DMET 702
Visualization and Animation

Multi-resolution Visualization

(Hierarchical Techniques for Multi-dimensional Visualization)

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Contents

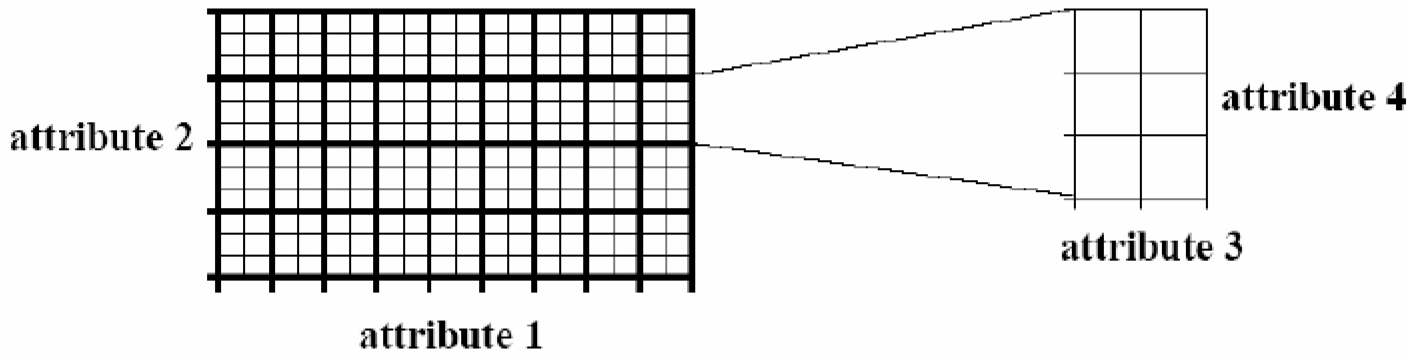
- Multi-resolution or hierarchical techniques are used to tackle how to visualize in *n*D space.
- The main idea is to hierarchically partition the nD space into subspaces.
- Hierarchical techniques
  - Dimensional stacking
  - Worlds-within-worlds

Dimensional Stacking

- Paper:
  - LeBlanc J., Ward M. O., Wittels N., "Exploring N-Dimensional Databases," Visualization '90, San Francisco, CA, pp. 230-239, 1990.

Dimensional Stacking

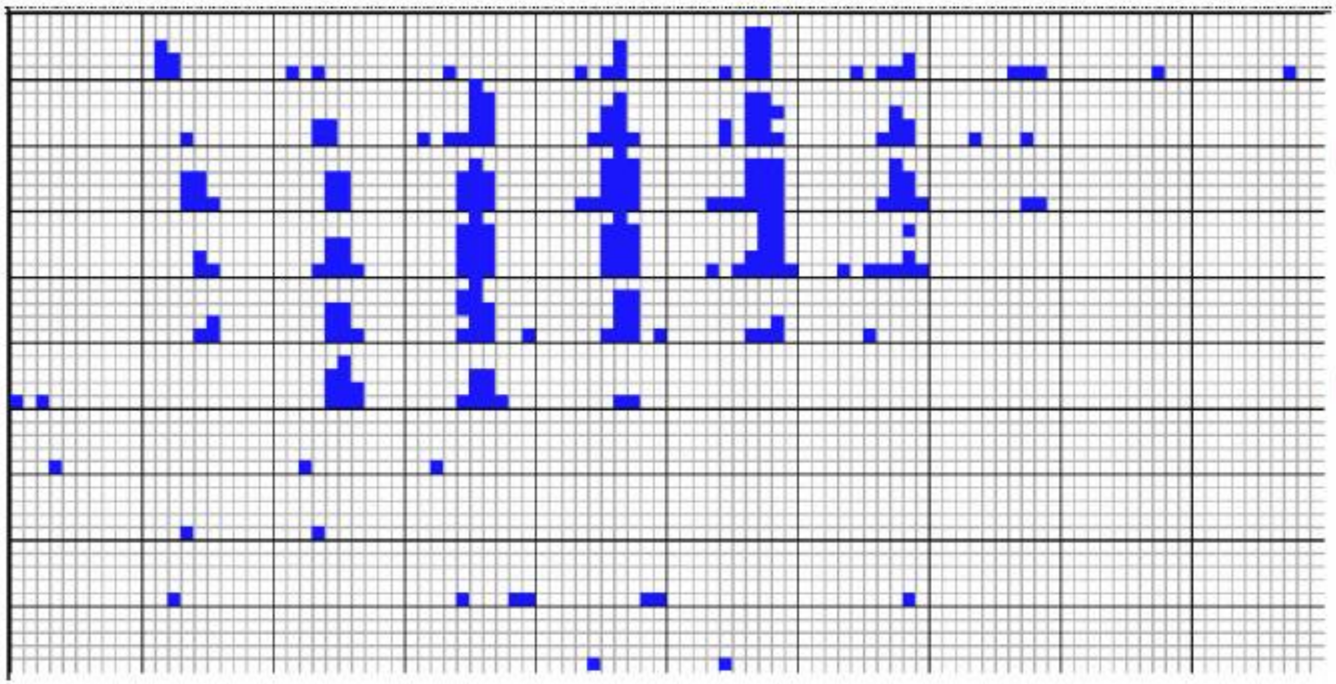
- Idea: **Embedding dimensions into dimensions.**
  - Partition the nD space into **2D** subspaces.
  - The subspaces are said to be stacked into each other.



An example of dimensional stacking for 4D data value. The first two attributes determine a slot where another two attributes are used.

The more important attributes should be on the outer levels.

Dimensional Stacking: An Example

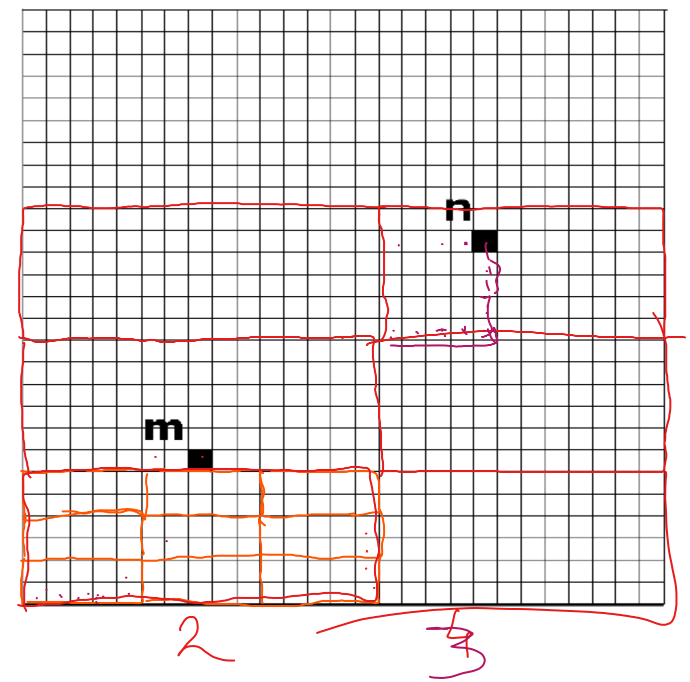


Oil mining data

- Outer axes:
  - X Longitude
  - Y Latitude
- Inner axes:
  - X Ore grade
  - Y Depth

Dimensional Stacking: An Example

Final Exam 2015: Shown is a dimensional stacking representation of two points; m and n where the origin is at the lower left corner of each nested coordinate system. Each point attribute is represented as an integer value. (As a convention, the first of any two attributes is displayed along the horizontal axis.) Determine the values of the attributes for the points shown. Consider each of the following cases:

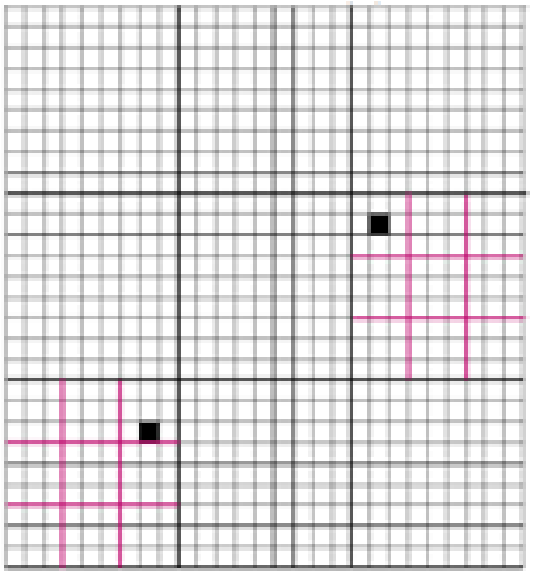


2, 3, 3, 2, 3, 0

3, 4, 2, 4, 5, 0

Dimensional Stacking: An Example

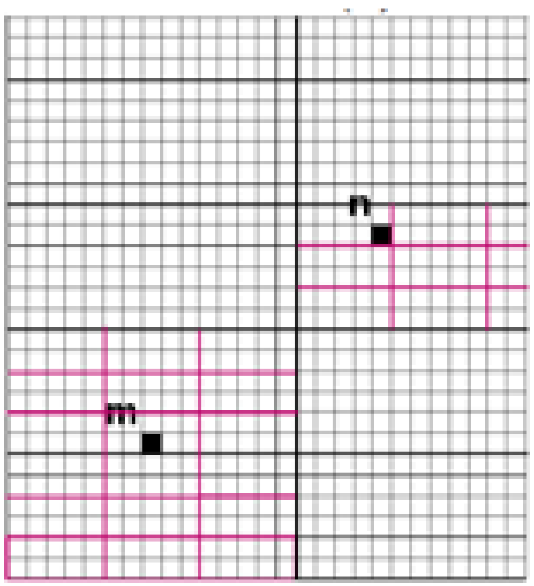
a) The points m and n are 6D points where the values of the first two attributes range from 0 to 2 and the rest of the attributes may range from 1 to 3 (i.e., the origins of the inner coordinate systems are at $[1,1]^T$).



$m=[0,0,3,3,2,1]$
$n=[2,1,1,3,2,2]$

Dimensional Stacking: An Example

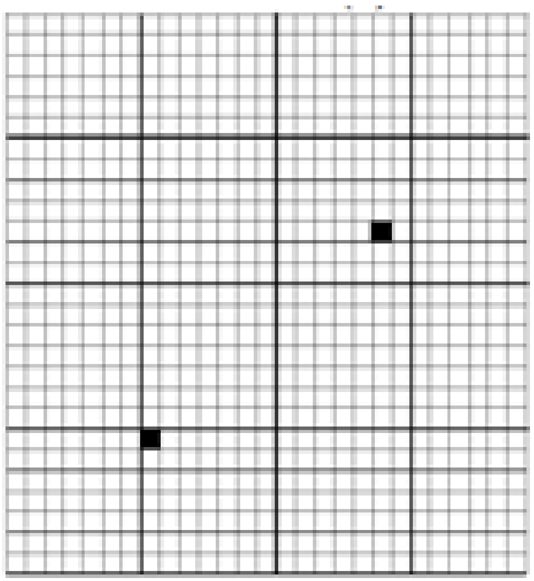
b) The points m and n are 6D points where the values of the first two attributes range from 2 to 6, the values of the third and fourth attributes range from 2 to 4, the value of the fifth attribute ranges from 1 to 5 while the value of the last attribute may range from 0 to 1.



m=[2,3,3,2,3,0]
n=[3,4,2,4,5,0]

Dimensional Stacking: An Example

c) The points m and n are 4D points where the values of any of the attributes may range from 0 to 6.



m=[1,0,0,6]
n=[2,2,5,2]

Dimensional Stacking: An Example

Example: *Dimensional stacking* is used to visualize 6D data points where the values of each attribute lies in the integer interval [0, 7]. If a data point is represented by a single pixel, determine the minimum size of the output image. Suggest an equation to estimate the location of a pixel given a 6D point vector $[a_0, a_1, a_2, a_3, a_4, a_5]^T$. Use this equation to determine the location of the point $[3,5,7,3,2,0]^T$. Assume that the attribute importance decreases from left to right (i.e., a_0 and a_1 are the most important attributes in the point given).

Dimensional Stacking: An Example

Answer:

We use 3 nested coordinate systems; each axis covers the interval [0,7]; i.e., 8 values.

Minimum size = 512 x 512 ← 8x8x8

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 8^2 a_0 + 8^1 a_2 + 8^0 a_4 \\ 8^2 a_1 + 8^1 a_3 + 8^0 a_5 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 64 \times 3 + 8 \times 7 + 1 \times 2 \\ 64 \times 5 + 8 \times 3 + 1 \times 0 \end{bmatrix} = \begin{bmatrix} 250 \\ 344 \end{bmatrix}$$

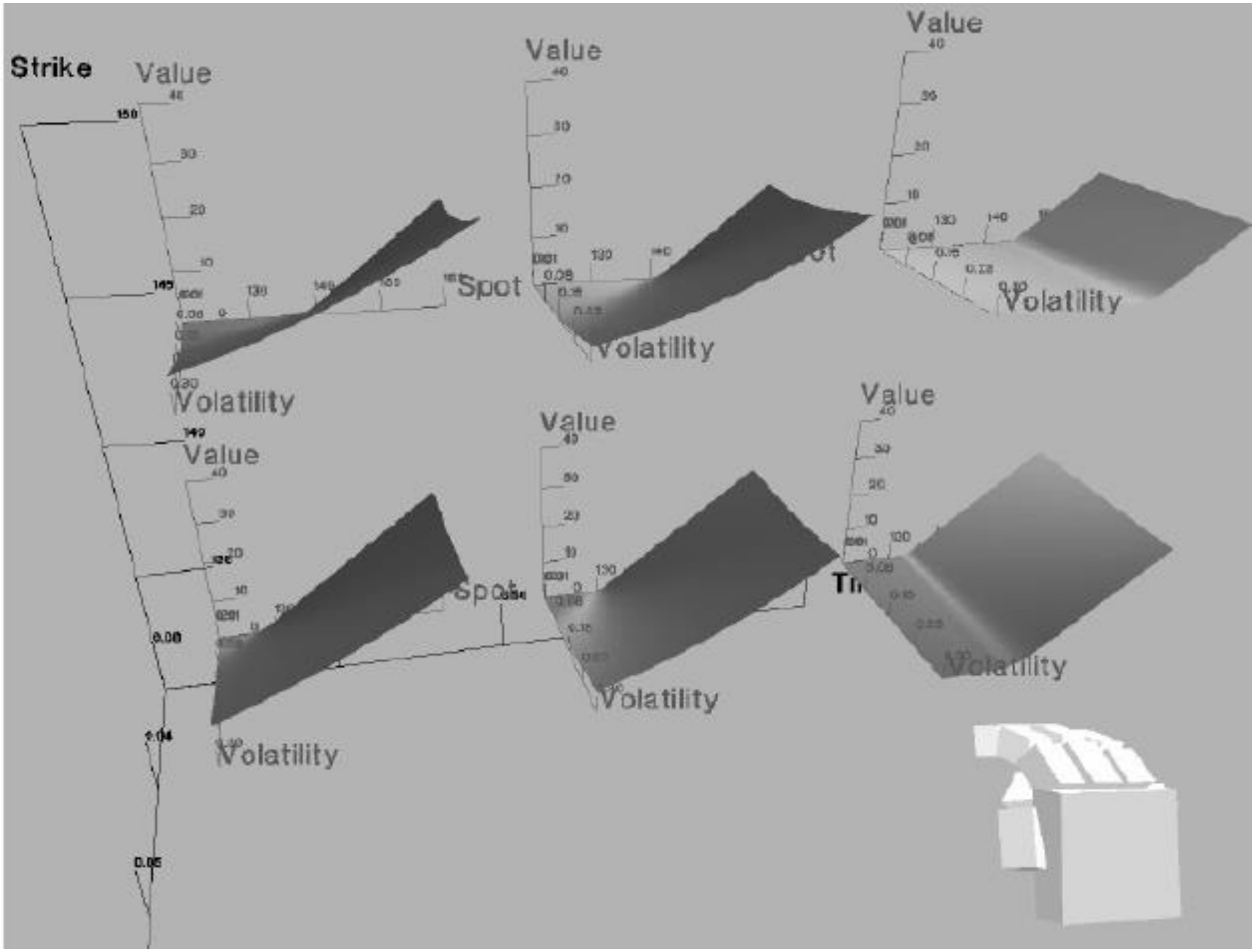
Worlds-within-Worlds

- Paper:
  - Feiner S., Beshers C., "World within World: Metaphors for Exploring n-dimensional Virtual Worlds," Proc. UIST, pp. 76-83, 1990.

Worlds-within-Worlds

- Idea:
  - Partition the nD space into **3D** subspaces.
  - Similar to the previous idea but implemented as 3D subspaces instead of 2D subspaces.
  - The first three attributes determine a 3D coordinate system. At each location, there are three more attributes used to determine a new coordinate system.

Worlds-within-Worlds: An Example

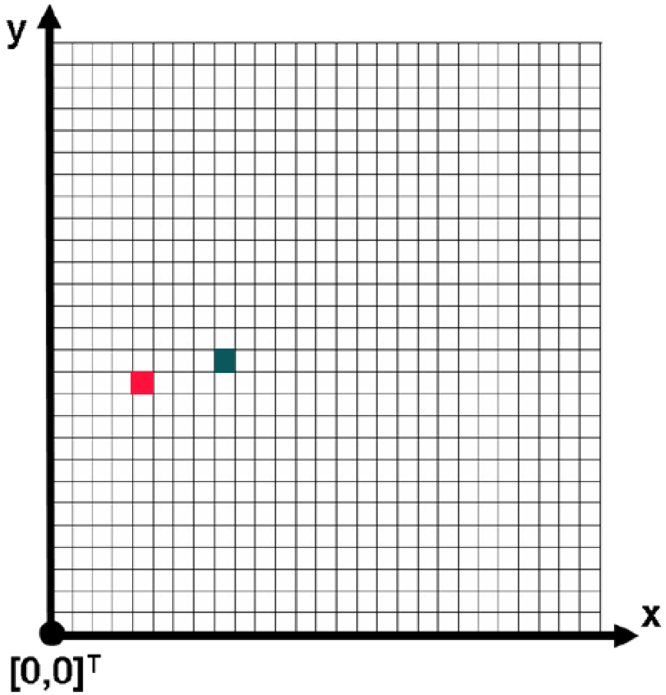


Worlds-within-Worlds: An Example

Final Exam 2014: If point space is partitioned into 3D subspaces, points can be represented using a technique called worlds-within-worlds. (You may call the axes *x*-, *y*- and *z*-axes.)

Consider two 6D points $\mathbf{m}=[1,2,3,3,2,1]^T$ and $\mathbf{n}=[0,2,3,4,1,0]^T$ to be represented using this technique. Each attribute value may range from 0 to 4. After placing the points in space(s), we project them onto the *xy*-, *yz*- and *zx*-planes. On the grids below, show the projections of those points where each square represents thee projection of 1 space unit. Write down the values under each grid.

Worlds-within-Worlds: An Example

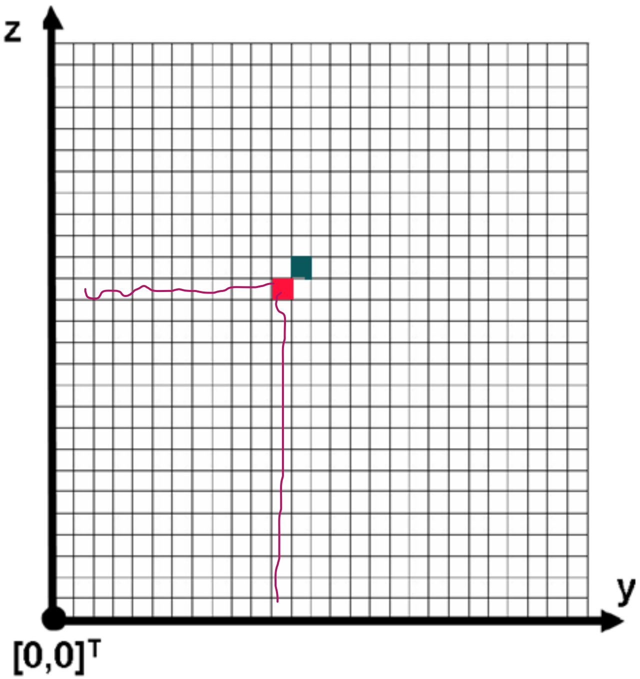


$\mathbf{m}=[1,2,3,3,2,1]^T$ and $\mathbf{n}=[0,2,3,4,1,0]^T$

$\mathbf{m}(x,y)= [\ 8,\ 12\ ]^T$
$\mathbf{n}(x,y)= [\ 4,\ 11\ ]^T$

$m=[1,2,3,3,2,1]^T$ ➔ **x=1*5+3=8, y=2*5+2=12, z=3*5+1=16**
$n=[0,2,3,4,1,0]^T$ ➔ **x=0*5+4=4, y=2*5+1=11, z=3*5+0=15**

Worlds-within-Worlds: An Example

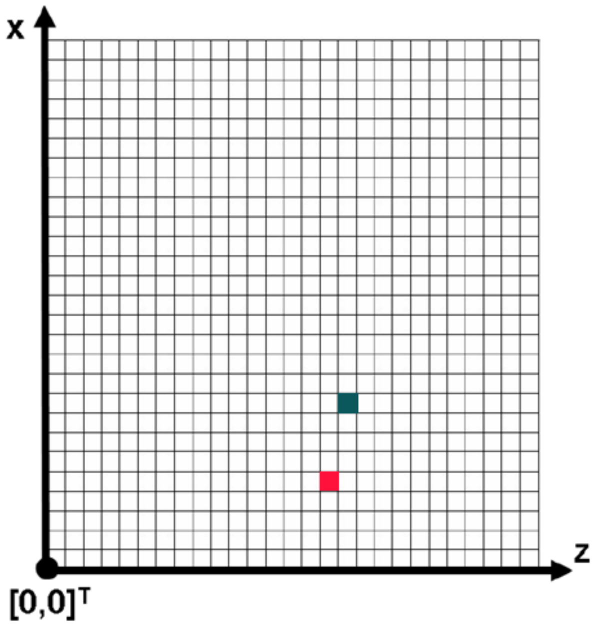


$\mathbf{m}=[1,2,3,3,2,1]^T$ and $\mathbf{n}=[0,2,3,4,1,0]^T$

$\mathbf{m}(y,z)= [\ 12,\ 16\ ]^T$
$\mathbf{n}(y,z)= [\ 11,\ 15\ ]^T$

$m=[1,2,3,3,2,1]^T$ ➔ **x=1*5+3=8, y=2*5+2=12, z=3*5+1=16**
$n=[0,2,3,4,1,0]^T$ ➔ **x=0*5+4=4, y=2*5+1=11, z=3*5+0=15**

Worlds-within-Worlds: An Example



m$=[1,2,3,3,2,1]^T$ and **n**$=[0,2,3,4,1,0]^T$

m$(z,x)=[\ 16,\ 8\ ]^T$
n$(z,x)=[\ 15,\ 4\ ]^T$

$m=[1,2,3,3,2,1]^T$ ➔ **x=1*5+3=8, y=2*5+2=12, z=3*5+1=16**

$n=[0,2,3,4,1,0]^T$ ➔ **x=0*5+4=4, y=2*5+1=11, z=3*5+0=15**

Summary

- Hierarchical techniques
  - Dimensional stacking
  - Worlds-within-worlds