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

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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

Temperature and emissivity retrieval

With Bouguer’s law and for infinitesimal surfaces:

\[ E_{\text{sensor}}(\Delta \lambda_i) = \int \frac{\cos(\theta_1) \cos(\theta_2)}{\pi^2} dA_1 dA_2 \]

\[ B_{k,\Delta \lambda_i} = M_{k,\Delta \lambda_i} + (1 - \epsilon_{k,\Delta \lambda_i}) \sum_{j=1}^{y} V_{B_j} F_{x_j} \]

\[ \Delta \lambda_{ij} \quad \text{Wavelength interval of } i^{th} \text{ band} \]

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

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

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

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

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

\[ \text{Non linear optimization} \]

\[ \arg\min \sum_{k=1}^{y} \frac{1}{\Delta \lambda_{ij}} \int \frac{\cos(\theta_1) \cos(\theta_2)}{\pi^2} dA_1 dA_2 \]

\[ \epsilon_{k,\Delta \lambda_i} = \sum_{j=1}^{y} \phi_j \Delta \lambda_i, \quad 0 \leq \epsilon_{k,\Delta \lambda_i} \leq 1 \]

\[ \text{Nonlinear basis (Chebyshev-1)} \]

\[ 200K \leq T \leq 400K \]

\[ \text{Bayesian (Monte-Carlo Markov Chain (MCMC))} \]

\[ \text{A priori known laws:} \]

\[ e = X(\mu_{\epsilon}, \sigma_{\epsilon}) \]

\[ T = \frac{1}{\text{ln}(T_{\text{min}} / T_{\text{max}})} \]

\[ \text{Draw variables } e \text{ and } T \text{ by using the targeted distributions } p(e | y) \text{ and } p(T | y) \text{ with a Slice-within-Gibbs sampler.} \]

\[ \mu_{\text{posterior}} = \mu_{\epsilon} \quad 0.8 \quad 0.8 \quad 0.8 \]

\[ \sigma_{\text{posterior}} = \sigma_{\epsilon} \quad 0.8 \quad 0.8 \quad 0.8 \]

\[ \text{Conclusion:} \]

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

\[ \text{Perspectives:} \]

- 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

\[ \text{References:} \]


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