Design and Implementation of Secure Control Architecture for Unmanned Aerial Vehicles

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Abstract. This paper describes secure control architecture for UAV control system for multiple operator environments. Multiple access of UAV is necessary because UAV must capture and process various data and UAV's functions become more complex and diverse. From this perspective, UAV control system needs to be secure because new control system will be exposed to multiple operators. To discuss this issue, the paper proposes new control architecture for UAV using RBAC (Roll Based Access Control). Generally, RBAC is applied and contributes to the security of computer systems, thus, we modified RBAC to apply to UAV control system. In this paper, we present how the modified RBAC model can be applied to UAV control systems and implement a prototype UAV control system based on the modified RBAC model.

1 Introduction

Nowadays, there are many researches on UAV (Unmanned Aerial Vehicle) control systems which mainly focus on flight performance of UAV or multiple UAV control by single operator. But this paper approaches come from a slightly different view point. That means the control system makes it possible to do multiple accesses to one UAV to deal function and share information. This system has an advantage of increasing efficiency due to the sharing of limited resources and it has possibilities of distributed processing control. But indiscriminate access and control should not be allowed.

On the other hand, if there are some rules which are named permission regarding access and control of each operator, the system allows control the UAV which is perform more complex functions and information very effectively. RBAC is the most appropriate model for this system but it need to slight variation of the model in order to satisfy the demands of the system. So this paper presents a Modified RBAC model then, the modified model will be implemented to the UAV control system and analyze the results.

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2 Related work

In the field of computer security, RBAC is a useful concept that has been researched for a longtime. Ferraiolo et al. presents concept of national standards for RBAC model [1]. Barkley et al. interpreter RBAC model from a mathematical point of view and represented by the formula. However, this study was limited to the company's intranet [2]. Grzonka et al. research for indoor quad rotor flight control system which is recognizing space by real-time image processing [3]. LihuiGu et al. focus on systems which are flying in formation, and each UAV is designed hierarchically depending on UAV's roles like flight leader or wingman [4]. Although there are many researches about the UAV control system, but most of all researches provide control system for Single-Access. So in this study, the control system will complement from a security point of view. Then we can make batter system by increasing the efficiency of information processing.

3 System Design

3.1 Modified RBAC

Ferraiolo et al. presents The NIST Model for Role-Based Access Control in field of computer security. According to this paper, RBAC is classified into two categories: Hierarchical RBAC, Flat RBAC. Those two RBAC model was distinguished by checking the presence of hierarchical roles in its structure. If there are no hierarchical roles, it will be flat RBAC. In this system, it should be flat RBAC. Because those settings for the following reasons. Suppose there are of two type role: Pilot, Sensor-Monitor. The role of authority is determined by only assigning permissions not by other roles. It should be perform independently to avoid confusion and to increase the efficiency of the authorization. So in this system has no Role Hierarchy.

In this system, it is more efficient to design hierarchical permissions. It makes simple to grant permissions to each role. From this perspective, the existing flat RBAC can be more useful by adding permission hierarchy to flat RBAC. It named Modified RBAC. So let's look at the following figure.

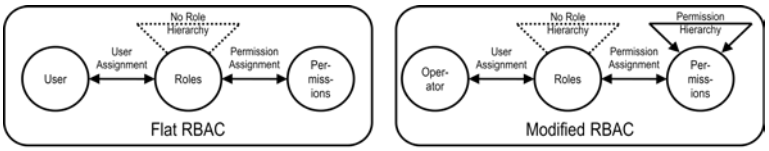

Fig. 1. Flat RBAC and Modified RBAC

As shown in the figure above, the Modified RBAC as a slight variation of an original model structure. The modified RBAC satisfies all needs in this UAV control system and it is also include security and authorization features of the original model.

3.2 Overall Architecture

This system consists of three functional parts. 'Operators' is a group of operators (users) who are connecting to the UAV control server to use the UAV. All operators in the Group should be assigned their role in order to control the UAV at the same time by unspecified number of users. Because it is essential to limit the commanding rights and protect the information from UAV. This process is the same as User assignment in a generic RBAC model. Each role is granted permission (In many cases, a role is granted multiple permissions.) by Role Manager depending on its mission then it can control UAV parts or get information according to their permissions. This step is named Permission assignment in the standard RBAC model and it is key concept because it makes a difference UAV control system from the past.

Modified RBAC is good for in the control system rather than flat RBAC. Because UAV has a lot of information and there are many elements to control. Above all, most permission has association with other permissions.

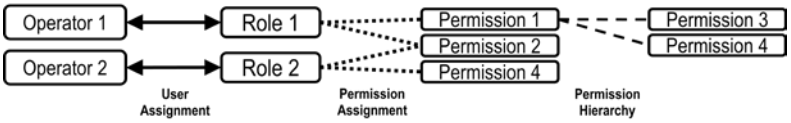

Fig. 4. Apply Modified RBAC model in UAV control system.

The figure above shows that applying Modified RBAC model to the UAV control system by extending the flat RBAC model. So The UAV control system combined with RBAC and the system can absorb the advantages of original RBAC models.

4 Implementation and Experiments

UAV Control Server is a bridge that connects the UAV and client. In order to perform this function Flex, java and C, are used because each language has different strength. Flash media server provides an environment that can stream H.264 video in real-time. Air server3.0 technology gives a solution for constructing TCP/IP server simply that provides multi socket. Modified RBAC is implemented using Air server3.0 language by control command/status packet (JSON). Operator is designed for users to control in real-time. So it needs to access to Air server through TCP/IP for exchanging packets. Also it should display H.264 video through RTMP protocol. In addition, lots of information should be effectively displayed so that GUI (Graphic User Interface) client application is adapt.

In this system, quad rotor is used as UAV. The system's controllability is good and reaction time is fast. Also its flight was stable without any error. Then, the system functionality has been expanded. Operate application is developed to an integrated information control system. It can stream H.264 video in real time and can pilot quad rotor by using joystick on windows7 system or using G-sensor on Android 4.0 Smart phone. It can also control other parts such as Camera tile, Light. HUD-like UI is

adopted to display IMU, GPS (with Google Map) and other sensors. Then multi-access environment is implemented. Operator1 is an Administrator on windows7 system and operator2 is a Camera man on Android 4.0. In this situation operator1 pilots the quad rotor and operator 2 controls camera tilt at the same time. Another situation is applied to the system. It is about granting exclusive right while Operator 2 is controlling camera tilting. Of course, other operators (including Operator 1) should not be able to control the same time.

5 Conclusion and future works

This work presents requirement of a multi-access environment for UAV control system because UAV's functions will become more complex and diverse in the future. So it is need to apply security model which is named RBAC to improve orderly and efficiency of multiple operators. Thus, Modified RBAC was applied to the flight system which has permission hierarchy by extending flat RBAC. The control system needs to pilot UAV without delay while other parts such as light and camera tilting are being controlled by multi operators. For real-time implementation, the system used various programming languages which are specialized in special function. Some physical functions should be granted exclusive rights and there are effort to improve the reliability of the system by optimizing wireless communications and systemizing the packets. Experimental results are successful. However, there is some limitation because this research only targeted the design and implementation of the system. That means this research did not reveal how effective. Leaves this part as following research topics, proof excellence of UAV control system by expanding the system as a sort of cloud UAV control system to process effectively high-precision sensor data.

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