Course Overview & Digital Terrain Data Models
Figure 19.1 The main tasks of a digital terrain modelling system. (Weibel and Heller 1988)
Digital Terrain

A digital representation of terrain surfaces.
- 2D, 2.5D, or 3D (?)

Representation of terrain surfaces:
- Maps (graphics)
- Physical models
- Mathematical models
- Digital terrain models
Digital Terrain Models (DTM)

- Trend surfaces (models)
- Digital contour lines
- Elevation points
- DEM
- TIN
- Object with z attribute
- Fractal
Fractal Terrain (created in Vue)
Why are DTM\textsc{\char19}s Required?

- Geographic processes
  - Watershed
  - Drainage network
  - Slope, aspect (solar illumination)
  - Viewshed
  - Analyzing volumetric change
  - Orthorectification
  - 3D simulation and visualization
  - ...
Digital Terrain Surface Modeling

- Data features (points, triangles, grids)
- Surface models
  - Surface interpolation
- Surface reconstruction
Trend Surface Analysis

Data features: points
Surface models: Polynomial Functions

<table>
<thead>
<tr>
<th>Individual Terms</th>
<th>Order</th>
<th>Descriptive Terms</th>
<th>No. of Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z = a_0$</td>
<td>Zero</td>
<td>Planar</td>
<td>1</td>
</tr>
<tr>
<td>$+a_1 X + a_2 Y$</td>
<td>First</td>
<td>Linear</td>
<td>2</td>
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<tr>
<td>$+a_3 X^2 + a_4 Y^2 + a_5 XY$</td>
<td>Second</td>
<td>Quadratic</td>
<td>3</td>
</tr>
<tr>
<td>$+a_6 X^3 + a_7 Y^3 + a_8 X^2 Y + a_9 XY^2$</td>
<td>Third</td>
<td>Cubic</td>
<td>4</td>
</tr>
<tr>
<td>$+a_{10} X^4 + a_{11} Y^4 + a_{12} X^3 Y + a_{13} X^2 Y^2 + a_{14} XY^3$</td>
<td>Fourth</td>
<td>Quartic</td>
<td>5</td>
</tr>
<tr>
<td>$+a_{15} X^5 + a_{16} Y^5 + a_{17} X^4 Y + a_{18} X^3 Y^2 + a_{19} X^2 Y^3 + a_{20} XY^4$</td>
<td>Fifth</td>
<td>Quintic</td>
<td>6</td>
</tr>
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</table>
Minimum Number of Points to Construct a Surface

\[ N = \frac{(t + 1)(t + 2)}{2} \]

<table>
<thead>
<tr>
<th>Order (t)</th>
<th>Type</th>
<th>Min # Pcts</th>
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<tr>
<td>0</td>
<td>Planar</td>
<td>1</td>
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<tr>
<td>1</td>
<td>Linear</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Quadratic</td>
<td>6</td>
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<tr>
<td>3</td>
<td>Cubic</td>
<td>10</td>
</tr>
<tr>
<td>-</td>
<td>Bi-linear</td>
<td>4</td>
</tr>
</tbody>
</table>
Bilinear Surface & Bilinear Interpolation

(a) Surface formed by bilinear surfaces
(b) Surface formed by triangles
Triangulated Irregular Network (TIN)

- Node \((x, y, z)\)
- Edge
- Triangles
- Topology
  - The triangle number
  - The numbers of each adjacent triangle
  - The three nodes defining the triangle
  - The \(x, y\) coordinates of each node
  - The surface \(z\) value of each node
  - The edge type of each triangle edge (hard or soft)
Hybrid Surface Modeling

Triangular regular network
- Formed from regularly distributed data
Fig. 19.11  Several alternatives to obtain averaged surface normals for square patches of either four or nine adjacent grid points.
## Conversions between Surface Models

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Point</th>
<th>Triangle</th>
<th>Grid</th>
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</thead>
<tbody>
<tr>
<td>Point</td>
<td></td>
<td>Spatial interpolation</td>
<td>TIN generation</td>
<td>Spatial interpolation, indirect interpolation</td>
</tr>
<tr>
<td>Triangle</td>
<td>Edge points</td>
<td>-NA-</td>
<td></td>
<td>Linear / curved surface interpolation</td>
</tr>
<tr>
<td>Grid</td>
<td>Nearest neighbor, linear/cubic interpolation</td>
<td>TIN generation</td>
<td>Nearest neighbor, linear/cubic interpolation</td>
<td></td>
</tr>
</tbody>
</table>
Generating TIN

- Selection of significant points from DEM
  - Very Important Points (VIP)
  - Maximum z-tolerance
- Delaunay triangulation
  - Mass points (->TIN nodes)
  - Breaklines - soft (form), hard (->TIN edges)
DEM & DSM

DEM: Digital Elevation Model (ground elevation)

DSM: Digital Surface Model (surface elevation, including trees, buildings, houses, etc)
Math Review

Similar triangles


Known: $x_0, y_0, x_1, y_1$, and $x$
Find: $y$

Example:
$x_0, y_0 = 3, 2$
$x_1, y_1 = 6, 6$
$x = 4$
y = ?