The Conference on Holography and the Computer

Holography and modern digital computing technology represent two apparently unrelated aspects of information processing, both of which have matured rapidly in the last five years. Over the past few years, however, interactions between the two fields have become more apparent. To take note of these interactions, a Conference on Holography and the Computer was held in Houston, Texas, December 10–12, 1969, under the auspices of the Gulf Coast Section of the Optical Society of America and the IBM Corporation. The bulk of this issue of the *IBM Journal of Research and Development* is devoted to selected papers presented at that Conference.

The possible interactions of holography with computers may be categorized in the following manner:

1) Computers may be used to synthesize holograms and kinoforms for visual two- and three-dimensional displays or image enhancement.
2) Computers may be used to reconstruct digital images from optical, acoustic or microwave holograms.
3) Holograms may be used in the computer-manufacturing process and even as integral components of computers.
4) The computer may be used as a scientific tool in the simulation of holography according to the various theoretical models.

Each of these facets of the holography-computer interaction was discussed at the Conference. In addition, several outstanding problems in the theory of holography and in the manufacture of efficient holograms were addressed, and several strictly holographic papers were included in the program to further stimulate the interaction. The Conference included both review papers and papers describing new work. Recent progress in optical holography was described by E. N. Leith (U. of Michigan), who stressed the recent work in interferometry for quality-control applications. In a complementary review paper, A. W. Lohmann (UCSD) discussed computer-holography, giving a unified treatment of the various techniques for generating holograms. A. F. Metherell (McDonnell-Douglas) reviewed recent progress in acoustic holography while W. Anderson (U. of Houston) discussed biomedical applications of holography.

The techniques for generating holograms and kinoforms were discussed in several papers. Those by R. Hickling (GM Research Labs), by J. P. Waters, (United Aircraft Research Labs), and by H. Longbotham and N. K. Shankar (Lockheed Electronics Co.) discussed the very difficult problem of generating holograms that will project lines and planes, rather than points, with redundancy of information across the whole of the hologram plane. The compromise between diffusion of information and, preferably, a closed-form solution for which computer time is minimized remains difficult to achieve. As noted by Lohmann, generation of a single hologram on a computer can take minutes and even hours. D. W. Jorgensen (McDonnell-Douglas) discussed the quality and scale of images that can be expected given realistic constraints on computer graphics equipment. A promising hybrid approach to holographic displays that reduces computer time was discussed by M. C. King, A. M. Noll and D. H. Berry (Bell Labs.); in this work, the computer is used to generate perspective views of a digitally defined object, and a mosaic of holograms is made optically. The kinoform, a computer-generated phase object, reported on by L. B. Lesem, P. M. Hirsch and J. A. Jordan, Jr., (IBM) also provides increased computing efficiency as well as diffraction into a single order and high efficiency in light usage.

Computer-holography has matured to the point where detailed studies of computer techniques can be made. For example, R. A. Gabel (U. of Colorado) and B. Liu (Princeton) described the optimization of binary mask holograms (for the highest quality images) given constraints on the hologram construction apparatus. J. W. Goodman (Stanford) and A. M. Silvestri (Tech/Ops) discussed the effects of amplitude and phase quantization on the image reconstructed from computed holograms and kinoforms. G. U. Ramos (Sylvania) reported on round-off errors in digital holograms.

Discussions of image processing by optical and digital techniques were given by A. Vander Lugt and S. B. Rotz (Radiation, Inc.) and by J. L. Harris, Sr. (SIO-UCSD), respectively. The former paper described recent advances using transpose techniques (the data and signal are placed in the Fourier and space planes, rather than in the conventional order), taking advantage of the nonlinear behavior of photographic emulsions to suppress noise and reduce abberations. Papers by Y. Ichioka, M. Izumi and T. Suzuki (Osaka) and by T. Huang (MIT) considered computer-generated holograms as image-processing elements. Ichioka reviewed the comprehensive on-line image processing station being built at Osaka around a small computer. Filtering using kinoforms and incoherent illumination was discussed by J. C. Patau, L. B. Lesem, P. M. Hirsch and J. A. Jordan, Jr. (IBM)

In the application of computer-generated holograms that is perhaps closest to being a manufacturing tool, A. J. MacGovern and J. C. Wyant (Itek) described the use of binary mask holograms for testing aspheric lenses by interferometrically comparing the wavefront resulting from the hologram with that from the lens.

Digital reconstruction from physical holograms was discussed in several papers. W. H. Carter (U. of Rochester) described the first digital reconstruction from an optical hologram, using an inverse scattering theory proposed by E. Wolf. Digital reconstruction is somewhat simpler for acoustic and microwave holograms. G. Tricoles and E. L. Rope (General Dynamics) presented a review of microwave holography, including their recent work on digital construction of binary microwave holograms and digital reconstruction. D. M. Milder and W. H. Wells (Tetra Tech) discussed simulation studies of computer reconstruction of acoustic holograms obtained using the crossed linear array method. J. Farr (Pan American Petroleum) reviewed his efforts in earth holography.

Holograms may be used as optical computing elements; e.g., as filters (see above). G. Stroke (SUNY at Stony Brook) discussed an additional application of holograms to image enhancement (e.g., image deblurring). A. Macovski and S. D. Ramsey, Jr., (Stanford Research Institute) presented results of a study of a real-time cross-correlation system in which temporal offsets and video techniques are used. Interferometry is one of the oldest and most successful optical data reduction techniques; a new holographic interferometer which operates on-axis and can be very large was described in a paper by S. Debrus M. Françon, and M. May (Paris). In addition, holograms may be used in the computer itself: J. Lipp and J. Reynolds (IBM) described a high capacity holographic read-only storage system which could provide very rapid, parallel input of thousands of bits. A. D. Tencza (IBM) reported on using holograms for the multiplex imaging of circuit patterns, a technique which possibly could increase the speed and reliability with which integrated circuits are made. In a paper by A. Bruel and J. C. Cazaux (Toulouse) computer generation of lenses was discussed. A. W. Lohmann discussed a compact zoom lens design based on kinoforms, together with other filtering and lens correction applications of binary mask holograms and kinoforms.

Computer simulations of the holographic process were discussed by J. M. Hood, Jr. (USNELC), by R. B. Green (UC Davis) and by F. J. Tischer (North Carolina State).

Among the several analytic papers, D. Gabor (CBS Labs) discussed laser speckle, a problem which serves to confound the optical and computer holographers alike. J. T. Winthrop (American Optical) discussed the structural information content (number of degrees of freedom) of the object wave field stored in a hologram. K. A. Haines (Holotron) described techniques taking into account the resolving power of the recording medium and the temporal coherence of the object illuminating beam, for improving the quality of the reconstructed image by using periodic diffuser plates in the construction step, thus permitting low space spatial band width products. F. T. S. Yu (Wayne State) described an analytical technique for nonlinear holograms, and V. I. Vlad (Bucharest) presented an extension of the lens-prism model of holography.

The materials used to form holograms constitute one of the central problems of both optical and computer holography. H. W. Lorber (EG&G) presented an extension of the Kelly three-stage model of silver halide film to include granularity and bleaching for holograms made with coherent light. D. G. Falconer (Stanford Research Institute) discussed the limits to holographic images because of noise and distortion in the photographic data storage medium. Improved experimental methods for making high-efficiency, low-noise holograms were discussed in a series of three papers by K. S. Pennington and J. S. Harper (IBM), by J. Upatnieks and C. Leonard (U. of Michigan) and by A. Schmackpfeffer, W. Järisch, and W. Kulcke (IBM).

In summary, the Conference indicates that computer-generated holograms for on-line 3-D display are still in the future. More efficient techniques are required, and solutions to the difficult line and plane problem are needed. On the other hand, computer-generated holograms and kinoforms do appear of use in information processing (filtering) applications, and computer-reconstruction is a promising research area. The range of topics discussed at the Conference indicates the robust health of holography, and shows the interaction between holography and the computer to be a fruitful one with considerable promise for the future.

The program for the Conference was prepared by J. A. Jordan, Jr., P. M. Hirsch and L. B. Lesem (IBM). A. W. Lohmann (UCSD) and R. V. Pole (IBM) served as advisors. C. Koester (American Optical) and M. Warga (OSA) contributed the good will and cooperation of the Optical Society of America. C. Alvarez (Philco-Ford), G. Bonner (NASA), A. L. Boyer (Rice), L. R. Lankes (Lockheed), D. Schiller (IBM) and D. L. Van Rooy (Rice) formed the nucleus of the local committee.

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