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Scanning the Issue

The Special Issue on Optical Computing

Optical Computing, in the simplest terms, involves the manipulation of photons rather than electrons, as is the case with the ubiquitous electronic computer.

Given the requirement to perform logical and arithmetic operations similar to the electronic computer, attempts have been made to produce optical systems which emulate electronic circuitry. These efforts have proved fruitless. The optical designer must provide an architecture which, in addition to performing the desired operations, takes advantage of the inherent parallelism of optics.

A major computational problem at the present time is the necessary practice to make approximations in order to limit the number of variables in an algorithm and size the computation to fit the machine. This is an accepted method to derive numerical results but it does not address the problem of the rapid stream of data which are collected in many physical problems of extreme scientific and engineering interest. In order to achieve significant results in real time, or approaching real time, a data-driven processor similar to the one described by Kung is required. These electronic systolic processors require a rest cycle after each processing cycle. Optics, on the other hand, provide a mechanism to pipeline computation continuously with the rate of data input acting as the driving force.

The applications heretofore have tended towards special-purpose machines for specific applications. It is our hope that this progress report on a rapidly growing technology will stimulate our readers' interests sufficiently to cause them to follow the field, and provide enough background to make following it easy as we progress to more general-purpose machines.

Optical Computing has evolved dramatically in the years since the previous special issue on this subject was published in PROCEEDINGS OF THE IEEE seven years ago (vol. 65, no. 1, January 1977). The present systems are greatly advanced over their predecessors in relation to speed, numerical accuracy, and power consumption.

Sawchuk and Strand entitled the first paper "Digital Optical Computing." However, as a survey paper, it does cover the field broadly as well as basically and provides an introduction to both analog and digital optical computation.

Huang's paper on "Architectural Considerations Involved in the Design of an Optical Digital Computer" provides a keen insight into the architectural problems involved. Huang's work is important not only in its own right, but also in its influence on investigators in government, industrial, and academic laboratories. Ichioka and Tanida provide a definitive tutorial on optical digital processing using shadow-casting techniques. Becker, Woodward, Leonberger, and Williamson in "Wide-Band Electrooptic Guided-Wave Analog-to-Digital Converters" not only provide a tutorial on these techniques but also have added much previously unpublished data.

Rhodes and Guilfoyle provide an overview of "Acousto-optic Algebraic Processing Architectures." The paper by Casasent covers the related algorithms and applications of Optical Systolic Array Processors with emphasis on applications to linear algebra. Goodman, Leonberger, Kung, and Athale provide an insightful hybrid approach to electronic VLSI using optical interconnections. This is followed by Kung's tutorial "On Supercomputing with Systolic/Wavefront Array Processors." Kung demonstrates the electronic analog of wavefront propagation as described by Huygens' principle. Computers based on this concept are called wavefront (or data-driven) processors.

Closely related to Kung's paper is that of Tricoles, Brundage, and Rope which with its parallel, wavefront processing is the logical precursor in both time and architecture of the electronic or optical wavefront processor. This paper represents an imaging system according to Huygens' principle by sampling an electromagnetic wavefront.

The next two papers describe large calculations which would be quite taxing if not intractable without optical computing.

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Lohmann and Wirnitzer describe a powerful new analysis approach using Triple Correlation which appears to be widely applicable. The paper by Szu and Caulfield describes a method for extracting mutual time and frequency information from two ongoing signals. A single ongoing signal requires two dimensions ("local" frequency as a function of time), as recognized by Gabor, Wigner, and others. Two ongoing signals require four dimensions to describe their absolute and relative relationships.

"Fiber-Optic Lattice Signal Processing" by Moslehi, Goodman, Tur, and Shaw is an alternative approach to optical computing. It is especially significant in offering an approach to digital logic using fiber optics as passive logical elements. The paper by Athale and Lee is an approach designed specifically for optics but similar in spirit to the electronic data flow systems. The paper by Verber is conceptually complementary and emphasizes integrated (as opposed to bulk) optical implementation. Kingston's paper reduces to practice the one-dimensional spatial light modulator and indicates direction for immediate application.

Psaltis shows that two-dimensional transducers are not needed to process two-dimensional information. He demonstrates various methods whereby well-developed one-dimensional devices can be configured to process two-dimensional data.

The PROCEEDINGS OF THE IEEE is an engineering research journal and the papers in this special issue represent research at various stages of reduction to practice. Viewed individually, the papers are interesting and exciting. Viewed as a whole, they appear to represent a major new development. Because the papers of this issue describe a wide range of theoretical and experimental aspects of both optical and optoelectronic computers, we who wish to advance optical computing must soon take steps to transform these building blocks into integrated systems for large-scale optical computing. This is a challenge to us and to our readers.

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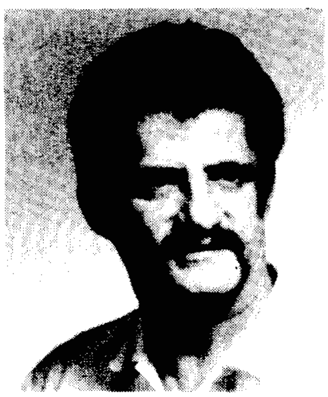
Dr. Tricoles received the B.A. degree in physics from UCLA in 1955, the M.S. degree in mathematics from San Diego State College in 1958, as well as the M.S. degree in physics and the Ph.D. degree in applied physics, both from the University of California in San Diego, in 1961 and 1971, respectively.

Since 1955 he has been at General Dynamics in San Diego, except for two years at Smyth Research Associates and a summer at the Scripps Institution of Oceanography. He is now Engineering Manager of Antenna and Radome Laboratory of the Electronics Division of General Dynamics. His research currently includes wave propagation through anisotropic dielectrics, scattering by dielectric structures, microwave imaging, and wavefront processing.

Dr. Tricoles is Secretary of the IEEE Antenna Standards Committee, a member of U.S. Commissions A, B, and C of the International Scientific Radio Union, and a Fellow of the Optical Society of America.



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Dr. Von Winkle received the B.E.E. and M.E.E. degrees from Yale University, New Haven, CT, and the Ph.D. degree in engineering sciences from the University of California at Berkeley.

Following a series of increasingly responsible assignments he was appointed Associate Technical Director for Research and Technology of the Naval Underwater Systems Center. He is responsible for defining, guiding, and managing the program of research and exploratory development that has made NUSC pre-eminent in the science and technology of sonar. NUSC is now the lead Navy laboratory for ship and submarine mounted active and passive, hull mounted, suspended, and towed sonars. He has been active in signal processing research and worked on coherent optical signal processing as early as the 1960s. From 1969 to 1980 he served as Associate Editor for Signal Processing of The Journal of the Acoustical Society of America.

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