Sensitivity of different methods for simultaneous evaluation of emissivity and temperature through multispectral infrared thermography simulation
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To cite this version:
Thibaud Toullier, Jean Dumoulin, Laurent Mevel. Sensitivity of different methods for simultaneous evaluation of emissivity and temperature through multispectral infrared thermography simulation. EGU 2019 - European Geoscience Union, Apr 2019, Vienne, Austria. 21, pp.2019 - 8692, 2019. hal-02264677
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

\[ F_{1,2} = \int_{A_1} \int_{A_2} \cos(\theta_1) \cos(\theta_2) \ dA_1 \ dA_2 \]

**Radiosity equation**

\[ B_{k,\Delta \lambda_i} = M_{k,\Delta \lambda_i} + \left( 1 - \epsilon_{k,\Delta \lambda_i} \right) \sum_{j=1}^{M} V_{k,j} F_{k,j} \]

**C++ Implementation**

- GPU acceleration through OpenGL’s API
- User-friendly graphical interface
- Python interpreter for user-case scenarios
- Sensor model for radiative illumination to image

**3D Model**

A target with 4 different materials properties

**Conclusion and perspectives**

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

**Introduction and nomenclature**

- \( \Delta \lambda_i \): Wavelength interval of \( i^{th} \) band
- \( \epsilon_{k,\Delta \lambda_i} \): Emissivity of patch \( k \) in \( \Delta \lambda_i \)
- \( T \): Object’s temperature
- \( B_k,\Delta \lambda_i \): Radiosity of patch \( k \) on \( \Delta \lambda_i \)
- \( M_k,\Delta \lambda_i \): Emittance of patch \( k \) on \( \Delta \lambda_i \)
- \( V_{ij} = \{ 0,1 \} \): Visibility between patches \( i \) and \( j \)

**Temperature and emissivity retrieval**

**Results**

**Non linear optimization**

\[
\text{argmin}_{\epsilon_{k,\Delta \lambda_i}} \sum_{k=1}^{N} \left( \frac{\sum_{j=1}^{M} \cos(\theta_j) \cos(\theta_{k,j}) \ dA_j \ dA_k}{\epsilon_{k,\Delta \lambda_i} \ cos(\theta_k) \ dA_k} \right)^2
\]

**Temperature Emissivity (TES) Method**

\[
\frac{T(\Delta \lambda_i) \ L^2(\Delta \lambda_i, T) \ 
}{\cos(\theta_k) \ dA_k} = \frac{\sum_{j=1}^{M} \cos(\theta_j) \cos(\theta_{k,j}) \ dA_j \ dA_k}{\epsilon_{k,\Delta \lambda_i} \ cos(\theta_k) \ dA_k}
\]

\[
\epsilon_{k,\Delta \lambda_i} \epsilon_{k,\Delta \lambda_i} \ L^2(\Delta \lambda_i, T)
\]

**Bayesian (Monte-Carlo Markov Chain (MCMC))**

A priori known laws:

\[
\epsilon = X(\mu, \sigma)
\]

With \( \mu_{\epsilon_{k,\Delta \lambda_i}} = 0.6 \) and \( \sigma_{\epsilon_{k,\Delta \lambda_i}} = 0.8 \)

**Conclusion:**

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**Bibliography**