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REPORT ON THE UNITED NATIONS/EUROPEAN SPACE AGENCY/COMMITTEE ON SPACE RESEARCH WORKSHOP ON DATA ANALYSIS TECHNIQUES, HOSTED BY THE BRAZILIAN NATIONAL INSTITUTE FOR SPACE RESEARCH ON BEHALF OF THE GOVERNMENT OF BRAZIL

(São José dos Campos, Brazil, 10-14 November 1997)

CONTENTS

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EXPLANATORY LIST OF TECHNICAL TERMS AND ABBREVIATIONS

2D	two-dimensional
3D	three-dimensional
AIX	Advanced Interactive Executive (an implementation of the UNIX operating system)
AGL	Astronet Graphical Library
ARC	Automatic Ratio Control
ASCII	American Standard Code for Information Interchange
BMP	Mackintosh graphic format
C	high-level programming language
CASE	Computer Aided Software Engineering tools
CDF	Comma Delimited Format (file name extension/file type)
DEC	Digital Equipment Corporation
DCF	Two-dimensional Graphics File Format
FFT	Fast Fourier Transform
FORTRAN	Formula Translator (programming language)
Free BSD	Free Berkeley Software Distribution (UNIX)
GIF	Graphics Interchange Format
GIS	Geographic Information System
GNU	“GNU’s Not UNIX” (Free Software Foundation operating system)
HDF	Hierarchical Data Format
HP-UX	Hewlett-Packard operating system
IDI	Image Display Interface
IDL	Interactive Data Language
I/O	input/output
IRIX	main operating system used by Silicon Graphics Workstations
JPEG	format for compressed graphics files (Joint Photographic Expert Group)
Linux	an implementation of the UNIX operating system
MCL	MIDAS Common Language
MIDAS	Munich Image Data Analysis System
NetCDF	Network Common Data Format
OS-routines	Operating System routines
RAW	a mode that allows a program to transfer bits directly to or from an I/O device without any processing, abstraction, or interpretation by the operating system
Solaris	Sun-UNIX-based user environment, including the UNIX operating system and an XII-based window system
Solaris x 86	Solaris implementation for personal computers
SPRING	Sistema de Processamento de Informações Geograficas (Remote Sensing Image Processing System)
TIFF	Tagged Image File Format
UNIX	AT & T Bell Laboratories operating system
VAX	Virtual Address Extended
VMS	Virtual Memory System (operating system on VAX computers)
Widget	window gadget (a combination of a graphic symbol and program code to perform a specific function in a graphical user interface (GUI)
WYSIWYG	“what you see is what you get”

INTRODUCTION

A. Background and objectives

1. The General Assembly, in its resolution 37/90, decided, on the recommendation[1] of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space that the United Nations Programme on Space Applications, should, *inter alia*, promote greater cooperation in space science and technology between developed and developing countries as well as among developing countries.

2. The Committee on the Peaceful Uses of Outer Space at its thirty-ninth session took note of the activities proposed for the United Nations Programme on Space Applications for 1997,[2] as recommended by the Scientific and Technical Subcommittee at its thirty-third session. Subsequently, in its resolution 51/123 of 13 December 1996, the General Assembly endorsed the activities of the Programme for 1997.

3. In response to General Assembly resolution 51/123 and in accordance with the recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, the United Nations/European Space Agency/Committee on Space Research Workshop on Data Analysis Techniques was organized within the framework of the activities of the Programme for 1997, particularly for the benefit of developing countries.

4. The Workshop was organized jointly by the Office for Outer Space Affairs of the United Nations Secretariat, the European Space Agency (ESA), the Committee on Space Research of the International Council of Scientific Unions (ICSU), and the National Institute for Space Research (INPE) of Brazil.

5. The objective of the Workshop was to provide a forum for educators and scientists concerned with access, analysis and interpretation of data from Earth observation satellites. Such a forum would foster communication between developers and users with a wide range of expertise in the production and use of software packages to pursue data management in remote sensing, satellite meteorology and astronomy. Another objective of the Workshop was to provide participants with an expert knowledge of the tools available for access, analysis, and interpretation of data acquired by digital data acquisition systems for a variety of educational, scientific and development-oriented applications.

6. Basic and advanced principles and methods were presented in the Workshop and reinforced with practical examples from everyday data access, analysis and interpretation operations. The presentations and discussions focused on promoting understanding of the concepts involved through practical exercises. Participants brought problems from their own practical experience for discussion.

B. Organization and programme of the Workshop

7. The Workshop was held at the National Institute for Space Research (INPE), São José dos Campos, from 10 to 14 November 1997. Participants evaluated the advances that had taken place since the subject of data analysis techniques had been addressed by a United Nations workshop organized in conjunction with the XVIIth Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS) at Washington, D.C. from 6 to 7 August 1992 (A/AC.105/545 and Corr.1).

8. The Workshop was attended by 50 space scientists from Argentina, Austria, Brazil, Chile, China, Ecuador, France, Germany, India, Indonesia, Lebanon, Nigeria, Paraguay, Slovakia, Sri Lanka, the Syrian Arab Republic, Thailand, the United States of America and Uruguay, and from Palestine. The United Nations and ESA provided financial support to defray the cost of air travel and living expenses of 17 participants from developing countries. Meeting facilities, equipment and local transportation were provided by INPE.

9. The programme of the Workshop had been developed jointly by the Office for Outer Space Affairs, INPE and the Committee on Space Research. The programme of the Workshop included presentations on:

(a) A review of basic concepts in data analysis techniques;

(b) The time and frequency domains;

(c) Time histories and time series analysis;

(d) Basic curve fitting;

(e) Yield point determination;

(f) Oscillating signal analysis;

(g) Spectral domain operations;

(h) Data filtering;

(i) Signal integration and differentiation;

(j) Transient data analysis;

(k) Continuous data analysis;

(l) Data averaging;

(m) Data compression;

(n) Neural networks and fuzzy logic in image processing;

(o) Neural networks for signal processing;

(p) Wavelets;

(q) Multidimensional signal processing;

(r) Applications of image processing and data analysis to all fields, including remote sensing, satellite meteorology, and astronomy.

10. Opening addresses were made by the representatives of the National Institute for Space Research of Brazil, the United Nations Office for Outer Space Affairs, and ESA.

11. The present report, which covers the background, objectives and organization of the Workshop and summaries selected presentations made at the Workshop, was prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. The participants reported on the knowledge acquired and the work conducted at the Workshop to the appropriate authorities of their Governments, universities, observatories and research institutions.

SOFTWARE SYSTEMS FOR IMAGE PROCESSING AND DATA ANALYSIS

A. Centres for space science and technology education

12. A major prerequisite for successful space science and technology applications in developing countries was the development of various essential indigenous capacities, particularly human resources, within each region. In recognition of that fact, the General Assembly, in its resolution 45/72, had endorsed the recommendation of the Working Group of the Whole of the Scientific and Technical Subcommittee (A/AC.105/456, annex II, para. 4 (n)), as endorsed by the Committee on the Peaceful Uses of Outer Space, that "the United Nations should lead, with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in existing national/regional educational institutions in the developing countries".

13. The Office for Outer Space Affairs, through the United Nations Programme on Space Applications, had translated that endorsement by the General Assembly into an initiative aimed at establishing regional centres for space science and technology education (affiliated to the United Nations) in developing countries. The concept behind those centres was based on the fundamental notion that it was vital for developing countries to have indigenous personnel trained in the use of space science and technology, particularly those applications relevant to their national development programmes, such as remote sensing, satellite meteorology and the use of geographic information systems, space communications and basic space science. Only then would the developing countries be able to contribute effectively to the solution of global, regional, and national environmental and resource management problems.

14. The Centre for Space Science and Technology Education for Asia and the Pacific (affiliated to the United Nations) had been established in India in November 1995. The Centre had its campus at the Indian Institute of Remote Sensing (IIRS), at Dehradun. The Centre used the infrastructure available at IIRS for conducting remote sensing and GIS courses; the Space Applications Centre, Ahmedabad, for courses on satellite communications and satellite meteorology; and the Physical Research Laboratory, Ahmedabad, for space sciences.

15. Brazil and Mexico had been selected as the host countries for the regional Centre for Space Science and Technology Education (affiliated to the United Nations) for the Latin America and the Caribbean region. The agreement establishing the Centre had been signed by Brazil and Mexico in March 1997 and the text of the agreement was being distributed to all Member States of the region for their concurrence.

16. Plans for the establishment of such centres, one in Western Asia and one each for the French-speaking and English-speaking regions of Africa, in Morocco and Nigeria respectively, were nearing completion.

B. Data management units of the centres

17. The initial programmes of each centre would focus on remote sensing and geographic information systems, meteorological satellite applications, satellite communications, and basic space science. Each centre would also have a data management unit (DMU), linked to relevant global data bases in order to meet the data needs at the centres. The functions of the DMUs would include data collection, key entry, programming, operations and maintenance of data files, programs, and hardware. The programme of the Workshop focused accordingly on data analysis techniques as part of computer software systems and languages.

C. Computer software systems and languages

18. In the 1970s until the mid-1980s, scientific computing had expanded to an extraordinary degree. The available technology had moved from the single campus computer to widely available minicomputers (workstations) and the personal computer (PC). What was missing, however, was a language-neutral environment, in which scientific programming could be carried out in any available computer language. Since then, a number of programming languages had begun to dominate the field, and a growing minority of scientists were using Interactive Data

Language (IDL), Mathematica and similar integrated total environments. Furthermore, programming languages like Fortran were gradually being upgraded and designed to produce codes for parallel processing on computers with multiple processors. Integrated total environments consisted of intrinsically higher-level programming languages. Eventually, IDL, Mathematica, and Fortran 90 (complemented by Numerical Recipes) had emerged as comparably high-level programming languages.

D. Interactive Data Language

19. IDL was a complete computing environment for the interactive analysis and visualization of data. It integrated a powerful, array-oriented language with numerous mathematical analysis and graphical display techniques. By programming in Fortran or C, using IDL, tasks that had required days or weeks of programming with traditional languages could be completed in hours. Users could explore data interactively using IDL commands and then create complete applications by writing IDL programs.

20. IDL had the following advantages:

(a) It was a complete, structured language that could be used both interactively and to create sophisticated functions, procedures and applications;

(b) Operators and functions worked on entire arrays (without using loops), simplifying interactive analysis and reducing programming time;

(c) Immediate compilation and execution of IDL commands provided instant feedback and “hands-on” interaction;

(d) Rapid 2D plotting, multi-dimensional plotting, volume visualization, image display, and animation made it possible to observe the results of computations immediately;

(e) Many numerical and statistical analysis routines—including Numerical Recipes routines—were provided for the analysis and simulation of data;

(f) The flexible input/output facilities of IDL made it possible to read any type of custom data format. Support was also provided for common image standards (including BMP, GIF and JPEG) and scientific data formats (CDF, HDF and NetCDF);

(g) IDL widgets could be used for the speedy creation of multi-platform graphical user interfaces to IDL programs;

(h) IDL programs ran the same way in all supported platforms (UNIX, VMS, Microsoft Windows, and Mackintosh systems) with little or no modification. The portability of applications made it possible to support easily a variety of computers;

(i) Existing Fortran and C routines could be dynamically linked to IDL to add specialized functionality. Alternatively, C and Fortran programs could call IDL routines as a subroutine library or display.

E. Geographic Information System and Remote Sensing Image Processing System

21. The Sistema de Processamento de Informacóes Geograficas (SPRING) was a state-of-the-art GIS and remote sensing image processing system, with an object-oriented data model that provided for the integration of raster and vector data representations in a single environment. It had been developed by INPE, with assistance from Brazil's Agricultural Research Agency (EMBRAPA), IBM Brazil, the Coordinating Commission for the System for Surveillance of the Amazon (CC/SIVAM) and the National Research and Development Agency (CNPQ). SPRING was being used for a number of important projects in Brazil, including the multi-temporal evaluation of deforestation in the Amazonia rain forest; ecological-economic zoning for Brazil; and the National soils data base.

22. The traditional data processing techniques supported by SPRING included the following:

(a) Image processing: registration, mosaicking, enhancement, filtering, IHS principal components transformations, arithmetical operations, maximum-likelihood pixel-based classifier;

(b) Digital terrain modelling: grid generation, contour plotting, slope/aspect maps, 3D visualization;

(c) Thematical and cadastral maps: digitizing, editing, topology generation, raster to and from vector conversion, mosaicking;

(d) Data base query and spatial presentation;

(e) Support for 14 cartographical projections;

(f) Import/export to ARC/INFO, DXF, ASCII, RAW and TIFF formats;

(g) WYSIWYG map production (with symbol library).

23. Among the innovative characteristic and techniques introduced by SPRING were the following:

(a) Menu-driven interface, presenting a unified environment for the geographical data types;

(b) Segmentation techniques and region-based classifiers (non-supervised and supervised);

(c) Restoration of Landsat and satellite pour l'observation de la Terre (Earth observation satellite) (SPOT) images;

(d) Mixture models for remote sensing imagery;

(e) Markovian techniques for post-classification;

(f) Radar image processing;

(g) Triangular grids generation with restrictions;

(h) Object-oriented Geographical Analysis Language.

24. In the interest of the widespread use and dissemination of remote sensing and GIS techniques for an ever-growing user community, SPRING had been made available as freeware software (http://sputnik.dpi.inpe.br/spring). SPRING currently supported the following UNIX environments: AIX 3.2.5, HP-UX 9.0, IRIX 4.0, Linux 2.0, Solaris 2.5 and Solaris x 86 2.5. INPE was working to make a full English-

language documented source code for SPRING available on the Internet, under the GNU General Public License, and on a version for FreeBSD, Windows 95 and Windows NT platforms.

F. Astronomical Data Analysis and Image Processing System

25. The Munich Data Analysis System (MIDAS) of the European Southern Observatory (ESO) was designed to allow easy integration of complex analysis algorithms, as well as greater flexibility in interactive use and in the creation of user-specific procedures from the basic building blocks. MIDAS was also available on the Internet (http://www.eso.org/research/data-man/data-proc/systems/esomidas/midas.html).

26. The first design proposal for MIDAS, made in the late 1980s, used ideas from the STARLINK project of the United Kingdom of Great Britain and Northern Ireland for the software interface definitions. The current version, which had become available in 1984, followed a similar philosophy in its application program interfaces but had been expanded to the new Standard Interfaces, which had a broader base.

27. The initial design of MIDAS was made on a DEC/VMS system in the early 1980s. In the late 1980s, however, with the acceptance of UNIX by the scientific community as a standard operating system and with the introduction of workstations, the system had been largely redesigned and currently ran on a wide variety of computers, with either DEC/VMS or one of the various implementations of UNIX as the operating system.

1. Design of MIDAS

28. In the design of MIDAS, a number of basic requirements had been taken into account in order to ensure that the system could evolve, namely:

(a) Modular design, which made it easy to adapt to different environments;

(b) Portability, to ensure that MIDAS could run on different computers;

(c) The adoption of standards, like the programming languages Fortran and C, and the X Window system. The use of standard programming languages enabled CASE tools to be used and made it simpler to shift to object-oriented coding;

(d) Easy programming through the provision of simple interface routines to access the data, and implementation of a flexible control language;

(e) Open design, which made it easy to add contributed software from other institutes.

2. Basic configurations and characteristics

29. The basic system was designed to work on a single computer with appropriate peripherals. It consisted of the following three parts: the monitor, the applications, and the interfaces. The MIDAS monitor included user interface, and routines for the administration of tasks and local variables. MIDAS was command driven. All the user interaction and the scheduling of processes to execute the commands was done through the monitor. The monitor had the following functions:

(a) To display on-line help with different levels of detail;

(b) To keep a log of all operations during a session;

(c) To serve as a command interpreter;

(d) To reprocess input strings to translate user defined symbols and to facilitate command numbering and buffering etc.;

(e) To execute applications on a subprocess.

30. MIDAS was a multiprocess system. In MIDAS, applications performed the actual operations on the data. They could be written in standard Fortran77, C, or the MIDAS control language. All communication must go through the monitor and was done through keywords and frame descriptors. The functions of the applications in MIDAS were divided into several levels of importance, the top level being the primary or core applications without which image-processing would be practically impossible. The core applications took care of:

(a) Image display, comprising all the usual functions expected from a mature image-processing system, such as displaying and retrieving data in full or split-screen mode, zoom and scroll, getting cursor values, modifying look-up tables, blinking etc. The kernel of the package was the Image Display Interfaces library (IDI);

(b) Graphics display, which provided the functionality needed for data presentation in graphical form, as well as interactive data reduction. The graphics package was device-independent, and based on the Astronet Graphic Library (AGL);

(c) General image processing, which included typical arithmetic operations like filtering, resampling, interpolation, rotation, extraction/insertion, FFT etc.;

(d) Table File System, which provided a complete set of functions for processing tabular data, including reading, writing, editing, searching, sorting, regression etc.;

(e) Fitting package, which afforded the necessary tools to fit non-linear functions and to model data distributions both in table and image format;

(f) Data I/O - to transfer the data from and to tape or disk.

31. The interfaces bound the applications to the monitor and defined the possible interaction with application and monitor. An additional level, the lowest, was used to interface MIDAS itself to the host operating system and was not to be used for application programs. MIDAS was based on three sets of general interfaces that allowed easy integration of application programs into MIDAS, namely: (a) the “standard interfaces” for general I/O and image access; (b) the “table interfaces” for access to table structures; and (c) the “graphics interfaces” for easy inclusion of graphical representation of the MIDAS data structures. To provide a portable system, a layer of OS-routines had been used to shield MIDAS from the local operating system.

MIDAS Command Language

32. The MIDAS Command Language, (MCL), provided the tools for constructing complex command procedures from existing commands. Since all application programs got their parameters through a set of standard interfaces, it was very simple to string commands together, each using results from the previous command. In fact, except for the system commands, all MIDAS commands were MCL procedures themselves. In general, MCL provided the basic features of a programming language, such as definition of parameters, looping, conditional statements and branching, global and local variables, procedure calls (also recurrent) with parameters, and built-in functions. MCL was an interpreted language, meaning that the definition of local variables could be done anywhere in a procedure and that no compilation and linking steps were required before executing a MCL procedure.

33. Data items in MIDAS could be divided into several groups:

(a) Frames - data sets that had a uniform sampling, for example images or spectra. Up to 16 dimensions could be supported; most applications, however, were limited to two dimensions;

(b) Tables - collections of heterogeneous data organized in columns and rows;

(c) Descriptors - variables related to the general database, e.g. frames and tables. They were used to describe the data in detail;

(d) Keywords - variables relating to processes or sessions. They were similar to descriptors and were mainly used to transfer information between, and to control, tasks;

(e) Catalogues, containing lists of either images, tables or fit files for the purpose of grouping data together.

Notes

[1]See *Report of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 9-21 August 1982* (A/CONF.101/10 and Corr.1 and 2), Part One, sect. III.F, para. 430.

[2]*Official Records of the General Assembly, Fifty-first Session, Supplement No. 20* (A/51/20), sect. II.B, para. 39.