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A Vision Chip for Color Segmentation and Pattern Matching

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A 128(H) × 64(V) × RGB CMOS imager is integrated with region-of-interest selection, RGB-to-HSI transformation, HSI-based pixel segmentation, (36bins × 12bits)-HSI histogramming, and sum-of-absolute-difference (SAD) template matching. Thirty-two learned color templates are stored and compared to each image. The chip captures the R, G, and B images using in-pixel storage before passing the pixel content to a multiplying digital-to-analog converter (DAC) for white balancing. The DAC can also be used to pipe in images for a PC. The color processing uses a biologically inspired color opponent representation and an analog lookup table to determine the Hue (H) of each pixel. Saturation (S) is computed using a loser-take-all circuit. Intensity (I) is given by the sum of the color components. A histogram of the segments of the image, constructed by counting the number of pixels falling into 36 Hue intervals of 10 degrees, is stored on a chip and compared against the histograms of new segments using SAD comparisons. We demonstrate color-based image segmentation and object recognition with this chip. Running at 30 fps, it uses 1 mW. To our knowledge, this is the first chip that integrates imaging, color segmentation, and color-based object recognition at the focal plane.

Keywords and phrases: focal plane image processing, object recognition, color histogramming, CMOS image sensor, vision chip, VLSI color image processor.

1. INTRODUCTION

CMOS-integrated circuits technology readily allows the incorporation of photodetector arrays and image processing circuits on the same silicon die [1, 2, 3, 4, 5, 6]. This has led to the recent proliferation in cheap and compact digital cameras [7], system-on-a-chip video processors [8, 9], and many other cutting edge commercial and research imaging products. The concept of using CMOS technology for combining sensing and processing was not spearheaded by the imaging community. It actually emerged in mid '80s from the neuromorphic engineering community developed by Mead and collaborators [10, 11]. Mead's motivation was to mimic the information processing capabilities of biological organisms; biology tends to optimize information extraction by introducing processing at the sensing epithelium [12]. This approach to sensory information processing, which was later captured with terms such as "sensory processing" and "computational sensors," produced a myriad vision chips, whose functionality includes edge detection, motion detection, stereopsis, and many others (examples can be found in [13, 14, 15, 16]).

The preponderance of the work on neuromorphic vision has focused on spatiotemporal processing on the intensity of light (gray-scale images) because the intensity can be readily transformed into a voltage or current using basic integrated circuit components: photodiodes, photogates, and phototransistors. These devices are easily implemented in CMOS technologies using no additional lithography layers. On the other hand, color image processing has been limited primarily to the commercial camera arena because three additional masks are required to implement R, G, and B filters [17]. The additional masks make fabrication of color-sensitive photodetection arrays expensive and, therefore, not readily available to researchers. Nonetheless, a large part of human visual perception is based on color information processing. Consequently, neuromorphic vision systems should not ignore this obviously important cue for scene analysis and understanding. This paper addresses this gap in the silicon vision literature by providing perhaps the only integrated large array of color photodetectors and processing chip. Our chip is designed for the recognition of objects based on their color signature.

There has been a limited amount of previous work on neuromorphic color processing. The vast majority of color processing literature addresses standard digital image processing techniques. That is, they consist of a camera that is connected to a frame grabber that contains an analog-to-digital converter (ADC). The ADC interfaces with a digital computer, where software algorithms are executed. Of the few biologically inspired hardware papers, there are clearly two approaches. The first approach uses separate imaging chips and processing chips [18], while the second approach integrates a handful of photodetectors and analog processing circuitry [19]. In the former example, standard cameras are connected directly to analog VLSI chips that demultiplex the video stream and store the pixel values as voltages on arrays of capacitors. Arrays as large as 50×50 pixels have been realized to implement various algorithms for color constancy [18]. As can be expected, the system is large and clumsy, but real-time performance is possible. The second set of chips investigate a particular biologically inspired problem, such as RGB-to-HSI (Hue, saturation, and intensity) conversion using biologically plausible color opponents and HSI-based image segmentation using a very small number of photodetectors and integrated analog VLSI circuits [19]. Clearly, the goal of the latter is to demonstrate a concept and not to develop a practical system for useful image sizes. Our approach follows the latter, however, we also use an architecture and circuitry that allow high-resolution imaging and processing on the same chip. In addition, we include higher-level processing capabilities for image recognition. Hence, our chip can be considered to be a functional model of the early vision, such as the retina and visual area #1 (V1) of the cortex, and higher visual cortical regions, such as the inferotemporal area (IT) of the cortex [20, 21].

2. COLOR SEGMENTATION AND PATTERN MATCHING

In general, color-based image segmentation, object identification, and tracking have many applications in machine vision. Many targets can be easily segmented from their backgrounds using color, and subsequently can be tracked from frame to frame in a video stream. Furthermore, the targets can be *recognized* and tagged using their color signature. Clearly, in the latter case, the environment must be configured such that it cooperates with the segmentation process. That is, the targets can be colored in order to facilitate the recognition process because the recognition of natural objects based solely on color is prone to false positives. Nonetheless, there are many situations where color segmentation can be directly used on natural scenes. For example, people tracking can be done by detecting the presence of skin in the scene. It is remarkable that skin, from the darkest to the lightest individual, can be easily tracked in HSI space, by constructing a model 2D histogram of the Hue (H) and saturation (S) (intensity (I) can be ignored) of skin tone in an image. Skin can be detected in other parts of the image by matching the histograms of these parts against the HS model. Figures 1 and 2 show an example of a general skin tone identification task, implemented in Matlab. Conversely, specific skin tones can be detected in a scene if the histogram is constructed with specific examples. The latter will be demonstrated later using our chip.

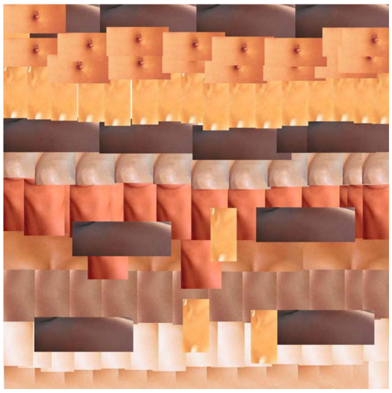
Color imagers, however, provide an RGB color representation. For the above example, a conversion from RGB to HSI is required. There are other benefits of this conversion. The main advantage of the HSI representation stems from the observation that RGB vectors can be completely redirected under additive or multiplicative transformations. Hence, color recognition using RGB can fail under simple conditions such as turning on the light (assume a white source; colored sources manipulate the color components in a more profound way). HS components, however, are invariant under these transformations, and hence are more robust to variations in ambient intensity levels. Equation (1) shows how HSI components are derived from RGB [19, 22]. Notice that H and S are not affected if $R \to \{R + a, aR\}$, $G \to \{G + a, aG\}$, and $B \to \{B + a, aB\}$. In the equation, R, G, and B have been normalized by the intensity, that is, $R/I = r$, $G/I = g$, and $B/I = b$:

$$H = \arctan\left(\frac{\sqrt{3}[g-b]}{2[(r-g)+(r-b)]}\right), \tag{1a}$$

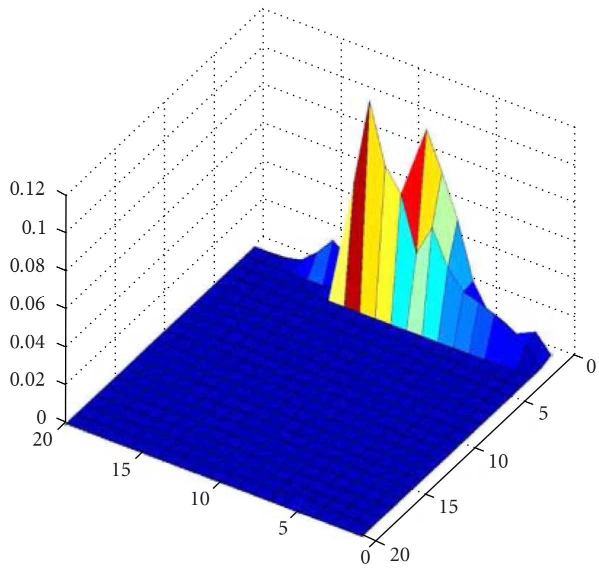
$$S = 1 - 3[\min(r, g, b)], \tag{1b}$$

$$I = R + G + B. \tag{1c}$$

The conversion from RGB to HSI is, however, nonlinear and can be difficult to realize in VLSI because nonlinear functions, such as arctangent, cannot be easily realized with analog circuits. Here, we present an approach for the conversion that is both compact (uses small silicon area) and fast. It is also worth noticing that the HSI conversion uses color opponents ($r-g$, $r-b$, $g-b$). Although we have made no attempt to mimic biological color vision exactly, it is worth noticing that similar color opponents have been identified in biological color processing, suggesting that an HSI representation may also be used by living organisms [19, 20, 21, 23]. Figure 3 shows the color opponent receptive fields of cells in the visual cortex [23]. Figure 4 shows how we implemented



(a)



(b)

FIGURE 1: (a) Examples of skin tones obtained from various individuals with various complexions. (b) The HS histogram model constructed from picture in (a).

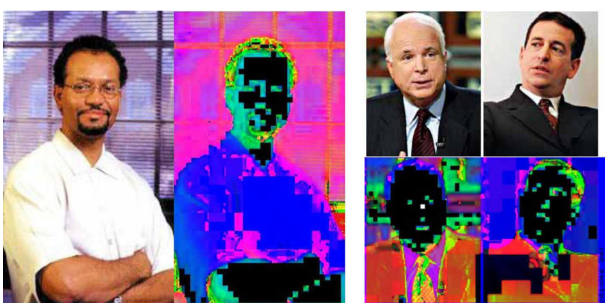


FIGURE 2: Skin tone segmentation using HS histogram model in Figure 1. Black pixels have been identified.

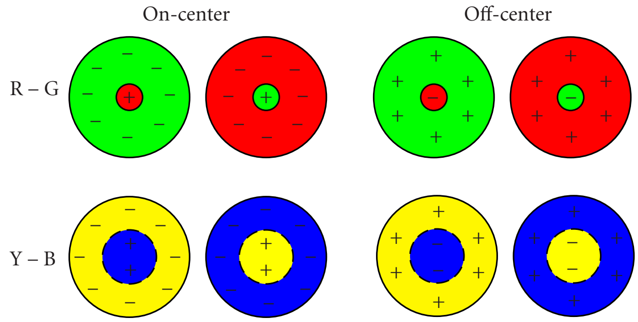


FIGURE 3: Color opponent receptive fields in the visual cortex. Unipolar off- and on-cells of G − B and Y − B are used to construct the HSI representation.

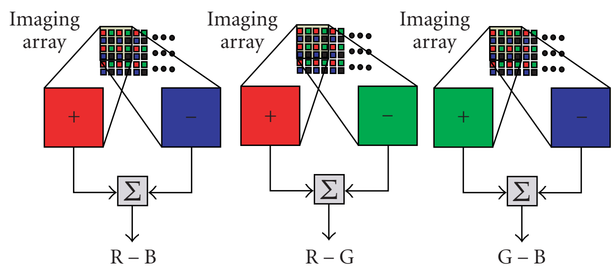


FIGURE 4: Color opponent computation performed by the chip. Bipolar R − B, R − G, and G − B are used to implement the HSI representation in (1).

color opponents on our chip. Using these color opponents, the RGB-to-HSI conversion is realized.

3. CHIP OVERVIEW

We have designed a 128(H) × 64(V) × RGB CMOS imager, which is integrated with analog and digital signal processing circuitry to realize focal plane region-of-interest selection, RGB-to-HSI transformation, HSI-based segmentation, 36-bin HSI histogramming, and sum-of-absolute-difference (SAD) template matching for object recognition. This self-contained color imaging and processing chip, designed as a front-end for microrobotics, toys, and "seeing-eye" computers, learns the identity of objects through their color signature. The signature is composed of a (36bins × 12bits)-HSI histogram template; a minimum intensity and minimum saturation filter is employed before histogramming. The template is stored at the focal plane during a learning step. During the recognition step, newly acquired images are compared to 32 stored templates using the SAD computer. The minimum SAD result indicates the closest match. In addition, the chip can be used to segment color images and identify regions in the scene having particular color characteristics. The location of the matched regions can be used to track objects in the environment. Figure 5 shows a block diagram of the chip. Figure 6 shows a chip layout (the layout is shown

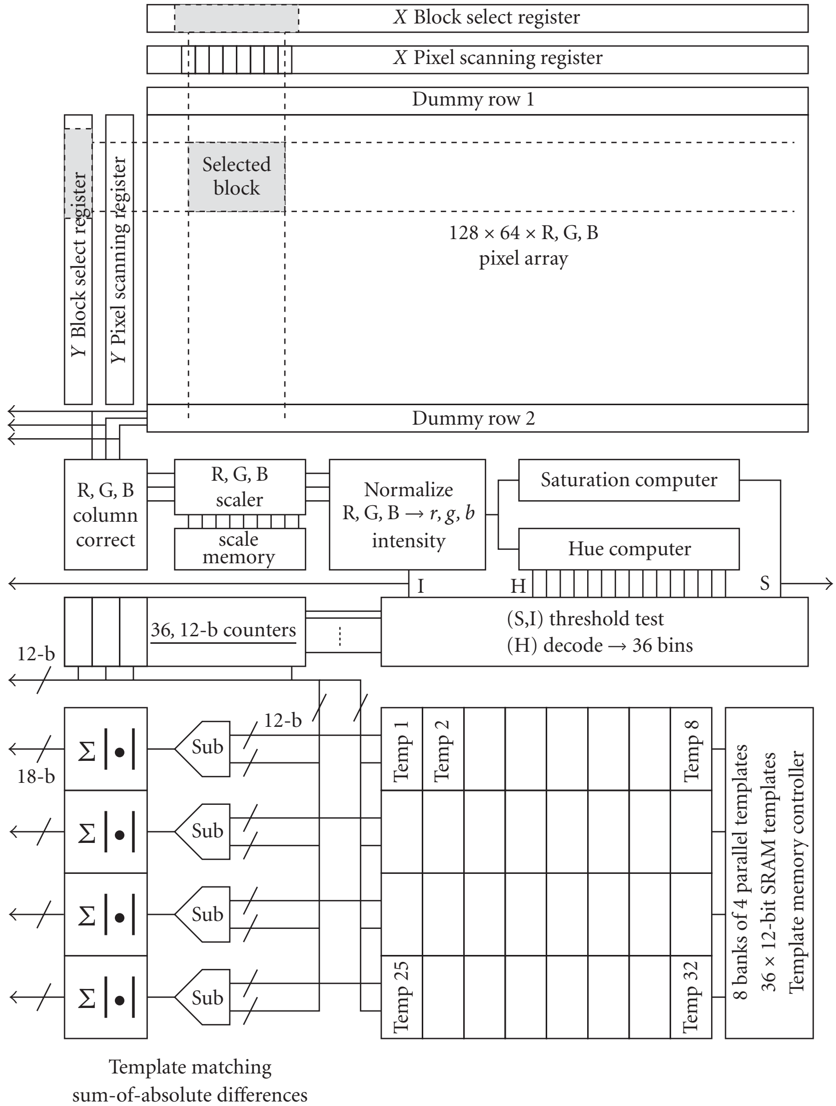


Figure 5: Computational and physical architecture of the chip.

because the light shielding layer obscures the details). To our knowledge, this is the first chip that integrates imaging, color segmentation, and color-based object recognition at the focal plane.

4. HARDWARE IMPLEMENTATION

4.1. CMOS imaging, white equalization, and normalization

In the imager array, three current values, corresponding to R, G, and B, are sampled and held for each pixel. By storing the color components in this way, a color filter wheel can be used instead of integrated color filters. This step allows us to test the algorithms before migrating to an expensive color CMOS process. When a color CMOS process is used, the sample-and-hold circuit in Figure 7 will be removed. An R, G, and B triplet per pixel, obtained from on-chip filters, will then be provided directly to the processing circuit. No change to the scanning or processing circuitry will be required. To facilitate processing, a current mode imaging approach is adopted. It should be noted, however, that current mode imaging is typically noisy. For our targeted application, the noisiness in the image does not pose a problem and the ease of current mode processing is highly desirable. Current mode imaging also provides more than 120 dB of dynamic range [10], allows RGB scaling for white correction using a multiplying DAC and RGB normalization using a translinear circuit [24]. The normalization guarantees that a large dynamic range of RGB currents are resized for the HSI transformer to operate correctly. However, it limits the speed of operation to approximately 30 fps because the transistors must operate in subthreshold.

For readout, the pixels can be grouped into blocks of 1×1 (single pixel) to 128×64 (entire array). The blocks can be advanced across the array in single or multiple pixel intervals.

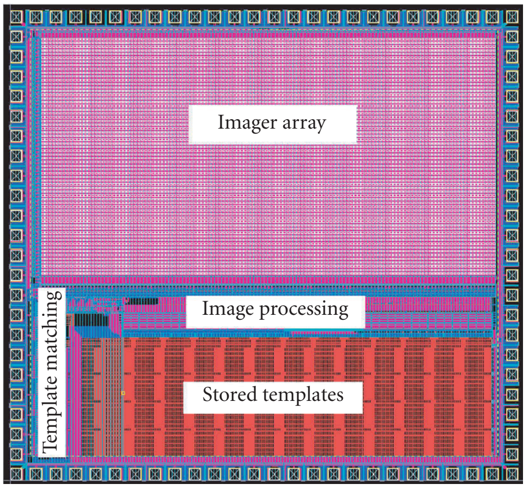
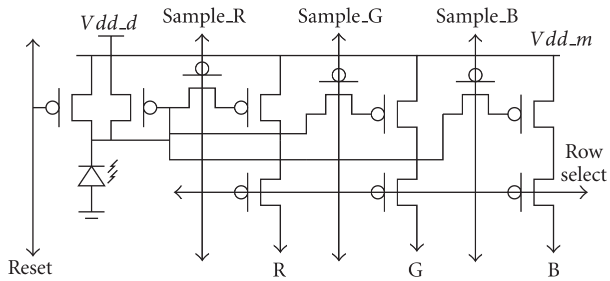
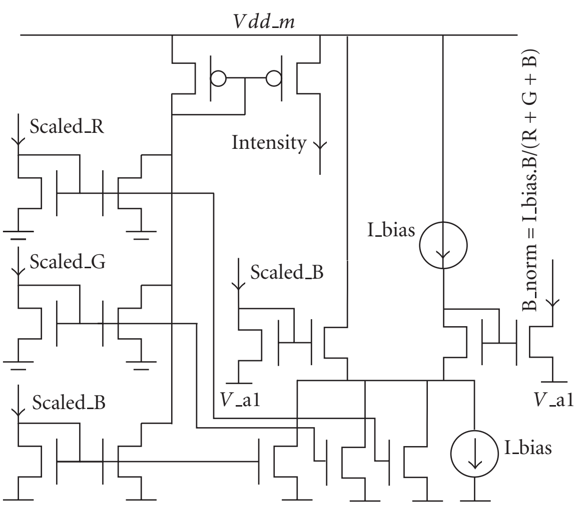


Figure 6: Chip layout (light shield layer obscures all details in micrograph).



(a)



(b)

Figure 7: (a) Schematic of the pixel. (b) Schematic of the normalization circuit.

Each block is a subimage for which an HSI histogram is constructed, and can be used as a learned template or a test template. The organization of the pixels and the scanning methods are programmable by loading bit patterns in two scanning registers, one for scanning pixels within blocks and the other for scanning the blocks across the array.

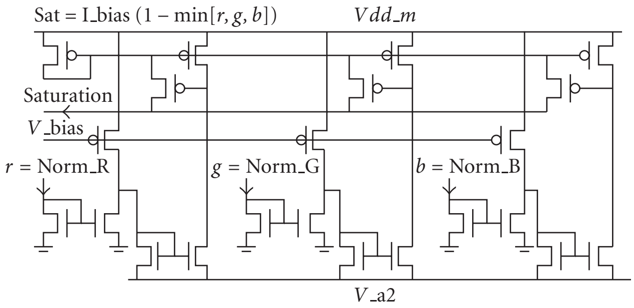
Figure 7 shows the schematic of the pixel and a portion of the RGB normalizer. The output currents of the pixel are amplified using tilted mirrors, where $Vdd\_d < Vdd\_m$. In light intensity for which this array is designed, a logarithmic relationship is obtained between light intensity and output current [25]. Logarithmic transfer functions have also been observed in biological photoreceptors [26]. This relationship has the additional benefit of providing wide dynamic range response. A reset switch is included to accelerate the off-transition of the pixel. Not shown in Figure 7b is the scaling circuit that simply multiplies the RGB components by programmable integer coefficients from 1 to 16. The scaling is used to white balance the image because silicon photodiodes are more sensitive to red light than to blue.

The normalization circuit computes the ratio of each color component to the sum of the three (i.e., intensity) using the translinear circuit in Figure 7b. The circuit uses MOSFETs operating in subthreshold so that the relationship between the gate-to-source voltages and the currents through the devices is logarithmic. Hence, the difference of these voltages provides the logarithm of the ratio of currents. By using the voltage difference as the gate-to-source voltage of another transistor, a current is produced which is proportional to this ratio (i.e., the anti-log is computed). This function is easily implemented with the circuit in Figure 7b, however, because all transistors must operate in subthreshold, that is, with very small currents on the order of $\sim$ 1 nA, the circuit can be slow. Using larger transistors to allow larger bias currents is countered by the increased parasitic capacitance. With a parasitic capacitance of $\sim$ 2fF and a bias current of 1nA, a slew rate of 2 μs/V is obtained, while at 30 fps, the circuit needs a time constant of $\sim 3300/(128 \times 64) = 4\,\mu$s. This circuit limits the speed of the system to a maximum speed of 30 frames per second despite the relatively small size of the array. In future designs, this speed problem will be corrected by using an above threshold "normalization" circuit that may not be as linear as the circuit depicted in Figure 7b.

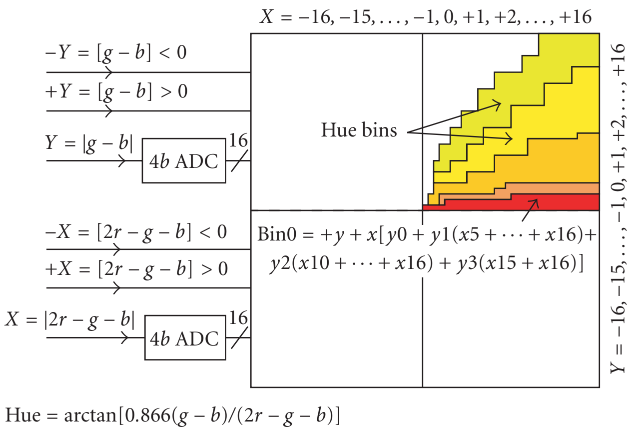
4.2. RGB-to-HSI conversion

The RGB-to-HSI transformer uses an opponent color formulation, reminiscent of biological color processing [19]. The intensity is obtained before normalization by summing the RGB components (see Figure 7b). To compute the saturation of the color, the function in (1b) must be evaluated for each pixel. Since the minimum of the three normalized components must be determined, an analog loser-take-all circuit is used. It is often difficult to implement a loser-take-all, so a winner-take-all is applied to $1-\{r, g, b\}$. The circuit is shown in Figure 8. The base winner-take-all circuit is a classical design presented in [27, 28].

For the determination of the Hue of the RGB values, the function in (1a) must be computed. Since this computation requires an arctangent function, it cannot be easily and compactly implemented in VLSI. Hence, we used a mixed-signal

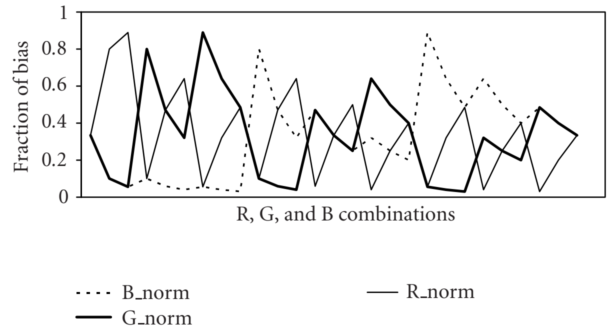


(a)

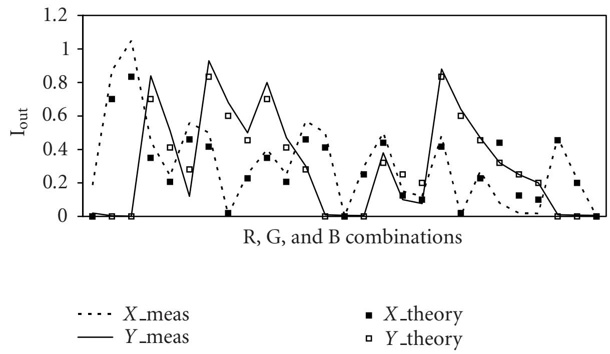


(b)

FIGURE 8: (a) Loser-take-all used for the saturation (S) computation. Actually computes the winner of $1 - \{r, g, b\}$. (b) The Hue (H) mixed-signal lookup table.



(a)



(b)

FIGURE 9: (a) shows the normalized rgb for various values of RGB. (b) shows the color opponents $X = 2\text{R} - \text{G} - \text{B}$ and $Y = \text{G} - \text{B}$.

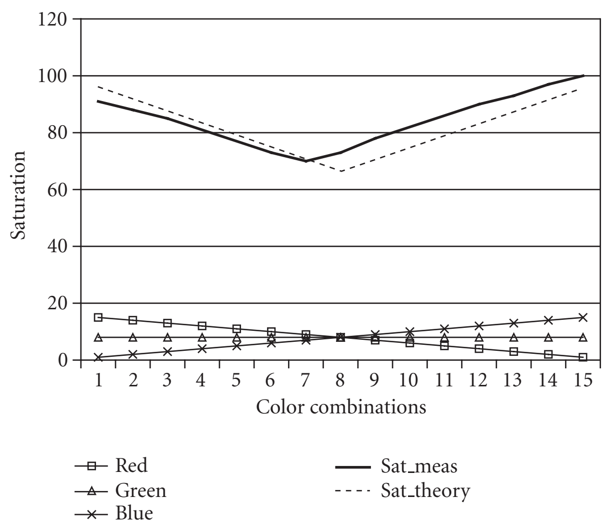


FIGURE 10: Measured saturation (S) as a function of rgb.

lookup table. We use a hybrid circuit that simply correlates the color opponents $(g-b)$, $(r-g)$, and $(r-b)$ to indicate Hue if the intensity and the saturation of the color are above a minimum value. The $(g-b)$ and $(2r-g-b)$ components are each quantized into 16 levels using a 4-bit thermometer code analog-to-digital conversion. The lookup table maps the 16×16 input combinations and the quadrant (as indicated by the two additional sign bits for X and Y) into 36 Hue intervals, each having 10 degrees resolution, to cover the 360 degrees of Hue space. The HSI computation is applied to each normalized RGB value scanned from the array; color segmentation is realized by testing each pixel's HSI values against prescribed values, and the appropriate label is applied to the pixel. Figure 8b shows the block diagram of the Hue computation circuits. Figure 9 shows the measured normalized currents, rgb, and the color opponents $X = |2r - g - b|$ and $Y = |g - b|$. The comparison between theoretical and measured X and Y is also shown. The variations are expected, given the analog circuits implementation. Figure 10 shows the measured relationship between the normalized rgb and the computed saturation. The deviation from the theoretical curve has two components: the difference in slope is due to some nonlinearity in the normalization circuit and a less than unity gain in the saturation circuit's output mirror, while the offset on the right side of the saturation curve is caused by a layout property that reduced Vdd for one part of the circuit. Consequently, the saturation current is higher than expected when the r component is minimum.

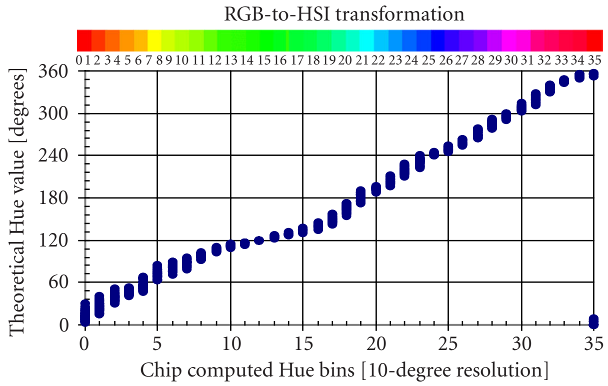
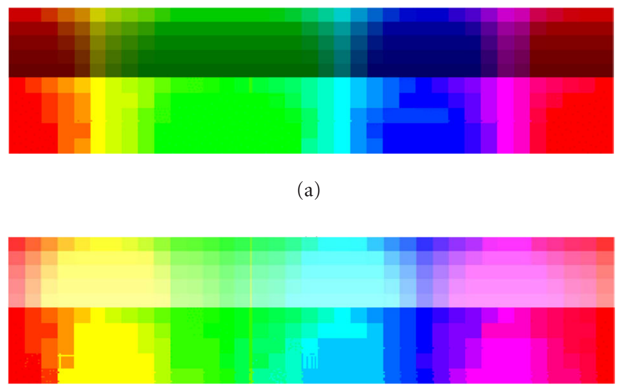


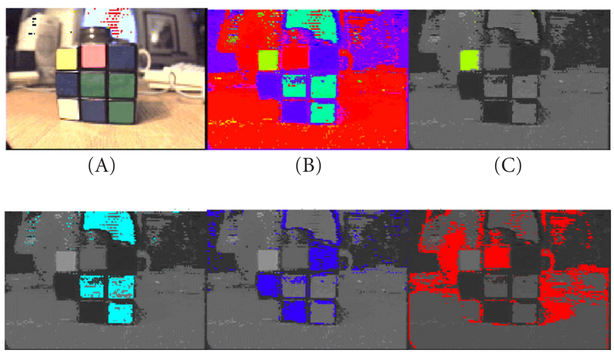
FIGURE 11: Hue (H) bin assignment for various RGB combinations. The color band shows the input.



(a)

(b)

FIGURE 12: (a) Measured RGB to Hue transformation as a function of intensity (multiplicative shift). (b) Measured RGB to Hue transformation as a function of saturation (additive shift).



(A) (B) (C)

(D) (E) (F)

FIGURE 13: Color segmentation on real images. (a) Input image. (b) Complete Hue image. (c) Yellow segment. (d) Cyan segment. (e) Blue segment. (f) One of the red segments.

Figure 11 shows the measured relationship between input Hue angle and bin allocation. The plot is obtained by presenting known values of RGB (i.e., Hue angle) to the chip and recording the Hue bins that are triggered. The presentation is done by using the DAC properties of the RGB scaler circuit (see Figure 5) with input currents fixed. This same strategy is used to present the processing core of the chip with images from a PC, as will be shown below. There are some overlaps in the response ranges of the individual Hue bins because of imprecision in creating the Hue table's input addresses. These addresses are created using a simple current ADC that depends on transistor size, gain, and threshold voltage matching. Despite using common centroid layout techniques, we found that the ADC was monotonic but not completely linear. Notice, however, that the overlaps are desirably restricted to the nearest neighbor bins. The invariance of the Hue computation to intensity and saturation variations is shown in Figure 12. The effects of impression in the Hue lookup are again visible in the figure. Nonetheless, this plot shows that the Hue computation is insensitive to multiplicative (here intensity variations) and additive shifts (here saturation variations), as designed.

Next, we tested the color segmentation properties of the chip using real images piped in from a PC. As indicated above, these images are presented by using the RGB scaler circuit as a current DAC. The image of the Rubik's cube in Figure 13 demonstrates the effectiveness of our chip on an image containing varying levels of lighting. That is, the foreground is well lit, while the background is in the shadows. Furthermore, it shows some of the limitations of "wide" Hue interval assigned to every bin. It shows that portions of the image that are highly desaturated or have low intensity can also have similar Hues to other highly saturated and well-lit parts of the image. Using programmable Hue intervals per bin, the transformation lookup table can easily be modified to have finer resolution in targeted portions of the Hue space so that these "similar" Hues can be disambiguated. The next design of this chip will have this capability.

5. HSI HISTOGRAMMING AND TEMPLATE MATCHING

The HSI histogramming step is performed using 36- and 12-bit counters to measure the number of pixels that fall within each prescribed HSI interval. Here the HSI interval is defined as a minimum intensity value, minimum saturation value, and one of 36 Hue values. In this chip, we count only pixels that pass the intensity and saturation tests. In future versions, we will also count the number of pixels that do not pass the test. Figure 14 shows a block diagram of the histogramming step. After scanning the imager, the counters hold the color signature of the scene or a portion of the scene (based on the block selection circuit described in Section 4.1). During the learning phase, the signature is transferred to one of the 32 on-chip SRAM template cells of 432-bits each. During the matching phase, the newly acquired signatures are compared to the stored templates, using 8 serial presentations of 4 parallel templates. Four parallel SAD cells perform the matching computation. The resultant error for each template is

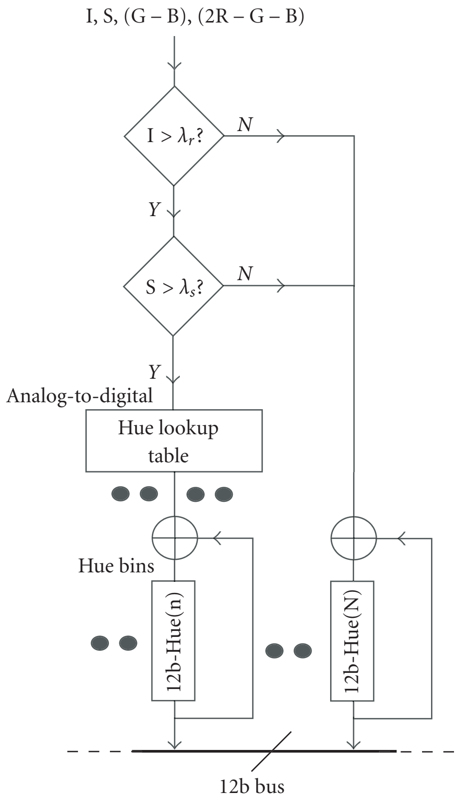


FIGURE 14: Block diagram of HSI histogramming.

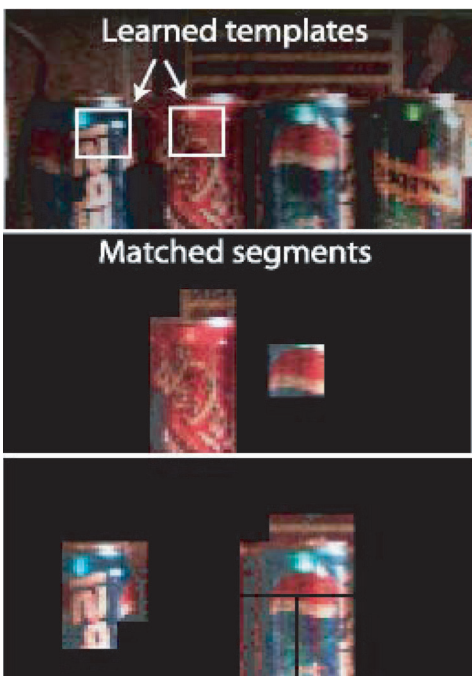


FIGURE 15: Function of the complete chip: images acquired by the array, learned templates, and locations of matches.

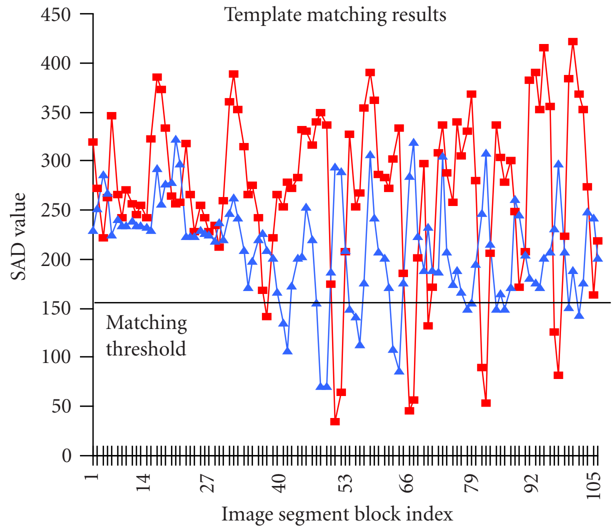


FIGURE 16: SAD template matching outputs. A threshold of 155 is used to identify the objects in Figure 15.

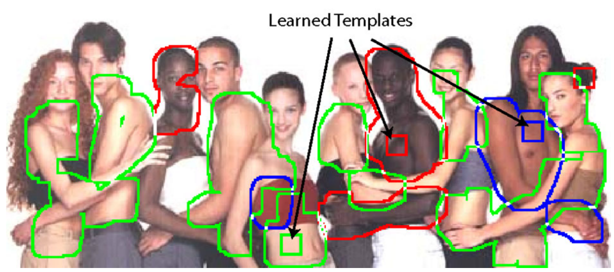


FIGURE 17: Skin tone identification revisited (using the processing core of the chip). The unimodal Hue distribution of skin leads to some misclassifications.

presented off-chip, where they are sorted using a simple microcontroller such as a PIC, to find the best match template. Figure 15 shows the whole chip in action, showing the image acquired by the array and blocks identified as templates for "coke" and "pepsi." Color signatures histograms of the templates constructed, the histograms are stored in the memory and, subsequently, "coke" and "pepsi" are localized in the scene containing multiple cans. The learned segment is 15×15; during matching, the image is scanned in blocks of 15×15, shifted by 8 pixels, for a total of 128 subimages. No scanned block matches the learned block exactly. A plot of the SAD error is shown in Figure 16. Match threshold is set to 155. Notice that the "coke" template also matches part of a pepsi can. This is easily explained by noting that the "coke" only template contains red and white pixels. Hence it matches the part of the pepsi can. On the other hand, the "pepsi" template contains red, white, and blue pixels. Hence it is not well matched to the other cans and only identifies the pepsi cans.

To further illustrate this point, Figures 17 and 18 show matching using templates with varying color content. In

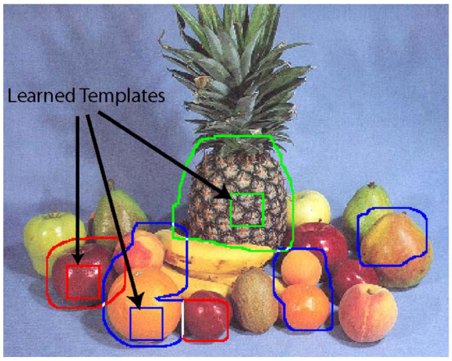


Figure 18: Fruit identification (using the processing core of the chip). The multimodal distribution of the pineapple eliminates misclassifications.

both figures, the images were piped through the processing core of the chip using the RGB scaler circuit as a DAC. In Figure 17, the task is to identify different skin tones by "learning" templates of various complexions. In all the cases, however, the Hue histogram is a unimodal distribution, similar to Figure 1b for constant saturation. Consequently, the template matching process misclassifies clothing for skin because the Hue distributions are similar. This misclassifications also happens for single-colored fruits, as seen in Figure 18. The plums and apples are matched, as are oranges and peaches. On the other hand, the pineapple contains at least two or three bumps in the Hue distribution (blue, green, and yellow). Hence, it can be easily identified and no misclassifications are made. Hence, we can conclude that this method of color-based object identification is more effective when the target is multicolored. This conclusion will be exploited in the applications of this chip. Table 1 gives a summary of the characteristics of this chip.

Table 1: Summary of performance.

Technology	0.5 μm 3M1P CMOS
Array size (R, G, B)	128 (H) $\times$ 64 (V)
Chip area	4.25 mm $\times$ 4.25 mm
Pixel size	24.85 μm $\times$ 24.85 μm
Fill factor	20%
FPN	~ 5%
Dynamic range	> 120 db (current mode)
Region-of-interest size	1 $\times$ 1 to 128 $\times$ 64
Color current scaling	4 bits
Hue bins	36, each 10 degree wide
Saturation	Analog (~ 5 bits) one threshold
Intensity	Analog (~ 5 bits) one threshold
Histogram bin counts	12 bits/bin
Template size	432 bits (12 $\times$ 36 bits)
No. stored template	32 (13.8 kbits SRAM)
Template matching	4 parallel SAD, 18 bits results
Frame rate	Array scan: ~ 2k fps HSI comp: ~ 30 fps
Power consumption	~ 1 mW at 30 fps on 3.3V supplies

6. CONCLUSION

The prototype demonstrates that a real-time color segmentation and recognition system can be implemented in VLSI using a small silicon area and small power budget. We also demonstrate that the HSI representation used in this chip is robust under multiplicative and additive shift in the original RGB components. We demonstrate color segmentation and template matching. Template matching is most effective when the target is composed of multiple colors. This prototype was tested using a color filter wheel, where R, G, and B images are sequentially stored in the pixels array. By using a fabrication technology with RGB filters, the entire system can be realized with a tiny footprint for compact imaging/processing applications.

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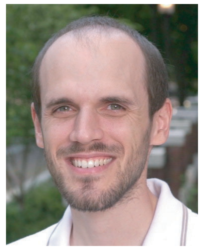

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Special Issue on Advances in Blind Source Separation

Call for Papers

Almost every multichannel measurement includes mixtures of signals from several underlying sources. While the structure of the mixing process may be known to some degree, other unknown parameters are necessary to demix the measured sensor data. The time courses of the source signals and/or their locations in the source space are often unknown a priori and can only be estimated by statistical means. In the analysis of such measurements, it is essential to separate the mixed signals before beginning postprocessing.

Blind source separation (BSS) techniques then allow separation of the source signals from the measured mixtures. Many BSS problems may be solved using independent component analysis (ICA) or alternative approaches such as sparse component analysis (SCA) or nonnegative matrix factorization (NMF), evolving from information theoretical assumptions that the underlying sources are mutually statistically independent, sparse, smooth, and/or nonnegative.

The aim of this special issue is to focus on recent developments in this expanding research area.

The special issue will focus on one hand on theoretical approaches for single- and multichannel BSS, evolving from information theory, and especially on nonlinear blind source separation methods, and on the other hand or their currently ever-widening range of applications such as brain imaging, image coding and processing, dereverberation in noisy environments, and so forth.

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Special Issue on
Tracking in Video Sequences of Crowded Scenes

Call for Papers

Object tracking in live video is an enabling technology that is in strong demand by large application sectors, such as video surveillance for security and behavior analysis, traffic monitoring, sports analysis for enhanced TV broadcasting and coaching, and human body tracking for human-computer interaction and movie special effects.

Many techniques and systems have been developed and demonstrated for tracking objects in video sequences. The specific goal of this special issue is to provide a status report regarding the state of the art in object tracking in crowded scenes based on the video stream(s) of one or more cameras. The objects can be people, animals, cars, and so forth. The cameras can be fixed or moving. Moving cameras may pan, tilt, and zoom in ways that may or may not be communicated to the tracking system.

All papers submitted must address at least the following two issues:

- Processing of live video feeds

For many applications in surveillance/security and TV sports broadcasting, the results of processing have value only if they can be provided to the end user within an application-defined delay. The submitted papers should present algorithms that are plausibly applicable to such incremental ("causal") processing of live video feeds, given suitable hardware.

- Handling of crowded scenes

Crowded-scene situations range from relatively simple (e.g., players on a planar field in a soccer match) to very difficult (e.g., crowds on stairs in an airport or a train station). The central difficulties in crowded scenes arise from the constantly changing occlusions of any number of objects by any number of other objects.

Occlusions can be resolved to some degree using a single video stream. However, many situations of occlusion are more readily resolved by the simultaneous use of several cameras separated by wide baselines. In addition to resolving ambiguities, multiple cameras also ease the exploitation of 3D structure, which can be important for trajectory estimation or event detection.

Topics of interest include principles and evaluation of relevant end-to-end systems or important components thereof, including (but not limited to):

- Handling of occlusions in the image plane in single-camera scenarios
- Handling of occlusions in a world coordinate system (3D, possibly degenerated to 2D) in single- or multi-camera scenarios
- Fusion of information from multiple cameras and construction of integrated spatiotemporal models of dynamic scenes
- 3D trajectory estimation
- Tracking of multiple rigid, articulated, or nonrigid objects
- Automatic recovery of camera pose from track data
- Detection and recognition of events involving multiple objects (e.g., offside in soccer)

Papers must present a thorough evaluation of the performance of the system or method(s) proposed in one or more application areas such as video surveillance, security, sports analysis, behavior analysis, or traffic monitoring.

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Special Issue on

Advances in Subspace-Based Techniques for Signal Processing and Communications

Call for Papers

Subspace-based techniques have been studied extensively over the past two decades and have proven to be very powerful for estimation and detection tasks in many signal processing and communications applications. Such techniques were initially investigated in the context of super-resolution parametric spectral analysis and the related problem of direction finding. During the past decade or so, new potential applications have emerged, and subspace methods have been proposed in several diverse fields such as smart antennas, sensor arrays, system identification, time delay estimation, blind channel estimation, image segmentation, speech enhancement, learning systems, and so forth.

Subspace-based methods not only provide new insight into the problem under investigation but they also offer a good trade-off between achieved performance and computational complexity. In most cases they can be considered as low cost alternatives to computationally intensive maximum likelihood approaches.

The interest of the signal processing community in subspace-based schemes remains strong as is evident from the numerous articles and reports published in this area each year. Research efforts are currently focusing on the development of low-complexity adaptive implementations and their efficient use in applications, numerical stability, convergence analysis, and so forth.

The goal of this special issue is to present state-of-the-art subspace techniques for modern applications and to address theoretical and implementation issues concerning this useful methodology.

Topics of interest include (but are not limited to):

- Efficient and stable subspace estimation and tracking methods
- Subspace-based detection techniques
- Sensor array signal processing
- Smart antennas
- Space-time, multiuser, multicarrier communications
- System identification and blind channel estimation
- State-space model estimation and change detection
- Learning and classification
- Speech processing (enhancement, recognition)
- Biomedical signal processing
- Image processing (face recognition, compression, restoration)

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EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on Image Perception

Call for Papers

Perception is a complex process that involves brain activities at different levels. The availability of models for the representation and interpretation of the sensory information opens up new research avenues that cut across neuroscience, imaging, information engineering, and modern robotics.

The goal of the multidisciplinary field of perceptual signal processing is to identify the features of the stimuli that determine their "perception," namely "a single unified awareness derived from sensory processes while a stimulus is present," and to derive associated computational models that can be generalized.

In the case of vision, the stimuli go through a complex analysis chain along the so-called "visual pathway," starting with the encoding by the photoreceptors in the retina (low-level processing) and ending with cognitive mechanisms (high-level processes) that depend on the task being performed.

Accordingly, low-level models are concerned with image "representation" and aim at emulating the way the visual stimulus is encoded by the early stages of the visual system as well as capturing the varying sensitivity to the features of the input stimuli; high-level models are related to image "interpretation" and allow to predict the performance of a human observer in a given predefined task.

A global model, accounting for both such bottom-up and top-down approaches, would enable the automatic interpretation of the visual stimuli based on both their low-level features and their semantic content.

Among the main image processing fields that would take advantage of such models are feature extraction, content-based image description and retrieval, model-based coding, and the emergent domain of medical image perception.

The goal of this special issue is to provide original contributions in the field of image perception and modeling.

Topics of interest include (but are not limited to):

- Perceptually plausible mathematical bases for the representation of visual information (static and dynamic)
- Modeling nonlinear processes (masking, facilitation) and their exploitation in the imaging field (compression, enhancement, and restoration)
- Beyond early vision: investigating the pertinence and potential of cognitive models (feature extraction, image quality)
- Stochastic properties of complex natural scenes (static, dynamic, colored) and their relationships with perception
- Perception-based models for natural (static and dynamic) textures. Theoretical formulation and psychophysical validation
- Applications in the field of biomedical imaging (medical image perception)

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Special Issue on Music Information Retrieval Based on Signal Processing

Call for Papers

The main focus of this special issue is on the application of digital signal processing techniques for music information retrieval (MIR). MIR is an emerging and exciting area of research that seeks to solve a wide variety of problems dealing with preserving, analyzing, indexing, searching, and accessing large collections of digitized music. There are also strong interests in this field of research from music libraries and the recording industry as they move towards digital music distribution. The demands from the general public for easy access to these music libraries challenge researchers to create tools and algorithms that are robust, small, and fast.

Music is represented in either encoded audio waveforms (CD audio, MP3, etc.) or symbolic forms (musical score, MIDI, etc.). Audio representations, in particular, require robust signal processing techniques for many applications of MIR since meaningful descriptions need to be extracted from audio signals in which sounds from multiple instruments and vocals are often mixed together. Researchers in MIR are therefore developing a wide range of new methods based on statistical pattern recognition, classification, and machine learning techniques such as the Hidden Markov Model (HMM), maximum likelihood estimation, and Bayes estimation as well as digital signal processing techniques such as Fourier and Wavelet transforms, adaptive filtering, and source-filter models. New music interface and query systems leveraging such methods are also important for end users to benefit from MIR research.

Although research contributions on MIR have been published at various conferences in 1990s, the members of the MIR research community meet annually at the International Conference on Music Information Retrieval (ISMIR) since 2000.

Topics of interest include (but are not limited to):

- Automatic summarization (succinct representation of music)
- Automatic transcription (audio to symbolic format conversion)
- Music annotation (semantic analysis)
- Music fingerprinting (unique identification of music)
- Music interface
- Music similarity metrics (comparison)
- Music understanding
- Musical feature extraction
- Musical styles and genres
- Optical music score recognition (image to symbolic format conversion)
- Performer/artist identification
- Query systems
- Timbre/instrument recognition

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Special Issue on Visual Sensor Networks

Call for Papers

Research into the design, development, and deployment of networked sensing devices for high-level inference and surveillance of the physical environment has grown tremendously in the last few years.

This trend has been motivated, in part, by recent technological advances in electronics, communication networking, and signal processing.

Sensor networks are commonly comprised of lightweight distributed sensor nodes such as low-cost video cameras. There is inherent redundancy in the number of nodes deployed and corresponding networking topology. Operation of the network requires autonomous peer-based collaboration amongst the nodes and intermediate data-centric processing amongst local sensors. The intermediate processing known as in-network processing is application-specific. Often, the sensors are untethered so that they must communicate wirelessly and be battery-powered. Initial focus was placed on the design of sensor networks in which scalar phenomena such as temperature, pressure, or humidity were measured.

It is envisioned that much societal use of sensor networks will also be based on employing content-rich vision-based sensors. The volume of data collected as well as the sophistication of the necessary in-network stream content processing provide a diverse set of challenges in comparison with generic scalar sensor network research.

Applications that will be facilitated through the development of visual sensor networking technology include automatic tracking, monitoring and signaling of intruders within a physical area, assisted living for the elderly or physically disabled, environmental monitoring, and command and control of unmanned vehicles.

Many current video-based surveillance systems have centralized architectures that collect all visual data at a central location for storage or real-time interpretation by a human operator. The use of distributed processing for automated event detection would significantly alleviate mundane or time-critical activities performed by human operators, and provide better network scalability. Thus, it is expected that video surveillance solutions of the future will successfully utilize visual sensor networking technologies.

Given that the field of visual sensor networking is still in its infancy, it is critical that researchers from the diverse disciplines including signal processing, communications, and electronics address the many challenges of this emerging field. This special issue aims to bring together a diverse set of research results that are essential for the development of robust and practical visual sensor networks.

Topics of interest include (but are not limited to):

- Sensor network architectures for high-bandwidth vision applications
- Communication networking protocols specific to visual sensor networks
- Scalability, reliability, and modeling issues of visual sensor networks
- Distributed computer vision and aggregation algorithms for low-power surveillance applications
- Fusion of information from visual and other modalities of sensors
- Storage and retrieval of sensor information
- Security issues for visual sensor networks
- Visual sensor network testbed research
- Novel applications of visual sensor networks
- Design of visual sensors

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EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on Multirate Systems and Applications

Call for Papers

Filter banks for the application of subband coding of speech were introduced in the 1970s. Since then, filter banks and multirate systems have been studied extensively. There has been great success in applying multirate systems to many applications. The most notable of these applications include subband coding for audio, image, and video, signal analysis and representation using wavelets, subband denoising, and so forth. Different applications also call for different filter bank designs and the topic of designing one-dimensional and multidimentional filter banks for specific applications has been of great interest.

Recently there has been growing interest in applying multirate theories to the area of communication systems such as, transmultiplexers, filter bank transceivers, blind deconvolution, and precoded systems. There are strikingly many dualities and similarities between multirate systems and multicarrier communication systems. Many problems in multicarrier transmission can be solved by extending results from multirate systems and filter banks. This exciting research area is one that is of increasing importance.

The aim of this special issue is to bring forward recent developments on filter banks and the ever-expanding area of applications of multirate systems.

Topics of interest include (but are not limited to):

- Multirate signal processing for communications
- Filter bank transceivers
- One-dimensional and multidimensional filter bank designs for specific applications
- Denoising
- Adaptive filtering
- Subband coding
- Audio, image, and video compression
- Signal analysis and representation
- Feature extraction and classification
- Other applications

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Special Issue on

Multisensor Processing for Signal Extraction and Applications

Call for Papers

Source signal extraction from heterogeneous measurements has a wide range of applications in many scientific and technological fields, for example, telecommunications, speech and acoustic signal processing, and biomedical pattern analysis. Multiple signal reception through multisensor systems has become an effective means for signal extraction due to its superior performance over the monosensor mode. Despite the rapid progress made in multisensor-based techniques in the past few decades, they continue to evolve as key technologies in modern wireless communications and biomedical signal processing. This has led to an increased focus by the signal processing community on the advanced multisensor-based techniques which can offer robust high-quality signal extraction under realistic assumptions and with minimal computational complexity. However, many challenging tasks remain unresolved and merit further rigorous studies. Major efforts in developing advanced multisensor-based techniques may include high-quality signal extraction, realistic theoretical modeling of real-world problems, algorithm complexity reduction, and efficient real-time implementation.

The purpose of this special issue aims to present state-of-the-art multisensor signal extraction techniques and applications. Contributions in theoretical study, performance analysis, complexity reduction, computational advances, and real-world applications are strongly encouraged.

Topics of interest include (but are not limited to):

- Multiantenna processing for radio signal extraction
- Multimicrophone speech recognition and enhancement
- Multisensor radar, sonar, navigation, and biomedical signal processing
- Blind techniques for multisensor signal extraction
- Computational advances in multisensor processing

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Special Issue on

Search and Retrieval of 3D Content and Associated Knowledge Extraction and Propagation

Call for Papers

With the general availability of 3D digitizers, scanners, and the technology innovation in 3D graphics and computational equipment, large collections of 3D graphical models can be readily built up for different applications (e.g., in CAD/CAM, games design, computer animations, manufacturing and molecular biology). For such large databases, the method whereby 3D models are sought merits careful consideration. The simple and efficient query-by-content approach has, up to now, been almost universally adopted in the literature. Any such method, however, must first deal with the proper positioning of the 3D models. The two prevalent-in-the-literature methods for the solution to this problem seek either

- Pose Normalization: Models are first placed into a canonical coordinate frame (normalizing for translation, scaling, and rotation). Then, the best measure of similarity is found by comparing the extracted feature vectors, or
- Descriptor Invariance: Models are described in a transformation invariant manner, so that any transformation of a model will be described in the same way, and the best measure of similarity is obtained at any transformation.

The existing 3D retrieval systems allow the user to perform queries by example. The queried 3D model is then processed, low-level geometrical features are extracted, and similar objects are retrieved from a local database. A shortcoming of the methods that have been proposed so far regarding the 3D object retrieval, is that neither is the semantic information (high-level features) attached to the (low-level) geometric features of the 3D content, nor are the personalization options taken into account, which would significantly improve the retrieved results. Moreover, few systems exist so far to take into account *annotation* and *relevance feedback* techniques, which are very popular among the corresponding content-based image retrieval systems (CBIR).

Most existing CBIR systems using knowledge either annotate all the objects in the database (full annotation) or annotate a subset of the database manually selected (partial annotation). As the database becomes larger, full annotation is increasingly difficult because of the manual effort needed. Partial annotation is relatively affordable and trims down the heavy manual labor. Once the database is partially annotated, traditional image analysis methods are used to derive semantics of the objects not yet annotated. However, it is not clear "how much" annotation is sufficient for a specific database and what the best subset of objects to annotate is. In other words how the knowledge *will be propagated*. Such techniques have not been presented so far regarding the 3D case.

Relevance feedback was first proposed as an interactive tool in text-based retrieval. Since then it has been proven to be a powerful tool and has become a major focus of research in the area of content-based search and retrieval. In the traditional computer centric approaches, which have been proposed so far, the "best" representations and weights are fixed and they cannot effectively model high-level concepts and user's perception subjectivity. In order to overcome these limitations of the computer centric approach, techniques based on *relevant feedback*, in which the human and computer interact to refine high-level queries to representations based on low-level features, should be developed.

The aim of this special issue is to focus on recent developments in this expanding research area. The special issue will focus on novel approaches in 3D object retrieval, transforms and methods for efficient geometric feature extraction, annotation and relevance feedback techniques, knowledge propagation (e.g., using Bayesian networks), and their combinations so as to produce a single, powerful, and dominant solution.

Topics of interest include (but are not limited to):

- 3D content-based search and retrieval methods (volume/surface-based)
- Partial matching of 3D objects
- Rotation invariant feature extraction methods for 3D objects

- Graph-based and topology-based methods
- 3D data and knowledge representation
- Semantic and knowledge propagation over heterogeneous metadata types
- Annotation and relevance feedback techniques for 3D objects

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EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING

Special Issue on Robust Speech Recognition

Call for Papers

Robustness can be defined as the ability of a system to maintain performance or degrade gracefully when exposed to conditions not well represented in the data used to develop the system. In automatic speech recognition (ASR), systems must be robust to many forms of signal degradation, including speaker characteristics (e.g., dialect and accent), ambient environment (e.g., cellular telephony), transmission channel (e.g., voice over IP), and language (e.g., new words, dialect switching). Robust ASR systems, which have been under development for the past 35 years, have made great progress over the years closing the gap between performance on pristine research tasks and noisy operational data.

However, in recent years, demand is emerging for a new class of systems that tolerate extreme and unpredictable variations in operating conditions. For example, in a cellular telephony environment, there are many nonstationary forms of noise (e.g., multiple speakers) and significant variations in microphone type, position, and placement. Harsh ambient conditions typical in automotive and mobile applications pose similar challenges. Development of systems in a language or dialect for which there is limited or no training data in a target language has become a critical issue for a new generation of voice mining applications. The existence of multiple conditions in a single stream, a situation common to broadcast news applications, and that often involves unpredictable changes in speaker, topic, dialect, or language, is another form of robustness that has gained attention in recent years.

Statistical methods have dominated the field since the early 1980s. Such systems tend to excel at learning the characteristics of large databases that represent good models of the operational conditions and do not generalize well to new environments.

This special issue will focus on recent developments in this key research area. Topics of interest include (but are not limited to):

- Channel and microphone normalization
- Stationary and nonstationary noise modeling, compensation, and/or rejection
- Localization and separation of sound sources (including speaker segregation)
- Signal processing and feature extraction for applications involving hands-free microphones
- Noise robust speech modeling
- Adaptive training techniques
- Rapid adaptation and learning
- Integration of confidence scoring, metadata, and other alternative information sources
- Audio-visual fusion
- Assessment relative to human performance
- Machine learning algorithms for robustness
- Transmission robustness
- Pronunciation modeling

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EURASIP JOURNAL ON EMBEDDED SYSTEMS

Special Issue on

Signal Processing with High Complexity: Prototyping and Industrial Design

Call for Papers

Some modern applications require an extraordinary large amount of complexity in signal processing algorithms. For example, the 3rd generation of wireless cellular systems is expected to require 1000 times more complexity when compared to its 2nd generation predecessors, and future 3GPP standards will aim for even more number-crunching applications. Video and multimedia applications do not only drive the complexity to new peaks in wired and wireless systems but also in personal and home devices. Also in acoustics, modern hearing aids or algorithms for de-reverberation of rooms, blind source separation, and multichannel echo cancelation are complexity hungry. At the same time, the anticipated products also put on additional constraints like size and power consumption when mobile and thus battery powered. Furthermore, due to new developments in electroacoustic transducer design, it is possible to design very small and effective loudspeakers. Unfortunately, the linearity assumption does not hold any more for this kind of loudspeakers, leading to computationally demanding nonlinear cancelation and equalization algorithms.

Since standard design techniques would either consume too much time or do not result in solutions satisfying all constraints, more efficient development techniques are required to speed up this crucial phase. In general, such developments are rather expensive due to the required extraordinary high complexity. Thus, de-risking of a future product based on rapid prototyping is often an alternative approach. However, since prototyping would delay the development, it often makes only sense when it is well embedded in the product design process. Rapid prototyping has thus evolved by applying new design techniques more suitable to support a quick time to market requirement.

This special issue focuses on new development methods for applications with high complexity in signal processing and on showing the improved design obtained by such methods. Examples of such methods are virtual prototyping, HW/SW partitioning, automatic design flows, float to fix conversions, automatic testing and verification, and power aware designs.

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Special Issue on Field-Programmable Gate Arrays in Embedded Systems

Call for Papers

Field-Programmable Gate Arrays (FPGAs) are increasingly used in embedded systems to achieve high performance in a compact area. FPGAs are particularly well suited to processing data straight from sensors in embedded systems. More importantly, the reconfigurable aspects of FPGAs give the circuits the versatility to change their functionality based on processing requirements for different phases of an application, and for deploying new functionality.

Modern FPGAs integrate many different resources on a single chip. Embedded processors (both hard and soft cores), multipliers, RAM blocks, and DSP units are all available along with reconfigurable logic. Applications can use these heterogeneous resources to integrate several different functions on a single piece of silicon. This makes FPGAs particularly well suited to embedded applications.

This special issue focuses on applications that clearly show the benefit of using FPGAs in embedded applications, as well as on design tools that enable such applications. Specific topics of interest include the use of reconfiguration in embedded applications, hardware/software codesign targeting FPGAs, power-aware FPGA design, design environments for FPGAs, system signalling and protocols used by FPGAs in embedded environments, and system-level design targeting modern FPGA's heterogeneous resources.

Papers on other applicable topics will also be considered. All papers should address FPGA-based systems that are appropriate for embedded applications. Papers on subjects outside of this scope (i.e., not suitable for embedded applications) will not be considered.

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EURASIP JOURNAL ON EMBEDDED SYSTEMS

Special Issue on Formal Methods for GALS Design

Call for Papers

As chips grow in speed and complexity, global control of an entire chip using a single clock is becoming increasingly challenging. In the future, multicore and large-scale systems-on-chip (SoC) designs are therefore likely to be composed of several timing domains.

Global Asynchrony and Local Synchrony (GALS) is emerging as the paradigm of choice for SoC design with multiple timing domains. In GALS systems, each timing domain is locally clocked, and asynchronous communication schemes are used to glue all of the domains together. Thus, unlike purely asynchronous design, GALS design is able to make use of the significant industrial investment in synchronous design tools.

There is an urgent need for the development of sound models and formal methods for GALS systems. In synchronous designs, formal methods and design automation have played an enabling role in the continuing quest for chips with ever greater complexity. Due to the inherent subtleties of the asynchronous circuit design, formal methods are likely to be vital to the success of the GALS paradigm.

We invite original articles for a special issue of the journal to be published in 2006. Articles may cover every aspect related to formal modeling and formal methods for GALS systems and/or target any type of embedded applications and/or architectures combining synchronous and asynchronous notions of timing:

- Formal design and synthesis techniques for GALS systems
- Design and architectural transformations and equivalences
- Formal verification of GALS systems
- Formal methods for analysis of GALS systems
- Hardware compilation of GALS system
- Latency-insensitive synchronous systems
- Mixed synchronous-asynchronous systems
- Synchronous/asynchronous interaction at different levels
- Clocking, interconnect, and interface issues in deep-submicron design
- Modeling of interfaces between multiple timing domains
- System decomposition into GALS systems
- Formal aspects of system-on-chip (SoC) and network-on-chip (NoC) designs
- Motivating case studies, comparisons, and applications

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EURASIP JOURNAL ON EMBEDDED SYSTEMS

Special Issue on Synchronous Paradigm in Embedded Systems

Call for Papers

Synchronous languages were introduced in the 1980s for programming reactive systems. Such systems are characterized by their continuous reaction to their environment, at a speed determined by the latter. Reactive systems include embedded control software and hardware. Synchronous languages have recently seen a tremendous interest from leading companies developing automatic control software and hardware for critical applications. Industrial success stories have been achieved by Schneider Electric, Airbus, Dassault Aviation, Snecma, MBDA, Arm, ST Microelectronics, Texas Instruments, Freescale, Intel .... The key advantage outlined by these companies resides in the rigorous mathematical semantics provided by the synchronous approach that allows system designers to develop critical software and hardware in a faster and safer way.

Indeed, an important feature of synchronous paradigm is that the tools and environments supporting development of synchronous programs are based upon a formal mathematical model defined by the semantics of the languages. The compilation involves the construction of these formal models, and their analysis for static properties, their optimization, the synthesis of executable sequential implementations, and the automated distribution of programs. It can also build a model of the dynamical behaviors, in the form of a transition system, upon which is based the analysis of dynamical properties, for example, through model-checking-based verification, or discrete controller synthesis. Hence, synchronous programming is at the crossroads of many approaches in compilation, formal analysis and verification techniques, and software or hardware implementations generation.

We invite original papers for a special issue of the journal to be published in the first quarter of 2007. Papers may be submitted on all aspects of the synchronous paradigm for embedded systems, including theory and applications. Some sample topics are:

- Synchronous languages design and compiling
- Novel application and implementation of synchronous languages
- Applications of synchronous design methods to embedded systems (hardware or software)
- Formal modeling, formal verification, controller synthesis, and abstract interpretation with synchronous-based tools
- Combining synchrony and asynchrony for embedded system design and, in particular, globally asynchronous and locally synchronous systems
- The role of synchronous models of computations in heterogeneous modeling
- The use of synchronous modeling techniques in model-driven design environment
- Design of distributed control systems using the synchronous paradigm

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Special Issue on

Embedded Systems for Portable and Mobile Video Platforms

Call for Papers

Video coding systems have been assuming an increasingly important role in application areas other than the traditional video broadcast and storage scenarios. Several new applications have emerged focusing on personal communications (such as video-conferencing), wireless multimedia, remote video-surveillance, and emergency systems. As a result, a number of new video compression standards have emerged addressing the requirements of these kinds of applications in terms of image quality and bandwidth. For example, the ISO/MPEG and ITU standardization bodies have recently jointly established the new AVC/H.264 video coding standard.

In such a wide range of applications scenarios, there is the need to adapt the video processing in general, and in particular video coding/decoding, to the restrictions imposed by both the applications themselves and the terminal devices. This problem is even more important for portable and battery-supplied devices, in which low-power considerations are important limiting constraints. Examples of such application requirements are currently found in 3G mobile phones, CMOS cameras and tele-assistance technologies for elderly/disabled people.

Therefore, the development of new power-efficient encoding algorithms and architectures suitable for mobile and battery-supplied devices is fundamental to enabling the widespread deployment of multimedia applications on portable and mobile video platforms. This special issue is focused on the design and development of embedded systems for portable and mobile video platforms. Topics of interest cover all aspects of this type of embedded system, including, not only algorithms, architectures, and specific SoC design methods, but also more technological aspects related to wireless-channels, power-efficient optimizations and implementations, such as encoding strategies, data flow optimizations, special coprocessors, arithmetic units, and electronic circuits.

Papers suitable for publication in this special issue must describe high-quality, original, unpublished research. Prospective authors are invited to submit manuscripts on topics including but not limited to:

- Power-efficient algorithms and architectures for motion estimation, discrete transforms (e.g., SA-DCT, WT), integer transforms, and entropy coding
- Architectural paradigms for portable multimedia systems
- Low-power techniques and circuits, memory, and data flow optimizations for video coding
- Adaptive algorithms and generic configurable architectures for exploiting intrinsic characteristics of image sequences and video devices
- Aspects specifically important for portable and mobile video platforms, such as video transcoding, video processing in the compressed domain, and error resilience (e.g., MDC)
- Ultra-low-power embedded systems for video processing and coding
- Heterogeneous architectures, multithreading, MPSoC, NoC implementations
- Design space exploration tools, performance evaluation tools, coding efficiency and complexity analysis tools for video coding in embedded systems

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NEWS RELEASE

Nominations Invited for the Institute of Acoustics 2006 A B Wood Medal

The Institute of Acoustics, the UK's leading professional body for those working in acoustics, noise and vibration, is inviting nominations for its prestigious A B Wood Medal for the year 2006.

The A B Wood Medal and prize is presented to an individual, usually under the age of 35, for distinguished contributions to the application of underwater acoustics. The award is made annually, in even numbered years to a person from Europe and in odd numbered years to someone from the USA/Canada. The 2005 Medal was awarded to Dr A Thode from the USA for his innovative, interdisciplinary research in ocean and marine mammal acoustics.

Nominations should consist of the candidate's CV, clearly identifying peer reviewed publications, and a letter of endorsement from the nominator identifying the contribution the candidate has made to underwater acoustics. In addition, there should be a further reference from a person involved in underwater acoustics and not closely associated with the candidate. Nominees should be citizens of a European Union country for the 2006 Medal. Nominations should be marked confidential and addressed to the President of the Institute of Acoustics at 77A St Peter's Street, St. Albans, Herts, AL1 3BN. The deadline for receipt of nominations is **15 October 2005**.

Dr Tony Jones, President of the Institute of Acoustics, comments, "A B Wood was a modest man who took delight in helping his younger colleagues. It is therefore appropriate that this prestigious award should be designed to recognise the contributions of young acousticians."

Further information and an nomination form can be found on the Institute's website at www.ioa.org.uk.

A B Wood

Albert Beaumont Wood was born in Yorkshire in 1890 and graduated from Manchester University in 1912. He became one of the first two research scientists at the Admiralty to work on antisubmarine defence. He designed the first directional hydrophone and was well known for the many contributions he made to the science of underwater acoustics and for the help he gave to younger colleagues. The medal was instituted after his death by his many friends on both sides of the Atlantic and was administered by the Institute of Physics until the formation of the Institute of Acoustics in 1974.

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EDITORS NOTES

The Institute of Acoustics is the UK's professional body for those working in acoustics, noise and vibration. It was formed in 1974 from the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society (a daughter society of the Institution of Mechanical Engineers). The Institute of Acoustics is a nominated body of the Engineering Council, offering registration at Chartered and Incorporated Engineer levels.

The Institute has some 2500 members from a rich diversity of backgrounds, with engineers, scientists, educators, lawyers, occupational hygienists, architects and environmental health officers among their number. This multidisciplinary culture provides a productive environment for cross-fertilisation of ideas and initiatives. The range of interests of members within the world of acoustics is equally wide, embracing such aspects as aerodynamics, architectural acoustics, building acoustics, electroacoustics, engineering dynamics, noise and vibration, hearing, speech, underwater acoustics, together with a variety of environmental aspects. The lively nature of the Institute is demonstrated by the breadth of its learned society programmes.

For more information please visit our site at www.ioa.org.uk.

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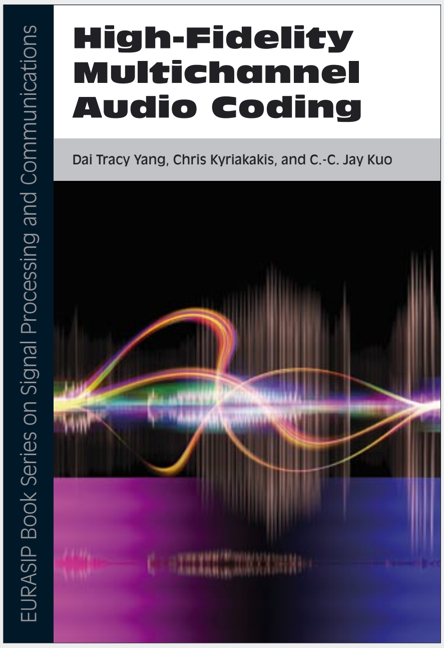
HIGH-FIDELITY MULTICHANNEL AUDIO CODING

Dai Tracy Yang, Chris Kyriakakis, and C.-C. Jay Kuo



This invaluable monograph addresses the specific needs of audio-engineering students and researchers who are either learning about the topic or using it as a reference book on multichannel audio compression. This book covers a wide range of knowledge on perceptual audio coding, from basic digital signal processing and data compression techniques to advanced audio coding standards and innovative coding tools. It is the only book available on the market that solely focuses on the principles of high-quality audio codec design for multichannel sound sources.

This book includes three parts. The first part covers the basic topics on audio compression, such as quantization, entropy coding, psychoacoustic model, and sound quality assessment. The second part of the book highlights the current most prevalent low-bit-rate high-performance audio coding standards—MPEG-4 audio. More space is given to the audio standards that are capable of supporting multichannel signals, that is, MPEG advanced audio coding (AAC), including the original MPEG-2 AAC technology, additional MPEG-4 toolsets, and the most recent aacPlus standard. The third part of this book introduces several innovative multichannel audio coding tools, which have been demonstrated to further improve the coding performance and expand the available functionalities of MPEG AAC, and is more suitable for graduate students and researchers in the advanced level.

Dai Tracy Yang is currently Postdoctoral Research Fellow, Chris Kyriakakis is Associated Professor, and C.-C. Jay Kuo is Professor, all affiliated with the Integrated Media Systems Center (IMSC) at the University of Southern California.