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Mobile Ground Control Station for Local Surveillance

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***Abstract*— The Fraunhofer Institute for Information and Data Processing operates different types of sensors on several mobile and stationary platforms for surveillance such as multiple micro UAVs, a helium captive balloon, networks of radio sensors, various network cameras, and mobile land and underwater robots. The surveillance system AMFIS presented in this paper is an integration platform that can be used to interconnect system components and algorithms. The specific tasks that can be performed using AMFIS include surveillance of scenes and paths, detection, localization and identification of people and vehicles as well as collection of evidence. The major advantages of this ground control station are its capability to display and fuse data from multiple sensor sources and the high flexibility of the software framework to build a variety of surveillance applications.**

Keywords - security; surveillance; ground control station; sensors; unmanned aerial vehicles

I. INTRODUCTION

This paper presents a complex surveillance system and its work station called AMFIS. AMFIS is a component based modular construction kit currently under development as a research prototype. It already has served as the basis for developing specific products in the military and homeland security market. Applications have been demonstrated in exercises for EU (PASR program), German Armed Forces, and the defense industry. The tasks that have to be supported by such products are complex and involve among others control of sensors, mobile platforms and coordination with a control center.

The surveillance system AMFIS [1] is an adaptable modular system for managing mobile as well as stationary sensors. The main task of this ground control station is to work as an ergonomic user interface and a data integration hub between multiple sensors mounted on light UAVs (unmanned aerial vehicles) or UGVs (unmanned ground vehicles), stationary platforms (network cameras), ad hoc networked sensors, and a superordinated control center.

The AMFIS system is mobile and portable, allowing it to be deployed and operated anywhere with relative ease. It can supplement existing stationary surveillance systems or act as a surveillance system on its own if no preexisting infrastructure is available. The sensor carriers in this multi-sensor system can be combined in a number of different setups in order to meet a variety of specific requirements. At present the system supports optical sensors (infra-red and visible) and alarms (PIR, acoustic, visual motion detection). There are plans to add support for chemical sensors in the future.

AMFIS has established standardized interfaces and protocols to integrate and control different kinds of sensors. This “plug and sense” approach allows the seamless integration of new sensors with a minimal effort. All sensor data is automatically converted to a format useable by the ground control station, if necessary.

After a short survey of related work an overview of the application scenarios is presented, followed by a brief description of the apparatus in section IV. Section V introduces a commercial flight platform modified to reach a higher level of autonomy and extending the ground control station presented in Section IV.

II. STATE OF THE ART

To the best of our knowledge the combination of heterogeneous sensors and sensor platforms (ground, air, water) in an open homogeneous system allowing the fusion of various sensor data to generate a complex situation picture is a quite unique project. The integration of different sensors into one system has already been realized in previous systems but mainly in order to create specialized individual solutions tailored to individual customer requirements. Many projects deal with the development of supervision systems, new sensor platforms or control of sensors. The combination of these innovative supervision and reconnaissance attempts to one modular system has not been done yet.

Systems similar to AMFIS are the ground stations of the French company Aerodrones [2] and the American company AII [3], both developed as stand-alone control stations for multiple airborne drones. Another example is the product of the US company Defense Technologies [4] which focuses on military standardized interfaces to control different sensor platforms on the ground, in the air and in the water.

In contrast to AMFIS, Aerodrones and AII deal exclusively with airborne sensor platforms. Defense Technologies does not commit itself in the kind of used sensor platforms and is therefore more similar to AMFIS. AII and Defense Technologies are concentrating on military solutions while AMFIS is mainly intended for civil applications.

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III. APPLICATION SCENARIOS

The security feeling of our society has significantly changed during the past years. Besides the risks arising from natural disasters, there are dangers in connection with criminal or terroristic activities, traffic accidents or accidents in industrial environments.

Even though a lot of effort is put into protecting threatened or vulnerable infrastructure, most threats cannot be foreseen in their temporal and local occurrence, so that stationary in situ security and supervision systems are not present. Such ad hoc scenarios require quick situation-related action.

Possible scenarios that deal with these specifications are the supervision of big events or convoys for security reasons, natural and man-made disasters such as earthquakes or major fire control but also unauthorized intrusion of persons into sites and buildings, e.g. to take hostages or place explosives.

Especially in the civil domain in case of big incidents there is a need for a better data basis to support the rescue forces in decision making. The search for buried people after building collapses or the clarification of fires at big factories or chemical plants are possible scenarios addressed by our system. Only in the minority of cases the rescue forces can rely on an already available sensor infrastructure at the incident site. If there were sensors available, there is a significant chance they will be destroyed or at least partially corrupted. A transportable sensor system to be used remotely at the site of the event is proposed to close this gap.

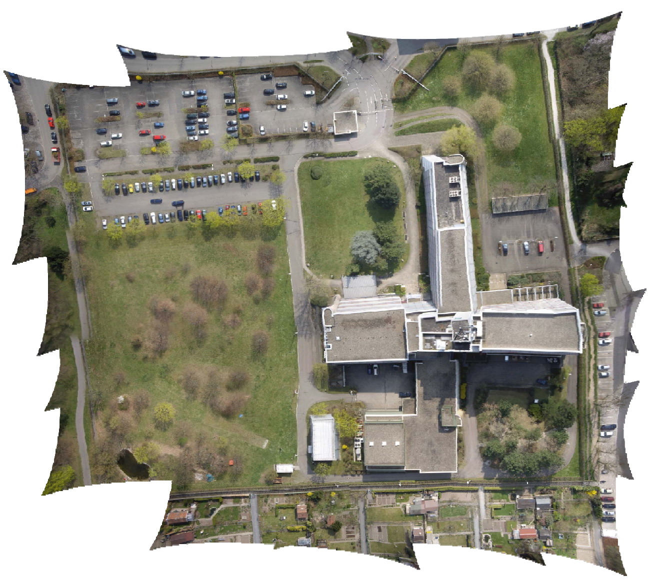

Figure 1. Situation picture generated with AMFIS (ca. 9500 x 9000 pixel)

The micro UAVs used in AMFIS can deliver a highly up-to-date situation picture from the air during a conflagration in a chemical factory or a similar scenario. Ground robots can enter the building in parallel to the fire-fighting work and penetrate areas which are not yet accessible for the fire fighter and search for injured people or unknown sources of fire without endangering human life. Additionally, the mobile sensor platforms can be complemented by stationary systems. These can be temperature sensors for the fire aftercare or the measuring of the fire development and expansion or vibration and motion sensors to use in a collapsed building. These sensors can be used to prevent or at least to warn of any further structural changes in a collapsed building by detecting vibration and movement in the debris. The UAVs or ground robots can also act as platforms to deploy sensors at points of interest.

Besides the system's capability of ad hoc deployment during disasters or accidents, AMFIS can also be used as a versatile protection and supervision system. Premises or vulnerable infrastructures can be monitored with all types of sensors and actuators. Equipping the perimeter with motion detectors and cameras is a typical setup. In addition, mobile ground robots can patrol the area and respond to events. Other tasks that can arise are the detection of danger potential, the supervision of scenes and ways or the localization, tracking and identification of people and vehicles.

When several sensor systems and platforms are used in a complex scenario at the same time, conventional control systems designed as single use- and controlling-systems quickly reach their limits. First of all, every subsystem needs its own console and a specially trained operator due to the fact that each system has its own interface. Secondly the fusion and synchronized filing of sensor and status data from different systems is not an easy task.

The control of the individual sensors and platforms from the situation center is hardly practicable on account of the complexity, delay in the data transfer and distance to the place of action (often several kilometers).

As a connection between the sensors and the situation center an authority directly on the site of the event is necessary which processes the reconnaissance missions independently. That includes steering sensor platforms, controlling sensors as well as filtering and densification of sensor data so that only information relevant for decisions like situation reports, alarms and critical video sequences are transmitted in an appropriate way, to the situation center.

An analysis of the demands in complex scenarios incorporating micro UAVs has shown that at least two operators are necessary on the ground control station to deal with the requirements and problems arising from such a scenario. One operator is exclusively responsible for the control and supervision of the mobile sensor platforms. The second operator looks after the evaluation of the sensor data streams and the communication with the situation center.

IV. PLATFORM

In order to be adaptable to a wide range of different requirements and applications, AMFIS was developed as a mobile and generic system which delivers an extensive situation picture in complex surroundings - even with the lack of stationary security technology. In order to achieve a maximum of flexibility the system is implemented open and mostly generalized so that different stationary and mobile sensors and sensor platforms can be integrated easily with low effort.

The system is modular and can be scaled arbitrarily or be adapted by choosing the modules suitable to the specific requirements. Because of the open interfaces the accumulated data can be delivered on a real-time basis to foreign systems. (e.g. guidance or evaluation systems.)

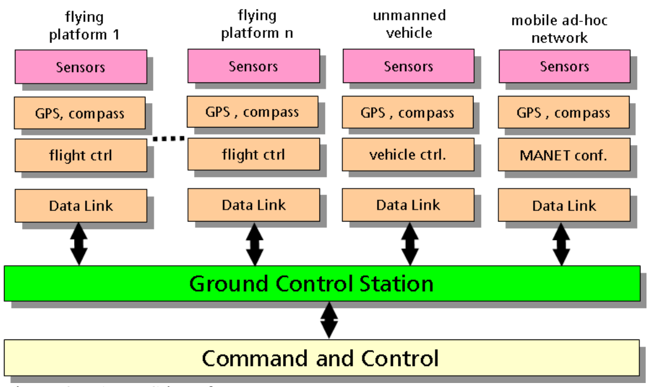

Figure 2. AMFIS interfaces

The AMFIS system can be divided into a mobile ground control station which can control and coordinate different UAVs, land vehicles or vessels (sensor platforms), as well as stationary autonomous ad hoc sensor networks and video cameras. Depending on the used sensors and sensor platforms, the system is extended with suitable broadcasting systems for the transmission of the control signals and the sensor data. (e.g. video recordings.)

By the generic approach the system is able to link with a wide range of sensors, and can be equipped with electric-optical or infrared cameras, with movement dispatch riders, acoustic, chemical or radiation sensors depending on the operational aim. If supported or even provided by the manufacturer these sensors can be mounted on mobile sensor platforms, or be installed in fixed positions. The only requirement such sensors have to fulfill in a mobile scenario is that they work properly without the need for any pre-existing infrastructure.

The AMFIS system is scalable and can be extended to any number of workstations. Due to this fact several sensor platforms can be coordinated and controlled at the same time. The most different sensor platforms can be handled in a similar manner by a standardized pilot's working station that in turn minimizes the training expenditure of the staff and raises the operational safety. The user interface is automatically adapted according to the sensor or sensor platform at hand.

Data fusion belongs to the most important tasks of a multi sensor system. Without merging the data from different sensors the use of such a system is very limited. Linking data of sensors that complement each other can generate an entire situation picture.

All information gathered during the operation is immediately available to the crew of the ground control station in which a GIS-supported, dynamic situation representation plays a central role. At the same time all received data is archived and stored into databases, e.g. a CSD (Coalition Shared Data)[5] or SSD[6]. This serves the perpetuation of evidence and allows an additional subsequent analysis of the events.

Figure 3. AMFIS ground control station

The open interface concept supports the integration of AMFIS in existing security systems so that data can be exchanged on a real-time basis with other guidance, supervision or evaluation systems.

Mission planning, manual and automatic vehicle guidance, sensor control, local and temporal linking (coalescence) of sensor data, the coordination of the people on duty, reporting and the communication with the leading headquarters in the situation center belongs to the other tasks of a reconnaissance system.

Combination of sensor events and appropriate actions are implemented by predefined rules with an easy to use production system.

A. User Interface

The user interface of the AMFIS ground control station at Fraunhofer IITB as shown in Fig. 3 consists of three workstations. Basically, the system is designed that each display can be used to interact with each function allocated by AMFIS. The standard setup consists of two workstations for one operator each, and one situation awareness display in between that supports both operators. The duties of the two operators can be divided into sensor and vehicle control, called pilot working place, and data fusion, archiving, exploitation and coordination tasks.

The user interface of the latter working place primarily provides a function for the visualization of sensor data streams. Therefore the operator gains access to the accumulated data. His task is to obtain and keep an overview of the situation and to inform the higher authorities about important discoveries and provide the associated data so that external systems or personnel can utilize that information. It is incumbent on him to mark important data amounts and to add additional information when necessary. Furthermore he is the link to the pilot and coordinates and supports the pilot in his work. The analyst as well as the pilot relies on the central geographical information system-supported situation representation that provides an overview of the whole local situation. The geographical relation is established here and the situation and position of the sensors and sensor platforms can be visualized. This includes for example the footprints of cameras or the position and heading of UAVs or UGVs.

The pilot's workstation is designed to control many different sensor platforms. It is not clear from the start which sensor platforms will be used in the future and it is also not clear which situation information will be provided by the different systems or which information is needed to control the future platforms in a proper way. For this purpose the pilot workstation provides a completely adaptable user interface which allows selectively activating or deactivating the required displays. An artificial horizon for example is completely useless in order to control a stationary swiveling camera but very helpful for controlling an airborne drone. The surface can be adapted to the particular circumstances and is configurable for a wide range of standard applications. No matter what sensor platform the user is currently controlling or supervising, the task is the same. He does not have to switch between different proprietary control stations. The user interface is identical except for individual volitional or necessary adaptations.

B. *System and Software Architecture*

The central component of the software architecture of AMFIS is a connector. It receives and dispatches all incoming sensor signals and data to all components using the .NET framework.

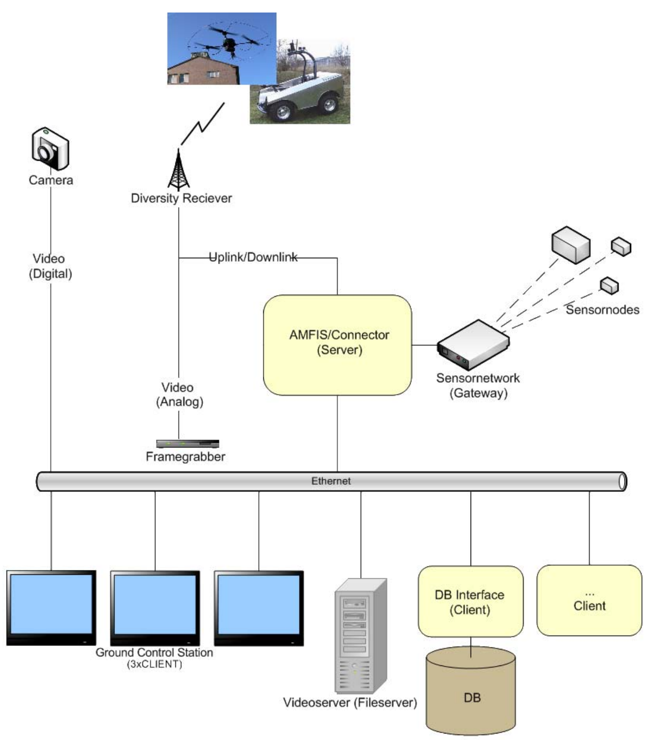

Figure 4. AMFIS network

The Connector is needed to cope with different protocols of the heterogeneous sensors that are used in AMFIS. A new COTS sensor that should be connected to AMFIS usually has its own communication protocol. That means a new interface has to be implemented, so that the Connector can interpret the sensor data. This interface is responsible for interacting with the sensor. It allows the Connector to transform incoming data to an AMFIS-specific system wide data model that is transmitted in an XML-based message format to all components that subscribe. It is also represented in a relational database schema.

The data model is built around a message which represents an event or single measurement. The message belongs to a certain sensor. The sensor is along with other sensors part of a sensor node which in turn is part of a sensor web. Sensor and message have a certain type that influences the interpretation of the associated message.

Not all sensors are directly connected via the Connector to the ground control station. Fig. 4 shows communication lines between the components in the system architecture of a specific application that was build with the generic construction kit. It demonstrates that sensor nodes are connected via a gateway, and that video data has to be handled separately because of the huge amount of data.

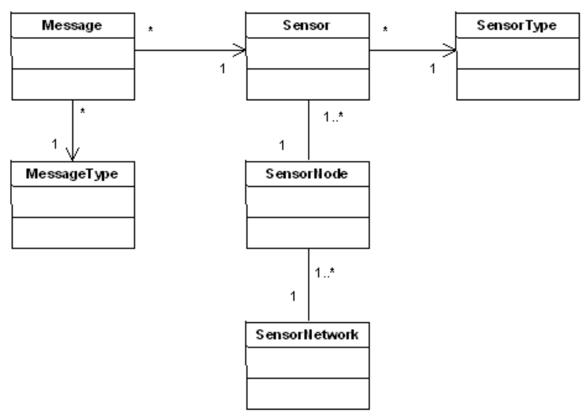

Figure 5. Message data scheme

C. *Support System*

The system offers support for information perception and management. This is achieved by optimized information visualization and information fusion e.g. in the situation display.

Besides this there are active means of supporting the coordination tasks of the sensor data exploitation workstation. Such a support system for the automatic combination and selection of sensor data sources in a surveillance task was implemented as an AMFIS component using a production system.

It is important that the implementation is generic so that the support system can be adapted to several scenarios at different individual sites. This is accomplished by the use of rule sets which are created site and task specific. These rules contain work flows which are pushed if a certain predefined event occurs. Thus, for example, a watchman can be automatically informed or a UAV can be sent off for reconnaissance of a defined area without any user interaction.

The support component in AMFIS is implemented with the Drools rule engine [7] using production rules for representing procedural task knowledge. The engine uses the Rete algorithm which repeatedly assesses the current situation and selects the most appropriate rules to execute.

V. AUTONOMOUS SENSOR PLATTFORMS

AMFIS as an open and generic system supports the simultaneous operation of a large number of sensors and sensor platforms. While the handling of single platforms is already well understood, control and coordination of several mobile platforms can be a challenging task.

For this purpose one of the research focuses lies on the improvement of the application of multiple miniature UAVs. Our approach is to raise the level of autonomy of each drone. Therefore a lot of effort has been put into the selection of the flight platform. Such a platform preferably comes with a range of sensors and an advanced internal control system with autonomous flight features which minimizes the regulation need from outside. When it comes to flying autonomously, the system has to be highly reliable and possess sophisticated safety features in case of malfunction or unexpected events.

Figure 6. Sensor platform AirRobot 100-B

Other essential prerequisites are the possibility to add new sensors and payloads and the ability to interface with the UAV's control system in order to allow autonomous flight. A platform that fulfils these requirements is the quadrocopter AR100-B by AirRobot. It can be both controlled from the ground control station through a command uplink and by its payload through a serial interface.

A. *Towards Autonomy via Hardware*

To support the pilot at his work at the ground control station and to give him the possibility to supervise multiple flying sensor platforms at the same time, several steps are necessary. The first step is to enhance the hardware in order to reach a higher level of autonomy. Therefore, a payload was developed which carries a processing unit that can take over control and thereby steer the quadrocopter.

Due to space, weight and power constraints of the payload, this module has to be small, lightweight and energy-efficient. On the other hand, a camera as sensor system should not be left out. An elegant solution is the use of a "smart" camera, i.e. a camera that not only captures images but also processes them. Processing power and functionalities of modern smart cameras are comparable to those of a PC. Even though smart cameras became more compact in recent years, they usually still are too heavy to be carried by a quadrocopter such as the AR100-B. In most applications, smart cameras are stationary where their weight is of minor importance. However, a few models are available as board cameras, i.e. without casing and the usual plugs and sockets. Thus, their size and weight are reduced to a minimum. The camera that was chosen has a freely programmable DSP, a real-time operating system and several interfaces (Ethernet, I^2C, RS232). With its weight of only 60g (without the lens), its compact size and a power consumption of 2.4W it is suitable to replace the standard video camera payload.

The camera can directly communicate with the drone's controller though a serial interface. The camera receives and processes status information from the UAV such as position, altitude or battery power, and is able to control it by sending basic control commands or GPS-based waypoints.

A drawback of the board camera is its lack of an analogue video output thus rendering the quadrocopter's built-in video downlink useless. Image data is only available through the camera's Ethernet interface. To enable communication between the smart camera and the ground control station, a tiny WiFi module was integrated into the payload. The WiFi communication link allows to stream live video images, still shots and status information from the UAV to the ground control station. Furthermore, programs can be rapidly uploaded to the camera during operation.

Currently, the so enhanced UAVs are able to perform basic maneuvers, such as take-off, fly to position, and landing, autonomously. Furthermore, a software module was implemented, that calculates the footprint of the camera, i.e. the geographic co-ordinates of the current field of view. In the future we will also use the camera's image processing capabilities to generate control information. As a safety feature, it is always possible for the operator to override autonomous control and take over control manually.

B. *Towards Autonomy via Software*

The second step to reach a higher level of autonomy is based on the development of a multi-agent system to implement team collaboration. An agent-based framework is implemented where the individual entities in a team of UAVs are represented by software agents. The agents implement the properties and logic of their physical counterparts.

An agent is "...any entity that can be viewed as perceiving its environment through sensors and acting upon its environment through effectors" [8]. Incorporating that "An agent is a computer system, situated in some environment that is capable of flexible autonomous action in order to meet its design objectives" [9], a multi-agent system seems to perfectly meet the challenges of realizing an intelligent swarm of autonomous UAVs.

Software agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so, realize a set of goals or tasks for which they are designed [10]. Hence, they meet the major requirements for a suitable architectural framework: to support the integration and cooperation of autonomous, context-aware entities in a complex environment.

The agent-based approach allows a natural system modeling approach facilitating the integration of flight platforms, sensors, actuators and services. The core-agents of the multi-agent system presented in this paper are based on the following three agent classes:

- Teamleader Agent: A team leader agent controls a group of agents consisting of at least one agent. It co-ordinates higher tasks and assigns sub-tasks to team members. A team leader is always aware of the positions and capabilities of all team members. A team leader itself can be controlled by a superordinate team leader.
- Copter Agent: A copter agent represents an individual drone and models the general characteristics of a quadrocopter. Each copter agent is assigned to a team leader on initialization. The corresponding team leader agent can access status data of the copter agent, such as the drone's current position.
- Sensor Agent: A sensor agent represents a sensor and is assigned to a copter agent. It implements the properties of the corresponding sensor.

Concrete implementations of these abstract classes are realized by combining a copter agent with a sensor agent. For example, an IRCameraCopter agent represents a quadrocopter with an infrared camera. It is an aggregation of a copter agent and an IRCamera agent. Both agents implement the concrete properties of the entities they represent.

Furthermore, a Communication Agent is responsible for the communication between agents. It implements the underlying communication protocol and network settings.

The use of this multi-agent system is not limited to quadrocopters. It can as well be applied to coordinate a heterogeneous fleet of ground and air assets.

Conclusion

The presented surveillance and reconnaissance system AMFIS with its extensions is constantly under development. Because of its generic nature it forms a rather universal integration platform for new sensors, platforms, interfaces, supporting application programs and customized solutions. The knowledge gained from the participation in various exercises is constantly used to optimize the ergonomics of the work stations and to improve the algorithms for data fusion. The advancement of sensor technology and robotics, increasing processing power, progress in information and network technology provide continuous input for the permanent development and optimization of the AMFIS system.

Today the human is still the most important link in the supervision chain. The operator must evaluate the data which is delivered by the sensors and there from derive the decisions to meet the existing dangers. At last it is a person that bears the responsibility for the resultant action and not the supporting machine.

The above introduced duties of the situation analysis and situation response are so versatile and complicated that further research is inevitable to fully automat them. Up to now humans are still indispensable in their varied roles as head of operations, pilot, analyst, watchman etc. The AMFIS system with its ability to integrate different sensors, sensor platforms and data sources can support and help people with those tasks.

By the use of the mobile AMFIS system in industry, as well as at authorities and organizations like fire brigade, rescue services, and police, the geo and information data bases can be improved decisively. With the gathered reconnaissance information fused or linked to information extracted from different sources the task forces deploying the AMFIS system can be better protected and coordinated and decision making in critical situations can be optimized.

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References

[1] S. Leuchter, T. Partmann, L. Berger, E. J. Blum, and R. Schönbein, "Karlsruhe Generic Agile Ground Station," In: J. Beyerer (ed.), Future Security. 2nd Security Research Conference 2007, 12th - 14th September 2007, Karlsruhe, Germany. Fraunhofer Defense and Security Alliance (pp. 159-162). Karlsruhe, Universitätsverlag.

[2] AERODRONES, France, http://www.aerodrones.com, 2009.

[3] AAI Corporation, USA, http://www.aaicorp.com, 2009.

[4] Defense Technologies, Inc., USA, http://www.dtiweb.net, 2009.

[5] B. Essendorfer and W. Müller, "Interoperable sharing of data with the Coalition Shared Data (CSD) server," North Atlantic Treaty Organization (NATO)/Research and Technology Organization (RTO): C3I in crisis, emergency and consequence management, 2009.

[6] B. Essendorfer, E. Monari, and H. Wanning, "An integrated system for border surveillance," In: R. Ege (ed.), ICONS 2009: The fourth international conference on systems, 1-6 March 2009, Gosier, Guadeloupe/France.

[7] M. Proctor, M. Neale, M. Frandsen, S. Griffith Jr., E. Tirelli, F. Meyer, and K. Verlaenen, "Drools Documentation (V. 4.0.4)," 2008, http://downloads.jboss.com/drools/docs/4.0.4.17825.GA/html_single/index.html

[8] S. J. Russell and P. Norvig, "Artificial Intelligence: A Modern Approach," Prentice Hall, ISBN 9780137903955, 2003.

[9] N. R. Jennings, K. Sycara, and M. Wooldridge, "A roadmap of agent research and development," Journal of Autonomous Agents and Multi-Agent Systems, 1(1), pp. 7–38, ISSN 1387-2532, 1998.

[10] P. Maes, "Agents that reduce work and information overload," Communications of the ACM 37, 7 (July 1994), pp. 30-40, ISSN 0001-0782, 1994.