Application of Human Modeling in Multi-crew Cockpit Design

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Abstract. Based on the need of multi-crew cockpit ergonomic design, we set up a parameterized digital human model. By virtually controlling digital human model to devices of cockpit, the potential conflicts in the process of multi-crew coordination were identified. The solutions on device layout were proposed. This method beforehand took human factors into account in the multi-crew cockpit design. Design efficiency was improved greatly.

Keywords: Human modeling, Cockpit design, Crew Coordination.

1 Introduction

The tasks in a multi-crew cockpit not only are completed by individual, but depend more on the coordination of crew. In the process of the coordination, the diversity of crew and their cognition will cause all kinds of conflict, some of which may influence the safety of the airplane. Statistics show that the craft accidents caused by coordination problems make up more than 70% of all the accidents that happened [1]. Most of the current studies on human factor analyze the field of vision in cockpit, the working area, and the arrangement of equipments and the amenity of working position [2-4]. But the study on the conflicts of the multi-crew cockpit is very poor. Therefore, in order to improve the safety of flight and avoid the conflict, in the stage of cockpit concept design, analyzing the working efficiency of the coordination is necessary by using digital human model in multi-crew cockpit.

2 Research on Human Modeling

2.1 Human Statistics

The accuracy of the size of human model is an important factor for assessing working efficiency. Digital human model, which is based on the statistics of anthropometry, is able to solve the accuracy issue. According to digital human body, the virtual working environment is made to stimulate. And the virtual working environment can support the analysis on working efficiency and acquire high credibility [4].

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Human body dimensions include static dimensions and dynamic dimensions. The static dimensions of human model in the paper were according to "Chinese male pilots' measurement" (GJB 4586-2003). 25 measurement statistics relating to working efficiency were used in the paper, including size of limbs e.g. the length of standing body, the length of sitting body, the length of arm and size of some specific point (e.g. the gap between eyes, the gap between hips.). The Dynamic range, by analysis of literature [5-8] in relation to the human body range of motion data, defined the final size of the dynamic range of the human body model, including the dynamic range data of 28 body parts(e.g. the neck, chest, shoulders and elbows, etc.).

2.2 Digital Human Model

The model adopted surface model method, dividing human body to skeleton layer and segment layer. Segment layer is over the skeleton layer. Skeleton layer conforms to human topology structure, and can express information of human body pretty precisely, by adjusting each joint's position to drive the segment layer to change accordingly. So the digital human model is conveniently controlled the movement.

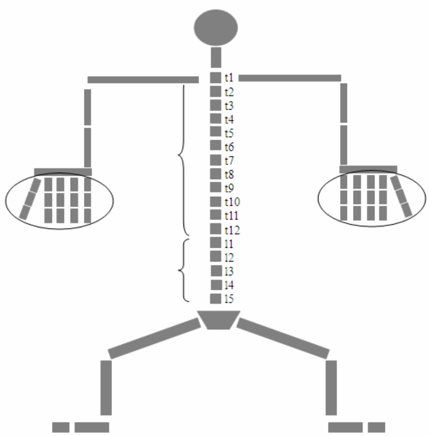

Fig. 1. Human skeleton model

When human skeleton pattern was set up, the paper considered the composition of skeleton and the function of every joint. Human skeleton pattern was divided to 66 segments and 65 joints including 131 freedom of motion. According to the feature of pilot's job and the need of analyzing cockpit, the micro-movement of trunk and hands of the digital human model was needed to simulate. Therefore, the trunk and the hand were divided to 50 segments, which met the real composition of human body. Human skeleton pattern is shown in Fig. 1.

2.3 Posture Control of Human Model

Human model must be set at a specific posture according to working condition in human-machine ergonomic evaluation of cockpit. In order to realize the setting of human model posture, the paper determined the position segments of human model by limiting joints angle which is called positive kinematic technology. Setting human model static posture depended on the angle of the whole body's 65 joints which consists of 131 degrees of freedom. So if the angle of joints was given, human model posture was completely set.

In the process of controlling actual posture, statistics of joint angle is confirmed in two ways: the first is to adopt the special work of pilots and the arrangement of the cockpit, which identify figure of each joint's angle; the second is to acquire Movement Capture System (MCS). For the first method, a lot of angles should be decided by human. Therefore, Vicon system was used for acquiring movement information of the pilots in the paper. The data points of capture are shown in Fig. 2. The acquired figures were amended, and then a figure document including spatial coordinates and main joint changing angle would be produced. The human model posture would be created by reading the figure document.

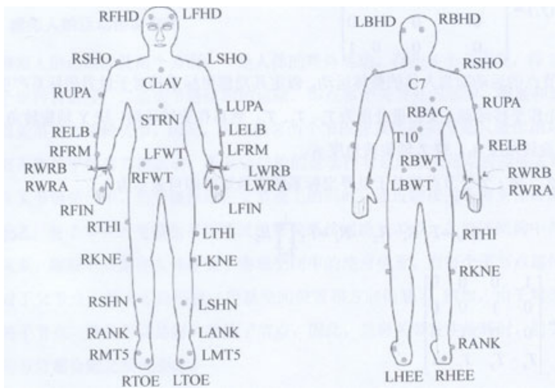

Fig. 2. The capture data points of MCS

3 The Application Research of Human Model

3.1 The Analysis of Human Factor in Multi-crew Cockpit

In the multi-crew cockpit, the coordination of the crew is inevitably needed in the process of completing the task, and makes human factor issues more complex than the single cockpit. So the coordination process is mainly to analyzed and evaluated in ergonomics issues of the multi-crew. Wesley Allan Olson (1999) [9] provided the definition of coordination: coordination can be viewed either as a cooperative process which requires agents to flexibly and adaptively work together towards goal attainment or it may be viewed as a conflict resolution process in which interactive participation is not required-instead the focus is on detecting and resolving conflicting goals and actions. Therefore, the multi-crew coordination is analyzed from two aspects: (1) the coordination process; (2) the conflicts during coordination.

By analyzing multi-crew coordination, Eugene and Grubb (2002) [10] proposed Crew Coordination Model (CCM). In the model, the crew cooperation process will

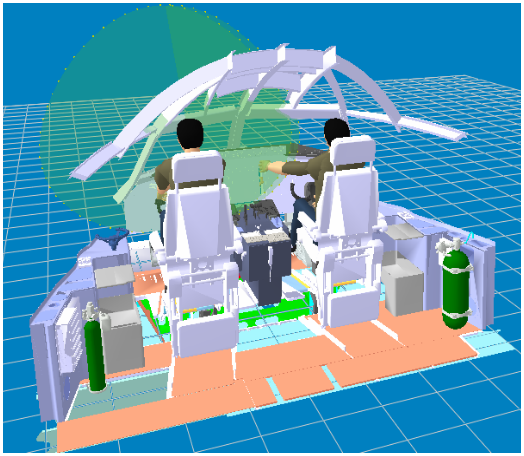

Fig. 3. The analysis of the multi-crew cockpit design

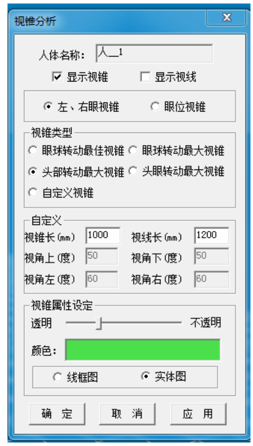

Fig. 4. The analysis interface of the vision

happen in these occasions: inputting when plan changed, informing when situation awareness changed, inputting when state of aircraft changed and supervising when operation operates. In the process of cooperation, the cooperation model can be divided into three categories (take two- pilot cockpit for example): one pilot operates while the other monitors; two monitor interactively; two operate interactively.

By analysis of multi-crew conflict, according to Jehn's (1995) [11] view, the conflict is divided into task conflict, relationship conflict and process conflict. In the multi-crew cockpit, the task conflict refers to the inconsistency of the content of the crew tasks in the cockpit; relationship conflict refers to the incompatible interpersonal relations between crew; process conflict refers to conflicts how to complete the task, especially the conflict of the monitoring and operation in the process of cooperative. Despite the different content of conflicts, the conflicts will affect the crews operating performance, increase the crew workload. The paper mainly studied ergonomics issues of the process conflict, which was analyzed and evaluated by the digital human model.

3.2 The Application Example of Human Model

Take two-person crew for example, the mode of the cooperation model is that one operates and the other monitors. The coordinated task was that the crews needed to reenter the data when situation awareness changed. In the coordination mode, the pilot on the right seat is in charge of entering new flying statistics, operating EICAS and controlling devices on the head plate, while the pilot on the left seat is in charge of supervising outside, the operating results of the pilot on the right seat and changes of the panel.

In the process of multi-crew cockpit design, the process conflict in coordination mode was analyzed and assessed by human model, as shown in Fig. 3. The human model in Fig. 3 is the 50 percentage human model. The assessments included: whether the position and arrangement of the monitor was in the best field of vision, whether the position of controller operated by right-seated pilot was inside the field of vision, whether the result of operation was blocked during the process of operation the right-seated pilot. The analysis interface of the vision is shown in Fig. 4. Analyze the accessibility of right-seated pilot, which was to assess whether the controller was in range of accessibility of the right-seated pilot. The analysis interface of the accessibility is shown in Fig. 5. In the analysis, the posture control and movement control of human model was accomplished by the control interface of human model (Fig. 6).

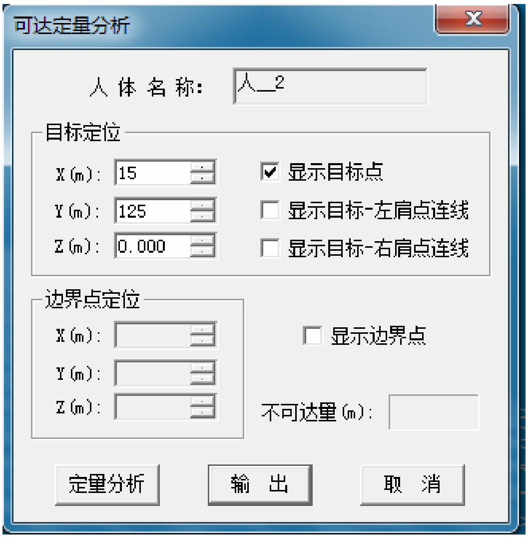

Fig. 5. The analysis interface of the accessibility

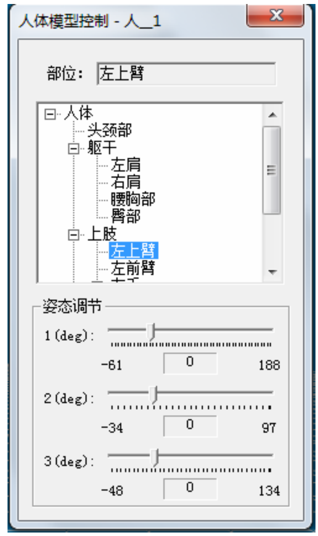

Fig. 6. The control interface of human model

4 Summary

By analyzing human factor of multi-crew design with digital human model, the paper evaluated the process conflict in multi-crew cockpit from the aspects of vision and accessibility. According to the result of evaluation, some advices were given on multi-crew cockpit design. The conflict would be reduced in cockpit, and the safety and efficiency could be increased in multi-crew flight operation.

But the conflicts in multi-crew cockpit are influenced by many factors. The paper just analyzed the process conflict. The influence of task conflict and relation conflict in multi-crew cockpit design needs further researching.

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