A CONCEPT FOR A NETWORK-BASED DISTRIBUTED IMAGE DATA ARCHIVE

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ABSTRACT:

Large image archives offering data from planetary missions and the Earth are being created. The searching for data about points and regions of interest and the request for a specific coverage remain tedious processes. Retrieved full resolution image data stored on a CD or a tape usually exceed the area of interest by far. The proposed GDSS (Graz Distributed Server System) therefore holds quicklooks of all available images and surface maps at different levels of detail representing the planet's surfaces, and supports the search for full resolution data of just the area of interest. GDSS provides remote access for searching, querying and image processing facilities via a high-speed ATM backbone. We present a snapshot of the system design and the expected results of the GDSS project: a functional prototype including software, a network testbed, a series of data experiments and some simulation results. Data management concepts and storage methods are being illustrated by means of the NASA Magellan data set of planet Venus although we expect GDSS to also be applicable to Earth based remote sensing data.

1. INTRODUCTION

An increasing number of Earth observation and planetary satellite missions have spawned large image archives. The search for specific image data by means of additional search criteria such as mission cycle, time and/or date, geographic location, type of surface features remains a tedious process due to the current need of either searching through low quality quicklooks of poster photo-prints or of dealing with large volumes of source data that are not organized by the preferred search criteria. That is why determination of the exact image content is difficult. Data are often stored in a format that usually exceeds an area of interest by far.

These experiences are shared by a wide scientific community and are exemplified in this paper by the image data set of planet Venus which was produced by NASA's Magellan spacecraft. NASA's Planetary Data System (PDS) (NASA PDS, 1995) offers access to the entire image data set from Magellan. We report on ideas and results in organizing this data set to ease the access from remote sites, and in the process also solve issues of data-specific processing software as well as access to specific remote computing resources. This work results from the European Magellan Data Node (EMDN, 1995) which is organized as part of NASA's PDS under an agreement between NASA, the Austrian Space Agency and the Institute for Computer Graphics at the University of Technology, Graz.

During the Magellan mission to Venus about 95% of the planet's surface was mapped by the spacecraft's sensors. The data set consists of SAR images (>5200 orbits) with a total volume of about 500 GByte. The raw images are strips which are about 350x220000 pixels in size at a resolution of about 75 meters/pixel. The orbits (polar, north to south) are grouped into three "cycles" defined by the different look angles of the SAR sensor. Images from cycles 1 and 3 can be used for stereo processing because of their different look angles, both looking at the surface from the same side. Cycle 2 was recorded from the opposite side. To get images of rectangular shape, Full resolution Mosaic Image Data Records (F-MIDR) have been created. These are 7000x8000 pixels in size and much more usable than the F-BIDRs in terms of searching, cropping, storing and visually interpreting. The F-MIDRs were only created for about 15% of the surface. The entire surface is covered by compressed mosaics (C-MIDR) at reduced resolutions. The desire to offer "Full" resolution, yet ease of visual interpretation, has led to a project at US-Geological Survey (USGS) to create a full resolution total coverage of mosaic images (F-MAPS) in 1995 (Walcher, 1995).

However, this is not supporting the idea of retrieving all images of a location of interest, and therefore exploiting the multiplicity of images. We propose that not only searching, but also processing and retrieving image data like Magellan's, be based on the Graz Distributed Server System (GDSS). It is designed for giving a geographically dispersed scientific community easy and unified access to all planetary data, source image processing capabilities and computing tools. The basic GDSS ideas are not restricted to the Magellan data set of Venus. Data management concepts, access to parallel computing resources and network design should be applicable to Earth based remote sensing data.

2. RELATED WORK

Basic differences exist in handling Earth and planetary data. Search and retrieval systems on Earth-based image data can take advantage of many named features, and just about one third of the surface is covered with land. These advantages do not exist on a planet like Venus. Therefore a raster image oriented map has to be used instead of a vector oriented one.

Earth observation with its large spatially organized data has spawned various systems for image cataloging and remote retrieval. Examples include GISIS (Graphical Intelligent Satellite Information System) (Lotz-Iwen, 1995) and VISTA (Visual Interface for Space and Terrestrial Analysis) (Snyder, 1994), which are designed to give remote access to various remote sensing data using a special purpose client software. GISIS supports the user with an intuitive GUI and a detailed zoomable 2D vector map of the Earth, VISTA additionally supports a 3D vector representation of Earth. The European Union's CEO (Center of Earth Observation) was initiated to develop a European wide support of multi mission data catalogues. A first spin off is the so called European Wide Service Exchange (EWSE, 1995). It has some special new features which allow registered users to search, input, update and customize the information content via their WWW browser. ImageNet from CORE Software Technology Inc. (CORE,

1995) supports data browsing and retrieval via WWW and a special purpose client. Furthermore the WWW Ionia AVHRR Net Browser (Mungo, 1994), the Arno project (Nativi, 1995) and the Landsat/Spot browser by the Canadian Center for Remote Sensing and Earth Observation (CEONet, 1995) should be mentioned.

In comparison, there is no proliferation of systems for planetary data retrieval. Publicly accessible applications for planetary data retrieval, provided by the member institutions of the PDS, allow searching databases for named features, or for image coverage by defining either a point or a region of interest. Two collaborative projects have recently started at NASA's Jet Propulsion Laboratory (JPL) and the US-Geological Survey (USGS): Planetary Image Access (PIA, 1995) and Interactive Planetary Atlas (IPA, 1995).

Current systems are greatly limited in their abilities such as user defined image cropping, billing for services and data, using a flexible network with high bandwidth, user management, supporting raster and vector representations, offering image processing facilities, sharing resources and dealing with distributed archives. Image data are conventionally organized by type of sensor, by satellite, by time of data acquisition and not by spatial coverage. It is the image's position or its coverage that a scientific user most likely uses in his queries. A distributed heterogeneous system like the GDSS giving remote access to image data has to support data exchange standards such as the International Directory Network (IDN) or Z39.50, a flexible scalable network structure, remote access to special hard- and software resources and transparency in terms of hiding the system's architecture from the user. The usage of available standards should be obligatory but is usually ignored.

3. PRELIMINARY SYSTEM DESIGN

3.1 Design Goals

The design goals are summarized in Table 1.

Goal	Purpose
Raster Image Oriented Browsing Interface	Planetary data suffer from a lack of named features. A zoomable raster image oriented browser interface is needed.
Search for Points and Regions of Interest	There is a need to handle queries for points and regions of interest via a spatial database. A reply with lossy compressed (>1:25) quicklooks of the available image data is useful.
Coverage Requests	Image data may be the subject of queries regarding the coverage with stereo, by a specific mission "cycle" or a particular type of feature. Coverage results will be visualized at the client site by overlaying colored areas (e.g. green areas showing stereo coverage)
Searching for Meta Information	Support of additional search criteria which can act as a filtering function on the data is needed, like addressing a cycle number, date or/and time, type of sensor, data processing history, computation algorithm, processing parameters.
Client-Server Architecture	The underlying concept of the system is a distributed client-server architecture (Vaughn, 1994) with an ATM backbone. The benefits of ATM include easy scalability, high-bandwidth, guaranteed quality of service, physical layer independence and support of connection-oriented and connection-less services.
Intelligent Local Caching	This feature keeps response times short and reduces network traffic.
Local server data prediction	The Retrieval Client connected to the Local Server has to download and visualize special rectangular data structures denoted as "map tiles". They exist at different levels of detail. To achieve high speed for interactivity the Local Server loads predicted tiles around the current user position and also tiles of the adjacent superior and inferior level of detail.
Batchjob Processing	The user has a batchjob interface for processing standard procedures in the background or during times of low use or cheap network connection (e.g. night).
User group management	Clients can be connected to one Local Server, resulting in the need for user management which includes building user groups, definition of user rights and defining priorities.
Network Security and Accounting	For commercial use a system must provide accounting facilities. Hence identification, authorization and charging is required. In such cases the system must guarantee privacy of communication.
Network management capabilities	Extensive O&M (observation and maintenance) features must be available to manage a system with global scope. These are addressed by performance observation and tuning, monitoring, security management, fault management (diagnostic tools, trouble ticket generation, ...) and configuration management.
Remote Data Processing	Special image processing facilities should be available on the distributed system. Therefore it would be useful to have a special remote processing interface for typical image processing algorithms. While histogram manipulation, contrast/brightness correction, filtering etc. are standard procedures, 3-D terrain restitution by shape from shading methods is not. The system needs to support computing at a Central Server, delivery of the results to the user and accounting.

Table 1: *Main design goals of the GDSS with a brief description of its purpose*

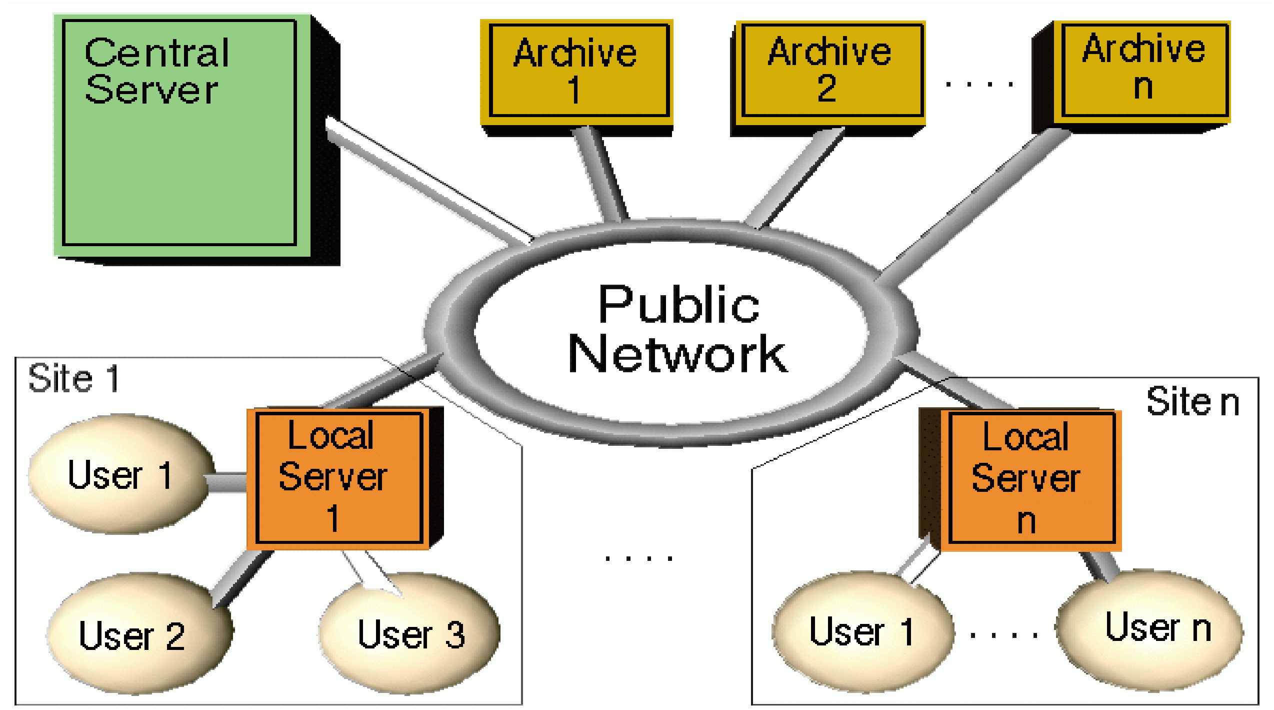

Figure 1: *General Layout of the GDSS. The Central Server(CS) holds the browsing map and quicklooks of all attached archives. The CS is accessed from Retrieval Clients via a Local Server at each site, archives remain invisible to the*

3.2 General Layout

The GDSS responds to the requirements in Table 1 with a layout of five main components, as illustrated in Figure 1.

The *Central Server* is the main component of the system and will be described separately in the next section.

Image Archives are maintained by commercial vendors or public institutions but have to fulfill special requirements in order to become participants of GDSS (Rehatschek, in print).

Local Servers have to be set up at every user site. This server is responsible for local caching, data prediction, user management, accounting and batchjob processing.

The *Retrieval Client* provides users with query definition forms and the interactive map browser. The map can be overlaid by vector and raster data. Vector data can be image borders, contour lines, names and extents of topographic features, user defined graphics like regions of interest, point marks or personal annotations. Raster data are quicklooks of available images.

The *Network* defines the overall system performance and the availability of the entire GDSS. In 1991 ATM (Asynchronous Transfer Mode) was proposed by the former CCITT (now: ITU-T) as the standard for B-ISDN. ATM is designed as a physical layer independent protocol and can transport all existing and future B-ISDN services. It supports connection-oriented and connection-less services as well as isochronous services (Prycker, 1994). Furthermore ATM is the only currently known network technology supporting high bandwidth up to 2.4 GBit/sec, a guaranteed quality of service throughout a session and WAN geographical scope (McDysan, 1994; Saito H., 1994; Sadiku M., 1995). Hence ATM is likely to become a world wide integrating network technology in the near future. In addition ATM defines standard interfaces to existing protocols (Ethernet, FDDI, Token Ring), which makes LAN integration of the Local Server sites easy. We propose an ATM network as the ideal backbone for a system having high requirements to the bandwidth like the GDSS. To grant worldwide scope the usage of the TCP/IP protocol is obligatory. TCP/IP, which is settled at OSI layers 3 (network) and 4 (transport) makes the GDSS independent of the underlying physical components. Because IP over ATM still suffers from lack of performance, there are several ongoing research projects investigating TCP/IP over ATM (IETF, 1995; Perloff, 1995; Hongqing, in print) for performance improvements.

3.3 Layout for the Central Server (CS)

Table 2 describes the CS components and Figure 2 outlines the main CS modules and communication paths.

4. IMPLEMENTATION MILESTONES

We have begun to implement a functional prototype of the proposed GDSS. This implementation initially focuses on the Magellan data set, the needs of PDS scientists and their hardware platforms. A functional prototype will be available by the second half of 1997. Milestones and expected results are addressed in the following subsections.

4.1 Building the Network

We have begun with a testbed for GDSS using a total of three institutions, initially all of them in Austria. The University of Vienna participates through the Vienna Parallel Computing Center (VCPC) with its massively parallel computer Meiko CS-2, setting it up as a CS. At two University institutes in Graz a Local Server is being set up with several user workstations attached to each server.

Module	Functionality
General Query Protocol (GQP)	The GQP connects the components of the GDSS on the OSI (Open Systems Interconnection) layer 4 (transport). GQP is a simple ASCII protocol to optimally address the issues of the GDSS. GQP handles four categories of services, these are (1) spatial queries, (2) service requests, (3) administrative queries and (4) data update commands. Furthermore the support of currently evolving international data exchange standards such as IDN and Z39.50 is being investigated.
Request distribution module	Distributes incoming requests and is responsible for security tasks (identification, authorization). GDSS uses a distributed user management strategy, hence it is up to the Local Server administrator to authorize users. The CS just takes an entire site into consideration.
Database Search Module	This module consists of a massively parallel spatial RDBMS handling multiple queries at the same time. It addresses coverage, points and regions of interest requests. The database holds coverage information and meta info but not any image data. They remain stored in the Disk Access Module.
Map Browsing Module	Provides the user with fast delivery of requested map tiles that should be currently displayed on the screen. If more than one user requests tiles they are parallel loaded from the Disk Access Module.
Archive Request Module	The Archive Request Module is responsible for the communication with the archive sites. Archives respond with the full resolution data and the billable costs. If the price has a non zero value, the account server will be started and accounting with the Local Server takes place. Privacy will be accomplished with a common key system (Stevenson, 1995). When the accounting process is finished, the full resolution data are passed to the cropping server, which crops the data exactly to the area defined by the user. The result, usually an image stack, is sent to the user.
Disk Access Module	The browsing maps of the entire planetary surface are stored here at different levels of detail with the successive 2:1 reductions of these maps forming a resolution pyramid. Furthermore 1:4 reduced quicklooks will be kept within this module. An additional color reduction to 8 bits is applied to all image data. In combination with low quality JPEG compression (>1:25) a data reduction of 100:1 or better is possible. The Disk Access Module is designed for giving many users parallel stream access to the image data.
Data Input Module	The Data Input Module is responsible for bringing in data as well as updating existing data.
Data Processing Server	This module provides users with remote access to image processing facilities which just can only run with expensive hard- or software. This feature makes it possible to achieve an efficient resource sharing, accounting for the usually non-free services will take place.

Table 2: *The main modules of the Central Server and a brief description of their functionality*

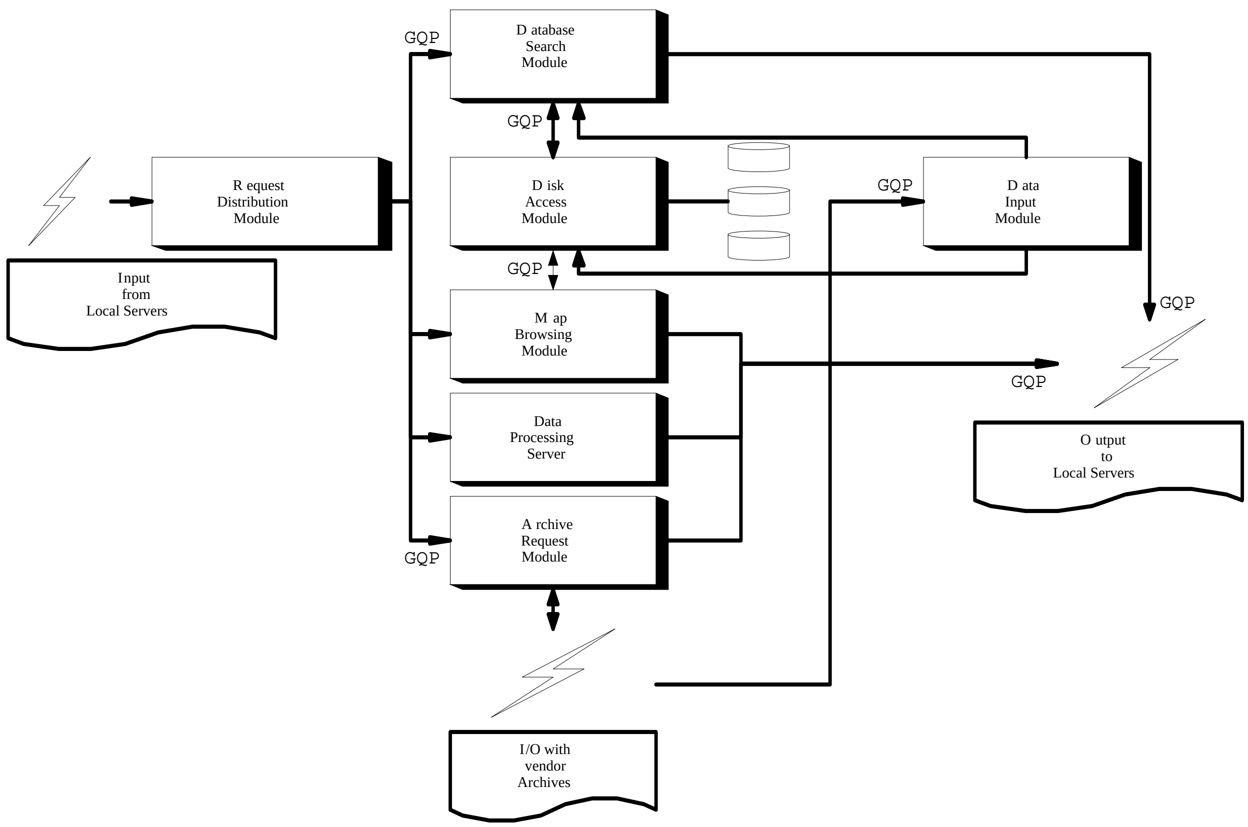

Figure 2: *The main modules of the Central Server, with the internal dataflow and the links to external components.*

An ATM network at OC-3 (155 MBit/s) and two FORE Systems switches (ASX-200, ASX-100) are currently in place for initial trials. An ATM connection to Vienna via the high-speed DQDB (E3, 34 MBit/sec) network is scheduled to be available on demand.

4.2 GDSS Software

Software is being created by means of several projects.

An *Interactive Venus Atlas* provides users with a tool to interactively browse the surface of planet Venus. This can be done via a GUI in different levels of detail. An important goal of the project is to guarantee a cross platform unified software tool. JAVA™ is used to implement the Venus Atlas as an interactive WWW page. A JAVA™ supporting browser like Netscape 2.x must be used to interact with the system.

The *Retrieval Client* implemented as a special purpose software gives the possibility to optimally address the needs of the GDSS. This could raise serious problems. The GDSS is designed as a large distributed system with WAN geographic scope. Hence many heterogeneous hardware platforms and operating systems at the user sites could be involved. The development of a version for each operating system would be necessary. Furthermore each time a new version is introduced a time consuming distribution has to take place and every single user site has to install the new software manually.
These problems can also be solved using the JAVA™ programming language. JAVA™ supports the development of so called "applets", software pieces that are sent via the net from the CS to the user site and are executed locally. COSMO, an integrated development environment for JAVA™ which is available from Silicon Graphics Inc. will be used for implementation. Due to using the Netscape's GUI the application always has the same appearance independent of the underlying operating system. In addition, the update problem is implicitly solved by storing the "applets" at the CS. The Web-browser will always download the latest version via the Local Server.

The *Spatial Data Structure* is based on an ongoing investigation of modified R-trees (Samet, 1990) for handling points/regions of interest and coverage queries. Results of this work will show whether a special more expensive spatial RDBMS must be used or a simple SQL capable RDBMS will address the requirements of the GDSS.

The *Data Processing Server* supports parallel execution of user requested image processing algorithms. Some computationally intensive image algorithms have already been parallelized. A tool named HUGO has been developed to distribute user defined jobs throughout a work station cluster, to collect the results and finally to present them to the user (Goller, 95).

4.3 Data Experiments

The validity and efficiency of the GDSS concepts will be tested by means of several remote access data experiments.

Distribution of the Interactive Venus Atlas: As soon as the Interactive Venus Atlas is working locally we will perform between the two institutes in Graz. The browser will be at one site and map tiles at the other. Interactivity via an ATM network will be verified.

Retrieval of full resolution data serves to list the WAN scope of an ATM based full resolution data retrieval from Vienna.

Distributed Image Processing is being built around a port of HUGO to SUN platforms using the public domain Parallel Virtual Machine (PVM) library for interprocess communication. This library is supported by several different platforms including Paragon, Meiko CS-2, SUN, SGI. As a result of this project a set of parallelized image processing algorithms will be running on a heterogeneous workstation cluster between the two participating institutes in Graz. Communication will be accomplished via an OC-3 (155 MBit/sec) ATM link and a FORE ASX-200 switch. The speed up in comparison to a standard Ethernet (IEEE 802.3) will be measured.

Annotation of remote sensing data: Scientific personnel as well as commercial users often need expert advice on the image data they want to order. Currently this is a tedious process in terms of not having the desired possibility to annotate the image data on-line during the browsing process. Participation in the European Union's DIANE project as an associated partner of the VCPC in Vienna results in a pilot trial showing the benefits of a multimedia annotation tool in connection with an on-line video conference.

4.4 Simulations

The efficiency and functionality of the suggested network layout is being tested using the CACI COMNET-III network simulator. A realistic implementation of the GDSS with an ATM WAN geographic scope must include applications and data transfer. ATM specific details such as Quality of Service, support of stream oriented traffic, isochronous services and the influence of different switch buffer sizes on the TCP performance (Hongqing, 1996) can be investigated in more detail by means of simulations.

5. FROM VENUS TO EARTH

A recent Austrian remote sensing initiative is a project denoted as "Multi-Image Synergistic Satellite Information for the Observation of Nature" (MISSION) (Leberl, 1995). This project combines more than 16 partners in a collaborative effort. The requirements for accessing images greatly resemble those of the GDSS. Data from multiple missions such as SPOT, Landsat, ERS 1/2, KFA-photography and MOMS-Priroda need to be made available to all participants, each having special interests and geographic requirements.
The Austrian Post and Telecom has introduced ISDN with an areal coverage of 100%. We want to investigate the usability of the GDSS concepts using ISDN technology by developing a prototype scenario within the MISSION project. This project could be extended to medical applications such as remote diagnostics and on-line annotation by multiple experts at locations all over Austria.
The stimulus for the GDSS project drives from the planetary image processing requirements, as reflected in NASA's PDS. However, we are optimistic that ideas, concepts and software of the GDSS can also be applied to international Earth-observation projects such as the European Union's Center for Earth Observation (CEO) or NASA's Mission to Planet Earth (MTPE), and national programs such as Austria's project MISSION. And we hope that the ideas, software and experiences of the GDSS can provide benefits to fields other than remote sensing.

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