University at Buffalo The State University of New York

RSL Remote Sensing Laboratory
Dept. of Geology, SUNY at Buffalo

From Multi-sensor Data to 3D Reconstruction of Earth Surface: Innovative, Powerful Methods for Geoscience and Other Applications

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Overview

- Goal
- Motivation
- UB-OSU surface reconstruction approach
- Applications
- Potential projects and collaborations

Goal

- The ultimate goal is to reconstruct, as automatically as possible, the 3D object space from multi-sensor, multi-source data, with respect to
  - Geometry (position, dimension of objects)
  - Radiometry (material properties of objects)
  - Semantics (labeled objects)

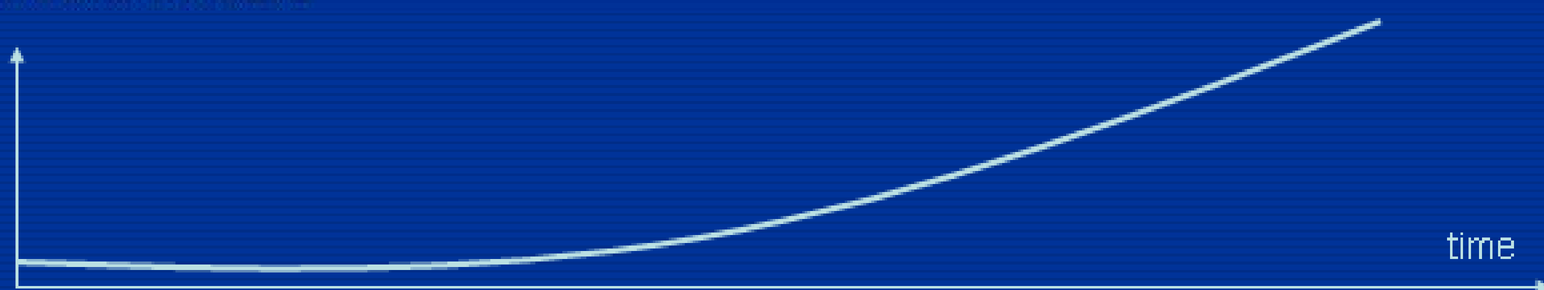
Motivation

- Volume and diversity of remotely sensed data rapidly increases
  - Increasing resolution: spatial, temporal and spectral resolution
  - Different viewing geometry: oblique, nadir
  - Different Sensor types: line, frame, whiskbroom, panoramic cameras, conical laser scanner
  - Different phenomenology: VIS, NIR, microwave, radar
- Negative effect: Analysis doesn't keep up with increasing data volume
- Positive effect: Multi-sensor data provides complimentary and redundant information and therefore supports automation

Example: Development of Polar Data Sets

- Data acquisition methods

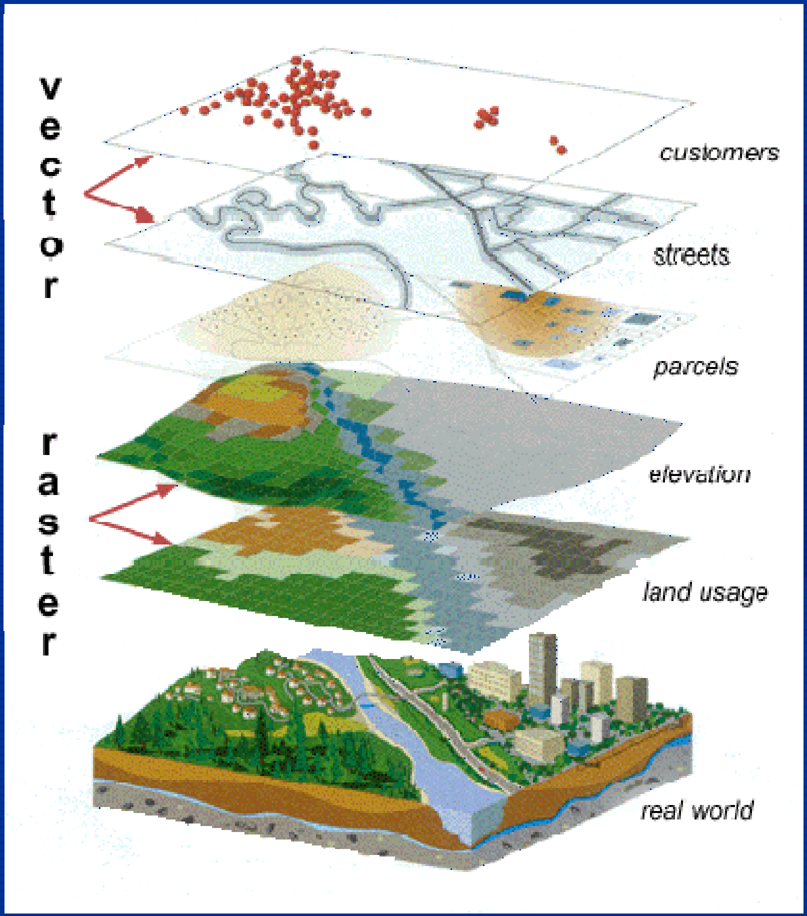
- Amount of data



Why Multi-Sensor, Multi-Source Data

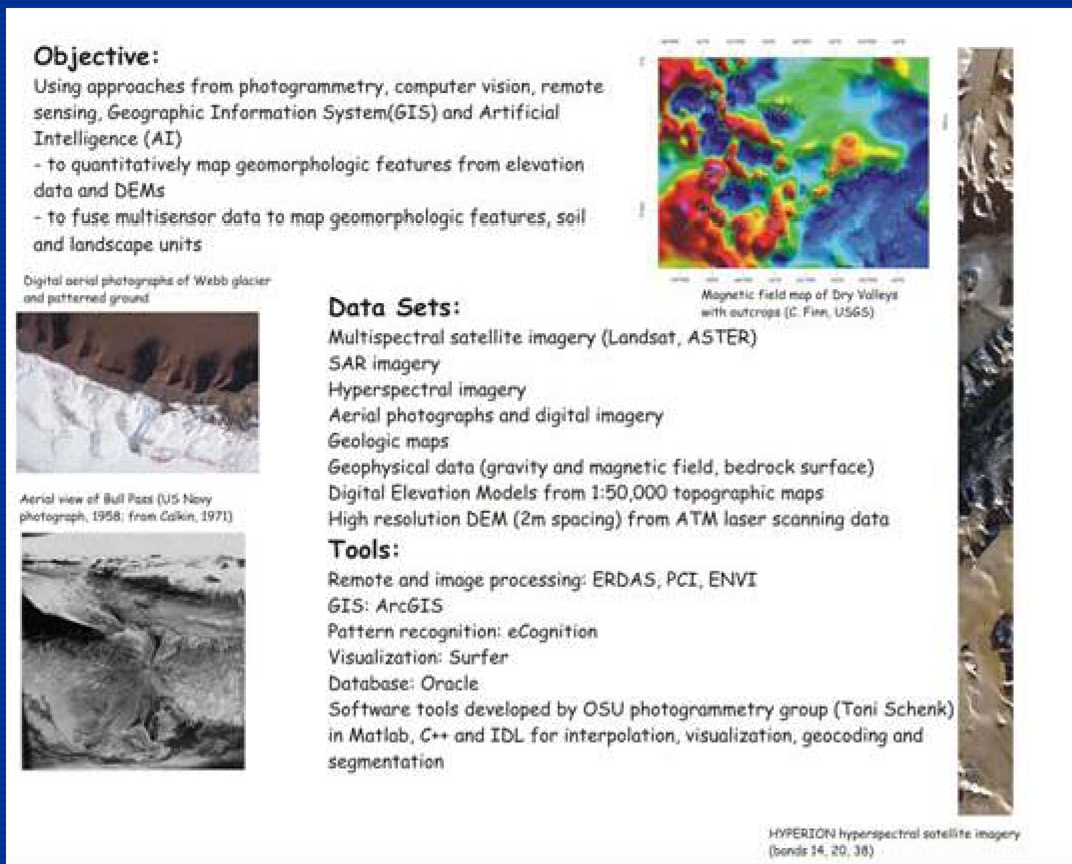
- The goal of automatically reconstructing a 3D scene is very difficult, it is a hard problem
- Sensors that record different and complementary properties (multi-sensor) contribute toward the solution
- Existing data and information (multi-source), such as GIS, maps of all kinds, must also be included, if appropriate

What we do Today, a Typical Solution from Geology



- All data are processed individually and stored and manipulated in a Geographic Information System
- Advantages:
  - GIS can handle raster, vector and point data;
  - GIS has advanced spatial queries and statistical tools;
- Disadvantages:
  - Surface are 2 and 2.5 D not real 3D
  - Data input to GIS requires extensive preprocessing
  - Correction of geometric errors is limited – e.g., rubbersheeting or affine transformation
  - Image layers are essentially orthophotographs – see demo!

Example: Antarctic Dry Valleys



Objective:
Using approaches from photogrammetry, computer vision, remote sensing, Geographic Information System(GIS) and Artificial Intelligence (AI)
- to quantitatively map geomorphologic features from elevation data and DEMs
- to fuse multisensor data to map geomorphologic features, soil and landscape units

Digital aerial photographs of Webb glacier and patterned ground

Aerial view of Bull Pass (US Navy photograph, 1958; from Calkin, 1971)

Magnetic field map of Dry Valleys with outcrops (C. Finn, USGS)

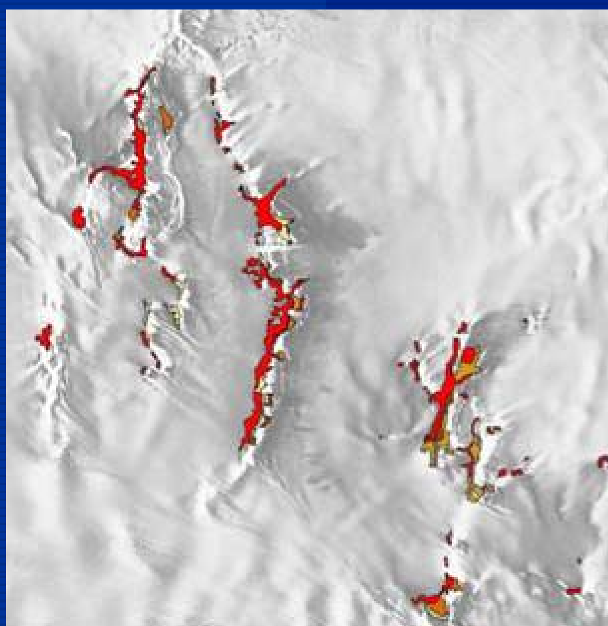
Data Sets:
Multispectral satellite imagery (Landsat, ASTER)
SAR imagery
Hyperspectral imagery
Aerial photographs and digital imagery
Geologic maps
Geophysical data (gravity and magnetic field, bedrock surface)
Digital Elevation Models from 1:50,000 topographic maps
High resolution DEM (2m spacing) from ATM laser scanning data

Tools:
Remote and image processing: ERDAS, PCI, ENVI
GIS: ArcGIS
Pattern recognition: eCognition
Visualization: Surfer
Database: Oracle
Software tools developed by OSU photogrammetry group (Toni Schenk) in Matlab, C++ and IDL for interpolation, visualization, geocoding and segmentation

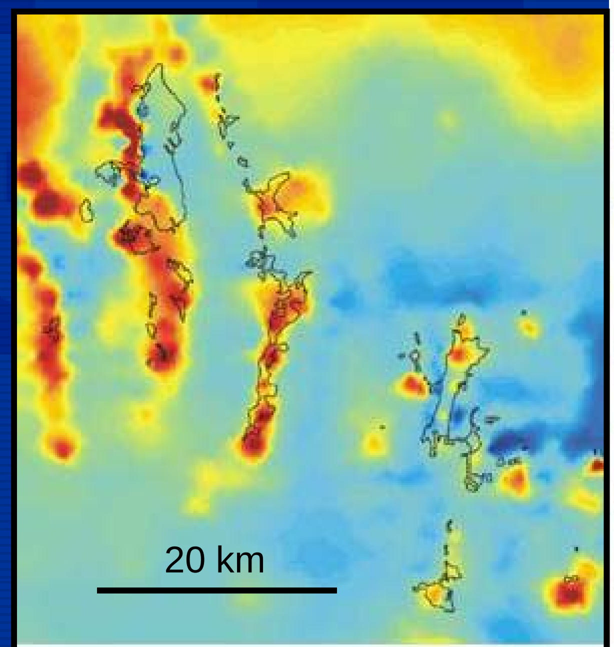
HYPERION hyperspectral satellite imagery (bands 14, 20, 38)

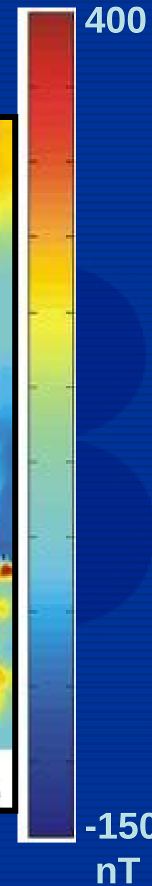
→ **GIS**

Task 1: Identify magnetic anomalies and ice flow pattern related to dolerites rock outcrops

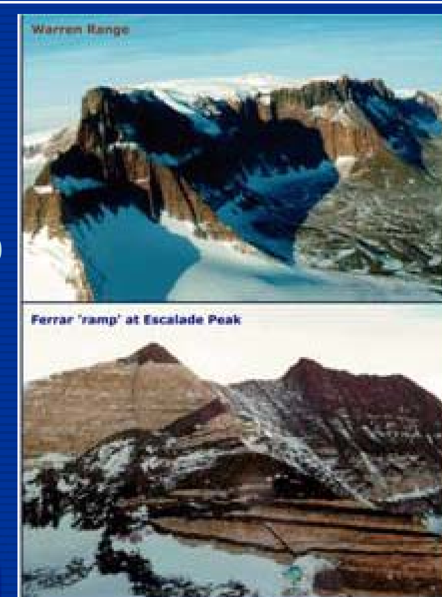


Relationship between ice flow and geology: Geologic map overlain on Landsat imagery





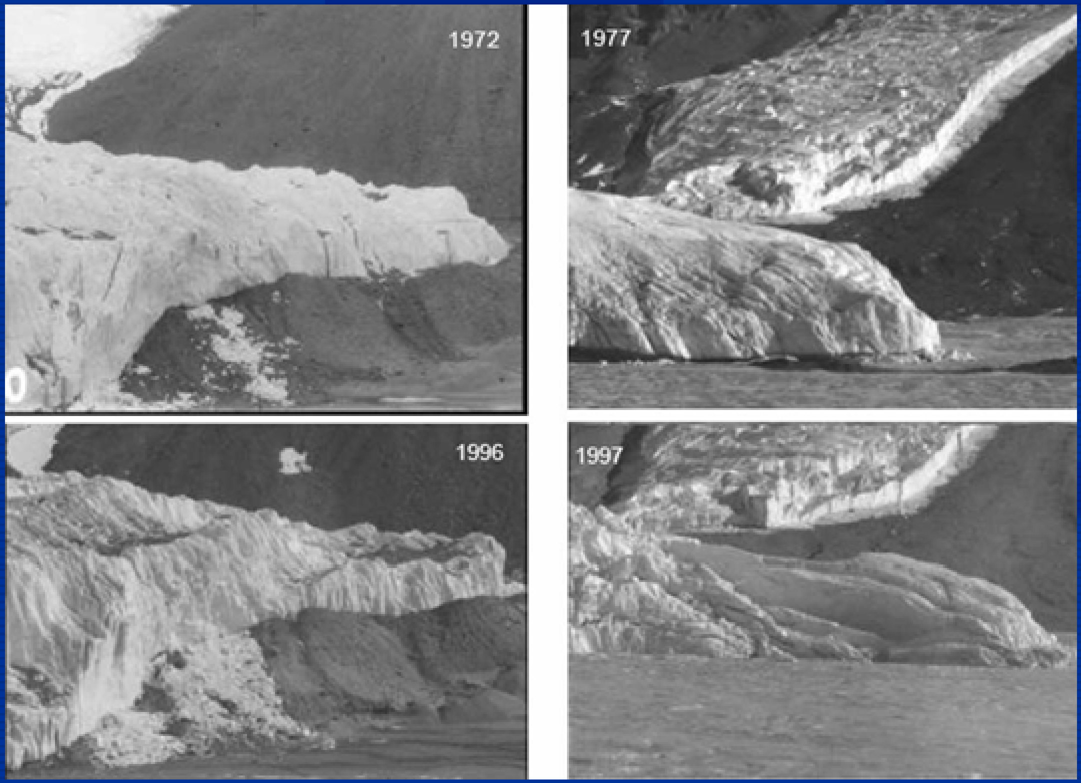
Delineation of subsurface structures: Geologic map overlain on magnetic field map



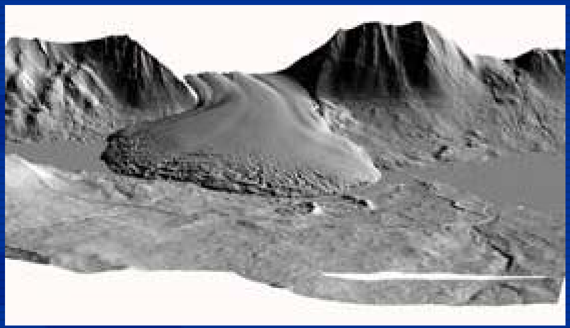
GIS ✔

Task 2: measure changes in glacier extent and thickness from multi-temporal terrestrial and aerial imagery and laser point cloud

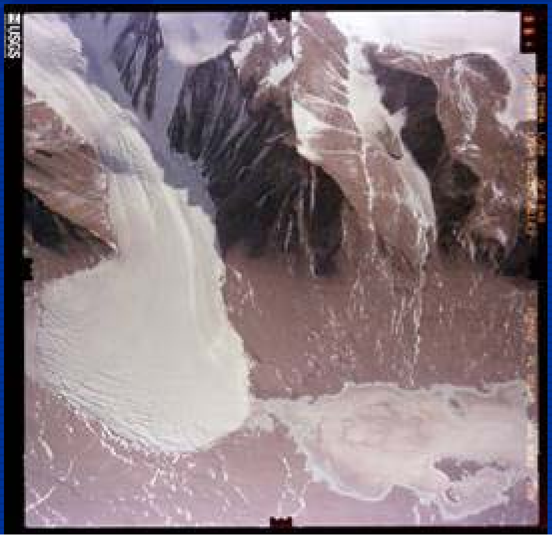
Terrestrial photographs since 1905 (Scott's expedition)



LIDAR measurements in 2001 (control information)



Aerial photographs since the1950s



GIS, photogrammetry workstations, LIDAR processing programs (e.g., QT Modeler) ????

UB-OSU Surface Reconstruction System
Step 1: Sensor Orientation

- An absolute prerequisite for fusing data from different sensors and different sources is establishing a common, well defined 3D orthogonal reference system. With many data acquisition systems equipped with GPS, a natural choice is the WGS-84 system, the default system for GPS positions

- Step 1: Feature-based, rigorous sensor orientation (alignment) by using point, linear and aerial features extracted from images, point clouds, GIS. The orientation is based on sensor modeling and errors are computed by error propagation.

UB-OSU Surface Reconstruction System
Step 2: Surface Reconstruction

- Surfaces in 3D object space play an important role for most applications. They can be generated from images, e.g. automatic matching of corresponding features, from LIDAR point clouds, from IfSAR, or from a combination of these methods. Surfaces are represented by regular grid structures (DEM) or by analytical functions that approximate surface patches

- Step 2. Matching and surface reconstruction in object space. Features are extracted, matched and fused on different levels of processing, e.g., from laser point clouds, DEMs, aerial and terrestrial images, classified hyperspectral data cube, etc. Registration is refined during surface reconstruction. Additional data, for example hyperspectral imagery or SAR, are ingested to identify surface materials.

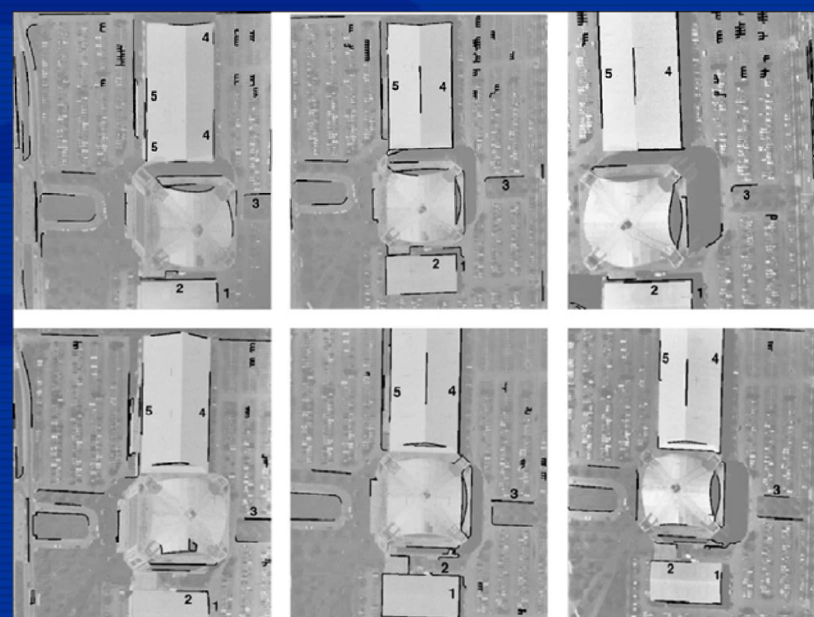
UB-OSU Surface Reconstruction System
Step 3: 3D Visualization, Measuring and Editing

- True 3D visualization greatly helps analysts to interpret 3D scenes. True 3D visualization of sensor data requires oriented sensors and the reconstructed surface.
- Step 3: True 3D visualization of multi-sensor data augmented by editing and measuring capabilities to fully exploit its potential.

Feature-Based Orientation

- Analytical representations of linear and aerial features are used as control features and tie lines.
- No point to point correspondence is needed
- Suitable for multi-sensor data, for example images, point clouds and GIS

Schenk, T., 2004. From point-based to feature-based aerial triangulation. *ISPRS Journal of Photogrammetry and Remote Sensing* 58, 315-329.



The six image patches show the area covered by six photographs. Superimposed are the edges as obtained with the Canny operator. Five edges that appear on all six images are manually selected as tie lines. These selected tie lines are numbered 1 to 5.

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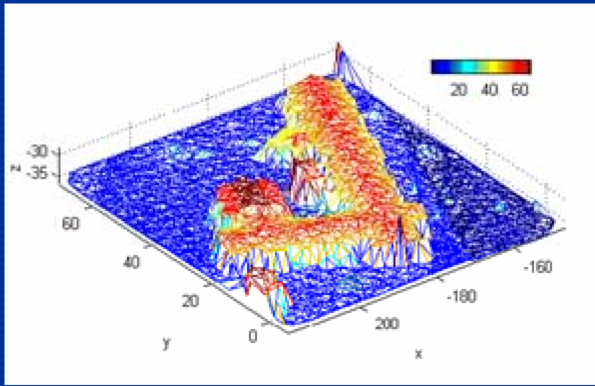
Feature-Based Block Adjustment: Orienting Images to 3D Point Cloud
First operational system in the world -- See UB demo

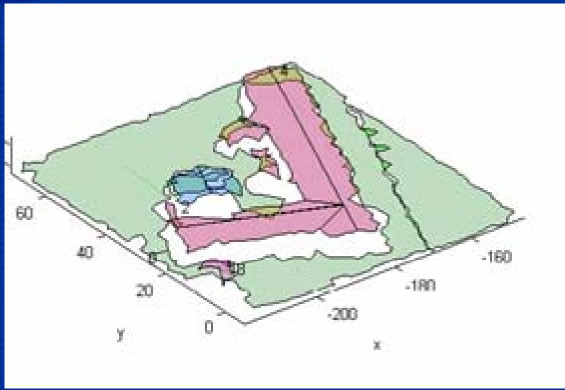
(Data from courtesy of M. Bevis, OSU)

Surface Reconstruction, Geometry

Fusing aerial images with LIDAR data in object space. From left to right: (1-2) edges of the aerial stereopair obtained by the Canny operator. (3) More specific edges derived by domain knowledge. These edges were matched in object space with the segmented LIDAR surface to obtain the final result (4). Colors of region boundaries: red: LIDAR+aerial+aerial;yellow: LIDAR+aerial; magenta: aerial+aerial; blue: LIDAR; green: aerial. (From Schenk, T. and B. Csatho, 2002. Fusion of LIDAR data and aerial imagery for a more complete surface reconstruction. *ISPRS Archive* 34(3A), 310-317)

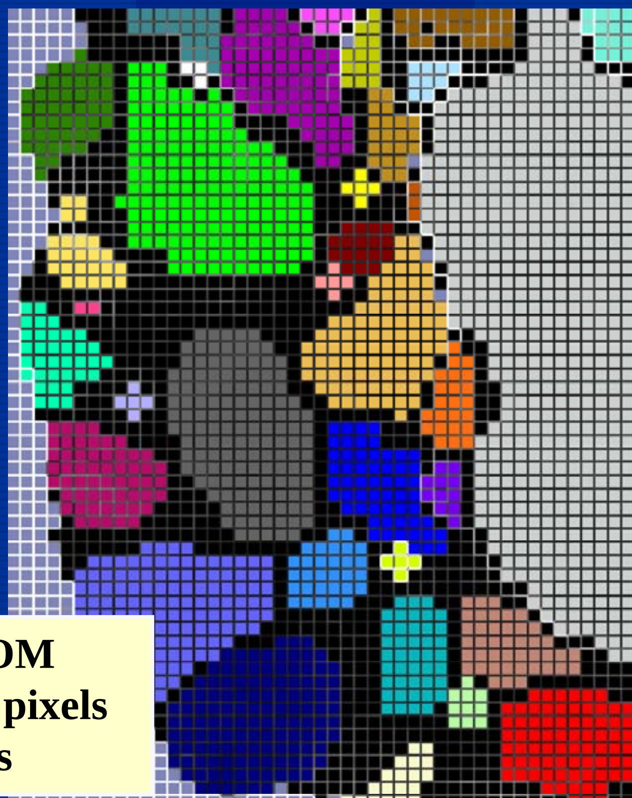


Perceptual organization of a LIDAR point cloud. Left: 3D view of Delaunay triangulation; right: visualization of perceptually organized surfaces showing ground surface (green) and polyhedral surfaces organized at the structural level. Colors indicates grouping. (From Lee, I. and T. Schenk, 2001. 3D perceptual organization of laser altimetry data. *ISPRS Archive* 34(3/W4), 57-65, and *PhD Dissertation at OSU)*

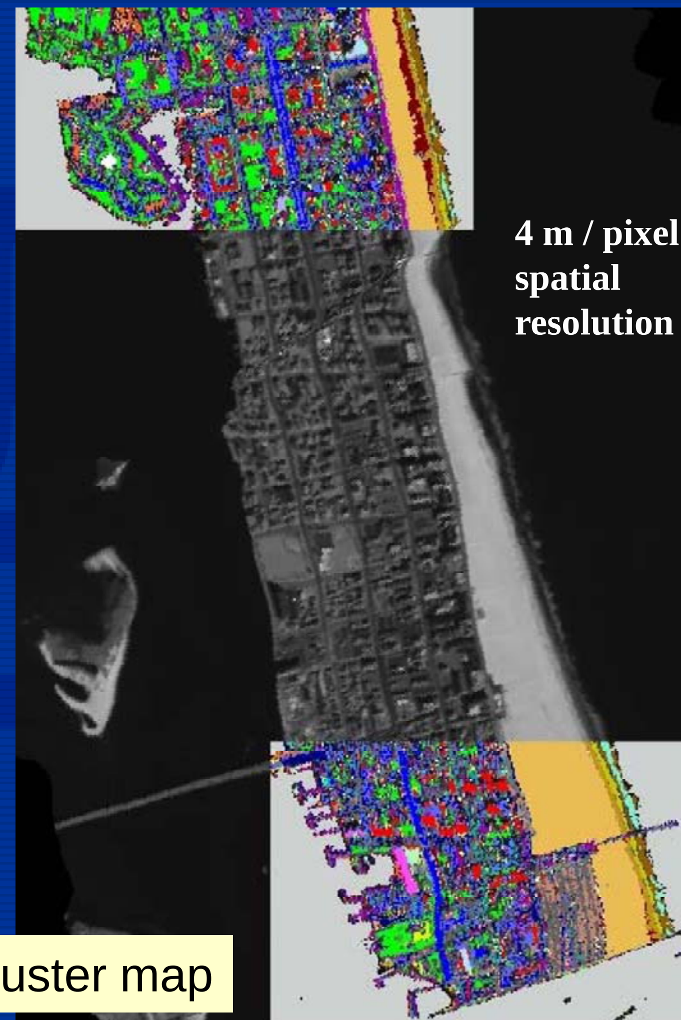


Surface Reconstruction, Surface Properties/Semantics

Self-Organizing Map (SOM) based clustering of AVIRIS hyperspectral imagery, Ocean City, Maryland



40 x 40 SOM
< 100,000 pixels
35 clusters



Cluster map

From Merenyi, E., B. Csatho and K. Tasdemir, 2007. Knowledge discovery in urban environments from fused multi-dimensional imagery. *Proc. 4th IEEE GRSS/ISPRS Joint Workshop on Remote Sensing and Data Fusion over Urban Areas (URBAN 2007)*, Paris, France, April 11-13, 2007. (invited paper) 13 pp. IEEE Catalog number 07EX1577.

Application: Reconstruction of Long-term History of Greenland Outlet Glaciers from Historical Aerial Photographs and Satellite Imagery

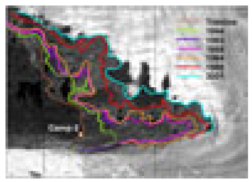
NEWS RELEASE

New Greenland Ice Sheet Data Will Impact Climate Change Models

With digital imaging techniques, scientists find new data in old aerial photographs

BUFFALO, N.Y. -- A comprehensive new study authored by University at Buffalo scientists and their colleagues for the first time documents in detail the dynamics of parts of Greenland's ice sheet, important data that have long been missing from the ice sheet models on which projections about sea level rise and global warming are based.

The research, published online this month in the *Journal of Glaciology*, also demonstrates how remote sensing and digital imaging techniques can produce rich datasets without field data in some cases.



Research conducted by a UB geologist on the Greenland ice sheet shows the trimline (broken brown line) that marks the maximum extent of the ice sheet at the end of the 18th century and the subsequent retreat of the glacier and land exposed since 1944.

Download JPEG

New Greenland Ice Sheet Data Will Impact Climate Change Models

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Science News

Keywords
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Description
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Newswise — A comprehensive new study authored by University at Buffalo scientists and their colleagues for the first time documents in detail the dynamics of parts of Greenland's ice sheet, important data that have long been missing from the ice sheet models on which projections about sea level rise and global warming are based.

The research, published online this month in the *Journal of Glaciology*, also demonstrates how remote sensing and digital imaging techniques can produce rich datasets without field data in some cases.

Traditionally, ice sheet models are very simplified, according to Beata Csatho, Ph.D., assistant professor of geology in the UB College of Arts and Sciences and lead author of the paper.

Image Gallery

This 1946 picture shows how the four-mile-wide Jakobshavn Isbrae, the white region in the middle, is flowing from the ice sheet (top) through Greenland's rocky coast.

Csatho et al., 2007. Intermittent thinning of Jakobshavn Isbrae, west Greenland since the Little Ice Age. *Journal of Glaciology*, 54(184), 131-144. and (http://www.buffalo.edu/news)

Potential Projects or Collaborations

- Develop a robust sensor orientation system (‘toolbox’), based on sensor invariant features. Such a system must be user-friendly, robust, and easy to be used by non-specialists
- Develop a surface reconstruction system based on fusing different sensor data or surface information from different sources.
- Develop a surface representation scheme that is based on approximating surface patches by analytical functions, including the surface patch boundaries

Potential Projects or Collaborations

- Develop a true 3D visualization system augmented with the capabilities
  - to interactively identify, move, and edit objects
  - to measure and edit features
  - to superimpose any data, features, information, or objects that are references to the common reference system

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Demonstration of UB-OSU Software Development and Visualization Environment at CEIS