Advances in Recognition Techniques, Part 1

Mohammad A. Karim, FELLOW SPIE
University of Dayton
Department of Electrical & Computer Engineering
Electro-Optics Program
300 College Park Avenue
Dayton, Ohio 45469-0226

Mohammad S. Alam, MEMBER SPIE
Purdue University
Department of Engineering
2101 Coliseum Boulevard East
Fort Wayne, Indiana 46805-1499

The breadth and depth of the advances in recognition techniques are rather broad. The active investigators thus come not only from the optics community but from many other disciplines. They work not only on the process segment, but also on the systems and devices that may make many of these processes meaningful. The response to this special section has been overwhelming. The fifty-two papers that were finally accepted had to be split into two different issues in January 1998 and March 1998. These papers summarize the works of 135 different researchers from Algeria, Australia, Canada, China, Finland, France, Hong Kong, India, Jordan, The Netherlands, Russia, Spain, the United Kingdom, and the United States.

The set of twenty-seven papers appearing in this current issue of *Optical Engineering* deal mostly with nonadaptive processes. They cover the recognition domains of fuzzy logic approach, joint transform correlation, matched filter based recognition, distortion invariant recognition, color pattern recognition, morphological processor based recognition, wavelet and fractional correlation based recognition, and detection and tracking.

In the first paper, Meitzler et al. use a fuzzy logic approach to predict probability of target detection in static infrared and visual scenes. This robust method is applicable to problems having to do with the modeling of human-in-the loop target detection in any spectral regime.

The next ten papers deal with the general area of joint transform correlation (JTC). In the first paper of this group, Johnson et al. demonstrate an optical security system using phase encryption of biometric identification data. For this effort, they use fingerprints as the biometric signature. The next paper is by Sánchez-de-la-Llave, Pommet, and Fiddy in which they implement an all-optical JTC using bacteriorhodopsin spatial light modulators. Due to the high spatial resolution of bacteriorhodopsin films, this system is able to offer the possibility of being reduced to a compact size.

Michel and Awwal offer a new implementation of the JTC utilizing the phase information in the Fourier plane. By using a phase-based thresholding scheme, they are able to have the computation significantly accelerated. Next, Ahmed, Alam, and Karim use a multi-reference JTC technique for rotation-invariant recognition as well as estimation of the rotational distortion of input scene targets. They synthesize reference patterns corresponding to different ranges of distortions from a set of training patterns and discuss various training set selection strategies. Thereafter, Pati and Singh use discrimination sensitivity of a preprocessed binarized JTC combined with rotational tolerance of circular harmonic component to realize a system that gives a discrimination sensitive, rotation-invariant pattern recognition system. In the next paper, Jutamulia and Gregory use a technique utilizing an electron trapping (ET) film to block the extended dc term in a Fourier optical system. Since the blocking process is based on the subtracting property of the ET film, it is a soft blocking which is better than simple hard blocking with a stop.

Yu, Li, and Yin evaluate the detection efficiencies for non-zero order JTC and conventional JTC. They show that the non-zero order JTC out-performs the conventional JTC under both the noiseless and noisy conditions. Then, in a follow-up paper, Li, Yin, and Yu demonstrate a simple method of removing the zero-order in a joint transform power spectrum. They show that the nonzero-order JTC offers a high detection efficiency, better pixel utilization, and avoidance of false alarms due to multi-target

intermodulation. Khoury et al. show that compansive diffraction nonlinearities reduce the noise and improve the performance of JTC. In this study, the compression and expansion of the photorefractive two-beam coupling parallel optical device was shown to be similar to that of the limiting square-law serial electronic receiver. Finally, Alam and Khoury propose a JTC scheme based on incoherent-to-coherent conversion with the erasure of a four-wave mixing arrangement in a real-time photorefractive media. The technique is able to eliminate the problems due to nonlinearities associated with the square law devices and spatial light modulators used for recording the joint power spectrum.

The third group includes seven papers that address the area of matched filter based recognition. First, Silva, Abdou, and Warren discuss an optimum method for target detection where the input data consist of a time series of images in one or more data channels. They use a pixel-based autoregressive model to describe multiple frames of multiple-channel data and a novel automated method for the detection of small targets in nonstationary background. Then, Davis, Haavig, and Cottrell introduce an optical correlator sensitive to rotations of the input object by introducing a rotationally sensitive multiplexed filter that senses both the direction and amount of rotation of the input object without employing iterative filter techniques. This approach is insensitive to changes in the input object intensity because the various correlation peaks are formed simultaneously. The third paper is co-authored by Mu et al. who introduce a computer-generated binary amplitude-compensated matched filter. They also investigate the circular harmonic version of the amplitude-compensated matched filter. This is followed by a paper in which Young and Chatwin investigate the high degree of robustness of the correlation response of a wide-band filter in the face of severe frequency domain modulus disruption. This allows for the relaxation of frequency domain constraints in the knowledge that correlation peak structure will not drastically deteriorate.

Khoury, Gianino, and Woods in their paper next develop several algorithms to produce optical correlation filters for obscured inputs. Their computer simulations using binary inputs indicate that some algorithms operate over a wide range of obscurations while others have restricted operating ranges. Next, Khoury et al. study the experimental and theoretical operation of the dc-blocked phase-only filter correlator for obscured inputs. The performance of the nearly optimal filter is compared with the performances of other varieties of simple optimal filters that are capable of real-time implementation with spatial light modulators. Finally, Kumar, Carlson, and Mahalanobis consider determining parameters to maximize the performance of optimal correlation filters for implementation on arbitrary spatial light modulators.

Chen, Karim, and Alam investigate a distortion-invariant JTC, based on the fractional power fringe-adjusted JTC and synthetic discriminant function. By suitable adjusting the parameters used to characterize the fractional power fringe-adjusted filtering, they are able to also consider JTC-based classical matched filtering, fringe-adjusted filtering and amplitude-modulated phase-only filtering. In the area of color pattern recognition, Moreno et al. use preprocessing of the input scene to improve the performance of an optical correlator. They present different procedures for the implementation of the bipolar real-valued signal with spatial light modulators that work either in amplitude-only or phase-only regimes and apply these techniques in color pattern recognition. This is followed by a work wherein Liu et al. consider a real-time optoelectronic morphological processor for face recognition. It has been based on an original-complementary composite encoding hit-or-miss transform, which combines the foreground and background of an image into a whole.

The next set of five papers deals with wavelet and fractional correlation based recognition systems. Fernández and Huntsberger introduce a wavelet-based system for polyhedral junction recognition that combines the wavelet derived edges and line elements at multiple levels of resolution to produce a labeled image. This addresses the concern that noise and inconsistent light in the images limit the amount of useful information than can be extracted for junction identification. Then, Espinal et al. introduce a new multichannel texture model that characterizes patterns as two-dimensional functions in a Besov space. The wavelet-based fractal signature generates an n-dimensional surface, which is then used for classification. Next, Almanasreh and Abushagur introduce a modified fractional correlation operation and propose two systems to implement it experimentally. Modified fractional correlation of two objects was shown to be equivalent to the conventional correlation modified by multiplying each by a quadratic phase factor that contains the parameter that determines the fractional order. The fourth paper by Feng et al. utilizes the concept of multiresolution analysis on the basis of multichannel filtering framework in the early stages of human visual theory to offer suitable methods for pattern recognition. A novel micro-optical multi-wavelet element, which has the functions of wavelet filtering, beam-splitting and self-imaging, is designed and fabricated by these authors for a hybrid texture segmentation processor. Finally, Atourian et al. propose a filter structure formed as the superposition of an impulse removal filter based on modified K-nearest neighbor type operation, and the discrete wavelet transform based noise reduction. They show that this filter removes impulsive, Gaussian, and mixed noises.

In the final paper of this special section, Tan describes a traffic vision system in three modules: movement detection, vehicle localization and discrimination, and vehicle tracking. He describes two classes of algorithms, one based on symbolic image features (line segments), and the other simply on image intensity gradients. *A priori* knowledge about traffic scenes and vehicles is exploited to improve the performance and efficiency of the algorithms.

In conclusion, this special section, along with part 2 which is yet to appear in March 1998, is well balanced and reports on the many ongoing efforts in recognition techniques at different government, university, and industrial laboratories. We would like to thank the many contributors and reviewers for their dedication. Without their help and timeliness and those of Karen Myers and Candice Macomber, this special section would not have been possible.

Mohammad A. Karim is chairperson and professor of the Department of Electrical and Computer Engineering as well as director and professor of the Electro-Optics Program at the University of Dayton, Ohio. He received his BS in physics from University of Dacca, Bangladesh, in 1976, and an MS in physics, an MS in electrical engineering, and a PhD in electrical engineering all from the University of Alabama respectively in 1978, 1979, and 1981. Dr. Karim authored the books *Electro-Optical Devices and Systems, Digital Design: A Pragmatic Approach, Optical Computing: An Introduction*, and *Electro-Optical Displays* and over 250 papers. He serves on the editorial boards of *Microwave and Optical Technology Letters, Optics and Laser Technology*, and *IEEE Transactions on Education*. Dr. Karim served in the past as the guest editor for four other special sections of *Optical Engineering* and one special issue of *Optics and Laser Technology*. He is a member of ASEE, a senior member of IEEE, and a fellow of both OSA and SPIE.

Mohammad S. Alam is an associate professor of electrical engineering at Purdue University, Fort Wayne, Indiana. He received his BS and MS degrees in electrical engineering from Bangladesh University of Engineering and Technology, an MS in computer engineering from Wayne State University, and a PhD in electrical engineering from the University of Dayton respectively in 1983, 1985, 1989, and 1992. He is author of more than 100 published papers including 52 articles in refereed journals, and three book chapters. He serves as the editor of the SPIE Milestone Series on ''Real Time Optical Pattern Recognition.'' Dr. Alam received the ''Excellence in Research Award'' in 1993 and 1997 and the ''Excellence in Teaching Award'' in 1995 from the School of Engineering, Technology and Computer Science at Purdue University, the ''1996 Researcher of the Year Award'' from Sigma Xi, and the ''1997 Faculty Colloquium on Excellence in Teaching Award'' from Indiana University. He is a member of SPIE and OSA and a senior member of IEEE.