

thermal imaging heats up

Tailoring IR cameras for firefighting applications presents challenges.

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Inside a burning building, firefighters and their equipment are routinely exposed to temperatures as high as 500°C. Fire scenes also place a tremendous emphasis on effective dynamic range control—a firefighter might go from a dank basement to the heart of the blaze, the thermal equivalent of stepping from pitch darkness into full midday sunshine. In designing a thermal imager for firefighting applications, we had to address these concerns, as well as issues of durability, reliability, compactness, and cost.



By imaging in high gain (left) and low gain (right) states, the camera reduces dynamic gain demands on the FPA.

Typically, so-called uncooled thermal detectors still require active temperature stabilization of the focal plane array (FPA), usually by thermoelectric cooler (TEC). Reliance on a TEC is especially problematic for firefighting because power consumption increases as the rest of the system heats up. In addition, system heating relative to a fixed FPA temperature erodes dynamic range as a result of out-of-field irradiance from the camera case and other sources outside the imaged field of view.

Eliminating the TEC makes sense, but uncooled detectors are highly sensitive to temperature change. Even slight pixel-to-pixel variations can radically degrade image quality. We used a combination of proprietary read-out circuitry and non-uniformity correction (NUC) algorithms to address the uniformity problem. Spanning the -20°C to +75°C operating range of the camera requires three NUC tables, each of which covers 35°C. The system automatically transitions from one table to the next as the camera heats or cools. The NUC tables overlap by several degrees, which prevents the camera from oscillating between tables at a boundary.

In the midst of a burning building, objects in the sensor field of view can easily exceed 500°C. In contrast, low-contrast tasks such as navigating through smoke demand sensitivity of below

0.05°C. These two extremes represent an instantaneous FPA dynamic range approaching 2^{15} (90 dB). Essentially, though, these scenarios represent two distinct modes of operation; the firefighter often needs high temperature range or high sensitivity but not both simultaneously. Accordingly, our imager features two operating states—a high-gain state for low-contrast conditions and a low-gain state for large scene temperature (see figure).

For this approach to be effective, the system must transition between gain states automatically, and the current state must always be obvious. Most important, the switching logic must transition appropriately and efficiently such that the firefighter is never forced to contend with a saturated image in high-gain state, a washed-out image in low-gain state, or a continuous hunting for the proper state due to slight changes in scene content.

For gain-state determination, our camera uses a temperature threshold and a population threshold (percentage of the scene above/below the temperature threshold). Hysteresis in both the temperature and population thresholds prevents oscillation. The transition switching speed is below 0.5 s.

Designers typically use nonlinear automatic-gain-control algorithms to map sensor dynamic range to the lower display dynamic range. The problem is that this method distorts absolute temperature information—a smoldering ember will show up bright white if it is the hottest object in the scene, but it will appear darker if a hot flame is nearby. This inconsistency in the display of an object can be extremely confusing, especially for firefighters trying to make life-or-death decisions.

We augmented our system to display objects above threshold as yellow (over 135°C in high gain, 450°C in low gain) or red (over 142°C in high gain, 475°C in low gain). With the rest of the image displayed in gray scale, colored objects stand out vividly as dangerously hot.

Other trade-offs involved sacrificing resolution for large field-of-view imaging, and choosing an economical small format (160 x 120), high signal-to-noise ratio FPA to allow us to reduce optical system size and cost.

Thermal imaging has the potential to radically improve the effectiveness and safety of firefighting. Today's designs can simultaneously satisfy competing environmental, ergonomic, performance, and cost requirements. **oe**

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