

EARTHSCAN - A range of remote sensing systems

D.R.Sloggett & C.McGeachy

Environmental and Space Systems Group, Software Sciences Limited, Farnborough, Hampshire, UK

ABSTRACT: Today's users of remote sensing systems require a capability to easily enhance and develop those systems to incorporate the results of state-of-the-art research, new applications and the launch of new satellites.

The EARTHSCAN range of remote sensing systems has been designed around a core set of image processing and image manipulation routines to provide a basic building block on which to carry out both operational remote sensing and research work. The systems are designed in a modular way, for expansion, and to be portable between different host computer systems. A user friendly MMI enables the operator to use the system, and images are displayed on an associated workstation. The systems incorporate an advanced Geographic Information System (GIS) capability.

The paper describes the architecture of the systems and their associated baseline image processing functions. Adaptation of the system to generate new products, enhance the catalogue, add new image processing routines is illustrated. The range of systems are unique and cater for future developments, applications and new satellites.

1 INTRODUCTION

The planned programme of remote sensing satellites due to be launched over the next 15 years has given a strong impetus to the development of remote sensing applications. The prospects for continued coverage and the long term availability of data across a wide geographic area have increased the interest of a number of user groups. In particular the prospects for the polar platform, to provide a long term facility, has been the focus of attention for a number of studies within the UK.

Currently there is one main source of operational remote sensing data for land applications, the American polar orbiting satellite LANDSAT, operated by the National Oceanic and Atmospheric Administration (NOAA). To date there have been four LANDSAT satellites and plans are advanced for the replacement of these satellites to provide a continuing service into the 21st century. A significant European contribution to satellite remote sensing is the deployment of the independent French remote sensing satellite, SPOT and the planned launch of ERS-1 in 1989.

During the last ten years the capabilities and accuracy of the satellite sensors has increased offering a more useful stream of data to a wider range of users. Techniques for processing satellite data have also been rapidly developing over the past few years, due to intensive research, rather than in operational systems.

The United Kingdom has recognised the benefits to be gained by playing a leading role in the remote sensing area and has invested considerable sums of money and effort into a national remote sensing programme.

The United Kingdom is currently playing a leading role in the ERS-1 project and this is paving the way for the development of a national remote sensing infrastructure of archiving, processing and dissemination facilities. Under development in the UK, and in collaboration with ESA, the ERS Data Centre is currently at the Phase B stage of project

definition. The consortium carrying out the design is led by Software Sciences with Huntings, Marconi Research Centre, Smith Associates and GEMS of Cambridge all collaborating in the project work. Resulting from this and other remote sensing projects, plus the investment of considerable private venture funds, a range of systems called the EARTHSCAN range have been developed by Software Sciences to cover a wide range of remote sensing applications. Growth is built into the systems to cater for the development of new techniques and application areas.

Input data can be from one of a number of primary sources, live data, or from secondary sources, via magnetic tape input.

The EARTHSCAN range is modular with a series of facilities from the 200 to the 5000 series system. The product range is divided, according to the primary sources processed, into three systems:

- CLOUDSCAN (TIROS-N, GOES, METEOSAT)
- LANDSCAN (LANDSAT, SPOT, IRS-1)
- SEASCAN (SEASAT, ERS-1, RADARSAT, NROSS)

The LANDSCAN system is one of this range of computer systems developed in the United Kingdom by Software Sciences Limited in collaboration with the UK National Remote Sensing Centre. These systems cover Land, Sea and Meteorological applications and are amongst the most advanced systems of their type in the world. The systems support the following satellites:

- LANDSAT (MSS, TM)
- TIROS-N
- SEASAT
- ERS-1 (simulated data)
- SPOT1

Growth exists in all systems for the introduction of imagery from a wide range of new satellite systems including:

- MOSS
- ERS-1

- RADARSAT
- JERS-1
- POLAR PLATFORM
- NROSS
- SPOT 2,3,4

The concept of the LANDSCAN system is to provide a high resolution multi-channel, multi-satellite receiving system, with extensive facilities to archive, catalogue and process the raw data. Facilities will be provided to enable researchers to investigate the techniques from which new products can be developed.

2 APPLICATION AREAS

The application areas for remotely sensed data are both wide and varied. These applications can usually be grouped around the sensor resolution and type. The increasing resolution of data now available to the commercial user, 10 metres in the case of SPOT, has greatly expanded these application areas. Satellite images are potentially useful in fields such as cartography, land use, agriculture, forestry, geology and pollution monitoring. Satellite data is now used in cartography for example, where a few years ago aerial photography was suitable. Images can detect geological faults and aid in the exploration of oil and gas. Individual crop types can be identified and their health and stage of growth noted. Civil engineering uses of the data as an aid to town planning and cartography are also under development.

Due to the high cover pass rate of the NOAA series of meteorological satellites, many users are finding it a valuable tool in non-meteorological fields, such as environmental monitoring and hydrology. Access to the data is also relatively easy and it is widely available and cheap.

The application areas can be increased by combining sensor types. LANDSAT with its 30 meter resolution metre resolution covers the same area once every 16 days. Coupled with AVHRR with its 1.1 km resolution but multiple daily passes, it can yield an increase in the usefulness of the data.

Some of the main application areas that benefit from the LANDSCAN range of system are:

- | | | |
|---------------|---|---|
| HYDROLOGY | - | Runoff estimation, hydrological planning, snow cover mapping. |
| AGRICULTURE | - | Crop monitoring, conservation, forestry, insect damage. |
| GEOLOGY | - | Mineral assessment, oil and gas exploitation. |
| ENVIRONMENTAL | - | Pollution monitoring, coastal zone monitoring, volcanic activity. |
| OCEANOGRAPHY | - | Sea surface temperatures, iceberg detection, ice edge mapping, meteorology. |
| LAND USE | - | Cartography, civil engineering. |

The interest flexibility of the LANDSCAN systems to support a whole range of different data types, catalogue the data, process orders for the data and distribute the data, offers a number of advantages to potential users.

They represent the state-of-the-art in national and regional data centre capabilities and are suitable for a wide range of application areas. They are also supported by the low and remote access

user terminals with electronic browse capabilities. The total integration of the system is therefore available from a single supplier.

3 SYSTEM ARCHITECTURE

The main processing features of this system can be summarised as follows:

- A computer system with sufficient disc, memory and I/O capability to store and process a range of image types. This will provide the basic processing capability for the:
 - Handling and control of the data
 - Storage
 - Applications software
 - Range of input data types on CCT
 - Two work stations for the presentation, analysis and interactive display of images received from both satellites (LANDSAT, SPOT)
 - Interface to photographic kit, film-writers etc.
 - Interface facilities to enable the output products from the LANDSCAN system to be easily available to other Remote Site Systems via an X25 network.
 - Interfaces to the Earthnet/SPOT catalogues for on-line order handling and product generation queries
 - Archive of system data
 - Data Catalogue
 - Tape/Archive Catalogue
 - Products can be specified in a user friendly product definition language for regular products to be generated
 - Order Handling
 - Log file generation
 - Sufficient space for future development of new facilities
 - Simple incorporation of user defined information into the software and system menu's

3.2 Design principles

The principal objectives of the design of the LANDSCAN range of systems ensures that:

- The overall design approach was simple.
- The proposed design was maintainable.
- A multi-user capability exists.
- The operating system interface has been optimised.
- An even distribution of CPU loading occurs.
- Files in the system can be easily accessed.
- The system is divided into a number of logical or modular entities.
- The system has no unnecessary constraints built into the design.
- The system can easily be expanded with the addition of new routines/modules.
- The system degrades in performance in a controlled way in the event of peripheral failure.
- Software in the system is run as and required i.e. modules are not always running but are started when they are needed to run to produce a series or set of output results.
- Errors in the system are handled in a systematic and consistent way.

3.3 Hardware architecture

3.3.1 Overview

This section briefly lists the overall hardware and proprietary software components of the LANDSCAN

system. The following aspects are covered:

- Hardware
- Software
- Input Data
- Output Data.

3.3.2 Hardware

This section describes the hardware used for the LANDSCAN 2000 central site system which has been developed on a DEC VAX computer system. The configuration of the hardware is as follows:

- VAX 8300
- 8 Mbytes of memory
- 2 Magnetic Tape Units (6250 bpi)
- 1 456 MByte Winchester disc drive unit
- 1 RA80 Disc drive unit
- 1 Console
- 3 Terminals
- 1 Multi Port Board
- 2 GEMS Image processing system.
- 4 1024 x 1024 by 8 bit memory planes
- 4 1024 x 1024 by 1 bit overlay plane
- 1 Cursor generator
- Hardware zoom (x1, x2, x4, x8)
- Hardware roam
- Trackball
- Alternate function button
- Real time switching of RGB planes
- RGB Lookup Tables.

3.3.3 Software

This section lists the software to be used in the system. This includes:

- Operating System
- GEMLIB* Software package
- A library of image processing software routines
- applications software for landscan:
- * c GEMLIB is a copyright of GEMS of Cambridge, Limited

3.4 INPUT DATA

This section covers those types of data that are input to the LANDSCAN system. The data supported by this system includes:

- Recorded (Archived) Data on CCT
 - LANDSCAN derived data
 - Land Contour Data
 - Landsat Data (MSS and TM)
 - SPOT data
 - TIROS-N data (Tromsø exchange format)
 - METEOSAT data (ESA exchange format)
 - SEASAT data
 - System Software
 - Console and terminal input
 - System Management
 - System Operation
- System Control Data
 - Calibration data
 - Command file data (Product Generation)
- Data from on-line catalogue via X25 links (e.g. SPOT).

3.5 Output data

This section covers those types of data output from the system. These include:

- Image Display
- Console and terminal output
- Image Hard copy

- All images received and processed by the system that can be archived on magnetic tape CCT
- Data over X25 links to remote sites.

4 IMAGE PROCESSING AND ALGORITHMIC OPERATIONS

4.1 Overview

This section describes the image processing and algorithmic operations that form the core of LANDSCAN, plus the additional processing and algorithms needed to interpret the GIS in LANDSCAN. The work presented here is based upon algorithms and techniques published in open literature on the subject of Remote Sensing.

To provide a complete list of references would be a large task, therefore a selection of the key references, on which this work is based is supplied at the end of the Section, General introductions to this subject can be found in Barrett and Curtis (1982), Pratt (1978) Swain and Davis (1978), and Williams (1979), Sloggett and Williams (1986).

4.2 The landscan library

The algorithms used in LANDSCAN will make extensive use of a library of image-processing routines that are available on a general suite of subroutines in the package.

The advantage of a modular approach is that it allows the same subroutines to be used by different processes within LANDSCAN.

The algorithms used in the LANDSCAN system are listed below. Where the algorithm is part of the GIS design it is indicated by GIS after the description:

- Calibration
- Calculation of image transformation
- Map Transformation
- Image sampling
- LUT control
- Image Transforms
- Filters
- Operations on objects
- Arithmetic operations
- Histogram plot
- Statistical analysis
- Classification (i) Training
- Classification (ii) Classify
- Overlay control
- Deconvolution
- Generating monospectral images
- Animation
- Digital map input and formatting (GIS)
- Transformation of Vector data (GIS)
- Vector-raster conversion (GIS)
- Raster-vector conversion (GIS)
- Contour to surface interpolation (GIS)
- Terrain model analysis (GIS)
- Interpretation of stereographic images (GIS).

4.3 Specific image manipulation facilities

Image manipulation functions available to the operators from the workstations include:

- Classification and training
 - Box
 - Parzen window
 - Minimum distance
 - Mahalanobis
 - Maximum likelihood
- Registration
 - Using ground control points
 - Three available resampling schemes

- (nearest neighbour, bilinear, cubic convolution)
- Second and third order polynomial transformations
- Accuracy checked by comparison with grid.

- Filtering
 - Linear using user-defined kernel
 - Non-linear filtering (median)
 - User defined weight and offset
- Editing of drop-outs
 - Line fix
 - Replace isolated errors
- Transforms
 - Fourier
 - Slant
 - Cosine
 - Haar
 - Hadamard
 - K-L
 - Principle component analysis
- Image Arithmetic
 - Logical and arithmetic operations
 - Add, multiply, divide, subtract
 - AND, OR
 - Two images or image and constant
- Animation
 - Continuous and single step
- Map overlay control and graphic annotation
 - Text
 - Symbols
 - Isoline contours
 - Map grids superimposed on images
- Scroll, pan, roam, scale, rotate, zoom
- Contrast stretch
 - Linear (manual and automatic)
 - Piecewise linear
 - Exponential
 - Logarithmic
- LUT manipulation
 - Density slice
 - Pseudocolour
- Pixel readback
 - Histogram of transect
 - Pixel value
- Texture analysis
 - Autocorrelation
 - Variation
 - Local rank
 - Local grey-level
- Image file handling
- Image statistics
 - Mean
 - Standard deviation
 - Skewness
 - Kurtosis
 - Image histograms

Other facilities available include:

- User defined functions keys
- Automatic help facility
- Archiving of images
- System message display.

5 LANDSCAN GIS

5.1 Overview

This section describes the design of the Geographic Information System (GIS), which is currently being implemented as an enhancement to the existing LANDSCAN systems.

A GIS is a unifying concept for the storage, manipulation and interpretation of all types of spatial data. The two types of spatial data of particular relevance to the LANDSCAN GIS are:

- Earth resources satellite data
- Digital map data.

The use of a GIS is of great relevance for the integration of these and other spatial datasets, and through progressive enhancements to the LANDSCAN range, ESSG are making use of their Systems Engineering expertise in the following key areas of GIS design:

- File creation, manipulation and display
- Search, retrieval and query satisfaction
- Output and display.

Of equal importance is our experience of many different applications and end-users of satellite imagery and weather radar data.

5.2 GIS hardware

The proposed GIS will run on the standard LANDSCAN VAX hardware using the GEMS Image Processing System. The GEMS has several features that recommend it for GIS applications:

- Pixel addressing allows incorporation of vector data
- Overlay planes allow digital maps to be superimposed on images
- Image operations can be applied to Digital Terrain Models (DTMs)
- Use of LUTS for enhanced visual interpretation.

The GIS will also be greatly enhanced by the addition of other hardware particularly:

- Digitising tables
- Plotters.

5.3 GIS software

The GIS will be based on existing software:

- The ESSG Image Processing Library (IPL)
- The LANDSCAN data-driven user-interface
- The GEMLIB software for GEMS.

Additional software specific to the GIS is being implemented:

- Digital map input and formatting
- Transformation of vector data
- Vector-raster conversion
- Raster-vector conversion
- Contour to surface interpolation
- Terrain model analysis
- Interpretation of stereographic images.

5.4 Input data

Sources of data for the GIS include the following:

- Image formats (current)
 - Landsat TM
 - Landsat MS
 - SPOT

- AVHRR
- Meteosat
- Aircraft MSS
- Seasat SAR
- SIR-B SAR
- SAR 580 Campaign
- Image formats (future)
 - Oceanographic (ERS-1, NROSS, Radarsat)
 - ESA ERS-1 campaign data
 - Simulated SAR imagery (European SAR database)
- Geophysical data
 - Oceanographic (SST, significant wave height)
 - Meteorological (temperature, pressure, rainfall)
 - Field surveys (land use, soil type, geology)
 - Data collection platforms (DCPs)
- Digital map data
 - Urban, political and administrative boundaries
 - Contour lines
 - Soil, geological, hydrological
 - Land/sea interfaces
- Digital terrain models
 - Height
 - Slope
 - Aspect.

5.5 GIS functions

Amongst the main tools the GIS will provide are:

- Overlay of maps on images
- Update of existing maps using imagery
- Incorporation of sparse geophysical datasets
- Use of maps in contextual classification of images
- Terrain model analysis

5.6 Output data

The primary output will be in the form of images and overlays on the GEMS display.

Secondary output in the form of statistics, tables and other alphanumeric information will be available on the Facit Twist terminal and at line-printer output from the existing LANDSCAN facilities.

Should a colour plotting device be available, "customised" maps will be produced from GIS output.

5.7 Operator control

The operator control of the LANDSCAN MMI has several features which suit it to GIS control:

- Menu system is easy to learn and understand
- Image or geographic coordinates can be used
- Use of overlay planes allows data to be instantly superimposed
- Terrain models easily analysed by density slicing.

Other options to be considered for the GIS include:

- Expert systems development for data interrogation
- Readback of cursor position in map coordinates
- Specification of features by cursor pointing
- More "natural language" input.

5.8 Database management

The LANDSCAN system design is based on a review of existing GIS. A major stumbling-block to successful GIS development in the past has been the design of Geographic databases from a computer science viewpoint with too little attention paid to the actual end-user.

To counter this the database for the LANDSCAN system is as flexible in design as possible with the major considerations being:

- The actual user requirements
- The particular characteristics of the data to be incorporated
- The output format desired by the user.

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