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Technical Domain / Task Number 2 Simulation

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Development of a navigational aid simulator

# Summary

It is an obvious fact that the visibility of navigational aids or sea marks such as lighthouses, beacons, buoys are very important for naval navigation. Although sea marks need to be visible across great distances, distance is in fact one of the main factors impacting their visibility. Hence, the design of sea marks is made in accordance with their target range. Physically, this range is mainly limited by two factors: Earth's curvature and the attenuation of light. Also, in order to be sufficiently visible in a pitch dark environment, the minimum illuminance of the light must be at least 2x10-7 lux. However, weather conditions and other light interference such as street lamps from surrounding areas require sea marks to have a stronger brightness in many cases. While it is possible to make very bright lighthouses, the impact on the surrounding and especially the residential areas is also to be taken into account. Ultimately, a well-balanced combination of brightness, colour, characteristic and number of lights must be found to guide ships safely around our coasts.

In this paper, we explain how by using a generic virtual reality software, we developed the first fundamental functionalities required to make navigational aids simulation. We also discuss various points that must be validated, improved or added in the future.

## Purpose of the document

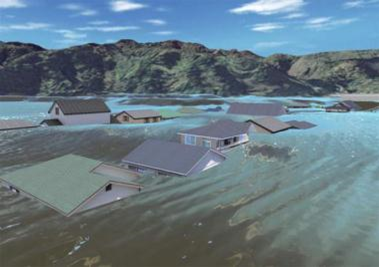
Presentation and introduction of a new navigational aids simulator developed in collaboration by Nippon Koki Kogyo Co.,Ltd. and Forum8 Co.,Ltd..

# Background

In an atmosphere of 0.74 transmittance and pitch dark conditions, the visibility range of a sea mark is defined by the distance from which the illuminance reaches 2x10-7 lux. Physical models exist that can determine this distance based on the measurement of light, but the actual visibility range is often less because of various atmospheric conditions and bright surroundings that might prevent distinguishing the sea marks from other lights. In order to study the influence of the environment on the visibility and vice-versa - the impact of the light on the environment, we started developing a new navigational aids simulator based on the existing virtual reality software, UC-win/Road.

## About UC-win/Road

Since 1999, Forum8 Co.,Ltd. has been developing a multipurpose 3D virtual reality software that is able to use digital terrain maps as a base to develop a detailed 3D environment. Both the natural environment and urban infrastructure can be virtually modelled in order to create several types of simulations such as landscape, traffic, driving, flood, acoustic and wind analysis.

1. Simulation examples using UC-win/Road (left: urban planning, right: tsunami)

Before this development, UC-win/Road allowed users to define several light sources per 3D object and use light beam pattern data for vehicles. While it was a powerful tool to visualise lighting and simulate realistic driving conditions, the physical model was not accurate enough to simulate the visibility of lights over long distances. With its extensive experience and long history of lamp manufacture for aid in navigation, Nippon Koki Kogyo Co.,Ltd. paved the way for UC-win/Road's expansion to include navigational aids simulation.



1. Lighting simulation using previous features of UC-win/Road.

## Implementation of the representation of light sources

Several new concepts and features had to be added as base features for the simulation of lights for aid in navigation.

1. Input data of a lighthouse lamp

In order to represent the lamp of a lighthouse, the data listed above serves as input for the simulation. It is mainly the brightness map, colour, masks and other characteristics. The following tables show the structure of such data.

1. Brightness data

|  |  |
| --- | --- |
| Item | Data format description |
| Colour | (x,y) coordinates of the CIE colour space |
| Horizontal brightness data information | Number of measured points  Minimum and maximum angular positions |
| Vertical brightness data information | Number of measured points  Minimum and maximum angular positions |
| Horizontal brightness data | Candela of each measured point |
| Vertical brightness data | Candela of each measured point where the horizontal brightness is at maximum and minimum |

1. Filter/mask data

|  |  |
| --- | --- |
| Item | Data format description |
| Horizontal mask data information | Number of definition points  Minimum and maximum angular positions |
| Horizontal transparency data | Transparency (0<n<1) of each definition point |
| Filter colour data | Filter color (x,y) coordinates in the CIE colour space |

1. Light characteristic

|  |  |
| --- | --- |
| Item | Data format description |
| Type of pattern | One of the following value:  Const (for fixed lights), VaryByTime (for other lights) |
| Period | Period (duration) of the pattern |
| Rotation direction | One of the following values:  None, Clockwise, Counter Clockwise |
| Pattern data information | Number of definition points |
| Pattern data | Brightness factor at each definition point |

1. Input data of as search light

The following data serves as input for simple search lights

1. Search light data

|  |  |
| --- | --- |
| Item | Data format description |
| Brightness | Maximum brightness value at the centre of the beam |
| Half-power beamwidth | Angle where the power of the light is half the power of the centre. |
| Colour | Colour (x,y) coordinates in the CIE colour space |

1. Light attenuation function

The default model that was implemented takes in account the value of the transmittance of the atmosphere and follows the following formula. It is also possible to input an arbitrary expression.

Standard attenuation function:

Where:

**E** = illuminance in Lux

**I** = luminous intensity in Candela.

**τ**= Air transmittance

**1NM** = length of one nautical mile (1852m)

The calculation of the illuminance is carried out on the GPU of the computer for each pixels of the rendered image.

1. Representation of the light beam

As the light goes through space, it reflects on small particles of dust or water and makes the beam visible to the eye. The more particles exist the more the beam becomes visible. In our model, we take the transmittance value of the air as input in order to approximate the amount of light reflected during its travel. We consider the light reflects equally in all directions.



1. Light beam representation
2. Light source representation

In order to represent the effect of the light arriving directly to the observer, we simulate a receiving surface placed just in front of the eye of the observer and calculate the light dispersion on this surface in a similar manner as for the representation of the light beam. Using this technique we can represent the glowing effect of the light that we can see when looking directly at the source.

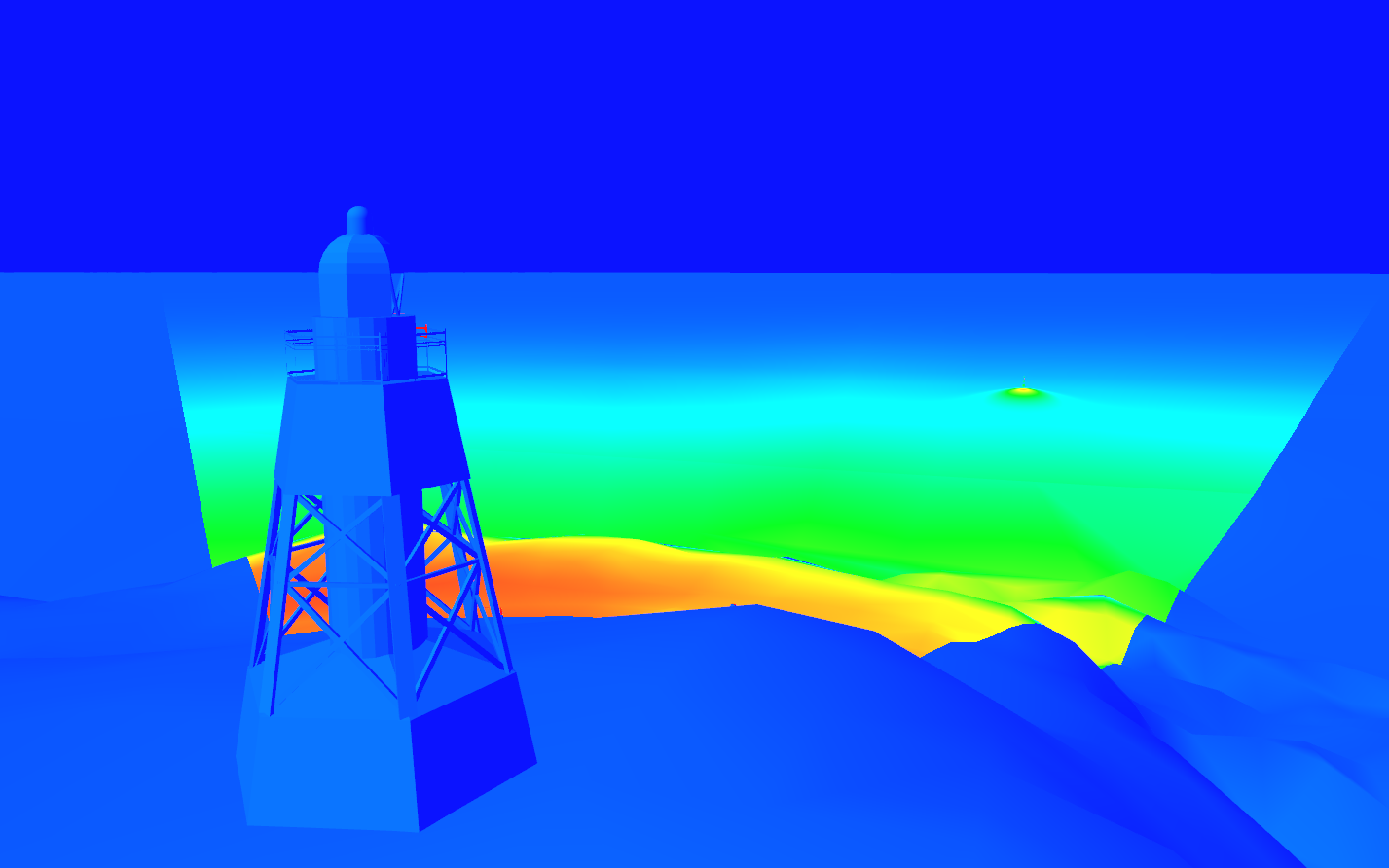


1. Light source representation

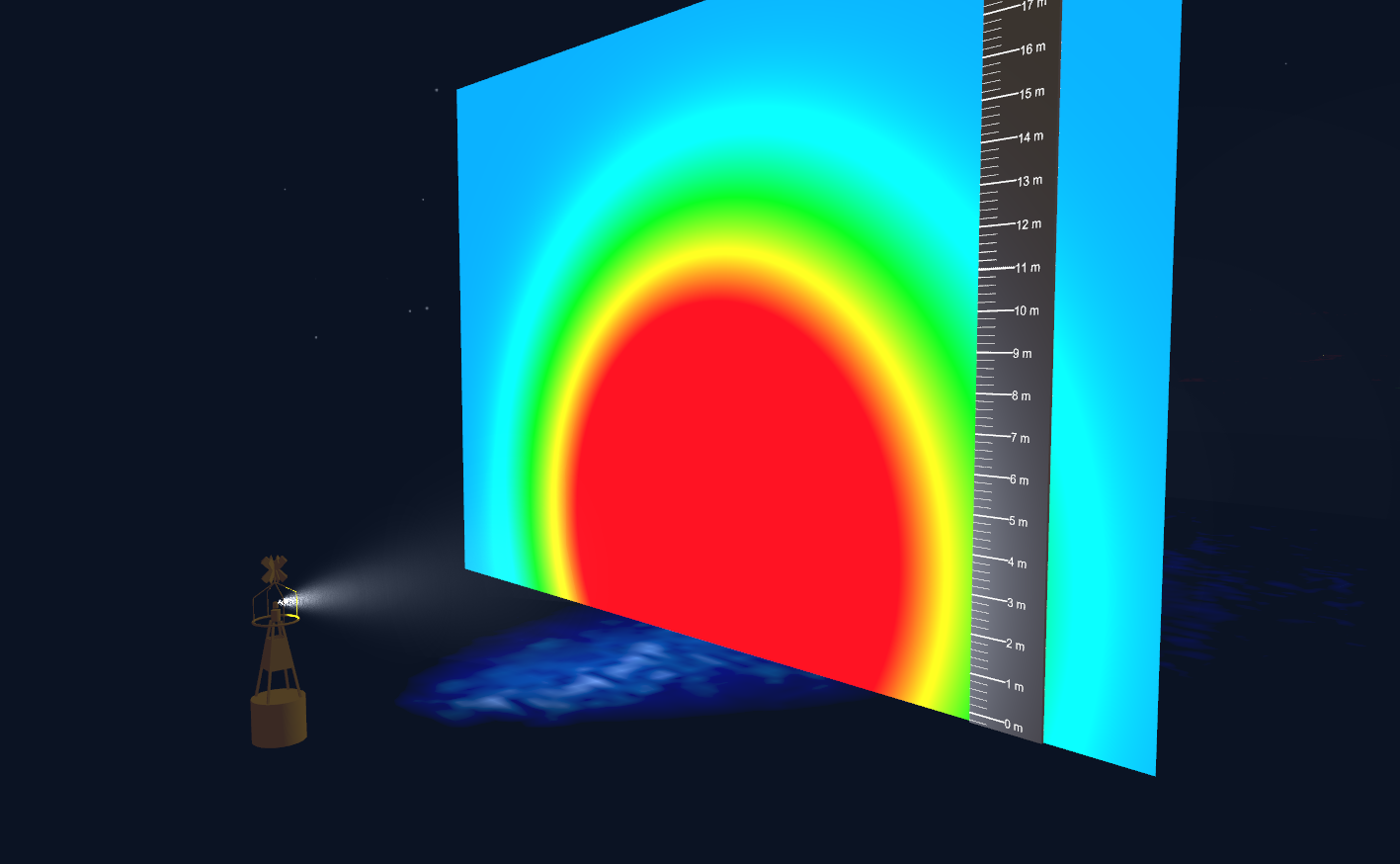
1. Light source seen from long (left) and short (right) distances
2. Normalisation and screen output

Because the result of the calculation is a physical value in Lux it is necessary to normalise it before the conversion to RGB. We use the Weber–Fechner law and Stevens' power law in order to normalise the Lux value, then the display gamma in order to convert it to the final RGB values. The tool also permits to display the illuminance value in a gradient contour style.



1. Gradient display
2. Other tools

As a way to visualise the illuminance, it is also possible to place any measurement (receiving) plan by a simple click as well as a ruler showing the height above the sea level.



1. Measurement plan and altitude ruler

# Discussion

## Validation

The tool has just been developed and while it uses physical concepts for the lighting simulation we would like to go through the following steps of validation.

1. Visibility distance

Compare simulation results with actual results to refine the model and the simulation parameters.

1. Visibility depending on the height of the view point above the sea level

Check the visibility distance depending on the height of the view point and compare with actual results.

1. Visibility in bright surrounding environments

Model an environment where navigational aids are closed to a bright urban area and compare visibility results in the simulation and in a real environment.

## Future developments

In order to improve the versatility of the tool and the accuracy of the simulation we plan to implement the following features in the future.

1. Material parameters

For a better representation of the different objects receiving the light a better description of the material must be used. In the current tool only a diffuse reflection is simulated but using reflection characteristic data an accurate representation of the objects such as mirrors or metallic surfaces can be achieved.

1. Secondary light source

As an extension of the improved material representation it would be possible to represent the light reflected by objects such as mirrors, windows, solar panels…

1. Shadows

Object casting shadows are not taken in account in the current simulation tool. An improvement of the rendering engine would allow to check if the light is occulted by other objects. (Occulting objects are already taken in account in the representation of the light source, paragraph 2.2-5).

1. Atmosphere model

At the moment the transmittance of the atmosphere is taken in account when representing the beam of the light and in the attenuation of the light. However the representation of fog is still very simplistic and does not follow a physical approach. Improving the model of the atmosphere would allow a good representation of the fog and brightness of the sky depending on the hour of the day.

# References

1. 灯台：海上標識と信号 /坪内紀幸,森勝三,稲垣襄二著
2. 照明工学 / 一般社団法人照明学会 編 １章
3. OpenGL 4.0 Shading Language Cookbook / David Wolff著
4. 視覚特性と画像の性質 [http://www.aist-nara.ac.jp/~manabe/09SIP2-haihu-2.pdf]
5. まつ毛の回折光を考慮したグレアの高速表示 /柿本正憲 松岡 薫 西田友是 苗村 健 原島 博[http://nae-lab.org/~kaki/paper/VCWS2003/Kakimoto2003EyelashGlare.pdf]

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
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