Two Dimensional Spatial Emissivity Correction Technique

By Gary Orlove

Using computer techniques it is possible to produce an image from an imaging radiometer which is a true temperature image rather than a radiance image; that is all temperatures in the field of view have been individually and discretely corrected for the emissivity at the individual points. This requires that the target be heated to two known temperatures and the background calculated using one of the known temperature images. This technique will automatically correct for all reflected temperatures no matter where they come from including narcissus effects (reflection of the detector itself) as it becomes part of the global radiation the target reflects.

To calculate the emissivity matrix we heat the target to two known uniform temperatures and measure the total radiances of the target ($T_2 > T_1$), which are converted to target radiance via the calibration lookup table. Assuming that the radiation representing the reflected environment is unchanged, they are eliminated between the two. This yields the emissivity at every pixel.

To measure the emissivity, the equations become:

At Temperature 2:

$$R'_{T2(x,y)} = \varepsilon_{(x,y)} \cdot R_{T2} + (1 - \varepsilon_{(x,y)}) \cdot R_{env(x,y)}$$

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Where:

$R'_{T2(x,y)}$ = Radiance received at (x,y) by the infrared camera
$\varepsilon_{(x,y)}$ = Emissivity of the target at (x,y)
R_{T2} = Radiance the target would emit if it were a blackbody
$R_{env(x,y)}$ = Radiance of the reflected environment at (x,y)

Similarly at Temperature 1:

$$R'_{T1(x,y)} = \varepsilon_{(x,y)} \cdot R_{T1} + (1 - \varepsilon_{(x,y)}) \cdot R_{env(x,y)}$$

Subtracting $R'_{T1(x,y)}$ from $R'_{T2(x,y)}$:

$$R'_{T2(x,y)} - R'_{T1(x,y)} = \varepsilon_{(x,y)} \cdot (R_{T2} - R_{T1})$$

So:

$$\varepsilon_{(x,y)} = \frac{(R'_{T2(x,y)} - R'_{T1(x,y)})}{(R_{T2} - R_{T1})}$$

We can calculate the radiance of the reflected environment at each point by:

$$R_{Env(x,y)} = \frac{(R'_{T2(x,y)} - \varepsilon_{(x,y)} \cdot R_{T2})}{(1 - \varepsilon_{(x,y)})}$$

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We are now able to use these values of emissivity and reflected environment to calculate and present a true temperature image of the target by converting to temperatures via the calibration lookup table:

$$R_{T(x,y)} = \frac{(R'_{T(x,y)} - (1-\varepsilon_{(x,y)}) \cdot R_{Env(x,y)})}{\varepsilon_{(x,y)}}$$

As background conditions can vary from test to test, the reflected environment matrix can be further recalculated with the target at ambient temperature.

$$R_{Env(x,y)} = \frac{(R'_{Ta(x,y)} - \varepsilon_{(x,y)} \cdot R_{Ta})}{(1-\varepsilon_{(x,y)})}$$

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Where:

R'_{Ta} = Radiance received when the target is at ambient temperature

R_{Ta} = Radiance target would emit if it were a blackbody at ambient temperature

Infrared cameras deliver a numerical signal coded in 14 or 16 bits. This is expressed for instance in DL or count. Assuming that the conversion is linear, radiance in the equations can be replaced by DL or count values.