Augmenting a Camera with a Thermometer

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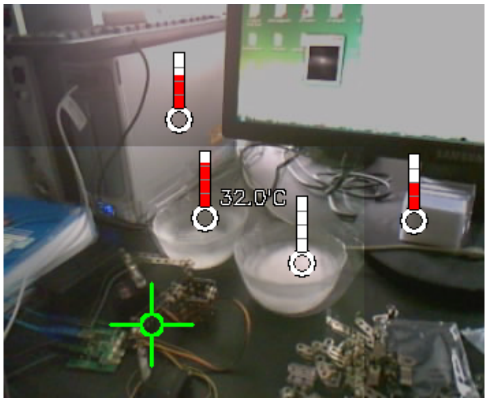

Figure 1: *The user shoots one main image which then serves as a backdrop for aiming the thermometer (as indicated by the green crosshairs) and for the display of the measurement data. The current camera image is overlaid for feedback (lower left).*

Figure 2: *A webcam and an infrared thermometer are coupled to augment each image taken by temperature measurements.*

1 Introduction

All of today's digital cameras record the date and time at which a photo has been taken; some cameras also record the geographical position. This work proposes yet another augmentation: to record temperatures at different spots picked by the user in the image. This has many applications for both family life and professional engineering: Was the water in the swimming pool heated? Was last Saturday night's party fever really a fever? On the serious side, an engineer may record the temperature of different chips on a printed circuit board or document heat loss due to bad building insulation.

These tasks could be addressed with a thermographic camera—at a steep price. In contrast to that, non-contact thermometers based on infrared sensors have become very affordable. They are based on thermopile sensors that could easily be added to digital cameras. One can employ image tracking on the camera to determine which spot is currently captured by the thermometer. The user takes one main image and then points the camera's case—and hence both the standard camera and the infrared thermometer—to all spots whose temperature he or she wants to record. The measurements are displayed in the main image, see Figure 1. A different option would be to store the data in specific tags inside the image, to be read by an image viewer or by data processing software.

2 Prototype

The prototype, see Figure 2, is based on the combination of a standard webcam with an inexpensive infrared thermometer that has a wireless serial connection to send the current measurement data. The software has been developed using two libraries: OpenCV for image processing and FFTW for the Fourier transform.

After the user has pressed a key to select the current image as the "main" one, the view-finder is frozen: It displays this image and no longer the current camera input. Crosshairs marks the current target point, see Figure 1. The measurements are indicated by thermometer icons. To not clutter the display, each value is available numerically when the mouse hovers over the measurement spot. The thermometer's spot size (field of view) is indicated by the circles in the crosshairs and the thermometer icons. The spot size of the infrared thermometer used in the prototype is 30:1 (distance:diameter), a typical value for these devices, which obviously guarantees enough spatial resolution for most applications. The separation of the webcam's and the thermometer's lenses—approximately 3 cm in the prototype—causes a parallax error, which is comparable to the spot size at 1 m distance and hence is negligible for larger distances.

Most infrared thermometers can mark the measurement spot by a laser. In the prototype, the laser's dot is used to align the image of the webcam. This has to be done once for a given setup of the webcam and the thermometer. In principle, the laser dot could also be used to track the measurement spot through a *fixed* camera that does not move in parallel with the thermometer. However, in preliminary experiments it turned out that the laser dot often appears much too bright in the camera image (and hence white but not red), appears blurred, or is not visible at all, depending on the surface.

Hence, the camera target is identified by cross-correlating the main image with the current camera image at a size of 128×128 pixels in RGB space. This cross-correlation is computed in real time with help of the FFT of the images padded with zeros to 256×256 pixels. To normalize the cross-correlation, summed area tables are used to determine the variances of the main image and the current camera image in the overlapping region. This approach does not employ frame-to-frame tracking, as such a method would be prone to lose the reference when the camera's target changes rapidly.

3 Conclusion and Outlook

This work demonstrated how a digital camera can be extended by an infrared thermometer to open up novel applications. Future work can address the miniaturization: A bare-bones thermopile together with infrared optics could be equipped with a BlueTooth transceiver and added to a mobile phone. Other data such as laser-based distance measurements could be incorporated in a similar way.

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