Contribution of Normalized Digital Surface Models used in Automatic Building Extraction

MGIS GEOG 596A
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Presentation Outline

1. Background
2. Challenges of extracting building data
3. Project Goals
4. Components need in building extraction
5. Methods of extracting buildings
6. Collecting Results
7. Accuracy Assessment
Background: 3D Building Simulation

Flat Imagery
Photo credit: Google Earth Pro

3D Scene
Photo credit: Google Earth Pro

Raster
Pixel Data

Feature Extraction
Photo credit: Trimble eCognition
Use of Accurate 3D Buildings

- Virtual Reality (VR)
  - Education – Virtual tours
  - Scientific analysis – modeling and simulation
  - Entertainment – modeling the real world
  - Business – Real Estate and Strategic Plans
  - Urban Planning – Urban Design

Augmented Reality
- Car Navigation
- UAV Navigation

- Surveillance
  - Monitoring military operations

- Mapping and Navigation
  - Reference information
Availability and Extent of 3D Building Data

Commercial Vendors and Open Community
- Sanborn (USA)
- Google (and 3rd party suppliers)
- Apple (and 3rd party suppliers)
- Open Street Maps
- Google Earth Community

Extent of Coverage:
- Building data is mostly available in large urban areas in the USA and major cities across the world.

Limitations
- Accessibility (Data from commercial organization is not released)
- Accuracy concerns
- Availability – Limited availability
Massive Collectives of Stereo Satellite Imagery is advancing elevation data

- As satellites are collecting imagery around the world, massive amounts of imagery are providing different orthoscopic views of locations anywhere on Earth.
- By combining images at different angles of observation, elevation data can be computed to identify the heights of features up to the resolution of the originating imagery.

**Very High Resolution Digital Surface Modeling at 3m to 50 cm Resolution And Global Extent**

*Photo credit: Satellite Imaging Corporation*

*Photo credit: Vricon, Corp.*
Challenges with extracting buildings

- Identification of a building (from all other objects)*
- Variability of the resolutions of the data**
- The enormity of the data:
  - Number of buildings in the USA:
    - USA Commercial buildings: 5,600,000+ (U.S. Energy Information Administration, 2016).
    - USA Residential Households: 133,957,180 (U.S. Census 2014)
      - Households include attached and detached buildings.
  - Number of buildings in the World:
    - Researching ORNL LandScan data for this statistic.
- Identifying buildings from different types of landscapes (i.e.g, tropical, arctic, and arid)

* The successful identification of a building using nDSM is a key focus in this study.
**The variability of the resolution of the data that is used to nDSM is a key focus in this study.
Capstone Objective

• Motivation
  • Improve the methods used to extract buildings through an automated process.
  • Incorporate state-of-the-art technology - Very High Resolution (VHR) elevation data to increase accuracy of extracting buildings.
  • Investigate the effects of using heterogeneous datasets that are different in resolution.

• Goals
  1. Research the impact that occurs when variable data resolutions are used to create nDSM products.
  2. Report the accuracy of the combination of nDSM products
  3. Report and compare the accuracy of building extraction without nDSM products.
What is a Normalized Digital Surface Model (nDSM)?

- nDSM is a derivative product of a Digital Surface Model and Digital Elevation Model.
  - DSM measure the height of features
  - DEM measures the height of the ground
  - nDSM measure the absolute height of features by subtracting the ground or DEM.
  - DSM-DEM = nDSM
Data availability for wide areas is heterogeneous

17,500 Sq Km
High Resolution Data Layers for Landscape and Urban Infrastructure can be Extracted Periodically from Newly Available Source Data

**Multispectral Imagery (MSI): Digital Globe**
- 0.5m / pixel
- 4-band satellite imagery
- enables discrimination of landscape types
  - trees / shrubs vs. grass vs. pavement vs. surface water vs. bare earth

**Digital Surface Models (DSMs): Vricon**
- 0.5 m / post
- derived from high res stereo pairs of overhead images
- DSMs express height above ground level (AGL)
- Ground level is captured in a low res Digital Elevation Model (DEM)
- DSM resolution is sufficient to capture the details of urban infrastructure
Goal 1: Research the impact that occurs when variable data resolutions are used to create nDSM products.

- Spatial accuracy of the product depends on the quality of the georeferencing. The georeferencing can be interpolated from ground control or provided by georeferencing and remote sensing technology.

The resolution samples used in this study are defined as follows:

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR1</td>
<td>30</td>
</tr>
<tr>
<td>LR2</td>
<td>15</td>
</tr>
<tr>
<td>LR3</td>
<td>10</td>
</tr>
<tr>
<td>HR1</td>
<td>3</td>
</tr>
<tr>
<td>HR2</td>
<td>1</td>
</tr>
<tr>
<td>HR3</td>
<td>0.5</td>
</tr>
<tr>
<td>HR5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

LR = Low Resolution
HR = High Resolution

DEM created at different source data resolutions.
Photo credit: PSU Imagery Analysis Course
Methodology

Basics Components for Building Extraction

Key Data Components
- Imagery with Near Infrared (NIR) Band
- Surface Model Data
- Digital Elevation Data

Additive Derivative Data
- Normalized Digital Surface Model (nDSM)*
- Normalized Digital Vegetation Index (NDVI)
- Slope
Methodology for Building Extraction from MSI and DSM Source Data

High Resolution MSI (DigitalGlobe)

High Resolution DSM (Vricon)

eCognition Software Platform

- vegetation rule set
- bare earth rule set
- roads rule set
- buildings rule set
- surface water rule set

Input Image → Processed Image

Shape Files for Current Data Layers

- vegetation
- bare earth
- roads / pavement
- buildings
Challenge

• Normalized Digital Surface Models are derived from Digital Surface Models and Digital Elevation Models – *and those models may be heterogeneous in spatial resolution*.
• Combining different elevation products for deriving an nDSM product can provide different results.
• This study was conducted to investigate the contribution of a nDSM and the results when using a variety of mixed resolutions.
Goal 2: Report the accuracy of the combination of nDSM products.

- The effects of combining different resolutions of DEM and DSM data to create a nDSM will be prepared as follows:

<table>
<thead>
<tr>
<th>Cohort 1</th>
<th>Low Resolution (LR1) DEM's are held constant while investigating higher resolutions of DSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>nDSM = DEM LR1 - DSM HR1</td>
</tr>
<tr>
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<td>nDSM = DEM LR1 - DSM HR2</td>
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<table>
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<tr>
<th>Cohort 2</th>
<th>Low Resolution (LR3) DEM's are held constant while investigating higher resolutions of DSM</th>
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<tr>
<td>Case 4</td>
<td>nDSM = DEM LR3 - DSM HR1</td>
</tr>
<tr>
<td>Case 5</td>
<td>nDSM = DEM LR3 - DSM HR2</td>
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<tr>
<th>Cohort 3</th>
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<tr>
<td>Case 7</td>
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Building Extraction Strategy

- Identify the range and types of building that will be extracted
- Identify the extent of the area
- Develop core strategy by evaluating the type of available data
- Develop core strategy by evaluating the resolution of the available data*
- Identify and develop derivative products that are needed for the execution
- Develop the algorithms for extracting the buildings
- Develop the algorithms for identifying non-buildings
- Identify data outputs
- Evaluate the results
- Refine algorithms
- Conduct accuracy analysis
Study Area:
San Diego, CA and Tijuana, Mexico
Feature Extraction Study Area
1: Mixed Use Area (Mexico)

Photo credit: Google Earth Pro
Feature Extraction Study Area 1: Mixed Use Area (Mexico)
Feature Extraction Study Area 2: Industrial Area (USA)
Feature Extraction Study Area
3: Business Area (Mexico)
Feature Extraction Methods

Feature Extraction Process
• To determine the applicability of using the different products, this analysis uses eCognition by Trimble (a Feature Extraction software) to identify and extract buildings within the area of interest.

Feature Types
• For completion, the entire scene was segmented and tagged into the following feature types:
  • Buildings
  • Other Structures (e.g., Walls, Equipment, Sheds)
  • High Lying Vegetation/Landscape (Vegetation at or above 1.5 meters)
  • Low Lying Vegetation/Landscape (Vegetation below 1.5 meters)
  • Water
  • Ground (Roads/Bare Earth)
Building Extraction Process

The eCognition Interface

- Main toolbar
- Legend of features being tagged
- Investigation Panel – measures, counts, identifies objects
- Algorithms: Logical and athematic rules
- Viewer for image products & spatial data
- Resources for products, derivative products, spatial properties, and variables
- Detailed description of algorithm
Building Extraction Processing in Study Area 1

4 Band Digital Globe Imagery Natural Color (1 meter)
Building Extraction Processing in Study Area 1

4 Band Digital Globe Imagery False Color NIR (1 meter)
Building Extraction Processing in Study Area 1

Vricon 1 meter nDSM

Digital Globe Imagery
Imagery credit: LLNL/Digital Globe
Collection of the Results

• Analysis of nDSM from the Combination of Elevation Products

• The effects of combining different resolutions of DEM and DSM data to create a nDSM will be prepared as follows:

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Goal 3: Report and compare the accuracy of building extraction without nDSM products.

Accuracy Assessment

Methods used to analyze the accuracy of the elevation of the nDSM:

1. Random Sampling – Building Identification
2. Verification Method
3. Statistical Results

Methods used to analyze the product combinations and the derived buildings:

1. Confusion Metrix Results*
2. Building Shape Results (for each)
3. Building Size Results (for each)

* The Confusion Matrix is a common method for assessing the classification accuracy of objects within a scene.
Error Matrix Assessment

Reference Image

Case 1: Classified Image

Case 2: Classified Image

Binary Error Matrix (Pixel Population)

Assessment Type

Adapted from Pope, P. Accuracy Assessment and Congalton, RG and Green, K, 2010
## Accuracy Assessment Results Matrix

- Accuracy Results for the nDSM Combinations

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<th>Elevation Accuracy</th>
<th>Overall Accuracy</th>
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Primary Focus:
User’s and Producer’s Accuracy

- User’s accuracy corresponds to error of commission (inclusion):
  - Buildings included erroneously in another category

- Producer’s accuracy corresponds to error of omission (exclusion):
  - Buildings omitted from the building category
Accuracy Assessment Goals

- Each case will be assessed for its accuracy.
- Successful rates of building identification for each case will be measured against the goals assigned below.

<table>
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<tr>
<th>Accuracy Assessment</th>
<th>Formula</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Accuracy</td>
<td>( \frac{(TP+TN)}{(TP+TN+FP+FN)} )</td>
<td>&gt;75%</td>
</tr>
<tr>
<td>User's Accuracy (Positives)</td>
<td>( \frac{TP}{(TP+FP)} )</td>
<td>&gt;75%</td>
</tr>
<tr>
<td>User's Accuracy (Negatives)</td>
<td>( \frac{TN}{(TN+FN)} )</td>
<td>&gt;75%</td>
</tr>
<tr>
<td>Producer's Accuracy (Positives)</td>
<td>( \frac{TP}{(TP+FP)} )</td>
<td>&gt;75%</td>
</tr>
<tr>
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<td>&gt;75%</td>
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<table>
<thead>
<tr>
<th>TP</th>
<th>False Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP</td>
<td>False Negative</td>
</tr>
</tbody>
</table>

TP = True Positive
TN = True Negative
FP = False Positive
FN = False Negative

Positives = Class category
Negatives = Non-Class category
Timeline

- August – October:
  - Data Acquisition
  - Data Preparation
  - Algorithm Development

- September-October:
  - Conduct analysis on all study areas
  - Evaluation of Results
  - Identify Accuracy Tests
  - Compare the Results

- November-December:
  - Complete Report
  - Request feedback and refine methods
  - Update Report

- March 2017: Target presentation at ASPRS
References


