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nonlinear mixing in two-photon media is also presented. The theory is also capable of accounting for the interparticle correlations. **(12 min)**

TUD8 Approximate expressions for radially symmetric solutions in nonlinear optics using a power series method

PARTHA P. BANERJEE, GUANGHUI CAO, Syracuse U., Department of Electrical & Computer Engineering, Syracuse, NY 13210; TING CHUNG POON, Virginia Polytechnic Institute & State U., Department of Electrical Engineering, Blacksburg, VA 24061.

The classic numerical solution to the nonlinear differential equation predicting self-trapping of beams in space reveals the existence of a number of different bounded modes, each satisfying different initial conditions. Incidentally, similar equations also predict the nature of radially symmetric stationary traveling wave solutions for envelope propagation through cubically nonlinear dielectrics and with cylindrical (or spherical) symmetry. Later, approximate analytic solutions for the lowest-order mode was developed, employing variational methods and the Rayleigh-Ritz procedure. The lowest-order mode, which resembles a bell-shape curve, was approximated by the sum of two Gaussians, with different amplitudes and widths, suitably chosen to meet the best-fit criteria. In this presentation, we propose a simple straightforward power series approach to the problem, which is extremely useful if we are interested in paraxial behavior of beams or pulses in space. Representation for the different nonlinear stationary modes is discussed. Convergence criteria for the power series are addressed, and the results are compared with previous solutions obtained numerically and by variational methods. **(12 min)**

TUD9 Interaction between ellipse rotation and Faraday rotation in birefringent nonlinear media

HERBERT G. WINFUL, GTE Laboratories, Inc., 40 Sylvan Rd., Waltham, MA 02254.

A lightwave propagating parallel to an applied magnetic field in a dielectric medium will experience a rotation of its plane of polarization by an amount given by $\theta = VHL$. Here V is the Verdet constant, H is the magnetic field strength, and L is the length of the medium. This effect, known as Faraday rotation, is the basis for the operation of magnetooptic current sensors which use optical fibers as the dielectric medium. It is also known through the work of Maker, Terhune, and Savage that an intense elliptically polarized lightwave in a nonlinear dielectric will suffer a rotation of its vibrational ellipse as a result of the intensity-dependent refractive index. Each of these rotatory effects is drastically influenced by the presence of linear birefringence which quenches the rotatory power in the Faraday effect and leads to polarization instabilities in ellipse rotation. In this paper we present a coupled mode theory that yields exact solutions for the interaction between Faraday rotation, ellipse rotation, and linear birefringence in a nonlinear dielectric. The theory shows that competition between the linear and circular birefringences leads to the formation of kink (topological) solitons. One practical result of the theory is that ellipse rotation can be used to enhance the sensitivity of magnetooptic current sensors that rely on Faraday rotation in birefringent fibers. **(12 min)**

TUD10 Paper withdrawn

Tuesday **MORNING**

21 October 1986 **TUE**

PLAYHOUSE ROOM

8:30 AM **Image Processing: 1**

John F. Walkup, Texas Tech University, Presider

TUE1 Use of the Wigner distribution function for time scaling with minimum spectral distortion

BAHAA E. A. SALEH, MOHAMAD ASI, U. Wisconsin-Madison, Department of Electrical & Computer Engineering, Madison, WI 53706.

An important problem in speech technology is the modification of the time scale of an audio signal by stretching or contracting without degrading the signal intelligibility. Simple time scaling by recording at a different speed (or by interpolation/decimation of samples) obviously modifies the signal spectrum and therefore degrades intelligibility. We report a new approach based on determining the Wigner distribution function (WDF), scaling its time dependence without changing its frequency dependence, and finding the signal whose WDF is as close as possible to the modified function. Let $S(t)$ be a signal whose time is to be modified by the transformation $t' = h(t)$. We determine its WDF $W(t,\omega)$ and modify it to obtain a new 2-D function $W_0(t,\omega) = W[h(t),\omega]$. The function $W_0(t,\omega)$ is not necessarily an admissible WDF. We find a modified signal $S'(t)$ whose WDF $W'(t,\omega)$ best approximates $W_0(t,\omega)$. This is accomplished by projecting $W_0(t,\omega)$ on the class of 2-D functions that are admissible WDFs. The result involves solving an eigenvalue problem whose eigenfunction of largest eigenvalue is the desired signal. Possible implementations are presented. A suboptimal signal $S'(t)$ may be obtained by applying an optimal linear transformation on $W_0(t,\omega)$. The operation can be implemented using an optical processor. **(12 min)**

TUE2 Analysis of microscopic surface by projection interference fringes

ROGERT W. WYGANT, SILVERIO P. ALMEIDA, Virginia Polytechnic Institute and State U., Physics Department, Blacksburg, VA 24061; L. M. BERNARDO, O. D. D. SOARES, U. Porto, Physics Center, 4000 Porto, Portugal.

Microscope projection fringes are formed by intersecting two expanded laser beams. Planes of interference exist within the entire interaction volume, the spacing being dependent on their intersecting angle. Inserting an object into this volume results in projection fringes on its surface which represent cross sections through the surface. The fringe pattern is then analyzed digitally to yield a contour map of the surface. A great advantage of this system is the case with which the resolution may be varied. Results are presented for two different surfaces. One surface is a block of aluminum into which submillimeter grooves have been machined. The other surface is an iron alloy into which grooves have been burned with a pulsed CO_2 laser. Results for this surface are shown at three different (microns) resolutions. **(12 min)**

TUE3 Synthesis of binary images and the zero-crossings of 2-D bandlimited functions

K. M. NASHOLD, B. E. A. SALEH, U. Wisconsin-Madison, Department of Electrical & Computer Engineering, Madison, WI 53706.

We investigate the synthesis of binary images through diffraction-limited cameras employing high-contrast detection. This involves finding an input image, which when passed through the bandlimited camera and clipped by the detector gives a desired binary image. The problem is equivalent to finding a bandlimited 2-D function with prescribed zero-crossings. In the 1-D case, one can always find a bandlimited function of finite energy whose zero-crossings within an interval of finite extent are prescribed. This implies that a form of superresolution is possible within an interval of finite extent. The method is based on modifying the zeros of $\mathrm{sinc}(2Bx)$ (B being the bandwidth) by inserting the prescribed zeros to replace an equal number of zeros. We have extended this method to a 2-D function $f(x,y)$ by dividing it into 1-D slices, $g_k(x) = f(x,y_k)$. Each slice is synthesized to have the correct zero-crossings up to an arbitrary scaling factor a_k. An orthogonal slice, say $h(y) = f(x_0,y)$, is synthesized to have the correct zero-crossings. The scaling factors are then determined by matching the amplitudes of orthogonal slices, $h(y_k) = a_k g_k(x_0)$. With sufficiently close slices, the synthesized 2-D function can satisfy all requirements. **(12 min)**

TUE4 Image sampling density reduction below that of Nyquist

KWAN F. CHEUNG, ROBERT J. MARKS II, U. Washington, Department of Electrical Engineering, Seattle; WA 98195.

A technique to uniformly decimate samples in a multidimensional low-pass bandlimited signal without information loss is presented. In many cases, the overall sampling density can be reduced below the Nyquist density[1] and ultimately to the hyper-area of the support of the function's spectrum. Two methods to regain the deleted samples are discussed. Both regain samples in forms of linear interpolations. The specific case of sampling images obtained through systems with circular pupils is addressed. An analysis of the noise sensitivity of the restoration is also presented. **(12 min)**

1. R. J. Marks II, "Multidimensional-Signal Sample Dependency at Nyquist Densities," J. Opt. Soc. Am. A **3,** 268 (1986).

TUE5 Stability considerations of active binarization procedures with feedback

MANFRED BROJA, REINER ESCHBACH, OLOF BRYNGDAHL, U. Essen, Physics Department, 4300 Essen 1, F.R. Germany.

Electronic halftoning techniques are used to convert graytone pictures into binary representations. With the processing possibilities active procedures—so-called error correction and distribution methods—were introduced. The sequential execution which these methods permit allows the local error between graytone and binary picture to be incorporated into the decision process of the states of the next unprocessed pixels. This process may be regarded as a feedback system where the error can be distributed with different weights and signs. With the choice of the possible parameters, the stability of the feedback system is influenced. The dependence of the binary picture on these parameters is described and illustrated by experimental results. **(12 min)**

TUE6 Recovery of images embedded in periodic interference by a Fourier transform phase

TARIQUL HAQUE, Suffolk U., Physics Department, Beacon Hill, Boston, MA 02114; ROBERT A. MEYER, Clarkson U., Potsdam, NY 13676.

If an unwanted image is superimposed on an original image, the Fourier transform phase of the degraded image highly depends on the Fourier transform magnitude of the unwanted image. The signals which produce negligible magnitudes do not significantly deviate the phase of the original image on superimposition. The degraded phase, which is approximately the original phase, can then be employed to reconstruct the original image. The class of signals which satisfy the above restriction on the magnitudes are generally periodic.

A 128 × 128 point 2-D signal with alternating bright and dark bands is constructed for use as an unwanted image. Each dark and bright band is 128-point long and 8-point wide. The Fourier transform magnitude of this periodic pattern contains only eight nonzero elements out of 128 × 128–16,384 elements. This pattern when superimposed on an original image has distorted only eight phase samples. Application of an iterative method[1,2] has produced an interference-free image.

As a second example, a 128 × 128 point checkerboard pattern is constructed in which the size of each black-and-white square is 8 × 8. Only 64 elements of the Fourier transform magnitude of this pattern are nonzero. The same iterative method when applied to the phase of the superimposed image has produced the original image. **(12 min)**

1. T. Haque, "Digital Image Reconstruction and Recovery from Fourier Transform Phase Using Moments," Ph.D. Dissertation, Clarkson University, Electrical Engineering Department, Potsdam, NY (1986).
2. M. Hayes, "The Reconstruction of a Multidimensional Sequence from the Phase or Magnitude of its Fourier Transform," IEEE Trans. Acoust. Speech Signal Process. **ASSP-30** (Apr. 1982).

Tuesday **MORNING**
21 October 1986 **TUF**
MERCER FORUM VI ROOM

8:30 AM **Symposium on Computational and Biological Approaches to Color Perception**

Brian Wandell, Stanford University, Presider

TUF1 Central pathways for color vision

PETER LENNIE, U. Rochester, Center for Visual Science, Rochester, NY 14627.

Psychophysical evidence suggests that signals from cones are later transformed to yield an achromatic signal and two chromatically opponent ones. Although physiological observations on the lateral geniculate nucleus (LGN) of the macaque monkey have confirmed the existence of opponent transformations, these differ in important respects from the kind inferred from psychophysical evidence. In particular, the red-green chromatic pathway appears also to carry an achromatic signal, to an extent determined by the spatial properties of the stimulus. The characteristics of the yellow-blue pathway also differ from those inferred from psychophysical observations. Although signals that arise in the LGN do not meet the requirements of the psychophysical model, a linear transformation of these signals could do the required job. Analysis of the chromatic properties of neurons in striate cortex (the recipient of information from the LGN) shows that signals from the LGN are transformed substantially, so as to resemble more closely those expected on psychophysical grounds. The second-stage mechanisms inferred from psychophysical observations therefore seem to reflect the action of at least two distinct physiological transformations. **(Invited paper, 25 min)**

TUF2 Optimal coding of spatiochromatic information in the retina

GERSHON BUCHSBAUM, U. Pennsylvania, Department of Bioengineering, Philadelphia, PA 19104.

Natural visual stimuli are multidimensional signals encompassing parameters of space, time, and color. Information in these signal dimensions is redundant because natural images exhibit some spatial, temporal, and chromatic regularities. Further, these signal dimensions are not independent. The incoming visual stimulus is processed and coded in the retina by spatially organized center-surround chromatically antagonistic receptive fields with complex temporal characteristics. The basic hypothesis is that the purpose of retinal signal processing is to reduce signal redundancy and to efficiently code visual information before transmission to higher stages of the visual system. Under this hypothesis it is shown that retinal coding is designed to obtain optimality in coding, considering the relative amount of information in each dimension, corresponding to a high bit rate in the spatial dimension and a low bit rate in the chromatic dimension. The coding in these dimensions achieves favorable image degradation minimizing sensitivity to picture-to-picture variations, considering the computational load required from the retina. **(Invited paper, 25 min)**

TUF3 Chromatic adaptation, the control of chromatic adaptation, and color constancy

LAURENCE T. MALONEY, U. Michigan, Ann Arbor, MI 48104; DENISE C. VARNER, Stanford U., Stanford, CA 94305.

Recent work in computational color vision[1,2] demonstrates that it is possible to achieve exact color constancy using only the kinds of information available to biological vision systems. These algorithms first compute an estimate of the illuminant in the scene and then transform the initial color signal so as to eliminate the contribution of the illuminant. We examine this work and relate it to research in color vision through the following linking hypothesis: local retinal state is chosen to compensate for the illuminant. With this linking assumption, we demonstrate that the computational work speaks directly to current and past models of adaptation in visual color psychophysics. Further, the work emphasizes the distinction first clearly drawn by Stiles between the local adaptation state of the retina and the (global) control of adaptation and suggests a broad class of experiments addressing these issues. **(Invited paper, 25 min)**

1. G. Buchsbaum, J. Franklin Inst. **310,** 1 (1980).
2. L. T. Maloney and B. A. Wandell, J. Opt. Soc. Am. A **3,** 29 (1986).

Tuesday **MORNING**
21 October 1986 **TUG**
PLAYHOUSE ROOM

10:00 AM **Image Processing: 2**

A. Gmitro, Yale University, Presider

TUG1 Imaging system design for estimation of partially coherent images

ROY M. MATIC, JOSEPH W. GOODMAN, Stanford U., Electrical Engineering Department, Information Systems Laboratory, Stanford, CA 94305.

An object, illuminated by partially coherent light, is composed of a signal plus a noise transmittance. The problem is to design the pupil screen of the imaging system so that the detected image of the object is the minimum mean-square error estimate of the image of the signal transmittance. This problem is not linear but is bilinear, because of the input–output relationship between input transmittance and output intensity. This problem is solved using a nonlinear parameter optimization approach where the parameters to optimize are discrete samples of the magnitude and phase of the pupil. The improvement factor, which compares system performance relative to the performance of a diffraction-limited imaging system, is defined. The design of several optimal pupil screens is presented. These designs verify the validity of our design technique and demonstrate that both the optimal pupil screen and the improvement factor are a function of the statistics of the signal and noise and a function of the coherence of the object illumination. Our results also show that preprocessing is more effective for coherent systems than for incoherent systems. **(12 min)**