How good is Quantitative Thermal Imaging?

Infrared thermal imaging cameras, or thermal imagers, are devices that detect the infrared radiation emitted by all objects and generate a detailed two-dimensional temperature map of a surface. They are becoming increasingly important in many industries for inspection and maintenance of plant and buildings.

Thermal imaging applications can be divided into two categories: qualitative and quantitative. In qualitative thermal imaging, temperature differences or temperature distributions are important. Such applications are often found in the areas of energy management and electrical fault finding, and include detection of heat loss through damaged insulation materials in buildings, furnaces and kilns, and identification of loose or corroded connections on high-voltage power lines, electrical load imbalances, and faulty electronic components on circuit boards. Infrared images are often displayed in false colour, so it is a simple matter to identify any unusually hot or cold regions in an image.

Quantitative thermal imaging is more demanding and requires that a true temperature value be assigned to each pixel in the image. Applications are found, for example, in the petrochemical, metal processing, plastics and ceramics industries, where accurate temperature measurement is critical to the manufacturing process.

There are several problems associated with the determination of true temperature using infrared techniques. Two of the most significant problems, namely knowledge of surface emissivity and reflections from surrounding objects, are present in all forms of infrared thermometry. These errors were discussed in the April/May 2004 issue of Automation & Control. An example of a reflection error is shown in the figure. The picture on the left is a thermal image of a switchboard (shown in a normal photograph on the right). Not only does the thermal image indicate unusually high temperatures for switches R7 and Y7, it also clearly contains a thermal reflection of the camera operator.

A third problem, which is especially significant in thermal imaging, is known as the size-of-source effect (SSE). The SSE arises from diffraction and inter-reflections among the optical components of the thermal imager, and from scattering caused by imperfections in the optical materials and by dust and dirt on the optical surfaces. This causes radiation from the target and its surroundings to be smeared throughout the image. The result is that, as the name suggests, the temperature registered by a pixel is dependent on the size of the source, or target, and the temperature of all the objects surrounding the target.

SSE errors can be surprisingly large, often considerably larger than the specifications quoted by the manufacturer. For example, in large petrochemical furnaces, the SSE can lead to errors easily as high as 50 degrees Celsius for a target at 850 degrees Celsius. This represents a six percent error in the reading, where the manufacturer may specify an accuracy of plus or minus two percent. This 50 degrees Celsius error would be in addition to errors arising from reflection and emissivity effects.

Unlike the latter two errors, the SSE error is extremely difficult to correct, and its nature depends on the conditions under which the thermal imager was calibrated. It is only when the conditions of use exactly mimic the calibration conditions that the SSE error is eliminated. The calibration conditions, generally comprising small area blackbodies in relatively cool surroundings, are rarely found in real applications.

There is a simple procedure to determine whether the SSE is a particular problem for your thermal imager. By measuring a hot constant-temperature object, such as a small hotplate or sight port in a furnace, over several different camera-to-object distances you effectively change its size in the image. Ideally, the temperature recorded by the pixels in the centre of the object should not change with measurement distance. However, if it does change, then this gives an indication of the SSE. Large apparent temperature changes indicate that the thermal imager is probably not suited to quantitative applications and should only be used qualitatively.