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Automated 3D Geological Surface Modelling With CDT

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Content

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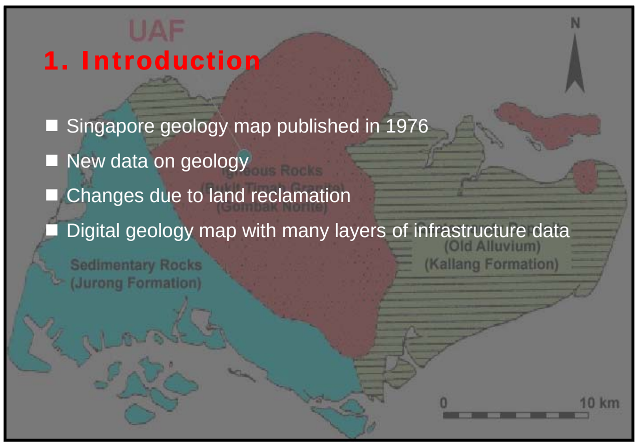

1. Introduction

- Singapore geology map published in 1976
- New data on geology
- Changes due to land reclamation
- Digital geology map with many layers of infrastructure data

3D Geological Map

- Traditional geological maps illustrate the distribution and orientation of geological structures and materials on a 2D ground surface
- 3D Geological Maps provide data models and functionality to represent sophisticated geological situations in three spatial dimensions as geomodels.

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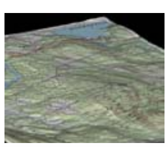
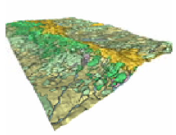
Surface Geological Models

- **Raster :**
  Scanned Geological Map



- **Vector:**
  0D – Point
  1D – Line
  2D – Face



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Related Work

- Vector Models

the ArcView® 3D Analyst™ extension to ArcView GIS software
http://www.esri.com/software/arcgis/extensions/3danalyst/index.html

- Advantage: directly convent 2D map into 3D views
- Disadvantage: do not provide automated 3D geological surface modelling in combination with DEM to convert 2D to 3D geological objects.

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2 Digital Elevation Model

- Grid
- Triangulated Irregular Network (TIN)

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Regular grid of elevation points

- Facilitates automated data capture, e.g. LIDAR, Radarsat, aerial
- Raster of Z values – X,Y is implied
- Regular grid can be interpolated from the original survey of irregularly spaced points
  - But lose the original elevations
- Simple to visualize
- Various simple methods for interpolating, e.g. nearest neighbours
- Has problems representing discontinuties: cliffs, ridges, peaks
- DEMs for entire world are publically available
  - Some are free

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TIN

- Efficient representation of a surface
  - More points in areas of rough terrain and fewer in smooth terrain
- Continuous
  - Sample points are connected by lines to form triangles.
  - Within each triangle the surface represented by a plane.
  - Each plane is defined by the elevations of the three corner points.
- Easily computed properties
  - TIN is a collection of polygons having attributes of slope, aspect and area, with three vertices having elevation attributes and three edges with slope and direction attributes
- Appropriate for certain types of terrain
  - Triangles work best in areas with sharp breaks in slope, where TIN edges can be aligned with breaks, e.g. along ridges or channels

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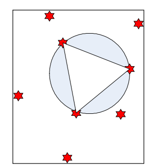
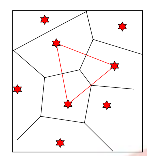
Delaunay Triangulation

- Two approaches
  - Define triangles by finding three points that define a circle that doesn't include any other points



  - Tesselate by assigning all locations to the nearest vertex
    - Boundaries form a set of polygons called Thiessen or Voronoi polygons



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Delaunay Triangulation

- The circumference of any triangle contains no other surface points
- Results in triangles with nearly equilateral shapes
- Widely used in practice
- Dual of Voronoi diagram
- Several algorithms to compute
  - Incremental algorithm

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Incremental Triangulation Algorithm

① To the user data, add four *enclosing points* that form a rectangle enclosing the data.

② Make two triangles out of those four points.

③ Repeatedly add a point to the triangulation by
  a. Find what triangle the point lies in *(Point Location)*,
  b. Subdivide that triangle into three triangles,
  c. Flip edges as necessary so that the new triangulation satisfies the Delaunay property *(Triangulation Update)*.

④ After all the points have been inserted, the triangles containing one or more of the additional enclosing points are identified and marked as invisible, so that what the user sees are only triangles containing the user data.

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Constrained Delaunay Triangulation (CDT)

- Major advantage of TINs is their ability to capture breaks of slope
- Requires edges to be aligned with known ridges or channels
- Requires a different approach, where "breaklines" are incorporated into the triangle network as edges after the points have been triangulated
- Result is generally non-Delaunay, i.e. an edge need not be an edge in the Delaunay network of the vertices

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CDT Algorithm

① First insert the breakline points, using the same method described above.

② Find and remove any triangle edges that the breakline edge crosses, creating a hole in the surface.

③ Refill the hole with triangles, making sure that the breakline edge is one of the new edges.

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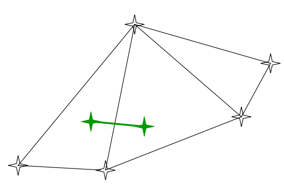
Triangulating Surfaces



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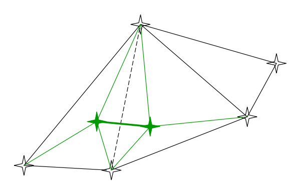
Triangulating Surfaces



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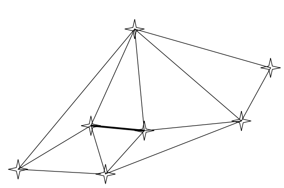
Triangulating Surfaces



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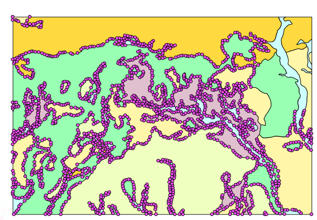
3 Geological Surfaces Built Using CDT

- Make use of the DEM data
- Import the geological boundary data from DXF map
- Texture mapping and attribute linking



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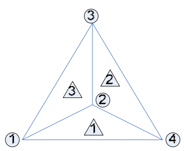
Triangle-Based Data structure



	Triangle			neighbors		
Triangle #	i	j	k	$T_{j,k}$	$T_{k,i}$	$T_{i,j}$
1:	1	4	2	-	2	3
2:	2	4	3	1	-	3
3:	3	1	2	-	1	2

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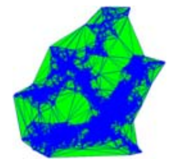
Building Geological Surfaces (I)

① Pre-process the targeted polygon and search all vertices of the DEM and polygons inside it

② Interpolate all nodes without elevation on the DEM

③ Construct CDT.



Constructed CDT

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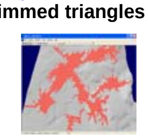
Building Geological Surfaces (II)

④ Clip all triangles outside the polygon and erase all triangles inside interior polygons if they exist, and

⑤ Map the texture/material of the resulting surfaces.

Trimmed triangles



Draped surface on DEM

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4 DEM Simplification

- Appropriate LOD selection and management reduces geometric complexity
- Image-based algorithms
  simplicity and high performance
- Efficient occlusion-culling algorithms
  DEM simplification

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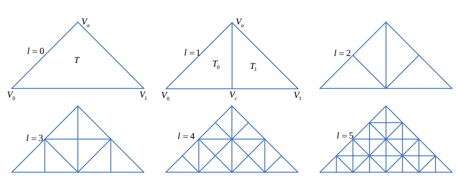
Binary Triangulation



Levels 0-5 of a Binary Tree

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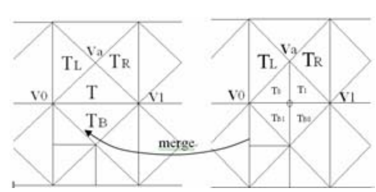
Merge Operation



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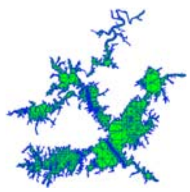
Resulting CDTs



0.5 metre resolution

2.5 metre resolution

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Resulting Table

Resolution	Point	Triangle	Time(s)
0.0	90000	46192	97.26
0.5	10041	9977	15.64
1.0	4529	7523	11.09
1.5	2880	6742	9.313
2.0	2199	6479	8.172
2.5	1879	6337	7.844

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5 Application

Map Index of Singapore

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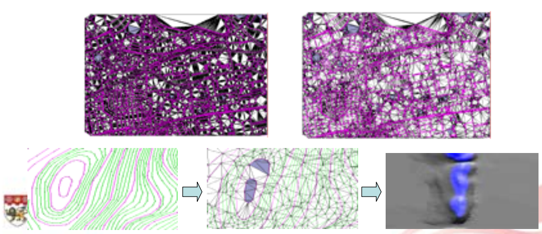
Generation of DEM for Test Zones

Networking the topographic map data for DEM generation

- to consider all the contour, water and road boundary as line features
- to consider them as random points



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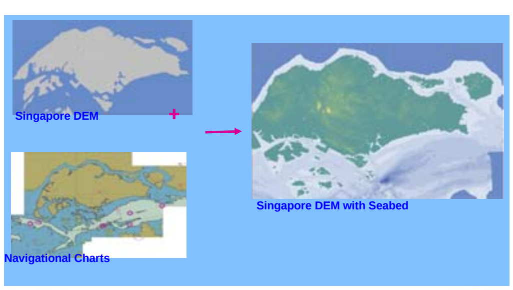
Integrated DEM of Singapore



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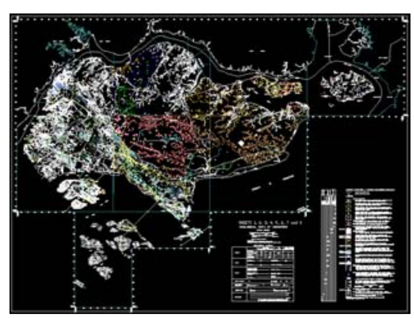

2D Geological Map

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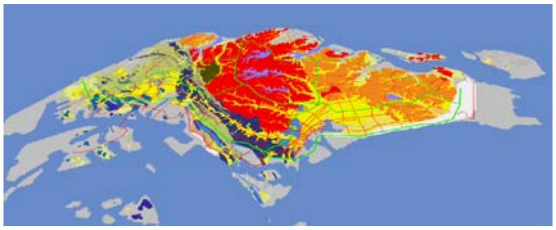
3D geological map



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6. Conclusion

- CDT was applied to automated 3D geological surface modelling.
- To maintain an acceptable level of performance LOD algorithm using regular grids managed in a binary tree data structure was deployed.
- Other issues such as the processes of conversion and attachment of object attributes are required to be resolved.

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Thank you

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