Guest Editors' Introduction:

DIGITAL IMAGING

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Humans interact with each other and with the computer via audio and visual clues. The user has favorably received the incorporation of audio capabilities in personal computers, which began in the early 1980s. Today, audio capabilities are standard features in personal computers. Visual information capture, display, transmission, and storage, will be the next leap in improved human-computer interactions. In this special issue of *IEEE Micro*, we feature digital imaging, with emphasis on still digital imaging for consumers.

Our articles span the gamut of image capture, manipulation, and display. The first article by S. Kawamura of Olympus describes an example of the system architecture of a consumer digital still camera. The sales of digital still cameras topped two million units in 1997 and should reach four million units at the end of 1998. Industry projections invariably predict sales of about 10 million units by the year 2000.

With the proliferation of digital still cameras, direct digital imaging is fast replacing the scanning of conventional silver-halide photographs as the preferred means to input a still image into a computer. Both consumer and professional use of the digital still camera continues to increase. With most digital still cameras offering instant preview and playback of the captured image, the user is lured by the instant nature of digital capture. Instant preview and playback enable the user to share the picture instantly with others as well as to ensure that the picture taken has the intended effect (and to retake the picture if necessary). The proliferation of the World Wide Web provides a new avenue for distributing photographs. People can conveniently and instantly distribute pictures of weddings and corporate functions to a variety of destinations.

Although Kawamura describes a digital still camera based on conventional charged-coupled device (CCD) technologies, image sensor chips based on CMOS imaging technologies are expected to capture a notable fraction of the application space. *Micro* has already reviewed CMOS imaging technologies (see E. Fossum, "Digital Camera System on a Chip," *IEEE Micro*, May-June 1998, p. 8-15), and we do not repeat it here. The *Proceedings of the International Solid-State Circuits Conference (ISSCC)* provide recent advances in image sensor technologies.

Our next article, by J. Adams, K. Parulski, and K. Spaulding of Kodak, reviews one of the most important aspects of digital image capture—the process of converting the raw captured color pixels into a pleasing image that retains its color fidelity. A mosaic of color filter materials is placed in front of the solid-state imaging chip to encode color information into the pixel response. While each pixel on the chip contains only a single color (red, green, blue, or some combinations of the primary and complementary colors), the final output must present the full tricolor (RGB) information.

Adams and colleagues detail the processes of color filter array interpolation, color calibration, anti-aliasing, infrared rejection, and white-point correction. The article provides an example of how the components of the color-processing chain are assembled in a commercially available digital still camera.

As the use of digital still images proliferates, creators and owners need to protect their rights and be able to authenticate the ownership of digital images. This may become a cornerstone for the wide dissemination and use of digital images. M. Yeung, B.L. Yeo, and M. Holliman of Intel survey the emerging field of digital watermarking for image protection and authentication. We expect that digital watermarking will become a standard feature

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in all future image capture, transmission, and viewing technologies.

Finally, image display is an indispensable link in the chain from image capture to user. P. Alt of IBM provides an overview of display technologies with an emphasis on the consumer application arena. While there are a variety of display technologies, it is most informative to examine the display phase space in a plot of pixel count versus image diagonal, as the article shows. Recent display prototypes have begun to reach into the limiting resolution of the human visual system. Alt describes displays for small, handheld gadgets; head-mounted displays; large projection displays; and typical flat-panel, active-matrix amorphous silicon, thin-film-transistor liquid crystal displays (AMLCDs). He points out that there are no technology barriers for a device that combines a camera, an image processor, and a display with photographic quality in a shirt-pocket-size package.

We thank the authors and many reviewers who spent time writing and reviewing the articles published here. As the application of images in the computer gain increasing importance, we expect to be returning to this theme in the not too distant future, with emphases on other aspects of digital imaging not covered in this special issue. MICRO

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