

Article

Image Archiving: An Opportunity and a Burden

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The advent of low-cost, high speed, high-density storage devices/media, high throughput digital networks, inexpensive and adaptable database servers, and full-featured archival software, such as the GeoVault Data Manager - currently under development at Leica Geosystems - provides the means whereby a digital image archive is both cost-effective and practical. A digital image archive must provide dependability, accessibility, and comprehensive data management for the data it stores, organises and protects. In addition, it may provide productivity enhancements to users who create and distribute that imagery. Design decisions and data management strategies for an image archive are discussed.

The domain of digital photogrammetric data extends beyond images to include other products such as terrain and feature data. Their preservation in a digital archive allows significant opportunities including the ability to generate additional revenue from the original investment, to satisfy requirements imposed by regulatory agencies, to preserve for posterity valuable historical records, and to organise the data to facilitate accessibility and exchange with other systems for research or other uses. But it also imposes a burden in the form of the challenging decisions and resources required for data management, accessibility, population, and backup strategies, and appropriate storage solutions.

A Dependable and Accessible Archive

Fortunately, the advent of low cost storage, network, and database technologies provides the means whereby a digital image archive is attractive. Leica Geosystems GIS & Mapping Division now offers the GeoVault Data Manager as an automated digital archive solution. The features include the dependable storage of work products in a continuously accessible manner, including the display of metadata, map overlays and image thumbnails, from both workstation and browser-based clients; the automated management of stored data, including transfer of data to the archive, extraction of metadata, and backup and archive operations; and productivity enhancements to expedite workflow. Although based on imagery typical of the photogrammetric workplace, the data model applies well to other images which have lasting value including medical imagery and imagery related to the preservation of historical sites and national treasures. While not a traditional GIS, GeoVault stores and displays geographic information in a map-based manner reminiscent of GIS systems.

Hardware-related Dependability Issues

One responsibility of a digital archive is a special case of an on-going IT problem: the protection of digital data from loss due to hardware component failure, software corruption, or human error. The definitions below are based on D.K. Pradhan's text Fault Tolerant Computing:

- Reliability R(t) is the probability that a system performs correctly over the entire interval [0, t].
- Availability A(t) is the probability that a system is running correctly at time t. Note that a system can be available without being reliable.
- Maintainability M(t) is the probability that the system will be restored to correct operation within a specified period.
- Safety S(t) is the probability that the system does not fail in the interval [0, t] in such a manner as to cause unacceptable damage or other catastrophic effects. Note that a system can be unreliable but safe.
- Dependability A qualitative term for the ability of a system to perform properly; it encapsulates the above measures in a general way.

For a digital image archive, the terms availability and reliability apply to online storage. Maintainability and safety refer to offline, backup or archival storage. Highly available and reliable systems, which offer real time protection from hardware faults, are still vulnerable to software faults and human error. Aaron Brown and David Patterson of the Computer Science Department at the University of California at Berkley report in a recent literature survey that many organisations, including Oracle and Hewlett Packard, find data corruption from erroneous software and human error are a significant source of data loss and system failure. Therefore, systems which provide high availability and reliability, do not in themselves provide better safety or maintainability when all sources of faults are considered.

Furthermore, a distinction must be drawn between backup which is a copy of online data and archive which is a copy of data that is then removed from online storage, to make room for more current data, but which can be restored to online status when needed. A properly designed digital image archive takes all of these issues into consideration.

Access	Technology	Cost per TB	Benefits	Drawbacks
Online	JBOD: EIDE	\$3-4K	Low cost	Limited capacity
	SCSI	\$7-8K	Fast access time	No fault tolerance
Online	RAID: EIDE	\$8-15K	High access speed,	High cost per TB
	SCSI	\$15-25K	High availability	
Nearline	Magnetic Tape (AIT-3, LTO, SDLT, DST) drives, robotic library, media	\$4-8K	Low cost	Moderate access speed
Offline	Tape	\$1.5K	Very low cost	Requires operator assistance for access
Nearline	Magneto-Optical	\$30-40K	Very long life Random access	High cost Slow write throughput Small per unit capacity
Nearline	DVD-RAM	\$30-40K	Long life Random access	High cost, Slow write throughput

Table 1, Current cost per terabyte of various types of digital storage technologies.

Before looking at hardware and software solutions we need to characterise the data that will be stored in the archive. For photogrammetric images, these characteristics include:

- (1) Very large file size (can be upwards of 1Gb per image before compression)
- (2) A large number of pre-existing but inaccessible files on various backup media
- (3) File contents which rarely change
- (4) A large investment made in data acquisition
- (5) Regulatory agencies may impose statutory or contractual requirements for safekeeping
- (6) Data has long-term value
- (7) Demand for access decreases over time
- (8) Files contain both data and metadata
- (9) Metadata also reside in supplementary files
- (10) Applications used to process data may be computationally intensive
- (11) Compression methods with acceptable levels of loss exist

Since many Terabytes (TB) of data can accumulate very quickly, high fidelity compression such as JPEG and wavelet can reduce the required storage space significantly. The

competing needs of minimal storage and content preservation can be arbitrated by a policy that allows compression after image processing is completed. Table II illustrates the increase in the number of compressed images that can be stored in 1 TB.

Fortunately, the increasing capacity and decreasing cost of disks offers archive owners many options. An article in the May 2000 issue of Scientific American summarized the situation.

Today disk capacities are doubling every nine months, fast outpacing advances in computer chips, which obey Moore's Law (doubling every 18 months). At the same time, the cost of hard-disk drives has plummeted...the average price per megabyte...plunged from \$11.54 in 1988 to \$0.02 in 1999.

The current price per megabyte is as low as \$0.003. Table I shows the current cost per TB of various forms of digital storage.

Whether JBOD (Just A Bunch of Disks) or RAID (Redundant Array of Independent Disks) is used for online storage, some form of backup and recovery is required to

Image type	Uncompressed	JPEG Compressed	Wavelet Compressed
Black and white	3,300	16,500 (5:1)	33,000 (10:1)
Colour	1,000	10,000 (10:1)	20,000 (20:1)

Table II, Number of images that can be stored in 1 TB with and without compression.

make a system maintainable and safe. Currently available backup media options are magnetic tape, DVD-RAM, magneto-optical platters (MO), or additional disks, both on and offline. Each has advantages and disadvantages in terms of access time, shelf life, and cost per GB. Linear Tape Open (LTO), Advanced Intelligent Tape (AIT-2, AIT-3), and Super DLT can store at least 100 GB per tape and perform streaming reads/writes at a sustainable rate of 10 MB/s. With much smaller capacities, DVD-RAM (4.7-9.4 GB) and MO (9.1 GB) also have slower write access times (4 MB/s). For efficiency, non-disk backup options should be married with a robotic library capable of loading and unloading the media into the drive unit. Another critical factor to consider are the time required for backup (backup window), and the recovery time or Mean Time to Repair (MTTR). As an example, a single LTO drive with a 10 MB/s write rate, 10 tapes per TB, and 1 minute robotic load/unload time has a backup window of nearly 28 hours, and the recovery time could be about the same:

$$(((10 \times 60) + (1,000,000/10))/3600 \text{ seconds} \approx 28 \text{ hours})$$

The various ways in which users access data in a shared environment should also be considered when designing an accessible archive. It should be possible to use the archive as a file server as well as to automatically distribute archive contents to client workstations when computationally demanding applications would clog the network or run too slowly in a shared environment.

While each archive system must be customised to the special needs of its domain, one candidate storage strategy, which attempts to encompass all the points in the preceding discussion, would provide sufficient RAID for all database storage thereby making metadata highly available to users. Low-cost JBOD would be used as needed to store uncompressed images for ongoing projects and compressed images for recently completed work. Additional JBOD would be used to backup the primary JBOD thereby speeding the backup and recovery process. This configuration also provides the ability to snapshot the database and other data with a high rate of change. This is not a mirrored configuration, but a true backup so that soft faults are also covered. Finally, compressed images would be archived to an acceptable long term storage media and removed from the online system as an ongoing, demand driven process, with automatic cataloguing and tracking provided by the archive management system. Traditional backup of the database and other forms of digital only data could also be provided by a robotic library for extra security. Thus data would move through the system and be stored according to pre-defined policies to make the most economical use of available resources and changing technology.

Software-related Dependability Issues

Ease of retrieval and automation are key to a reasonably managed and readily accessible archive. This includes back-

up and archival operations. There are three four methods of backup: full (transfers every file to the backup medium), incremental (backs up all the files that have changed since the last backup, incremental or full), differential (backs up all the files that have changed since the last full backup), and progressive (described below). The drawback of full backups is the time required to complete them. The drawback of incremental is that many tapes may be needed to recover. The drawback of differential backups is that intermediate file versions are lost.

An automated archive can utilise four key features to simplify backup administration: a database to track its own activity, a progressive backup methodology, compression of data after a pre-determined point in processing is achieved, and archival of files based on demand for access. In progressive backup, an initial full backup is made. Subsequently, files are copied to backup media only if they have changed or are new, but only up to a pre-set number of versions. When disk is used as the backup medium, space reclaimed from compression or overwriting of an older version by a new version is immediate and requires no additional effort. If tape media is used, older versions become obsolete 'waste space' on the media. In this case, a process called reclamation or compaction recovers the waste space when it reaches some predefined threshold. The contents of the tape are transferred to another piece of media, minus the obsolete files. Reclamation also provides a non-intrusive way to gracefully upgrade to new tape technologies.

Automation can help solve the problem of data consistency and data integrity. When a file contains metadata, it is relatively inaccessible. This metadata must be extracted by reading the file, or by reading an ancillary file, and promoting this information to a more visible place in the database where it is continuously available for query. Metadata that is not embedded in the file itself may need to be attached to imagery by an operator. Finally, the file system and the database must be self-consistent, each reflecting the state of the other. An automated tool that extracts metadata, provides an operator lists from which to choose values of non-embedded metadata, and that maintains the link between the file system, archived components, and the database is critical to the proper operation of an image archive. The architecture of GeoVault allows users to customise the components of an archivable entity such as a set of files, easily attach user defined metadata, and add plug-in components capable of extracting metadata at the time files are added to the archive. An automated query tool, which dynamically adapts to the contents of the archive, allows users to formulate and save custom queries to later view information in the archive.

Data Management within GeoVault

As John C. Dvorak points out in his article *Bad Habits Develop Fast*, "the bountiful harvest of storage capacity" creates serious organisational problems for a file system.

He goes on:

As it now stands it's almost impossible for people to find files ... despite their use of long filenames. ... I've come to rely on the Windows Find program using the "containing text" option. But this doesn't do much good with photographs...

Data management is one of the most important features of an image archive system. Included in data management are data classification, data query, data security, data access, data customisation, and system performance.

GeoVault allows users to define management policies and then automates the maintenance of those policies. In addition to data management, potential digital archive owners must decide which metadata is important to them. For geographic metadata guidelines, there are various published standards such as ANZLIC Metadata Guidelines, the Content Standard for Digital Geospatial Metadata, and the emerging ISO 19115 standard.

Security is another important factor in an archive. In general, archive administrators will wish to restrict access to a set of qualified individuals. This group may be further partitioned into users with read access and users with both read and write access.

An image archive is not a passive container of data. Therefore, one other role an image archive can perform is to assist

its owners in the production of the images and other geographic data by providing tools to manage workflow. GeoVault offers tools including automated project setup, workflow tracking and management, automated file and metadata ingest, and special features such as a control points database.

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