Web-based System for Visualization of Distribution Patterns of Solar Energy and Sky Factor on Outdoor Open Spaces

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1 Introduction

In the viewpoint of saving the energy consumption, sunlight should be distributed fairly to each lot. Thus, it is very useful for city planning to construct the system to evaluate the impact of buildings on received solar irradiance and sunshine duration on outdoor open spaces by visualizing these distribution patterns.

1.1 Index for evaluating the development plan

To evaluate development plans, the selection of the index is significant. Sunshine duration at a house on the winter solstice have been used as the most basic and general index for evaluation of residential environment in Japan, because it is easy to measure and understand the meanings. Solar irradiance is a suitable index for received solar energy. While heating by the sun is useful in winter, summer solar irradiance is considered as more important index for residential environment as urban heating occurs recently. Sky factor has been used for the index of the brightness at a place under the overcast condition. In residential areas in Japan, the building regulation that limits the shadow duration on adjacent lots has implemented to secure sunlight for houses. However, the regulation to keep sunlight and skylight access to public open spaces that has not been implemented is needed for highly dense residential areas.

1.2 Purpose of this Study

Based on such a point of view, this study aims at constructing the simulation system of distribution patterns of solar irradiance, sunshine duration and sky factor with the user-friendly interface and sharing this system with users on the Internet.

2 Simulation System

The characteristics of this simulation system are as follows:

- Web-based user interface
- Accessible system through the Internet
- Sunlight and skylight simulation based on physically accurate equations with considering various sky conditions and the reflection from the surface of objects.

2.1 Web-based user interface

Such an evaluation of impacts of development plans mentioned above has been made by experts who can operate the simulation system on the specific computer. However, in many cases, people interested in the evaluation of the plan can only see the final results of the simulation by the experts. On the other hand, the planner, architects or other users can make access to the system proposed in this paper from computers connected with the Internet. They can use it with changing parameters by themselves to obtain the results of the simulation that meet their demands.

From such a point of view, WWW browser is the best interface for the system. The user-friendly web-based interface should be developed by which users can make the simulation with changing parameters such as the viewpoint, the reflectance of the wall and so on easily. Users can make access to the system from almost all of the computers connected with the Internet and be unconscious of the difference of the operating systems.

2.2 Process of the simulation (Fig. 1)

At first, 3D urban data of the buildings is modeled and inputted to the computer using CAD software. Then the data format is transformed to be read by the software for the simulation using the MACRO language included in the CAD software. In this system, we use VectorWorks to make models of development plans on Windows.

To compute solar irradiance, sunshine duration and sky sfactor and visualize the results of the simulation, we use Radiance on Linux. The merit of using Radiance is that the calculation is done according to the physically accurate equations with considering the sky luminance under various conditions at different time and the reflection from surface of objects.

Some parameters needed for calculation such as the viewpoint, the reflectance of the surface of objects and so on are decided by users on the WWW browser and sent to the program (Fig. 2-5).

Solar Irradiance and sunshine duration are calculated at every measurement point at fixed intervals. The measurement points of each index are set on intersections of the grid overlaid virtually over the development plan. The interval of the grid can be modified by the user. The measured values are summed up from the sunrise to sunset to compute the total amount and distribution patterns of them. As for sky factor, calculation at a time is enough because the illuminance of the sky is regarded as uniform in computing sky factor.

In the process of the simulation, modeling of the sky should be considered. Daylight is a continually varying and unpredictable quantity, so for analysis and comparison purposes, virtual sky distributions that approximate average skies are necessary. The CIE clear sky model is used for calculating solar irradiance and sunshine duration. As for sky factor, the uniform sky luminance is assumed.

Another important factor for the simulation is reflection from the surface of objects. It is considered in computing solar irradiance and reflectance value of the wall and other surfaces can be changed. When calculating sunshine duration and sky factor, Reflection from the objects does not have to be considered.

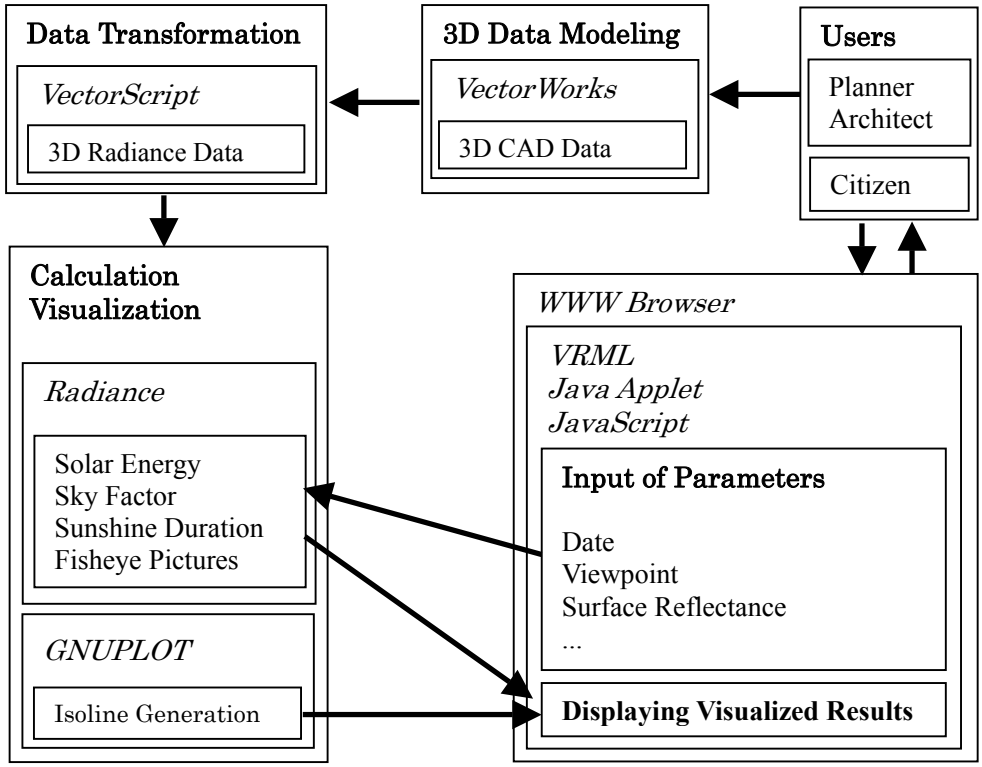

Fig. 1　A schematic diagram of the proposed system

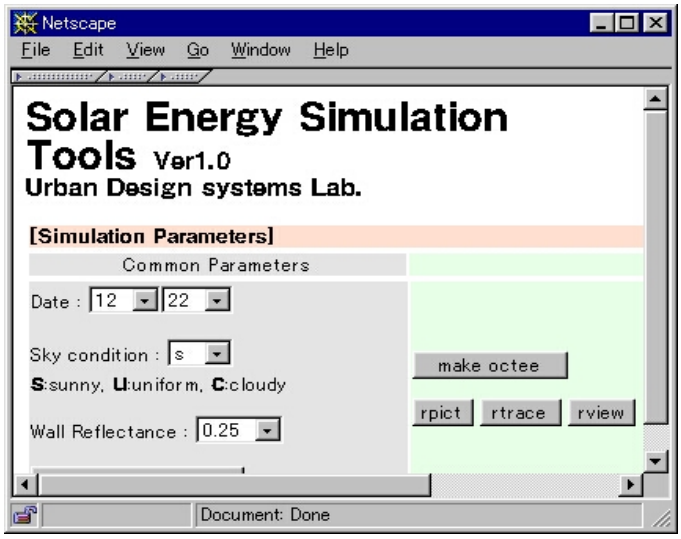

Fig. 2 Setting of common parameters

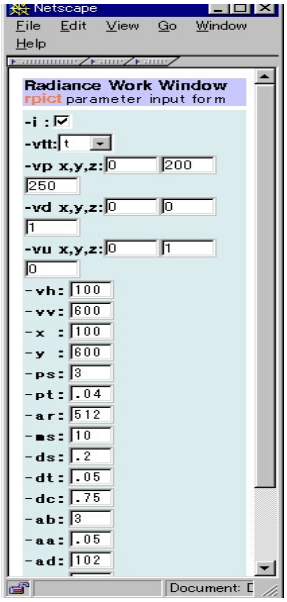

Fig. 3 Detailed setting of parameters of a command

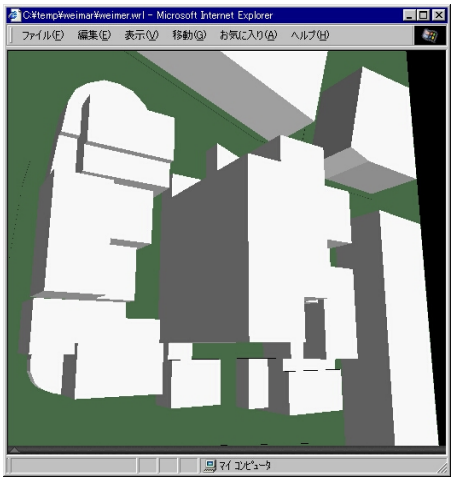

Fig. 4 Setting of the viewpoint by handling VRML 3D model

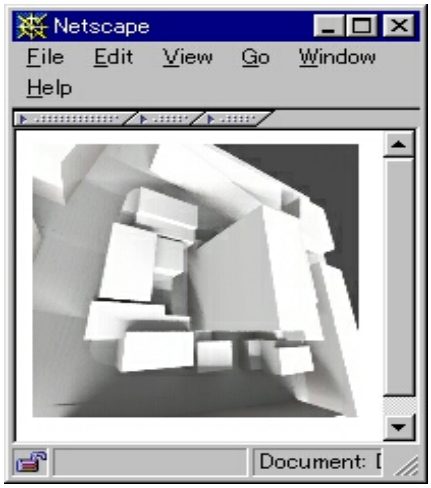

Fig. 5 Verification of the viewpoint

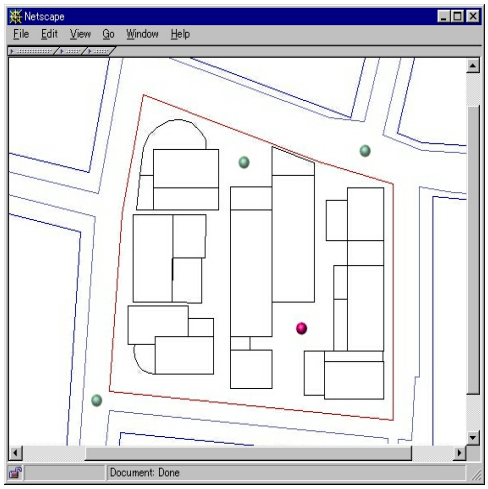

Fig. 6 A development plan with measurement points of Fisheye Pictures

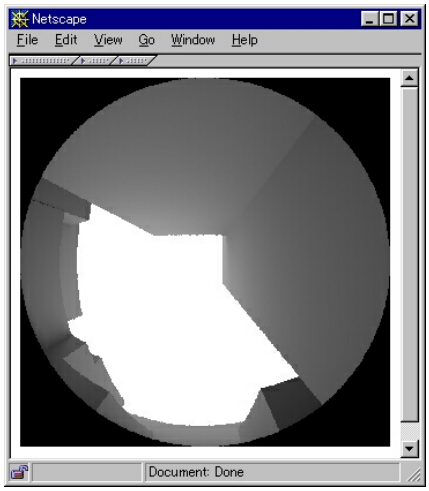

Fig. 7 Fisheye Picture

Finally, The distribution patterns of solar irradiance, sunshine duration and sky factor on outdoor open spaces around buildings can be displayed with or without gradation. As for sky factor, fisheye pictures at some measurement points in the development area can be displayed also (Fig. 6, 7).

3 example of analysis of development plans

The impact of the development plans are analyzed and evaluated using this system. Solar irradiance, sunshine duration and sky factor are calculated at the surface of the buildings and open spaces every 10 minutes from 8 to 16 on the winter solstice. The values of these indices are expressed as the ratio to those calculated under the condition with no buildings.

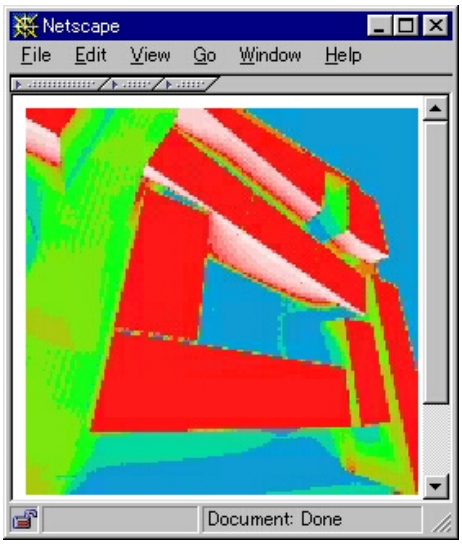

Fig. 8 Distribution of solar irradiance (A)

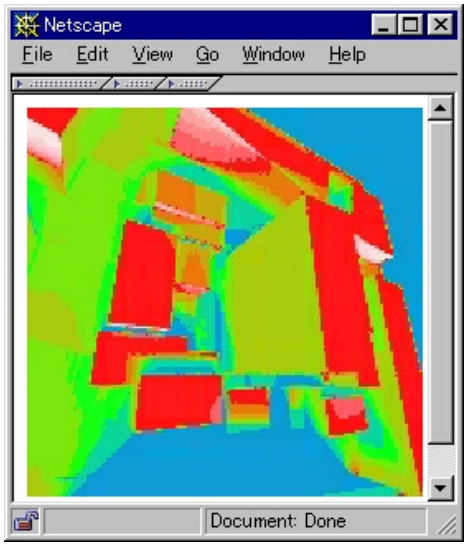

Fig. 9 Distribution of solar irradiance (B)

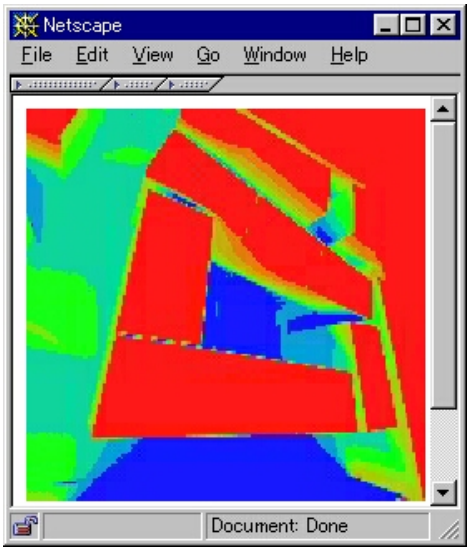

Fig. 10 Distribution of sunshine duration (A)

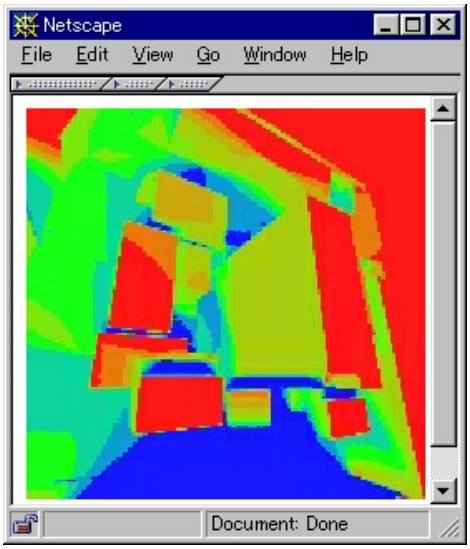

Fig. 11 Distribution of sunshine duration (B)

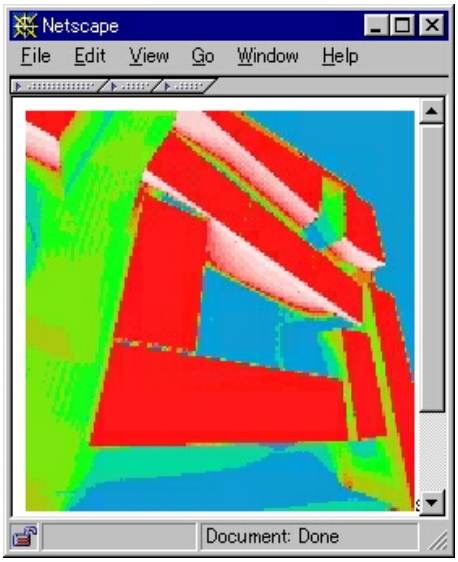

Fig. 12 Distribution of sky factor (A)

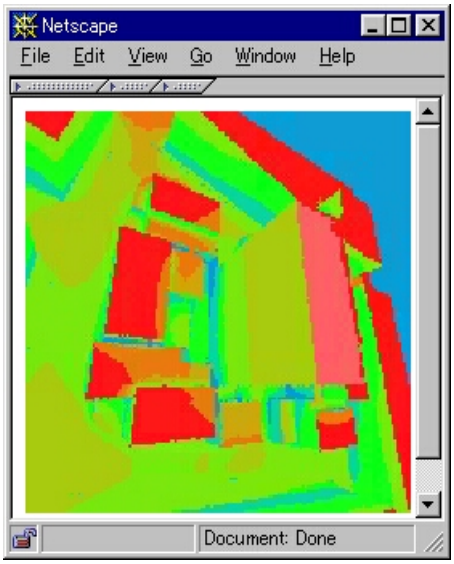

Fig. 13 Distribution of sky factor (B)

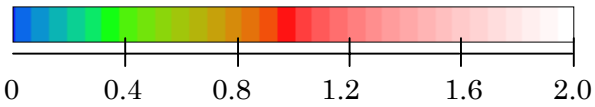

Fig.8 – 13 show the examples of the results of the simulation. In this project, two different types of the development plan are compared. A 4-story building with an inner court is proposed in one plan (A) and a 6-story building is located at the middle of the block in another plan (B). These results shows that solar energy and sunshine duration are hardly secured in this small inner court and that the brightness there under the overcast condition is obtained to some extent.

4 Conclusion

This web-based simulation system can be useful for visualizing the sunlight and skylight conditions on outdoor open spaces and the surface of the buildings to evaluate development plans objectively. Users can make access to the system from almost all of the computers connected with the Internet and modify parameters by themselves to get desirable results. Further improvement of the user interface is necessary using more advanced technology of CGI, Java and JavaScript.

References

[1] Kuwata H, 1995. *A Tool for Evaluating the Urban Outdoor Environment Using Fisheye Pictures*, 6th International Conference on Computing in Civil and Building Engineering pp.845-850
[2] Shinozaki M., Kuwata H., 1999. *An Analysis of Distribution Patterns of Sunlight Energy on Urban Open Space*, The 5th International Congress of Asian Planning Schools Association pp.443-451