Euclideon White Paper

Summary:

3D point cloud software in the geospatial industry has been steadily improving as LiDAR and 3D imaging technologies have rapidly evolved. New innovative breakthroughs have now made it possible to move from traditional limiting data management techniques to instantaneous data access and visualization. Recent technological developments such as Semi-Global Matching (SGM) and Structure From Motion (SFM) are creating enormously dense and massive 3D point clouds. These technologies along with hardware advancements of terrestrial, mobile, and aerial LiDAR scanners are generating huge datasets that contain an enormous amount of exploitable detail. End users are often not able to take advantage of all the data. A new revolutionary approach offers a solution to access and visualize unlimited amounts of data density and size in real-time on a typical workstation or laptop. By providing real-time visualization and 3D data retrieval, decision makers are afforded unbounded access to all full resolution data for rapid and enhanced decision making. This solution now provides the ability to host 3D point cloud data in a central repository for enterprise dissemination and visualization. Fast and usable internet streaming of dense 3D data is also now available. As this technology matures, user specific data analysis tools will be developed providing instant data access and manipulation allowing for improved data quality and more efficient project turnaround. The grey line between real world and virtual world is rapidly becoming smaller.

The Problem

Computer power doubles every four years, but computer storage requirements increase by up 200 times every four years. The world has moved from megabytes to gigabytes (1000 megabytes) then from gigabytes to terabytes (1000 gigabytes), and already we are hearing the word "Petabyte" (1000 terabytes). This presents challenges for the visualization and sharing of large volumes of Big 3D Data.

"Big data is the term for a collection of data sets so large and complex that it becomes difficult to process using on-hand database management tools or traditional data processing applications. The challenges include capture, curation, storage, search, sharing, transfer, analysis and visualization." *Wikipedia*

- "Big data is a pressing issue for the National Geospatial-Intelligence Agency (NGA)," and "expects storage requirements to grow exponentially over the next decade because of planned intelligence collection sensors." *Canadian GIS and Geomatics*
- "…big data" is emerging as a major research theme for the academic community." *ESRI*
- "…the Department of Defense alone is investing $250M annually into Big Data research projects." *Sensors and Systems*

Traditional Methods for Display and Rendering

Most 3D point cloud applications apply traditional (and limited) display and rendering methods to visualize massive amounts of data. These methods include:

Loading Points into RAM

Pros	Cons	Conclusion
Potential for fast 2D and 3D point rendering, depending on data size	Data processing and view rendering sessions are limited by RAM – performance can degrade even with large amounts of RAM utilized	Great for small datasets, commonly used for creating static videos of point clouds (must recreate video from scratch for alternative perspectives)
Fast access to data for processing, depending on data size	Wait time for points loading into RAM is typically slow, impracticable for massive LiDAR datasets	Ineffective for very dense LiDAR data captures, or extensive geographic regions. Impossible to render huge volumes of point clouds ("Big Data") at full resolution

Point Streaming, Low Resolution Block Technique, and Point Decimation

Pros	Cons	Conclusion
Special (not typical) point decimation techniques can "intelligently" reduce the data size while preserving the important details (i.e. model keypoint creations)	Data rendering is decimated during navigation and then streamed in when movement stops, still a slow rendering processes as the software fetches points from disc	This is the current accepted technique for rendering large point clouds. Most geospatial analysts are trained to accept the visual limitations imposed by software, hardware, and "Big Data".
Less RAM is required than previous technique, though more RAM does increase the performance	High risk of missing small or key features during navigation due to minimal point display during movements	Unsatisfactory for many applications where access to all the data at full resolution should be mandatory

Euclideon Pty Ltd of Brisbane, Australia has solved some of the biggest limitations facing users of point cloud data, saving time and money, increasing productivity, and changing the ways that it can be used.

Euclideon – Overview

In late 2009, Euclideon began as a gaming company, and shot to fame when it released its now famous 'Unlimited Detail' demonstration video onto YouTube. However, the company soon realized that its technology offered incredible benefits to the geospatial industry. In 2010, Euclideon received one of the largest government grants to commercialize Unlimited Detail with the first offering being its geospatial software, Geoverse, based on Unlimited Detail technology.

By continually developing technologies that redefine the status quo, Euclideon has positioned itself as a pioneer in the field of 3D visualization – setting new industry benchmarks, and enabling customers to use data in completely new ways.

Unlimited Detail (UD) Technology

At the heart of the technology is a 3D search algorithm that can render unlimited quantities of point cloud data in real-time. Because this algorithm efficiently retrieves only one point for every screen pixel, it can display models of previously unimaginable sizes at interactive frame-rates, without the need for a powerful CPU or graphics card. By removing the hardware bottleneck from the process of 3D visualization, Euclideon has simultaneously removed any limitations on the amount of detail that a scene can contain.

Euclideon's Unlimited Detail technology, used in its Geoverse software, is based on the concept of atoms in 3D space – that is, storing objects as collections of 3D pixels. This is a better way of representing real-world objects, as it doesn't 'fill in' objects with homogenous textures and repetitive shapes. Rather, it represents every point of a scanned object just as it appears in the real world. Just as Google or Yahoo! are search algorithms that go searching for words on the Internet, Geoverse technology looks for points in point cloud data. It only retrieves one point per screen pixel and it retrieves them straight from the hard drive so there is no need to load data into RAM.

As part of the move towards the geospatial industry, Euclideon has created specialized software – Geoverse – that can view point cloud data converted from industry standard formats (e.g. .LAS). Data is viewed in 2D or stereoscopic 3D without loading times through Geoverse's intuitive interface using either a mouse or a gaming controller. There is no dependency on high end computer hardware:

- o Utilizes multi-core and/or multi-threaded CPUs but does not require high end models
- o Does not require GP-GPU processing for high speed performance
- o Does not require large amounts of RAM, 2 GB is adequate
- o Does not require high speed disc I/O. Rendering speed is similar whether the data is local, on a network, or even accessed through a USB 2.0 port

For purposes of definition, Euclideon is the name of the company, Unlimited Detail is the technology and Geoverse is the product line.

Geoverse Products

- Geoverse Massive Data Manager (MDM) - Viewing software sold as:
    - Single seat – one license per computer
    - Site license - unlimited seat use per physical site
- Geoverse Convert Package - 1 Convert + 5 MDM viewers
- Unlimited Detail SDK – Software Development Kit

Geoverse Convert

The Geoverse Convert functionality converts 3D point cloud data to Unlimited Detail proprietary format, UDS/UDG. It compresses data to 5-20% of its original size without degrading quality and enabling it to be viewed in the Geoverse Massive Data Manager (MDM) package in less than a second – no matter how large the data is, or if it's coming from a hard drive, flash drive, local server, or the internet.

Feature and benefits of the Geoverse Convert functionality include:

- Convert at least 4 billion points / hour to Unlimited Detail format
- Render all point cloud data with no size limit in less than one second
- Reduce the data volumes to 5 to 20% of its original size
- Centrally store data models and load over network
- Load in one second regardless of data size
- Run client data on entry level computer, laptop systems, and even some tablets
- Stream directly from the hard drive or USB external drives
- Manage large point cloud data sets
- Process data sets for visualisation and dissemination
- Support for data conversion in following point cloud data formats:
    - BIN, e57, LAS, LAZ, FLS, PTS, PLY, PTX, XYB XYZ/TXT and llargBin and configurable text input processor.
- generate point clouds from OBJ files (polygonal data); rasterizing the polygons at a desired resolution

Euclideon's compression algorithms are able to shrink point cloud data without compromising any of the data. Conversion can be completed using either lossy or lossless compression by setting the "Resolution" (decimal precision) in the Geoverse Convert application. Greater resolution yields lossless compression and retains all points while setting a lower resolution would yield more compression but some detail could be generalized. Typically, the value of retaining all information with a lossless compression will outweigh the value of higher compression.

Geoverse Massive Data Manager

Geoverse Massive Data Manager, based on Euclideon's Unlimited Detail technology, has created a new way of visualizing, interacting with, managing, and disseminating point cloud data that removes the need for dedicated 3D graphics cards or powerful CPUs for display – no matter what the size or detail of the dataset. Traditionally, 3D models had to be stored on every computer that they were required to run on. After creating a way to instantly stream data from a hard drive or USB stick, Euclideon has created a way to stream 3D data to multiple users from a central server or computer. Geoverse Massive Data Manager features including the ability to:

- Create annotated presentations with bookmarks and labels
- Take measurements at the precision of the data set
- Overlay data onto base maps, including OpenStreetMaps and Bing Street, Aerial & Hybrid
- View at an average screen refresh rate of 30 frames per second
- Synchronized 2D and 3D navigation
- View entire models at full resolution and in real time
- Data accessed locally or from URL internet path
- Edit, measure, label and bookmark key points within a data set
    - 3D measuring with point snapping as well as slant distances, true vertical, and true horizontal distances
    - 3D labels with hyperlinking capabilities, exportable to CSV
- Red-blue anaglyphic stereoscopic 3D display mode
- Free and elevation-locked camera navigation modes
- Bookmarking functionalities
    - ability to specify a separate dataset per bookmark
    - ability to record/playback a flight path per bookmark
- 'Plane' and 'helicopter' camera mode
- Ability to record and playback a flight / drive path
- Display position under mouse cursor
- support for relative paths in projects (useful for moving projects around)
- Ability to export regions of data to LAS
- Data navigation support for mouse or Xbox controller

Internet Streaming

By far the most powerful feature of the Unlimited Detail engine is the ability to stream point clouds over the Internet.

Competing software packages generally pre-render the camera's view of the point-cloud on the remote server, then transmit the entire image (typically using JPEG compression) to the client. Not only is this wasteful, but it leads to severe input lag even on very good internet connections due to the close coupling between input and display.

Euclideon's Unlimited Detail renderer has a completely different approach to remotely viewing point clouds - the actual 3D points are streamed. The engine only needs to retrieve points visible on-screen and not the entire scan, allowing the user compose the view very quickly and with only a minimal amount of streaming. Streaming using this technique also allows the engine to completely decouple the streaming and rendering threads. This provides the user a smooth, interactive rendering while simultaneously streaming data. Measurements and linking and tagging can all occur while the data streams.

3D models can be accessed worldwide across a network or the internet. Features and benefits of the streaming technology include:

- No need for multiple local storage points of 3D models if an internet connection is available - 3D models can be hosted at a single location
- Only a single copy of the data needs to be stored which can be served up to unlimited internet users, thus decreasing data storage requirements, costs, and complexities
- Simple setup and inexpensive hosting
  - Streams 3D points and not images, no server-side processing is required
  - Simple file hosting is massively scaleable
- Decoupled streaming and display threads permit continuous smooth movement through scene
- Smooth frame rates even when Internet bandwidth is low or patchy
  - Decoupled streaming and display threads permit continuous smooth movement through scene
  - Streaming never stalls the display or input threads
- Geoverse Project files can contain links to large numbers of archived UDS or UDG data-sets of considerable size
- Secure access using encrypted HTTPS
  - Restrict access to sensitive data
  - Uses industry-standard HTTPS protocol supported by most cloud hosting providers
- Version control - if changes to the data are required, these are done only one time to the source data
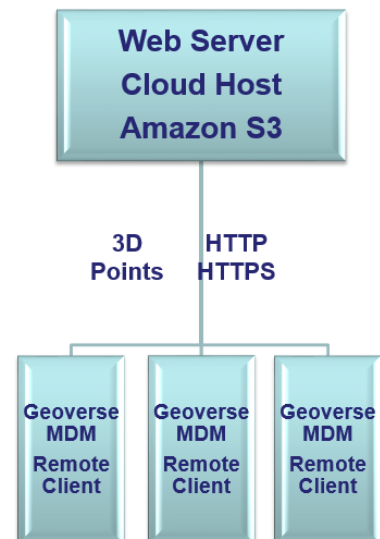
Software Development Kit

Euclideon offers a Software Development Kit (SDK) that allows for the integration of Unlimited Detail tools and features within a third party's geospatial application. This SDK is advantageous to organizations that currently have robust functionalities in their own applications and want to improve performance through UD technology. The structure of the SDK provides the flexibility to incorporate only those UD functionalities that are pertinent to the third party's application.

Functionalities in the SDK include:

udRuntime
- Core module with base types, initialization and resource management.
- Render Application Programming Interface (API) for .UDS and .UDG Euclideon file formats.
- Accessing model attributes (intensity, classification) to generate a color for rendering.
- Support for view-dependent streaming of data from a local hard drive or windows network share.
- Example sample code demonstrating how to integrate support for HTTP streaming of datasets.

udExport
- Low-level interface for generating UDS and UDG file data from raw point data.
- Support for merging new data with existing datasets.
- Ability to add custom attribute data per-point into files (eg. Classification, intensity etc)

udConvert
- Data Conversion API for converting common geospatial data formats to UDS and UDG data formats.
- Supported industry formats include: las, laz, fws, fls, e57, xyb, xyz, ply, pts, ptx, llargebin, txt.
- Support for rasterising polygonal data obtained from a .OBJ file at a desired resolution.
- Plugin API allowing the user to create their own data format importers.
- Currently only supports converting of color data.

udQuery
- Retrieves points from a dataset that satisfy a geometric constraint.
- Define geometric constraints using volume primitives and Constructive Solid Geometry (CSG) combinations.
- Support for maximum point count and minimum separation filters when querying points.
- Alternate 'rendering' of the visible points to a list of model space X,Y,Z values and ability to obtain the attribute values.
- Query N nearest Neighbours.

More than just LiDAR

3D data can represent imagery or originate from imagery. For example, if imagery is collected simultaneously with LiDAR data, RGB (or other imagery values) can be fused with the LiDAR for viewing with Geoverse. For greater resolution, 3D LiDAR data can be interpolated at the resolution of the

companion imagery. Even if LiDAR data is not available, colorized 3D point clouds may be derived from stereo pairs using dense matching techniques (i.e. semi-global matching or multi-ray photogrammetry). Textured image files in OBJ format can also be converted to .uds for rendering and streaming in unlimited amounts and detail.

Customized Applications Development
Euclideon and some distributors offer custom development for specific end user applications. Custom functions can be integrated into Euclideon products (e.g. MDM) and other Smart Partner Derivative Products. Programming support is also available from Euclideon and some distributors for development of plugin's and SDK implementations.

Future Enhancements

Html5 Internet Streaming
Euclideon will soon be releasing an HTML5 point cloud viewer called Geoverse Web® running without plugins on major browsers. This viewer will work on any platform that supports HTML5, including tablets and phones that support HTML5This functionality will allow quick and easy 3D data dissemination to multiple users.
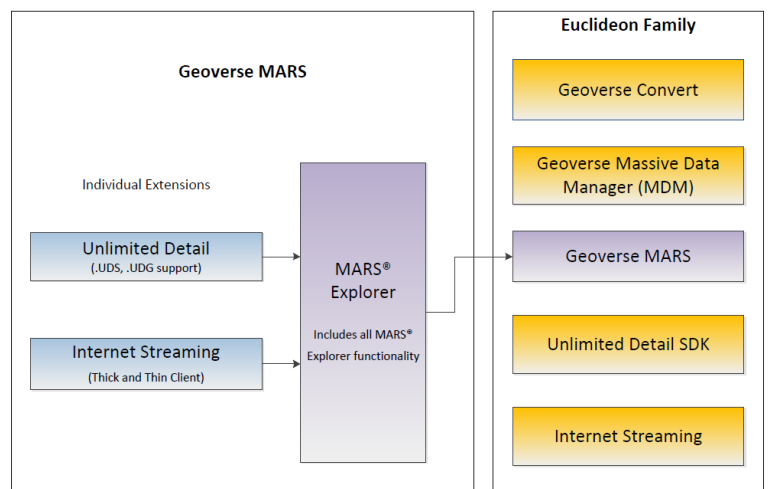
Unlimited Attribution Preservation
A new feature of the Converter we be the ability to carry all LAS attributes (payloads) through to .uds and then allow MDM and the udSDK to extract those attributes back out to the original LAS file level with respect to coordinate values and attributes. This functionality will be applicable to all five versions of LAS (1.0, 1.1, 1.2, 1.3, 1.4) as well as all point data record combinations of these versions. This functionality is currently available in the Software Development Kit (SDK).

Tablet Capability
Euclideon has developed a hand-held tablet capability on the Android OS platform with basic viewing and navigation capabilities utilizing Unlimited Detail technology.

Geoverse MARS
Euclideon Smart Partner and distributor, Merrick & Company, will soon be releasing Geoverse MARS. This application will enhance Merrick's current Merrick's Advanced Remote Sensing (MARS®) 3D point cloud processing and analysis application with Euclideon's Unlimited Detail technology.

Geoverse MARS

Individual Extensions

Unlimited Detail
(.UDS, .UDG support)

Internet Streaming
(Thick and Thin Client)

MARS®
Explorer

Includes all MARS®
Explorer functionality

Euclideon Family

Geoverse Convert

Geoverse Massive Data Manager (MDM)

Geoverse MARS

Unlimited Detail SDK

Internet Streaming

Links:
For more information on Euclideon and their technology, visit their website at:
http://www.euclideon.com/

For more information on Merrick and their MARS® application, visit our website at:
http://www.merrick.com/Geospatial/Software-Products/MARS-Software

For more information on Merrick's distribution of Euclideon's Geoverse software product line, visit our website and YouTube channel:
http://www.merrick.com/Geospatial/Software-Products/Euclideon
http://goo.gl/wH2Oqp

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