

Applications of Digital Image Processing XIV

Andrew G. Tescher
Chair

22–26 July 1991
San Diego, California



Volume 1567

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Sponsored and Published by
SPIE—The International Society for Optical Engineering



Volume 1567



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Please use the following format to cite material from this book:

Author(s), "Title of Paper," *Applications of Digital Image Processing XIV*,
Andrew G. Tescher, Editor, Proc. SPIE 1567, page numbers (1991).

Library of Congress Catalog Card No. 89-643506
ISBN 0-8194-0695-3
ISSN 1042-4687

Published by
SPIE—The International Society for Optical Engineering
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone 206/676-3290 (Pacific Time) • Fax 206/647-1445

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(continued)

APPLICATIONS OF DIGITAL IMAGE PROCESSING XIV

Volume 1567

Session 9—HDTV Image Transmission
Hamed Amor, Robert Bosch GmbH (FRG)

Session 10—Analysis and Theory II
Bobby R. Hunt, University of Arizona

Conference 1567, *Applications of Digital Image Processing XIV*, was part of a four-conference program on Mathematical Imaging held at SPIE's 1991 International Symposium on Optical Applied Science and Engineering, 21–26 July 1991, in San Diego, California. The other conferences were:

Conf. 1568 *Image Algebra and Morphological Image Processing II*

Conf. 1569 *Stochastic and Neural Methods in Signal Processing, Image Processing, and Computer Vision*

Conf. 1570 *Geometric Methods in Computer Vision*

Program Chair: **Gerhard X. Ritter**, University of Florida

INTRODUCTION

The 1991 symposium on Applications of Digital Image Processing XIV brought together a large international group of engineers and scientists. Following the trend of previous SPIE conferences in the image processing field, this symposium attracted several exciting papers from Europe and the far East in addition to those from the United States.

The quality of presentations was high and topics included a large number of diverse applications, including theoretical approaches, specialized architectures, image coding, and medical and various industrial applications.

In particular, several invited special sessions and their organizers deserve special recognition:

- Applications of Image Understanding (J. J. Pearson).
- Hubble Space Telescope Imagery: Problems, Approaches, and Solutions (R.A. Gonsalves).
- Fluid Dynamics and Wavelets Applied to Image Processing (H.S. Wisniewski).
- HDTV Image Transmission (H. Amor).

The reader will find that the published papers are well representative of the exciting field of digital image processing and are indicative of the significant continuing progress in this field. The more recent advances in applications areas, such as in hardware implementations, are particularly noteworthy.

It is a pleasure to acknowledge the technical as well as administrative contributions of the co-chairs.

Andrew G. Tescher
Lockheed Palo Alto Research Laboratory

CONTENTS

	Conference Committee	ix
	Introduction	xi
SESSION 1	SYSTEMS AND SOFTWARE	
1567-01	Integrated image processing and tracker performance prediction workstation T. J. Schneeberger, H. D. McIntire, Applied Technology Associates, Inc.	2
1567-02	Imagetool: image processing on the Sun workstation M. E. Zander, Los Alamos National Lab.	9
1567-03	Toros: an image processing system for measuring consignments of wood B. A. Correia, R. Davies, F. D. Carvalho, F. C. Rodrigues, LNETI-OPTICA (Portugal).....	15
1567-04	Binary object analysis hardware area parameter acceleration T. M. Seitzler, Perceptive Machines.	25
1567-05	MIMS: a medical image management system S. Badaoui, ORACLE (France); F. Aubry, INSERM (France).	31
1567-74	Relationships between autofocus methods for SAR and self-survey techniques for SONAR D. E. Wahl, C. V. Jakowatz, Jr., D. C. Ghiglia, P. H. Eichel, Sandia National Labs.	32
SESSION 2	IMPLEMENTATIONS I	
1567-07	Detection of surface-laid minefields using a hierarchical image processing algorithm J. E. McFee, K. L. Russell, Defence Research Establishment Suffield (Canada); M. R. Ito, Univ. of British Columbia (Canada).	42
1567-08	Affine-invariant recognition of gray-scale objects by Fourier descriptors A. Fenske, H. Burkhardt, Technische Univ. Hamburg-Harburg (FRG).	53
1567-09	Application of super-resolution techniques to passive millimeter-wave images D. G. Gleed, Royal Signals and Radar Establishment (UK); A. H. Lettington, Reading Univ. (UK).	65
1567-10	Vision-based strip inspection hardware for metal production T. M. Seitzler, Perceptive Machines.	73
1567-11	Calibration issues in the measurement of ocular movement and position using computer image processing A. R. Weeks, H. R. Myler, Univ. of Central Florida; A. S. Jolson, Vision Research Labs.	77
1567-12	Application of morphological pseudoconvolutions to scanning-tunneling and atomic force microscopy E. R. Dougherty, Rochester Institute of Technology; A. Weisman, Rochester Institute of Technology and Univ. of Rochester; H. Mizes, Xerox/Webster Research Ctr.; R. J. Miller, Univ. of Rochester.	88
1567-13	Automated visual inspection for LSI wafer patterns using a derivative-polarity comparison algorithm S. Maeda, T. Hiroi, H. Makihiro, H. Kubota, Hitachi, Ltd. (Japan).	100
1567-14	Nonlinear optical flow estimation and segmentation A. M. Geurtz, Ecole Polytechnique Federale de Lausanne (Switzerland).	110
SESSION 3	APPLICATIONS OF IMAGE UNDERSTANDING	
1567-15	Model-based vision: an operational reality? (Invited Paper) J. L. Mundy, GE Corporate Research and Development Ctr.	124

(continued)

APPLICATIONS OF DIGITAL IMAGE PROCESSING XIV

Volume 1567

1567-16	Linear resection, intersection, and perspective-independent model matching in photogrammetry: theory E. B. Barrett, Lockheed Missiles & Space Co., Inc.; M. H. Brill, N. N. Haag, Science Applications International Corp.; P. M. Payton, Lockheed Missiles & Space Co., Inc.	142
1567-17	Feature discrimination using multiband classification techniques J. Ivey, S. Fairchild, J. R. Peterson, C. G. Stahl, ESL, Inc.	170
1567-18	Neural network for improving terrain elevation measurement from stereo images M. Jordan, Lockheed Missile & Space Co., Inc.	179
1567-19	Feature selection technique for classification of hyperspectral AVIRIS data S. S. Shen, B. Y. Trang, Lockheed Palo Alto Research Labs.	188
1567-20	Learning object shapes from examples H. Shariat, Lockheed Palo Alto Research Labs.	194
1567-81	Antialiasing-warped imagery using lookup-table-based methods for adaptive resampling M. T. Waltermann, Evans and Sutherland; F. M. Weinhaus, ESL, Inc.	204
SESSION 4 IMPLEMENTATIONS II		
1567-21	Moiré image overlapping method for PCB inspection designator R. Chang, Y. Hu, National Central Univ. (Taiwan).	216
1567-22	Machine vision feedback for on-line correction of manufacturing processes: a control formulation A. T. Taylor, Univ. of California/Los Angeles and The Aerospace Corp.; P. K. Wang, Univ. of California/Los Angeles.	220
1567-23	CT image processing for hardwood log inspection D. Zhu, R. W. Connors, Virginia Polytechnic Institute and State Univ.; P. A. Araman, Brooks Forest Products Ctr./USDA Forest Service.	232
1567-24	Image processing methodology for optimizing the quality of corks in the punching process R. Davies, B. A. Correia, F. D. Carvalho, LNETI (Portugal).	244
1567-25	Crystal surface analysis using matrix textural features classified by a probabilistic neural network C. R. Sawyer, EG&G Energy Measurements, Inc.; V. Quach, EG&G Energy Measurements, Inc. and U.S. Dept. of Energy/Nevada Operations Office; D. Nason, EG&G Energy Measurements, Inc.; L. van den Berg, EG&G Energy Measurements, Inc. and U.S. Dept. of Energy/Nevada Operations Office.	254
1567-26	Automatic shape recognition of human limbs to avoid errors due to skin marker shifting in motion analysis H. Hatze, A. Baca, Univ. of Vienna (Austria).	264
1567-27	Digital-signal-processor-based inspection of populated surface-mount technology printed circuit boards D. A. Hartley, C. A. Hobson, F. Lilley, Liverpool Polytechnic (UK).	277
SESSION 5 HUBBLE SPACE TELESCOPE IMAGERY: PROBLEMS, APPROACHES, AND SOLUTIONS		
1567-29	Hubble Space Telescope optics status C. J. Burrows, Space Telescope Science Institute and European Space Agency.	284
1567-30	HST image processing: an overview of algorithms for image restoration R. A. Gonsalves, Tufts Univ.; P. Nisenson, Smithsonian Astrophysical Observatory.	294

APPLICATIONS OF DIGITAL IMAGE PROCESSING XIV

Volume 1567

1567-31	HST image processing: how does it work and what are the problems? R. L. White, R. J. Hanisch, Space Telescope Science Institute.	308
1567-32	HST phase retrieval: a parameter estimation R. G. Lyon, P. E. Miller, A. Gruszczak, Hughes Danbury Optical Systems.....	317
1567-33	Phase retrieval for the Hubble Space Telescope using iterative propagation algorithms J. R. Fienup, Environmental Research Institute of Michigan.	327
SESSION 6 IMAGE COMPRESSION		
1567-35	Neural networks in bandwidth compression A. Habibi, The Aerospace Corp.	334
1567-36	Numerical design of parallel multiresolution filter banks for image coding applications A. C. Popat, W. Li, M. Kunt, Ecole Polytechnique Federale de Lausanne (Switzerland).....	341
1567-37	Hilbert scanning arithmetic coding for multispectral image compression A. Pérez, Instituto Tecnológico y de Estudios Superiores de Monterrey; S. Kamata, E. Kawaguchi, Kyushu Institute of Technology (Japan).....	354
1567-38	Coding of digital TV by motion-compensated Gabor decomposition F. Dufaux, T. Ebrahimi, A. M. Geurtz, M. Kunt, Ecole Polytechnique Federale de Lausanne (Switzerland).....	362
1567-39	Hierarchical motion-compensated interframe DPCM algorithm for low-bit-rate coding K. Xie, L. Van Eycken, A. J. Oosterlinck, Univ. of Leuven (Belgium).	380
1567-40	New method for chain coding based on convolution P. Qing, R. W. Means, HNC, Inc.	390
1567-41	Reversible compression of industrial radiographs using multiresolution decorrelation K. Chen, T. V. Ramabadran, Iowa State Univ.....	397
1567-78	Recursive scaled DCT H. S. Hou, The Aerospace Corp.....	402
SESSION 7 FLUID DYNAMICS AND WAVELETS APPLIED TO IMAGE PROCESSING		
1567-42	Shocks and other nonlinear filtering applied to image processing S. Osher, L. I. Rudin, Cognitech, Inc.	414
1567-43	Texture discrimination using wavelets P. Carter, Naval Surface Warfare Ctr.	432
1567-44	Nonlinear signal processing using integration of fluid dynamics equations S. Eidelman, W. Grossmann, A. Friedman, Science Applications International Corp.	439
1567-77	Polynomial neural nets for signal and image processing in chaotic backgrounds S. Gardner, Naval Research Lab.	451
SESSION 8 ANALYSIS AND THEORY I		
1567-46	Advanced in-plane rotation-invariant filter results G. Ravichandran, D. P. Casasent, Carnegie Mellon Univ.....	466
1567-47	Distortion- and intensity-invariant optical correlation filter system M. Rahmati, L. G. Hassebrook, M. Bhushan, Univ. of Kentucky.	480

(continued)

APPLICATIONS OF DIGITAL IMAGE PROCESSING XIV

Volume 1567

1567-49	Recovering 3-D translation of a rigid surface by a binocular observer using moments A. Al-Hudaithi, Colorado State Univ.; S. S. Udpa, Iowa State Univ.....	490
1567-50	Unsupervised target detection in a single IR image frame Y. Zhou, HNC, Inc.	502
1567-51	Resolution enhancement of blurred star field images by maximally sparse restoration B. D. Jeffs, M. Gunsay, J. Dougal, Brigham Young Univ.	511
1567-52	Modified Laplacian enhancement of low-resolution digital images D. C. Naylor, M. F. Daemi, Univ. of Nottingham (UK).	522
1567-79	Fast one-pass algorithm to label objects and compute their features T. Q. Thai, Sandia National Labs.	533
SESSION 9 HDTV IMAGE TRANSMISSION		
1567-53	Present state of HDTV coding in Japan and future prospect H. Murakami, KDD Research and Development Labs. (Japan).....	544
1567-54	Digital picture processing for the transmission of HDTV: the progress in Europe Y. Le Paner, P. Tourtier, Thomson-CSF (France).	556
1567-55	Performance of an HDTV codec adopting transform and motion compensation techniques M. Barbero, RAI-Centro Ricerche (Italy); S. Cucchi, TELETTRA (Italy); M. Muratori, RAI-Centro Ricerche (Italy).	566
1567-56	140-Mbit/s HDTV coding using subband and hybrid techniques H. Amor, J. Wietzke, Robert Bosch GmbH (FRG).	578
1567-76	Comparison of image compression techniques for high quality based on properties of visual perception V. R. Algazi, T. R. Reed, Univ. of California/Davis.	589
SESSION 10 ANALYSIS AND THEORY II		
1567-57	Imagery super-resolution: emerging prospects B. R. Hunt, Univ. of Arizona.	600
1567-58	Maximum likelihood estimation of affine-modeled image motion S. J. Shaltaf, N. M. Namazi, Michigan Technological Univ.	609
1567-59	Assessment of the information content of patterns: an algorithm M. F. Daemi, R. L. Beurle, Univ. of Nottingham (UK).	621
1567-60	Three-dimensional target recognition from fusion of dense range and intensity images M. Ramirez, S. Mitra, Texas Tech Univ.	632
1567-61	Extracting features to recognize partially occluded objects M. W. Koch, Clarkson Univ.; A. Ramamurthy, Electro-Optical Information Systems.	638
1567-62	Image resampling in remote sensing and image visualization applications T. J. Trainer, F. Sun, The Analytic Sciences Corp.	650
1567-73	Nonuniform image motion estimation in transformed-domain N. M. Namazi, J. I. Lipp, Michigan Technological Univ.	659
1567-64	Automatic searching center measurement of profile of a line (Proceedings Only) X. Qiang, Xian Automobile Fitting Works (China); Q. Yang, Northwestern Univ. of Agriculture (China).	670

APPLICATIONS OF DIGITAL IMAGE PROCESSING XIV

Volume 1567

1567-66	Optical 3-D sensing for measurement of bottomhole pattern (Proceedings Only) W. Su, Southwestern Petroleum Institute (China); X. Su, Sichuan Univ. (China).....	680
1567-80	Morphological processing for the analysis of disordered structures (Proceedings Only) D. P. Casasent, Carnegie Mellon Univ.; R. Sturgill, Motorola Communications Sector; R. H. Schaefer, Carnegie Mellon Univ.....	683
1567-65	Inverse filtering technique for the synthesis of distortion-invariant optical correlation filters W. Shen, S. Zhang, C. Tao, East China Institute of Technology (China).....	691
1567-68	New method of 3-D object recognition A. Z. He, Q. Li, P. C. Miao, East China Institute of Technology (China).....	698
1567-69	New method of adjusting color of pseudocolor encoding image H. Cai, Z. Chen, Sichuan Univ. (China).....	703
1567-70	Parallel DC notch filter K. Kwok, M. Chan, Hong Kong Baptist College (Hong Kong).....	709
1567-71	Identification and restoration of images with out-of-focus blurs K. Liu, J. Quan, J. Y. Yang, Y. Cheng, East China Institute of Technology (China).....	720
	Addendum	729
	Author Index	730

APPLICATIONS OF DIGITAL IMAGE PROCESSING XIV

Volume 1567

SESSION 1

Systems and Software

Chair

Andrew G. Tescher

Lockheed Palo Alto Research Laboratory

Integrated image processing and tracker performance prediction workstation

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ABSTRACT

Extensive research has shown that including target aspect angle measurements from an optical sensor can significantly improve the performance of radar tracking systems. Integrating sequences of target imagery with the kinematic information involves sets of image processing and sensor data fusion algorithms. A workstation has been developed to expedite the analysis of the algorithms and to integrate the image processing with selectable extended-state tracker modules. This workstation can access analog video imagery from a video optical disk controlled by a PC, segment the target in the image, and perform target identification and aspect angle estimation using a database of target models which span the range of possible aspects. The angle information is then "fused" with kinematic data to augment the tracker state estimator. The workstation is implemented with a powerful visual user interface in a UNIX/X-Windows environment, and includes a wide array of image and signal processing algorithms. Interactive modifications of processing sequences and "what if" analyses are easily conducted. The workstation provides a consistent user interface across a variety of applications. This system has also been used to implement phase retrieval and related image recovery algorithms.

1. INTRODUCTION

The performance of radar tracking systems designed to follow highly maneuvering targets can be improved if additional information on possible target future motion is available.^{1,2,3} Target aspect angle information can be used to estimate the orientation of the wing plane of fixed wing aircraft and hence the direction of maximum maneuverability (normal to this wing plane). The application of target orientation information to tracking problems typically requires the extraction of three dimensional object orientation information from two dimensional object projections (images), and these techniques must be robust against scale and intensity fluctuations. Approaches utilizing Fourier descriptors and moments have been applied to this information extraction problem.^{4,5,6} The extracted target orientation information must be temporally synchronized and rotated to the radar tracker coordinate system in order to be included as additional information to an extended state tracking filter. Extended state radar/aspect tracker analyses then is a multi-disciplinary sensor fusion problem, involving image processing and pattern recognition, estimation and position prediction, and performance improvement assessment. We have developed a modeling and simulation workstation designed to flexibly support such analyses and to extend analyses with a powerful array of support utilities and capabilities.

The workstation includes the following capabilities:

- access to time sequenced digital image data,
- preprocess the image data (calibrate, threshold, segment, etc),
- identify and estimate aspect angles of the target,
- rotate aspect angles to radar coordinate system,
- time synchronize image and radar data,
- select state estimator algorithm,
- select position predictor algorithm,
- compare predicted positions to known positions.

These functions are generic to any computer simulation of the radar/imagery tracking problem. The workstation we have developed incorporates these functions in a software executive which integrates graphical user interface, code generators, instructional aids, information processing and data visualization in a comprehensive information processing research tool.

2. THE WORKSTATION ENVIRONMENT

Evaluation of several software packages to serve as the simulation environment, including an image processing system we previously developed for algorithm analyses⁷, was based on the following factors :

Portability: minimum machine dependency and maximum adherence to emerging software standards;

Development efficiency: ease of incorporating new functions and routines, and a robust set of existing routines was desired. Ease of performing "what-if" type analyses, and support for code documentation and code generation were also of interest.

Flexibility: A software environment that can be easily utilized for expanded studies in a variety of areas related to signal and image processing was required.

Visual user interface: we sought to maintain a high level of user productivity by providing a high level visual interface to the simulation and to all supporting function.

Based on these criteria and trial examinations of a number of software systems, we selected Khoros, a code which was currently under development at the University of New Mexico Vision Laboratory⁸. This code in many ways represented the natural evolution of our previous work⁷ to a standard environment with a visual interface. Several extensions to the Khoros environment were required to support simulations:

- implementation of looping capability and control (if .. then blocks)
- implementation of support features to reference sequences of image data
- implementation of a "macro" capability to reduce workspace complexity;
- implementation of global parameter and variable utilities to allow simulation modules to pass scalar information.

These features have been incorporated in the recently released Khoros 1.0 software⁸. The Khoros user interface can be described as a visual programming language using graphical icons as functional primitives, and structured pipelined data flow as the programming paradigm. This interface is supported with a user interface specification language and graphical interactive interface prototyper, a code and documentation tool set and a large array of image and signal processing routines. The interface provides productivity increasing capability - the interface is consistent across applications, file names are automatically generated, multiple levels of "help" exist, and the system contains integrated 2D and 3D vector graphics packages, and a rich complement of interactive raster display utilities.

The Khoros software is based on the X-11R4 standard and is implemented under the UNIX operating system on a variety of platforms. The simulation or any other application code is developed in a workspace which can be custom configured. Functions are represented as " glyphs" and connections indicate data flow. Dialog boxes support user inputs and selections. Figure 1 shows a Khoros workspace with a simple process which displays an image and a histogram of the image executing.

We have implemented our tracker simulation under the Khoros environment on a SUN 4/470 workstation with color monitor and 32 Mbytes of memory. Both "C" and Fortran functions are incorporated in the simulation. Image data can be acquired by ethernet transfer of digital images obtained

from a PC-386 with a frame grabber board and a video optical disk as a programmable analog video mass storage device. We showed that this process can be controlled from within Khoros on a frame by frame basis but we have found it more convenient to digitize a sequence of frames and pass the file to the SUN. The segmenting operation can occur on the PC or the SUN. Figure 2 is a schematic of image data transfer to the workstation.

3. THE SIMULATION APPLICATION

A block diagram of the Khoros glyph structure we have implemented to produce the tracker simulation is shown in Figure 3. At the bottom of this figure the existence of data and temporary files is indicated. The system is designed to be easily modified, with functions being added or subtracted as new algorithms are developed. For example, the segmentation operation is currently performed on a PC/386 using an intelligent region growing algorithm⁹; however unsegmented images could be transferred from the PC and an existing Khoros segmentation algorithm executed (or a new segmenter could be added).

The simulation architecture represents the integration of three major algorithmic steps - segmentation, pattern recognition, and estimation/prediction. Currently these modules are based on the following contributors:

Segmentation: The intelligent region growing algorithm was developed for PC/386 systems at SRE, Inc.⁹.

Pattern Recognition: the identify function is based on modules extracted from the VISIX¹⁰ package, and is based on a "standard" moments feature vector⁵. Individual VISIX functions can be incorporated into the simulation by a command line reformatter interface we developed. In addition, data format conversions are available for a wide variety of format types. The segmented image is identified and rotation angles estimated by referencing the extracted feature vector to a database of targets at a selectable range of view angles. Thus the current simulation performs target identification and aspect angle recognition functions. Support functions allow the generation of new target database entries. These functions require a wire grid model of the target. This model is then rotated and projected onto an image plane at the selected view angles, and the computed feature vector is stored in the library.

Tracking algorithms : the tracker modules support two modes of operation. In the first mode, all data is presumed to be pre-computed and the tracker module computes the entire time history of radar and aspect data in one step, producing at the end of this step the error as a function of time. In mode two the tracker processes each set of new information in the simulation loop as shown in figure 2. The tracker module allow selection of a variety of estimator and predictor routines - the user selects the desired routines from the modules forms before executing the simulation. The tracker modules implemented in the simulation were developed at Purdue University and were converted to run under Khoros¹¹.

4. SUMMARY

We have developed an integrated image processing and tracker performance prediction workstation which has wide applicability to signal processing and simulation problems. This workstation is the result of an integration of a recently developed software executive with a powerful visual user interface (Khoros), and application software from a variety of sources. The workstation is especially adept at integrating such diverse inputs into a modular structure, and the simulation data processing flow can be easily changed to support what-if type analyses. This approach has lead to a number of applications in imaging system simulation and image data processing which bear witness to the flexibility of the system design.

5. ACKNOWLEDGEMENTS

The product of this effort is the result of integrating a variety of software systems.. The Khoros environment was developed by Dr. John Rasure and his team at the University of New Mexico. We appreciate the many discussions and resulting enhancements that were integrated into Khoros based on our requirements. Dr. Dominick Andrisani and Timothy Tao at Purdue provided the tracker modules. Dr. Tony Reeves of Cornell University provided the VISIX target identification routines, and Dr. Shin-Yi Hsu of SRE, Inc. developed the image segmentation code. The considerable effort required to integrate this set of contributions was supported by Dr. Norm Coleman and Dr. Frank Kuhl at ARDEC, Picatinney Arsenal under contract DAAA 21-89-C-0071.

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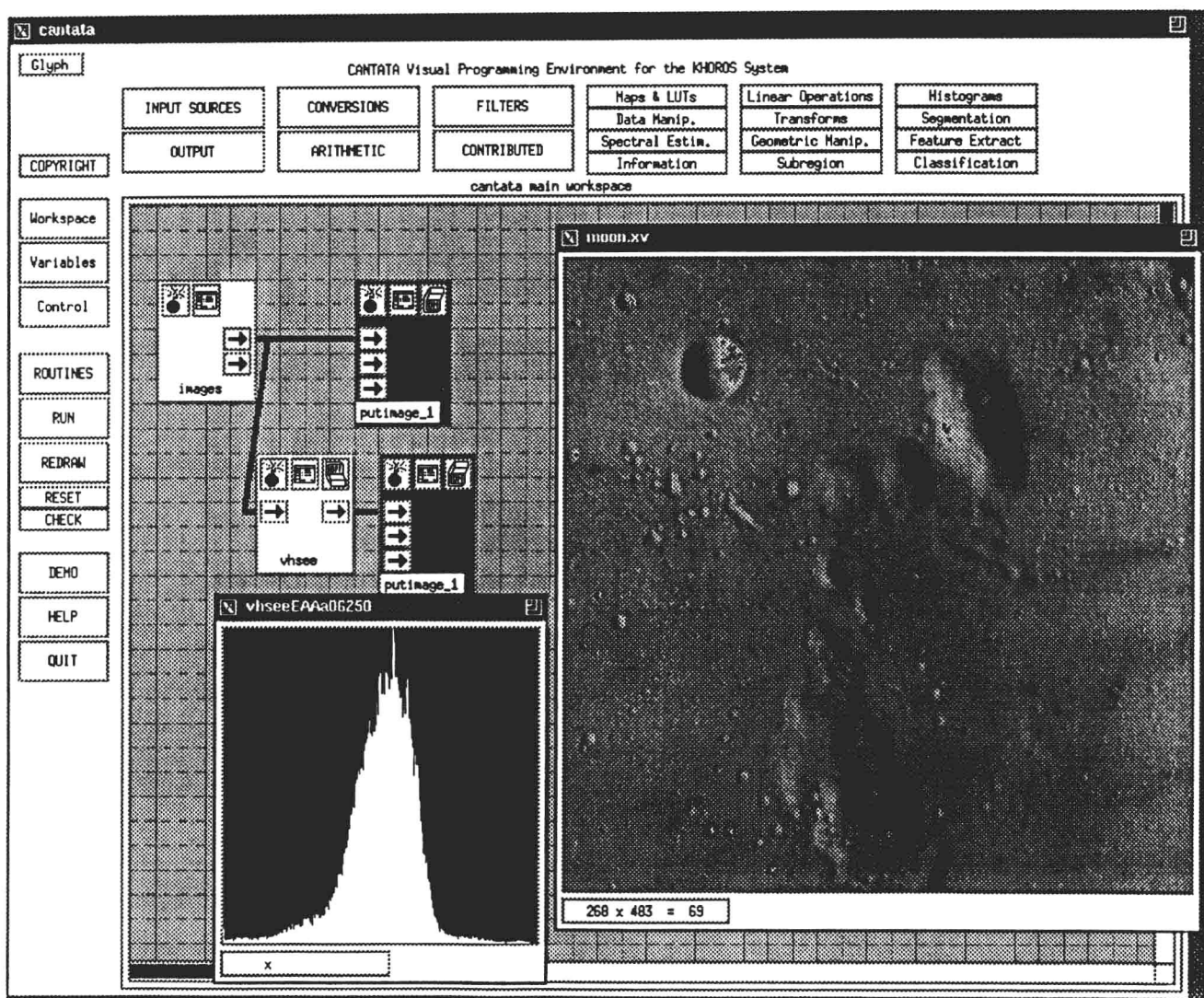


Figure 1. A sample workspace with image display, histogram, and histogram display processes.