Infrared camera calibration

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Why calibration?

- Each physical process involved in an infrared camera (conversion of a scene emitting infrared radiation into a clean image) may leave a signature on the data that has ideally to be removed by calibration

  - If not removed, each aspect eventually results in artifacts
What is to be calibrated? (1/2)

- Photons: from scene to FPA
  - Optic
    - Transmission
    - Reflection
    - Emission
  - Geometry
    - F#
    - Pixel size
What is to be calibrated? (2/2)

From incident photons on FPA to digital world

- **FPA**
  - Transmission
  - Absorption
  - Electrons generation
  - Electrons collection
  - Electrons accumulation

- **ROIC**
  - Charge transfer (current)
  - Transimpedance amplification (conversion to voltage)
  - Amplification and buffering
  - Voltage conditioning
  - Analog-to-digital conversion
Parameters governing calibration

- Pixel
- Integration time (exposure)
- Frame rate
- Sub-windowing
- Optics
- Ambient temperature
- Non-linearity of analog channels
- Cooldown
- FPA temperature
Pixel spectral responses

- Spectral responses of random pixels and percentiles over wavelength (µm) are shown.
- The graphs compare spectral responses for different percentiles (99%, 95%, 90%, 75%, 50%, 25%, 10%, 5%, 1%).
- The data is presented in arbitrary units (a.u.).

The graphs illustrate the variation of spectral response across different wavelengths and percentiles, highlighting the differences in signal strength and response characteristics.
Calibration methods

- Blackbody acquisitions at different temperatures (close to scene radiance temperatures)
  - 2-point calibration
  - Multi-point (multi 2-point) calibration
  - Multi-point (continuum) calibration

- Integration time
  - Single integration time
  - Multi-integration time (discrete)
  - Multi-integration time (continuum)
Calibration: “local” vs. “global”

- Local methods
  - Provide *excellent* results in a very limited environment (e.g. integration time, scene temperature range, ambient conditions)
  - *Poor* results otherwise
  - “Volatile” data

- Global methods
  - Provide *very good* results for a wide range of operating parameters
  - Involve compromises to support wide ranges of operating parameters
    - E.g. dealing image quality vs. accuracy (through uncorrelated spatial “noise”)
  - “Permanent” data
2-point calibration

Method

- 2 blackbody acquisitions
  - Single integration time
  - Pair of temperatures
  - Either temperature or in-band radiance

- Application of pixel-wise gain and offset: linear interpolation

Characteristics

- Simple
- Provide quantitative estimates
- Applicable to low-contrast scenes
- Valid for a single integration time
- Valid for a single ambient temperature
2-point calibration

measured blackbody temperature

calculated blackbody in-band radiance
Multi-point calibration

**Method**
- Many blackbody acquisitions (*very large number of acquisitions*)
  - Preselected integration times
  - Many temperatures (large number)
  - Either temperature or in-band radiance
- NUC with gain and offset: piece-wise linear interpolation
- Separate pixel-wise NUC and single global radiometric calibration

**Characteristics**
- Moderate to large complexity
- Provide quantitative estimates
- Applicable to contrasted scenes
- Valid for all *preselected* integration times
  - Though (non-linear) interpolation may be used to create NUC data for intermediate integration times included in the preselected range
- Valid for a single ambient temperature
  - Though compensation may be added by taking another dataset at a different ambient temperature (and apply interpolation)
Telops calibration – From digital counts to flux

Variations of measured digital counts as a function of the exposure time

- Ideally, the number of accumulated electrons \( T_{bb,4} < T_{bb,3} < T_{bb,2} < T_{bb,1} \) linearly increases with exposure time.
- Detected electron flux (slope) increases with blackbody temperature.

\[ D_p = F_p \times ET + D_{\text{offset},p} \]
Telops calibration – From flux to temperature

Strong similarity between curves corresponding to various pixels

May be represented with an affine transformation

- Representative nominal curve
- Gain and offset parameters for each pixel

\[ F_p(T_{bb}) = \alpha_p \times \tilde{F}(T_{bb}) + \beta_p \]
Telops calibration – Ambient temperature

Increase of ambient temperature simply adds a given flux, independent from the scene.

\[ F \text{ [counts/\mu s]} \]

\[ T_{\text{amb},2} > T_{\text{amb},1} \]

\[ T_{\text{bb}} \text{ [°C]} \]
Unique capabilities of Telops calibration

- Permanent calibration (factory made)
  - No need of any blackbody measurements under field conditions
  - Camera ready to provide calibrated images once FPA has cooled down to its operating temperature

- Automatic Exposure Control (AEC)
  - Camera autonomously and dynamically adapts its integration time to the scene radiance level, while always providing uniform and calibrated images in real-time
AEC demonstration
Conclusions

Telops innovative calibration

- Simplicity of use with accurate temperature calibration