

LIDAR TIN CLUSTER- RECONSTRUCTION

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ING FOR 3D

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AeroMap – www.aeromap.com

TerraPoint – www.terrapoint.com

AAMHatch – www.aamhatch.com

Abstract

Applications of 3D Reconstruction of Urban and Residential Buildings

<ul style="list-style-type: none">• Urban Planning	<ul style="list-style-type: none">• Tourism Information Systems
<ul style="list-style-type: none">• Spatial Analysis of Air Pollution	<ul style="list-style-type: none">• Noise Nuisance
<ul style="list-style-type: none">• Microclimate Investigations	<ul style="list-style-type: none">• Geographical Information Systems
<ul style="list-style-type: none">• Network Planning for Mobile Communication	<ul style="list-style-type: none">• Transmission Line Corridor Mapping

Research Purpose

To develop an algorithm capable of constructing three dimensional models of urban and residential buildings from LiDAR height field data and digital aerial imagery.

Presented Research Work

The current focus of this portion of the presented research work is to implement the necessary preprocessing techniques needed for 3D Reconstruction:

- The LiDAR data must be partitioned into smaller manageable files to be made easier to work with
- The Triangulation of LiDAR Height Field
 - Greedy Insertion Triangulation Algorithm
- Planar Segmentation of TIN using Fuzzy SART
 - Fuzzy Simplified Adaptive Resonance Theory (SART)

Light Detection And Ranging (LiDAR)



*Reprinted from <http://www.aeromapss.com/lidar.htm>

Height Fields Derived as Follows:

1. Laser beam emitted from plane
2. Transmitted light reflects off of target
3. Transmitted light returns to plane
4. Time difference from transmission to receiving of Laser pulse determines range to target

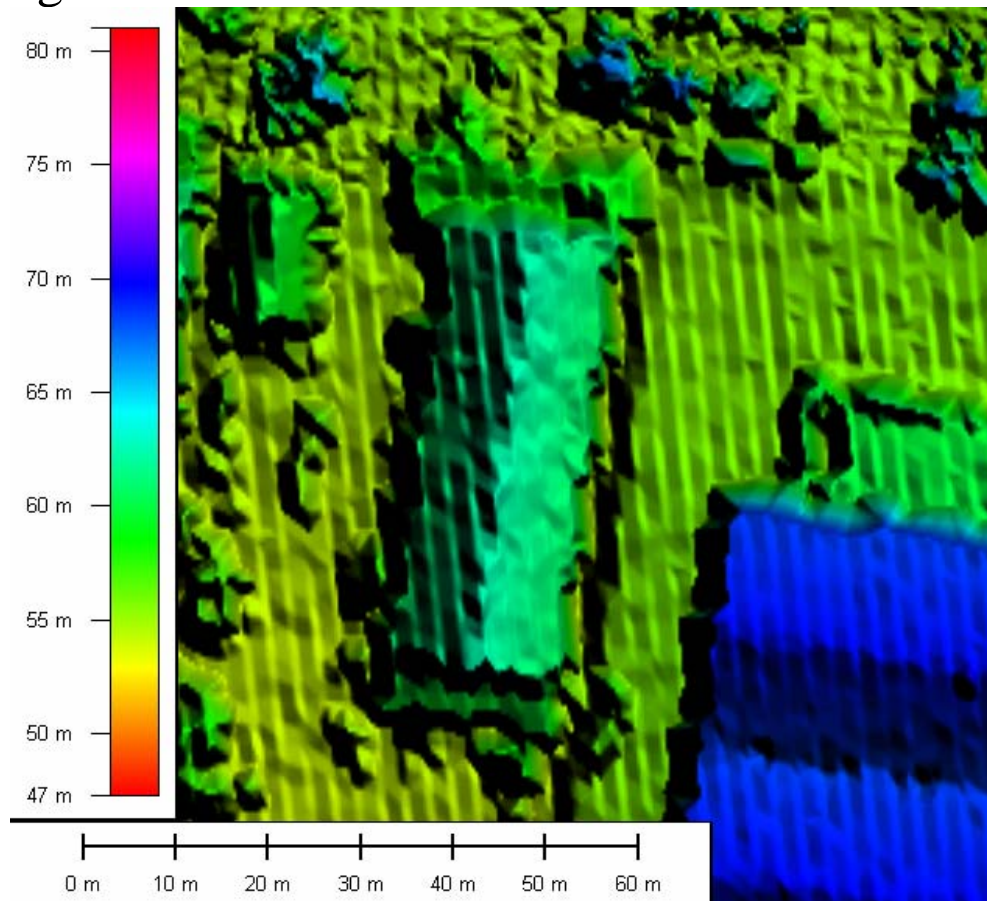
State of the Art LIDAR Technology is capable of capturing the following characteristics:

1. Range to target (elevation)
2. Longitude and Latitude (of target interacted with Laser beam)
3. First and Last Return Pulses
4. Time Stamps
5. Returned Laser Intensity (typically weaker for shrubbery and stronger for beams refracted off of building surfaces)

First/Last Return Pulse – First/Last return laser pulse is the First/Last pulse to return from entire laser wavelength transmitted. First pulses are typically laser beams interacting with shrubbery. While last return laser pulses are beams interacting with building surfaces.

Algorithm Inputs (Data Sources):

LIDAR Height Field -

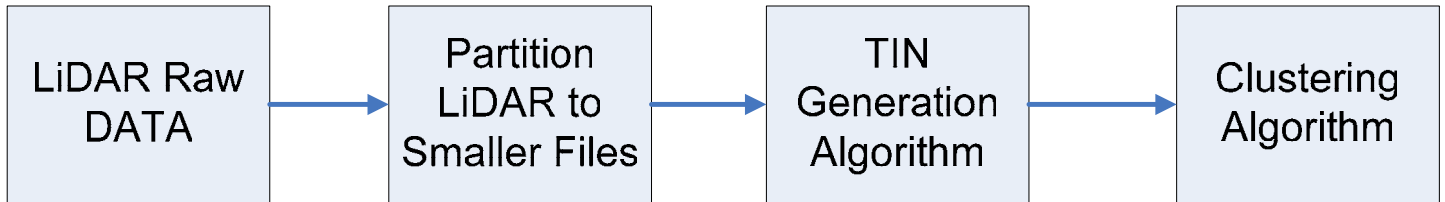


Digital Aerial Imagery -

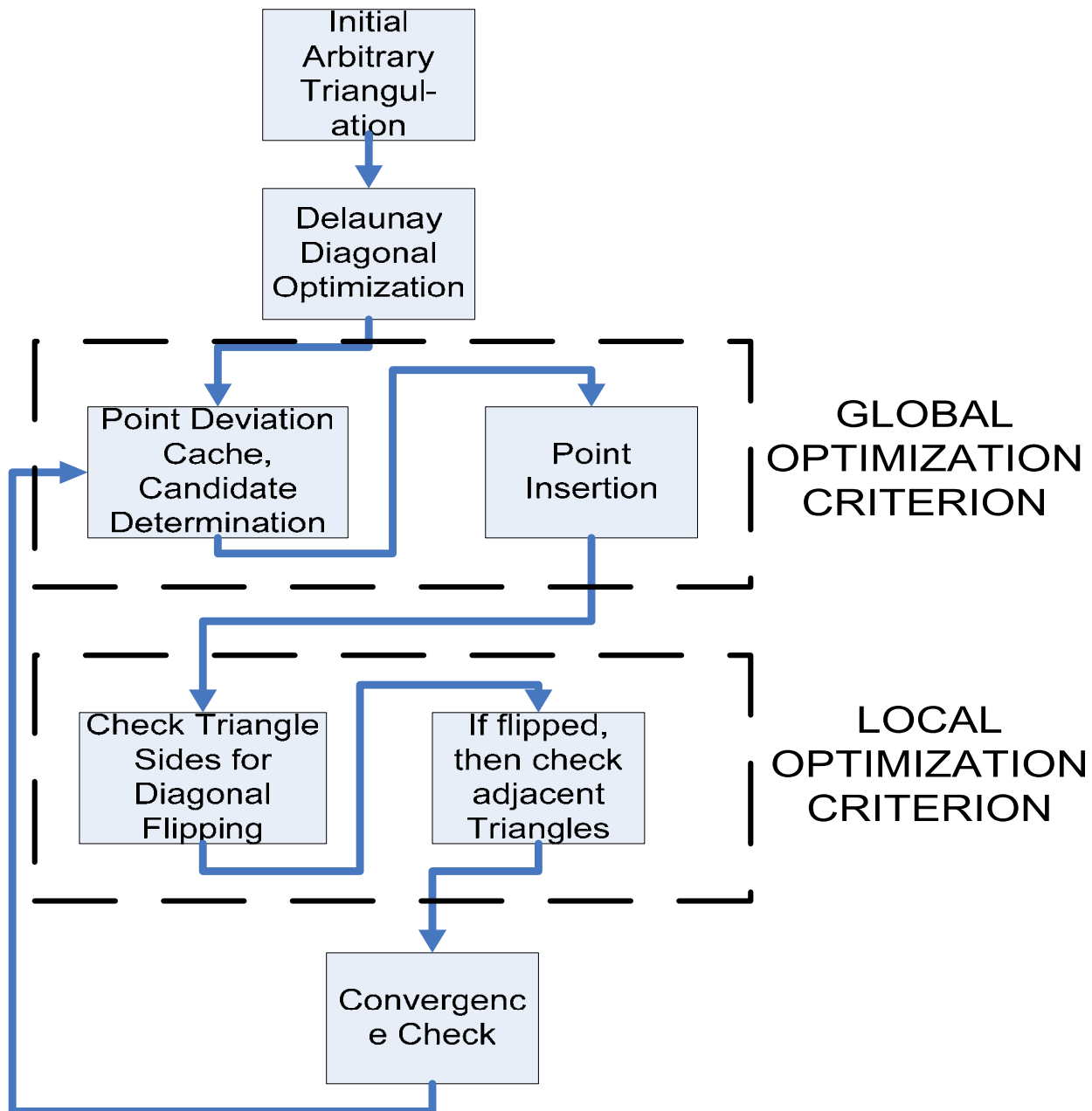


ALGORITHM BLOCK DIAGRAM

3D Planar Segmentation Architecture



Greedy Insertion Algorithm Architecture



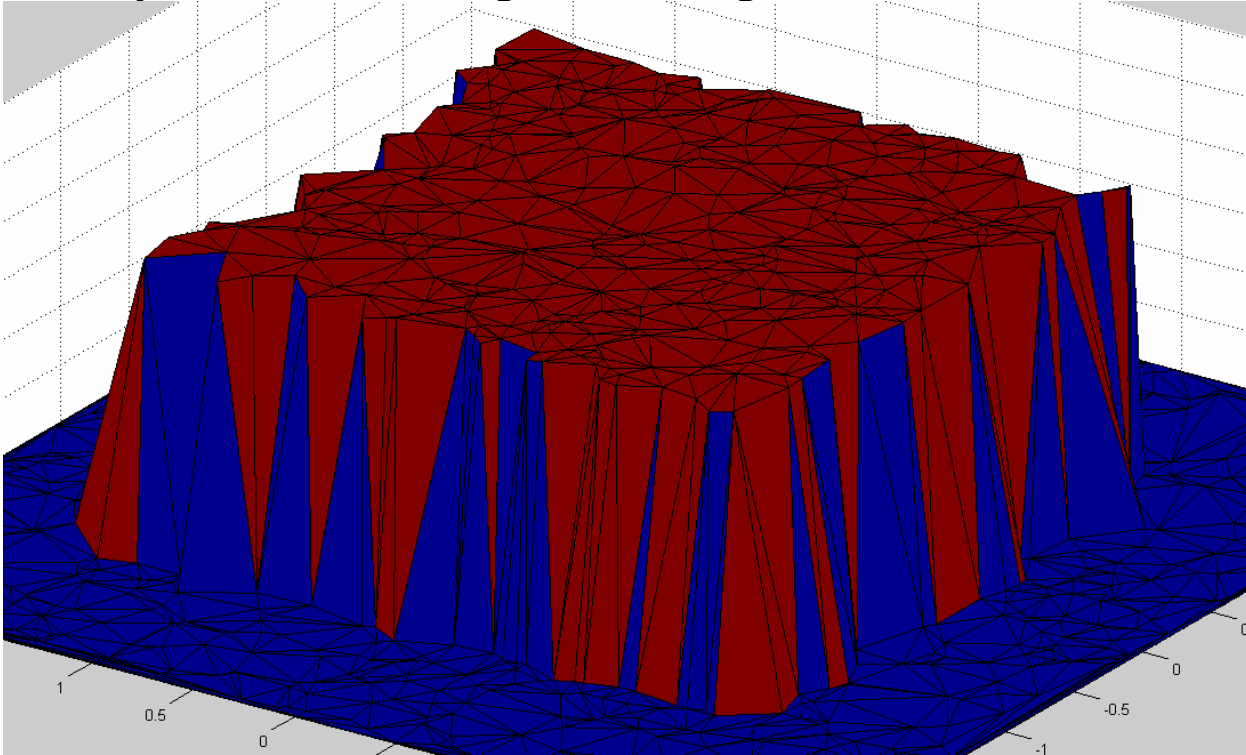
ALGORITHM EXPLANATION

The raw LiDAR height field data is partitioned into smaller, square sections, thereby making it easier to manipulate. The smaller sections are then triangulated by a greedy insertion triangulation algorithm. The algorithm generates a triangulated irregular network (TIN), which is a three-dimensional representation of the height field created by strategically forming triangles from the points captured from the LiDAR data. A detailed description of the inner workings of this algorithm are presented in the document labeled “The development of 3-D Triangulated Irregular Networks of LiDAR data as a preprocessing technique for clustering of LiDAR point cloud data.” This document is contained in the Supplemental Data pocket of this presentation board.

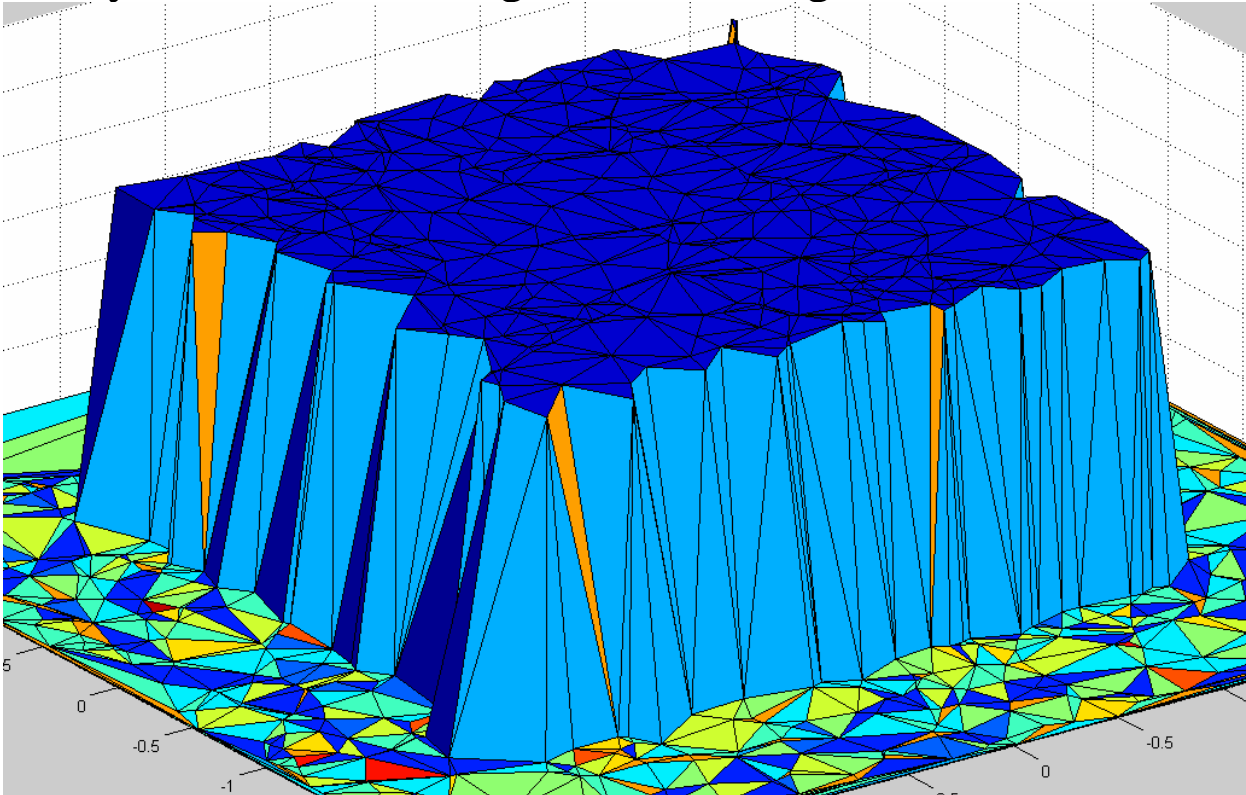
Characteristics of these triangles, such as their orientation, are then fed into a Fuzzy Simplified Adaptive Resonance Theory (FSART) clustering algorithm. This algorithm creates a number of hyper-dimensional radial shapes which enclose patterns in a given input space (in this case the TIN). Fuzzy SART detects clusters of triangles holding similar properties to one another and conversely dissimilar properties distinguishing those triangles from other triangle clusters. These clusters are then labeled accordingly. The FSART clustering algorithm is used to detect coplanar triangles in a given TIN. The goal of the utilization of these preprocessing techniques is to segment the TIN and isolate coplanar triangles with the intent of later forming planes with those clustered triangles. The planes will be created by employing a least mean square method to derive a plane representing the coplanar triangle cluster which minimizes a cost error function. A detailed analysis of the Fuzzy SART Clustering algorithm is contained in the document labeled “Fuzzy Simplified Adaptive Resonance Theory” found in the Supplemental Data pocket of this presentation board.

PREPROCESSING RESULTS (Test, Created)

Greedy Insertion Triangulation Algorithm –



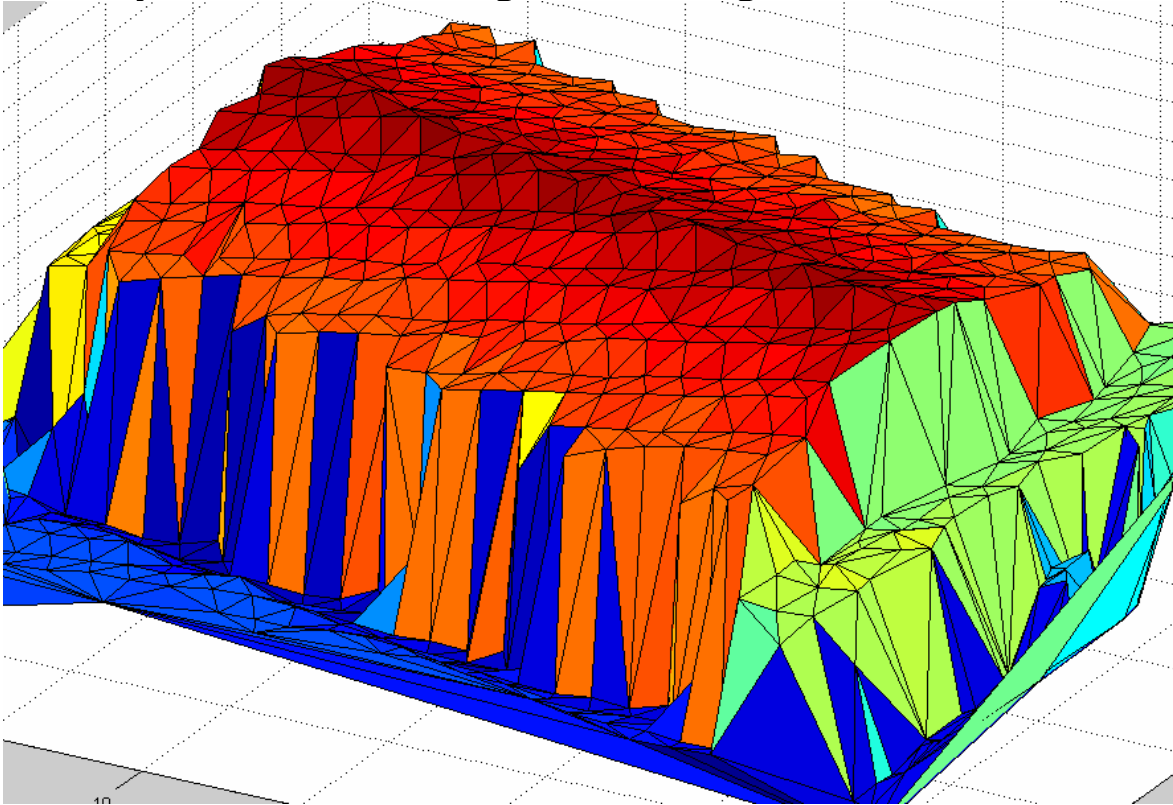
Fuzzy SART Planar Segmentation Algorithm -



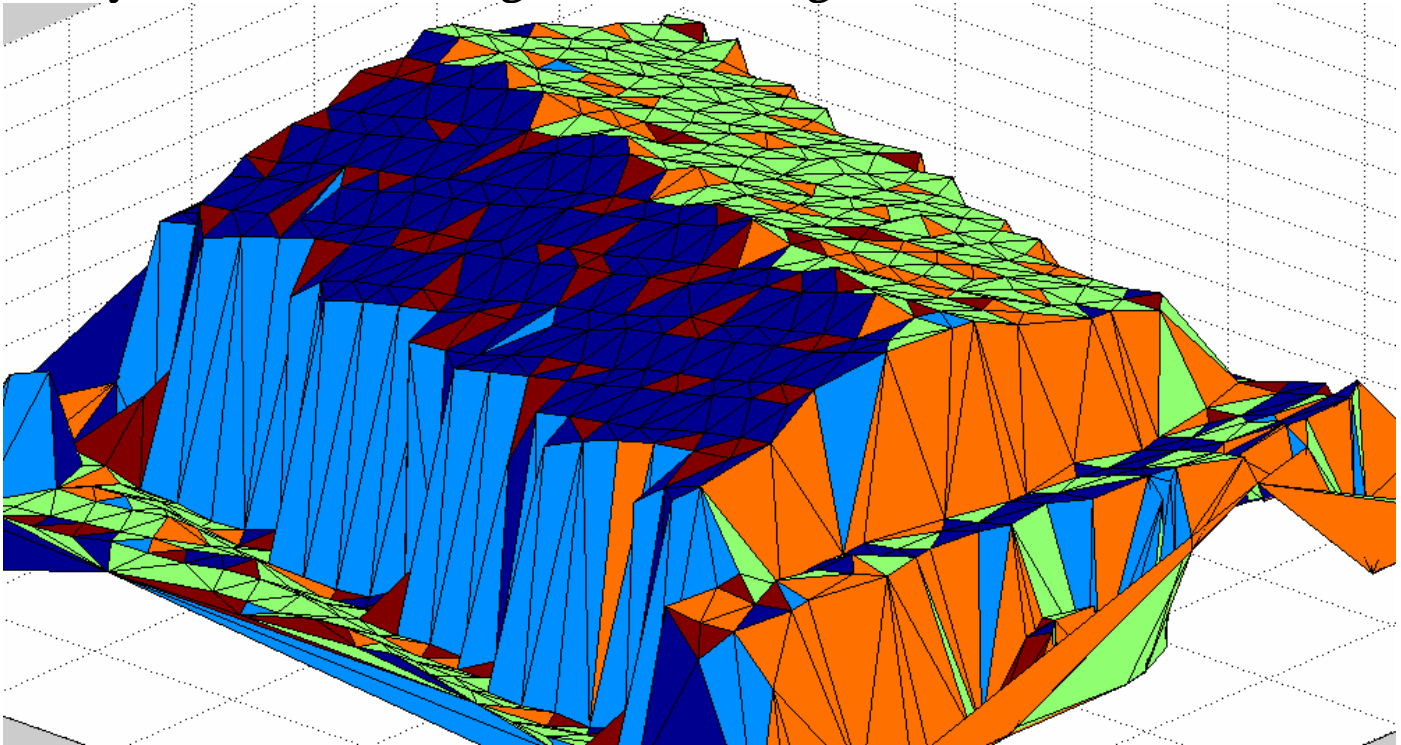
PREPROCESSING RESULTS

(Actual)

Greedy Insertion Triangulation Algorithm –



Fuzzy SART Planar Segmentation Algorithm -



CONCLUSIONS

Greedy Insertion Triangulation Algorithm –

In the previous two frames, the TINs presented in the upper half are produced from the Greedy Insertion algorithm. The colors of the triangles correspond to the elevation of the majority of the vertices composing that given triangle:

1. The ‘hotter’ the color (closer to red), the higher the elevation of its vertices.
2. Conversely, the ‘colder’ the color, the lower the elevation of the triangle’s vertices.

Fuzzy SART Planar Segmentation Algorithm -

In the previous two frames, the TINs presented in the lower half are clustered via a Fuzzy SART clustering algorithm. The colors correspond to the different clusters presented. Ideally, all of the colors corresponding to a given roof plane should be the same color. Only roof planes are considered. The actual walls of a given building are assumed to be vertical from the edge of the detected roof planes (wall colors are therefore ignored).

Two cases were considered to test the algorithm. The first case is an artificial example test set. The set depicts a simple cube-like building. The algorithm segments the building’s roof panels with 100% accuracy. The second case considered is taken from actual LiDAR data and depicts a commercial building. The LiDAR and digital aerial imagery of this building is presented in frame 5.

The gaping whole seen in the lower picture in frame 9 corresponds to the edge of the TIN and where upon a tree exists. This whole is expected and would be non-existent if more of the TIN was depicted. In frame 5, one can see several trees depicted adjacent to the building.

For the second case, Fuzzy SART correctly classified 76% of the coplanar triangles existent in the roof panels of the commercial building.

FUTURE WORK

Greedy Insertion Triangulation Algorithm –

- Make use of both First and Last Return Pulses
 - Only Last Return Pulses were used in the results presented. Making use of both first and last return pulses will increase the effective sampled resolution of the depicted building thereby increasing the Accuracy of the generated TIN and resultant clustering.
- Test algorithm on more complex building structures
 - Complex Roof Structures; Circular, curving building structures
- Investigate the effect of different local cost functions on the development of the TIN (in addition to Delaunay Triangulation)
 - Data Dependent Triangulation
- Test additional methods for presenting input data to Fuzzy SART Clustering Algorithm
 - Different Combinations of Cartesian, Spherical, and Cylindrical Coordinates
 - Normalization of Input Space
- Explore the use of other clustering methods to segment planes existent in TIN
 - Fuzzy Adaptive Resonance Theory (ART)
 - Ellipsoidal ART (EART)
 - TIN Region Growing Algorithm
- Implement LSM algorithm to approximate plane from clustered triangles
- Implement procedure for automatically isolating building structures

SUPPLEMENTAL DATA