A Novel Approach to Temperature-Emissivity Separation Using a Multiple-Window Smoothness Criteria

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Introduction

- Calculating temperature and emissivity of targets using aerial imagery is a complicated problem requiring optimization.
  - The target's temperature must be known in order to calculate the emissivity.
  - Aerial imagery gives the spectral radiance, but not the temperature.
- An optimization approach called the spectral smoothing method is modified to test three novel approaches:
  - Moving-window method
  - Variable-width moving-window method
  - Multiple-moving-windows method
- 17 targets of varying materials were tested.
- The goal is to find a method which:
  - Works well on a wide range of target materials.
  - Accurately estimates the temperature and emissivity of highly reflective targets.

Spectral Smoothing

- The spectral smoothing method states that the atmospheric emission lines in a subregion, or window, of the spectra from $8.12 - 8.6\mu m$ are accentuated when the incorrect target temperature is used to calculate emissivity.
- This means that when the emissivity is the smoothest, or has the least change in slope, then the corresponding temperature should be the temperature of the target.

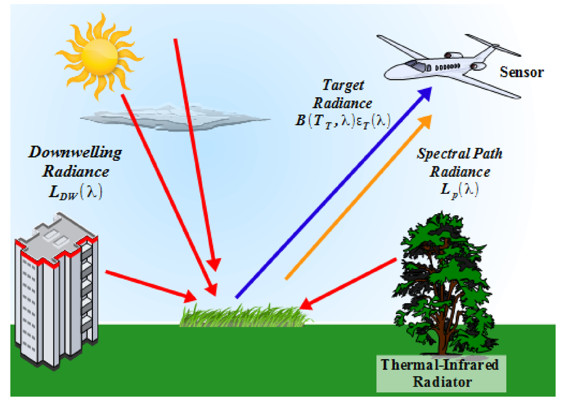


Figure: Shown is a graphic illustrating the sources of radiation which enter the sensor. Not only does the target radiance enter the sensor, but so does atmospheric radiance, and radiance reflected off the target from nearby sources.

Problem

- Highly reflective targets.
  - Targets such as polished metal have a low emissivity, which is strongly effected by any changes in the atmosphere during measurements. It is very difficult to get accurate results for these targets.

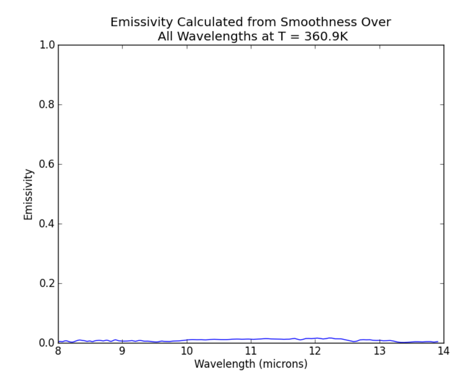
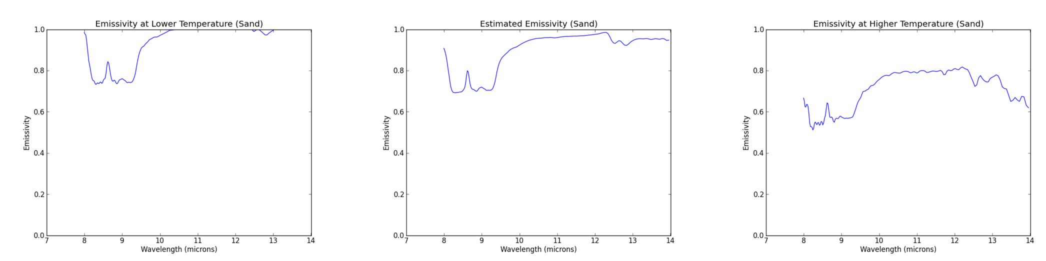


Figure: Emissivity of a collected sample of aluminum foil. Notice the very low magnitude. The calculated results are often negative. This is likely due to a faulty measurement, as essentially any change in the surrounding atmosphere will have a great effect on the emissivity.

- Incorrect temperature estimation.
  - Atmospheric emission lines are at a minimum given the correct target temperature, when using the spectral smoothing method.



(a) Under-estimated temperature, at 311K

(b) Estimated temperature, at 312.5K

(c) Over-estimated temperature, at 320K

Figure: Demonstration of the effects of using the incorrect temperature to estimate emissivity.

Current Method

- The emissivity is calculated inside the windowfor a range of temperatures, and the temperature which produces the smoothest curve is used.

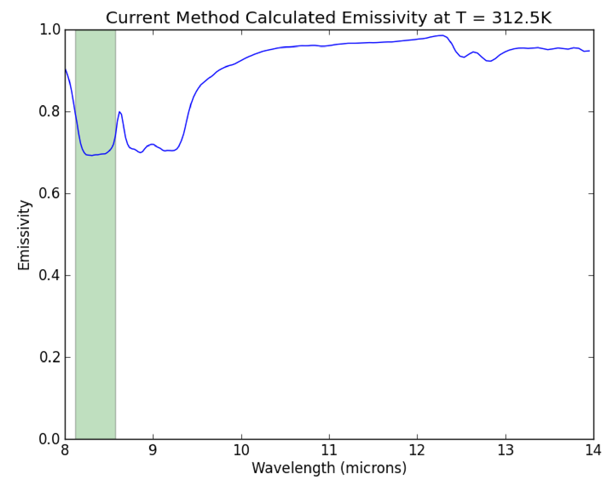


Figure: Spectral emissivity of sand using the current spectral smoothing method. The green bar is the window.

Moving-Window Method

- This method is the same as the current one, except that instead of a fixed subregion from $8.12 - 8.6\mu m$, the subregion changes position over the entire spectra, from $8 - 14\mu m$. The smoothest region is selected to find the temperature.

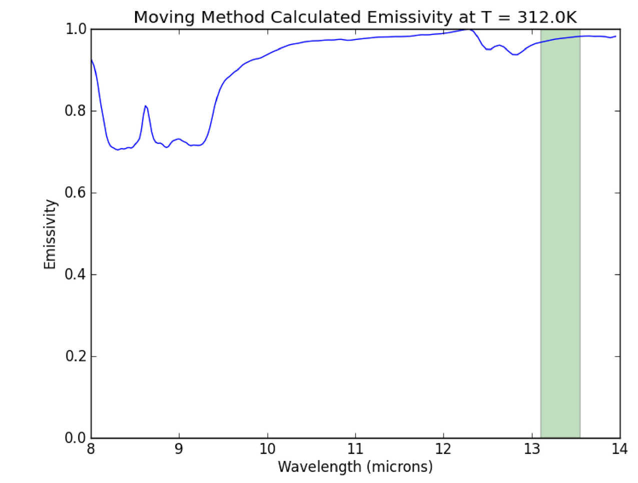


Figure: Spectral emissivity of sand using the moving-window method. The green bar shows the window.

Variable-Width Moving-Window Method

- Similar to the moving-window method, but the window also varies in width.
- For each predefined width, the window moves through all positions in the spectra in order to find the best temperature.

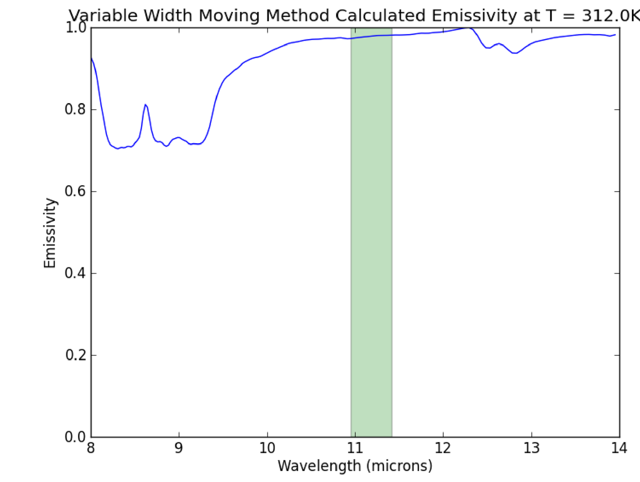


Figure: Spectral emissivity of sand using the variable-width moving-window method. A $0.5\mu m$ width was chosen in this case.The green bar shows the window.

Multiple-Moving-Window Method

- Using a window with a predefined, fixed width, this method uses every possible combination of a predefined number of windows to find the combinations which produces the smoothest curve.
  - Four windows with a width of $1\mu m$ were arbitrarily chosen in this research.

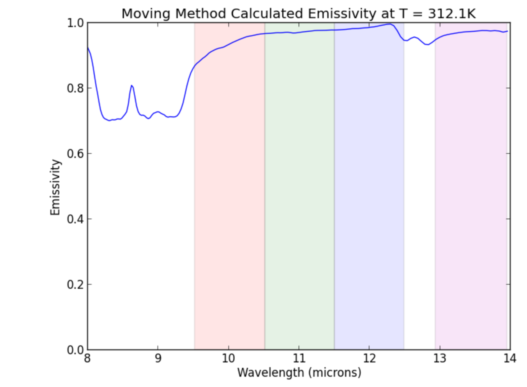


Figure: Spectral emissivity of sand using the multiple-moving-window method with four windows having a width of $1\mu m$. Each window is a different color block.

Results

- The difference between each of the new methods, and the existing method is negligible according to unpaired t-tests between the new and current methods.
  - Using an α of 0.05, p-values of 0.5624, 0.7566, and 0.9780 were found.
- None of the novel methods produced usable results for highly reflective targets.
- Future work includes continued testing with a larger number of samples.

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