Automatic Creation of Massive Virtual Cities

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Talk Overview

- Applications of 3D models
- Problem Statement
  - Automatic Creation of Massive Virtual Cities
- Related Work
  - State of the art and current limitations
- Objectives
- System Overview
  - Modeling & Texturing
- Integrated System
- Summary
- Q & A

Applications of 3D Models

- Increasing demand for applications which employ a 3D model representation of the real world in a virtual environment
  - Virtual Reality
    - Disaster simulations of man-made or natural events
    - Personnel training (military, emergency response, etc)
    - Urban development and planning

Flood

Military training. Courtesy of U.S. Army

Applications of 3D Models (Cont'd)

- Increasing demand for applications which employ a 3D model representation of the real world in a virtual environment
  - Virtual Reality
  - Computer Graphics
    - Games & Feature Films
      - Reconstructed city of London using SketchUp, used in the game Crysis by Crytek. Courtesy of UCL

Applications of 3D Models (Cont'd)

- Increasing demand for applications which employ a 3D model representation of the real world in a virtual environment
  - Virtual Reality
  - Computer Graphics
  - Surveillance
    - Situational awareness. Augmented Virtual Environment (AVE)

Applications of 3D Models (Cont'd)

- Increasing demand for applications which employ a 3D model representation of the real world in a virtual environment
  - Virtual Reality
  - Computer Graphics
  - Surveillance
  - Geographical Information Systems(GIS)
    - Google Earth, Microsoft Virtual Earth
    - GPS navigation devices

Courtesy of 3DLabs

Problem Statement

- Virtual 3D models are desirable because:
  - Provide a *compact representation* of *large-scale* areas
    - No maintenance
  - *Controlled environment* to simulate various scenarios
    - No damage to structures or human life for simulations of natural or man-made events or military training
- However, the production of 3D model representations of the real world is:
  - Complex: Requires personnel with extensive training to produce models
  - Expensive: Manual work
  - Slow: Time consuming
- Gap between current state of the art and the desired goal
  - Rapid, automatic reconstruction of large-scale areas

Related Work

- *Urban site modeling from LiDAR (You et al, 2003)*
- *Constructing 3D city models by merging ground-based and airborne views (Zakhor et al, 2003)*
- *3D building detection and modeling from aerial LiDAR data (Hsu et al 2006)*
- *Building segmentation for densely built urban regions using aerial LiDAR data (Kumar et al, 2008)*
- Airborne LiDAR(Light Detection and Ranging)
  - Advantages
    - Moderate accuracy->Moderate level of details
    - Scalable. Captures large-scale areas
  - Limitations
    - No building facades

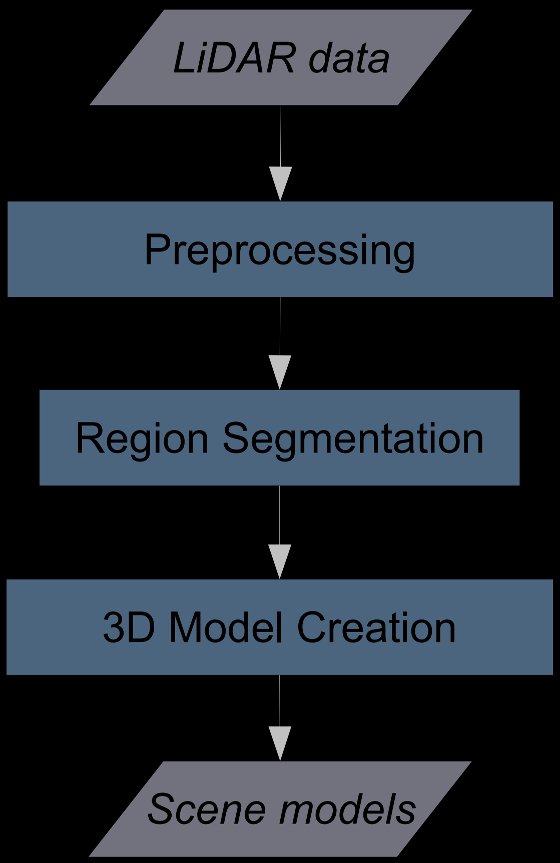
Downtown Atlanta,GA

Objectives

- In this work we address these problems and current limitations of state of the art techniques and present solutions for the automatic creation of massive virtual cities.
- Creating large-scale(city-size) scene models from LiDAR data
  - Rapid extraction & modeling of geometric models

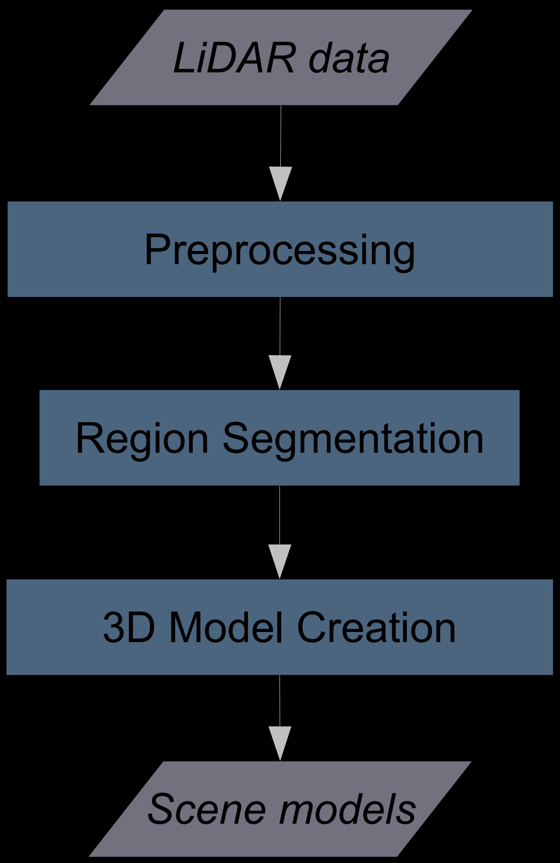
System Overview

- Three modules:
  - Preprocessing
    - Unstructured 3D pointcloud data -> structure and subdivide into manageable components
    - Resampling and Hole-filling



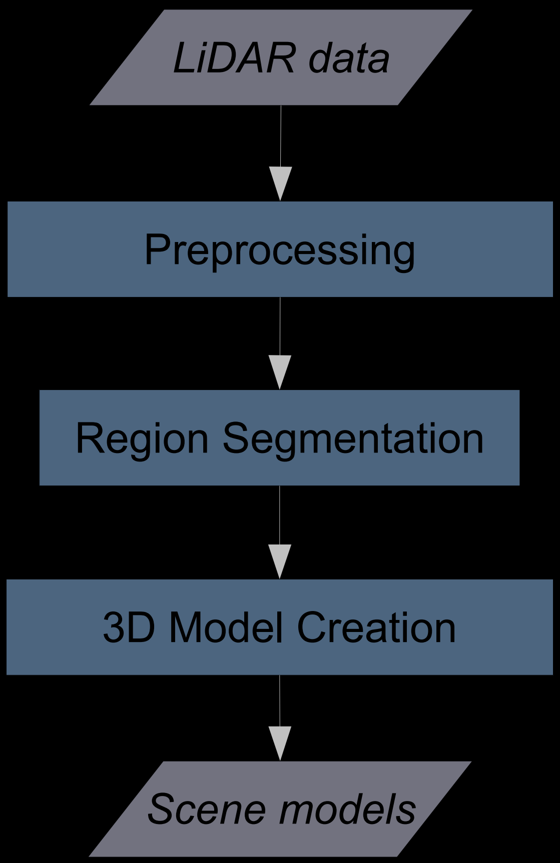
System Overview

- Three modules:
  - Preprocessing
  - Region Segmentation
    - Segment into components



System Overview

- Three modules:
  - Preprocessing
  - Region Segmentation
  - 3D Model Creation
    - Geometry reconstruction



Preprocessing

- The input 3D pointcloud data is:
  - unstructured and large in size
  - contains holes

- Preprocessing is performed in two steps:
  - Resampling
  - Hole-filling

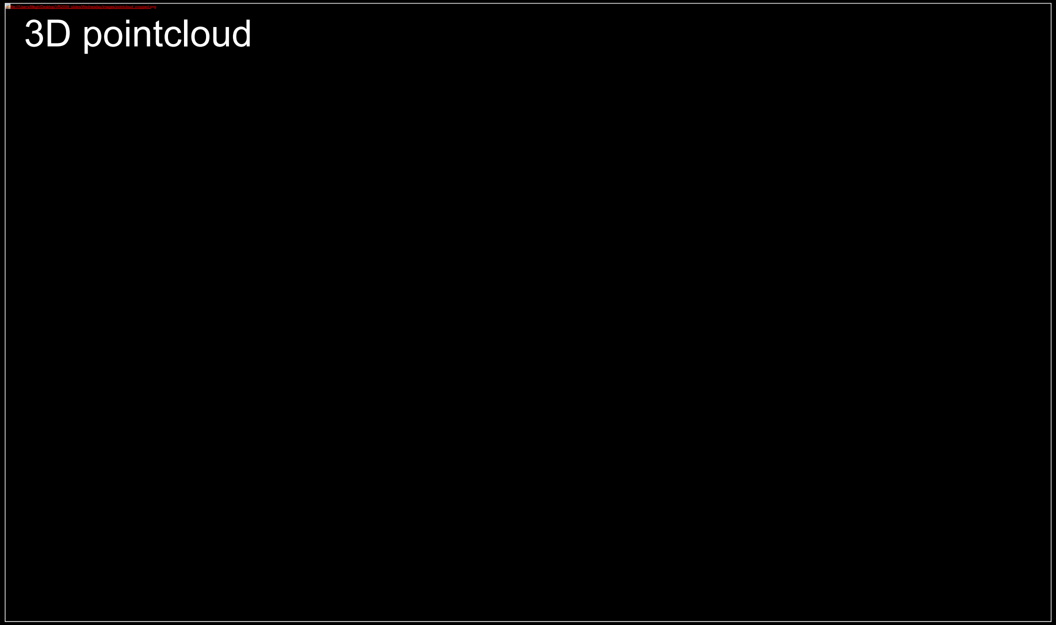
- Input : 3D pointcloud data
- Output: 2D XYZ maps

Preprocessing

- Resampling
  - Convert into 2D XYZ maps
    - Internal data representation
      - 2D -> faster computational times
  - What is the size of the map?
    - Ideally it should minimize information loss by keeping all samples
      - Not feasible due to space and memory limitations
    - Trade-off
      - User defines the error tolerance between neighboring samples
      - User defines the maximum map size
- Hole filling
  - Iterative process using local neighboring information to fill-in holes

Preprocessing

- Resampling
- Hole-filling

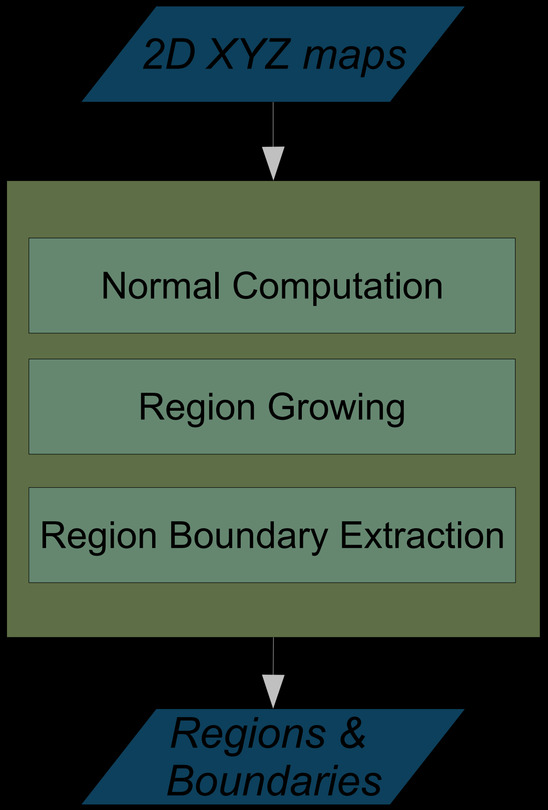


Region Segmentation

- The data contains a complete representation of the scene
  - Buildings, trees, ground, etc
  - Need to extract each component separately
- Input: 2D XYZ maps
- Output: Regions & Boundaries

Region Segmentation

- Three steps
  - Normal Computation
    - Normal for each point in the XYZ map
    - Local neighborhood information
  - Region Growing
    - Keep statistics for each region
      - Depth variation
      - Normal variation
    - Disjoint, contiguous regions
  - Region Boundary Extraction
    - Closed contours



Region Segmentation

- Robust to variations while preserving important details

Region Segmentation

Region Boundary Extraction

- Extract the boundaries from segmented regions

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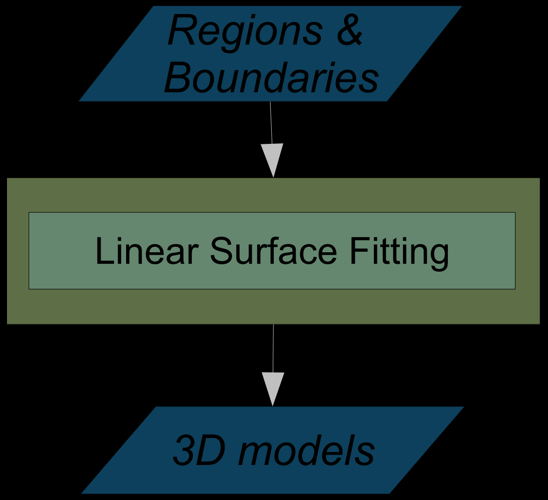
file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/dense_boundaries1_cropped_regions.png

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/dense_boundaries1_cropped.png

3D Model Creation

- Linear Surface Fitting
  - Surface fitting on all segmented regions



Boundary Simplification & Refinement

- Roof types can have an arbitrary shape
  - Linear and non-linear boundaries

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/round_building_croppend.png

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/render.jpg file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/top_view_render3_cropped.png

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/intensity_return_combined.png

Reconstruction Results: Baltimore

Reconstruction Results: Baltimore

Reconstruction Results: Atlanta

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/atlanta_south.png

Reconstruction Results: Atlanta

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/atlanta_north.png

Reconstruction Results: Atlanta

Reconstruction Results: Oakland

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Reconstruction Results: Oakland

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Reconstruction Results: Oakland

Reconstruction Results: Denver

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/denver_cleanup.0002_cropped.png

Reconstruction Results: Denver

Reconstruction Results: Denver

file:///Users/Megh/Desktop/VR2009_slides/Wednesday/images/denver_google.png

Reconstruction Results: Denver

Evaluation

- Difficult
  - No ground truth
- Qualitative and Quantitative evaluation in terms of
  - Completeness
    - Number of modeled buildings
  - Quality
    - Visual inspection of models
  - Geo-referencing
    - Error of registered imagery to the models

Evaluation

- Correctness
  - Fitting error
- Geometry Reduction
  - Atlanta 96.4%
    - 17.8GB -> 637.1MB
  - Oakland 95.69%
    - 3.1GB -> 133.6MB
  - Denver 91.4%
    - 3GB -> 255.2MB
  - Baltimore 94%
    - 3GB -> 180MB

Evaluation

- Correctness
  - Fitting error
- Scalability

A robust approach for automatic registration of aerial images with untextured aerial LiDAR data, Wang et al

Summary

- A fully automatic technique for the extraction of polygonal 3D models from LiDAR data
  - Light-weight, water-tight, polygonal 3D models for large-scale areas
- A region segmentation technique
  - Robust to variations while preserving important details
  - No data dependencies
    - One free parameter (fixed for all datasets shown)

Thank you!

- More information
  - Personal website

    http://www.poullis.org

  - USC Computer Graphics and Immersive Technologies Lab

    http://graphics.usc.edu
- Questions