Unity3D-based Visual Field Obstruction Analysis and Simulation of Sensor

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Abstract—Due to the limited resources available for spacecraft installation, various influencing factors and constraints need to be considered in order to better accomplish the relevant tasks. The solar panels unfolded will block the field of view of the sensor and will interfere with the normal operation of the sensor. In this paper, we build a virtual sensor working environment based on the unity3D engine to simulate the field of view and the completion of the space station's orbit around the Earth in the virtual environment. And using the STL gridded data from the solar sailplane 3D model, we analyzed how the sensor field of view was obscured by the components and then calculated the shielding rate. Finally, the results are validated in a virtual presentation system. The simulation results validate the feasibility of using Unity3D for a sensor field of view presentation. The method has the advantages of being simple to use, intuitive and good simulation results.

1. INTRODUCTION

With the development of spacecraft payload technology, more and more products are being carried on spacecraft, and spacecraft installation resources are very limited. The unfolded solar panels will block the field of view of the sensor, which will affect the normal operation of the sensor and thus the attitude of the spacecraft\cite{1}. During the spacecraft design phase, it is necessary to take into account the layout orientation of the sensor in a comprehensive manner and to study and analyse the obscuring conditions of the sensor's field of view. In this paper, we use STL meshed data from a three-dimensional model of the solar panel and then calculate the field-of-view shielding rate of the sensor. We translate the solar panel occlusion problem into a problem of judging the range of grid coordinate point positions. This approach solves the problem of inefficient analysis in field-of-view occlusion.

Traditional digital simulation models can only display simulation data in digital or graphical form, which is not intuitive enough and lacks authenticity, and it is difficult for researchers to find problems with simulation objects from the simulation process. In this paper, we use the example of a sensor to build a virtual working environment for a sensor, and to simulate the load field of view and the spacecraft's complete orbit around the Earth in a virtual environment presented by a computer. The process of visualizing the simulation is clearer, more intuitive and more vivid, and the simulation results are easier to understand. It effectively verifies the correctness of the simulation results.

In this paper, realistic three-dimensional simulation models of spacecraft are established, which play a critical role in improving the effectiveness and enhancing the credibility of the simulations. Based on
the existing research results, we propose a visual field simulation system based on the visual development engine Unity3D, which has many advantages in the field of virtual simulation. Unity3D has a rich API interface and two programming languages, C# and JavaScript can be used in Unity3D's application editor. Developers can directly call Unity3D's encapsulated module tools to quickly and easily develop the required functionality.

Reference [2] carried out the design of an intelligent manufacturing simulation system for the automatic production assembly line of bearings and shafts, and conducted a feasible research analysis of the system. The entire process utilizes the viewfinder simulation software Unity3D engine and 3DS Max modeling software. Reference [3] combined SolidWorks, 3DS max and Unity3D development engine as development platform, adopted the idea of modular design, designed and realized a new CNC lathe simulation system. Reference [4] designed a Unity3D-based visualization system for satellite operation. The system provides a real-time display of the full course of a satellite's orbital operations, providing important supplementary decision-making for real-time satellite management. From this, Unity3D engine can greatly reduce the underlying development workload, with low development volume, strong interaction and other features.

2. VIRTUAL PROTOTYPE MODEL

2.1 Spacecraft motion attitude
The geocentric inertial coordinate system does not rotate with the rotation of the Earth. It is a system of right-angle coordinates in space established with the earth's center as its origin. The X-axis in the equatorial plane points to the equinox, the Z-axis points to the Earth's north pole, and the Y-axis, along with the X-axis and Z-axis, form the right-hand coordinate system[5].

![Figure1 geocentric inertial coordinate system](image1.jpg)

The spacecraft's celestial orientation is always pointed toward the earth's center. The established satellite ontology coordinate system is shown in Fig.

![Figure2 Spacecraft ontology coordinate system](image2.jpg)
2.2 Initial model design
The initial model of the spacecraft is built in Solidworks, as shown in Fig. 3.

![SolidWorks model for spacecraft](image1)

After exporting the model in STL format, import 3Ds Max for optimization and format conversion. The optimization of the number of model faces is first performed, with the option of removing the two-sided and uniform normal. Reduce the number of facets in the model by adjusting the parameters such as the facet threshold and the amount of deviation in the panel [6]. The model is then mapped to increase the realism of the spacecraft model and enhance the visual effect of the model. Finally, the model is then adjusted for the axes.

![FBX format model for spacecraft](image2)

2.3 Model Additions
Add a parallel light source to simulate a solar light source in the unity3D scene. Use the HD Earth Texture Map to create a texture ball. Add diffuse mapping, concave mapping, highlight mapping, dark mapping and cloud mapping to the planetary ground shader.

![Earth Mapping Settings in Unity3D](image3)
Set the tilt angle of the earth and add a C# script to make the earth rotate at the same speed. The Earth model is shown below.

![Figure6 Earth model in Unity3D](image)

Import the spacecraft model from the Asset folder. Set the orbital inclination angle of the spacecraft to the orbital altitude. Ideally, the spacecraft attitude angle is \((0^\circ, 0^\circ, 0^\circ)\). Simulate a realistic scenario of a spacecraft flying around a circular orbit by mounting a C# script.

To display the layout scene, add the main interface camera to follow the spacecraft around. Set the solar panels plane to always be perpendicular to the parallel light source, as shown in Fig. 7.

![Figure7 Spacecraft model in Unity3D](image)

3. OCCLUSION ANALYSIS

Spacecraft flight in space is a dynamic process. Sensor fields of view may be obscured by spacecraft components such as solar panels[7].

The STL part format is simple and contains geometric information about the 3D model. The information unit of the triangular slices in the STL file is a triangular slices with a vector direction. The triangular slices are discrete approximations of the three-dimensional model. Using the STL-formatted sailboard model exported from SolidWorks, read the three vertex coordinates of each triangle sheet in ASCII format in turn.

![Figure8 Triangulation of the model in the STL file](image)

In the solar panel occlusion analysis, the field of view of the sensor is viewed as a cone, the center of the sensor is the apex of the field of view cone, half of the tensile angle of the field cone is the
amplitude angle, and the mounting orientation of the sensor is the point of the field cone. The radius of the circle at the base of the cone can be obtained by selecting the appropriate size of the field of view cone height. And use the circular plane at the bottom of the view cone as a projection plane for the solar panel model.

![Field of view cone model](image)

Figure 9 Field of view cone model

Project the three vertex coordinates of the triangular slices onto the plane of the cone bottom circle in the field of view. If the projection point is within the circle at the base of the cone, occlusion has occurred; if there is no projection point within the circle, occlusion has not occurred. After the projection is complete, fill the part enclosed by the projection point inside the circle at the base of the cone; this part is the part of the field of view that is obscured. The solar panel shielding rate is the area of the obscured portion divided by the circular area of the bottom surface of the cone.

The process for the analysis of the sensor solar panel is as follows:
- Determine the field of view orientation of the sensor and build a complete spacecraft model.
- Read the vertex coordinates of the discrete triangular slices in the file.
- Project the vertex coordinates into the plane of the circle at the base of the field cone to determine whether obstruction has occurred.
- If occlusion occurs, fill the portion of the cone surrounded by the projection point in the bottom circle of the cone and calculate the shielding rate.

4. VIRTUAL PRESENTATION SYSTEM

4.1 System requirements analysis

The demonstration system developed in this paper is a mapping of a real spacecraft layout in a virtual environment, so the functionality of the system should correspond to a real space agency model with consistent behavior and characteristics. The ultimate goal of the system is to achieve real time simulation of the sensor field of view. The model is built and presented in the 3D simulation interface. The field of view presentation system design scheme is shown in the Fig. 10.
In the presentation system, the resulting optimized layout is demonstrated in the field of view. The parameters can be modified repeatedly for adjustment and optimization. The system needs to meet the following requirements:

- Establishment of a realistic virtual spacecraft and Earth model and orbiting environment.
- With mouse click, user input, animated presentation and other functions.
- Real-time observation of the camera interface of the sensor device during the orbiting process.

First, build the FBX format model needed for the Unity3D engine and import it into the Asset resources folder to simulate a realistic in-orbit flight environment by inserting functional components, building prefabricated bodies, and mounting C# scripts. Layout designers have a more intuitive sense of the field of view in the presentation system, and can also make iterative adjustments to the parameters of the sensor. Design the mouse click response and visual simulation functions, and design the system's UI interface to facilitate user interaction with the system and make the system interactive. Users use external devices such as mouse, keyboard, etc. to perform various operations and demonstrations of the model on the computer. After entering sensor parameters in the system, it allows the user to change and adjust the parameters again.

By mounting the C# script, the spacecraft can be orbited at a specified orbital altitude and at a specified orbital inclination.

4.2 Field of view presentation system

Setting the field of view of a sensor and related parameters in the field of view presentation system. We manually set the orientation of the observing load on the spacecraft and visualize the field of view of the observing load. By placing the "Camera" in the center of the load, the user can visualize the real-time observation of the sensor in the camera view.
5. SIMULATION VERIFICATION

Based on the built presentation system system, an orbiting environment is built by simulating spacecraft motion, Earth motion, etc. We check whether the field of view of the sensor is obscured by the solar panel in the presentation system.

The spacecraft orbits in near-Earth orbit at an orbital altitude of 400 km and an orbital inclination of 42°. We set the field of view of the sensor to 60°. Set the sensor to 70° azimuth and -50° elevation. We calculate to get a 20.6% shielding rate, as shown in Fig.11.

Figure11 Sensor field of view presentation diagram

Set the sensor to an azimuth angle of -34° and an elevation angle of -40°. The shield rate was calculated to be zero. It was verified in the field-of-view presentation system that there was no solar panel occlusion in the field-of-view of the sensor during the cycle, as shown in Fig.12.

Figure12 Sensor field of view presentation diagram

6. CONCLUSION

In order to address the problem of the sensor field of view being obscured by the solar panel, this paper proposes a visual field simulation system based on the Unity3D engine to simulate the sensor field of view in a virtual environment. The STL meshing model is used to analyze the field of view shielding rate of the sensor. It improves the efficiency and facilitates engineering design compared to previous methods. The simulation results validate the feasibility of using Unity3d for a sensor field of view presentation. The method has the advantage of being simple and intuitive. It can be used as an effective tool for field-of-view occlusion analysis of sensors in spacecraft development.

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