地理資訊系統

空間資料模型與位相關係：
網格式資料模型
向量式資料模型
數位地表資料

地理資料模式化程序

- Physical reality→Real World Model →Data Model→Database→Maps/Reports
- 資料（data）→資料模型（data models）→資料結構（data structure）→檔案結構（file structure）
  - 資料實體層次（physical data）
  - 資料模型層次（data model）
  - 資料結構層次（data structure）

資料實體層次

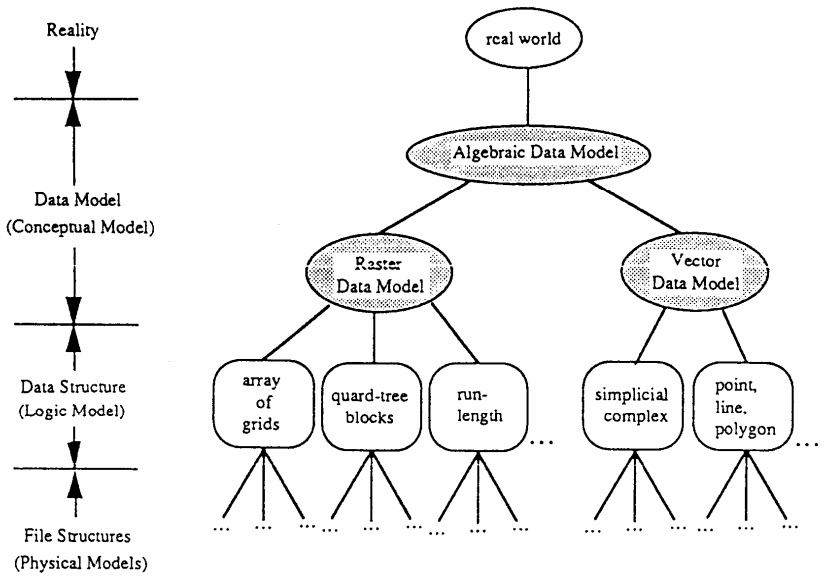
- 真實存在的各種現象，一般稱之爲「原始資料」（Raw Data）
- 資料是否有意義，其意義與重要性爲何，完全依使用它的人而定
- 這些資料經過有規範的整理與處理之後，方能發揮其應有的效益，稱之爲有意義的「資訊」

資料模型層次

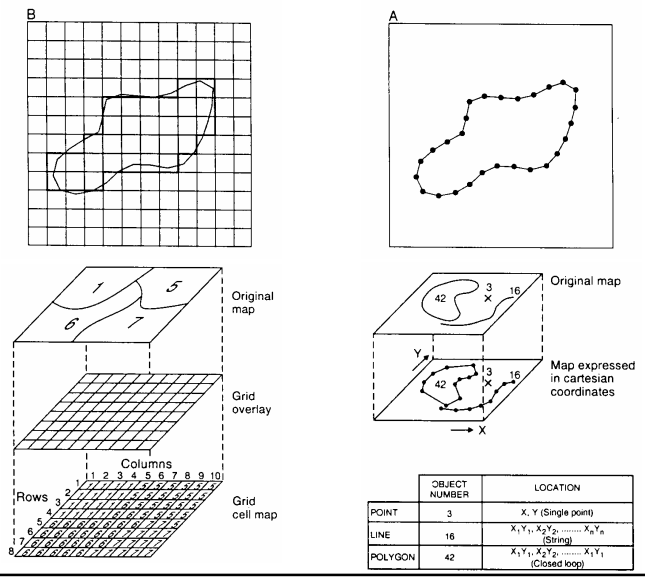
- 模型化→簡化、一般化
- 對於真實世界資料的萃取，由各種大小細節的資料中，留下所要處理應用的資訊
- 資料模型是一組如何表示資料庫內資料的邏輯架構之指引。它是一個樣態，資料以及資料彼此間的關係可以根據此一樣態而加以邏輯化的整理
- 資料模型所討論的，包括資料的架構，以及在這些架構下可能對它們所採取的各種處理與運算

資料結構層次

- 資料模型在電腦內部的表示法，稱之爲資料結構（data structure）
- 用陣列（Array）、串列（Linked List）、樹（Tree）、圖形（Graph）、……等各種資料結構，在電腦程式中來表示這些資訊
- 同樣的資訊，由於電腦軟體將來預計對它所進行的處理方式以及處理方式之不同，而可能適合用不同的資料結構來加以表示
- 資料結構所討論的即是系統實作的層次

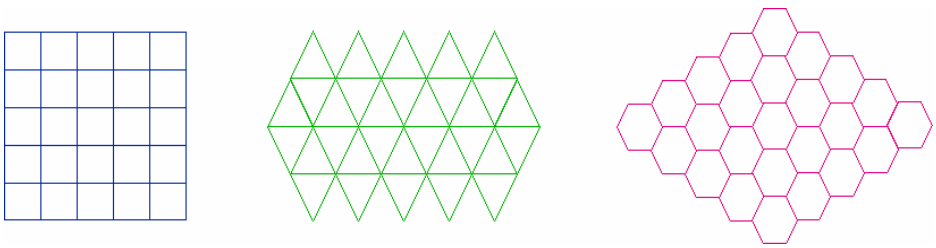


網格模型與向量模型



	OBJECT NUMBER	LOCATION
POINT	3	X, Y (Single point)
LINE	16	$X_1Y_1, X_2Y_2, \ldots\ldots X_nY_n$ (String)
POLYGON	42	$X_1Y_1, X_2Y_2, \ldots\ldots X_1Y_1$ (Closed loop)

網格資料模型

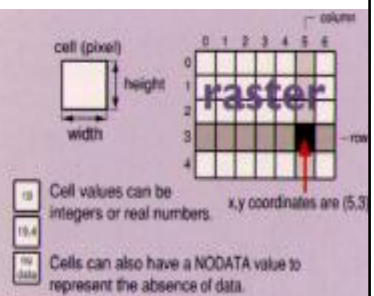


Inside a Raster

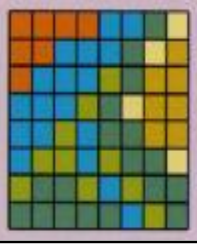
Rasters are two-dimensional arrays of cells (or pixels). The height and width of each cell are fixed and the same. A raster spans a rectangular area.

Each cell has a value. This value can represent many qualities of a location, including reflectance, color, precipitation, and elevation.

Rasters have an integer coordinate space. You can determine the coordinate of a cell by counting columns from the left and rows from the top. Row and column values begin with 0.



The attribute table



Value	Count	Type	Code
23	7	Fir	400
29	18	Juniper	410
31	10	Aspen	420
37	18	Piñon	500
41	4	Cottonwood	510
43	7	Walnut	600

Rasters that have integer valued cells can be defined with an optional attribute table, which records attributes for each unique cell value.

You can add custom fields to the attribute table.

Types of Data Represented in Cells

The data stored in a raster can be categorized as one of these types.

Nominal Data

Nominal data values are categorized and have names. The data value is an arbitrary type code. Examples are soil types and land use.

21	17	17	18	22	18
18	16	17	19	24	19
21	19	19	19	22	22
26	23	21	20	18	21
24	23	18	16	20	19
18	14	16	17	19	20

Nominal and ordinal data represent discrete categories. They are best represented with integer cell values.

Ordinal Data

Ordinal data values are categorized, have names, and the value is in a numerical rank. Examples are land suitability classifications and soil drainage rank.

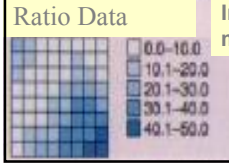
Interval Data

Interval data values are numerically ordered and the interval difference is meaningful. Examples are voltage potential and difference in concentration.

21.1	17.3	17.2	18.1
18.5	16.2	17.3	19.1
21.0	19.1	19.4	19.2
26.3	23.1	21.6	20.5

Interval and ratio data represent continuous phenomena and are usually measured with real cell values.

Ratio Data



Ratio data values measure a continuous phenomenon with a natural zero point. Examples are rainfall and population.

網格資料類型

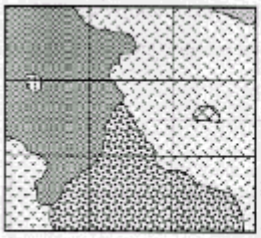
- picture
  - –具備絕對座標或相對座標，通常做爲背景資訊或輔助資訊，以視覺分析爲主，例如掃瞄之航空照片，實景照片等
- image
  - –主要指衛星影像，利用波譜資訊進行處理與分析
- grid
  - –每一網格可以儲存多種屬性，與向量資料類似，惟地物整體特性被切割，不適合部分資料的表達，但是有其運算上的效率性
- DEM (digital elevation model)
  - –數值地形

Representing Geography with Rasters: Forms of Raster Data

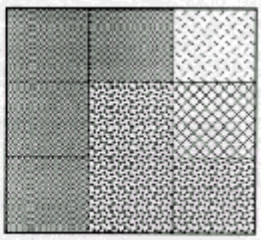
Satellite imagery | Aerial imagery | Pictures

Scanned maps | Converted data

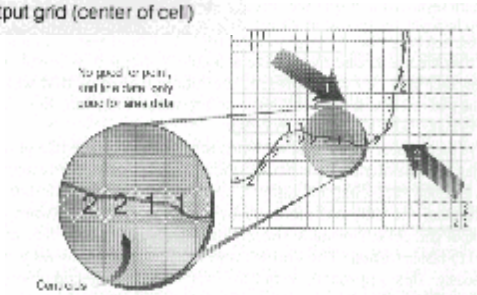
Raster Encoding (Centroid)



Input vegetation map

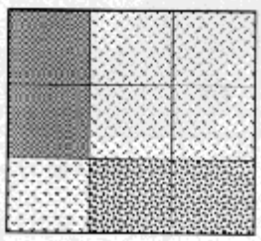


Output grid (center of cell)

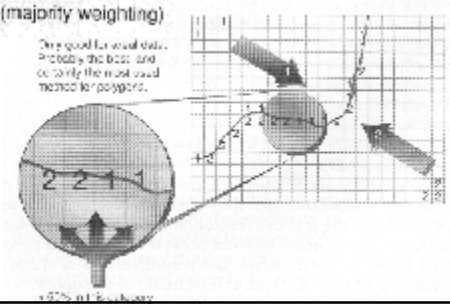


Raster Encoding (Predominant)

Input vegetation map

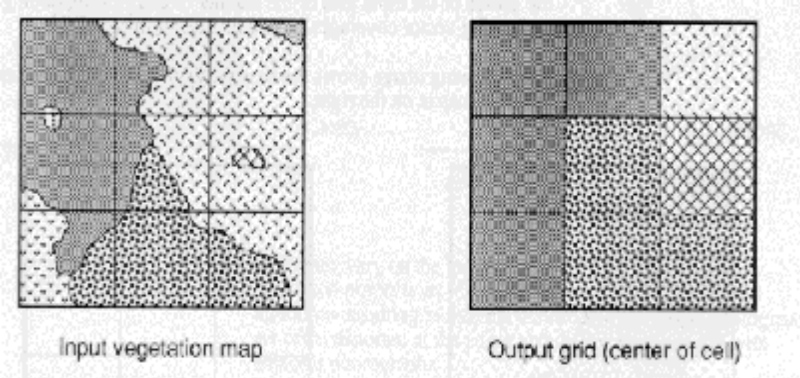


Output grid (majority weighting)

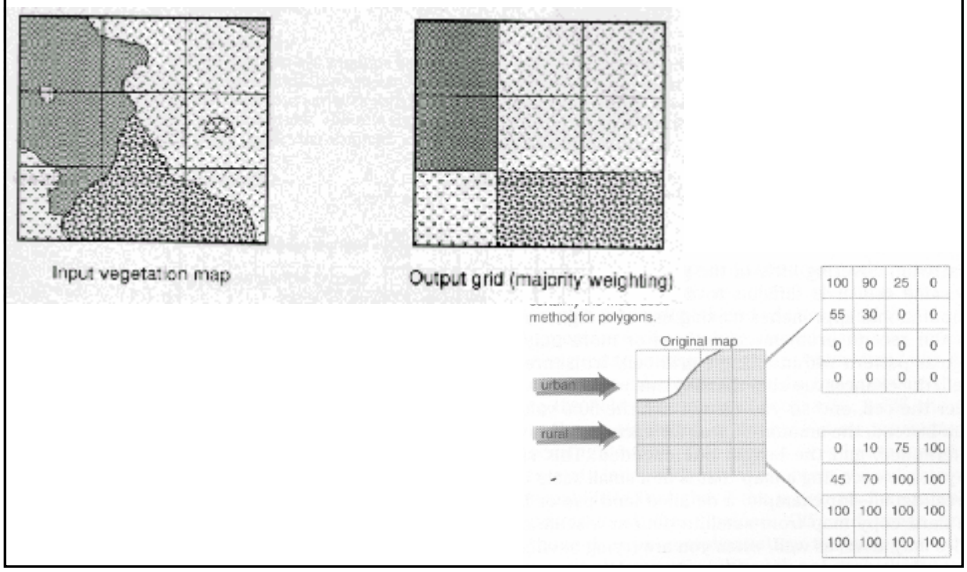


Raster Encoding (Most importance)

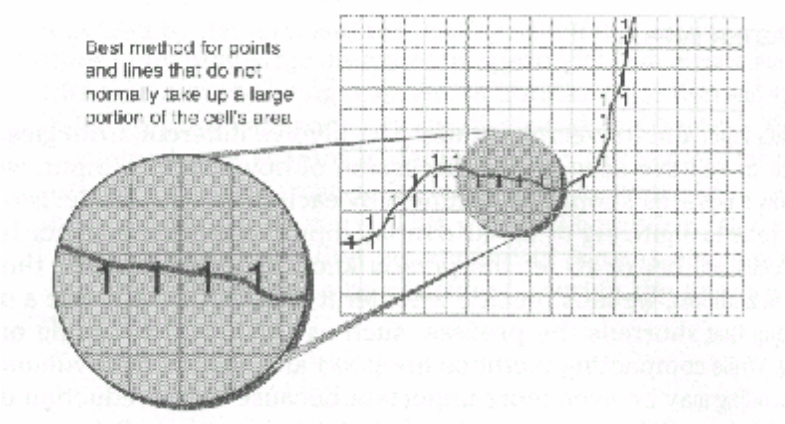
- Most importance



Raster Encoding (Percentage breakdown)

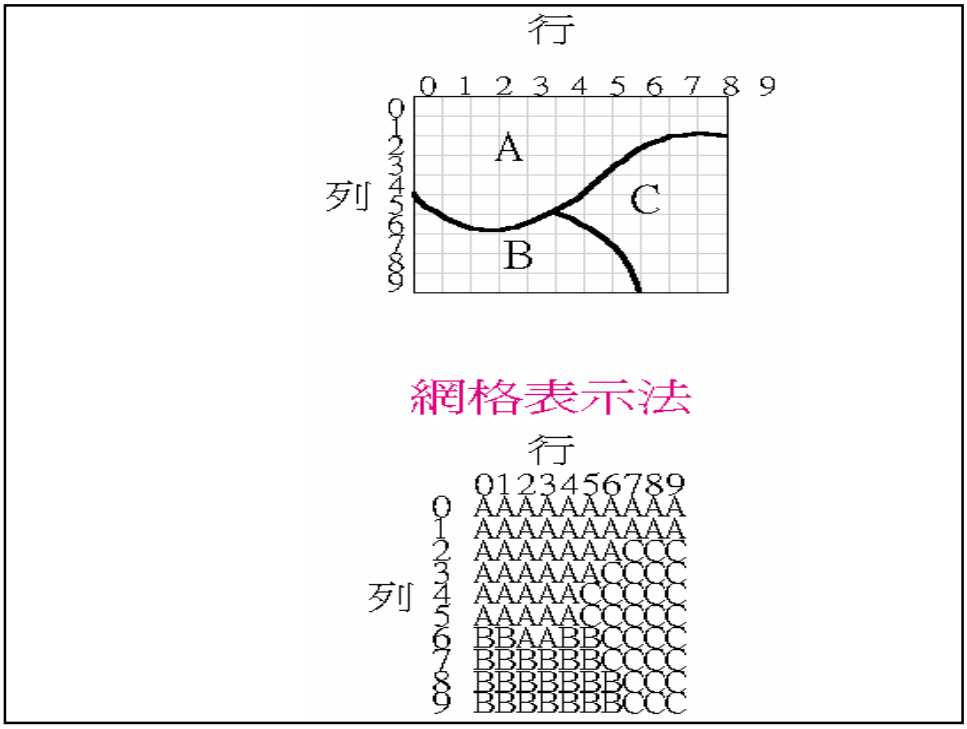


Raster Encoding (Present/Absent)



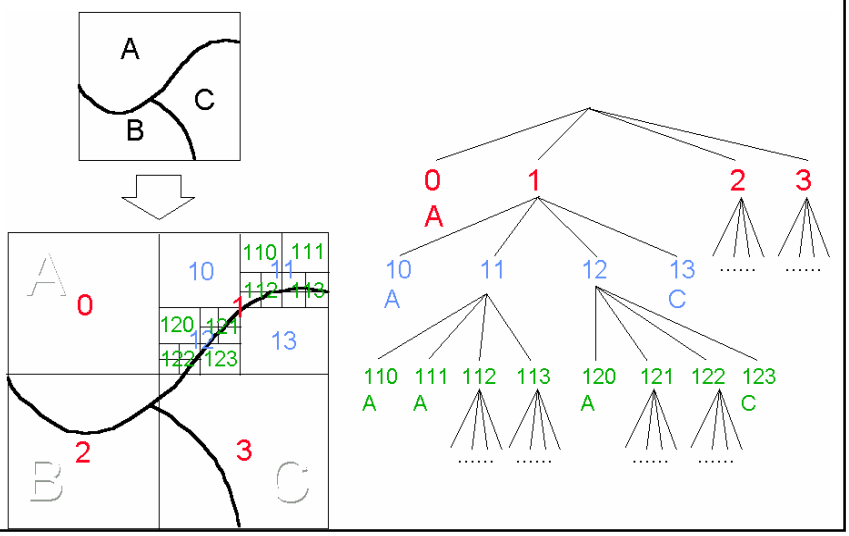
資料結構

- 完全網格結構（full raster）
- 簡單網格式結構
  - 區段長度編碼法（run-length）
  - 值點編碼法（value point）
- 階層網格式結構
  - 四元樹模式（quad-tree）
    - 常規（normal quad-tree）
    - 線性（linear quad-tree）
  - 摩頓碼（Morton code）
  - 皮亞諾鍵（Peano key）

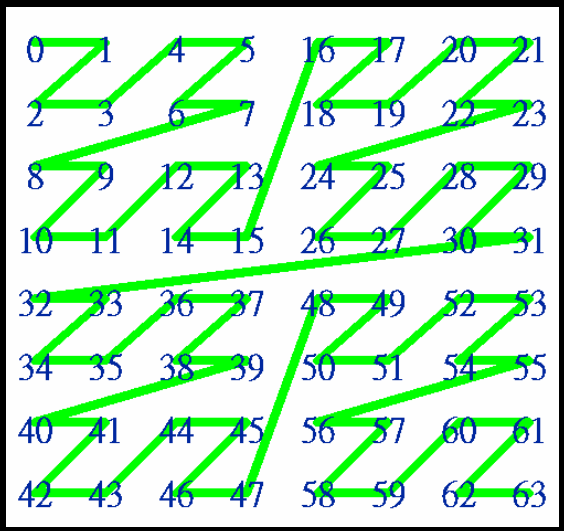


四元樹（Quad-tree）結構

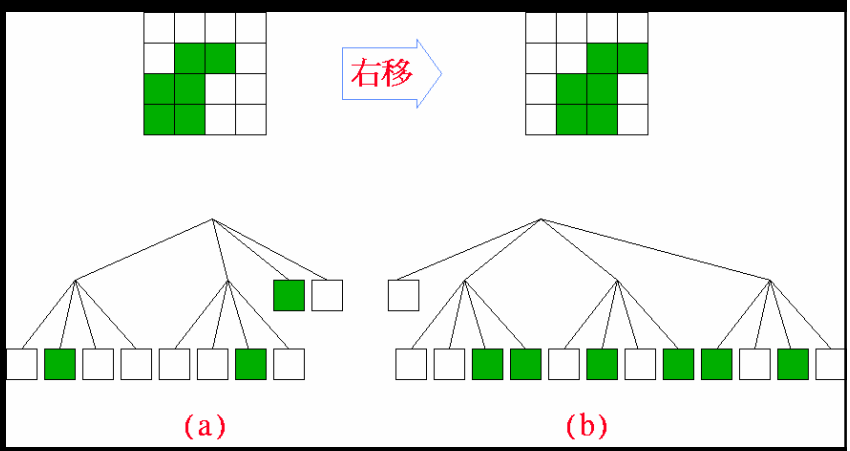
Klinger於1971年提出



皮亞諾鍵（Peano key）



四元樹結構問題

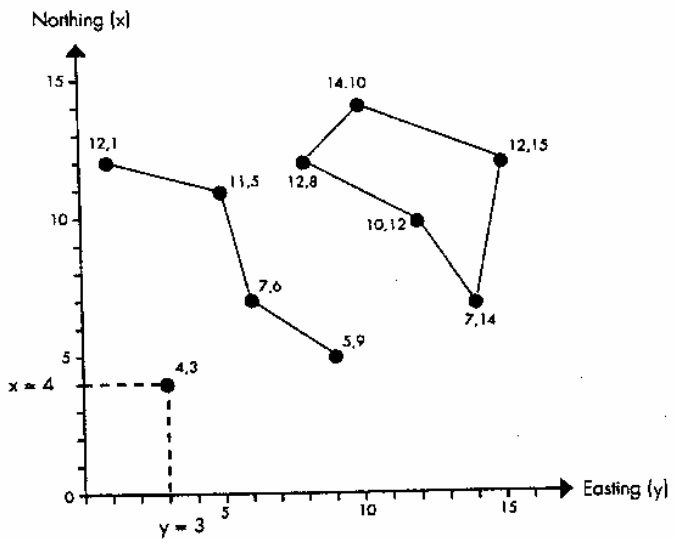


網格資料特性

- 優點：結構簡單，疊圖操作容易
- 缺點：精度不足，資料量大

向量式資料模型

- 以一系列的點座標來加以表示地理資料（點、線、以及多邊形的面）
- 元素
  - 節點（node）與轉折點（vertices）
  - Link、 Arc、 Chain 、Ring
  - Polygon
- 點圖徵紀錄座標值
- 線圖徵記載兩端點及各轉折點的座標值
- 面（多邊形）圖徵則是記錄其邊界上各轉角的座標
- 向量式資料結構中，點、線、面各自代表一個均質的地理現象
- 精密度高，資料概略化的問題較少



ZERO-DIMENSIONAL OBJECTS:

Point: A zero-dimensional object that specifies geometric location specified through a set of coordinates.

Node:.A zero-dimensional object that is a topological junction and may specify geometric location.

ONE-DIMENSIONAL OBJECTS

Line segment (vector): A one-dimensional object that is a direct line between two end points.

Link: A one-dimensional object that is a direct connection between two nodes.

Directed link: A link between two nodes with one direction specified.

String: A sequence of line segments.

Chain: A directed sequence of nonintersecting line segments with nodes at each end.

Arc: A locus of points that forms a curve that is defined by mathematical function. Also defined as a string or chain.

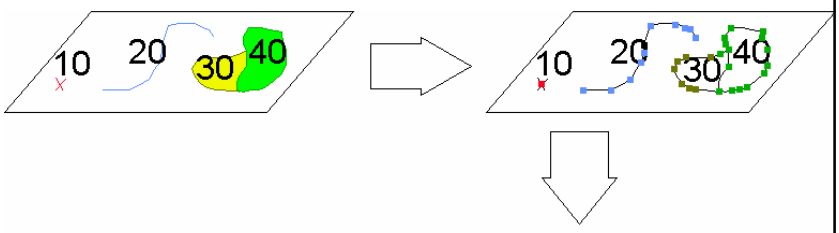
Ring: A sequence of any line segments with closure.

TWO-DIMENSIONAL OBJECTS

Simple area/polygon: An area defined by an outer ring that may not have inner rings (holes).

Complex area/polygon: An area defined by an outer ring with optional inner rings defining holes.

麵條式資料結構
Spaghetti Structure



圖徵	編號	位　置
點	10	XY
線	20	X1Y1 X2Y2 ....
面	30	X1Y1 X2Y2 X3Y3 ....
面	40	X1Y1 X2Y2 X3Y3 ....

麵條式資料結構

ID #	X	Y	A_1	A_2	..	A_n
1	x_1	y_1	a_{11}	a_{12}	.	a_{1n}
2	x_2	y_2	a_{21}	a_{22}	.	a_{2n}
3	x_3	y_3	a_{31}	a_{32}	.	a_{3n}
.	.	.	.	.	.	.
...	.	.	.	.	.	.
m	x_m	y_m	a_{m1}	a_{m2}	.	a_{mn}

1	5	2	7	Header for line 1
	x_1	y_1		
	x_2	y_2		Coordinates of vertices for line 1
	x_3	y_3		
	x_4	y_4		
	x_5	y_5		
2	2	4	7	Header for line 2
	x_1	y_1		Coordinates for line 2
	x_2	y_2		
3	15	2	8	Header for line 3
.	.	.		.
m	etc	etc		etc

[1] The table is nonstandard, because it contains more than one kind of record.

1	5	429	18	Header for poly 1
	x_1	y_1		
	x_2	y_2		Coordinates of vertices for polygon 1
	x_3	y_3		
	x_4	y_4		
	x_5	y_5		
2	4	39	12	Header for poly 2
	x_1	y_1		
	x_2	y_2		Coordinates for polygon 2
	x_3	y_3		
	x_4	y_4		
3	81	9	3	Header for polygon 3
.	.	.		.
m	etc	etc		etc

[1] This table is also nonstandard, because it contains more than one kind of record.

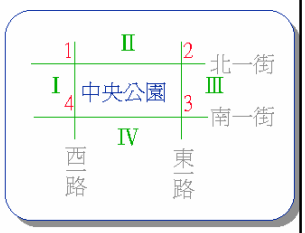
位相關係（Topology）

- 電腦輔助設計軟體vs.GIS ⇒ 位相關係（Topology）⇒ 加速分析與處理工作的進行
- 位相關係是一種用來定義空間關連性的數學方法，一般儲存的位相關係包括：
  - 區域定義（Polygon Definition）
  - Direction - defines a "from node" and a "to-node" of a chain
  - Nestedness or contain - what simple spatial objects (node, chain, smaller polygon) are within a polygon
  - 連結性（Connectivity of Arcs）：各個弧間，哪一個在前，哪一個在後，彼此間的連接情形如何。
  - 鄰接性（Contiguity）：面之間彼此相鄰的關係。

弧-節點（Arc/Node）資料模式

節點

編號	東 距	北 距	紅綠燈	其它屬性
1	32102	12305	有	.
2	32115	12308	閃黃燈	.
3	32100	12204	有	.
4	32117	12200	無	.



弧

編號	由	至	長 度	線道	其它屬性
Ⅰ	4	1	100.5	4	.
Ⅱ	1	2	20	4	.
Ⅲ	2	3	103.2	4	.
Ⅳ	3	4	21.5	2	.

多邊形

名 稱	所有人	線段	面 積	其它屬性
中央公園	市政府	Ⅰ、Ⅱ、Ⅲ、Ⅳ	210.5	....

GBF/DIME

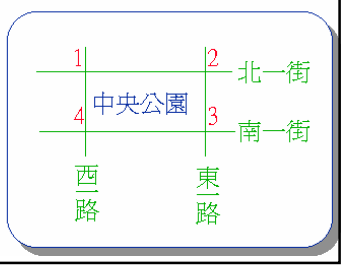
Geography Base File or Dual Independent Map Encoding

線段：

線段名稱	點		多邊形		地址				其它屬性
	由	至	左	右	左高	左低	右高	右低	
北一街	1	2	—	中央公園	100	10	—	—	.
南一街	3	4	—	中央公園	73	3	—	—	.
東一街	2	3	—	中央公園	98	90	—	—	.
西一街	4	1	—	中央公園	85	32	—	—	.

點：

編號	東距	北距
1	9102	7305
2	9115	7308
3	9117	7200
4	9100	7204

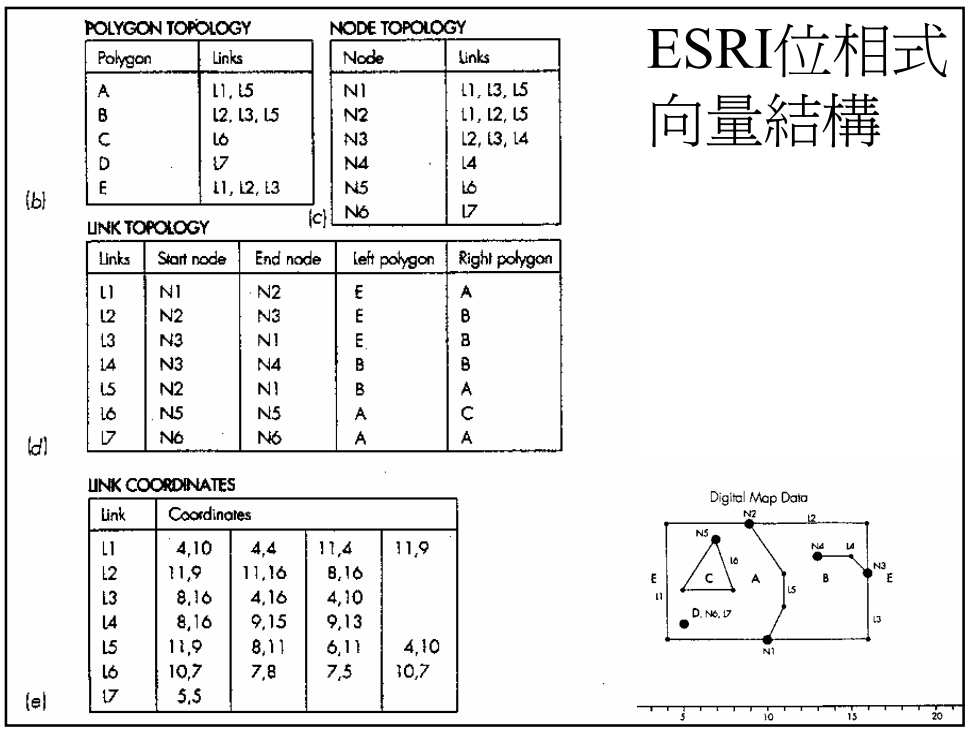


TIGER

- Topologically Integrated Geographic Encoding and Referencing, developed by the Census Bureau to geo-code census information
- the entire country of the U.S. is covered
- lines features such as roads, railroads, hydrography, and political boundaries such as county, census tracts and block groups
- related products are produced by companies such as ETAK, Geographic Data Technologies (GDT), Road Net Technologies, Navigation Technologies, Claritas, and BLR

Digital Line Graph (DLG)

- a vector format; the U.S. Geological Survey (USGS) has converted many of its hardcopy maps into DLG
- large scale DLG created from the USGS 1:24,000 topographic maps
- data are available in 7.5' x 7.5' quadrangles corresponding to topographic maps



(b) POLYGON TOPOLOGY

Polygon	Links
A	L1, L5
B	L2, L3, L5
C	L6
D	L7
E	L1, L2, L3

(c) NODE TOPOLOGY

Node	Links
N1	L1, L3, L5
N2	L1, L2, L5
N3	L2, L3, L4
N4	L4
N5	L6
N6	L7

(d) LINK TOPOLOGY

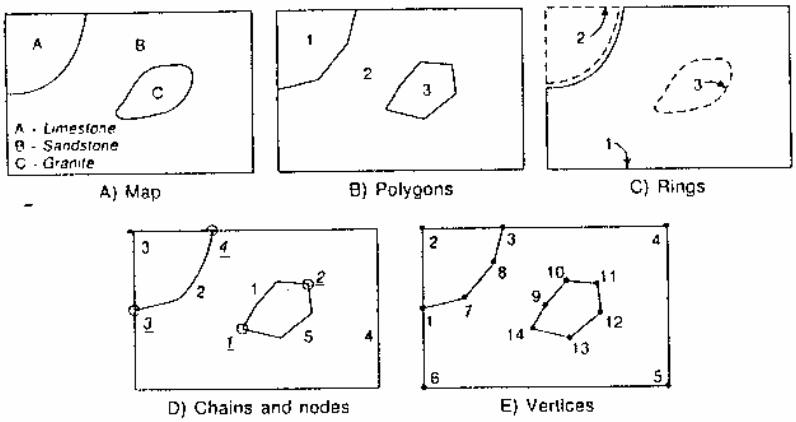
Links	Start node	End node	Left polygon	Right polygon
L1	N1	N2	E	A
L2	N2	N3	E	B
L3	N3	N1	E	B
L4	N3	N4	B	B
L5	N2	N1	B	A
L6	N5	N5	A	C
L7	N6	N6	A	A

(e) LINK COORDINATES

Link	Coordinates			
L1	4,10	4,4	11,4	11,9
L2	11,9	11,16	8,16	
L3	8,16	4,16	4,10	
L4	8,16	9,15	9,13	
L5	11,9	8,11	6,11	4,10
L6	10,7	7,8	7,5	10,7
L7	5,5			

ESRI位相式向量結構

Russel Topological Structure



Contiguity

Nestedness or contain

C. Chain topology table

Chain #	Start Node	Stop Node	Left Polygon	Right Polygon
1	1	2	2	3
2	3	4	1	2
3	4	3	1	0
4	4	3	0	1
5	1	2	3	2

D. Node-to-vertex table

Node #	Vertex #
1	14
2	11
3	1
4	3

A. Polygon topology table

Polygon #	Ring #	Ring Sequence #
1	2	1
2	1	1
2	3	2
3	3	1

B. Ring topology table

Ring #	Chain #	Chain Sequence #
2	3	1
2	2	2
1	2	1
1	4	2
3	1	1
3	5	2

E. Chain-to-vertex table

Chain #	Vertex #	Vertex Sequence #
1	14	1
1	9	2
1	10	3
1	11	4
2	1	1
2	7	2
2	8	3
2	3	4
3	3	1
3	2	2
3	1	3
4	3	1
4	4	2
4	5	3
4	6	4
4	1	5
5	14	1
5	13	2
5	12	3
5	11	4

F. Coordinates of vertices table (part only)

Vertex #	X	Y
1	x_1	y_1
2	x_2	y_2
.	.	.
.	.	.
14	x_{14}	y_{14}

向量模型之比較

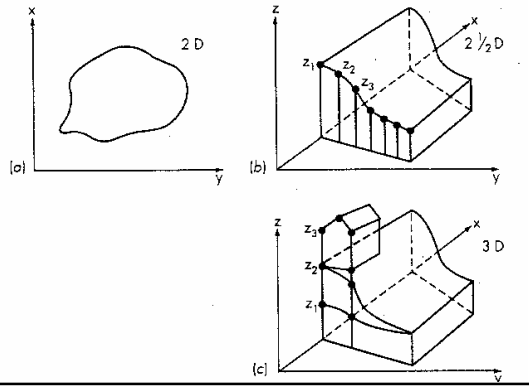
- 非位相資料結構
  - 優點：記錄方式簡單，只要記錄簡單的幾何位置即可。
  - 缺點：由於無法記錄空間物件間的位相關係，故無法了解各組成物件間的關係。
- 位相資料結構
  - 優點：有相對關係，空間物件組成間，其記錄的資料彼此有層級關係，各種物件間記錄的方式相對簡化許多，也較易於了解。
  - 缺點：資料的記錄相對複雜，資料間互動關係較強，一旦位相資料有誤，即容易影響地理資料中，空間物件的變化。

網格模型與向量模型比較

	Raster	Vector
Data collection	Rapid	Slow
Data volume	Large	Small
Graphic treatment	Average	Good
Data structure	Simple	Complex
Geometrical accuracy	Low	High
Analysis in network	Poor	Good
Area analysis	Good	Average
Generalization	Simple	Complex

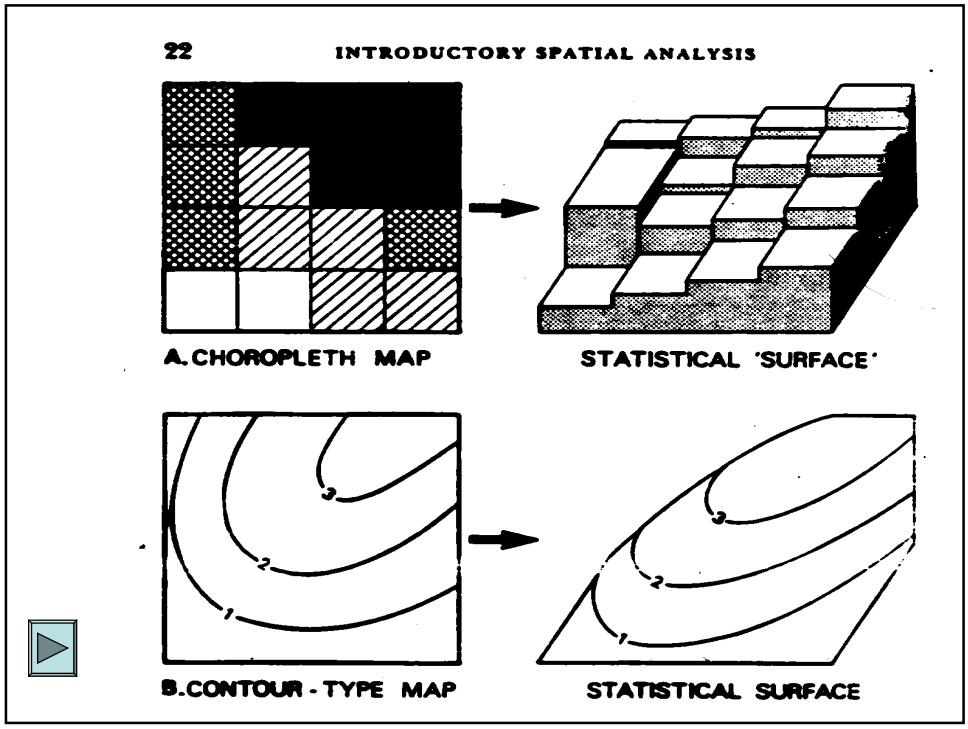
地表模型（Surface Model）

- 數值地形模型（ Digital Terrain Model, DTM ）、數值高程模型（ Digital Elevation Model, DEM ）
- 以數值化的方式，來表現地表三度空間的起伏變化情形。
- 2.5D vs. 3D

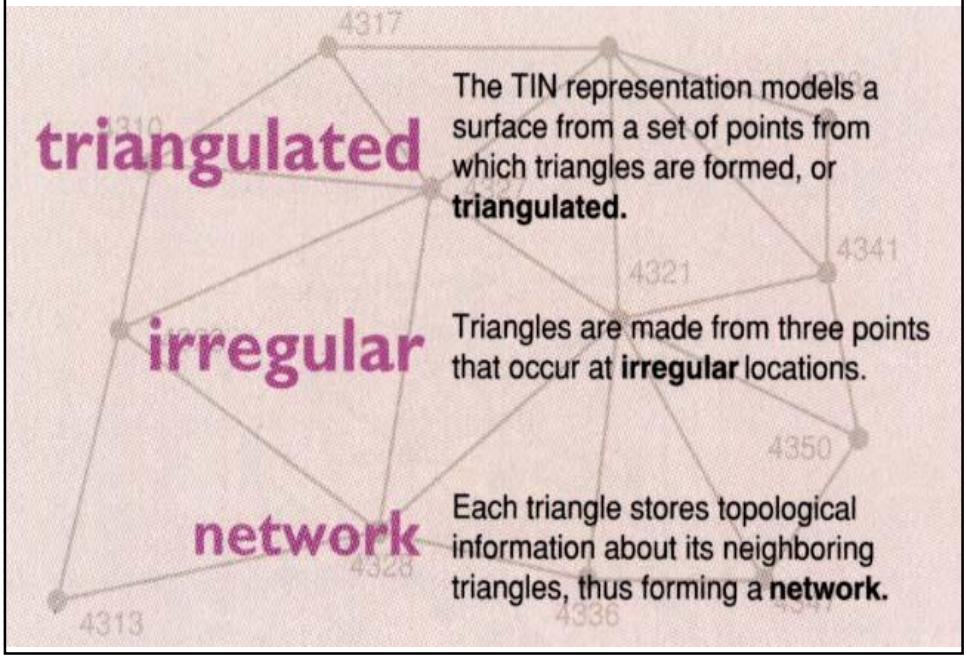


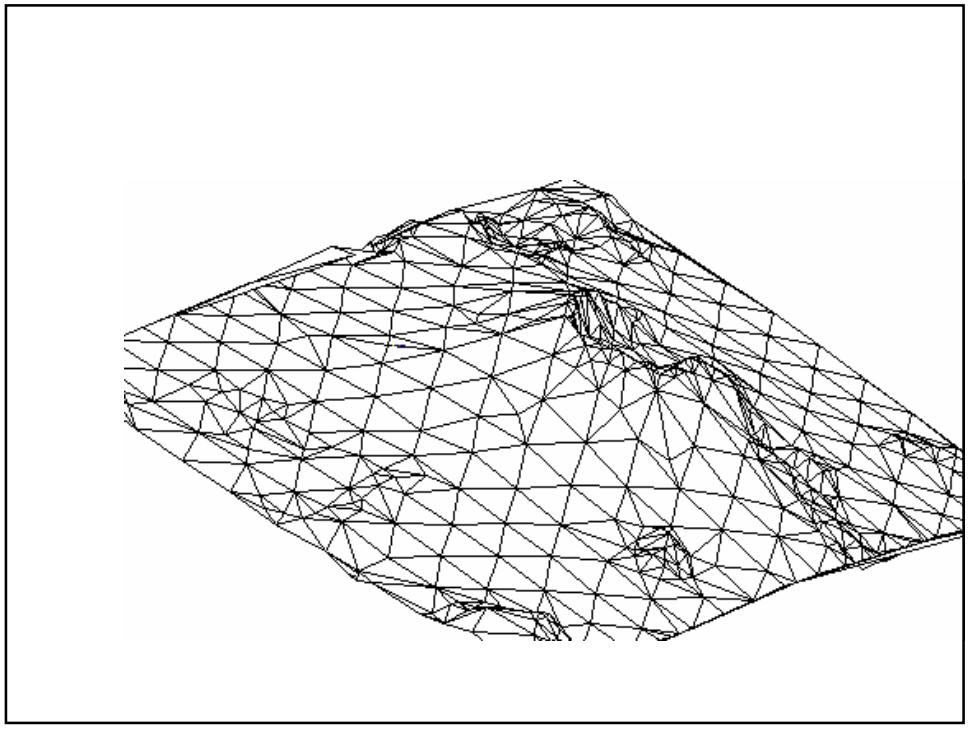
DTM資料模型

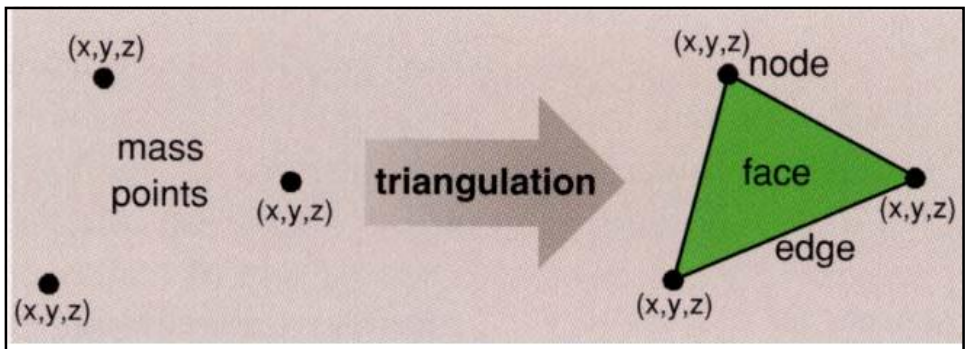
- 規則的網格點（Regular Grid）
  - 在一組正交的網格上，每一個網格點均量取其高度值，這些高度值便組成一個規則矩陣的結構，即數值高程模型（Digital Elevation Model, DEM）
- 數值等高線（Digital Contour）
  - 連結地形資料中高度相同的點
- 不規則三角網（Triangulated Irregular Network, TIN）
  - 以連續不規則的三角形，來代表連續的三度空間資料的結構。其解析度可隨空間資料複雜度之不同而改變，因此，地形上的劇烈變化亦可以有效的加以表示。



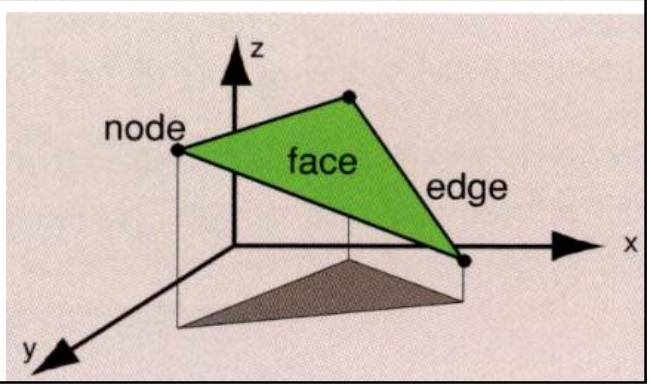
Definition of a TIN



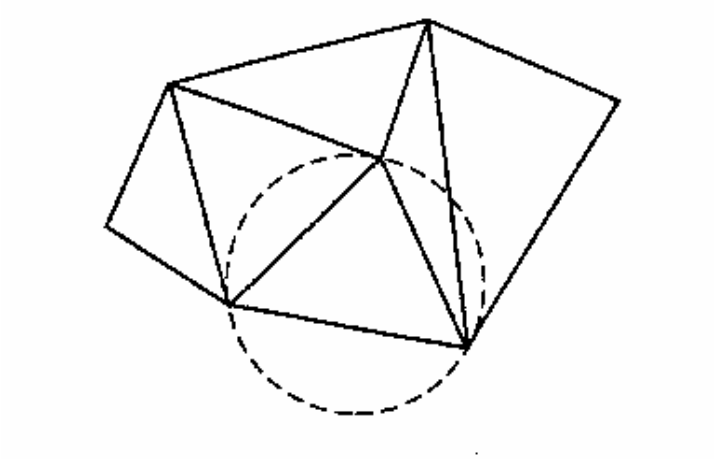


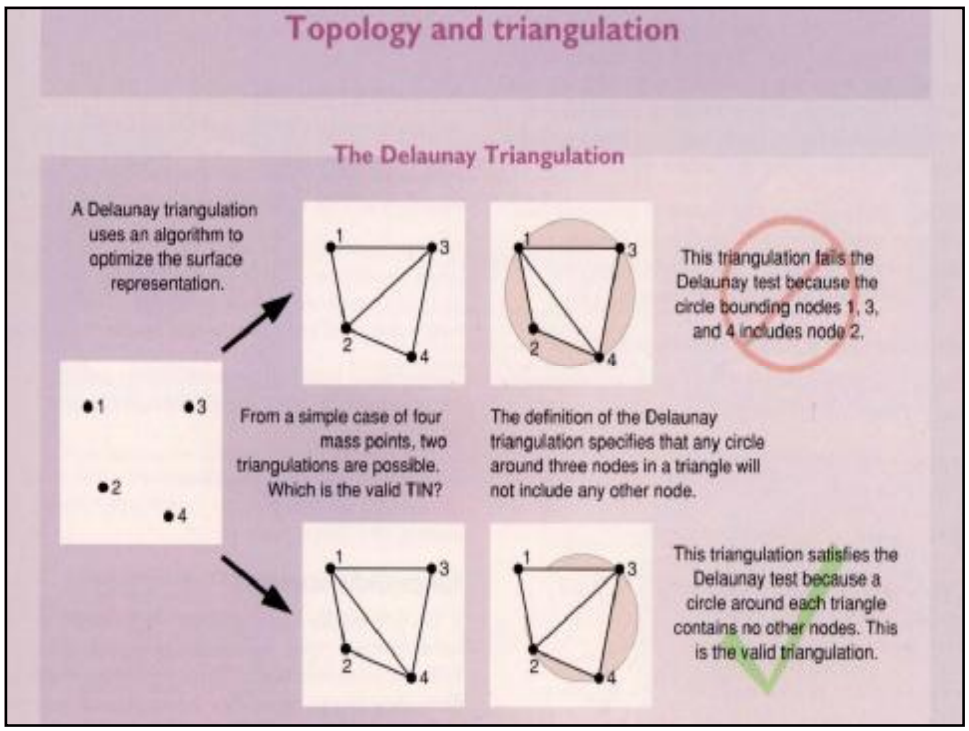


Creating TINs
Sources:
photogrammetry,
survey data,
digitized contours,
rasters with z-values,
pointsets in other
databases/files,
& operations on other
TINs



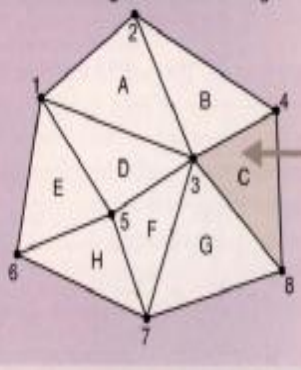
TIN模型之構成




Topology and triangulation
The Delaunay Triangulation
A Delaunay triangulation uses an algorithm to optimize the surface representation.
1
3
2
4
This triangulation fails the Delaunay test because the circle bounding nodes 1, 3, and 4 includes node 2.
From a simple case of four mass points, two triangulations are possible. Which is the valid TIN?
The definition of the Delaunay triangulation specifies that any circle around three nodes in a triangle will not include any other node.
This triangulation satisfies the Delaunay test because a circle around each triangle contains no other nodes. This is the valid triangulation.

Topology in a TIN

A TIN is a topological data structure that manages information about the nodes that comprise each triangle and the neighbors to each triangle.



Triangle	Node list	Neighbors
A	1, 2, 3	–, B, D
B	2, 4, 3	–, C, A
C	4, 8, 3	–, G, B
D	1, 3, 5	A, F, E
E	1, 5, 6	D, H, –
F	3, 7, 5	G, H, D
G	3, 8, 7	C, –, F
H	5, 7, 6	F, –, E

Triangles always have three nodes and usually have three neighboring triangles. Triangles on the periphery of the TIN can have one or two neighbors.

TIN資料模型

Triangle table

Triangle	Adjacent
A	B, E
B	A, C
C	B, D
D	C, E
E	D, A

Triangle/node table

Triangle	Nodes
A	N3, N4, N6
B	N4, N5, N6
C	N1, N5, N6
D	N1, N2, N6
E	N2, N3, N6

Coordinate table

Node	Coordinates
N1	X_1, Y_1, Z_1
N2	X_2, Y_2, Z_2
N3	X_3, Y_3, Z_3
N4	X_4, Y_4, Z_4
N5	X_5, Y_5, Z_5
N6	X_6, Y_6, Z_6