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# ASIMUT PROJECT: AID TO SITUATION MANAGEMENT BASED ON MULTIMODAL, MULTIUAVS, MULTILEVEL ACQUISITION TECHNIQUES

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**This document summarizes the activities and results of the ASIMUT project (Aid to SItuation Management based on MUltimodal, MUltiUAVs, MUltilevel acquisition Techniques) carried out by the consortium composed of Thales, Fraunhofer IOSB, Fly-n-Sense, University of Bordeaux and University of Luxembourg. Funded by the European Defence Agency (EDA), the objectives of the ASIMUT project are to design, implement and validate algorithms that will allow the efficient usage of autonomous swarms of Unmanned Aerial Vehicles (UAVs) for surveillance missions.**

الكلمات الرئيسية
multilevel UAV swarm; decisional autonomy; mobility management;

## مقدمة

**The development** and usage of UAVs has quickly increased in the last decades, mainly for military purposes. Nowadays,this type of technology is also used in non-military contexts, for instance for environment protection, by search and rescue teams, by fire fighters and police officers, for environmental scientific studies, etc. Although the technology for operating a single UAV is now mature, efforts are still necessary for using swarms of UAVs. Even if UAV swarming has already stimulated a lot of research, many open issues must still be addressed, such as the use of multiple, multilevel cooperating autonomous swarms. This is the goal of the ASIMUT project, which results are described in this paper. It is a follow-up to [1], in which a detailed analysis of the current technologies and related works regarding ASIMUT was already provided. The remainder of this article is structured as follows. Section 2 provides an overview of the ASIMUT project. Then the results obtained for each component is presented in section 3. Finally section 4 draws extensive conclusions to illustrate the capabilities of the ASIMUT system.

## 2. THEASIMUTPROJECT

The ASIMUT project relies on the collaboration among swarms of UAVs evolving at different altitudes: e.g., fixedwing UAVs covering the area at a high altitude with coarse grain acquisition capabilities and low-altitude multirotor UAVs in charge of precise measurements. The goal of this project is to address scenarios where a mission has to be achieved based on decisions made from data collected from different sensors in a number of UAVs that constitute swarms. High-altitude and low-altitude swarms are tasked based on the fusion of information coming from multiple sources. From an early warning process where data are provided by the UAV swarm payloads, the target localization, monitoring and classification processes are achieved using advanced techniques from the domains of artificial intelligence, machine learning, and statistics. The objectives of the ASIMUT project are to design, implement and validate algorithms that will allow the efficient usage of autonomous swarms of UAVs for surveillance missions. To support situation management, the ASIMUT project focuses on: • Providing automated assistance to human operators with regard to high level data fusion tasks. By doing so the project can significantly improve their capabilities for making efficient and effective decisions. • Developing methods and algorithms to improve moving target detection in a video flow. • Handling several swarms of UAVs including their communications, networking and positioning. This thus motivates the development of multilevel cooperation algorithms, which is an area that has not been widely explored, especially when autonomy is also a challenge. Thus, additional problematics appear, and it becomes necessary to focus on: – Providing techniques to optimize communications within a swarm and between swarms (including multilevel swarms); – Developing distributed and localized mobility management algorithms to cope with conflicting objectives, such as connectivity maintenance and geographical area coverage.

## 3. PROJECTRESULTS

The goal of the ASIMUT project was to provide a model combining detection, data fusion and mission management, including the use of new solutions such as UAV manoeuvrability and autonomy in swarms, to assist operators to better decide the course of actions when facing situation awareness. The Fig. 1 provides an overview of a mission as seen from the ASIMUT project perspective. Each step (from 1 to 6) is detailed in the following subsections. A video illustrating the simulation of the ASIMUT framework on a realistic scenario is also available online1.

### 3.1 MissionManagement(1&2inFig.1)

Using multilevel swarming reconnaissance assets requires completely different approaches (compared to standard single UAV approaches) in the domain of mission management. In order to keep the operators situational awareness focused on the relevant aspects of the current mission the developed ASIMUT smart mission management system has been abstracted from the classical single or multi UAV management system to achieve a target or objective oriented mission management system. Possible operator interactions combined with the reconnaissance assets are shifted to a macro level of control by introducing the doctrine of network centric multiple mission objectives management allowing the user to concentrate on the goals of active missions. Decisional autonomy within the reconnaissance assets combined with ergonomic human device interfaces and automation within 1https://asimut.gforge.uni.lu/ downloads/asimut.mp4 the mission creation and management process is freeing capacities to raise the effectiveness and efficiency of the reconnaissance product creation cycle and making complex and parallel missions controllable.

### 3.2 Swarm Decisional Autonomy and Mobility Management(3&4inFig.1)

The ASIMUT project requires cooperation within and between UAV swarms, the latter being an area that has not been widely explored, especially when autonomy is also a challenge. The management and the optimization of the interactions between the swarms that take part in the mission are provided. This permits to understand how the swarms local decisions and work impact the behaviour of the other swarms. SnT and LaBRI developed a dedicated framework to manage the autonomy of UAVs that permits scalability over the number of swarms [3]. Another contribution lies in the mobility management for both the High Level Coordination Swarm and Low Level Swarms which fulfil their objectives without any (predefined) flight plan. Novel distributed and online mobility models have been developed to enable efficient and unpredictable trajectories for UAVs. These rely on a chaotic behaviour and Ant Colony Optimization (ACO) method in order to handle conflicting objectives such as area coverage maximization and revisit time minimization [4].

### 3.3 Moving Target Detection in a Video (3 & 5inFig.1)

In order to significantly reduce the operator workload during a surveillance mission, a ground moving vehicle detection algorithm has been developed. The Low Level UAVs are mainly equipped with electro optical/infrared cameras which video flow is sent to the ground combined in a single demonstration framework and evaluated via state-of-the-art simulations. After testing all the interfaces, the different components (each implementing an innovative technology), have been integrated in a global single system. Therefore, we consider that IRL (Integration Readiness Level) level 3 has been reached and demonstrated. After the evaluation done in a simulation environment, the individual TRL (Technology Readiness Level) of each component reaches, by definition, level 3. The SRL (System Readiness Level) is therefore evaluated to be at level 2 (see [5] for details about TRL and SRL). In terms of swarming, we have been able to setup a multilevel configuration with UAVs that play different roles in the mission and that support resilience (regarding loss of UAVs) while on the field. The cooperation between the C2 (Command & Control), the High Level Coordination Swarm and the Low Level Swarms has shown that the situation management process has been improved and leads to a decrease of pressure on the C2 operator. The simulations have demonstrated that there are a number of parameters that impact the efficiency of the mission (coverage time, revisit time, etc.). Still, the covering based on the new mobility model that has been introduced has proven very efficient. Nevertheless, in order to further improve the efficiency of the area coverage and reduce the revisit time, all the UAVs in the swarms must be able to share their future trajectory plan. Regarding future work on the swarming issues, the following directions should be studied: resilience to messages loss, load and decision sharing between the UAVs of the low level swarms, the high level UAV swarm and the C2. The simulation results gave direction to define additional tests that need to be run. Considering the video flow, the ASIMUT project deals with a lot of data. This work permitted to have a global idea of new problematics rose by such an amount of data for real time processing. The tools developed in the ASIMUT project permit to handle this data flow and especially the workload of the operators. In the future, it will be interesting to work on load balancing between the elements of the system (drones, GCS, etc.). Considering high level data fusion for supporting intelligence analysts and decision making, both the approach used for fusion of observed video track data with intelligencebased prior information and the approach for analyzing the dynamic behavior of vehicles, are ready for evaluation (and subsequent refinement of parameters) in more complex realworld scenarios (more vehicles, real-world driving behaviors, real-world ground truth data). In such scenarios, the level of support to analysts (i.e., the reduction of workload and information overflow) and decision makers should be evaluated in more detail in order to acquire directions for further improvements of high level data fusion. From the Mission Management perspective the human to device interfaces have been tested and their capabilities have been proven. Due to the automation of the mission creation process and the operator support by simple and intuitive interfaces the workload on the operator could be reduced leading to a shortened reaction time for commanding the swarm. To push this development further the automation of mission control has to be enriched with additional artificial intelligence to react based on the situation and the results coming from the reconnaissance assets following the dogma of “management by objective”. In combination with a more complex real-world scenario the intelligent mission

station by the High Level Coordination Swarm. These dynamic data coming from all the UAVs of the Low Level Swarms coupled with the geolocation of the UAVs are automatically analysed in real time, without any human intervention. A major innovation is the possibility to detect small moving targets, with a size under five pixels in the video. For each detected vehicle, an alert is displayed on the Human Machine Interface, and the operator identifies the target emphasised on the video. Then, data concerning the targets is sent to the Intelligence Center which will classify the vehicle.

**3.4 HighLevelDataFusion(1,5&6inFig.1)**

In ASIMUT, high level data fusion (HLDF) is applied in the Intelligence Center to support human operators. There are several tasks in the ASIMUT scenario which are supported by HLDF. The first task concerns the initialization of the scenario, where a request for information (RFI) is created (step 1), which in turn causes the creation of a mission (step 2). In the Intelligence Center, information is extracted (with the help of natural language processing) from intelligence reports and provided to an information integration and management system, called the Object-Oriented World Model [2] (OOWM), which integrates this information with prior knowledge from an intelligence database. As a result, HLDF using first-order probabilistic reasoning can derive a critical event, being a possible assault with a certain vehicle, from the integrated information and the RFI is created to search for the vehicle.The second task (steps 5 & 6) is to process surveillance data on vehicles provided by the UAVs and the video target detection. This data is again passed to the OOWM, which applies HLDF in order to integrate the data with previous information stored in the OOWM. Here, the task is to identify the vehicle being searched for in the surveillance data (by associating it to the vehicle description known from the intelligence database). The third task concerns performing a behavior analysis on vehicles observed by the UAVs in order to identify suspicious behaviors. The results of this analysis are then combined using HLDF with the results of the two previous tasks and provided to the OOWM (step 6). Finally, these integrated results, containing an estimate of the threat posed by each observed vehicle, are presented to the mission commander in an operational picture.

## استنتاج

The ASIMUT project proposed, developed and validated beyond state-of-the-art technological building blocks for the enhancement of the autonomy of surveillance missions based on multilevel UAV swarms. We proposed new algorithmic approaches to address the different components of the functional chain of the underlying distributed system. The swarm decisional autonomy and mobility management took profit of past expertise of the consortium members on swarms of UAVs and of new technologies for the application to multilevel swarms. Automatic processing of the detection of (even small) moving vehicles from real-time video acquisition by an electro-optical payload looks promising to decrease the operator workload. By providing automated assistance for human operators with regard to high level data fusion tasks, ASIMUT significantly improves the capabilities of new algorithms for making efficient and effective decisions. Solutions for smart mission management and operator support have been developed. Information coming from the swarms can now be used to display the Common Operational Picture and other results within the ground control station and to compare the current situation with the planned one. The most promising approaches implemented in the different algorithms that we have designed have been management could be evaluated in more details to identify the gaps and the strength of the system. The objective to evaluate the benefits and relevance of the developments made went successful and provided fruitful results which are relevant for further steps towards a future demonstration of the system in a real configuration representative of an operational environment. Additionally, running a real world demonstrator would make thus possible to identify additional issues that can only be seen at runtime and to prove the concepts that we have developed really make sense on the field in the presence of real potential threats.

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