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Research on Service-oriented UAV Route Planning Component Design

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Abstract. In the field of aviation equipment, with the development of airborne avionics systems towards systemized multi-platform coordination, the service-oriented architecture (SOA) has become an important trend for the development of open avionics system. Based on the idea of SOA, the service-oriented design of the UAV route planning component is proposed in this paper. Firstly, the functions of avionics are abstracted out from generally involved avionics missions with focus on the conception of avionics service. Then the function-directed servitization process of the UAV avionics resources is studied, based on which, a set of callable UAV route planning components are further constructed. The UAV route planning service component set can be flexibly deployed according to different task requirements, which solves the problem of resource-application coupling for the UAV avionics, and provides support for the intelligent and autonomous operation of UAV.

1. Introduction
In the public and civilian fields, with the complex and diversified development of system services, system resources are gradually integrated to achieve integration linkage.[1] By constructing an information system through a collection form of easily replaceable services, in the case of task changes, the configuration can be completed simply by replacing the related services, which means that the changed requirements can be responded to in a very short time. In the field of aviation equipment, from the international perspective, the US military and North Atlantic Treaty Organization are is approaching to apply a service-based architecture for their weapon systems in order to effectively adapt to the ever-changing operational environments and achieve inter-system connectivity.[2] What’s more, as UAV plays an increasingly important role in modern warfare, the avionics system that is used as an intelligent flight support technology for UAVs is becoming more and more complex. However, in traditional UAV avionics systems, the resources and applications are tightly coupled with each other, which results in the low flexibility and scalability and high maintenance cost of existing UAV avionics systems.[3] For realization of interconnection and interoperability of UAV avionics resources, and further truly reliable intelligence and autonomy of UAVs, the research on the servitization of UAV avionics system is highly desired, through which the flexible invocation of service avionics resources can be possible to meet the diversified requirements for UAV to perform various tasks. [4]

In addition, the research on the key technologies of UAV route planning is of great significance for the improvement the autonomy of UAVs.[5] However, for the UAVs in service or development, the
route planning still remains in the “manual planning” or “manual planning + computer aided” mode with a low level of autonomy, in which the decision-making process under complex situations mainly depends on the prior judgment of human experience or switching to the remote control mode. The control of the UAV is mainly realized by the onboard equipment while the task management is performed on the ground control station. This separation of control and management leads to command lag and delay due to data link processing and transmission. In recent years, the drawbacks of this separation of control and management have gradually emerged, and many cases of UAV crashed due to satellite data link corruption. Therefore, it is urgent to systematically develop research on the dynamic route planning method of UAV under the conditions of full consideration of actual environmental constraints to improve the autonomy of drones.

This paper proposes a service-oriented design of the UAV route planning component library. Firstly, the functions of avionics are abstracted out from generally involved avionics missions with focus on the conception of avionics service. Then a set of callable UAV route planning components are further constructed on the basis the function-directed servitization of the UAV avionics resources. The obtained UAV route planning service component library can be flexibly deployed according to different task requirements, which is crucial for the intelligent and autonomous operation of UAV.

2. Service-oriented open avionics system architecture

Based on the service-oriented idea, the development of UAV avionics service component needs to be carried out under an open system framework. Therefore, this paper first introduces the open UAV avionics system architecture, then studies the UAV avionics task decomposition to lay the foundation for abstracting the avionics system function.

2.1. Service-oriented open avionics architecture

The core idea of the open avionics architecture is to adopt a layered concept and establish a generalized and standardized interface according to the open system interface standard, which ensures that the different layers of the system are independent of each other. Therefore in this architecture, the modifications and extensions within certain hierarchy will not affect other levels of the same system, nor affect the corresponding levels of other systems, besides, module replacement of hardware and software is to be feasible, which means the systems can be upgraded and maintained with minimal redesign of existing systems in the future.

The open UAV avionics architecture can be divided into an application layer, a service layer, and a resource layer, as shown in Figure 1. The application layer encapsulates the complete system function, and provides the function of the logic control system to the upper layer user; the service layer provides data management, system configuration and other services, as well as the direct access to the hardware components; the resource layer provides a direct interface between different resources for service layer access. Broadly speaking, the application layer, the service layer, and the resource layer all provide services in the form of software components.

Figure 1. Service-oriented open avionics system architecture for UAV
Then an open UAV avionics service framework is constructed by applying the above open system architecture to the integration of UAV avionics resources. This framework provides basic functional components for the task application layer, as well as a resource-invoking interface. This method can improve the versatility of resources in the design stage, avoid the tight coupling between the previous avionics resources and the aircraft platform, and further realize the flexible management and use of the avionics resources.

![Diagram](image.png)

**Figure 2.** The open UAV avionics service framework

The open UAV avionics service framework is as shown in the figure 2, which describes the interaction and interface relationships among the UAV avionics application software, service components and hardware resources, and how the service components are organized, interacted and communicated.

### 2.2. Task decomposition for UAV avionics system

In fact, the UAV avionics system tasks are determined by operational requirements, therefore, in order to abstract the functions for the service layer of UAV avionics design, it is necessary to decompose the UAV avionics system tasks hierarchically.

The task decomposition needs to follow the following principles:

1. The hierarchy is clear. From the perspective of system, UAV tasks can be divided into cooperation level tasks, platform level tasks and system level tasks. Therefore, UAV task decomposition needs to establish a hierarchical task structure, and can also break down complex tasks into task trees.

2. Relatively independent. Different levels of tasks and different tasks at the same level should not be crossed.

3. The system is complete. Task decomposition should be implemented according to the conception of system integration, and the overall task is regarded as the integration of specific tasks.

In this section, as shows in the Figure 3, a decomposed task tree of the UAV avionics system was created based on the above underlying principle. Firstly, the UAV tasks, namely the root of the tree, was classified into universal avionics tasks and domain avionics tasks according to mission requirements. The universal avionics tasks which support the UAV flight include communication tasks, navigation tasks, flight control tasks, etc.; The domain avionics tasks which support the UAV operation include fire control tasks, mission planning tasks, reconnaissance surveillance tasks, and electronic warfare tasks. Then the universal avionics tasks and domain avionics tasks were refined into several child nodes according to their function requirements respectively. For example, the former can be divided into route planning, sensor load planning, link use planning, task allocation, etc. After that, according to the function of the module algorithm, the granularity of the 2nd generation nodes were again refined to form 3rd generation meta-task nodes. For example, the route planning tasks were divided into search route planning, cruise route planning, tracking route planning, etc. Finally, the service layer functional requirements could be obtained through the meta-task analysis.
3. The servitization of UAV avionics system

3.1. The process of the servitization for UAV avionics system

In the face of increasingly complex tasks, the UAV avionics system should possess dynamic, distributed, and heterogeneous features, which are difficult to port on heterogeneous platforms because of task-specific interfaces. In this section, the servitization model method of avionics system is put forward to shield the realization process and mechanism of various functions in its internal, and the avionics mission requirements abstraction into a service description is encapsulated by a unified structure, so as to achieve the purpose of effective classification and combination of avionics service, and to achieve the goal of resource on-demand and dynamic expansion in avionics system.

The service component mainly undertaking the task demands were divided into two categories: basic service components and domain service components, the domain service components are mainly related to the specific application domain and the basic service component mainly provides common services such as health management, data loading, and log management for the system. The service components design mainly includes three parts: service component interface design, component set design and management scheme. The service component interface design forms a common interface data file for the platform through abstracting and unifying the data formats of different components.

In process of service component set design, in the first place, it is necessary to decouple the organization structure of each software in the system, and abstract the functions and resources of each system. After that, the diversified functions in the system should be further abstracted into service components in the service layer. The service component set can be regarded as a "container", and different services communicate interactively according to the needs of the application to form a larger service. In order to make the design of the service component library more logical, versatile and flexible, layered design pattern was used in this paper to design the service component library. In this process, it mainly completes:

(1) Modular functional processing: isolating the relationship between the specific service components for a specific application through modular processing, so that the cross influence between each component is minimal to keep a high stability of the system.

(2) Standardization processing: after modular processing, it is necessary to establish a unified standard to realize multi-module simulation integration.

By taking the above requirements into consideration, an function-directed servitization process of
the UAV avionics resources (Figure 4) was designed in this section. The integrated servitization process takes the task application as input, and refines the specific system task requirement information through task decomposition, and then the functional description of the service component can be obtained according to the corresponding task-function mapping rules. Finally the service component set was obtained through service combination.

![Figure 4. Process of the servitization for the UAV avionics application](image)

3.2. Componentization design of UAV route planning service

For the existed UAV route planning software development model was unable to cope with the continuous development of combat methods and the increasingly complex battlefield environment, in this section, the componentization of the UAV route planning service was studied on the basis of the analysis of the current situation of route planning software design, which can provide ideas for the further development of the route planning component set. Figure 5 shows the design block diagram of the route planning service component set, which mainly includes three levels: the route planning function component set, the dedicated planning processing component set, and the universal data processing component set.

![Figure 5. Route planning service component library](image)

Route planning function component set is designed to meet the functional requirements of route planning by inductive combat applications, and corresponds to task-oriented specific route planning functions including: search route planning, tracking route planning, attack route planning, and cruise route planning, obstacle avoidance route planning, etc. The above components can be directly called...
by the application layer designer, which is convenient for the application layer designers to quickly perform service combination and packaging to form an application according to the combat task requirements.

Dedicated planning processing component set involving specific route planning algorithm implementation module plays a decomposition for each route planning service component. It mainly includes: heuristic A* algorithm, PH path algorithm, fast extended random number algorithm, co-evolution algorithm, genetic algorithm, Voronoi diagram and so on. [8] These algorithm components here can be called by the service layer developers, helping developers to focus on the evolution of technology, enabling incremental development for services. Service layer developers can form various processing components according to specific application requirements. However, dedicated processing components are shielded from application layer developers because there is no need for application layer developers to understand how design application-oriented processing components. In addition, due to the complexity of the route planning algorithm itself (some algorithms can be considered as a subset of other algorithms taking different advantages and disadvantages in performance, and cannot be used exclusively), the corresponding formed components own different granularity and logical relationships, and can only support calling from service developers who are familiar with the route planning profession.

Universal data processing component set mainly contains the mathematical functions invoked by the route planning processing algorithm, which is the basis for the implementation of the route planning algorithm and can provide support for the upper layer other services (such as data fusion services, sensor management services, etc.).

4. Conclusions
In this paper, a service-oriented design of the UAV route planning component library was realized though task decomposition, function abstracting and the process of the servitization for the UAV avionics system, which provides an effective approach for solving the problem of coupling the avionics resources and applications of UAV. This research could pave the way for intellectualization and autonomization of UAV.

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