

AD-A266 772 TATION PAGE

Form Approved

OMB No. 0704-0188



1 to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering the collection of information. Send comments regarding this burden estimate or any other aspect of this form to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Avenue, Washington, DC 20540.

DATE

4/15/93

3. REPORT TYPE AND DATES COVERED

Final

15 Jan 90 - 14 Jan 93

4. TITLE AND SUBTITLE

A Multilevel-Multiresolution Method for Image Processing, A Bayesian Framework for Reconstructing and Representing Shapes

5. FUNDING NUMBERS

DAAL03-90-G-0033

6. AUTHOR(S)

Basilis Gidas

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Brown University
Providence, RI 02912

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U. S. Army Research Office
P. O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AR026811.7-MA S O I

11. SUPPLEMENTARY NOTES

The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

During the period of the grant, 1/15/90 - 1/14/93, we have developed:

- 1) a coherent multiresolution framework for image analysis tasks, in particular, for estimating 3-D shapes from a single video or SAR image; the algorithm has been applied to constructing topographic maps of Venus' terrain, and to segmentation/classification of textures,
- 2) efficient procedures for estimating the parameters of Markov Random Fields (MRF's) from noisy and degraded data,
- 3) a fixed-length noiseless source coding for MRF's using large deviations, and
- 4) a multi-grid type algorithm for maximum-likelihood estimation in tomography.

In addition, we have begun a new non-parametric approach to speech recognition.

93 7 08 08 5

93-15503



10P6

14. SUBJECT TERMS

multiresolution, image analysis, texture classification, tomography, Markov random fields

15. NUMBER OF PAGES

9

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT

UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT

UNCLASSIFIED

20. LIMITATION OF ABSTRACT

UL

DTIC QUALITY INSPECTED 5

FINAL REPORT

Summary of Research

Accession For	
NTIS	CRA&I ☒
DTIC	TAB ☐
Unannounced ☐	
Justification _____	
By _____	
Distribution / _____	
Availability Codes	
Dist	Avail and/or Special
A-1	

Our research supported by the ARO/SDI grant, has had several successes in Image Processing and Computer Vision. A general theme of our work is to guide the development of algorithms and the solutions of the computational problems by carefully articulated mathematical models. The modelling approaches have been strongly influenced by applications. The applications stimulate the mathematical research and, in turn, the algorithms derived from the mathematical analysis provide new methodological approaches for the applications. Our main projects and contributions to applications and theory, may be divided into five groups:

1) Shape Reconstruction: We have developed a coherent Bayesian framework for estimating 3D shapes (or topographic maps), and surface composition (albedo, or dielectric properties) from a single noisy Video or SAR image. Image 1 shows a reconstruction experiment with video data acquired under uncontrolled illumination; Figure 2 shows a surface reconstruction from simulated SAR data. The method has been applied to the estimation of topographic maps of Venus' terrain using SAR data from the Magellan spacecraft.

Our approach to the reconstruction of 3D shapes explores certain *random surface* models, and is formulated as a global optimization problem. To solve this problem, we developed a new multiresolution algorithm inspired from recent studies in the simulation of statistical mechanics systems at criticality. The algorithm appears to be useful in many image processing tasks, including texture segmentation/classification.

2) Texture Synthesis and Classification: We have introduced a appealing class of Markov Random Fields (MRF's) models for texture synthesis and segmentation/classification. The models are defined at all levels of resolution and are convenient for scale and rotation invariant segmentation/discrimination. Image 3 shows the synthesis of a wood-like texture; Image 4 shows the segmentation/classification of four textures. We have

two segmentation procedures one *supervised* and one *unsupervised*. The modelling of textures via MRFs involves the estimation of certain parameters from training data. We have developed practical statistical procedures for parameter learning, that apply to a host of other applications. The mathematical study of consistency and asymptotic normality has led to a number of mathematical problems and to an interesting interplay between statistical inference and the phenomena of phase transitions. We have settled these problems in a number of publications.

3) Tomography: We have introduced a *two-stage* EM algorithm for 3D emission tomography to account for blur due to 2D scintillation cameras; the procedure makes the 3D problem computationally feasible. Also, we developed a *multi-grid* type algorithm for maximum likelihood and back-projections estimation. To our knowledge, this is the first multiresolution procedure in the tomography problem.

4) Coding Theory for MRFs (work by Y. Amit who was partially supported by this grant): the theory of large deviations was used to show the number of bits per symbol for Ziv-Lempel codes is given by the maximum entropy of all MRFs with the same potentials. The work provides also a new way for looking at the classical 1-D Markov source coding problem.

5) Speech Recognition: During this grant, we undertook a systematic study of speech recognition, by exploring a new framework which is conceptually similar to, but considerably different in details from the Hidden Markov Model (HMM) approach. Our results to date will appear in a series of articles (during 1993/94). Our procedure aims at changing the *acoustic model* in the HMM approach in a fundamental way, by using modern non-parametric/nonlinear prediction techniques to model the acoustic waveform in the time domain. Our program has led to an effective algorithm for discriminating the *stop consonants* of English, and to two interesting mathematical problems, one of which is a conceptually new form of the classical Wiener-Kolmogorou prediction theory.

LIST OF IMAGES

Image 1: (a) original image: an egg imaged under uncontrolled illumination (using a desk lamp), (b) reconstruction; a matte surface was assumed; the algorithm estimated height, albedo, and an effective light source direction; (c) and (d) show the reconstructed scene illuminated from the x -, y - direction.

Image 2: (a) plot of a simulated surface, (b) a 32 - look SAR image, (c) plot of the reconstruction using (b) as the data.

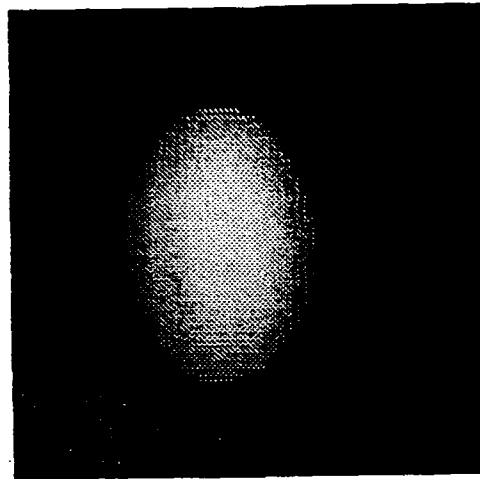
Image 3: Simulation of wood-like texture.

Image 4: Segmentation of four textures: wood, carpet, cloth, plastic background.

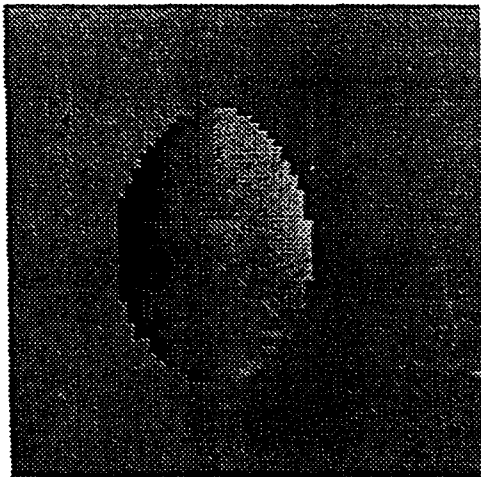
(a)



(b)



(c)



(d)

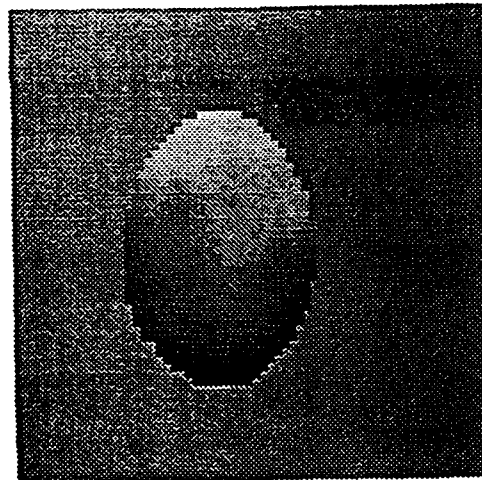
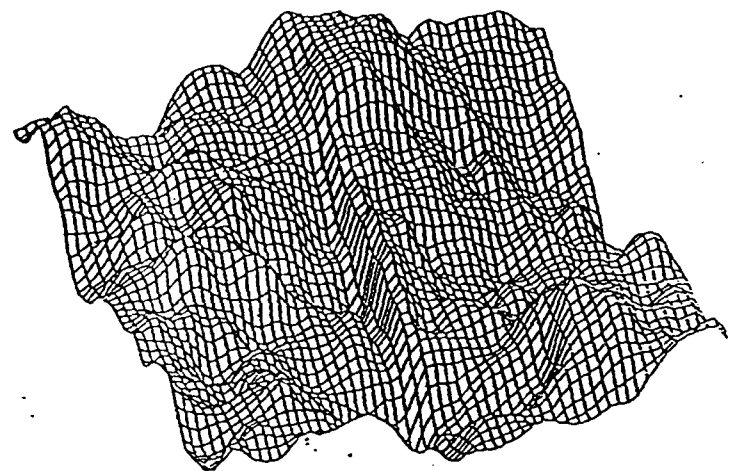
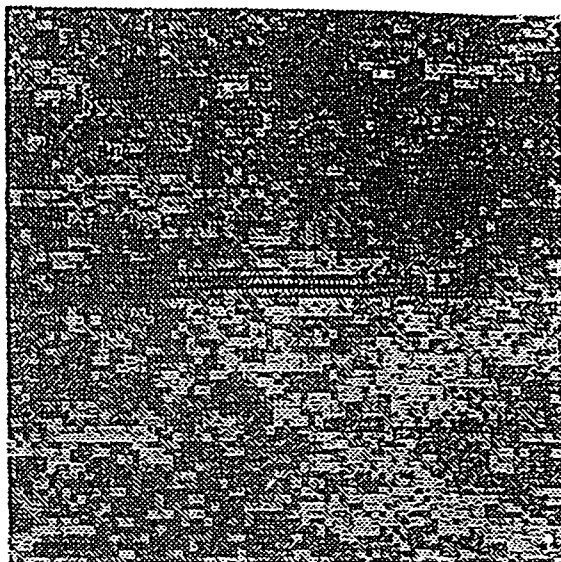


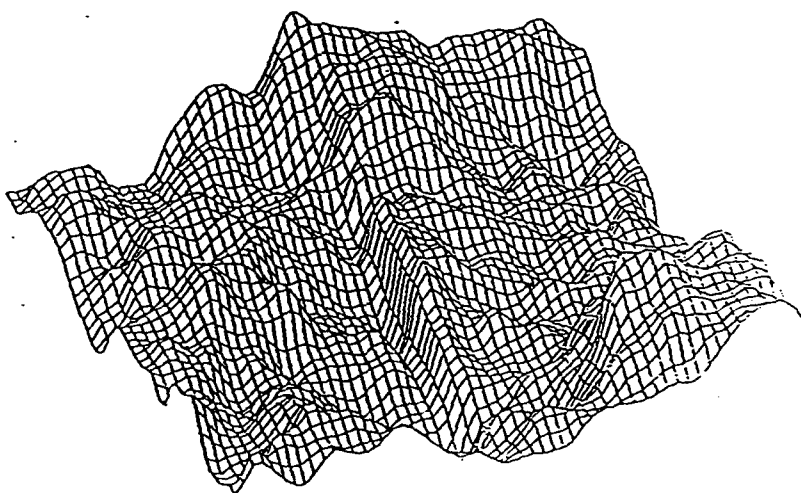
Image 1: real egg, uncontrolled illumination
 (a) original, (b) reconstruction
 (c) illumination from x-direction
 (d) illumination from y-direction



(a) plot of original surface



(b) 32-look SAR image of (a)



(c) plot of reconstructed surface

Image 2

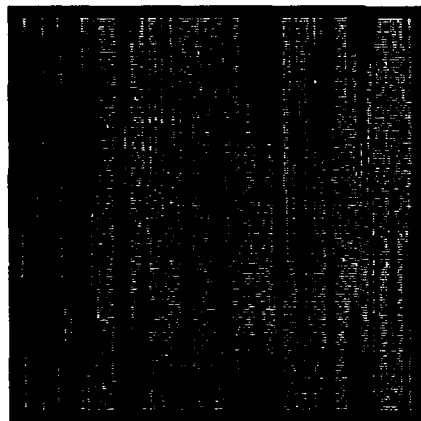


Image 3: Simulated wood-like texture

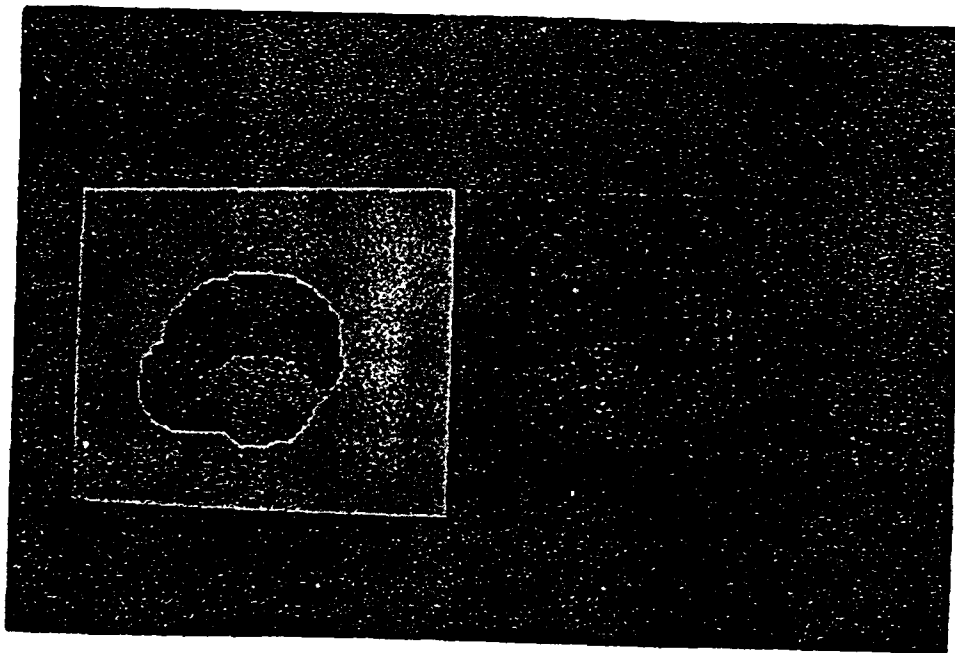
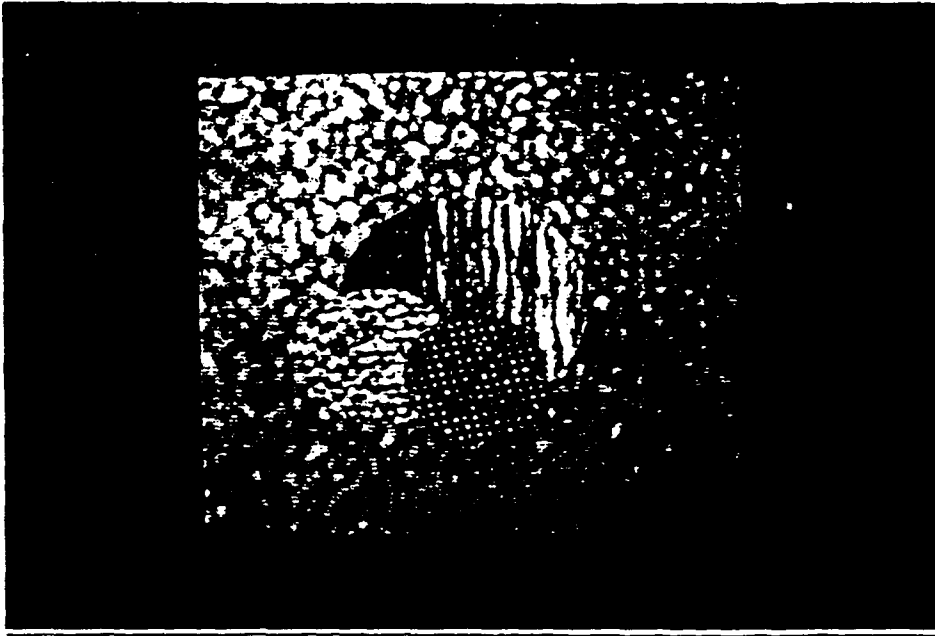


Image 4: Segmentation of four textures

LIST OF PUBLICATIONS

1. "Asymptotics of Maximum Likelihood Estimators for the Curie-Weiss Model" (with F. Comets), *Annals of Statistics* 19 (1991) 557-578.
2. "Image Analysis and Computer Vision" (with D. Geman), in *Spatial Statistics and Image Processing*, National Research Council, National Academy Press (1991) pp. 1-36.
3. "Parameter Estimation for Gibbs Distributions from Partially Observed Data" (with F. Comets), *Annul of Applied Probability* 2 (1992) 142 - 170.
4. "A Two-Stage EM Algorithm with Applications to Emission Tomography" (with M. Hudson), submitted for publication (1991).
5. "A Nonlinear Multi-Grid EM Algorithm for Emission Tomography" (with M. Hudson), submitted for publication (1991)
6. "Parameter Estimation for Gibbs Distributions from Fully Observed Data", in *Markov Random Fields: Theory and Applications*, Academic Press (1993) pp. ..., eds.: R. Challappa and A. Jain.
7. "A Variational Method for Estimating the Parameters of MRF from Complete or Incomplete Data" (with M. Almeida) *Annals of Applied Probability* 3 (1993) ? - ?.
8. "Metropolis - Type Monte Carlo Simulation Algorithms and Simulated Annealing" to appear in *Topics in Contemporary Probability Theory* (1994), eds.: J. L. Snell and P. Doyle.

LIST OF PARTICIPANTS

1. Dr. Yali, Amit, Visiting Assistant Professor
2. Dr. Chris Raphael, Visiting Assistant Professor
3. Murilo Almeida, Ph.D. 1990
4. Jose Torreao, Ph.D. 1990
5. Alejandro Murua, Ph.D. 1993
6. Panos Paraskevopoulos, Ph.D. 1993