Spatial Analysis

using

Continuous Fields

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http://pirun.ku.ac.th/~fengwks/gis/lecture//9Continuous_Fields_6p.pdf

Continuous Field?

- Where data is held in square raster or grid format
- Each datalayer is in georeferenced raster layer

Map Algebra

- Mathematical operations on whole raster layer
- Easy to write numerical models

Basic Operations

Map Algebra and Cartographic Modelling

- Same algebraic notation can be used on a grid data as on single numbers.
- This method is called MAP ALGEBRA.
- The procedure for using the algebraic techniques to build models for spatial analysis is called CARTOGRAPHIC MODELLING

Advantage of Raster Data

- The loss of information due to rasterising smooth polygon boundaries is more than offset by the advantage of not having to create new polygons by intersection.
- By choosing a grid size as remote sensing data can allow use of remote sensing data also in numerical model
- Attributes are stored in separate layer, it is a major advantage

COMMAND

NEWMAP = MAP1 + MAP2 + MAP3

NEWMAP = (MAP1 + MAP2 + MAP3) / 3

NEWMAP = ((MAP1 - MAP2) / (MAP1 + MAP2)) + MAP3

All operations are left to right

All these operations compute new values cell by cell basis

COMMAND Language Interface (CLI)

CLI allows the user to express the basic functions in the mathematical language

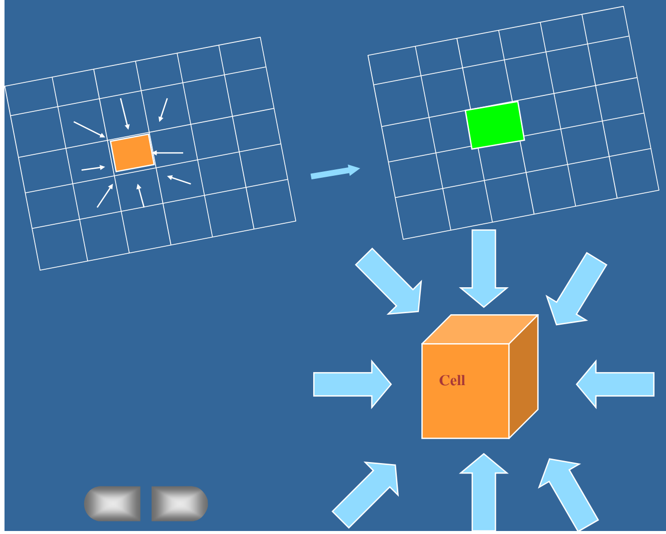
It makes easy to write mathematical models to operate on gridded data

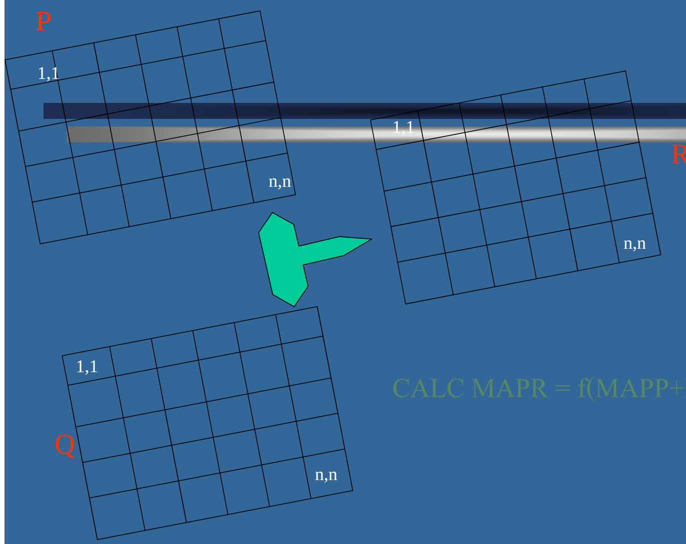
Many GIS packages provide Macro Language for this purpose

ARC INFO -	AML (ARC MACRO LANGUAGE)
PC ARC INFO-	SML (SIMPLE MACRO LANGUAGE)
ARC VIEW-	AVENUE

POINT OPERATIONS

All the Logical and Numerical operations for discrete entities can be applied to continuous grid





CALC MAPR = f(MAPP+MAPQ)

Spatial Operations

- DISADVANTAGES OF USING GRIDDED DATA
  - Exact shapes of entities are just approximated by the grid cells
  - Directed operations over a network can not be operated without first deriving the topology from the properties of the surface
- ADVANTAGES OF USING GRIDDED DATA
  - Continuous field model provides a much richer suite of truly spatial analysis operations
  - These have many practical usages
  - Neighborhood is generally isomorphic but not necessary

Spatial Operations

- *Interpolation*
- *Spatial Filtering*
- *First and High order derivatives*
- *The derivation of surface topology: drainage networks and catchment delineation*
- *Contiguity assessment (clumping)*
- *Non-linear dilation (spreading with friction)*
- *Viewsheds, Shaded relief, and Irradiance*

Interpolation

Interpolation is the prediction of a value of an attribute at an unsampled site from the measurements made at other sites falling within a given neighborhood.

Interpolation *is used to create discretized continuous surfaces from observations at sparsely located points or resampling a grid to a different density or orientation as in remote sensing images.*

Interpolation (contd...)

Operations may include

Once we have random points

Developing a TIN model

Conversion of TIN to grid

Apply different interpolation techniques to obtain a continuous surface

Spatial Analysis using Square Window

Spatial Filtering

Discretized square window – or – Filter or a Kernel

$$c_{i,j} = f\left(\sum_{i-m}^{i+m}\sum_{j-n}^{j+n} c_{i,j}\right)$$

where f stands for a given window operator for windows of dimension 2m+1, 2n+1

Spatial Analysis using Square Window

Spatial Filtering

Spatial filtering involves passing a square window over the surface and computing a new value of the central cell of the window $C_{i,j}$ as a function of neighboring cell values inside the window.

$C_{i-1, j-1}$	$C_{i, j-1}$	$C_{i+1, j-1}$
$C_{i-1, j}$	$C_{i, j}$	$C_{i+1, j}$
$C_{i-1, j+1}$	$C_{i, j+1}$	$C_{i+1, j+1}$

Window Operations for Spatial Filtering

2	3	4
1	5	5
3	4	6

RANGE

2	3	4
1	3	5
3	4	6

2	3	4
1	31	5
3	4	6

TOTAL

Window Operations for Spatial Filtering

2	3	4
1	1	5
3	4	6

MIN

2	3	4
1	3	5
3	4	6

2	3	4
1	3.4	5
3	4	6

MEAN

Window Operations for Spatial Filtering

2	3	4
1	6	5
3	4	6

MAX

2	3	4
1	3	5
3	4	6

2	3	4
1	3	5
3	4	6

MODE

First and higher order derivatives of a continuous surface

2	3	4
1	1.5	5
3	4	6

STD. DEV.

2	3	4
1	3	5
3	4	6

2	3	4
1	6	5
3	4	6

DIVERSITY

Generic Command for Filtering

- To compute low-pass and high-pass filters:
  - low-pass = windowaverage(continuous_surface, n)
  - high_pass = continuous_surface – low_pass

    where, n is the size of the square window in cells or distance unit

Generic Command for Filtering......

- To compute modal filters:
  - modal_map = windowmajority(continuous_surface, n)
- To compute range filters:
  - range_map = windowrange(continuous_surface, n)

    where, n is the size of the square window in cells or distance unit

Low_pass filtering......

- Low_pass filtering removes extremes from the data, producing a smoother image
- If mean is replaced by the mode then it becomes majority filter. Mode is the most common value
- A modal or majority filter is useful for simplifying a complex map

Diversity filtering......

- For nominal or ordinal data the MINORITY and DIVERSITY are useful operations to find out local complexity in the data
- A MINORITY operation involves finding the least common value in the window
- A DIVERSITY operation involves finding the number of different values in the window

High_pass filtering......

- High_pass filter enhances local variations in the continuous surface – specially near the boundaries
- If there is a change from one homogenous class to another in the continuous surface then there will be enhancement at that location
- high_pass image = Original_image – Low_pass image

High_pass filtering operators......

0	-1	0
-1	4	-1
0	-1	0

HP Filter - Point

1	0	0
0	1	0
0	0	1

edge Filter – Diagonal at 135^0

edge operators......

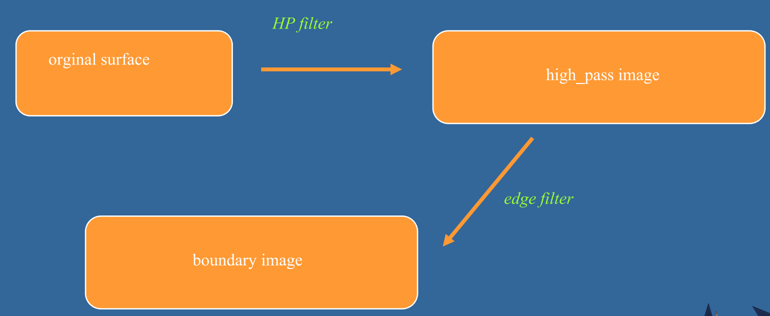
0	0	0
1	1	1
0	0	0

edge filter - horizontal

0	1	0
0	1	0
0	1	0

edge filter – Vertical

Using an edge filter to extract boundaries



First and Higher order derivatives of a continuous surface

- Derivatives are approximated either by computing differences within a square window or
- by fitting a polynomial to the data within a filter
- The two first order derivatives are SLOPE and ASPECT of the surface
- The two second order derivatives are the PROFILE CONVEXITY and PLAN CONVEXIT

Slope

- SLOPE is defined as a plane tangent to the surface as modeled by the DEM at any given point and comprises two components:
  - Gradient
    - The maximum rate of change of altitude
  - Aspect
    - the compass direction of this maximum rate of change in altitude
- Slope and Aspect provide sufficient data about the terrain or the surface
- But for Geomorphologist it is insufficient

Slope

- Maximum downward Gradient:

$$[\delta z / \delta x]_{ij} = \max \left(z_{i+1,j} - z_{i-1,j} \right) / 2\delta x$$

Where,

δx is the distance between cell centres

- It is the finite difference estimate of the gradient in the x direction at point i,j

Slope

Slope is given by

$$\tan S = \left[(\delta z / \delta x)^2 + (\delta z / \delta y)^2 \right]^{1/2}$$

where, z is altitude and x, y are latitude and longitude

The ASPECT is Given by

$$\tan A = -\left((\delta z / \delta Y) / (\delta z / \delta x) \right)$$

A third order finite difference estimator for gradient

The East - West gradient is given by

$$\delta z / \delta x = \left[\left(z_{i+1,j+1} + 2z_{i+1,j} + z_{i+1,j-1} \right) - \left(z_{i-1,j+1} + 2z_{i-1,j} + z_{i-1,j-1} \right) \right] / 8\delta x$$

where, z is altitude and x, y are latitude and longitude

and for the South - North gradient :

$$\delta z / \delta x = \left[\left(z_{i+1,j+1} + 2z_{i,j+1} + z_{i-1,j+1} \right) - \left(z_{i+1,j-1} + 2z_{i,j} - 1 + z_{i-1,j-1} \right) \right] / 8\delta x$$

Difference estimator for gradient – computing derivatives with simple filters

2	3	4
1	3	5
3	4	6

W-E Difference →

2	3	4
1	4	5
3	4	6

S-N Difference ↓

2	3	4
1	-1	5
3	4	6

Max. Difference ↘

2	3	4
1	4	5
3	4	6

Find W-E Difference, S-N Difference and MAX. Difference

5	4	4
7	3	5
6	8	6

W-E Difference →

5	4	4
7		5
6	8	6

S-N Difference ↓

5	4	4
7		5
6	8	6

Max. Difference ↘

2	4	4
7		5
6	8	6

Find W-E Difference, S-N Difference and MAX. Difference

5	4	4
7	3	5
6	8	6

W-E Difference →

5	4	4
7	-2	5
6	8	6

S-N Difference ↓

5	4	4
7	-4	5
6	8	6

Max. Difference ↘

2	4	4
7	-4	5
6	8	6

Window Operations for Spatial Filtering

RANGE

2	3	4
1	?	5
3	4	6

2	3	4
1	3	5
3	4	6

TOTAL

2	3	4
1	?	5
3	4	6

Window Operations for Spatial Filtering

RANGE

2	3	4
1	5	5
3	4	6

2	3	4
1	3	5
3	4	6

TOTAL

2	3	4
1	31	5
3	4	6

Window Operations for Spatial Filtering

12	13	10
6	?	9
13	10	11

MIN

12	13	10
6	8	9
13	10	11

12	13	10
6	?	9
13	10	11

MEAN

Window Operations for Spatial Filtering

12	13	10
6	6	9
13	10	11

MIN

12	13	10
6	8	9
13	10	11

12	13	10
6	10.22	9
13	10	11

MEAN

Window Operations for Spatial Filtering

2	3	4
1	?	5
3	4	6

MAX

12	13	14
11	13	15
13	14	16

2	3	4
1	?	5
3	4	6

MODE

Window Operations for Spatial Filtering

12	13	14
11	16	15
13	14	16

MAX

12	13	14
11	13	15
13	14	16

12	13	14
1	13	15
13	14	16

MODE

Window Operations for Spatial Filtering

20	30	40
10	60	50
30	40	60

MAX

20	30	40
10	30	50
30	40	60

20	30	40
10	3	50
30	40	60

MODE

First and higher order derivatives of a continuous surface

20	30	40
10	?	50
30	40	60

STD. DEV.

20	30	40
100	90	50
30	40	60

20	30	40
10	?	50
30	40	60

DIVERSITY

First and higher order derivatives of a continuous surface

20	30	40
10	15	50
30	40	60

STD. DEV.

2	3	4
1	3	5
3	4	6

20	30	40
10	7	50
30	40	60

DIVERSITY

Question?

Thank you for your attention