SDR AND COGNITIVE SYSTEMS SOFTWARE DEFINED RADIO INTEGRATED WITH FLIGHT SAFETY AND MISSION MANAGEMENT INTO IOT SUBSYSTEMS - A CASE STUDY AT AMAZONIAN SCENARIO

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Abstract

Due to the variety of Embedded Systems available on the market, the sensors that can be mounted on these platforms, the inherent risks of autonomous navigation and the various waveforms available for communication, it is necessary to develop an architecture in the context of the Internet of Things (IoT) To facilitate the portability of applications. It is also desirable that this architecture enables the adaptability of the waveform according to the application and the operating context. Thus, considering an embedded system with a Mission Oriented Sensors Array (MOSA) that does the mission management associated with a navigation safety system, the In-Flight Awareness Augmentation System (IFA2S), both transmitting data through an Software Defined Radio, it is desired to develop a IoT architecture that standardizes the data processing and communication of the applications that run on the network, with the waveform control system. One of the advantages of this standardization is the construction and portability of adaptive systems, modifying the SDR waveform and processing the data according to the operating conditions. One way to achieve this standardization is to use the standard middleware architecture employed for waveforms, in conjunction with the structure of a MOSA supported by an IFA2S. Thus, an architecture that integrates a MOSA and an IFA2S to an SDR, all in an IoT context, will be presented, which will promote greater interoperability and portability of hardware and software. The introduction of this article presents the SDR Project of the Ministry of Defense of Brazil. Section 2 presents MOSA and IFA2S. Section 3 describes the interaction of MOSA and IFA2S with RDS within an IoT architecture. Section 4 presents a case study of the IoT architecture proposed in the Amazonian environment. Section 5 presents the final considerations.

1. Introduction

In the past the simplicity of wars allowed victories to be won by the action of only one Armed Forces. Succeeding in missions was more related to the leadership of the chief, to the difference of personnel, to the use of mass and personal bravery than to the judicious coordination of elements of nature and of different organizations. The latest wars and conflicts have revealed that great victories have been achieved through integrated naval, land and air forces. Current conflicts tend to be limited, undeclared, of unpredictable duration, with fluid and diffuse threats.

This context requires military forces capable of working together, with flexibility, versatility and mobility. The planning of a Joint Operation differs from the Singular Operations by the heterogeneity of the employment processes and by the technical-professional peculiarities of the Component Forces. The importance of coordinating and integrating command, control, communication, computing and intelligence structures in order to facilitate surveillance and reconnaissance operations, C 4 IST AR Systems, as well as logistical operations is directly related to success in the operations of the knowledge age [4].

The network-centric warfare (NCW) elevated situational awareness to a level unimaginable ten years ago, for both the individual combatant and the chain of command. It streamlined decision-making, ensuring mission accomplishment, and controlling its execution over time. This made it possible to adapt them in real time to the need for combat. In this interoperability scenario, the need arose for integration of existing Decision Support Systems (C4IST AR).

Therefore, it became necessary to develop communication systems that interacted with heterogeneous systems without major changes in hardware.

In this scenario emerges Software Defined Radio, capable of using various waveforms and cryptographic algorithms, defined through the software, according to the operational scenarios. This has been possible due to advances in several areas such as: analog-to-digital conversion, antennas, digital transmission, digital signal processing, software architecture and device processing capability such as General Purposeprocessor (GPP) [2].

The versatility of RDS allows embedded systems to operate in a variety of conditions and environments. Unmanned Systems are composed by a lot of embedded systems such as: communication, control, navigation, positioning, sensors payload.

The main task of civil and military applications in Unmanned systems is the acquisition of data. However, due to the low data rate and the time requirements of the real time applications, on-board pre-processing is required before its transmission. The MOSA (Mission Oriented Sensor Arrays) [6] is a type of hardware and software architecture for Autonomous Systems that meets these requirements.

To allow the reuse of components (e. g. middleware), to avoid unnecessary processing between the two systems and to enable the development of adaptive applications, it is necessary to integrate the two architectures. With this, one can develop an application that, according to channel conditions, modifies the pre-processing of data.

An on-board human pilot has an important role in maintaining flight safety. For unmanned aircraft, this role is transferred for an on-the-ground operator that do not have the same consciousness. In this work, as it was already proposed in (Rodrigues et al., 2011) and (Mattei, 2013), this ability is called In-flight Awareness (IFA). A human pilot can notice strange smells or vibrations, hear non-habitual noises, evaluate cloud formations, as well as be aware of political borders and the characteristics of the terrain. All those knowledge can be utilized to avoid or mitigate dangerous situations and select the best emergency protocols to use.

When interconnected, the aircraft and MOSA communicate using a Smart Sensor Protocol – SSP to exchange data and decide about the necessary requirements to fulfill the mission. As a result, the specified mission can be classified as: feasible, partially feasible or non-feasible. This phase is performed always when a different MOSA is connected and a new mission is specified. Missions can be adaptive and some configurations can change during the execution of a mission.

Due to the size of the Amazon jungle, its not enogth to have only one or two UAVs monitoring the region of Tabatinga. For the survaillance missions in that region, its necessary to have sensor's deployed over the territory so as to enable continuous activitie monitoring. So, for that end, a wireless network of sound sensor's (WSN [10]) can be deployed in order to aid in the survailance. Combined with the MOSA, this enables a more robus system for the monitoring application.

Structure of this work: Section 2 presents MOSA and IFA2S. Section 3 describes the interaction of MOSA and IFA2S with RDS within an IoT architecture. Section 4 presents a case study of the IoT architecture proposed in the Amazonian environment. Section 5 presents the final considerations.

2. MOSA and IFA2S

The development of the control systems of an unmanned aircraft must follow safety-critical methodologies and be certified under strict standards such as the DO-178C. On the other hand, the mission software can be mission-critical but must not interfere with the safety-critical nature of the entire system. Separating mission systems from control systems helps to achieve this goal. This is the main reason for MOSA. Besides that the MOSA concept makes easier to adapt the aircraft for different missions and the development of the non-safety-critical mission related systems.

The MOSA (Mission Oriented Sensor Arrays) architecture discussed in this article has the potential to provide real-time, ready-to-use information made in embedded data processing machines embarked on Unmanned Vehicle Systems (UVS), reducing the need to send video streams or high resolution images. As a consequence, the minimal communication bandwidth to carry on data in real time reduces significantly. Its main characteristic is the division of the system into two distinct modules: the vehicle module (the safety-critical UVS element) and the MOSA module (the non-critical UVS part). It also includes a set of embedded sensors that provide raw data for specific applications. In addition to hardware, a MOSA system also includes the software required to perform a mission, to communicate with all sensors, and send / receive data to / from the vehicle. Integrated processing reduces the complexity of raw data in ready-to-use information.
The topology of the system may change according to the application. [2]

IFA dimensions are the domains that provide the data input to the decision algorithms. They are: time; airworthiness; flight conditions; and information from the rest of the world. Time is an important dimension as an event has different meanings depending on the moment it occurs. An engine failure situation with the aircraft aligned and close to the runway is quite different when during the flight over a crowded city, for instance. Airworthiness is defined as the safety in the operation of an aircraft in a specific airspace and has some components: aircraft certification (project, simulation, and test), aircraft manufacture (shall reflect project), and maintenance (in accordance with the recommendations from both manufacturer and aeronautical authority). IFA must check airworthiness looking at all possible changes in the aircraft system. Finally, flight conditions refer to both current and future positions of the aircraft along the flight path. IFA must check weather conditions, local air traffic, and overflown terrain. IFA may also recognize a dangerous cloud in the vicinity, another aircraft in a collision path, or a fire in the woods, deciding to change the route, taking control over MOSA, and sending navigation commands directly to the autopilot. [1]

3. IoT Architecture: Integrating MOSA and IFA2S with the SDR Concept

This chapter presents the design to tackle with the data exchange different elements onboard the Unmanned Aerial Vehicle (UAV) and the real-time safety critical operation of In-Flight Awareness Augmentation System (IFA2S) and non-safety critical Mission Oriented System Array (MOSA), respectively to take care of flight safety and mission accomplishment. System architecture design presented makes use of a sdr as the communication interface with either ground stations or others aerial platforms.

The recent advances in onboard systems of Unmanned Aerial Aircraft (UAV) aiming both flight safety, In-Flight Awareness Augmentation System (IFA^{2}S) [1], and mission management, Mission Oriented System Array (MOSA) [2], have created the demand for innovations in the avionics design. In order to be integrated into an aircraft, these subsystems shall comply with many different requirements, such as time constraints, share computational resources, and share the data from several sensors (that may change in time or in different aerial platforms), [3]. In order to enable flexibility, improve data management efficiency as well as make it easier future integrations (either services or hardware), it is necessary to have an integration environment capable of dealing with different tasks, protocols, time constraints, and priorities. Service-Oriented Architecture (SOA) provides this environment using a middleware that enables information interchange between services on a loose coupling, [4] and [5].
Although IFA^{2}S and MOSA have different purposes (flight safety improvement and mission accomplishment efficiency, respectively), most data used by both come from same sensors and they share most of the produced information. Both subsystems act as service providers and consume data from sensors, which are also considered as service providers. The subsystem IFA^{2}S is a safety critical, real-time system designed to semi-automatically (with human supervision) both identify and avoid flight hazards and accidents, from either internal or external causal factors. MOSA is a non-safety critical system designed

to manage the mission accomplishment by decoupling the mission-oriented part of the system from the aircraft control systems (safety-critical).

The IFA^{2}S is a novel autonomous decision-taker onboard the aircraft aiming to improve flight safety. It makes the UAV more conscious (situational awareness increase) about its subsystems conditions (internal health), flight profile, intruders presence (other aircrafts), and surrounding conditions (ground and meteorological), keeping pilots on the ground as system managers. It provides a platform-centric Situational Awareness (SA), instead of relying on human pilots' perceptions. It allows the system to act as soon as it identifies a situation that potentially leads to an accident.

MOSA is an architecture created to improve mission management during the flight, [2]. The integration of MOSA with a set of sensors provides information for specific applications. MOSA also manages mission accomplishment during flight and interfaces with the safety-critical part of the UAV (automatic pilot). In addition to the hardware, a MOSA system also includes the software necessary to carry out a mission, communicate with all sensors, and send/receive data to the aircraft.

The design of the Real-Time Service-Oriented Architecture was accomplish by using Model Based Space System Engineering (MBSSE) using SysML as language for system definition, [6], and the free software TTool, [7]. The MBSSE is the choice for this project since it facilitates application of concurrent engineering in the early phases of the aerospace system life cycle, 0, A, and B, [8]. Phase 0 refers to mission analysis and needs identification. Phase A is a feasibility study containing possible system concepts and assess its technical and programmatic aspects. Phase B establishes a preliminary design definition by confirming the technical solutions using trade-off studies for the selected system concept.

The SOA is responsible for the integration of service providers (e.g. GPS, cameras, accelerometers, gyros, and VOR) and high-level systems, such as IFA^{2}S, MOSA, and the autopilot service providers and data consumers. It is implemented by using a deterministic design (same input always leads to the same output) capable of respecting time constraints in order to carry out common functionalities and data exchange.

The realization of SOA by using a middleware, as may be seen on the architecture depicted by the SysML block diagram in Fig. 1. This software architecture provides the autonomy necessary to make the platform more capable for both managing its mission (non safety-critical service) and avoiding dangerous situations (safety-critical service). The design controls services and provides both resources and priorities necessary for task accomplishment. The SDR serves as the means of communication for exchanging information with ground stations as well others authorized sources, such as another aircraft.

SOA middleware implementation explores communalities between services and make it easier information access. The Resource Manager is the integration interface for sensors, IFA^{2}S, and MOSA and uses standard interface, SSP/SSI (Smart Sensor Protocol/Smart Sensor Interface). MOSA, IFA^{2}S, and Reroute Planner use sensor's data for different purposes and the Resource Manager makes them available. Reroute Planner updates the mission route due to either an emergency or mission update. The Admission Controller supervises the access to both Reroute Planner and Resource Manager giving priority to IFA^{2}S in case of conflict with MOSA. IFA^{2}S is an event based service and have priority over MOSA when either sending orders or requesting data. The direct connection between IFA^{2}S and the flight control surfaces aims emergency landing in the case of autopilot failure.

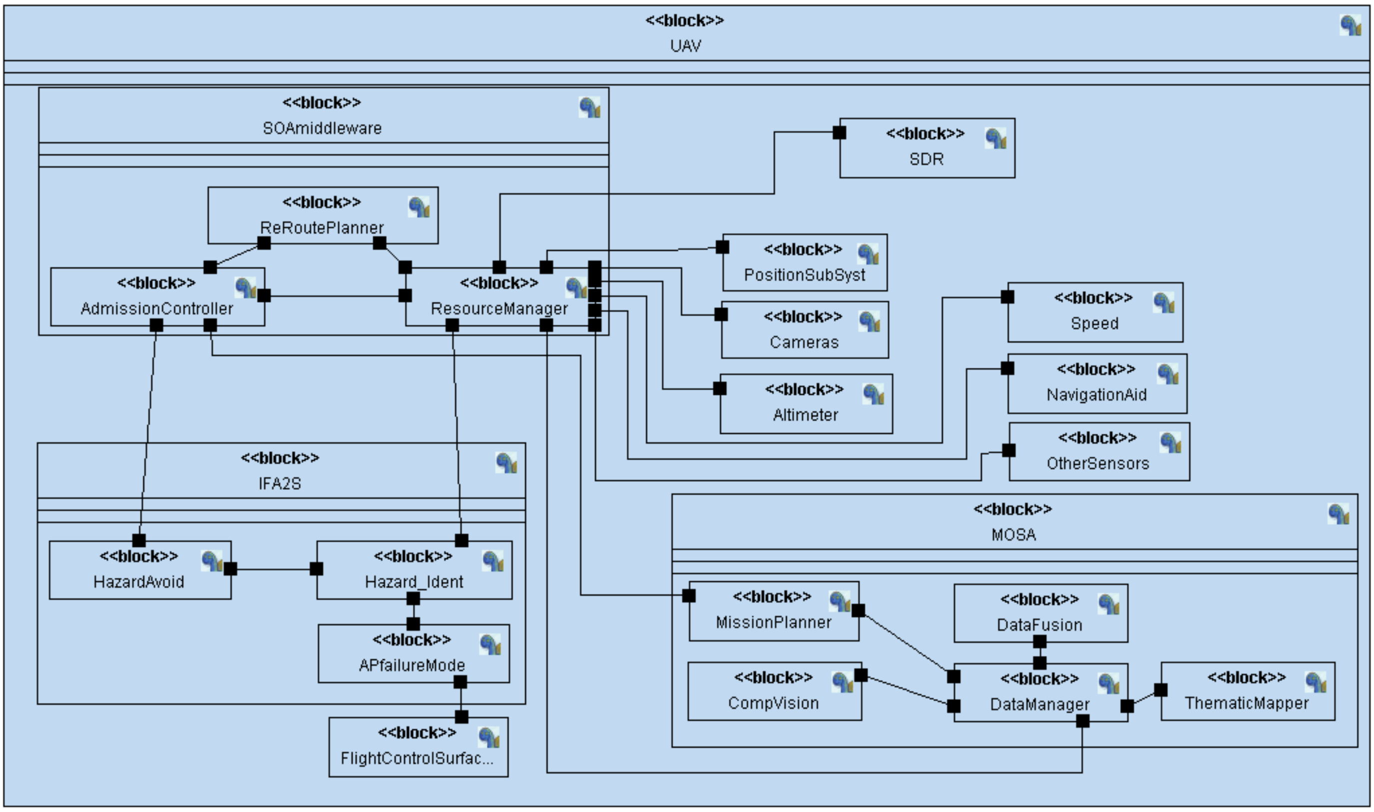

Fig. 1: SOA architecture.

- Wireless Sensor Networking & IoT [9][10]
  - MANET
  - Sensor Network deployment methods
- Integration with MOSA as data collection to C4ISR systems [2]
  - Dive into C4ISR system functionalities/data flow

4. Case Study

To apply the concepts proposed in this paper we choose as a scenery a big brazilian military operation called AMAZONLOG that will occur next november in Tabatinga, Amazon, . The activity in question is inspired by the Logistical Exercise "Capable Logistician - 2015", which was conducted by countries that are part of the United North Atlantic - NATO in 2015 in Hungary, in which a Logistics Base was deployed Multinational, composed of Integrated Multinational Logistics Units (ULMIs).

The goals of this operation are:

- Train the Logistics System to support civilian and military personnel employed in Remote and unassisted regions, as typically occurs in Peacekeeping and Humanitarian Operations;
- To test the Transport Logistics Activity, moving means and supplies to the amazonian region, in operations;
- To test the Logistics Activity of Maintenance, mainly material Cl VI (generators Etc.), Vessels (outboards etc.) and others typically used or severely affected in the amazonian region, in operations;
- To test the Supply Logistics Activity in the amazonian region, in operations.
- Supervise Controlled Products;
- To train for the execution of actions in the field of Humanitarian Logistics;
- Prediction of a Symposium on this theme in Manaus, September 2017;
- Open space for defense companies to show their products in operation Or on display, especially those working with clean energy generation and can thus have dual use and benefit of the amazonian communities; and
- Seek interoperability with armies from bordering countries in the region and other traditional allies, creating multinational responsiveness in the field of logistics.

4.1. Geographic Description – AMAZON

The Amazon Rainforest is one of the largest tropical forests in the world and is located in the North region of South America. It occupies more than 61% of the Brazilian territory. It is a region of rugged relief and rich in biodiversity. It has a fauna that corresponds to 80% of the species in Brazil and a flora that contains 10 to 20% of the vegetal species of the world. The Amazon rivers represent the largest reservoir of freshwater in the world.

"The prediction of loss of wave propagation is the basis for many calculations in the planning of modern wireless communication systems." However, in certain environments of great practical interest, such as in the case of forest environments, this modeling of Loss of propagation presents itself as an extremely complex electromagnetic problem.

This complexity is mainly associated with the fact that the electromagnetic wave transmitted in such environments suffer several effects (attenuation, scattering, absorption, etc.) that depend on several parameters, such as: frequency, antenna height, , Air), atmospheric conditions, non-homogeneity of vegetation, movement of trees due to wind speed, trunk density, leaf density, etc.

Thus, in the sense of modeling signal behavior in forest environments, some studies have been done in order to establish an analytical model that approximates the situations observed in practice. Among the classical approaches that refer to these studies, we can highlight the models of Bertoni [1], Tamir [9], Tewari et al. [10], Kovács et al. [13] and Cavalcante et al. [2].

In addition to these traditional models, one can also highlight the Chinguto model [4], which was recently developed based on field measurements carried out in the Amazon forest. Although there is a relative variety of forest propagation models based on theoretical and / or experimental foundations, it is recognized that they lose efficiency when applied in environments with relatively different characteristics from which they were originally developed.

An attempt to circumvent this problem and adapt the models to a given forest environment is to make a parametric adjustment of its coefficients through the measurement campaign carried out in the environment of interest.

Models following this methodology were denominated, in this work, of "adapted models". Although this class of models present a better performance than the original models, it usually has the deficiency of representing loss of propagation by functions that are monotonically increasing with distance.

Thus, these models can not accurately perform the non-linear mapping of radio signals in forest environments, which are random and non-linear [7]. In this context, this paper proposes a new class of loss prediction models, called "neuro-adapted" models (or "hybrids"). This class consists of a model adapted in parallel with an artificial neural network.

In this approach, the neural network used has the function of compensating the error of the adapted model in relation to the data obtained in the measurement campaign. In this way, the neuro-adapted model will have the capacity to predict the nonlinearities that are intrinsic to the environment and the communication system itself. Thus, with a more efficient prediction of loss of electromagnetic signal propagation in a forest, coverage and some quality of service (QoS) parameters can be predicted more effectively.

<A reference implementation of a MOSA system for automatic mapping of sound sources activity on the ground is presented in this section. These sound sources include internal combustion engines and firearms activity, both related to illegal activities in preservation areas in Brazil.> [2]

Figure 1. MOSA_IFA2S Functional Organization

4.2. Tracking Illegal Activities

As a case study, to apply the concepts presented in this work, we describe in the next sections a MOSA system to monitor and track illegal activities in preservation areas focusing on the location and detection of human presence and medium-sized animals, gunshots and fires. The chosen area is the Brazilian cerrado. As can be seen in Figure 2, this is a type of biome similar to the African savannah, considering the techniques used for aerial monitoring. The very first implementation of a MOSA array in The Ranger Drone Project (Hemav Academics, 2014), was for surveillance of a savannah region.

Figure 2. (left) Brazilian cerrado, (right) African savannah.

The described scenario usually is a poorly mapped area of difficult access, where there may be poaching, incidence of environmental crimes (such as illegal logging and silting of riverbeds), and even endangered species that need to be frequently monitored.

To plan a surveillance mission it is important to know:

1. The types of data describing the phenomena / elements under study;
2. The detection methods of the phenomena / elements that enable the selection of the sensors;
3. The sensors selected.

In the context of this work, we address the following results:

• Map updates to reflect the cartographic reality of the area under monitoring;
• Automatic detection of gunshots, large animals and humans, characterized by sound and thermal emission;
• Animal movement and hunting activity: characterized by animal sounds, animal and human presence detected by thermal images and firearm activity.

4.3 Organization of the Proposed System

The system proposed in this paper consists of a Ground Sensor Network (GSN) integrated with the UAS and the MOSA system.

4.3.1 UAS and the MOSA_IFA2S System

The UAS chosen for this work is the Ararinha (Figueira, 2013), that can be seen in Figure 3 (left). It is an academic test platform for embedded systems used in many academics researches (gisa.icmc.usp.br). It is noteworthy its simplicity of construction, flight characteristics appropriate to this case study and the ease of operation. In addition, this project has autonomous flight capability and it is open source.

Figure 3: The Ararinha (left) and the case study illustration (right).

4.3.2. Ground Sensor Network

In the context of environment monitoring, the acquisition, processing and analysis of sounds are important since they may increase the perception of the phenomena that occur in a given area. Inspired by the *Soundscape*, which is the study of sound in a specific scenario (Pijanowski et al., 2011), embedded audio recorders could be used in multiple ground-based sensor stations to register occurring sounds in the monitored area. These stations can be connected wirelessly to form a Ground Sensor Network (GSN).

The GSN collect environment sounds, pre-process and send them (via a radio modem) to an UAV overflying the area. In the GSN, sound data are processed by Freire's method (Freire, 2014a) and sent to the UAV. This process reduces the volume of data over the limited bandwidth channel between the GSN and the UAV. The sound information, images and GPS coordinates are processed on-board, in the MOSA system.

The following elements, illustrated at Figure 3 (right), compose the system:

1. A GSN composed by microphone arrays and sound processors deployed in the geographical area of interest. Continuous processing of raw sound data results in time stamps, DOA vectors and sound classification;
2. UAV flights over the GSN area collecting the processed data;
3. On-board sound data processing, by the MOSA payload, to detect and locate targets. It is also possible to use algorithms to determine the angle of incidence of the sound and the source motion;
4. On-board processing of aerial thermal imaging for the detection of the presence of large animals (including humans) in the area;
5. On-board merging of the thematic information from the sound sensors with the thematic information obtained from the thermal sensor to extract the following information: presence of animals and humans; detection of poaching activity; detection of routine animal activity.

It must be understood that communication between the GSN and the MOSA payload is not always possible, since the UAV will not always be flying over the GSN. For example, ground sensors can record and store chainsaw sound signatures over a whole week, and these data will be sent to MOSA for analysis only when the UAV flies over the GSN.

4.3.3. Audio Signal Processing

Global time of event occurrence at the source position may also be estimated from local times evaluated by the microphone arrays, and their respective distances to the source. Once this global time is known, along with global position, other local sensors may be queried for information: images from cameras facing that point, at that time (for light sources we approximate local time = global time), or from microphone arrays at corresponding tuples (position, time), where calculation of time takes into account the speed of sound.

The processes in this DFD are:

- P1: FRAME SELECTION: a process that receives a video stream N frames per second and separates periodic frames from the sequence, since there is a huge image overlap among adjacent frames in the time sequence;
- P2: HOT SPOTS DETECTION: this process uses a search window to find clusters of pixels in thermal images that represent elements that have temperatures above a given threshold;
- P3: THERMAL IMAGE GEOREFERENCING: process that correlates elements in the thermal images to coordinates from different sources (GPS, IMU and documents in the geographic database);
- P4: BINARIZATION: process that converts an image into another image with two groups of pixels: cluster of hot spots and the rest of the image;
- P5: IMAGE FEATURES EXTRACTION: process that analyzes binary image produced by P4 and extracts the contour of the cluster of pixels with high temperature;
- P6: THERMAL IMAGE CLASSIFICATION: process that compares the temperature of the element contained in the binary image with a calibration table that contain the temperature function;
- P7: AUDIO PROCESSING: continuous processing of DOA received from the GSN. The DOA, timestamps, and possible source classifications, linked to their respective probabilities, are sent to the global event database in the UAV.
- P8: TARGET POSITIONING: a fusion process for the coordinates of targets calculated from the images and from sound processing;
- P9: DATA FUSION (GLOBAL EVENT BINDING): When local information from various sources could plausibly refer to the same source event, data fusion, or event binding, occurs.

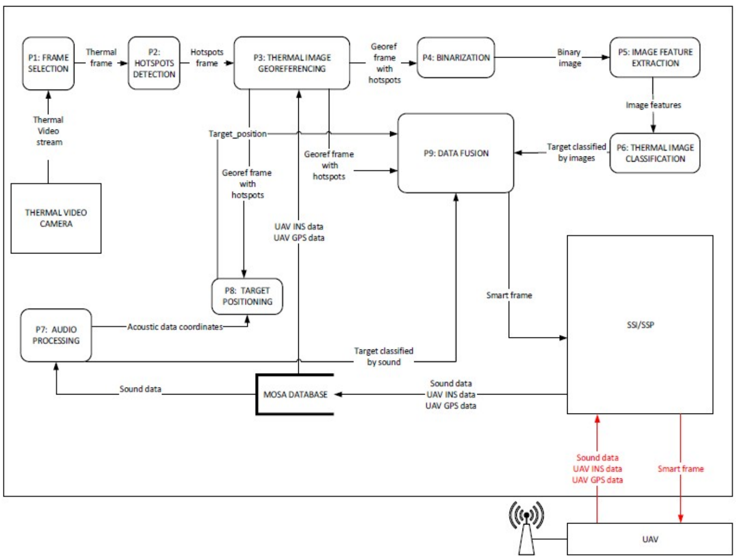

Figure 5. DFD of the MOSA System.

5. Final Considerations

Several IoT Systems using RDS. MOSA and IFA2S are under development at the time of this writing. Most of them are simple systems with proven results from previous developments. The main task in these cases is the automation of some processes and changes in some others in order to comply with the MOSA_IFA2S architecture. On the other hand, the automatic generation of targets is a quite complex system where we can work out most aspects of the MOSA architecture.

This work was structured based on association between the MOSA_IFA2S and a collaborative GSN. The feasibility of using microphones arrangements embedded in UAVs for the detection and localization of sounds was proven in Basiri et al (2012).

In addition to the environmental monitoring it is possible to implement the proposal of this work the following scenarios:

- Soundscape ecology;
- Search and rescue people;
- Disaster Monitoring;
- Urban Surveillance.

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7. References

[1] A. L. P. Mattei, A. M. d. Cunha, L. A. V. Dias, P. C. d. S. Euphrasio, O. Trindade and C. M. Toledo, "IFA2S -- In-flight Awareness Augmentation Systems," in *12th International Conference on Information Technology - New Generations (ITNG)*, Las Vegas, 2015.

[2] N. M. Figueira, I. L. Freire, O. Trindade and E. Simões, "Mission-oriented sensor arrays and UAVs - A case study on environmental monitoring," in *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Toronto, Canada, 2015.

[3] J. d. S. Arantes, M. d. S. Arantes, C. F. M. Toledo, O. T. Júnior and B. C. Williams, "An embedded system architecture based on genetic algorithms for mission and safety planning with UAV," in *Proceedings of the Genetic and Evolutionary Computation Conference*, 2017.

[4] M. Panahi, W. Nie and K.-J. Lin, "The Design of Middleware Support for Real-Time SOA," in *14th IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing*, 2011.

[5] D. Rodrigues, R. d. M. Pires, E. A. Marconato, C. Areias, J. C. Cunha, K. R. C. Branco and M. Vieira, "Service-Oriented Architectures for a Flexible and Safe Use of Unmanned Aerial Vehicles," *IEEE Intelligent Transportation Systems Magazine,* vol. 9.1, pp. 97-109, 2017.

[6] S. Mazzini, E. Tronci, C. Paccagnini and X. Olive, "A Model-Based methodology to support the Space System Engineering (MBSSE)," in *System Design & Simulation Workshop*, Rome, 2010.

[7] L. Apvrille, "TTool," Telecom ParisTech, Campus SophiaTech, 2016. [Online]. Available: http://ttool.telecom-paristech.fr/. [Accessed 26 04 2016].

[8] European Space Agency, "Space project management," ESA Requirements and Standards Division , Noordwijk, 2009.

[10] “Internet of Things: Wireless Sensor Networks”, IEC White paper

[11] “Towards a definition of the Internet of Things (IoT)”, Roberto Minerva, Abyi Biru and Domenico Rotondi (IEEE); Revision 1 – Published 27 MAY 2017