ADVANCES IN FOREST FIRE RESEARCH

2022

Edited by
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A study on the 3D Unreal Engine visualization technology of WFDS Plot3Ddata for the development of a virtual forest fire training simulator

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Keywords

VR (Virtual Reality), 3D Visualization, Unreal Engine, WFDS, Virtual Training

Abstract

The expression of flames and smoke in the existing VR engine is an image-based fake flame and smoke that does not have a physics analysis process. In this study, after converting the operation data analyzed in the wildland-urban interface fire dynamics simulator (WFDS) into an FGA file containing vectors and physical quantities at intervals of N seconds, the 3D Unreal engine developed an expression technology for values and vectors movement for smoke and heat. In addition, a visualization program was developed for the movement of flames and smoke according to wind speed and direction in the Unreal engine using a physics analysis model. As a result, the grid data values of the SMV and the UE virtual reality engine showed a 100% coincidence rate, and the visual difference between heat and smoke showed similarity through contrast ratio and lighting effect. The fire visualization expression of the 3D object value of combustibles according to the reduction in mass due to combustion was expressed by automatically updating the 3D object combustible material per unit time through material rendering for each combustion stage.

1. Introduction

The deaths and injuries of firefighters due to forest fires occur continuously around the world every year. In order to effectively suppress forest fires and prevent safety accidents for firefighters, forest fire-related organizations are operating forest fire education programs. Due to the nature of wildfires, firefighters must improve their ability to respond to each forest fire situation for effective suppression at the fire site based on their knowledge of the forest fire environment. However, there are many differences from the actual forest fire suppression environment in theoretical learning and training on the nature of wildfires on a laboratory scale. Recently, building fire education and training simulators using 3D virtual reality technology and game-type forest fire suppression training programs are being developed. Here, the expression of flame and smoke, which are the main components of fire, is used by a training instructor to create each fire situation by adding a simple image as a fire icon. This does not apply chemical species and physical analysis. Therefore, this study proposes to develop a 3D virtual reality education and training authoring tool based on chemical species and physics analysis for more realistic forest fire field experience and effective education by firefighters. This study proposes a technology and method to visualize forest fire flames and smoke through physical analysis in 3D virtual reality UE using the temperature and smoke results analyzed in WFDS.

2. Methods

2.1. WFDS analysis

WFDS was developed to analyze fire spread in open spaces adjacent to forests by applying topography and vegetation fuel by extending FDS developed for structural fire analysis. In this study, the X-axis, Y-axis, and Z-axis were set to 200 m, 160 m, and 50 m, respectively, and the cell spacing was set to 2 m, resulting in a total of 200,000 cells were configured as 100 cells on the X-axis, 80 cells on the Y-axis, and 25 cells on the Z-axis.

For forest fuel, a combustion material, combustion properties were applied to Pinus densiflora with an average height of 17 m and 400 trees/ha, and Cone type was applied for the grid configuration.

2.2. Visualization of VR contents forest fires spread simulation

Result values analyzed with WFDS are stored as Plot3Ddata files, velocity vectors, and physical quantities for fire analysis, and then extracted as vector files FGA files with a cycle of N(3~5) seconds so that they can be imported into 3D Unreal Engine. The FGA file contains data values of vectors and physical quantities in the analysis result. FGA file imported from 3D UE is created as a vector field, and Boundary values such as position, rotation, stile, intensity, and tightness are set. With the generated vector field, the particles are completed by applying the fire and smoke effect used in VR 3D contents. For visualization of forest fire diffusion and forest fuel combustion, first, for visualization of flames and smoke, FGA temperature and smoke (CO, CO_2) concentration data are expressed through particle contrast and lighting effect functions. Second, image change due to forest fuel combustion used the Mesh Decal function as a visualization method with image values created according to the mass reduction rate. Mesh Decal uses the mixed function of semi-transparent Blend Mode and Deffered Decal by updating GBuffer and DBuffer after rendering 3D object surface geometry. In addition, it was configured so that external results such as changes in heat flow of each grid value, wind speed, and wind direction in the UE can be reflected in the impact effect. This is useful for expressing the movement and concentration of smoke in each grid cell differently.

3. Study Results

As a result of expressing the file extracted from the WFDS analysis result as an FGA file with the Unreal Engine, the vector and physical quantity data values such as heat and smoke of each 200,000 grid cells expressed 100% the same value without error even with time series changes. For the visualization of the flame temperature and smoke values for the grid cell, the color and smoke concentration of the flame were adjusted and expressed through the particle contrast and lighting effect on the grid. The results are shown in Figures 1 and 2. The accuracy of the visualization image for the flame intensity and smoke concentration was implemented so that it could be adjusted through the particle lighting function.


Flame #1

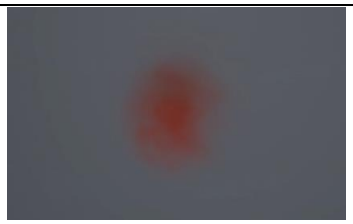

Flame #2


Flame #3


Flame #4


Flame #5

Figure 1- Forest fire flame visualization image results in 3D UE


Smoke #1


Smoke #2

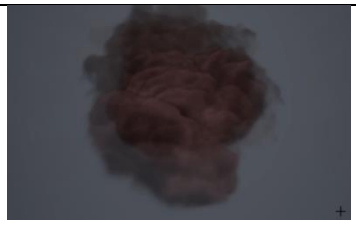

Smoke #3

Figure 2- Forest fire smoke visualization image results in 3D UE

In addition, for the image change according to combustion of the 3D combustion material object data, the Mesh Deca technique was applied to create a material image, and then a method was used to replace the image by mass reduction rate. Figure 3 is a screen visualized in 3D UE according to flame temperature, smoke, and combustion of trees.


Visualization scale 1


Visualization scale 2


Visualization scale 3

Figure 3- Forest fire visualization image results to flame temperature, smoke, trees in 3D UE

Figure 4 shows the simulation results of forest fire spread in Unreal 3D engine using the forest fire diffusion formula of Alexandridis, Alex, et al. There were 2400 grids used for the terrain, and the prediction of wildfire volcanoes was expressed by applying the following conditions to each variable value such as wind, inclination, ambient temperature, and type of fuel material.

- Wind speed: 4.6 m/s

- Wind direction: southwest wind

- Temperature: 32 ℃, FMC (Fuel Moisture Contents): 6.3 %

- Cell size: 5cm²

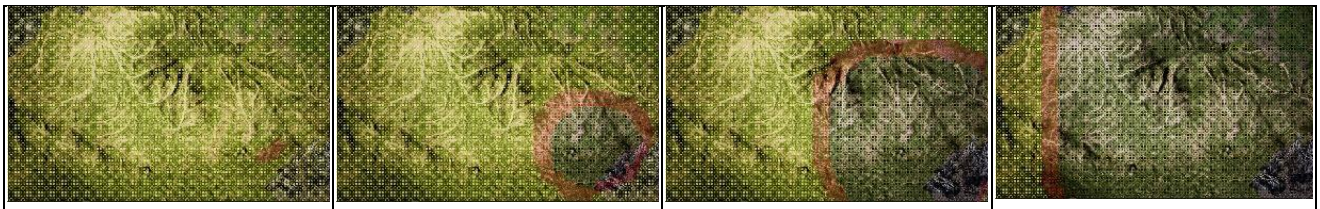

Fire break | after 30 sec. | after 60 sec. | after 120 sec

Figure 4- Result of forest fire spread analysis using Unreal 3D engine

4. Conclusions

As a result of this study on the visualization program of VR UE for virtual reality forest fire training, the following conclusions were obtained.

First, the SMV data and the UE visualization program grid value showed 100% agreement with respect to temperature and smoke, which are the calculation results of WFDS.

Second, in the comparison of the displayed images of flame and smoke concentration, there was a difference in visual brightness and contrast.

Third, the difference in the visual effect was developed to be similar to the SMV visualization data by adjusting the color and smoke concentration of the flame through each particle contrast and lighting effect of the 3D UE.

Fourth, through this study, a methodology for visualizing the accuracy of the properties of forest fires for realistic experience among various element technologies of forest fire education and training contents using virtual reality was presented. However, in this study, visualization studies that reflected real-time changing weather conditions were not yet reflected in the study.

In the future, if the development of fire training contents in virtual space, including the development of educational and training evaluation scenarios, along with the results of this research, is made, it will be a more useful and safe learning tool for forest fire extinguishers.