



Managing Very Large LIDAR Point Clouds in Oracle 10g Spatial

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Tampa Convention Center
Tampa, Florida, USA

Overview

- Examples of Data (taken from NWA collection)
 - Raw returns
 - Bare earth
- Quality Control Activities
 - Vendor
 - Independent QA/QC
- Enterprise Database Storage and Manipulation
 - Storing and indexing large, point clouds
 - Querying point clouds

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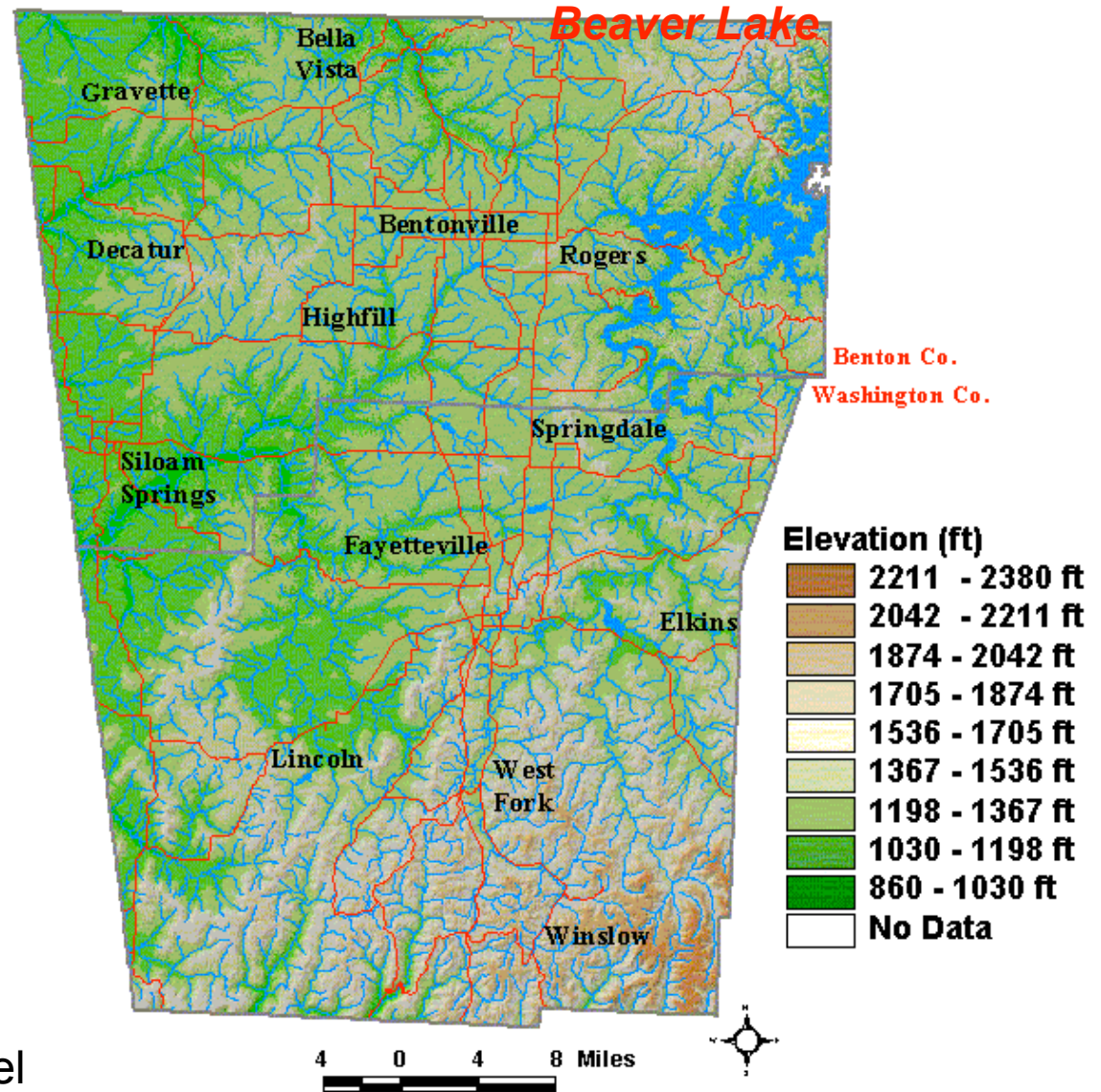
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Northwest Arkansas Collection Area

- Two Counties
 - 1800 mi²
 - 2,380 ft high
 - 860 ft low
- Area gently slopes towards the North and West

DEM: 30m Digital Elevation Model



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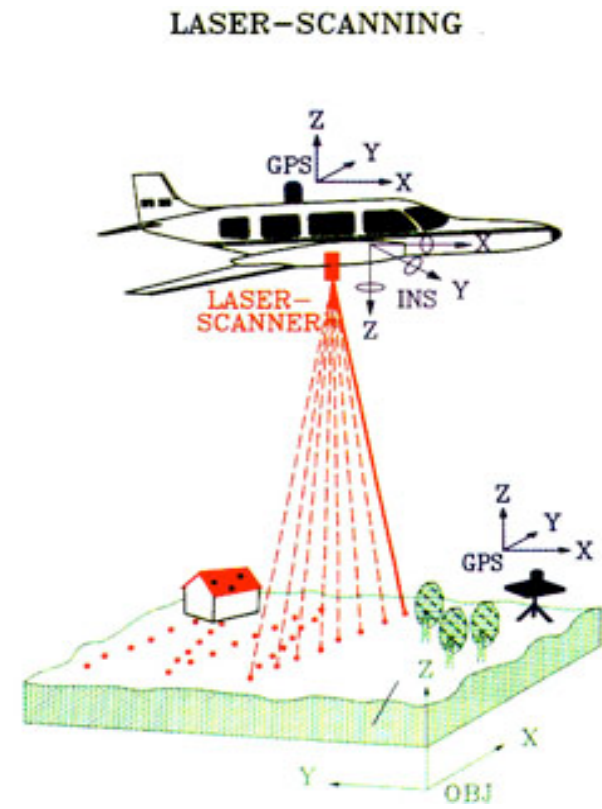
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DELIVERABLES

- Ortho-images
 - 1-foot GSD
 - DOQQ tiling scheme
 - NSSDA 5.7 ft
- Elevation Data
 - Bare Earth returns
 - ASCII xyz point list
 - Interpolated DEM grid (25 ft posting)
 - ArcGrid ASCII
 - LIDAR Raw return information (LAS format)
 - 1st and last returns
 - Intensity, pulse number, return number, scan angle, etc

LIDAR Collection Parameters

Laser Frequency	25 KHz
Height of Flight Above Mean Terrain	12,000 ft
Aircraft speed	120 mph
Swath of flight	1.67 miles
Flight line spacing	15% of swath width
Field of View	40 Degrees
Scanning rate	14 Hz
Maximum Point Spacing	14 ft (4.2m)



LIDAR derived DEM was intended to only support orthorectification.

Flight Lines



65 flight-lines, each with approximately 10 - 20 million returns.

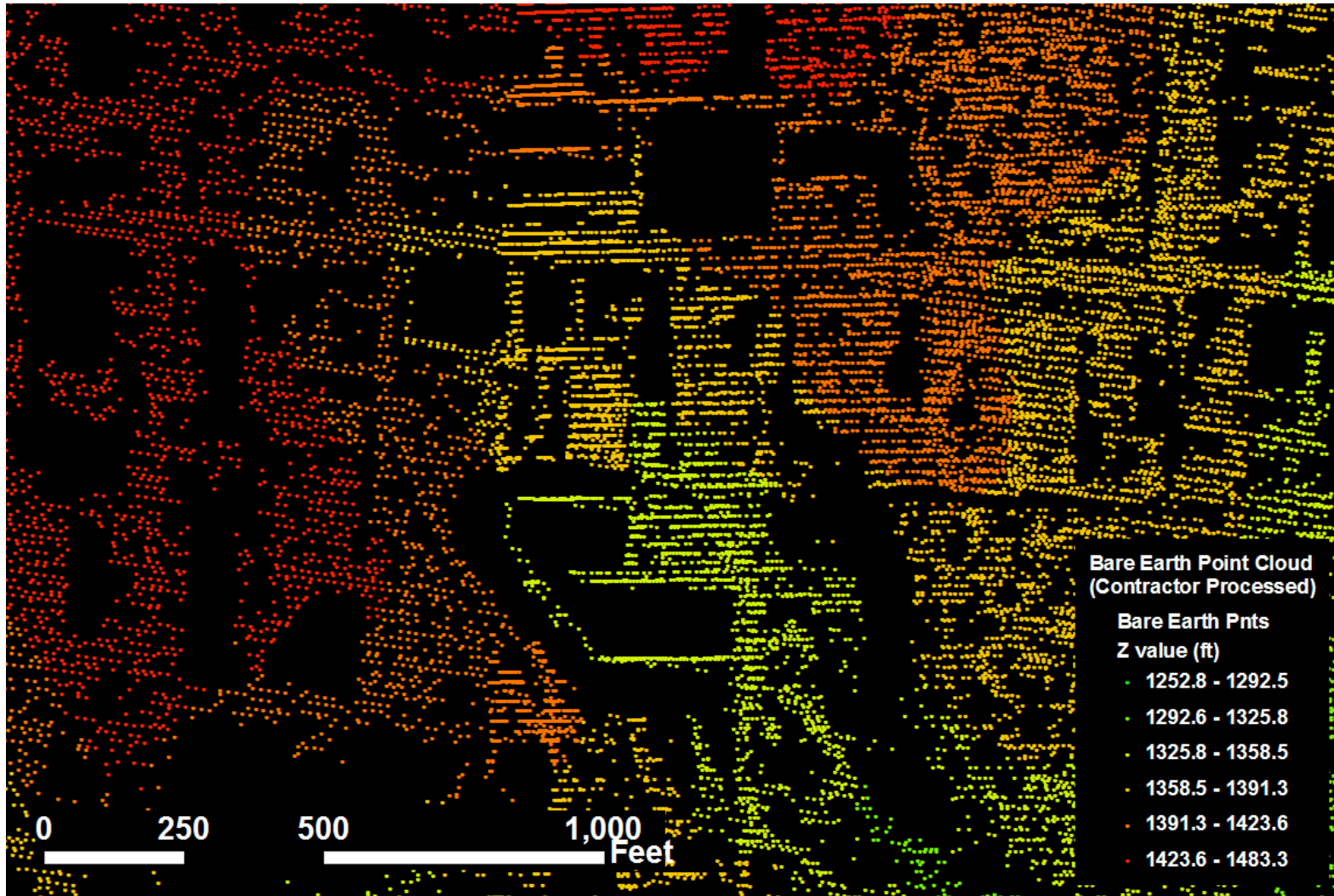
Side-lap > 50%

Higher point densities in multiple side-lap areas.

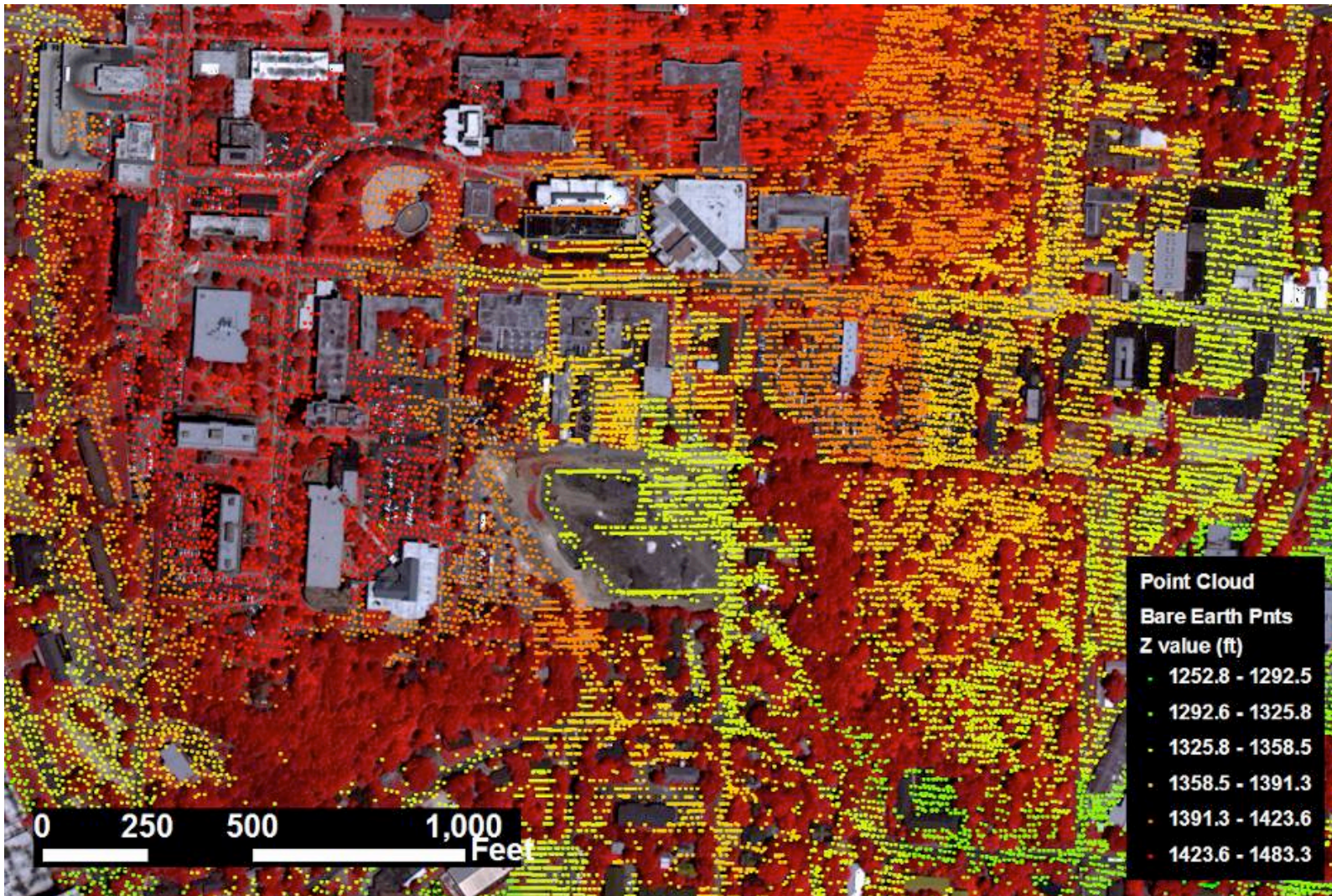
Swath width ~ 3,000 m.

LAS format (www.asprs.org)

Bare earth points



Bare earth and structures



Tree canopy



Statistical Analysis (Vendor)

Control Id	Y	X	Zc	Zl	Zl-Zc	Min. D_XY
1	655759.6	578522.7	1108.75	1107.77	-0.98	5.69
2	777390.6	545120.8	1183.22	1182.72	-0.5	7.45
3	729221.6	690174.5	1347.6	1347.35	-0.25	6.84
4	795332.4	617557.6	1264.09	1263.52	-0.57	5.23
5	741037.4	739717.8	1189.76	1189.27	-0.49	10.92
6	741038.4	739717.9	1189.76	1189.21	-0.55	11.53
7	749090.9	650165.4	1268.5	1268.63	0.13	6.82
8	741145	770845.3	1383.7	1384.56	0.86	8.72
9	722914.9	660425.2	1182.8	1182.47	-0.33	6.14
10	668971.3	660823.8	1300.83	1300.93	0.1	7
11	798225	562018.8	1092.69	1091.55	-1.14	5.12
12	618177.8	670275.3	1246.94	1246.53	-0.41	6.49
13	785926.9	767157.3	1595.44	1594.9	-0.54	5
.
.
.
114	772341.1	755856	1455.84	1456.73	0.89	8.72

NSSDA 1.20 ft

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Independent Vertical Quality Control Checkpoints

20 Forest Cover

OPUS / GPS Static Survey

21 Brush Heavy Grass

OPUS / GPS Static Survey

235 Built-up areas (combination land cover in developed areas)

Variety of sources

City of Springdale aerial control (GPS)

City of Fayetteville aerial control (GPS)

City of Bentonville aerial control (GPS)

Brush / Heavy Grass Category



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Forest / Tree Canopy





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From: opus@ngs.noaa.gov
Sent: Saturday, October 16, 2004 8:20 AM
To: gdenzer@mwyusa.com
Subject: OPUS solution : 42782681.obs 000220101

FILE: 42782681.obs 000220101

1-2A

NGS OPUS SOLUTION REPORT =====

USER: gdenzer@mwyusa.com DATE: October 16, 2004
RINEX FILE: 4278268v.04o TIME: 13:19:45 UTC

SOFTWARE: page5 0407.16 master10.pl START: 2004/09/24 21:28:00
EPHEMERIS: igs12895.eph [precise] STOP: 2004/09/24 23:45:00
NAV FILE: brdc2680.04n OBS USED: 4915 / 5242 : 94%
ANT NAME: TRM33429.00+GP # FIXED AMB: 26 / 29 : 90%
ARP HEIGHT: 2.0 OVERALL RMS: 0.019 (m)

REF FRAME: NAD83 (CORS96) (EPOCH:2002.0000) ITRF00 (EPOCH:2004.7321)
X: -353043.853 (m) 0.022 (m) -353044.510 (m) 0.022 (m)
Y: -5132229.262 (m) 0.053 (m) -5132227.860 (m) 0.053 (m)
Z: 3758383.201 (m) 0.025 (m) 3758383.070 (m) 0.026 (m)

LAT: 36 20 5.07812 0.022 (m) 36 20 5.10071 0.022 (m)
E LON: 266 3 53.44958 0.022 (m) 266 3 53.41944 0.023 (m)
W LON: 93 56 6.55042 0.022 (m) 93 56 6.58056 0.023 (m)
EL HGT: 346.725 (m) 0.057 (m) 345.557 (m) 0.057 (m)
ORTHO HGT: 374.852 (m) 0.062 (m) [Geoid03 NAVD88]

PLANE COORDINATES North(Y) East(X) Convergence (deg) Point Scale
UTM (Zone 15): 4021483.314 (m) 416073.402 (m) -0.55411211 0.99968678
SPC (0301 AR N): 223756.354 (m) 226267.260 (m) -1.12606378 1.00002162

US NATIONAL GRID DESIGNATOR: 15SVA1607321483 (NAD 83)

BASE STATIONS USED
PID DESIGNATION LATITUDE LONGITUDE DISTANCE (m)
DE7172 OKMU MUSKOGEE CORS ARP N354300.062 W0952405.820 148910.8
AF9565 SALL SALLISAW 1 CORS ARP N352201.460 W0944859.709 133672.0
AH9092 CNWM CONWAY CORS ARP N373122.177 W0924212.540 171540.5

NEAREST NGS PUBLISHED CONTROL POINT
GF0874 LARUE N361846.850 W0935902.382 5004.1

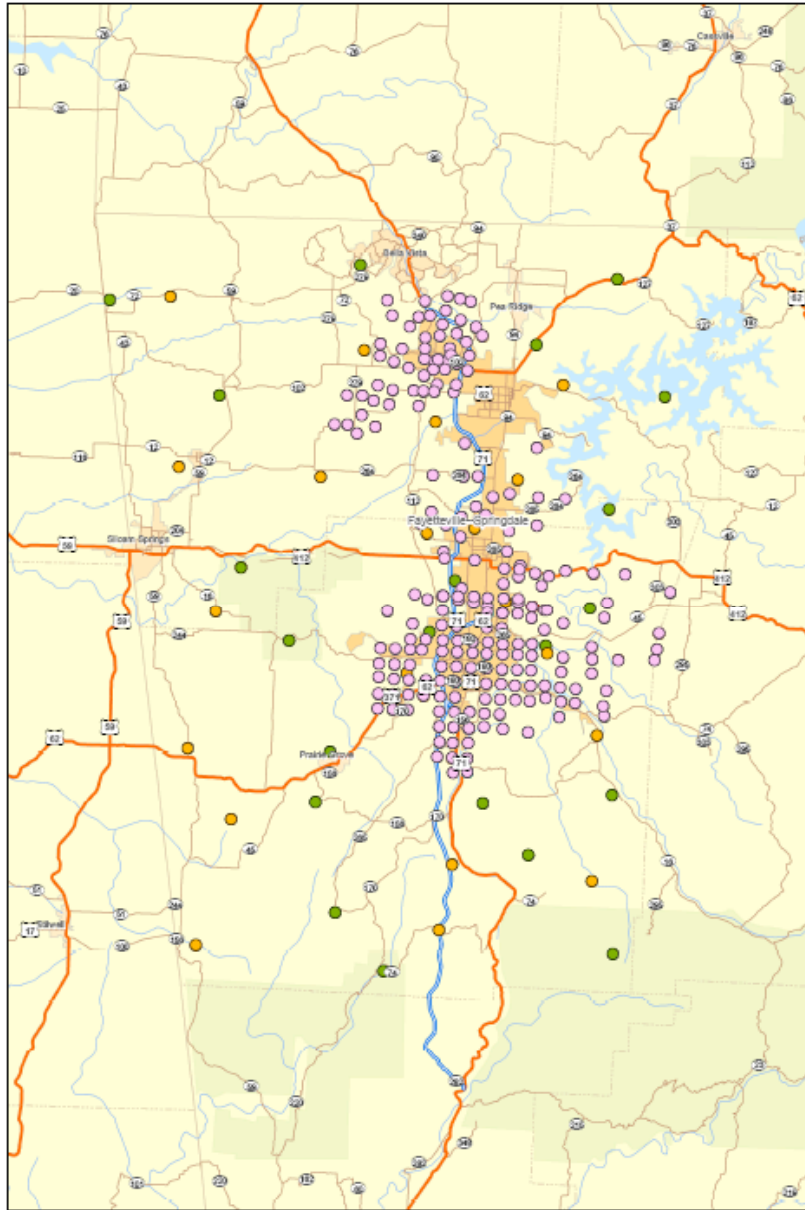
This position was computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

Online Positioning User Service (OPUS)

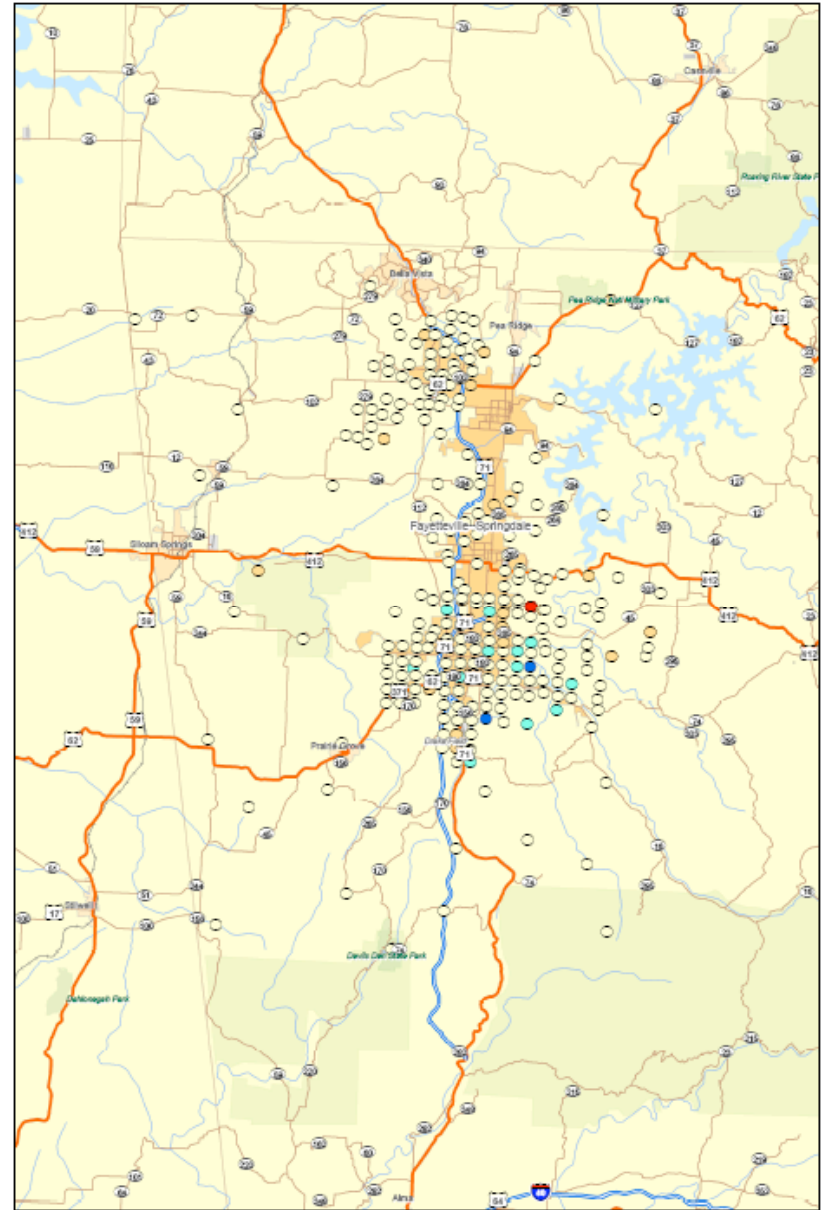
Report

Ellipsoidal Height
Predicted Error = 5.7 cm
(NOT RMSE)

QA Checkpoints by Land Cover Type



QA Checkpoints by Standardized Elevation Differences



Map data source: StreetMap USA, ESRI, Copyright 2001-2004

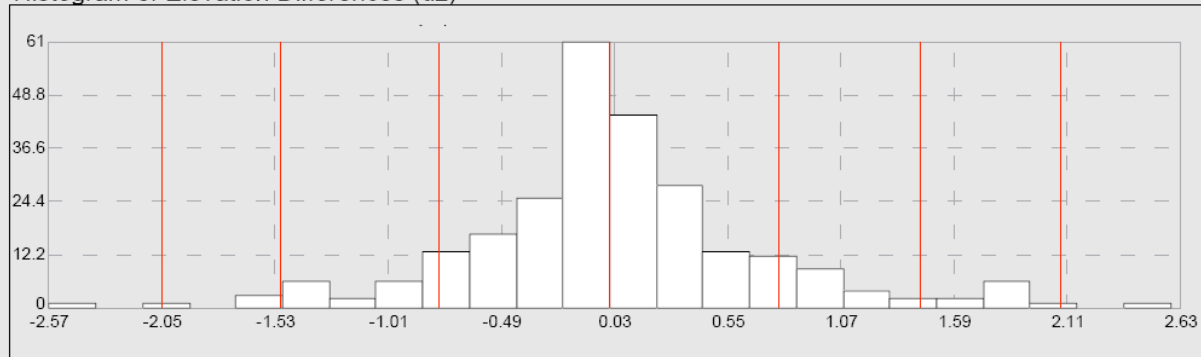


Projection: State Plane Coordinate System Arkansas North, U.S. Feet
Horizontal Datum: NAD83
Vertical Datum: NAVD83

January 10, 2005

Detailed Error Analysis

Histogram of Elevation Differences (dz)



All Control Points	NSSDA	RMS	Mean	Median	Skewness	Std Dev	No. of Points
Total	1.34	0.68	0.03	0.00	0.21	0.68	257
Forest (Coniferous, Deciduous, Mixed)	1.23	0.63	0.26	0.11	0.51	0.58	20
Brush, Heavy Grass	1.27	0.65	-0.10	-0.15	0.68	0.65	21
Built-up, Bare Earth, Short Grass	1.36	0.69	0.02	0.00	0.19	0.69	216

Tested 1.34 feet vertical accuracy at 95% confidence level using RMSE procedures with 3 outliers (larger than 3 times std dev).

95th Percentile Points (< 1.59 feet)	NSSDA	RMS	Mean	Median	Skewness	Std Dev	No. of Points
Total	1.05	0.54	-0.01	-0.01	-0.02	0.54	244
Forest (Coniferous, Deciduous, Mixed)	1.23	0.63	0.26	0.11	0.51	0.58	20
Brush, Heavy Grass	0.73	0.37	-0.12	-0.15	-0.11	0.36	19
Built-up, Bare Earth, Short Grass	1.06	0.54	-0.02	-0.01	-0.14	0.54	205

Tested 1.59 feet vertical accuracy at 95% confidence level determined by the 95 percentile method.

Percentile	dZ
100	2.58
99	2.10
98	1.89
97	1.82
96	1.69
95	1.59
94	1.47
93	1.41
92	1.31
91	1.27
90	1.14

Reference: Muane, D.F. (2001). Digital Elevation Model Technologies and Applications: The DEM Users Manual, Chapter 12. ASPRS.



Analysis was performed at the Center for Advanced Spatial Technology (www.cast.uark.edu) at the University of Arkansas with funding from the National Consortium for Rural Geospatial Innovations in America (www.ruralgis.org) and from the Northwest Arkansas Regional Planning Commission (www.nwarpc.com).

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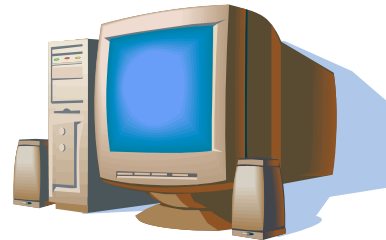
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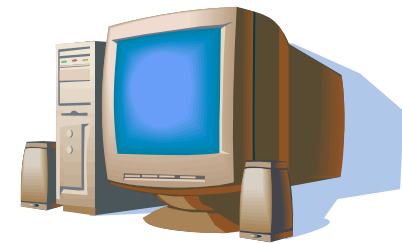
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Manipulating Airborne LIDAR Returns in an Enterprise Environment

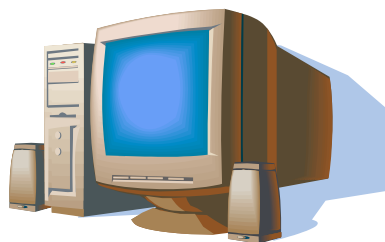
- Enterprise implies...
 - data stored and updated in a distributed database
 - data is accessed by clients locally



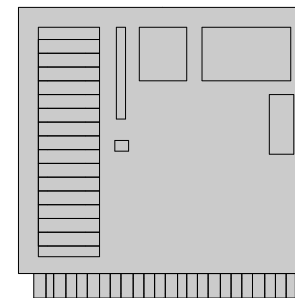
GeoMedia



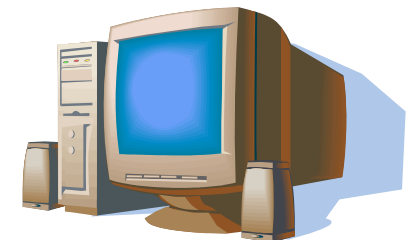
ArcGIS



AutoCad



Oracle 10g



ERDAS
Imagine, LPS

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Manipulating Airborne LIDAR Returns in an Enterprise Environment

- Oracle 10g R2 Spatial (SDO geometries)
- Enable analytical work with raw data (all returns and breaklines)
- Classification aided by existing vector geometry
 - Coordinate system transformations handled in the database
 - All spatial operators available
- Fast retrieval and aggregation based on combination of geometry and attributes
- SDO_NN (*n* nearest neighbors) and SDO_WITHIN_DISTANCE operators enable filtering operations

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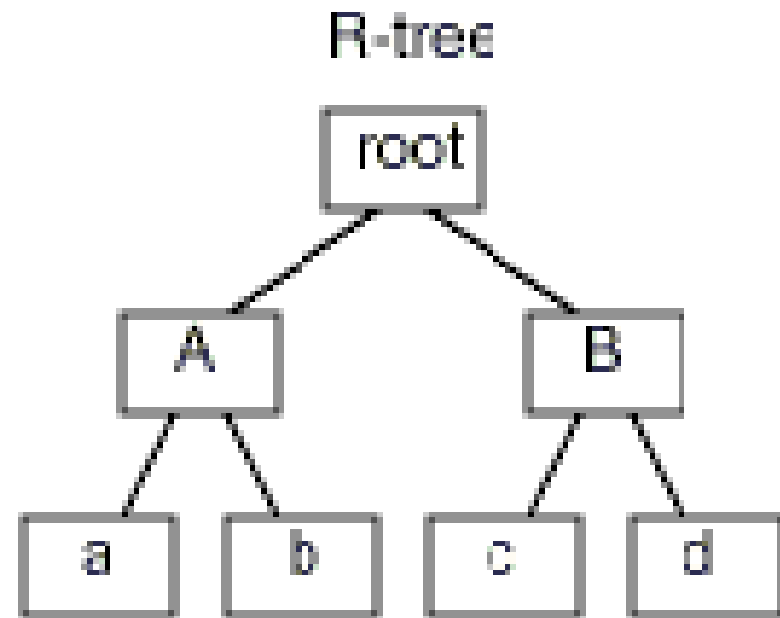
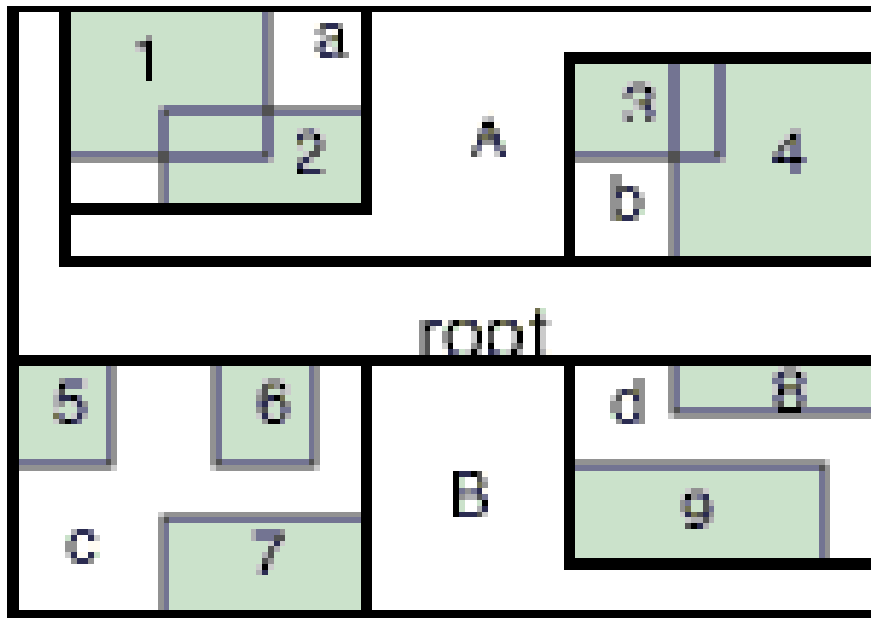
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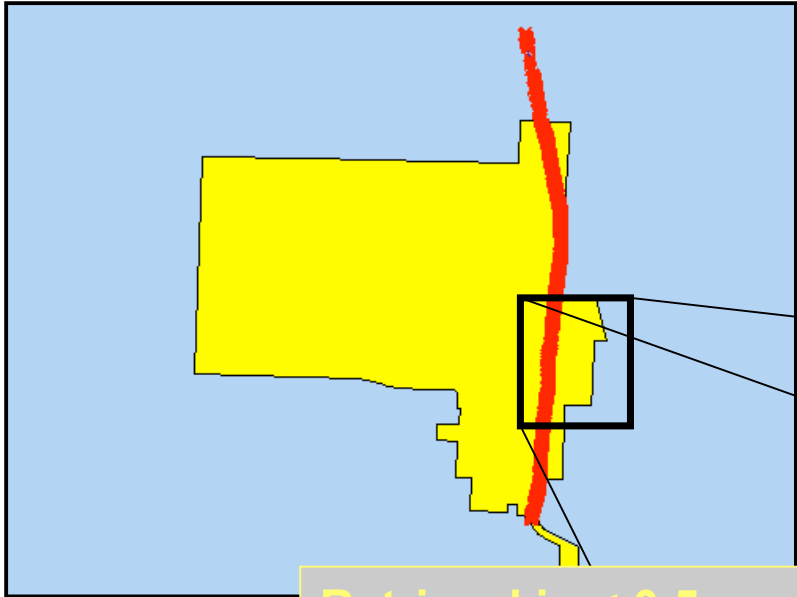
Pre-processed bare-earth points

- Loaded 196 million bare earth xyz points
 - State Plane Coordinates in US Survey Feet
 - Cover Washington and Benton Counties
 - From ALS40 sensor flown at 12,000 feet AGL
- Generated three-dimensional spatial index on X,Y,Z coordinates
 - Used default R-tree index
 - Required < 5 hours on a Xeon server (single-processor) computer
 - Partitioning will allow effective use of multi-processor machine
- Resulting database table space ~ 12 GB
 - Index table space also ~ 12 GB
 - Typical of spatial indices

R-tree Indexing

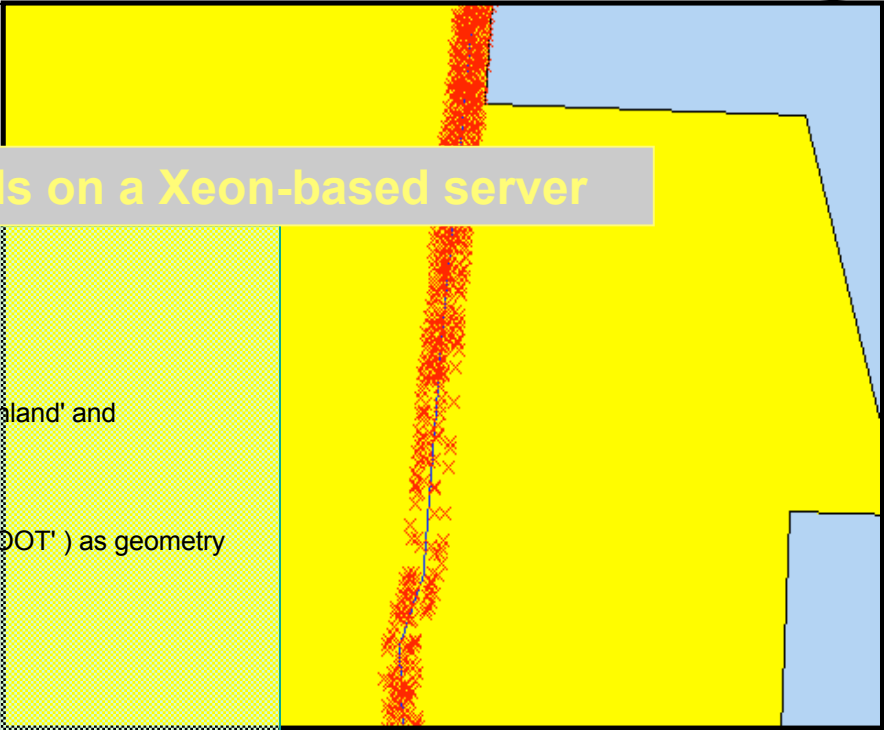


Interactive Demonstration: <http://www.dblab.ece.ntua.gr/~mario/rtree/>



Extract all “surface” returns within 50ft of all railroad tracks through Greenland, AR

Retrieval in < 0.5 seconds on a Xeon-based server

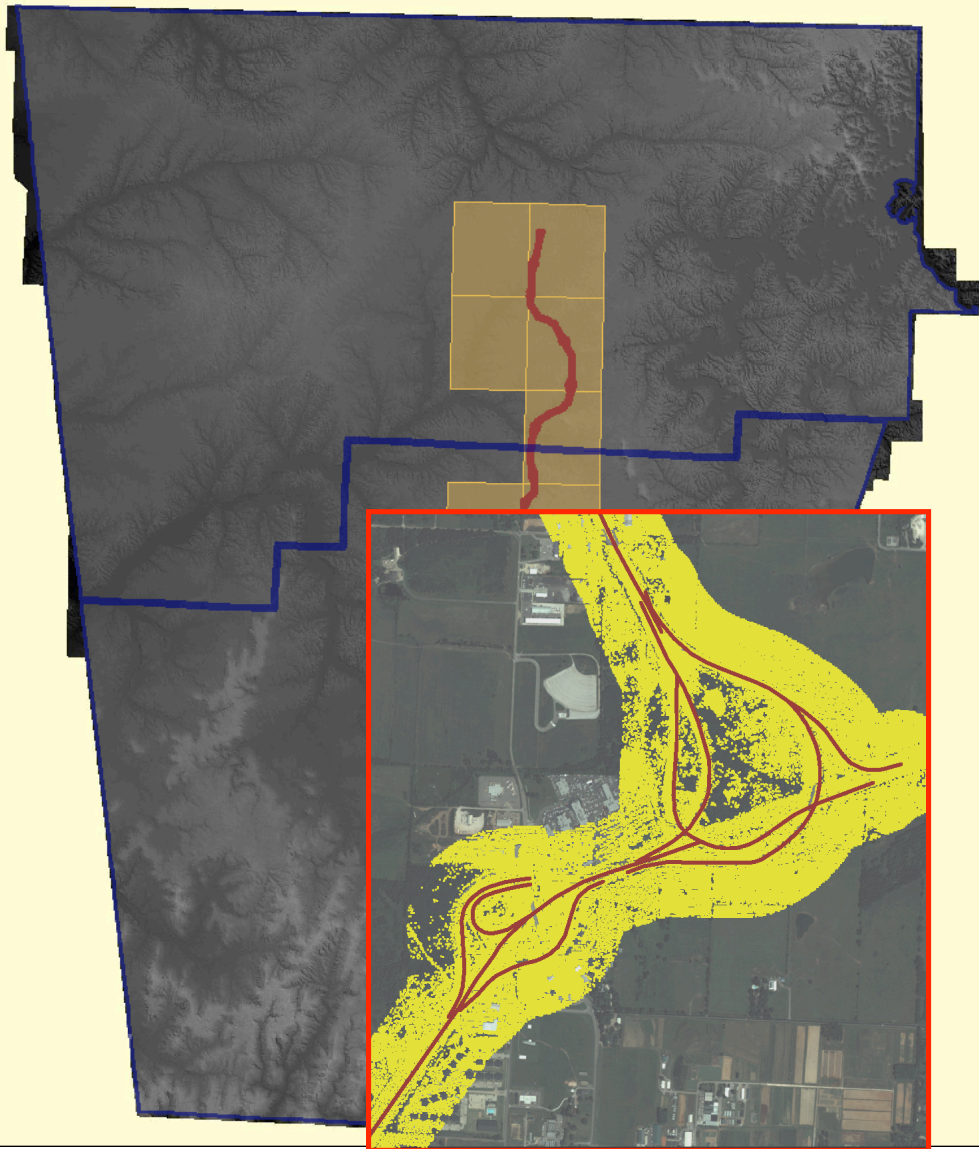


```
SELECT a.geometry
FROM city_limits2003_ahtd a
WHERE a.city_name = 'Greenland'

SELECT a.geometry
FROM railroads_tig99 a, city_limits2003_ahtd b WHERE b.city_name = 'Greenland' and
SDO_RELATE(a.geometry,b.geometry,
'mask=ANYINTERACT') = 'TRUE'
SELECT SDO_CS.TRANSFORM(a.geometry,8265) FROM beaver a,
(SELECT SDO_GEOM.SDO_BUFFER(a.geometry,50.0, 0.0005, 'UNIT=FOOT' ) as geometry
FROM railroads_tig99 a, city_limits2003_ahtd b
WHERE b.city_name = 'Greenland' and
SDO_ANYINTERACT(a.geometry,b.geometry) = 'TRUE') b WHERE
SDO_ANYINTERACT(a.geometry,b.geometry) = 'TRUE';

RETURN COUNT: 4579
```

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Generate the best possible surface representation along part of the I-540 corridor (500 ft buffer).

Existing tiling scheme requires 18 quarter-quads containing 31,269,468 surface points.

Spatial SQL query results in a view with ~3M points inside the corridor buffer.

Elapsed time: 3 min 50 sec

Different surface point densities (caused by foliage and buildings) support different interpolation sample and contour interval.

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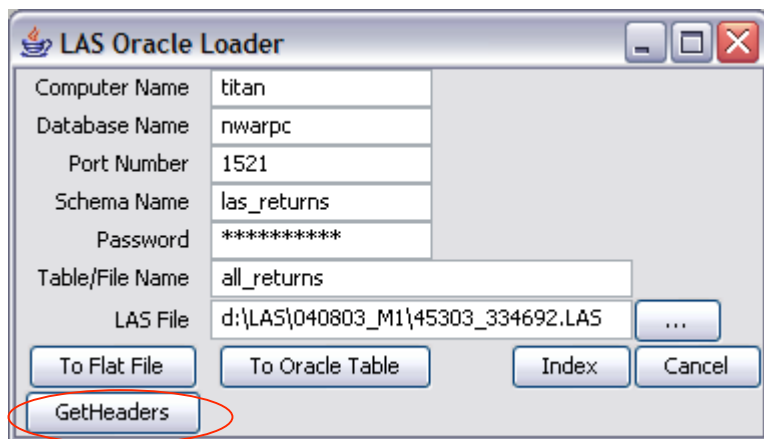
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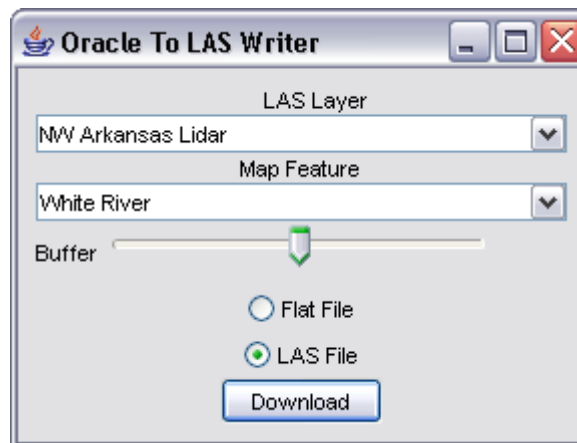
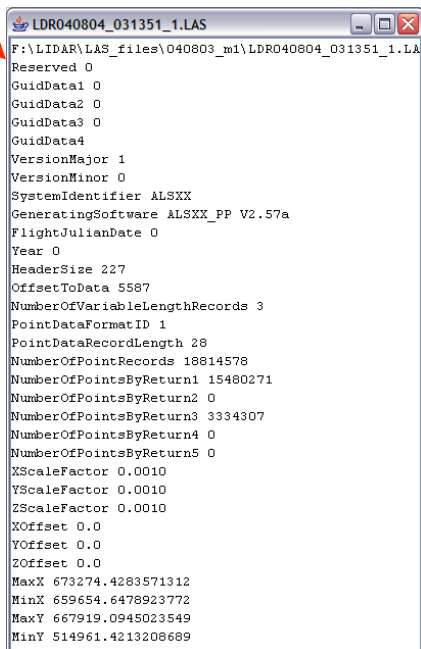
All returns (no pre-processing)

- Useful for more in-depth land cover analysis
- Load returns in LAS format directly
 - Have approximately **1 billion** returns from NWARPC (ALS40)
 - Study best storage and indexing options
- Select by spatial queries, return number, return number and pulse number combination
- LAS to Oracle application (version 0.8.7)
 - Reads full header and all combinations of data (e.g. up to 5 returns, classification, intensity, etc)



LAS Return Data

id
 point_geometry
 pulse_number
 x
 y
 z
 intensity
 return_number
 number_of_returns
 scan_direction_flag
 edge_of_flight_line
 classification
 scan_angle_rank
 file_marker
 user_bit_field
 gps_time



LAS from Oracle

Subset of returns for transfer to other packages.

Full Header Supported for both Loader and Writer

- datum and projection (per GeoTiff header)
- bounding box
- date of flight
- return counts (1,2,3,4,5)
- scale factor

www.asprs.org

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Full return information allows more detailed analysis.

Blue = last returns
Red = first returns
Existing geometries may be used in the classification process.
For example, building heights may be estimated from building returns and surrounding ground returns.

e.g. Hotels near JFK

Fayetteville, AR

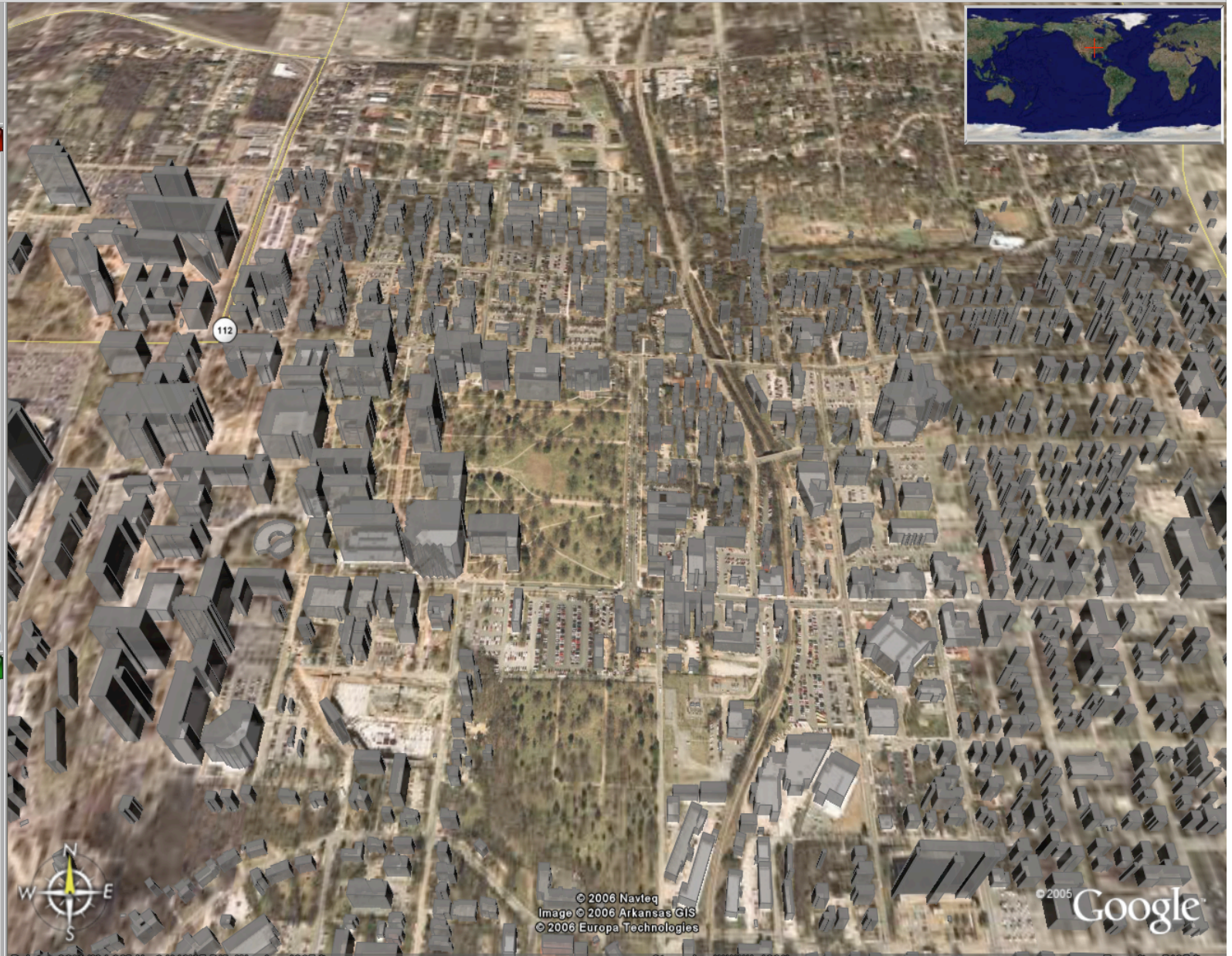
Places

My Places

- gcps_nad83.txt
- Google Earth - New Placemark
 - This is the location of a
 - MSS4
- gcps_nad83.txt
- gcp.kmz
- Hoover Dam
 - Rising more than 700 feet above the raging waters of the Colorado River, it was called
- Sightseeing
 - Start your Google Earth world tour here!
 - Click on an underlined
 - default
 - Google Earth default view.
 - Edit/Snapshot a new view to change your
- Temporary Places
 - Temporary Places
 - Layers
 - building_heights2
 - Data

Layers

- Layers
 - terrain
 - National Geographic Magazine
 - Google Earth Community
 - Community Showcase
 - Google Earth Community (Unrank
 - Populated Places
 - Alternative Place Names
 - borders
 - Dining
 - Lodging
 - Banks/ATMs
 - Bars/Clubs
 - Coffee Shops
 - Shopping Malls
 - Major Retail
 - Movie/DVD Rentals
 - Grocery Stores
 - Pharmacy
 - Gas Stations
 - Golf
 - Sports Venues



Pointer 36°04'04.80" N 94°10'07.51" W elev 1397 ft Streaming ||||| 100% Eye alt 5185 ft

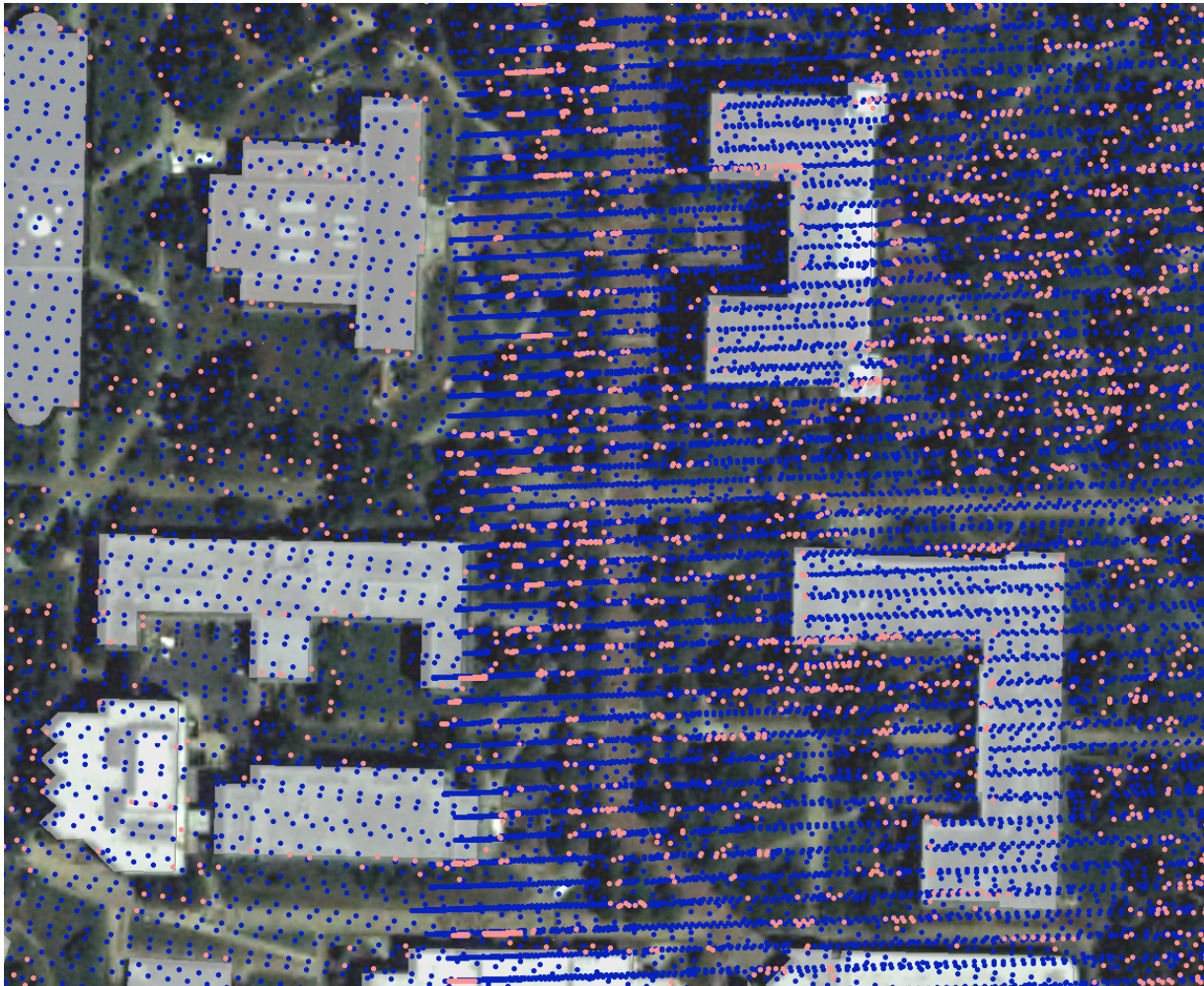
Lodging Dining
 Roads Borders
 Terrain Buildings

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Classification (or filtering) may also be accomplished in the database using neighborhood operations.

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Filtering operations may be implemented in the database.

Median of all returns with 15 ft of each return

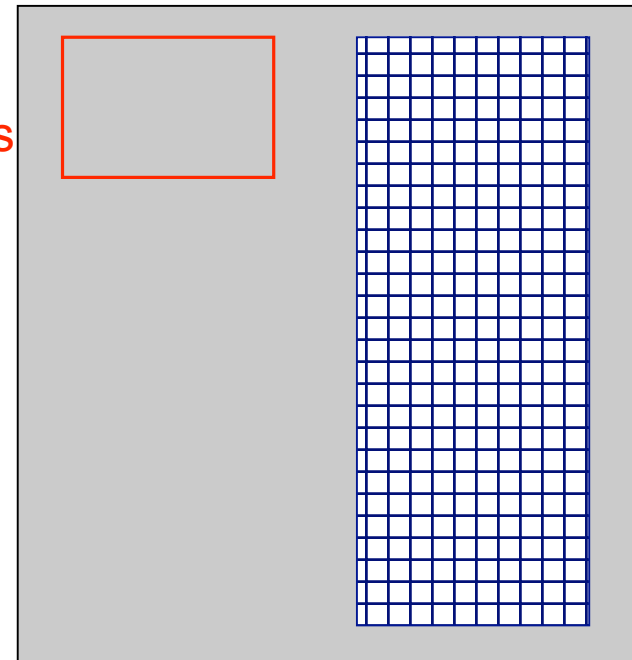
Std Dev of all returns with 15 ft of each return

Correlation between height and intensity

Identifying efficient storage options in Oracle 10g

- Table Partitioned Index
- Nested tables
 - Enables indexing in a distributed computing environment
- Indexing options
 - by point
 - by clusters (defining optimal size and density)
 - by pulse number (linear)
- Based on predominate queries
 - spatial operators
 - attribute operators

MBR containing
subset of records



Returns in MBR stored as
table or perhaps as indexed
VARRAY

Future Directions

- Indexing
 - Multiple processors
 - Variable partitions
- Retrieval
- Classification
 - Multiple processors
- Product generation
 - TIN
 - DEM
 - Variable contours

Q & A



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Questions?

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