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Sensitivity of different methods for simultaneous evaluation of emissivity and temperature through multispectral infrared thermography simulation

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Introduction and nomenclature

This study focuses on the simultaneous evaluation of temperature and emissivity with multispectral infrared thermography (IRT). It leans on the study and development of an IRT simulator able to address 3D scene in static or dynamic configuration. The sensitivity of 4 different temperature and emissivity joint estimation methods are then evaluated.

IRT Simulator through the radiosity method

View factor

Geometrical coefficient for radiative exchange between two diffuse elements

\[ F_{A \rightarrow B} = \int_{A} \frac{\cos(\theta) \cos(\phi)}{\pi r^2} dA_1 dA_2 \]

Radiosity equation

\[ B_{k,\Delta \lambda_i} = M_{k,\Delta \lambda_i} + (1 - \epsilon_{k,\Delta \lambda_i}) \sum_{j=1}^{J=N_{gels}} V_{B_k} F_{A_{j} \rightarrow B_k} \Delta \lambda_i \]

Temperature and emissivity retrieval

With Bouguer’s law and for infinitesimal surfaces:

\[ E_{\text{sensor,}\Delta \lambda_i} = \frac{I_{\text{sensor,}\Delta \lambda_i}}{\pi^2} \frac{\cos(\theta_{\text{sensor}})}{d_{\text{object}}} \cos(\phi_{\text{sensor}}) \text{d}S_{\text{object}} \]

\[ \Rightarrow \text{Undetermined system with } \epsilon_{k,\Delta \lambda_i} \text{ and } T \text{ unknowns} \]

\[ E_{\text{cepater,}\Delta \lambda_i} = g(\theta_{\text{cepater,}\text{object}}, \tau) \epsilon_{k,\Delta \lambda_i} L(\Delta \lambda_i, T) \]

3D Model

A target with 4 different materials properties

- GPU acceleration through OpenGL’s API
- User-friendly graphical interface
- Use models from literature
- Sensor model for radiative illumination to image

C++ Implementation

- Simulation results for \( T = 313.15K \)
- Camera, target and environment in the visible
- Temperature and emissivity retrieval

Theory

\[ \Delta \lambda_i \text{ \ Wavelength interval of } i^{\text{th}} \text{ band} \]

\[ \epsilon_{k,\Delta \lambda_i} \text{ \ Emissivity of patch } k \text{ in } \Delta \lambda_i \]

\[ T \text{ \ Object’s temperature} \]

\[ \Delta \lambda_i \text{ \ Emissivity of patch } k \text{ on } \Delta \lambda_i \]

\[ M_{k,\Delta \lambda_i} \text{ \ Emissivity of patch } k \text{ on } \Delta \lambda_i \]

\[ V_{B_k} \text{ \ Visibility between patches } k \text{ and } j \]

3D Model

- Visualization of emissivity with 3 bands
- Simulation results for \( T = 313.15K \)
- Camera, target and environment in the visible
- Temperature and emissivity retrieval

Conclusion and perspectives

- Comparison of 4 methods to estimate simultaneously emissivity and temperature
- Study and development of a 3D scene IRT simulator

Perspectives:

- Add measurement noises in the simulation process to observe their effect
- Combine temporal and spatial information in Bayesian methods for further improvements of joint estimation

Conclusion:

- Authors wish to thanks Bretagne Region for its financial support

Bibliography


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