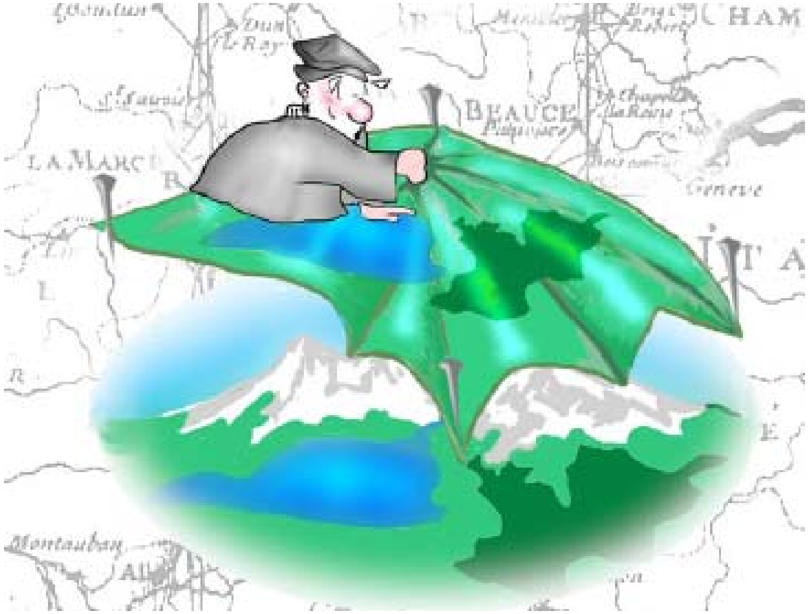
3D Object Extraction Using LIDAR data & Orthoimages



Hetti Arachchige Nalani
Department of Cartography, Photogrammetry, Remote Sensing & GIS
Faculty of Geomatics, Sabaragamuwa University of Sri Lanka

Overview

- Introduction
- Purpose of the Study
- Project Approach
- Testing and Result
- Conclusion and Future Work

Introduction

3D Object Extraction: Collect 3D data/ information from the Earth surface

Aspects ..

- analysis of Geographic data
- creation of 3D models of Earth surface
- many aspects

  technical, social, economical, engineering …

Aim and Objectives

- application areas are increasing
- low cost algorithms

Main aim: 3D object extraction (focus buildings)

Objectives:

- Detect the object outline, ridges
- Create models for the objects
- Visualization of created model
- user friendly functionalities

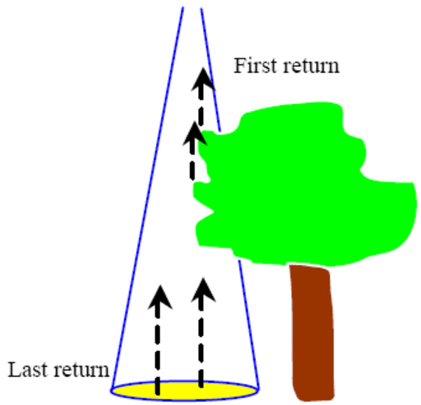
LiDAR Systems

Light Detection and Ranging (LiDAR) or Airborne Laser Scanning (ALS)

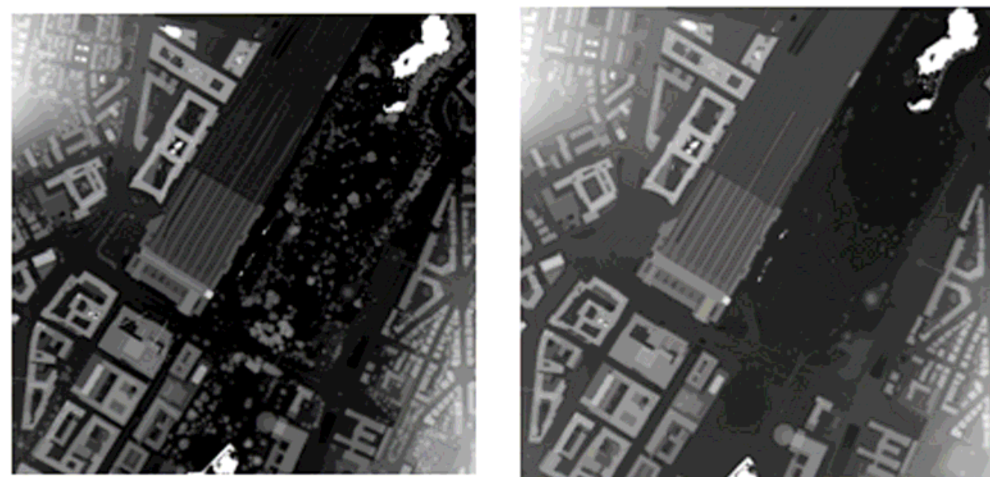
- most accurate and expedient and cost effective ways of capturing elevation data
- Penetrating vegetation
- But, not easy to detect the precise boundary: limited planimetric resolution

(Maas, 1999; Brenner and Haala, 1999; Weidner and Förstner, 1995)

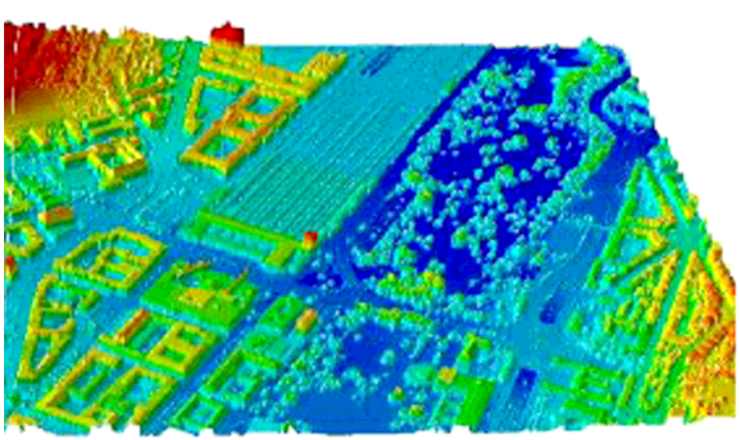
LiDAR Systems

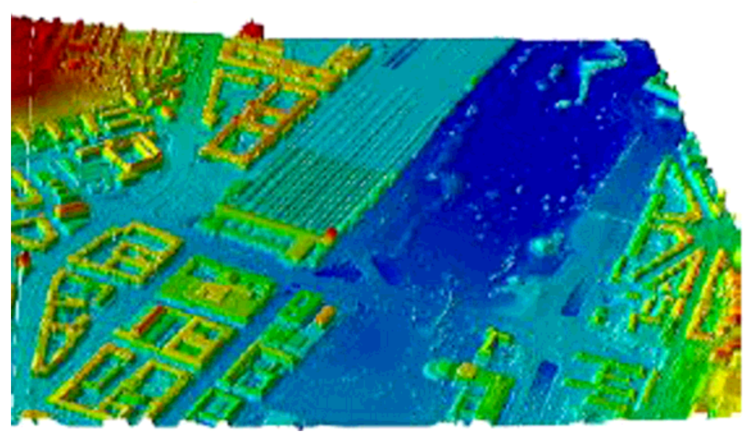


First & Last pulse data
(Source: Alharthy and Bethel, 2003)



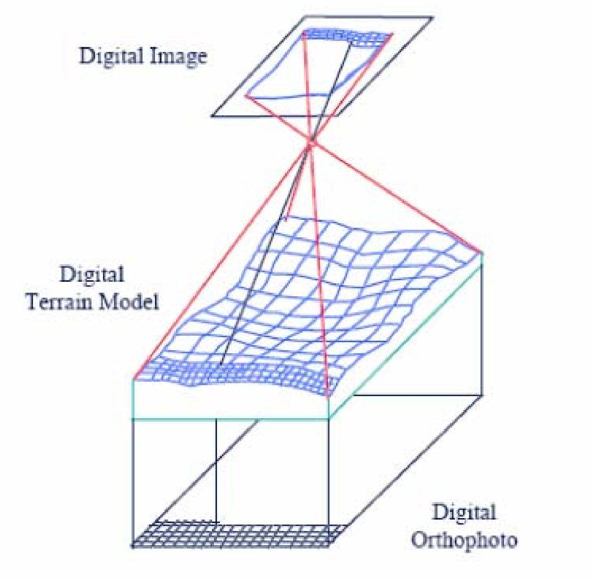
First pulse & last pulse intensity image





OrthoImages & True orthoimages

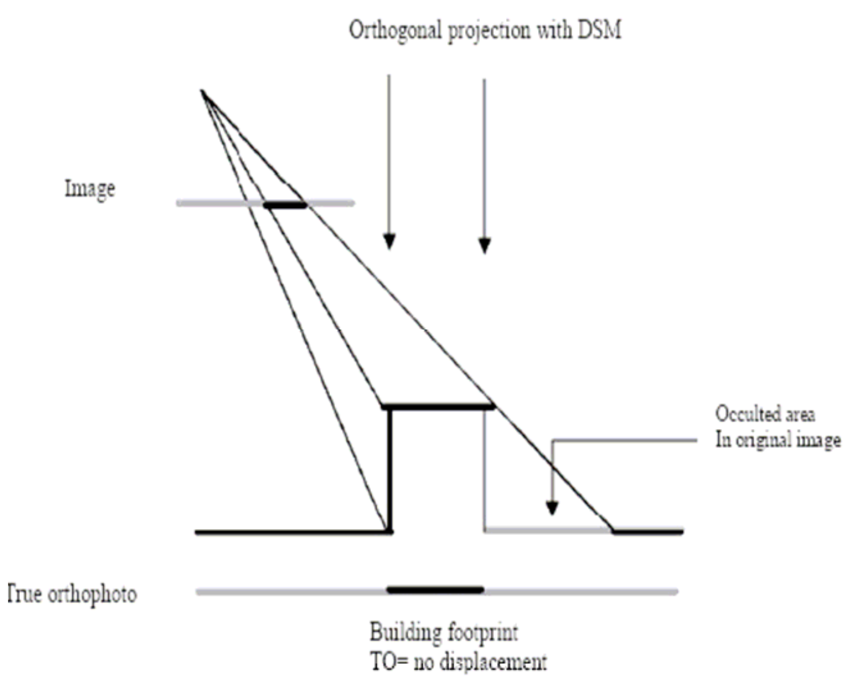
- the relief displacements caused by perspective projection are removed by taking the DTM into account during the rectification process.
- the resulting orthophoto is shown in Parallel (orthogonal) projection and at a constant scale.

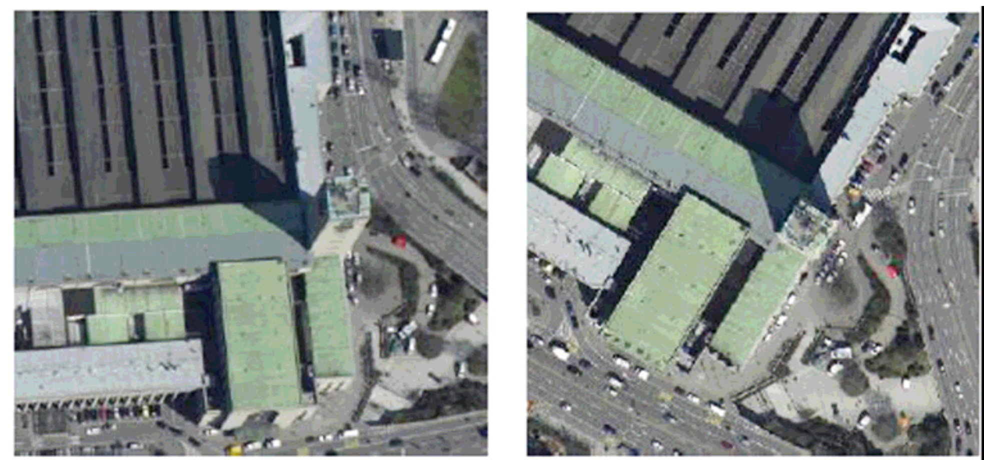


(Source: S.S.Siribounma, 2005)

OrthoImages & True orthoimages

- Orthogonal Projection Using DSM – True Orthoimages





(Source: M. Ettarid, 2005)

Background Information

Available tools/technologies?

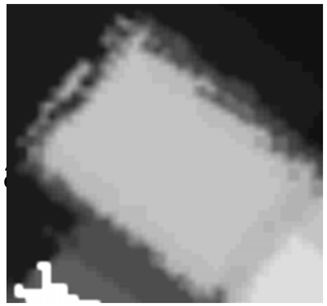
- TOBAGO
- ARUBA
- CC-Modeler

→ Based on the photogrammetric work station.
No capabilities for LIDAR data.
Need experience

- Inject → No capabilities for LIDAR
- …
- Some few specialized systems with LIDAR image
- most, based on the 2D ground plans
- geometry and image processing techniques
- complexity/ high density objects, limits

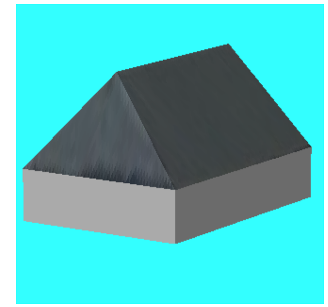
Project Approach

Ortho image



Lidar image

Object Extraction



Manual Detection (Digitize)

- Outer Boundary Detection
- Ridge Points Detection

Height Extraction and Structuring

Geometric Reconstruction

Semantic Attributes

DXF
VRML
ASCII

Methodology: Building Outlines extraction

- Remove NaN values in LIDAR data
- Digitize object in ortho image: *C,R*

$$\begin{pmatrix} X_T \\ Y_T \end{pmatrix} = \underbrace{\begin{pmatrix} a & b \\ -b & a \end{pmatrix}} \bullet \begin{pmatrix} C \\ R \end{pmatrix} + \underbrace{\begin{pmatrix} X_O \\ Y_O \end{pmatrix}}$$

Transformation parameters

- Measure elevation data and ground height from LIDAR: Z_T, H_g

  Target coordinates of object: X_T, Y_T, Z_T

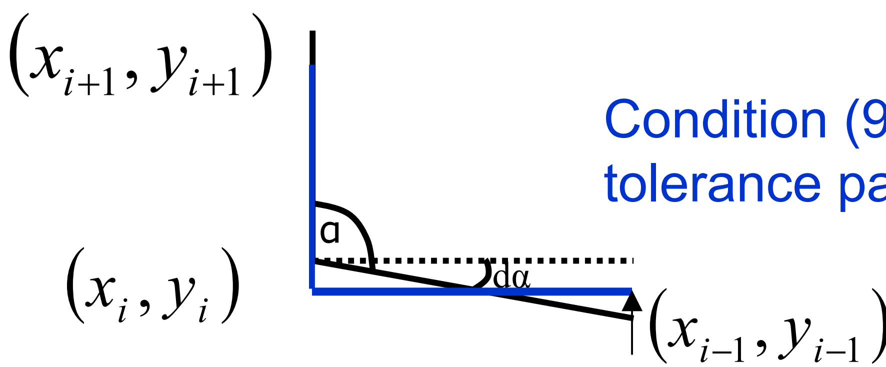
  Ground height: H_g

Methodology : Roof Reconstruction

- **Height condition:** all group of eaves have a same height: (same also for ridges)

- **Rectangularity condition:** right angle at roof corners

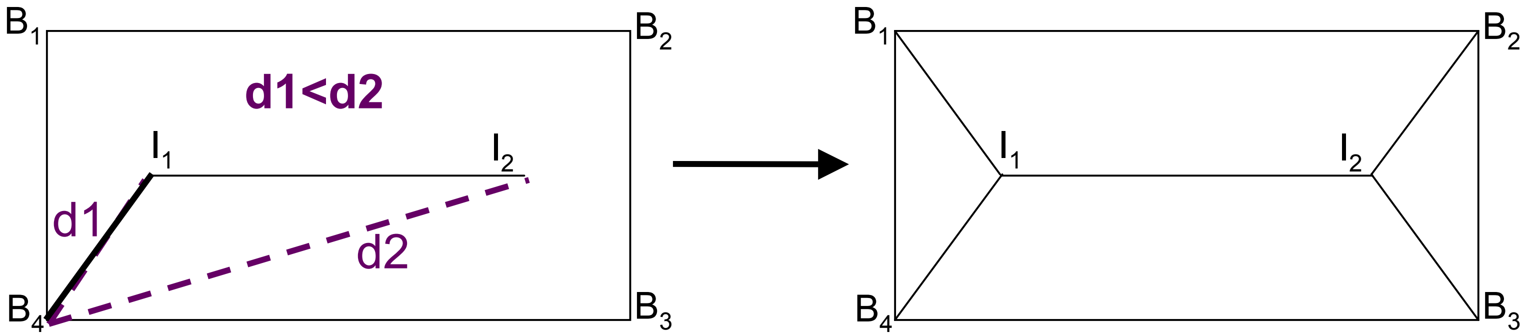
$$\overline{Z} = \frac{\sum_{i=1}^{n} Z_i}{n}$$



Condition (90 deg)
tolerance parameter = ±4°

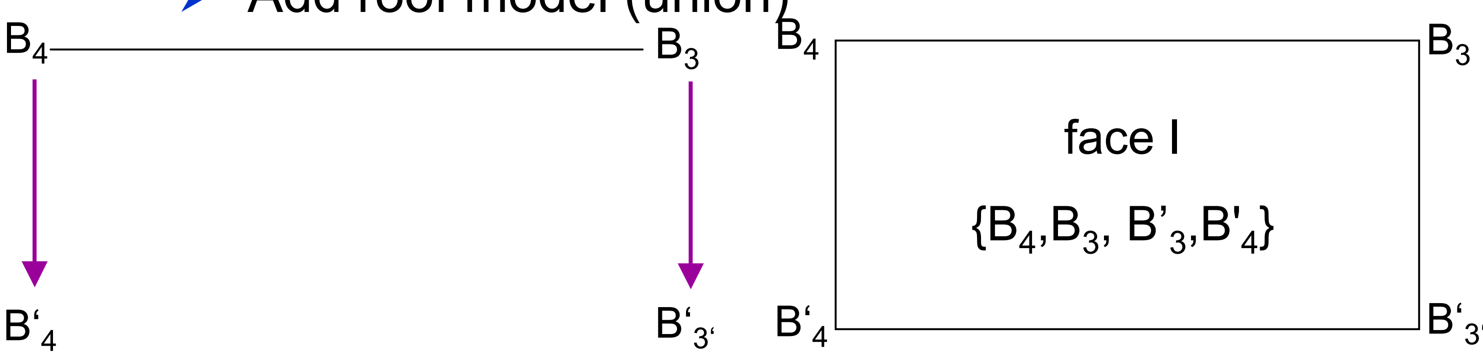
- **Roof Topology:** Topology describes the relationship of nodes, lines, faces/polygon
  - Minimum distance to the ridge point from eaves
  - Every two adjacent boundary points are always part of a face

Methodology : Building Reconstruction



$\{B_1,I_1, I_2,B_2\}$, $\{B_2,I_2,B_3\}$, $\{B_3,I_2,I_1,B_4\}$ and $\{B_4,I_1,B_1\}$

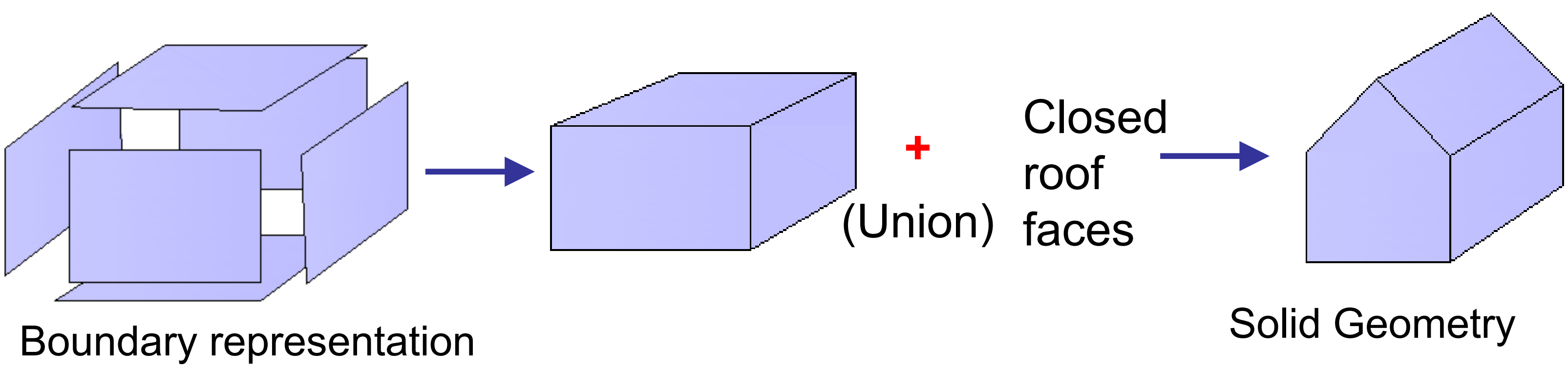
- Building Topology:
  - Eave points projected to the ground & create faces (building part below the roof)
  - Add roof model (union)



$\{B_4,B_3, B'_3,B'_4\}$, $\{B_3,B_2, B'_2,B'_3\}$, $\{B_2,B_1, B'_1,B'_2\}$, and $\{B1,B_4, B'_4,B'_1\}$

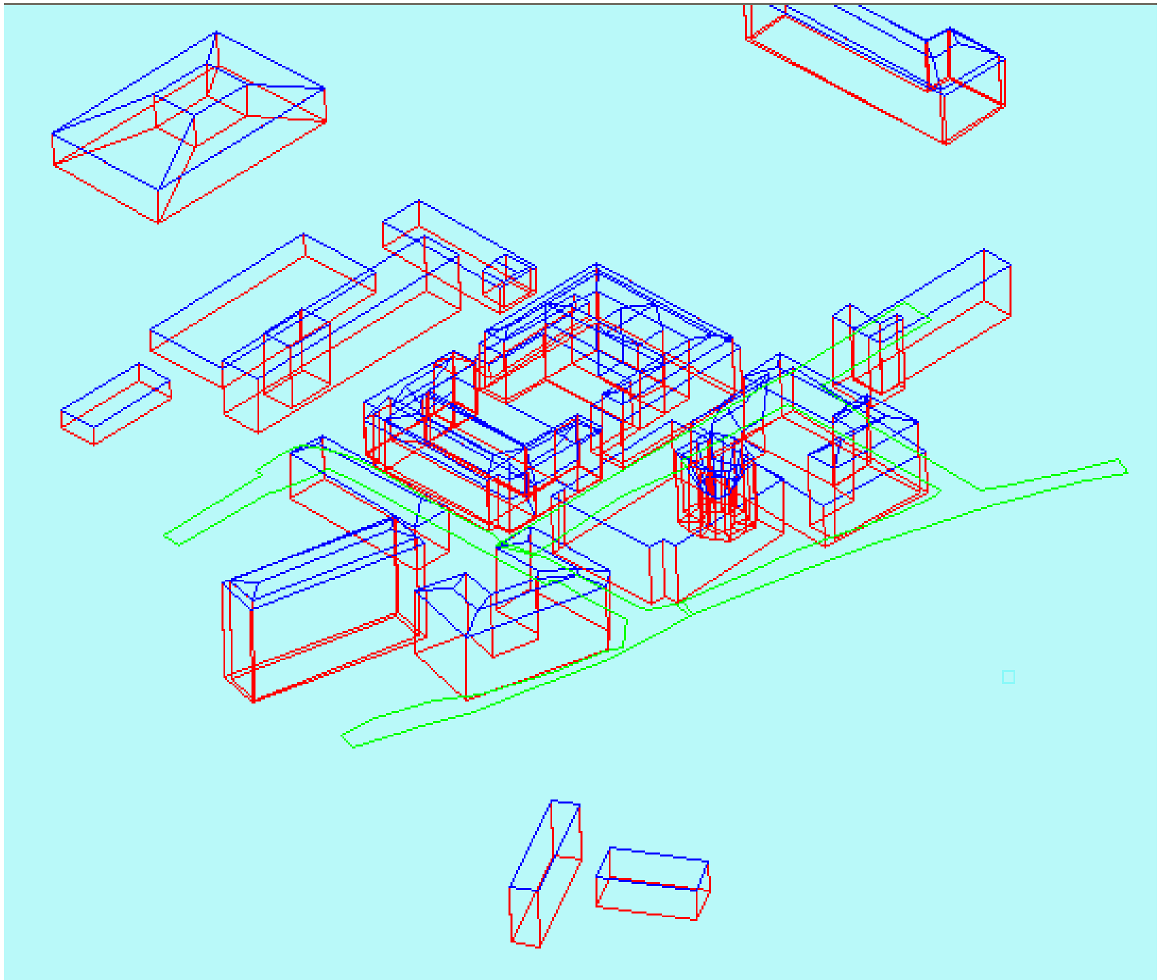
Methodology : Create 3D Objects

- Visualize in vrml or AutoCAD
  - BREP: Building volume is defined indirectly by a set of faces
  - Add roof model
  - Output as closed 3D space in vrml and AutoCAD



Results

- Digitized objects in orthoimage (2D)
- Super impose objects in LIDAR image (2D)
- 3D model in VRML
- 3D model in VRML with roof texture
- 3D model in AutoCAD



Results

```
============================================================

                    Project Data information

============================================================
  Project                     :      E:\GUI\working_dir\HFT_project
  Project Date                :          01-Mar-2007
  Ortho image                 : E:\GUI\Data\OrthoImages\1_hft_andAround.tif
  Refernce Data               :
  -------------
   Pixel size in X direction : 0.20
   Rotation in X direction   : 0.00
   Rotation in Y direction   : 0.00
   Pixel size in Y direction : -0.20
   Shift Value in X direction: 32512208.30
   Shift Value in Y direction: 5403381.10

   LIDAR image                 :  E:\GUI\Data\hft\hft_around_new.mat
   Refernce Data
   -------------
   Pixel size in X direction : 0.50
   Rotation in X direction   : 0.00
   Rotation in Y direction   : 0.00
   Pixel size in Y direction : -0.50
   Shift Value in X direction: 32512500.75
   Shift value in Y direction: 5403499.25
 ============================================================

       Deatil of all connected faces in object

============================================================

Object Type    : Building with    flat roof type
Line Properties    : Color=  g, Marker Type=  +, Line Width= 1, Line style=  -
----------------------------------------------------------------
              Object  Coordinates
     No      X coordintes       Y coordinates      Z coordinates
               ( meters)         (meters)         (meters)
     1      32512686.179        5403112.908       308.930
     2      32512700.000        5403119.400       308.930
     3      32512678.712        5403164.722       308.930
     4      32512664.892        5403158.231       308.930
     5      32512686.179        5403112.908       300.260
     6      32512700.000        5403119.400       300.260
     7      32512678.712        5403164.722       300.260
     8      32512664.892        5403158.231       300.260
----------------------------------------------------------------
              Face set of object - Topology data
----------------------------------------------------------------
 Face 1 :  1,   2,   6,   5,
 Face 2 :  2,   3,   7,   6,
```

ASCII:

- topology data
- coordinates
- Project description
- Summary of project

Conclusion and Future work

Test Result analysis:

- Accuracy investigation – not in the focus of this research
- rough estimates (for given test site)
  - horizontal accuracy 0,2 m (= ortho image pixel size): if boundary is not well defined in the ortho image -> 1m
  - vertical accuracy 0,2 – 0,5 m: if boundary is not well defined -> 1-5 m

Benefits:

- Non photogrammetrists can measure 3D objects with this tool
- DXF output, useable in GIS/CAD/Visualization environments

Conclusion and Future work

Problems:

- Geometry error (height) in shed roof building
- Failure, if roof type is not available in OET(fix)
- Some details are missing: chimney
- Offset between True ortho image and LIDAR data
- Unsharp (or not available) borders in the ortho image: difficult to mod

Conclusion and Future work

Improvements:

- Improve the quality of the true orthophotos
- Extend for additional type of roof structures
- Automatic process for object detection is essential
- Improve geometrical inconsistencies originating from small gaps or overlap between adjacent building for visualization
- Include façade texturing and Extend for other objects
- Editing capabilities needed, read external data source

Thank you