Simulation Analysis of Ground Infrared Background Based on Numerical Fitting Model

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Abstract. In view of the poor real-time and authenticity of the ground scene generation in the infrared scene simulation, a method of ground infrared background generation based on numerical fitting model is proposed. Combining with the main influencing factors of ground infrared scene, a numerical fitting model of surface temperature field of typical ground material is established. On the basis of the texture of the ground material area, the infrared texture of the ground is dynamically generated in the shader by combining the numerical fitting model of the temperature field and the texture mask generated by the multi-spectral image method. The simulation results show that the numerical fitting model of ground temperature field is in good agreement with the measured data, and the generated infrared texture is more realistic, which meets the real-time and authenticity requirements of infrared scene simulation system.

1. Introduction
Infrared modeling and simulation of ground background is an important part of infrared battlefield environment simulation. The ground includes natural ground and artificial ground. There are many factors affecting the ground temperature, and the composition of the ground material is more complex, which brings a certain degree of difficulty to the ground infrared scene simulation. The generation of ground infrared texture based on visible remote sensing image or aerial image is a research direction in recent years [1-3]. According to the meteorological conditions and the measured data sets of several typical ground material temperatures, this paper establishes the engineering calculation model of ground temperature field, and then uses multi-spectral image fusion method to generate realistic ground infrared texture.

2. Analysis and modeling of ground temperature field
The theoretical modeling of ground temperature field is a complex problem. In addition to the thermal properties of the ground material, the ground temperature is also affected by many environmental
factors\textsuperscript{[4-7]}, such as solar radiation, weather, temperature, wind speed and air relative humidity (RH). In theoretical research, the ground temperature is often calculated by the theoretical model shown in Formula (1).

\[
\eta c \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} (k \frac{\partial T}{\partial z}) + E_s + E_c + E_g + q + EL + G = 0 \quad (1)
\]

\[
T \big|_{z=z_0} = T_0
\]

In the upper formula, \( t \) is time, \( C \) is specific heat, \( k \) is the thermal conductivity of the material, \( I_{\text{sun}} \) is solar irradiance, \( T_0 \) is temperature, \( I_{\text{sky}} \) is sky irradiance, \( E_s \) is the surface radiation, \( EL \) is sensible heat transfer, \( G \) is downward heat transfer to the surface.

Based on the measured results of temperature, wind speed, solar hourly radiation, atmospheric humidity and ground temperature, a data sample set is established. The mathematical expression of the final fitting model is

\[
T = a + b T_{\text{sun}} + c H^f + d R_{\text{sun}}^g + e R_{\text{hyd}}^{1-h} \quad (2)
\]

Among them, the atmospheric temperature, \( H \) convective heat transfer coefficient, solar hourly radiation, RH for atmospheric humidity, \( a, b, c, d, f, g, h \) for the fitting coefficient, the value is determined according to season and material. The ground is used as a diffuser, and the infrared radiance of the ground to the detector can be calculated according to formula (3).

\[
I_{\text{ground}, \lambda_1-\lambda_2} = \frac{1}{\pi} (E_{\text{ground}, \lambda_1-\lambda_2} + \rho_g (E_{\text{sun}, \lambda_1-\lambda_2} + E_{\text{sky}, \lambda_1-\lambda_2})) \quad (3)
\]

Among them, the upper and lower limits of the working band and the band of the detector are in the middle band. Limited in length, table 1 gives the fitting coefficients of several typical material floors in spring.

| Numerical | asphalt | concrete | pasture | soil (dry) | marble |
|-----------|---------|----------|---------|------------|--------|
| a         | -182.56 | -258.379 | -63.48  | -169.628   | -171.91|
| b         | 1.565   | 1.791    | 1.152   | 1.4943     | 1.627  |
| c         | -0.822  | -1.10    | -0.432  | -0.455     | -9.04  |
| d         | 8.4\times10^{-9} | 6.6\times10^{-9} | 0.84\times10^{-8} | 1.02\times10^{-8} | 9.2\times10^{-9} |
| f         | 0.5     | 0.5      | 0.5     | 0.5        | 0.5    |
| g         | 3       | 3        | 3       | 3          | 3      |
| h         | -0.052  | -0.047   | -0.345  | -0.195     | -0.045 |

3. Research on realistic generation technology of infrared texture on the ground

In this paper, the multi spectral image fusion method is used to generate the reality of the infrared texture of the ground. The method uses the texture mask generated from the visible spectrum image to fuse the pixel gray level to realize the reality of the infrared image. The method is as follows:

- Transforming visible light into gray image and finding the gray mean of the same material area.
• Subtract the gray mean of different regions of the visible light gray image to get the texture mask of the region.
• According to formula (2) and formula (3), the temperature and infrared radiance of each region are calculated, and then the infrared texture image of the ground is obtained.
• Texture mask is multiplied by a texture depth adjustment factor, which is used to adjust the depth of mask.
• The sum of infrared gray and mask gray at the same texture coordinate point is taken as the gray value of the final texture pixel. Figure 1 shows the comparison between the actual ground infrared image and the simulated ground infrared image.

![](image1)

(a) infrared real photo (b) visible light real image (c) to simulate ground image

**Figure 1.** Realistic IR texture of ground

In Figure 1, the ground is cement road and Dali slate. Because the temperature of cement pavement is lower than that of marble surface, the gray level of cement pavement in the image is lower than that of marble surface. In addition, the detail of the simulated ground image is clearer than that of the real image. This is mainly due to the fact that the texture mask is based on the visible image, and the resolution of the visible image is higher than that of the infrared detector.

4. Simulation results evaluation

The accuracy of ground temperature field modeling is evaluated by comparing the predicted results with the measured ones. Figure 2 shows the comparison of the model temperature prediction results with the measured data of several typical materials. Table 2 gives the corresponding mean square error evaluation. In Figure 2, the ground is horizontal, and the numerical label indicates the simulation date. 1 is July 2, the weather is cloudy and clear, 2 is May 8, the weather is clear and cloudless.

![](image2)

(a) asphalt (b) concrete
Table 2. MSE of values between model and real measurement

| Date | Asphalt | Soncrete | Pasture | Soil  |
|------|---------|----------|---------|-------|
| 1    | 1.52K   | 0.80K    | 0.70K   | 0.62K |
| 2    | 1.79K   | 0.96K    | 0.53K   | 0.37K |

According to Figure 2 and Table 2, the predicted results of the ground temperature field model are in good agreement with the measured data, and the accuracy can meet the requirements of Engineering calculation. Obviously, the calculation speed of the ground temperature field model is obviously faster than that of the theoretical model based on the finite difference method.

Figure 3. Simulation of IR ground

Figure 3 shows the final 3D scene simulation of the ground infrared scene. The ground texture details in the map are generated based on the texture mask generated from the 15m visible light remote sensing image. The ground material is mainly grassland and asphalt pavement. Ground buildings as part of the ground are rendered together with the ground in the simulation. Because the ground temperature is higher at noon, the infrared gray level of the ground and buildings is obviously higher than that of the ground and buildings in the morning. The frame rate of the scene is kept at around 60Frame/s because of the use of shaders to render the scene grayscale.

5. Concluding remarks

Aiming at the problem that the real-time and authenticity of ground scene dynamic generation in infrared scene simulation are poor, a method of ground infrared background dynamic generation based on numerical fitting model is proposed. Firstly, the engineering calculation model of surface temperature field of typical materials is established based on meteorological conditions and ground temperature data sets. Then, the infrared gray level of ground texture is calculated in real time by Colorer according to the texture and texture mask of the material area on the ground. The simulation results show that the method based on the numerical fitting model is feasible and the computational
speed meets the requirements of dynamic real-time simulation. The generated infrared texture has a strong sense of reality. The method has a strong practical significance in engineering.

6. References
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