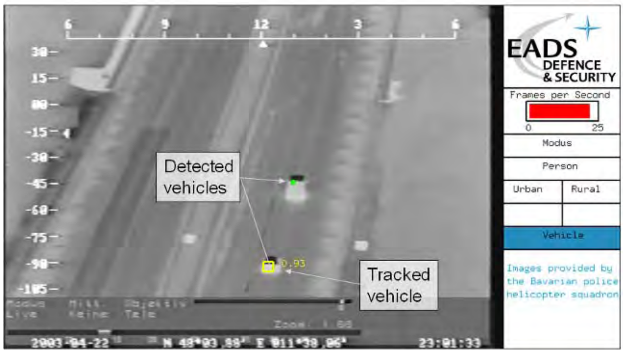

Figure 10: Sensor Graphical user interface of the mobile exploitation station showing a sample image provided by the Bavarian police helicopter squadron.

The user interface starts below the company logo with a Frames per Second (fps) indicator, illustrating with a red bar the reached performance ranging from zero to 25 fps. In the depicted case the indicator shows a performance of nearly 25 fps, which could be interpreted as nearly real time performance. Below the indicator a sequence of labels shows the current classification mode of the software. The vehicle label with the blue background displays that the software is currently in the vehicle detection mode. Possible other modes would be person detection in urban or rural scenarios.

To support the operator with the pursuit of a high jacked car – as was the task for scenario 2 - the software consists of a tracking capability. To enable the tracking mode the operator has to mark the object which has to be tracked. A successful track is indicated by a yellow rectangle and a number. The printed number illustrates the returned confidence value of the tracking function. The value could range from zero to one, numbers near one indicates a good tracking whereas values below 0.5 stands for a low quality tracking.

5.2. ATR Results for Scenario 2

The results descript are based on the algorithm adaption which was founded on an available video sequence recorded only on one day. The sequence has a total length of approximately 10 minutes and was used to generate the parameter sets enabling the software to detect and track vehicles within this special scenario.

The following figure illustrates the already introduced GUI including a video frame taken from the demonstration event.

Figure 11: Sample frame taken from scenario 2 result video

The target vehicle could be seen in the lower part of the video frame, driving on a road. A small green dot as well as a yellow rectangle indicates the successful detection and tracking of the target.

The target vehicle used within the demonstration could be detected and tracked throughout the complete event with confidence values ranging from 0.83 to 0.96. No false alarms were generated during the demonstration. This indicates a good performance of the used tracking algorithm.

Summarizing the project results it could be stated that the goal of a successful demonstration of UAV's for police missions has been reached.

Functional enhancement potential is available due to the fact that no sensor or platform metadata like sensor field of view, altitude or recording time has been associated and transferred with the image. The availability of this information could enable a lot more functions like autonomous camera steering or vehicle tracking.

6. HMI FOR MANNED - UNMANNED TEAMING IN THE HELICOPTER

Another part of the research project DEMUEBP was the investigation and development of a specialized HMI in the helicopter for manned – unmanned teaming between UAV and helicopter. The main requirement for such a HMI is to ensure the separation between UAV and helicopter and so to maintain the flight safety during such missions. Therefore the task of the HMI was to keep the helicopter pilot aware of the location of the UAV in relation to his own and generate warnings.

Eurocopter developed a solution based on the PILAS HMI philosophy and the already existing traffic symbology. The position of the UAV is depicted both in the 3D synthetic vision presentation and in the 2D map display.

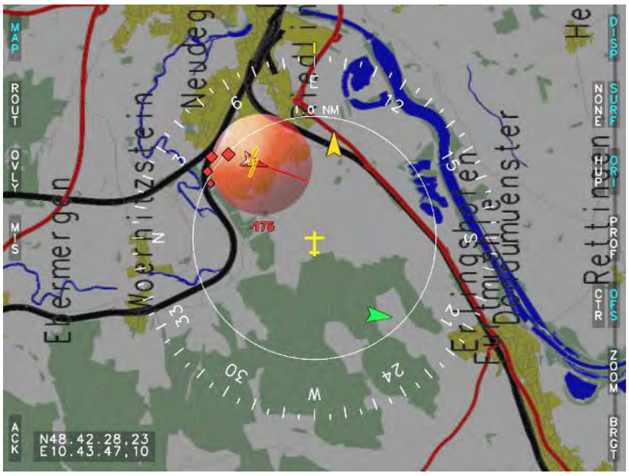

Figure 12: Presentation of the UAV on the helicopter's 2D moving map system

In the 2D map display the UAV is depicted as arrow, which is coloured depending on the criticality level of its flight path compared to the helicopter's flight path. In the front of the arrow symbol a flight vector shows the actual flight direction and speed. In order to specially highlight the UAV, a transparent circle around the UAV is marking a safety zone of 1 nm in diameter. A warning will be generated, if the helicopter enters this safety zone.

Figure 13: Presentation of the UAV (here: LUNA) on the helicopter's 3D synthetic vision system (SVS)

If the UAV gets out of control through a loss of the data-link this is immediately recognized by a watchdog and is symbolized by a lightening symbol over the UAV symbol. The track of the UAV can be depicted as small rhomboids behind the UAV symbol.

In the 3D SVS in front of the pilot the UAV is depicted as 3D-cone with the flight vector in front of it. Also here the colour corresponds to the criticality level of the UAV's flight path.

7. DEMONSTRATION TEST FLIGHTS

In preparation for the demonstration in front of the customer several ground and flight tests and a general rehearsal took place for both scenarios. A main issue during the ground testing was the adaptation of the different participants in the network. Interfaces had to be adjusted. For the WLAN-type data links the right antennas had to be found. At the end omnidirectional antennas had been selected.

At the 30th of June 2009 the demonstration took place in a special flight test area south of Manching airport. The airspace over this area has been closed dedicated to the demonstration campaign. The airspace was managed by the tower of the company airport close to the area and a controller on location. A small house was used as ground station and coordination centre. The LUNA GCS was also located there. The coordination centre was equipped with several screens showing different scenes caught by webcams from the whole scenario setup as well as live sensor images received by data links. Both scenarios were explained to the customer and the visitors of the demo.

For scenario 1 one of the colleagues had layed down in the meadows of the test area. The rotary wing sensor UAV flew a predefined search pattern. The IR sensor image was transmitted via sensor UAV to the coordination centre, where the ATR software analysed the image and – after a while – detected the person lying on ground. The coordinates could be read out and given to the rescue team.

In scenario 2 a car was taken as demo-vehicle, to simulate the high-jacked car. This car had to use the straight street in the middle of the test area and had to keep a speed of around 80 km/h. This requirement was necessary for this feasibility demonstration, as the fixed wing drone otherwise could not follow the car. First the LUNA drone was started remote controlled from its catapult and sent to a holding area inside the test area. Then the helicopter – simulating a future police helicopter – started and flew to a hovering position, where he could see the street, but was keeping a safe distance to the UAV. Once the "high-jacked" car started, the LUNA was manually guided to the car for the first contact. The LUNA sensor operator caught the car by controlling the steerable sensor platform. Once the car was visible in the sensor image, the operator in the helicopter, who also received the sensor image, marked the car in the ATR software. Now the ATR software started to track automatically the car and calculate offset coordinates, which were sent to the GCS of the drone. The GCS calculated respective next waypoints for the LUNA and transmitted it. So the drone followed the car and provided videos of what the car was doing. The “police” operator in the helicopter could use this information and decide, how to react.

8. RESULTS, CONCLUSIONS AND OUTLOOK

The flight tests and the demonstration showed the full complexity of the setup of both scenarios. A lot of computers, equipments and partners had to be harmonized to realize the complete data flow. The stability of the data links showed to be a major point to be considered. The selection of WLAN-based data links might be the right solution for micro- and mini-UAVs, but not for the bigger ones used here. Nevertheless inside the test area in a range of 1 km the data flow could be realized with the WLAN data link.

The ATR software used in scenario 2 on board the helicopter proved its functionality as described in chapter 5.2. The “high-jacked” car was recognized and tracked by the software, which was then able to provide the tracking data for the LUNA drone. In the cockpit of the helicopter the pilot always was aware of the location of the UAV, which otherwise was very difficult to be seen by the bare eyes. The demonstration resulted in video sequences as transmitted by the sensor UAV.

The visitors and the customer could follow the take-off and landings of the UAVs and the helicopter directly. During the mission they followed all available videos on large screens in the coordination centre, where they got explanations to each phase of the scenarios.

The successful demonstration of scenario 1 and 2 at the 30th of June 2009 was very well appreciated by the visitors and especially by the customer! That resulted recently in a follow-up project DEMUEB III for the partners.

9. ABBREVIATIONS

2/3/4 D	2/3/4 dimensional
AFCS	Automatic Flight Control System
ATC	Air Traffic Control
ATD	Automatic Target Detection
ATR	Automatic Target Recognition
C²	Command and Control
CDU	Control and Display Unit
COTS	Commercial off the shelf
DeCo	Demonstration Cockpit
DEMUEBP	Demonstration project for UAV-operations at the Bavarian Police
DEMUEB III	Demonstration project for UAV-operations for Bavaria, Phase III
DLR	German Aerospace Centre
FMS	Flight Management System
GCS	Ground Control Station
GUI	Graphical User Interface
H/C	Helicopter
HMI	Human Machine Interface
HMIC	HMI Computer
IR	Infra Red
NMD	Navigation Management Display
MAS	Military Air Systems
PFD	Primary Flight Display
PILAS	Pilot Assistance System
RCC	Rescue Coordination Centre
SA	Situation Awareness
SATCOM	Satellite communication
SVS	Synthetic Vision System
TAWS	Terrain Awareness and Warning System
UAV	Unmanned Aerial Vehicle
WLAN	Wireless LAN

10. ACKNOWLEDGMENTS

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