# A Development of Platform of 3D Visual Simulation System for Cockpit Design

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Abstract: This paper describes a method for developing a platform for 3D visual simulation system for cockpit design. The system is developed for reducing negative effects for visual sensation of an air-craft pilot on the illumination environment. The visual sensation is the most important sense organs for the air-craft pilot. However, the pilot operates an air-craft in severe situation such as under strong sun light with ultraviolet rays. In order to examine visibility of outside scene or dashboard, we develop a visual simulation system for air-craft cockpit based on Image Based Lighting (IBL) method. First, the degree of visibility of air-craft cockpit is simulated using illumination and reflection model. Second, air-craft and cockpit is made by 3D shape data and reflection properties. Illumination environment is made by omni-directional image which have spatial illumination distribution. Third, we develop the device which imitate a cockpit with have stick, throttle lever and ladder pedal. Then, a subject can experience of air-craft operation. Finally, pilot visual filed is reproduced by 3D computer graphics (CG) based on illumination and reflection model.

***Key words: cockpit design, air-craft, illumination simulation, reflection model, image based lighting***

## 1. Introduction

Recently, a physical experiment is replaced by a numerical experiment in the air-craft design field[1]. The efficiency of the air-craft design improves by a numerical experiment with computer. The numerical experiment of the air-craft is used for a numerical wind tunnel test called Computational Fluid Dynamics (CFD) mainly. In this study, we apply the numerical experiment to visibility design of cockpit of air-craft operation. In the design of the cockpit, it is important to simulate such situation of visual sensation. For example, we have to notice the outbreak of the accident by the adjustment of the pupils of the eyes to increasing or decreasing light. Therefore we implement a visual simulation system which can reproduce of various illumination environments to a flight simulator in the virtual scene. The visibility design of the pilot is important in discussing the safety of air-craft operation. The cockpit is affected by various lights such as direct sunlight or reflected light from ground. The light environment changes by weather or time. The light environment has a serious influence on acquisition of the sight information that is the most important to the pilot. In this case, we have to design to help reduce negative effects of pilot such as to shield pilot's eyes against the sun. Moreover, under the bad weather, the pilot is hard to see the far-off topography and runway. The technique that a CG reproduces the state in the cockpit by simulating the illumination environment inside and outside the cockpit of the air-craft is useful.

Therefore, we develop the cockpit simulation system for designing visual field of pilot based on CG reproduction technique of viewing and illumination environment. In this paper, we describe as follows, (1) perspective calibration method for pilot, (2) construction of 3D model and user interface, (3) design of visual field of pilot in air-craft cockpit based on reflection model and Image Based Lighting (IBL)[2]. Finally, pilot visual field is reproduced by 3D computer graphics (CG).

## 2. Perspective calibration of pilot

There is a problem that is difference of perspective of CG and human visual. Therefore, we calibrate perspective of human visual. In this study, we assume that human visual has camera parameters such as a camera. This reason is that camera lens and human eyes have different focal length. In order to estimate focal length of human eyes, we propose a calibration method of using relation of apparent length and actual length. Figure 1 shows viewing geometry of pilot visual field. In this model, the coordinate on screen is $(x, y)$, image center is $(x_0, y_0)$ and viewing vector is **V**. The viewing vector **V** is described as,

$$\mathbf{V} = \frac{[(x - x_0)/\alpha,\ (y - y_0)/\alpha,\ 1.0]}{\left|[(x - x_0)/\alpha,\ (y - y_0)/\alpha,\ 1.0]\right|}, \tag{1}$$

where the focal length is $\alpha$. The $\alpha$ is a parameter of the perspectives of human visual. Figure 2 shows diagram of calibration system of $\alpha$. We use two standard objects of the same length. The actual length of the object is $L$. The apparent lengths of the objects are $l_A, l_B$. Then, the focal length $\alpha$ is estimated as

$$a = \frac{l_A l_B d}{L(l_A - l_B)}, \tag{2}$$

where $d$ is distance between the objects.

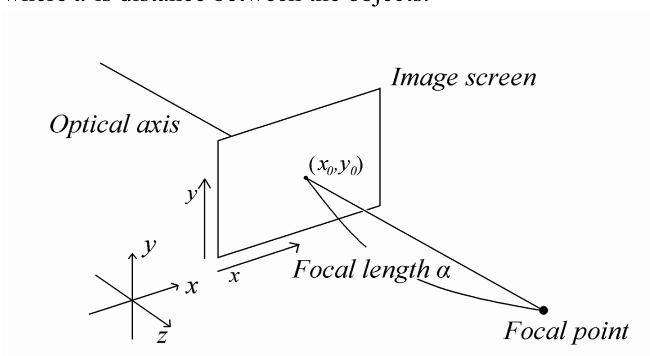

Figure 1. viewing geometry of pilot visual field.

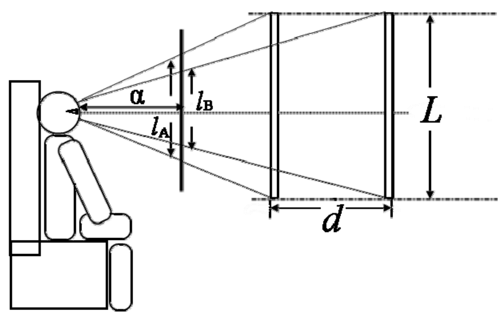

Figure 2. Diagram of focal length calibration system.

## 3. 3D model of air-craft and user interface

An air-craft and its cockpit are constructed in 3D model (Figure 3). The whole air-craft and the cockpit are built in the same 3D model. A physical user interface is developed for air-craft operation. Figure 4 shows a prototype of physical user interface of the air-craft. In this system, the subject (pilot) can operate numerical air-craft model based on aero dynamics.

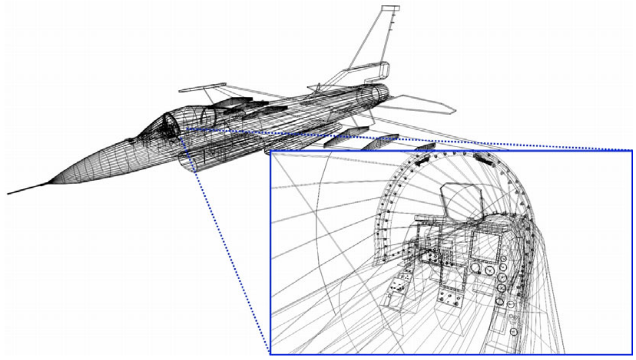

Figure 3. 3D model of the air-craft and its cockpit.

Figure 4. A prototype of physical user interface of air-craft.

## 4. Design of visual field of pilot in air-craft cockpit

### 4.1. Illumination and reflection model

The view from the cockpit calculates as strength of the light to arrive at the human visual system based on reflection models and outside information such as the topography or the sky. Illumination model is built in the scenes. In this study, we assume that there is the spatial distribution of the light source on all directions in the scene. In order to simplify the calculation, we assume that all light sources are parallel beam. The spatial distribution of light source is expressed as illumination direction and intensity. Figure 5 shows illumination and reflection model[3] of visual field of the pilot. We assume that the spatial distribution of light source is on the hemisphere (Figure 5(a)). In this figure, light beam is came from the hemisphere and arrived at visual sensation. The color signal is calculated by reflection model (Figure 5(b)). In this study, the illumination directions are expressed as azimuth angle is $\theta$, and elevation angle is $\varphi$. Then, $\theta$ and $\varphi$ are calculated from lighting direction vector **L**. The element of **L** is described as $\mathbf{L}=[x_s, y_s, z_s]$, and the lighting direction is estimated as follows,

$$\phi = \tan^{-1}\left(\frac{y_s}{x_s^2 + z_s^2}\right), \quad \theta = \tan^{-1}\left(x_s / z_s\right). \tag{3}$$

The spatial distribution may be considered to be a kind of a map with azimuth angle and elevation angle, where all direction in the scene can be described as $0 \leqq \theta \leqq 2\pi$, $0 \leqq \phi \leqq \pi$. If the pilot looks light beam, the viewing direction vector is described as **L**=**V**.

### 4.2. Image rendering

Computer graphics images of the scene are created using the above illumination model. We examined the appearance of the scene. A Z-buffer algorithm was adopted for the image rendering under parallel rays from the light source distribution. The color signal $\mathbf{C}(\theta,\varphi)$ is described as

$$\mathbf{C}(\theta,\varphi) = \sum_j \cos\theta_{ij}(\theta,\varphi)\mathbf{e}(\theta_j,\varphi_j)\,, \tag{4}$$

The light beam that is looked by pilot is attenuated by atmosphere. The light into the visual sensation of the pilot is described based on the Lambert-Beer theory as follows

$$\overline{\mathbf{C}}(\theta,\varphi) = \exp(-kl)\mathbf{C}(\theta,\varphi), \tag{5}$$

where $l$ is distance from the ground. The attenuation of the light with the atmosphere decreases exponentially. The unit of attenuation is dB/m.

## 5. Experimental results

The Visual field of the pilot was simulated using the flight simulation system which we developed in this study. Figure 6 shows image rendering results by proposed system. Figure 7 shows image rendering results in the phenomenon of a glowing sunset. The phenomenon of illumination can be confirmed in these images. Figure 8 shows image rendering results in bad weather condition.

## 6. Conclutions

This paper described a method for developing a platform for 3D visual simulation system for cockpit design. The system was developed for reducing negative effects for visual sensation of an air-craft pilot on the illumination environment. The visual sensation is the most important sense organs for the air-craft pilot. We can obtain the visual stimuli of the pilot in the cockpit and its analysis the influence of the entering outside light under several scenes.

## References


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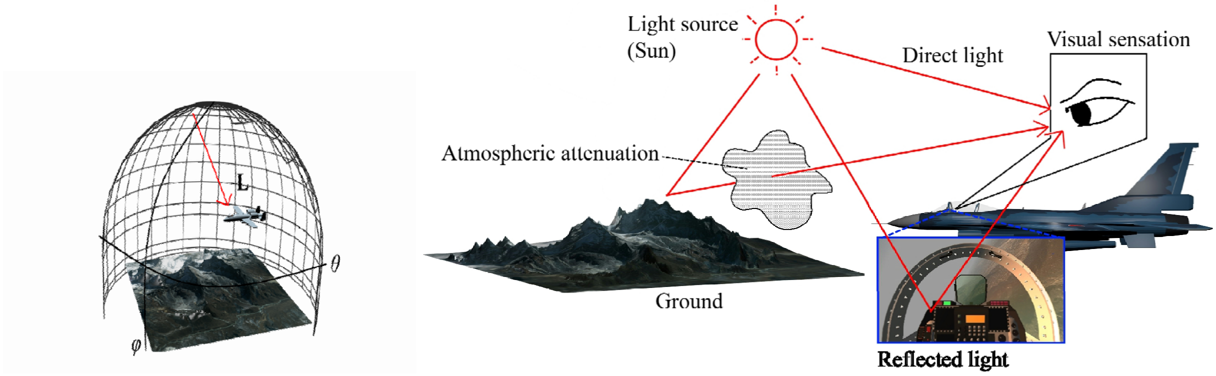


(a) Spatial distribution of light source. (b) Reflection model with atmospheric attenuation.

Figure 5. A diagram of Illumination and reflection model of visual field of pilot.

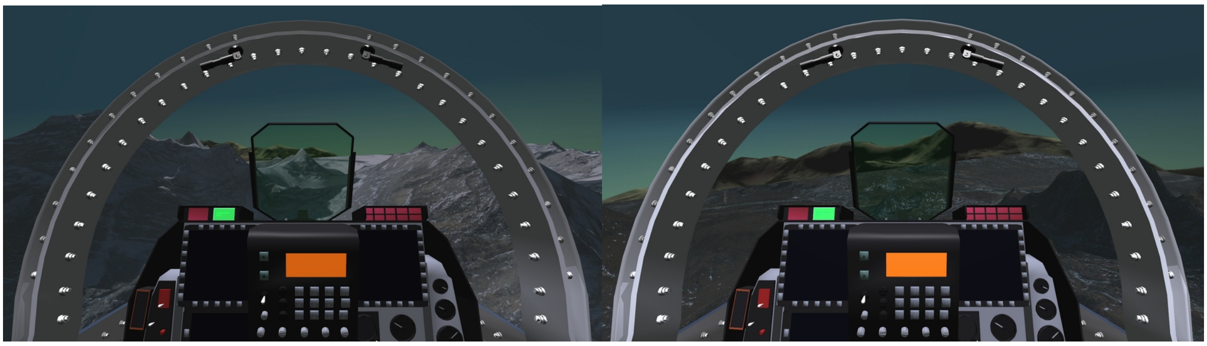

Figure 6. Image rendering results by proposed system

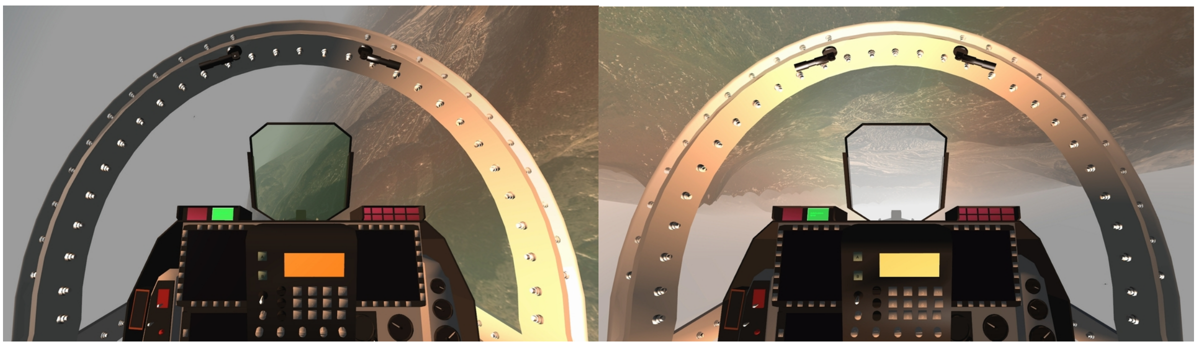

Figure 7. Image rendering results (the pilot view of the phenomenon of a glowing sunset).

Figure 8. Image rendering results (bad weather condition).