

Discrete Spatial variables

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Contents

Table Of Content	2
1 Discrete Spatial variables	4
1.1 Basic concepts	5
1.1.1 Geographic Objects	6
1.1.2 Spatial Features	8
1.1.3 Develop a simple data model	9
1.2 Individual spatial properties of features	10
1.2.1 Individual spatial properties of Point Features	11
1.2.2 Individual spatial properties of Linear Features	13
1.2.3 Individual spatial properties of Aeral Features	15
1.2.4 Questions	18
1.3 Spatial pattern and neighborhood of features	19
1.3.1 Spatial pattern and neighborhood of Point Features	20
1.3.2 Spatial pattern and neighborhood of Linear Features	23
1.3.3 Spatial pattern and neighborhood of Areal Features	25
1.3.4 Questions	27
1.4 Weighted spatial pattern and neighborhood	28
1.4.1 Weighted Spatial Patterns and Neighbourhoods of Point Features	29
1.4.2 Weighted neighborhoods of Linear Features	30
1.4.3 Weighted neighborhoods of Areal Features	31
1.4.4 Questions	32
1.5 Regionalization	33
1.5.1 Setting of spatial features (Regionalisation)	35
1.5.2 Spatial object labeling	36
1.5.3 Questions	37
1.6 Transformation of spatial features	38
1.6.1 Aggregation: a spatial generalization	39
1.6.2 Thematic criteria of aggregation	40

1.6.3	Spatial criteria of aggregation	41
1.6.4	Spatial and thematic criteria of aggregation	42
1.6.5	Breaking up of spatial features	43
1.6.6	Practice	44
	Glossary	45

1 Discrete Spatial variables

In this lesson, you will learn to work with the following spatial data representation models:

1. *Feature data*, which represents spatial features as points, lines and polygons and is best applied to discrete objects with defined shapes and boundaries.
2. *Raster data* represents imaged or continuous data. Each grid cell in a raster is a measured quantity. The most common source for raster dataset is a remote sensing image or aerial photograph. A discrete object can be stored in a raster dataset by assigning the identifier value to the grid cell.

Raster datasets excels in storing and working with continuous data, such as elevation data, pollution concentration and temperature.

Learning Objectives

- In unit 1: Introduction, you will learn the discrete and continuous nature and behavior of spatial objects and, how to describe them in image mode and feature mode based on the analytical tasks you need to perform. Actually, you have learnt these concepts in the basic module Spatial Modelling of Real World. The purpose of this unit is to recall your memory on spatial modelling.
- In unit 2: Individual spatial properties of features, you will learn the spatial properties of spatial objects and how to describe these in feature mode and image or raster mode.
- In unit 3: Spatial pattern and neighborhood features, you will learn different indices and implement the concept of largest proximity and minimum distance based on Euclidian distance. Moreover, you will learn how to allocate spatially in relation to the proximity of a spatial feature.
- In unit 4: Weighted spatial patterns and neighborhood, you will learn and implement the concept of largest proximity and minimum weighted distance based on weighted Euclidian distance. Moreover, you will learn how to allocate spatially in relation to the proximity and weighted minimum distance of a spatial feature.

1.1 Basic concepts

In this unit, you will learn characteristics and different behaviour of continuous and discontinuous spatial distribution of spatial phenomena. Spatial variables are used to describe and analyze the spatial distribution of phenomenon. We will focus on discrete spatial variables that describe the discrete spatial distribution of phenomenon. Then you will learn a priori features and a posteriori features which can be defined based on the spatial variables and regionalisation. Moreover, representation of real world spatial features in object mode and image mode will be presented. We will introduce orientation of units that you will learn after this unit based on the knowledge you gained. Moreover, the linkage to the other lessons and modules are presented for your reference.

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1.1.1 Geographic Objects

G of GIS can be interpreted as *Geographic Object* or *Spatial Object* or Spatial feature or Geographic Individuals. At the planet scale, our world is only one object with the defined boundary. At the global scale, you can view our planet as water and land mass. They have their own defined boundaries. In our planet, there is more water mass than land mass. It is interesting why our planet is called Earth rather than Water. Anyway, at the more refined scale, electric poles, rivers, roads, tramlines, water pipes, fire hydrants, lakes, vineyards, agricultural land and the forest patches are examples of geographic objects. Most of the tangible geographic objects have the defined acceptable boundary and properties such as name, types and status etc. These are called discrete geographic objects. These are also called discrete objects. For example, lake Geneva has a defined boundary. Its name (*property*) is called Geneva lake. After that boundary, it is not known as Geneva lake. It is one of the most famous (*status*) urban lakes in the world. Therefore, Geneva lake is a discrete geographic object.

- The geographic boundaries are defined non thematically or thematically.
- The national boundaries are defined as the nationality as a theme.
- Land use and land cover boundaries are defined thematically.

These geographic objects have the phenomena too. It is difficult to delineate the boundary of these phenomena. Most phenomena are intangible or perceptible by sense such as temperature. Some phenomena are tangible such as distribution of vegetation at ecotone. *Ecotone* is the fuzzy boundary between two ecological communities. Temperature, rainfall, elevations and ecotones are good example of phenomenon. At the global scale, we cannot draw the *temperature* temperature boundary of our earth. At the more refined scale, we cannot still draw the temperature boundary of Geneva lake. Because, the boundary of the phenomenon does not truly exist. It exists arbitrarily as the fuzzy boundaries. The phenomena are continuous in nature. Therefore, these phenomena are illustrated with arbitrarily defined boundary which are normally fuzzy. We will learn how to draw the fuzzy boundaries for phenomena.

These phenomena are illustrated as continuous surfaces using grid cells. Each grid cell has a *real* value of phenomenon (e.g. continuous temperature) based on field measurements and interpolated values.

More detail on sampling and interpolation to generate the continuous phenomenon of geographic objects will be discussed in a dedicated lesson. More-

over, we will learn how to represent continuous phenomenon surfaces into *arbitrarily* defined *fuzzy* boundaries as discrete objects in the future units.

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Figure 1: Definition and example of discrete spatial variables (discontinues)

1.1.2 Spatial Features

The spatial objects can be represented in object (vector) mode or image (raster) mode. In object mode, individual spatial objects can be defined as point or line or polygon. In image mode, individual spatial objects can be defined as a set of contiguous cells, which are known as regions.

Although a spatial object and phenomenon can be defined in object mode and image mode. Discrete spatial objects can be more accurately present in object mode and continuous phenomena of spatial objects are more meaningfully presented in image mode.

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Figure 2: Spatial features (reminder)

The following presentation will focus on structures of lessons that illustrate concepts, techniques and methodologies on how to represent features in object mode or image mode based on discrete sample data collection of geographic features and their phenomena.

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Figure 3: Structure of the lesson

1.1.3 Develop a simple data model

1. Develop a simple data model for an urban road transportation information system.
2. Develop a simple data model for Soil pH distribution.

1.2 Individual spatial properties of features

As you have learnt in the spatial modelling lesson, spatial objects can be described as point, line and polygon (areal) features. Moreover, the spatial objects can be represented in object mode and/or image (raster) mode. In this unit, you will learn how to describe the geometric properties of spatial objects in image mode and object mode.

At the end of the unit, you should be able to describe geometric properties of point features, linear features and polygon features in image mode or object mode especially for your spatial analysis projects.

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Figure 4: Description of spatial properties

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1.2.1 Individual spatial properties of Point Features

Point features can be described as single x, y values in object mode or single column, row values in image mode.

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Figure 5: SpatialPropertiesPoint.swf

Example of representation of point features

The following graphic illustrates the representation of point features in object mode.

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Figure 6: Pointfeature.gif

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Figure 7: PointfeatureGISvector.gif

Create point features in point mode and image mode

1. Create a point feature file based on the following table using available GIS system, at your lab.

PointID	X(m)	Y(m)
1	2	3
2	3	1
3	6	2

Table 1: Legend missing

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Figure 8: PointfeatureGIS.gif

2. Create a raster representation of a point feature based on the point feature vector data that you have created above using available GIS system, at your lab.
3. Create an ASCII raster file based on the raster representation of the point feature.

1.2.2 Individual spatial properties of Linear Features

Linear spatial features such as road, railway and footpath can be represented as the series of single x, y values as a chain in object mode or a series of grid cells with respect to row and columns in image (raster) mode. The length, sinuosity and direction, are some geometric properties of line features.

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Figure 9: SpatialPropertiesLine.swf

Some Examples

Representation of *line feature* in image mode is similar to the structure of representation of *point feature* in image mode as you can see in the following example:

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Figure 10: Example of line feature in object mode

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Figure 11: Example of linear feature in image mode

Example of calculating length in image mode

Calculate the length in object mode

Create the line feature using available GIS system, from your lab, based on the following table. Then find out the length of the line feature manually.

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Figure 12: lineobjectimagemode.gif

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Figure 13: lineobjectcentercells.gif

Point	X (m)	Y (m)
1	247	133.5
2	251.5	136
3	256	133
4	263	137

Table 2: Legend missing

Calculate the length in image mode

Calculate the length of the linear feature in image mode based on the following presentation. In this presentation, all the cells that are passed through by the line **significantly and insignificantly** are considered for calculation of length in image mode.

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Figure 14: lineobjectimagemodeexercise.gif

1.2.3 Individual spatial properties of Aeral Features

Areal features such as forest land, agricultural land, park and land parcels etc. can be represented as the series of single x, y values as a closed chain in object mode or a set of contiguous grid cells with respect to row and columns in image (raster) mode. The location (position), size (area, perimeter) and shape (compactness) are the geometric properties of areal (polygon) features.

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Figure 15: SpatialPropertiesArea.swf

Examples

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Figure 16: Example of creating an areal feature in object mode

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Figure 17: Example of creating an areal feature in image mode

Calculate area and perimeter in object mode

1. Create a polygon feature in object mode based on the following table, using available GIS system at your lab. Find out the area and perimeter values calculated by the GIS system.

Point	X(m)	Y(m)
1	248	138
2	252	143

Table 3: Legend missing

3	262	142
4	263	133
5	255	132
6	250	129

Table 3: Legend missing

2. Calculate the area and perimeter of the created polygon using GIS. 3. Calculate the perimeter and area manually based on the created polygon feature.

Calculate the area and perimeter in image mode

Calculate the area, perimeter of the envelope and linear perimeter in image mode at 1 meter grid cell resolution based on the following presentation.

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Figure 18: Example of calculating area and perimeter in image mode

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Figure 19: polyexersel.gif

1.2.4 Questions

- Describe the geometric properties of the point feature
- Describe the geometric properties of the line feature
- Describe the geometric properties of the areal or polygon features

Share your results

- Share your answers with the class, using the class email list
- Submit your practical work of following sections as the attachment to the instructor by email:
 - Create point features in point mode and image mode
 - Create line feature in GIS
 - Calculate the length in image mode
 - Create areal feature in GIS

1.3 Spatial pattern and neighborhood of features

In this unit, you will learn the important concepts on spatial patterns, neighbourhoods, proximity and distance. After understanding the concepts, we will learn how to create buffer polygons around specified input features. Moreover, this unit will introduce how to convert point features to Thiessen or proximal polygons. The distance between features is also important; calculation of distances between features will also be introduced. In addition, you will learn how to create buffer regions around grouped input features.

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Figure 20: SpatialPatt_Introduction.swf

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1.3.1 Spatial pattern and neighborhood of Point Features

Here we will learn about spatial patterns and neighbourhoods of point features. Especially, how to measure the distance between point features, how to create a buffer polygon or polygons from a point feature and how to create proximal polygons from the point features.

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Figure 21: SpatialPatternPoint.swf

The linear distances (Euclidean distances) among the point features are fundamental properties to describe the spatial patterns of point features.

Example of distance calculation

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Figure 22: PointDistance.gif

The following is the result of calculating distances among point features or houses. The distance between a point and itself is 0.

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Figure 23: PointDistanceResultNew.gif

Example calculation of Thiessen Polygon

First, all points are triangulated into a Triangular Irregular Network (TIN) that meets the Delaunay criterion. Then, the perpendicular bisectors of each triangle edge are generated, forming the edges of the Thiessen polygons. The locations at which the bisectors intersect determine the locations of the Thiessen polygon vertices.

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Figure 24: PointDistanceForThiessen.gif

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Figure 25: ThiessenPolygons.gif

Example of buffering point features

Buffer polygon or polygons can be created by using a constant buffer distance or variable buffer distance around the specified input point feature.

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Figure 26: PointDistanceForBuffer.gif

Example of calculating closest distance

Closest distances can be calculated from the point features using Euclidian distance. The following example is calculated based on the on the point distribution map illustrated to the 0.5 m raster grid.

Then raster grid cells are allocated to the properties of point features based on the nearest proximity from the point feature (Thiessen's region).

Calculate the distance in object mode

1. Calculate the distance among point features, using the available GIS software from your GIS Lab, based on the point distribution map illustrated.
2. Calculate the linear distance between Migros and individual houses, using the available GIS software from your GIS Lab. The result should be similar to the following.

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Figure 27: PointDistanceForBuffer15.gif

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Figure 28: PointDistanceEC.gif

From Migros	To house	Distance
Migros	1	6.708
Migros	2	8.246
Migros	3	7.071
Migros	4	6.000
Migros	5	4.123
Migros	6	5.385
Migros	7	3.606
Migros	8	4.000

Table 4: Legend missing

Generate the Thiessen Polygons

Generate the Thiessen Polygons, using the available GIS software from your GIS Lab based on the point distribution map illustrated. The output area values should be similar to the values mentioned in the example illustration.

Calculate the closest distance in image mode

1. Calculate the closest distance, using the available GIS software from your GIS Lab, based on the point distribution map illustrated. You may choose the resolution of the grid cell.
2. Then allocate the grid cells to the property of the point feature based on proximity, using the available GIS software from your GIS Lab.

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Figure 29: PointDistanceECallocatev2.gif

1.3.2 Spatial pattern and neighborhood of Linear Features

Here we will learn about spatial patterns and neighbourhoods of line features. Especially, how to measure the distance between line features, how to create a buffer polygon or polygons from a line feature and how to create proximal polygons from the line features.

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Figure 30: SpatialPatternLinear.swf

Example of minimum distance calculation from a line feature

Closest distances are calculated using Euclidian distance formula in a similar way to calculating distances between point features, as illustrated above.

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Figure 31: lineecdistance.gif

Then the grid cells are allocated based on proximity distance.

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Figure 32: lineecallocate.gif

The following figure illustrates the result in vector or object mode.

Example of buffering line features

Buffer polygon or polygons can be created by using a constant buffer distance or variable buffer distance around the specified input line feature.

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Figure 33: lineecallocatevector.gif

Please note:

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Figure 34: linebuffer5.gif

Calculate the minimum distance of line features

1. Calculate the closest distance, using the available GIS software from your GIS Lab, based on the line distribution map illustrated. You may choose the resolution of grid cells.
2. Then allocate the grid cells to the property of the point feature based on proximity, using the available GIS software from your GIS Lab.

Create Buffers from linear features

1. Create the 0.5 meter constant buffer, using the available GIS software from your GIS, Lab based on the linear feature map illustrated.
2. Create the 1 m buffer around the linear features 1, 2, 3, and 4 and 0.5 m buffer around the linear features 5, 6, 7, and 8 at the same time, using the available GIS software from your GIS Lab, based on the linear feature map illustrated.

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Figure 35: linebuffer15v1.gif

1.3.3 Spatial pattern and neighborhood of Areal Features

Here we will learn about spatial patterns and neighbourhoods of areal features. Especially, how to measure the distance among areal features, how to create a buffer polygon or polygons from areal features and how to create proximal polygons from the areal features.

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Figure 36: SpatialPatternAreal.swf

Example of minimum distance calculation from the areal features

The distance value of each cell is not illustrated for the clarity of presentation. The euclidean distance is applied in a similar way to the distance calculation for point and linear features.

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Figure 37: aeraldistance.gif

Then the grid cells are allocated to the properties of areal features based on the nearest proximity distance between the cell and areal feature. The result should be similar to the following.

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Figure 38: aeraldistanceallocate.gif

The result can be represented as vector or object mode as the following example.

Example of buffering areal features

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Figure 39: aeraldistanceallocatevector.gif

Buffer polygon or polygons can be created by using a constant buffer distance or variable buffer distance around the specified input areal feature.

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Figure 40: areabufferconstant.gif

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Figure 41: areabuffervariable.gif

Calculate the minimum distance of areal feature (image mode)

1. Calculate the closest distance, using the available GIS software from your GIS Lab, based on the areal feature distribution map illustrated. You may choose the resolution of grid cells.
2. Then allocate the grid cells to the property of the areal feature, based on proximity using the available GIS software from your GIS Lab.

Create buffers around the areal features

1. Create the 0.5 meter constant buffer, using the available GIS software from your GIS Lab, based on the areal feature map illustrated.
2. Create the 1 m buffer around the linear feature 1 & 4 and 0.5 m buffer around the linear features 2 & 3 at the same time, using the available GIS software from your GIS Lab, based on the areal feature map illustrated.

1.3.4 Questions

1. Explain the method of Euclidian distance calculation in object mode and image mode. Then calculate the distance between Migros and House No.1 manually, based on the example presented in this unit.
2. Create Thiessen polygons based on the following presentation. Find out the errors on the example result, with respect to your result.

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Figure 42: thiessentest.swf

Submit and share your answer and results for question 1 and 2 among the class and to the instructor through email.

1.4 Weighted spatial pattern and neighborhood

In the previous unit, you have learnt the spatial patterns and neighbourhoods of features, based on the assumption that the space is homogeneous. Therefore, you can move throughout the space freely to any direction at the same amount of energy, time, cost etc.

In this unit, the space will be considered as heterogeneous. There is friction to your movement. This friction can be translated as cost, energy, attractiveness, time etc.. Firstly, time will be considered. If you are moving from town A to B through the highway, you use less time than through the footpath. The friction of the highway is lower than the friction of the footpath. This friction can be presented as weight. The higher the weight, the more preference you have. Although the distance along the highway may be longer than the footpath, the time distance is shorter. Therefore, the highway will be given higher weight and the footpath will be given lower weight in considering time of movement.

The weight value can be given to spatial objects based on preference, cost, energy, time etc. In this unit, you will learn about weighted spatial patterns and neighbourhoods of point features, line features and areal features.

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Figure 43: WegSpatPatt_introduction.swf

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1.4.1 Weighted Spatial Patterns and Neighbourhoods of Point Features

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Figure 44: WeightPoint.swf

Step by step illustration of weighted minimum distance surface based on the point feature

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Figure 45: WeightPointActNew.swf

Create weighted minimum distance surface

Create a weighted minimum distance based on the following point dataset. Minimum x and y is zero. Maximum x and y is 10. Select the resolution 1 meter or 0.5 meter, according to your choice.

Point	X	Y	Weight
A (id = 1)	2	2	3
B (id = 2)	3	5	2
C (id = 3)	6	4	1

Table 5: Legend missing

1.4.2 Weighted neighborhoods of Linear Features

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Figure 46: WeightLine.swf

Step by step illustration of weighted minimum distance surface based on the linear feature.

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Figure 47: WeightLineAct.swf

Create a weighted minimum distance surface

Create a weighted minimum distance, based on the following point dataset. Minimum x and y is zero. Maximum x and y is 10. Select the resolution as 1 meter or 0.5 meter, according to your preference.

Road	From	To	Weight
A (id = 1)	1,1	9,9	5
B (id = 2)	9,1	1,9	1

Table 6: Legend missing

1.4.3 Weighted neighborhoods of Areal Features

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Figure 48: WeightArea.swf

Step by step illustration of weighted minimum distance surface based on the polygon feature

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Figure 49: WeightPolyAct.swf

Create weighted minimum distance surface

Create minimum weighted distance surface, based on the following polygon feature. The list of vertices for each polygon is provided. Minimum x and y is zero. Maximum x and y is 10. Select the resolution as 1 meter or 0.5 meter, according to your preference.

Polygon	List of vertices	Weight
A (id = 1)	(1,1); (3,1); (3,3); (1,3); (1,1)	3
B (id = 2)	(7,1); (9,1); (9,3); (7,3); (7,1)	2
C (id = 3)	(7,7); (9,7); (9,9); (7,9); (7,7)	3
D (id = 4)	(1,7); (3,7); (3,9); (1,9); (1,7)	1

Table 7: Legend missing

1.4.4 Questions

1. Refer to Step-4 of the step by step illustration on the minimum weighted distance surface presentation for point or line or polygon features above. Why is the Euclidian surface is divided by the weight value?
2. Refer to Step-5 of the step by step illustration on the minimum weighted distance surface presentation for point or line or polygon features above. What is your strategy or concept to derive minimum weighted distance values based on weighted distance surfaces of each feature ID. How do you implement your concept in your GIS system? Describe in detail, the steps of implementation in your GIS System.
3. RRefer to Step-6 of the step by step illustration on the minimum weighted distance surface presentation for point or line or polygon features above. What is your strategy or concept to find out the influenced zone by each feature id based on the minimum weighted surface? How do you implement your concept in your GIS system? Describe in detail, the steps of implementation in your GIS System.
4. Refer to Step-7 of the step by step illustration on the minimum weighted distance surface presentation for point or line or polygon features above. How do you combine each zone in order to produce a map that shows all the zones? How do you find out which zones are influenced by more than one zone? How do you implement your concept in your GIS system? Describe in detail, the steps of implementation in your GIS System.

Share your results

Submit your answer to the instructor through email. Post your answer to the discussion board.

1.5 Regionalization

This unit will introduce how to delineate or define a boundary of a **spatial object (non pre-existed) and assign a value (nominal, ordinal and ratio) to it** or **label a pre-existed spatial object** Such as your farm based on point sample measurements of particular phenomena, such as soil texture and assign a value or label, such as sandy clay loam to your farm through the process of *regionalization*¹. At the end of the unit, you will learn how to assign or label the spatial objects (pre-existed or non pre-existed) using the regionalization concept. When the spatial distribution of phenomenon properties is assumed as discontinuous, it is important to consider several situations for assigning properties to features. Most of the time properties of a phenomenon are measured at specific locations (measurement sites). This set of data is called sample. From these point feature measurements thematic properties should be assigned to a set of spatial features.

Please note:

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Figure 50: objectconstruction.gif

Please note:

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Figure 51: thematicallocation.gif

Download the PDF version of the graphic and animation presentation of this unit.: www.gitta.info/DiscrSpatVar/en/download/regionalization.pdf

Learning Objectives

The following two complementary objectives will be accomplished during this unit of study:

¹Regionalization can be defined as: "The process of generalizing properties of a phenomenon throughout space, based on a set of observations". This definition is common to both continuous and discrete spatial distributions.

- To derive spatial features from the spatial distribution of measured properties: This process of object construction is called regionalization in the strictest sense.
- To assign a global thematic property to each spatial object from a pre-existing set, based on sample data: This process is called thematic allocation or labelling and can be considered as part of the regionalization.

1.5.1 Setting of spatial features (Regionalisation)

Regionalization: Regionalization can be defined as: "The process of generalizing properties of a phenomenon throughout space, based on a set of observations". *This definition is common to both continuous and discrete spatial distributions.*

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Figure 52: condistribution.gif

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Figure 53: discondistribution.gif

The following series of slides attempt to explain how to define a boundary of a spatial object (non pre-existed) using sample point measurements and regionalization processes.

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Figure 54: Regionalis.introduction.swf

1.5.2 Spatial object labeling

Labeling: Labelling is the process of thematic allocation to each pre-existing object, based on point measurements.

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Figure 55: labelling.swf

1.5.3 Questions

1. What are the two purposes of regionalization?
2. What is the basic data requirement for regionalization?
3. Describe the conceptual process of regionalization.

1.6 Transformation of spatial features

This unit will introduce how to aggregate the spatial features on the basis of spatial and/or thematic properties. Such as, aggregating the spatial features such as the dryland agriculture, wetland agriculture and mixed agriculture to agriculture, based on the thematic properties. Moreover, this unit will also introduce how to disintegrate or break up the spatial features according to spatial and/or thematic criteria; such as allocating a forest area within 200 meter from the drainages as riparian vegetation protection forests. The existing spatial features that are represented as forest will be broken up according to the aforementioned criteria. The process of spatial aggregation and spatial breaking up can be carried out using spatial analysis and overlay functions. Therefore, the process will not be repeatedly illustrated in this unit.

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Figure 56: Introduction to spatial feature transformations

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Figure 57: Example 1 of a spatial feature transformation process

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Figure 58: Example 2 of a spatial feature transformation process

Download the PDF version of the graphic and animation presentation of this unit.: www.gitta.info/DiscrSpatVar/en/download/B-AN-Les2-Un6-EN-5.pdf

1.6.1 Aggregation: a spatial generalization

The following illustration will explain the concept of aggregation for spatial generalization.

Please note:

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Figure 59: aggregatedetail.swf

1.6.2 Thematic criteria of aggregation

The following illustration will explain the concept of the thematic criteria of aggregation.

Please note:

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Figure 60: thematicaggregate.swf

1.6.3 Spatial criteria of aggregation

The following illustration will explain the concept of the spatial criteria of aggregation.

Please note:

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Figure 61: spatialaggregate.swf

1.6.4 Spatial and thematic criteria of aggregation

The following illustration will explain the concept of spatial and thematic criteria of aggregation.

Please note:

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Figure 62: spatialthematic.swf

1.6.5 Breaking up of spatial features

The following illustration will explain the concept of disintegration or the breaking up of spatial features.

Please note:

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Figure 63: breakingup.swf

Examples of braking up features

In the following example, land use and soil thematic spatial features will be broken up into new spatial units that illustrate distribution of land use on different soil types.

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Figure 64: breakingupfeature.swf

1.6.6 Practice

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Figure 65: practiceagg7.gif

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Figure 66: practiceagg8.gif

Glossary

Labeling: Labelling is the process of thematic allocation to each pre-existing object, based on point measurements.

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Figure 67: labelling.swf

Regionalization: Regionalization can be defined as: "The process of generalizing properties of a phenomenon throughout space, based on a set of observations". *This definition is common to both continuous and discrete spatial distributions.*

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Figure 68: condistribution.gif

Please note:

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed.

Figure 69: discondistribution.gif