Knowledge-Based Framework: its specification and new related discussions

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Abstract. Unmanned Aerial Vehicle is a common application of critical embedded systems. The heterogeneity prevalent in these vehicles in terms of services for avionics is particularly relevant to the elaboration of multi-application missions. Besides, this heterogeneity in UAV services is often manifested in the form of characteristics such as reliability, security and performance. Different service implementations typically offer different guarantees in terms of these characteristics and in terms of associated costs. Particularly, we explore the notion of Service-Oriented Architecture (SOA) in the context of UAVs as safety-critical embedded systems for the composition of services to fulfil application-specified performance and dependability guarantees. So, we propose a framework for the deployment of these services and their variants. This framework is called Knowledge-Based Framework for Dynamically Changing Applications (KBF) and we specify its services module, discussing all the related issues.

1. Introduction
Unmanned Aerial Vehicle (UAV) is a common application of critical embedded systems. The term UAV was adopted by FAA (Federal Aviation Administration) and by the international academic community to describe systems that include not only the aircraft, but also all the associated elements, like payload, ground control station and communication links. UAVs have been widely used in precision agriculture, remote sensing, mapping, traffic monitoring, air support for oil stations and pipelines, environmental monitoring, and national security. Several papers have been published in this area, demonstrating the feasibility of using these vehicles as important tools to perform those tasks, specially precision agriculture and environmental monitoring [1].

The heterogeneity and constraints of UAVs and the distinct nature of their interactions are challenges for their successful integration into an architecture for a shared exploitation of UAS’s. The heterogeneity prevalent in UAVs in terms of services for avionics is particularly relevant to the elaboration of multi-application missions. Besides, this heterogeneity in UAV services is often manifested in the form of characteristics such as reliability, security and performance. Different service implementations typically offer different guarantees in terms of these characteristics and in terms of associated costs. The initial choice of a particular avionics service implementation can, therefore, become sub-optimal as new applications/services are deployed, needing a careful selection of services to fulfil particular performance and operational guarantees and, subsequently, to avoid compromising the mission.

Therefore, the main goal of this ongoing research is to investigate the degree of heterogeneity present in UAVs in terms of services and propose architectural abstractions for the integration of these service-variants. Particularly, we explore the notion of Service-Oriented Architecture (SOA)
in the context of UAVs as safety-critical embedded systems for the composition of services to fulfil application-specified performance and dependability guarantees. Based on a study of UAS’s and their incumbent services [2], we propose a framework for the deployment of these services and their variants. This framework is called Knowledge-Based Framework for Dynamically Changing Applications (KBF) and we specify its services module, discussing all the related issues.

The rest of this paper is organized as follows. In Section 2, we describe related works in the field of SOA in embedded and safety-critical embedded systems. Section 3 specifies the KBF and its services module. Finally, Section 4 presents our conclusions regarding this paper and also some future prospects for this research.

2. Related works
Many complex embedded systems are coupled with a high-level information system. SOA can provide the integration of low-level embedded system services and high-level information system services. This integration is still an incomplete work, despite the many related works found in the literature [3] [4] [5] [6] [7]. In practice, the use of SOA in embedded systems can provide a lot of benefits, such as decoupling configuration from environment, improvement of reusability and maintainability, higher level of abstraction and interoperability, more interactive interface between devices and information systems, and easy use of resource-hungry services provided by more powerful internet servers.

The increasing use of SOA in critical applications demands for dependable and cost-effective techniques to ensure high security. SOA technology, underpinned by Web services (WS), are widely used for linking suppliers and clients in different sectors such as banking and financial services, transportation, manufacturing, to name a few. However, the problem of engineering secure Web services is a non-trivial task as several studies [8] [9] show that a large number of WS implementations are deployed with security flaws that range from code vulnerability to inadequate use of standards and protocols.

Most work related to UAVs in the literature and military roadmaps show implementations using traditional approaches [10] [11]. However, the USAF’s roadmap [12] suggests the use of SOA in long term. This roadmap indicates that SOA can facilitate the modularization of the system components. Also, it is considered that the adoption and maintenance of standardized interfaces for UAVs can protect clients’ investment in the development of new systems.

Our work has a different focus from the works reviewed, a large portion of which do not address critical systems. For this class of systems, the references on the use of SOA are poor and almost nonexistent. This is due to the specific requirements that standard SOA does not address.

3. KBF: Knowledge Based Framework for Dynamically Changing Applications
KBF was proposed in [13] and is currently under development. KBF extends the capability of a SOA broker’s service discovery, adding knowledge about the application domain. In addition, KBF uses context and monitoring information to select or compose dynamically the best service to perform a specific mission. This selection or composition is based on a set of usage rules and quality attributes, like reliability, security, and performance. Figure 1 illustrates the KBF.

KBF uses a knowledge database to store all information and quality attributes defined by the user and the application. Another key factor is the assembly of reconfigurable matrix, a data structure that correlates the chosen service, its functionality, and the quality attribute to mission procedures.

3.1. Services module
Initially, a service provider develops its service, describes its interface (WSDL, for example), and publishes it in a service registry (UDDI, for example). Shortly after the publication, an automatic
classifier rates the service according to the defined quality attribute (reliability, security and performance). This operation will be repeated for each new service being published.

Regarding to the quality attributes, the reliability of services is ensured using the WS-ReliableMessaging standard [14], responsible for ensuring the messages delivery. The security of services is ensured with the use of the following standards: WS-Security [15], XML Encryption [16], XML Signature [17], and WS-SecurityPolicy [18].

In the KBF’s application domain, the published services use the basic information of the UAV (e.g., maximum cruise altitude, cruise speed, and others). Some of these services are illustrated in Figure 2.

![Figure 1. Knowledge Based Framework for Dynamically Changing Applications (KBF).](image)

![Figure 2. UAV’s basic services.](image)

Usually, static services are invoked only once, when the client is connected to the UAV, in
order to the client gets specific information about the aircraft. Dynamic services may be invoked multiple times during the mission execution, since they can be very important to the mission success.

4. Conclusions
Several papers have been published in this area, demonstrating the feasibility of using UAVs in many different tasks. However, the references on the use of SOA in critical embedded systems and UAVs are poor and almost nonexistent. This is due to the specific requirements that standard SOA does not address. That is the reason we proposed the KBF.

KBF extends the capability of a SOA broker’s service discovery, adding knowledge about the application domain. Moreover, KBF uses context and monitoring information to select or compose dynamically the best service to perform a specific mission.

Currently, the KBF is still in development, because the steps that compose the project continue to be implemented due to the high degree of difficulty. Moreover, most of the steps have been completed successfully. Therefore, the next papers will focus on the integration of KBF modules, making the framework fully operational.

When finished, the main result of this work will be the implementation and validation of KBF, with the establishment of the necessary resources to make the selection and composition of services more flexible and context-oriented, meeting the requirements established by the application in a more simple and efficient way.

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