SPECIAL ISSUE

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PROCEEDINGS

Guest Editor: Judy M Bishop

Organised by the SA Institute of Computer Scientists
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When the first SA Computer Symposium was held at the CSIR in the early eighties, it was unique. There was no other forum at the time for the presentation of research in computer science. In the intervening decade, conferences, symposia and workshops have sprung up in response to demand, and now there are several successful ventures, some into their third or fourth iteration. Each of these addresses a specific topic - for example, hypermedia, expert systems, parallel processing or formal aspects of computing - and attracts a specialised audience, well versed in the subject and eager to learn more. For the main part, the proceedings are informal, and certainly not archival.

SACRS, though, is still unique, in that it deliberately covers a broad spectrum of research in computing, and in addition, seeks to provide a lasting record of the proceedings. To achieve the second aim, we negotiated with the SA Institute of Computer Scientists for the proceedings to form a special issue of the SA Computer Journal, and the copy you have in front of you is the result. The collaboration between the symposium committee and the journal’s editorial board placed high standards on the refereeing and final presentation of the papers, to the symposium’s benefit, while we were still able to maintain a fresh, audience-oriented approach to the selection of papers.

This is SACU’s first such special issue, and the largest issue (at 145 pages) to date. We hope that it is only the beginning of future such collaborations.

In all 29 papers were received, all were refereed twice, and 19 were chosen for presentation by the programme committee. All the papers were thoroughly revised by the authors on the basis of the referee’s comments, and the committee’s suggestions aimed at making the material more accessible to a broadly-based audience. Papers had to be new, and not to have been presented elsewhere, a requirement that is still unusual within the SA conference round.

A third goal of SACRS has been to invite keynote speakers, usually from overseas. This year, we are fortunate to present Dr Vinton Cerf, the father of the Internet and a world-renown expert on computer networks. Although his paper is not available for this special issue, it will appear later in SACJ. Through the good offices of Professor Chris Brink of UCT, we also have three other speakers from Germany, Canada and the US adding interest to the event, and two of their papers appear in this issue.

The programme committee originally devised a theme for the symposium - "Computing in the New South Africa". We received several queries as to the meaning of this theme, but unfortunately few papers that addressed it directly. One prospective author went as far as to enquire whether computer research would survive in the new South Africa. Another felt that his work was definitely not in the theme, as it was genuine, old world, basic, theoretical science! Nevertheless, there are two papers that consider one of South Africa’s key issues, that of language. Others look at the success we have achieved in applying technology to mining, and the future of low-cost operating systems. In all, the mix of papers represents a balance between the theoretical and the practical, the past and the future, all firmly based in the computing of the present.

Organising the symposium has involved the hard work of several people, and I would like to thank in particular:
- Derrick Kourie, my co-organiser, and the editor of SACJ for his invaluable advice and hard work throughout the planning and implementation stages;
- Riel Smit, the production editor, for attaining such a high standard in such a short time for so many papers;
- Gerrit Prinsloo and the staff at the CSSA for their efficient and quite delightfully unfussy organisation;
- Persetel for their very generous sponsorship of R25000, and Tim Schumann for taking a genuine interest in our events;
- the Foundation for Research Development for sponsoring Vint Cerf’s visit;
- and finally the Department of Computer Science of the University of Pretoria for providing the ideal working conditions for undertaking ventures of this kind, and especially Roelf van den Heever for his unfailing encouragement and support.

Judy M Bishop
Organising Chairman, SACRS 1992
Guest Editor, SACJ Special Issue
Referees

The journal draws on a wide range of referees. The following were involved in the refereeing of the papers selected for this special issue. Their role in certifying the papers and their contribution to enhancing the quality of papers is sincerely appreciated.

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Abstract

The routine use of satellite remotely sensed imagery for a variety of applications is twenty years old this year. In addition to these digital photographs of the earth's surface, subterranean views are made using gravity, magnetics, electrical techniques, seismics and the electromagnetic spectrum from microwaves to radio waves. The need to process these large volumes of data in an interactive manner leading to a visual result has made very specific demands on computer hardware, system design and processing algorithms. From large mainframe computers running in batch mode, the market has moved through mini to personal computers. New algorithms too, have emerged and a start has been made at identifying an objective criterion to evaluate processed images. We discuss some of these issues in the application of image processing to mineral exploration in South Africa.

Keywords: Geophysical Visualization, Image Processing, Mineral Exploration, Remote Sensing.
Computing Review Categories: 1.4, J.2

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1 Introduction

Image processing is the name given to the manipulation of arrays of numbers comprising features of interest embedded in a matrix of noise and irrelevance. These features may be physical objects such as rock outcrops in a satellite image, properties of objects like their size and spatial arrangement or even some underlying model giving rise to the observed image. The aim of image processing is to enhance the information content of the image leading, hopefully, to image understanding. Image processing is applied in medical diagnoses, in the computer aided manufacture of goods, weather forecasting, surveillance and numerous other activities. In South Africa, image processing of remotely sensed data is used by government and the private sector for the optimal utilization of our natural resources. There are some common threads linking all these activities:

- Images are quantized representations of a continuous reality. They share a common data structure – discrete grids with at least two dimensions.
- Image processing takes place on ‘fast’ computers, often having some form of parallel processing capability, and processed results may be visualised on a display screen.
- Similar numerical techniques are used across diverse applications. Most applications make extensive use of statistical techniques – after all, the image mean is the average brightness of the picture (regardless of its subject). Digital filters, pattern recognition and classification methods find wide application.

Mineral exploration is a science. Although some governments may “invest” in a plane that can sniff-out oil deposits and Uri Geller claims a psychic ability to find minerals, the most successful exploration techniques rely on the measurement and interpretation of data. These data have to be sensed remotely and then there is an inverse problem to solve: formulate a plausible geological model (which hopefully has something to do with reality!) which would explain the data.

2 Data

Remote Sensing of the environment took off with the launch of the first Earth Resources Technology Satellite ERTS-1 on July 23, 1972. This satellite was the first in a series of LANDSAT satellites which produce multispectral digital imagery of the earth’s surface. The data have many uses:

- Repeated coverage of an area provides a multitemporal view of a region which is useful in monitoring of forests, crops, water resources and the marine environment.
- Increased spatial resolution of the systems aids in cartographic applications.
- The synoptic view that is provided is useful for mapping geological structures and drainages.
- Increased spectral resolution allows the direct mapping of mineral assemblages and the identification of lithologies from space.

To expand on this last point, consider the occurrence of gold in Archean greenstone belts [6]. Current geological thinking [1] is that gold was deposited in and around greenstone belts from hydrothermal solutions. The wall rocks of the mineralized veins are typically altered by the hydrothermal fluids and the mineral products of this alteration and subsequent weathering products occur in the soil profiles above the gold deposits.

The LANDSAT Thematic Mapper (TM) satellite collects data in a number of spectral wavebands ranging from the visible to the near infrared. The various reflectance
properties of the minerals present in hydrothermally altered rocks and the soils developed above them enable detection of the hydrothermal alteration zones on TM images. These zones are thus potential areas of gold mineralization in granite and greenstone terrains.

The main disadvantage of satellite images for the explorationist is that only the surface of the earth is sensed. By measuring the strength of the earth's gravitational field, information can be inferred about the densities of rock at depth. These measurements may be gridded to form a gravity image. In the same way, measurements of the earth's magnetic field, seismic observations and other geophysical phenomena may be imaged. Two exciting local examples are the use of radio waves to image the electrical properties of rock in situ in a mine [9] and the imaging of the electrical conductivity of the earth using an airborne electromagnetic system [5].

Geophysical grids may be visualized in a number of different formats - as black and white images with grey levels proportional to the data values, as three-dimensional perspective plots, or as images having colour-coded values. This use of colour is a very useful interpretive tool since the human eye is a colour device with the ability to discriminate millions of colour hues and saturations. Grey level images are perceptually more restrictive having only about sixteen distinguishable shades of grey.

The representation of data as a grid of values facilitates spatial processing (using neighboring data values to enhance the information content of an image element), which is severely limiting in the analysis of point, profile or flight-line data. Homogenous regions may be identified and spatial structures such as dykes, lineaments and circular features may be enhanced. Spatial information is also used extensively in modelling the observed image as being generated by geological bodies with certain physical properties at depth.

Image processing of these data opens up the application of many processing techniques from the fields of computer vision, signal theory and robotics and may provide innovative and effective new insights into exploration problems.

If we adopt an image processing strategy, our data sets are automatically all compatible. Grids in the data base may be integrated with other data sets and the combined analysis of multiple data sources is a powerful tool in an integrated approach to mineral exploration or a more complete geographical understanding of an area. In this way co-registered images naturally form a raster-based GIS system.

3 Machines

Image processing systems as specialised machines for the analysis of grids of digital data have come to the fore in the last decade. Information processing technology, and image processors in particular, have recently shown remarkable progress in both computer hardware and application software. An image processing workstation may be either attached to a host computer or be a stand-alone device with a local processor and data input, storage and output facilities. The central processor is often paired with a specialized array or pipeline processor with the computational ability to perform arithmetic operations, convolutions and more recently, geometric transformations on images, in near real-time. Images are displayed on a high resolution monitor with typically 512 x 512 or 1024 x 1024 image values filling the screen with 256 possible values for red, green and blue, resulting in the simultaneous display of over sixteen million possible colours. Large images may be processed and viewed in screenfulls - with the processor handling the necessary data addressing and housekeeping. Graphics facilities exist for plotting histograms, scattergrams, profiles through the image and annotating the data. Output is available via snapshots of the screen, printouts and the digital production of very high resolution photographic negatives. Data may be entered into the system via computer tapes, or directly through the use of table or video digitizers.

The types of near real-time processing possible include:

- the collection of image statistics and histograms
- convolution (spatial filtering)
- warping of an image to conform to a map or another image
- magnification or minification of images
- arithmetic operations on two or more images.

Most remotely sensed satellite data is quantized to eight bits (= one byte) of precision allowing for 256 distinct data values. Although a case can be made for the effective processing of gravity data at byte precision through the judicious use of scaling, this is certainly not the case for magnetic data. Magnetic images typically have a range of many thousands of values and if any processing is to be done in the Fourier domain, full floating point precision is indicated. It is imperative that image processing hardware and software be able to handle data at a reasonable level of precision.

Remotely sensed images are large - a TM quarter scene covering a 90km x 90km area occupies 60 Mb. The trend in proposed systems is to even larger data volumes, indicating a persistence of the current bottleneck between disk and central memory.

Image processing was historically done on large mainframe computers in batch mode. Next came the cheaper, faster mini of which the VAX 11-780 is a good example. Recent hardware developments have allowed the PC to offer the reality of distributed image processing where each user has a workstation with local processing and data storage, networked to shared peripherals and an image data base. The PC world offers a myriad of cheap peripheral devices including video capture boards, image scanners, cordless digitizers and solid ink and colour sublimation printers. Many high resolution display boards are offered with hardware zoom and image scrolling capabilities. Database, CAD and GIS software is available on such machines giving us low cost, fully integrated, image processing workstations.
4 Algorithms

Processing algorithms often endeavor to enhance aspects of the information content of the image by emphasizing or suppressing specific components of the data to facilitate recognition of features by man or machine. Information in a remotely sensed image can be considered to be of two broad types: spectral and spatial. Spectral information is related to the digital measurements of the scanner. If we jumbled up all the pixels in an image, the spectral information content would remain the same while the spatial information component would be destroyed. Spectral algorithms consist of operations on the image histogram e.g. contrast stretching. The simple algorithms may be achieved (often in hardware) by the use of look-up tables which are simple linear maps from an input to an output greylevel distribution. More complicated transformations - for example principal components analysis - need the computation of the image multispectral covariance matrix along with a little linear algebra (calculation of eigenvalues and eigenvectors, in this case). These operations can be fairly time consuming.

Spatial algorithms consist of changing image geometry (image resampling) and may be computationally very expensive. A further class of spatial operation is the application of convolution masks, either for noise removal or edge enhancement, which again requires lots of arithmetic operations.

A large area of image processing is concerned with the classification of imagery — whether it be a simple clustering of pixels into statistically homogenous classes or a more elaborate maximum likelihood classification using spectral and spatial information. Classifications nearly always involve large amounts of computation. This will be more so in the future as there is a clear trend towards increased spectral dimension in both aircraft scanning systems and proposed satellite systems. These multispectral images of very high dimension need special algorithms for feature classification [7, 8]. Artificial neural networks have come to the fore recently for such classification problems. They have several advantages over conventional statistical techniques:

- Neural networks are distribution free — no assumptions are made about the statistics of the data.
- Data with high dimension may be classified. Many multivariate statistical methods rely on non-singular covariance matrices. This requirement may be problematic for data with correlated components or in cases where only limited training samples are available.

The virtues of neural nets for classification are also their weaknesses: ignoring the statistical nature of the data may result in slow convergence during training. In addition, neural nets have an ad-hoc organization, the number of layers, neurons and parameters is often heuristic and bad choices of topology may result in poor performance of the net. In spite of these drawbacks, neural nets are used for certain image classification tasks [2, 3].

After we have processed our image, how do we know whether it is any better than when we started? We can look at it and appraise the results in a qualitative manner but can't we be more precise? The answer is a qualified yes, but first we will have to decide on a suitable criterion for evaluation. If we have additional information about the geology of our TM image, we can measure whether we have enhanced or suppressed a particular feature. Very often, this approach can introduce bias into our image — if our processing strategies depend too heavily on immutable geological laws we will simply reinforce our preconceived ideas about the image before we have let the data tell their side of the story. A more honest approach would be to apply the maximum entropy principle. To illustrate this approach, suppose we observe some gravity values over a region \( \{ g_1, g_2, \ldots, g_n \} \). These \( g_i \) comprise our image \( G \). We are interested in testing the hypothesis \( D \) that the density of the rock underlying the area where we measured \( g_i \) is \( d_i \). An orthodox statistician would embed our image \( G \) in a sample space of other images \( \{ G_1 \ldots G_N \} \) we could have observed and then try to estimate the probabilities \( p(G_1|D) \) that the image \( G_i \) would be observed if \( D \) were true.

Our reasoning, using a maximum entropy formalism [4], is almost exactly the opposite. Instead of the class of all possible images \( \{ G_1 \ldots G_N \} \) consistent with \( D \), we consider the class of all hypotheses (density distributions) \( \{ D_1 \ldots D_K \} \) consistent with the \( G \) we have observed. Our knowledge of the possible ways in which nature could have generated the various \( D_i \) (based on a best guess of possible rock types occurring in the area) is used to pick the hypothesis with greatest entropy. This chosen hypothesis yields an image of densities \( \{ d_1 \ldots d_n \} \) which we also have reason to believe is the most honest image we could construct from \( G \).

The main task of the exploration geologist is to determine the structure of the earth from data obtained at the surface. Although some data sets do indeed have a z-component (e.g. seismic and borehole logs), they are usually cross-sections or projections and may have their own unique processing problems. This inverse problem of the explorationist may be tackled using many different approaches: least squares or predictive deconvolution-type methods are widely used and may be implemented to run on image processors, often in an interactive way. The parallel processing capabilities of image processing computers provide the exploration geologist/geophysicist with the ability to achieve fairly sophisticated transformations in real time. This is of great value to the answer of what if? — type questions and the choice of suitable parameters for processing algorithms. Interactive image processing/interpretation devices are fast replacing the magical black boxes of mysterious algorithms and monster batch job computers in the earth sciences.

5 Conclusions

Visualization is an important strategy for mineral exploration. It facilitates pattern recognition in data sets which have a spatial organization. The ability to visualize geo-
logical, geochemical, geophysical and geostatistical data at the same time may indicate a viable mineral deposit which would be inconclusive if the data were viewed independently. Image processing provides a tool for the combined analysis of disparate data sets using data structures which authentically represent the natural environment. Distributed image processing on low cost personal computers allows us to effectively use image processing to solve real world problems.

References

Notes for Contributors

The prime purpose of the journal is to publish original research papers in the fields of Computer Science and Information Systems, as well as shorter technical research papers. However, non-refereed review and exploratory articles of interest to the journal’s readers will be considered for publication under sections marked as Communications or Viewpoints. While English is the preferred language of the journal, papers in Afrikaans will also be accepted. Typed manuscripts for review should be submitted in triplicate to the editor.

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  - author’s affiliation and address;
  - an abstract of less than 200 words;
  - an appropriate keyword list;
  - a list of relevant Computing Review Categories.
- Tables and figures should be numbered and titled. Figures should be submitted as original line drawings/printouts, and not photocopies.
- References should be listed at the end of the text in alphabetic order of the (first) author’s surname, and should be cited in the text in square brackets [1, 2, 3]. References should take the form shown at the end of these notes.

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Charges per final page will be levied on papers accepted for publication. They will be scaled to reflect scanning, typesetting, reproduction and other costs. Currently, the minimum rate is R20-00 per final page for \LaTeX\ or camera-ready contributions and the maximum is R100-00 per page for contributions in typed format.

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