CHAPTER 7

Spatial data analysis: retrieval, (re)classification and measurement operations

In chapter 5 you used a number of table window operations, such as calculations, aggregations, and table joining, in the analysis of attribute data. In the previous chapter you have seen the most important image processing tools that ILWIS provides for the analysis of satellite data. In this chapter, and also in chapters 8 and 9, attention will be paid to the data analysis tools, specifically for maps.

ILWIS for Windows provides a wide range of tools to perform operations on spatial data. These tools enable you to transform your input data into useful information.

There are several ways in which the data analysis tools can be subdivided. We have chosen the subdivision as suggested by Aronoff (see section 1.1 for reference):

– **Retrieval, (re)classification & measurement operations**

These operations mostly form the starting point in the data analysis process. They enable you to explore your data, without making changes to the location of spatial elements and without creating new spatial elements. Data retrieval involves the selective search of data. Reclassification involves the (re)assignment of thematic values to categories of an existing map. Measurement operations involve the measurement of distances between points, lengths of lines, area and perimeter of polygons, determination of volumes and counting.

All operations in this category are performed on single, vector or raster maps, and often in combination with attribute data.

Retrieval, (re)classification and measurement operations will be treated in this chapter.

– **Overlay operations**

This group of operations forms the core of many GIS projects. With the help of these operations, a number of maps are combined and new information is derived. New spatial elements are created. This set of operations is only performed on raster maps in ILWIS.

ILWIS has a powerful tool to combine maps, called *Map Calculation*. Many maps can be combined at the same time using arithmetic, relational, or conditional operators and many different functions in formulas that you can type on the command line of the main window.

Two other important tools to overlay raster maps are the *Cross* operation, which calculates the frequency of occurrence of all possible combinations of two maps, and the use of a *Two-dimensional table* which is a matrix in which the user can define how all classes of two maps should be combined.

Overlay operations will be treated in the next chapter, including an extensive demonstration of Map Calculation.

– **Neighborhood operations**

Where the overlay operations only consider the combination of raster cells in different maps at the same location, the neighborhood operations evaluate the characteristics of an area *surrounding* a specific location. These operations make use of small windows (e.g. of 3 by 3 cells) which perform one calculation on a center raster cell and its eight neighbors. The result is stored in the central cell. Four neighborhood operations will be treated in chapter 9: neighborhood operations in Map Calculation, *Filtering* (as was shown in the previous chapter for satellite images, but now applied to thematic maps), *AreaNumbering* and *Distance* calculation.

For many operations Map Calculation can be used. *Map Calculation* is treated as a single block of exercises in the next chapter.

Before you can start with the exercises, you should start up ILWIS and change to the subdirectory c:\ilwis21\data\usrguide\chap07, where the data files for this chapter are stored.

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- Double-click the ILWIS program icon in the ILWIS program group.
- Change the working drive and the working directory until you are in the directory c:\ilwis21\data\usrguide\chap07.

7.1 Retrieval using the pixel information window

Data retrieval involves the (selective) search, manipulation and output of spatial and/or attribute data. Retrieval operations can be subdivided into the following groups:

– **What is at... ?.**

To find out what is present at a particular location. Reading of the contents of maps and related attribute tables at specified XY-coordinates. In ILWIS, the pixel information window can be used to read the values from vector and/or raster maps, with their accompanying tables.

– **Where is ....?.**

Retrieval of spatial data (points, lines, polygons or mapping units in a raster map) to find an answer to questions such as: "Where are the forested areas?"

The *pixel information window* is used to interactively inspect coordinates, class names, IDs or pixel values, in one or more maps and map-related tables. The pixel information window shows information for the mouse pointer's position in a map window. In chapter one, the functionality of the pixel information window was already introduced to you.

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- Open raster map FCC.

- Open the pixel information window by clicking the button on the button bar.

- Open the Help menu and select the command Help on this window. Click the hypertext word: Introduction. You can use the forward button at the top of the Help window to read more information.

- When you have finished reading the help on the pixel information window, close the Help window.

To view attribute information in a pixel information window, you have to add one or more maps that have an attribute table to the pixel information window. You should display at least one map in a map window.

In this exercise you will start to read the information from four polygon maps Geology, Geom (geomorphology), Landuse, and Catchmen (watersheds in the mountain area) together with their tables. In the map window you will display a false color composite made of the TM bands 4,3 and 2.

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- Drag polygon map `Geology` from the Catalog and drop it in the pixel information window.

- Then, add the polygon maps `Geom`, `Landuse` and `Catchmen` to the pixel information window in the same way.

For this exercise we have also prepared some maps that are made from the segment map `Contour`: a Digital Elevation Model (`Dem`) and a slope map (`Slope`). The DEM shows the altitude of each raster cell, and the slope map shows the slope angle in degrees. The procedure to construct such maps is explained in chapter 10.

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- Also add the raster maps `Dem` and `Slope` to the pixel information window.

Firstly, the pixel information window receives the XY-coordinate from the mouse pointer (located in a map window) or the digitizer cursor (located on a referenced paper map on the digitizer). Then, for this received coordinate, information of all raster, polygon, segment and point maps that were added to the pixel info window is retrieved and displayed simultaneously. For raster maps, the retrieved information refers to the pixel pointed at with the mouse pointer, hence pixel info.

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- Click somewhere in the map window. You can see the corresponding information of that location in the pixel information window.

- Move the mouse pointer through the map to continuously display the information.

The three polygon maps do not cover the entire area displayed in the false color composite. If you move to the right of the image, you will see that the information from the geologic and geomorphologic maps is missing. Only question marks are shown, which mean *undefined*.

You can use pixel information to become familiar with the data and to find out certain relations between one map and another. To find such relations it may be also useful to display these maps on top of the false color composite.

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- In the map window, open the Layers menu and select Layer Management.

- Add the following *polygon maps* to the list in Layer Management (select for each map Boundaries Only in the Display Options - Polygon Map dialog box):

  Geology (boundary color: Magenta)

  Landuse (boundary color: Green)

  Geom (boundary color: Yellow)

  Catchmen (boundary color: White).

For more information on how to use the Layer Management dialog box we refer to chapter one and to the on-line Help.

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- Click the Help button in the Layer Management dialog box.
- After reading the help information, close the Help window.
- Click OK in the Layer Management dialog box.

All layers are now displayed in different colors on top of each other. Let us only display one layer: Landuse.

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- From the Layers menu, select Layer Management.
- Select each layer and clear the Show check box (except for layers Landuse and FCC).
- Click OK.

Now you can only see the green boundary lines of the land use polygons.

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- Move the mouse pointer through the map, while you keep the left mouse button pressed. You can read simultaneously the land use information in the map, and all other information from the pixel information window.

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- Find the answer to the following question:

  What is the predominant geological unit which is used for irrigated agriculture?.

By manipulating layers that are displayed in a map window and information shown in the pixel information window, you can easily evaluate your data.

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- Find the answer to the following questions (use the information in the pixel information window, and change the displayed polygon layers using Layer Management in the map window as you wish):

  - What is the predominant land use type on the alluvial fans, just north of the city of Cochabamba?

  - What is the maximum elevation at which we still find forest?

  - For which catchment do we not have geological nor geomorphologic information?

  - Are there parts of the city of Cochabamba that may be flooded?

  - Which one of the geomorphologic zones (column zonation) has the steepest slope? In which range are these slopes?

When you finish the exercise:

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- Close the pixel information window and the map window.

7.2 Retrieval of information by displaying attributes

The pixel information window allows you to retrieve information for the X Y-coordinates where the mouse pointer is located. However, in many cases you do not want to have the information for one location only, but for an entire map.

In this exercise you will learn how to display attribute data from a column in a table, which replaces the original information in a map.

The city block map is taken as an example. In chapter 5 (attribute data handling) you worked with table Citybl (which contains information such as area, land use, district number, population and population density for each city block).

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- Open table Citybl and inspect the properties of the various columns, by double clicking column titles. As you can see, the column Landuse has a class domain (Cityluse), the column District has an ID domain (District), and the columns Area, Population, and Popdens all have a value domain. When you have seen the properties of the columns, close the table again.

- In the Catalog, double-click polygon map Citybl. Accept the defaults in the Display Options - Polygon Map dialog box and click OK.

The city block map is now displayed in seven different colors. Each city block has a unique code.

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- Click some of the units in the map and find out their codes.

- Double-click a unit in the map to find information in the attribute table that is connected to the map.

- Close the Edit Attribute window.

As you can see, there is information on each city block. The white areas (the roads in-between the city blocks) have no information. Although you could, for example, double-click each city block to find out its land use, it is obvious that this is a tedious procedure. ILWIS has a more flexible way: you can display a map by one of its attributes.

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- In the map window, open the Layers menu and select Layer Management. The Layer Management dialog box is opened. As you can see there is only one layer: the polygon map `Citybl`.

- Select the map `Citybl` in the Layer Management dialog box and click the Display options button.

The Display Options dialog box is opened.

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- Select the check box Attribute. Now a list box appears to the right of the word Attribute, containing columns of the attribute table `Citybl`.

- Select the column `Landuse`. This column contains the dominant land use type of each cityblock.

- Select the option Representation. After a moment the representation `Cityluse` will appear in the list box to the right of the word Representation.

Column `Landuse` has a class domain (called `Cityluse`) which has a representation (`Cityluse`).

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- Click OK in the Display Options - Polygon Map dialog box.
- Click OK in the Layer Management dialog box.

The map `Citybl` is re-displayed, but now in such a way that the colors no longer represent the various codes of the city blocks. The colors now show the land use types according to representation `Cityluse`.

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- Click on the different units in the map. You can see that for each city block the land use type is shown as well as the code of the city block.

Displaying a map by one of its attributes allows you to get a good idea on the distribution of the different attribute values throughout a map.

You will display another attribute of the city block map: `District`. Each city block forms part of a cadastral district of the city. The `District` column uses an identifier domain.

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- Click with the right mouse button while the mouse pointer is in the map window. Select the last line from the context-sensitive menu (`1 pol Citybl`). This is a short cut to go to the Display Options dialog box of the layer.

- Select the check box Attribute, and select column `District`. Since this column uses an identifier domain, you cannot select a representation. Instead, you can display districts in 1, 7 , 15 or 31 colors.

- Select the option Multiple colors, and 15. Click OK. Now the map is displayed according to the districts of the city.

- Check the content of the map by clicking a few different units.

Now the map `Citybl` will be shown by the attribute population density. The column `Popdens` uses a value domain.

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- Change the options in the Display Options dialog box in such a way that the attribute `Popdens` is displayed with the representation `Pseudo`. Stretch between 0 and 1000.

- Check the contents of the map window.

- Close the map window after you have finished the exercise.

You can display both raster and vector maps by one of its attributes, as long as the map has a class or ID domain and an attribute table is linked to the map. This is defined in the Properties dialog box of the map.

Retrieval with a mask

Finally, you will have a look at some other useful options in the Display Options dialog box that help you to evaluate the data.

We will switch to another example: the land use map of the region around the city of Cochabamba, called `Landuse`. You can selectively display units in a map, e.g. only the land use type `Forest`.

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- In the Catalog, double-click polygon map `Landuse`. The Display Options dialog box is opened.
- Select the check box Mask, and type the class name `Forest` in the appearing text box.
- Click OK in the Display Options dialog box.

Only the land use unit `Forest` is shown in the map window. Suppose you want to show the following four units: `bare rock`, `bare soils`, `agriculture`, and `agriculture (irrigated)`. Instead of typing the full names you can use *wildcards*: the asterisk * to replace zero or more characters, and the question mark (?) to replace one character.

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- Open the Display Options dialog box of polygon map `Landuse` again.
- Select the check box Mask, and type the following search strings in the appearing text box: `Bare*,Agri*`
- Click OK in the Display Options dialog box.

  Now only four units of the map are displayed: `Bare rock`, `Bare soils`, `Agriculture` and `Agriculture (irrigated)`.
- Close the map window.

A mask can be used to selectively display vector data. For maps with many different units this can be quite useful, e.g., to show specific contour lines.

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- In the Catalog, double-click segment map `contour`.
- In the Display Options dialog box, select the check box Mask, and type the following search strings in the appearing text box: `30*,31*,32*,33*,34*`
- Select the check box Info.
- Click OK in the Display Options dialog box. Only the contour lines from 3040 to 3440 are displayed.
- Click with the right mouse button and select the last line from the context-sensitive menu.

- In the Display Options dialog box, select the check box Mask, and type the following search strings in the appearing text box: ??00
- Click OK in the Display Options dialog box. Only the hundred meter contour lines are displayed.
- Close the map window.

For more information , open the Help, search for Mask, and open the Help topic: How to use masks.

Summary: retrieval operations

In the previous exercises methods were shown that can be used to retrieve information from maps and from the connected attribute tables.

- In exercise 7.1, you practiced with the pixel information window. The pixel information window allows you to read data from many maps and tables simultaneously, for the X Y-coordinate that you point at with your mouse pointer.
- In exercise 7.2, you displayed a map by one of its attributes. An attribute table should be linked to the map, and the column values that you show may use a representation.
- Both vector and raster maps that have a class or identifier domain and that have an attribute table linked to it, have the possibility to display attributes instead of their own classes or IDs.
- Displaying a map by one of its attributes is useful to investigate the spatial distribution of attribute information, without the need of generating a new map.
- You can also use a Mask to selectively display some classes, IDs or values of a map.

7.3 Reclassification with Map Calculation formulas

In the previous exercises we have seen several tools that can be used for data retrieval in ILWIS. There is another important tool: *Map calculation formulas*. The Map Calculation tool forms the core of ILWIS. With this operation you can do all kinds of calculations with maps. In the next chapter we will treat Map Calculation in depth. Here we want to show you some examples of how it can be used for data retrieval and classification.

The expression of a Map calculation formula often has the notation *IFF(.... , ... , ...)* : an IFF function consists of a condition, a then part and an else part. The condition that should be met is written first, followed by the result if the condition is met, and by the result if the condition is not met (Figure 7.1). The result of data retrieval using MapCalc is a new raster map.
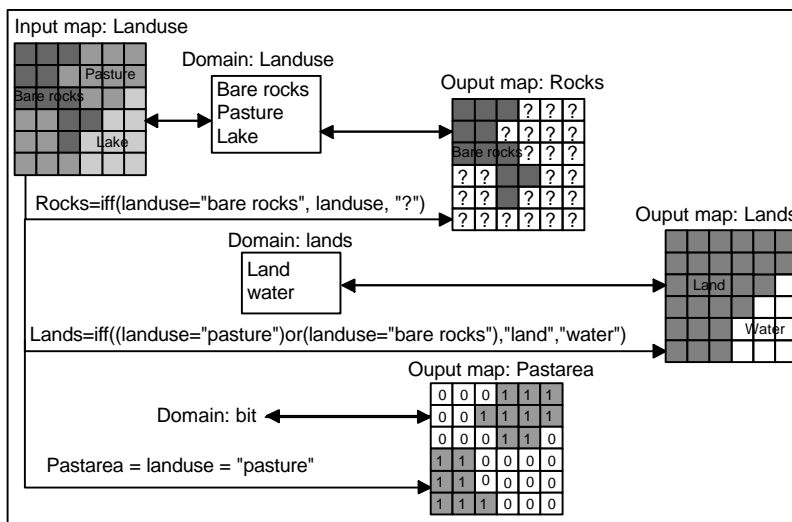

Figure 7.1: Examples of data retrieval and classification using different MapCalc formulas (see the following exercises for explanation)

Using a Map Calculation formula for data retrieval

In this exercise the raster map Landuse is used for a retrieval operation. This map has a class domain, representing the land use types in the Cochabamba area.

Suppose you are interested in defining the location of the bare rocks in the area, this can be done by selecting the mapping units with a MapCalc formula.

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>
> • Type the following formula on the command line in the main window:
>   Rocks=iff(Landuse="Bare rock",Landuse,"?")

In words this formula means: If the land use type is `Bare rock`, then the resulting map (`Rocks`) will contain the information from the `Landuse` map (thus class `Bare rock`). Or, if the land use is not bare rock, then the pixels in the output map will be classified as undefined, indicated by the "? "sign. The resulting map `Rocks` is also a class map and uses the same domain (`Landuse`) as the input map.

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- Press Enter after typing the formula. The Raster Map Definition dialog box is opened. Accept the defaults by clicking OK.

At this stage only the definition, i.e. the formula to calculate the output map (the text box Expr. in the dialog box) is saved but the actual calculation has not yet been performed. When you now open the map, the formula will be calculated.

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- Double-click the raster map `Rocks` in the Catalog. The Display Options - Raster Map dialog box is opened. Accept the defaults by clicking OK.

The map `Rocks` is displayed on the screen; it only contains one unit: `Bare rock`. The rest of the map is undefined.

It is important to note that this is an example of a rather inefficient way to carry out data retrieval. To get an answer to our question: "where are the bare rocks" we have created another raster map, which occupies a considerable amount of disk space, and which contains about 90 % undefined values. The information where bare rocks can be found, could be obtained more easily by displaying the polygon map land use with the mask "`Bare rock`", as was demonstrated in the previous exercise.

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- Close the map window.

Data retrieval with a Boolean statement

Let us give another example of the use of a MapCalc formula for data retrieval (see figure 7.1). Suppose we are interested to know the location of the areas with the land use "`Grassland`". We will use a so-called *boolean* statement. A boolean statement has only two possibilities: the statement is true (if the condition is met), or it is false (if the condition is not met).

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- • Type the following formula on the command line in the ILWIS main window:

        grass = Landuse = "Grassland" ↵

- • The Raster Map Definition dialog box is opened. As you can see, the suggested domain is called: bool (for Boolean).Click OK.

- • Double-click the raster map Grass in the Catalog. Accept the defaults in the Display Options - Raster Map dialog box. Then the map is displayed.

- • Click the various units to find out what they mean.

As you can see the pixels in a raster map with a bool domain can only be True or False. Undefined pixels in an input map remain undefined in the output map. This is logical, because if you do not know what the land use type is (that is the meaning of the undefined values), you cannot say whether it is grassland or not. A bool domain thus also allows undefined values. This is different for a similar domain type called *bit*. The bit domain also allows only two conditions: 1 (true) or 0 (false), but it doesn't allow undefined values.

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- • Close the map window.

- • Repeat the calculation, but now select the bit domain in the Raster map definition dialog box. Display the map Grass (now with bit domain) again, and click on the units to see their meaning

- • Close the map window when you have finished.

If you use the bit domain, the undefined values also become 0 (false). Therefore, it is better to use the bool domain unless you are sure that you want to include the undefined values also.

Simple reclassification with a MapCalc formula

The previous two examples were more intended for data retrieval rather than for reclassification. No new values were assigned to pixels in the output map. Let us now look at a simple example in which we do want to give the output map a meaning which is different from the input map.

Suppose, in this example (similar to the one shown in figure 7.1), that you are interested to differentiate between land and water in the area. The land use units are reclassified into new names, either "Land" or "Water". These two new class names (Land, Water) do not occur in the domain Landuse.

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- Type the following formula on the command line:
  ```
  Landwat=iff((Landuse="Lake")or(Landuse=
  "Riverbed"),"Water","Land")
  ```
- Press Enter. The Raster Map Definition dialog box is opened.

The domain list box in the Raster Map Definition dialog box is empty. This is because the program does not know which domain to select, since both the names "Water" and "Land" do not occur in the domain of the input map Landuse. Now there are two options:

− Either you add the items "Water" and "Land" to the domain Landuse, or

− you create a new domain with these two class names.

We will select the latter option here. Since "Land" and "Water" are not really land use types, it is better to put them in a separate domain.

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- Select the Create button of the domain list box. The Create domain dialog box is opened.
- Type the domain name Landwat. Click OK. Now the Domain Editor is opened. Close the Domain Editor. You are back in the Raster Map Definition dialog box. Click OK.
- The Merge domains dialog box appears, with the question: Add string 'Water' to domain 'Landwat'. Answer with Yes.
- The Merge domains dialog box appears, with the question: Add string 'Land' to domain 'Landwat'. Answer with Yes.
- Open the representation Landwat and change the color of the class Land to Green, and the one of Water to Blue. Close the Representation Editor.
- Open the map Landwat. Accept the defaults in the Display Options -Raster Map dialog box and click OK. In the map window, use the left mouse button to inspect the meaning of the units.
- Close the map window.

MapCalc formulas are a suitable tool to perform simple reclassifications of class maps, such as the one you just did. However, if you want to assign different values to each of the land use units, the MapCalc formula would become too long and too complicated. Therefore, for more complex reclassifications of raster maps with a class or ID domain, it is easier to store the attributes in a table, and to reclassify the map with the values from the table. This will be demonstrated in the next exercise.

Classifying value maps with Map Calc formulas

The final example of the use of Map Calc formulas for (re)classification shows how to classify data from a raster map with domain type value. In this exercise the raster map Dem (digital elevation model) is used. The values in this map represent the altitude of the terrain and range from 2640 to 4500 meters. By performing the next operation a class map with three classes is created: (low = <3000 meters, moderate = 3000-4000, and high >= 4000 meters).

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- Double-click the MapCalc item in the Operations-list.

The Map Calculation dialog box is opened. This is another way to work with Map Calc; of course you can also type the formula directly on the command line.

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- Type the following expression in the text box Expression:
  `iff(Dem<3000,"Low",iff(Dem<4000,"Moderate","High"))`

This is called a *nested IFF statement*: one IFF statement within another.

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- Type Demc in the text box Output Map Name. Click the check box Show.
- Click the Create Domain button next to the Domain list box. The Create Domain dialog box is opened. Type Demc in the text box Domain Name.
- Accept the defaults by clicking the OK button in this dialog box. The Domain Editor is opened. Close the Domain Editor.
- Click OK in the Raster Map Definition dialog box.
- Add the following items to the domain Demc: Low, Moderate and High.

The Display Options - Raster Map dialog box is opened.

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- Select the check box Legend.
- Accept the other defaults and click OK. The map is displayed. Click the units to find out their meaning.
- Close the map window when you are ready.

We can draw the same conclusion as before: Map Calculation formulas are suitable for simple classifications. If we want to make more complex classifications, we would need to make many nested IFF statements, which would make the formula too long and too complex. Unlike class and IF maps, there is no possibility to reclassify value maps by an attribute table as value maps cannot have an attribute table.

To solve this problem of complex classifications, we can make use of a special operation, called *Slicing*. This will be explained in section 7.5.

Summary: Using Map Calc formulas for retrieval and (re)classification

– In this exercise we have seen that it is possible to retrieve information from a map, using a Map calculation formula.

– The expression of a Map calculation formula often has the notation **iff(.... , ... , ...)** which is called an IFF function with conditional, then and else parts.

– The result of a Map calculation formula is a new output map. The domain of this output map depends on the contents of the formula. The domain of the output map can either be class, ID or value. A combination of the three is not possible.

– If you use a Map calculation formula for the retrieval of one unit in a map, you can use the same domain for the output map as for the input map, and assign undefined to all other classes.

– Another option for data retrieval using a Map calculation formula is to use a so-called Boolean statement, which can either be true or false.

– Data retrieval with a Map calculation formula is rather inefficient. The same information can be found easier by displaying the polygon map with a mask.

– Data retrieval with a Map calculation formula is required in those situations where you want to use the result map in other calculations.

– MapCalc formulas are a suitable tool for performing simple reclassifications of class maps. More complex reclassifications would require many nested IFF statements.

– Therefore, for more complex reclassifications of raster maps with a class or ID domain, it is easier to store the attributes in a table and to reclassify the map with the values from the table.

– For value maps, the problem of complex classifications can be solved by using a special operation called Slicing.

In this exercise we have only seen some aspects of the Map Calculation functionality. In chapter 8, dealing with overlay operations, there will be a more in depth discussion on the use of Map calculation.

7.4 Reclassifying a map with attribute data

In exercise 7.2 you saw that it is possible to display attributes related to a map, without actually generating a new map. In many cases, however, when you want to use such an attribute map in further analysis, it will be necessary to generate a map from the attributes, in an operation called reclassification, or Attribute map. Reclassification involves the (re)assignment of thematic values to the categories of an existing map. In the previous exercise we have seen that for simple reclassification also Map calculation formulas can be used. If we want to reclassify many classes, the formulas become too complex, and it is better to use attribute tables.

Raster, polygon, segment or point maps with the domain type class, ID or group can have an attribute table with additional information on the elements in the map. The relationship between the table and the map is provided by their common domain.

When a map is linked to an attribute table, an attribute map can be created based on the columns of the table. In other words, a map linked to an attribute table can be re-classified based on its attribute data. The domain type of the column is selected for the new map. The data in the new map represents the information of the column which can be values, class names or IDs. An example of a reclassification using an attribute table is shown in figure 7.2.

Map: city blocks   **Attribute table: City blocks**   **Attribute map: Land use**

	Landuse
001	Residential
002	Residential
003	Residential
004	Commercial
005	Commercial
006	Recreational
007	Residential
008	Residential
009	Residential
010	Residential
011	Residential
012	Commercial
013	Residential
014	Residential
015	Institutional
016	Residential
017	Residential
018	Residential
019	Commercial
020	Residential
021	Residential
022	Institutional
etc.	

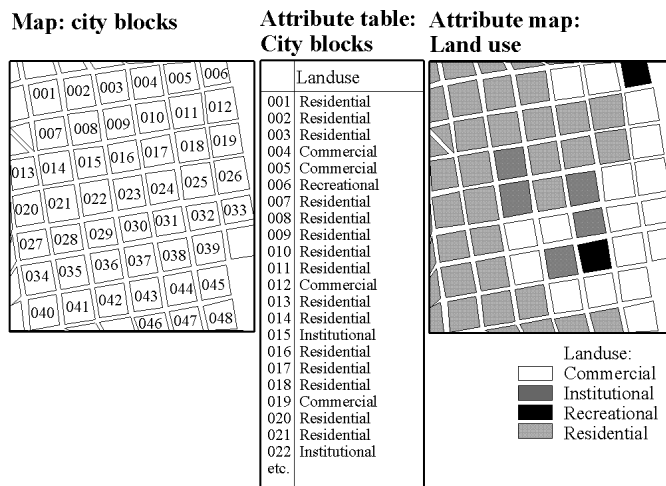Landuse:
Commercial
Institutional
Recreational
Residential

Figure 7.2:: Example of a reclassification using an attribute table. The map city block (with a domain ID) is reclassified to the map Landuse (with a class domain) using the column Landuse from the attribute table.

In this exercise you will first use the polygon map Citybl to create a new polygon map representing the land use of the city blocks of Cochabamba. The polygon map Citybl has an identifier domain; each unit is codified by an ID from 1 to 717. This map has an attribute table which is also called Citybl. One of the columns

in this table (Landuse) shows the dominant land use class for each city block. The Landuse column is used to reclassify the polygon map and create a polygon map with domain type class representing the land use in the city.

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- Double-click the icon AttribPol in the Operations - list.

The Attribute Map dialog box is opened.

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- Select polygon map Citybl in the list box Input Map.
- Select column Landuse in the list box Attribute.
- Type Cityluse in the text box Output Map.
- Click the check box Show.
- Type Dominant land use in the text box Description.
- Click OK.
- In the Display Options - Polygon Map dialog box, accept the defaults by clicking the OK button.

The output map is displayed on the screen.

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- Evaluate the content of the map by clicking some units.
  Note that the reference to the city block code is no longer displayed (as was the case in the previous exercise, when we displayed the map Citybl by its attribute Landuse).
- Also generate a polygon attribute map District, by using the column District and the map Citybl.

In chapter 5 (attribute data handling) you have created a table District with information on each district of the city. Now that you have also generated a district map, and as both the map and the table use the same domain (District), you can link the table District to the map District.

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- In the map window, open the Edit menu and select the Properties command. The Polygon Map Properties dialog box appears.

- Click the check box Attribute. Select the table District. Click OK to close the dialog box.

- Open the pixel information window, and drag the polygon maps Citybl, Cityluse and District to it. Evaluate the contents of the maps and tables while moving with the mouse pointer over the map.

- Close the map window and the pixel information window.

An attribute map can also be made by typing an expression on the command line of the main window. You will now use the Landuse map, showing the land use in the entire study area (not just within the city), and the column Landvalue from the accompanying table Landuse to reclassify the map.

☞

- Position the mouse pointer on the command line of the main window and type the following command:

    Landvalu=Landuse.Landvalue ↵

- Click OK in the Raster Map Definition dialog box.

- Display the map Landvalu with a pseudo representation, and stretch between 100 and 750. Close it when finished.

Summary: Reclassifying a map with attributes

– Vector or raster maps with a class or identifier domain often have an attribute table linked to it.

– The attribute table and the map have the same domain. The table contains columns with attribute information on the units of the map.

– Each of the columns in an attribute table also has a certain domain (either another class domain, an identifier domain, or a value domain).

– You can substitute the classes of the original map by the attribute values from one of the columns in the attribute table. The new map always uses the same domain as the selected attribute column.

– You can make a reclassification using a dialog box, or using the command line.

7.5 Classifying a value map (Slicing)

A raster map with the domain type value cannot be reclassified by the method explained in the previous exercise, since you cannot attach a table to it. Take for example a Digital Elevation Model (DEM). This is a value map which contains a wide range of values. The DEM in the demo data set, for example, contains values between 2520 and 4560, with a precision of 0.1. Suppose we would like to classify this map into five different height zones. It would require a very large table, with an attribute column containing a lot of repetitive values.

In such a case it is much easier to use a so-called *classify table*. A classify table contains only the input boundary values and the output class names. In ILWIS the concept of classify tables is applied in the Slicing operation (Figure 7.3). The classify table in ILWIS is called a *Group domain*; it contains the input boundary values and output class names.

Ranges of values of the input map are grouped together into one or more output classes. The output map resulting from the Slicing operation is a map with the domain type group. A domain *group* should be created beforehand or during the operation using the Map Slicing dialog box; it lists the upper boundaries of the groups and the group names.

!   For ILWIS 1.41 users: the domain type group acts as a classify table. The Slicing operation can be also performed on images (see chapter 6).
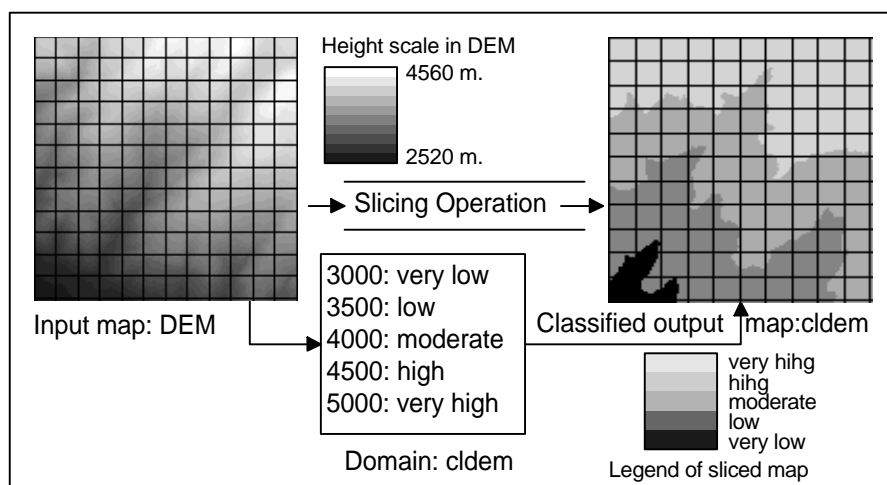

Figure 7.3: Process of slicing operation using DEM as an input map.

In this exercise the Slicing operation is performed on the raster map Dem in order to group the altitude values (ranging between 2520 to 4560 meter) into five relative altitude classes, shown in table 7.1.

Table 7.1: Boundary values and class names for the group domain Demc1

Upper boundary	Group name
3000	altitude less than 3000 meters
3500	altitude between 3000 and 3500 meters
4000	altitude between 3500 and 4000 meters
4500	altitude between 4000 and 4500 meters
5000	altitude between 4500 and 5000 meters

The raster map Dem (to create a DEM see chapter 10) has a domain type value in which pixel values refer to the height of the terrain.

Before a Slicing operation is performed, it is useful to firstly apply a method which shows the map, as if it was classified, by manipulating the representation.

☞

- Double-click raster map Dem. The Display Options dialog box is opened.

- Click the Create button next to the Representation list box. The Create Representation dialog box is opened.

- Type for Representation Name: Demc1. Click OK. The Representation Editor is opened.

- Open the Edit menu and select Insert Limit. The Insert Limit dialog box is opened. Enter the limit: 3000 and select the color Red.

- Insert also the other limits shown in the table above (3500, 4000, 4500) and select a color for each.

- Open the Edit menu and select Stretch Steps. Change the Stretch steps to 1. Click OK.

- Double-click the word Stretch between two limits. It changes now to upper. Double-click again. Now it changes to lower. Do the same for all the others.

- Close the Representation Editor. You are back in the Display Options dialog box. Click OK. The map is now displayed as if it was classified.

The representation can be edited, and the result shown on the screen (using the redraw button in the map window, will redraw the map with the updated representation). This allows you to interactively select the best boundaries for the

classification. Now you will do the actual classification, using the Slicing operation.

☞

- Double-click the Slicing operation in the Operations-list.

The Map Slicing dialog box is opened.

☞

- Select Dem in the Raster Map list box.
- Type Cldem in the Output Raster Map text box.
- Select the Show check box.
- Type Classified DEM in the Description text box.
- Click the Create Domain button next to the Domain list box. The Create Domain dialog box is opened.
- Type Cldem in the Domain name text box.
- Make sure to select the option Class and the check box Group.
- Click the OK button of this dialog box.

The Domain Editor is opened. For a group domain, you can enter an upper boundary, a name and a code for each class/group. This domain will be used to slice or classify the raster map Dem. The upper boundaries and group names, shown in the previous table, will be used in this exercise.

☞

- Open the Edit menu of the Domain Editor and select Add Item. The Add Domain Item dialog box is opened.
- Type 3000 in the Upper Bound text box.
- Type altitude less than 3000 meters in the Name text box. The use of a code is optional. It will not be used now.
- Click OK.
- Press the Insert key of the keyboard to enter the next upper boundary and name.
- Repeat the steps and add the other classes with boundary values: 3500, 4000, 4500 and 5000.

When you create a domain group, a representation is also created. It is possible to edit the colors of the output groups/classes from the Domain Group Editor, or by opening the representation. To edit the representation:

☞

- Open the Edit menu in the Domain Editor and select Representation.

The Representation Editor is opened, showing the five groups/classes that are present in the domain with different colors.

☞

- Double-click a color of a group name and select a pre-defined color, or edit the colors of the selected group by changing the amount of Red, Green and Blue.
- Exit the Representation Editor when you are satisfied with the colors.
- Exit the Domain Editor.
- Click OK in the Map Slicing dialog box.

The Display Options - Raster Map dialog box is opened.

☞

- Select the Legend check box.
- Accept the defaults by clicking OK. The map and the legend are displayed on the screen.
- Use the pixel information window to compare the values of the original map (Dem) with the names in the classified map (Cldem).
- Close the Pixel information window and the map window.

A value map can also be classified by typing an expression on the command line of the main window. You will now use this method to classify the Landvalue map (Landvalu), generated in the previous exercise. This map shows the value of the land in fictitious monetary values per hectare for each land use type. The values in the map Landval1 range from 50 to 1000. You will classify this map into three classes: Low: land value lower than 100, Moderate: land value between 100 and 750, and High: land value higher than 750.

> ☞
>
> - Create a group domain `Landvalc`. Add three classes with the boundaries as given above. Use 1000 as Upper Boundary for the third class.
> - Locate the mouse pointer on the command line of the main window and type the following command:
>
>   `Landvalc=clfy(Landvalu,Landvalc)↵`

The expression has the following structure:

`OUTMAP=CLFY(InputMapName,DomainGroup)`

in which:

`OUTMAP` is the name of your output map. `CLFY` is the function to classify values according to a domain group. `InputMapName` is the name of the input map (domain value map). `DomainGroup` is the name of the domain group; it lists the boundaries of the values and the group names for the output map.

> ☞
>
> - Click OK in the Raster Map Definition dialog box.
> - Display the map `Landvalc`.
> - Use the left mouse button in the map window to inspect the result.
> - Close the map window.

Summary: Classifying a value map

- A value map cannot be reclassified from an attribute table.
- A value map can be classified with the Slicing operation, which requires a group domain. A group domain is a special class domain, containing the names of the classes and the boundary values.
- A group domain can also be used for classifying values in tables (see chapter 5).

7.6 Measurement operations on point maps

In the remaining part of this chapter a new group of operations will be shown: *measurement operations*. Measurement operations enable you to obtain all kinds of statistical information on vector and/or raster maps. You can do different types of measurement operations, depending on the type of map:

– Points. The number of points in a point map can be calculated, using a histogram, or the number of points that fall within the same pixel, using the point density operation. The distance between points can easily be measured.

– Segments. The number and length of segments (such as drainage lines, roads, or geological faults) can be calculated with the Histogram operation. The direction of segments can also be calculated. Measurement operations on segments will be treated in section 7.7.

– Polygons. For polygons we can calculate the area of the different units, and the length of the borders around them using the Histogram operation. This is shown in section 7.8.

– Raster maps. For raster maps we can also calculate histograms. A histogram of a class or ID map will be different from the one of a value map. Both types are shown in section 7.9.

Measurement operations on point data

In this section three measurement operations dealing with points will be shown:

– Calculation of histograms for points
– Calculation of point density within pixels
– Calculation of distance between points
– Point in polygon calculation

Other statistical operations which can be performed on point maps, such as spatial correlation and pattern analysis, are treated in chapter 11, together with the various point interpolation techniques. There are a series of calculations that can be done with the coordinates of point maps. An overview of these and several examples are given in the On-line Help and the Reference Guide.

Calculating the number of points

You will first look at the calculation of histograms for point maps. Since there is no appropriate example ready in the demo data set, an operation that will generate points from the geomorphologic polygons (polygon map Geom) will be applied first.

☞

• Double-click the Polpnt operation (polygons to points) in the Operations-list.

- Select the Polygon map `Geom.` Type for the Output Point Map: `Geomp.`
- Select the Show check box. Type the Description: `Center point of geomorphologic polygons`
- Click OK. The point map is calculated.
- Click OK in the Display Options- Point Map dialog box. The point map is displayed.

The points you see are the center points of the geomorphologic polygons. The colors are according to the geomorphologic representation (`Geom`).

☞

- Close the point map `Geomp`.
- Click with the right mouse button on the point map `Geomp`.
- Select Statistics, Histogram from the context-sensitive menu. The Calculate Histogram dialog box is opened. Since you used context-sensitive menu on the point map `Geomp`, this map is already shown as the Input Map. Click OK.

The histogram table shows the number of points for each geomorphologic class.

☞

- In the table window, open the Options menu and select the Show Graph command.
- Select `Geom value` for the X-axis and `Nrpnt` for the Y-Axis. Click OK.
- Change the X-axis Name to: `Geomorphologic unit`, and the Y-axis Name to: `Number of points`. Click OK. The bar-graph is displayed.
- Close the graph window and the table window.

Point density

Another measurement operation for points is PntDensity (Point Density). This operation calculates the number of points that fall within each pixel. This depends of course on the size of the pixel, which is defined in the georeference. All raster maps (except the satellite images) in the demo data set have the georeference `Cochabam`, which has a pixel size of 20 meters. Counting the number of points that fall in each pixel with such a small size, will not make much sense (there will

be always only one point in the cell, unless the points are very close). Therefore we will generate another georeference with a much larger pixel size. The same point map (Geomp) as in the previous exercise will be used.

☞

- Click with the right mouse button on the point map Geomp.

- Select Rasterize, Point Density from the context-sensitive menu. The Point density dialog box is opened. Since you used the context-sensitive menu on the point map Geomp, this map is already shown as the Input Map. Defaults are available for the Point Size and the Output Map name. Accept these defaults.

- Select the Show check box.

- Click the Create button next to the Georeference list box. The Create Georeference dialog box is opened.

- Type the Georeference Name: Cocha400.

- Type the description: Georeference with 400 meter pixel size.

- Change the pixel size to 400. The number of lines of the raster map will only be 47 and the number of columns 29. Click OK.

  You return to the Point Density dialog box. Type the description: Number of points within pixels of 400 meters.

- Click OK.

  The map is calculated and the Display Options dialog box appears. Select the representation Pseudo and click OK.

- Press the left mouse button on a few pixels in the map. The points are widely spaced, since also with a pixel size of 400 by 400 meters, we only get a maximum of 4 points in 1 pixel.

- Close the map window.

The Point density operation is useful, when you are working with point maps that are derived from detailed surveys in which points are measured at close intervals. It may then happen that several points occur within one pixel of the thematic raster maps that you are using. For example, when you are using GPS (*Global Positioning Systems*), you make take a number of very closely spaced (X, Y, Z) coordinates in the field. An example of an engineering geological application: sample points for soil tests taken in a certain area may be so close to each other that several sample points fall in the same pixel of the soil map that you are using.

Distance between points

The distance between two points, and the direction of the line connecting these points, can easily be measured using the distance button in the map window.

☞

- Open point map Geomp.
- Click the Distance button on the button bar of the map window.
- Locate the mouse pointer on a point in the map and press the left mouse button. Move to another point, while keeping the left mouse button pressed. When you release the mouse button, a window will appear with the distance between the two points, and the direction of the line connecting the points.
- Close the map window.

Point in Polygon

The last measurement operation that will be shown here is the so-called *point in polygon* operation, that allows you to rapidly find out in which mapping units the points of a point map are located. This information can be obtained after opening the point map as a table.

☞

- Click point map Geomp with the right mouse button and select Open as Table from the context-sensitive menu. The point map is now opened as a table, with three columns: X, Y and Name. Now it is also possible to use table calculation expressions.
- Type the following formula on the command line:

  Geology=Mapvalue(Geology.mpa,coord(X,Y)) ↵

The function Mapvalue allows the extraction of thematic information from a map at a specific location. In this case information is extracted from the polygon map Geology (Geology.mpa) using the X and Y columns as coordinates.

☞

- The Column Properties dialog box is opened. Accept the defaults and click OK. The column Geology now appears in the table window.
- Close the table window.

Check the On-line Help or the Reference Guide for more useful functions for calculating with coordinates of a point map.

Summary: measurement operations on point maps

– A point histogram for a point map with a class or ID domain shows the number of points having the same class or ID.

– A point histogram for a point map with a value domain shows the number of points with the same value, as well as the cumulative number of points (all points with the same value or a smaller value)

– The Point density operation calculates the number of points that fall within the same pixel. It is useful when you want to combine very closely spaced point data with raster maps having a relatively large pixel size.

– With the Distance button in a map window you can measure the distance (in meters) between two points. If the map window has no coordinates, the distance is measured in pixels.

– A point map can be opened as table.

– The function Mapvalue allows the extraction of thematic information from a map at a specific location. In this case information is extracted from the polygon map Geology (Geology.mpa) using the X and Y columns as coordinates.

7.7 Measurement operations on segment maps

You can also calculate histograms of segment maps. In this case, the length of the segments are important, as well as the number of segments. This will be demonstrated by calculating the length of the Geological faults and lineaments of the map Faults.

☞

- In the Catalog, click with the right mouse button on the segment map Faults.

- Select Statistics, Histogram from the context-sensitive menu. The Calculate Histogram dialog box is opened.

- Click OK.

The segment histogram table shows that there are 17 segments with the code Fault, with a total length of 71 km, and 72 segments with the code Lineament, with a total length of 219 km.

It is also possible to calculate the length of every individual segment. In this case you need to convert the fault map, which has a class domain with two classes, to a *unique identifier map.* You can do this with the operation UniqueID. This operation calculates unique codes for all points in a point map, segments in a segment map, and polygons in a polygon map.

☞

- Close the table window with the segment histogram.

- Click with the right mouse button on the segment map Faults.

- Select Vector operations, Unique ID from the context-sensitive menu. The Unique ID dialog box is opened.

- Type the name of the output map: Faultid.

- Select the option New domain and call it Faultid. Select Show. Type the description: Individual fault segments.

- Click OK. The Display Options dialog box of the segment map is shown after a while.

- Select the Info check box and select the option: Multiple colors, and 15. Click OK. The map is displayed.

- Press the left mouse button on some of the segments to check their codes.

You will see that each segment now has a different code. You can now calculate the Segment histogram for the map Faultid.

☞

- Close the map Faultid.

- Calculate the segment histogram of the map Faultid, in the same way as you did before.

- Have a look at the segment histogram. You can see the length of each individual fault segment. Further more, you still need to know, for each segment, whether the segment code refers to a fault or a lineament.

- Close the histogram table.

- Open the table Faultid. From the Columns menu select the Join command. The Join Column dialog box is opened.

- Select the histogram: Faultid. Select the column: Length. Select the output column: Length. Click OK .

- Click OK in the Column Properties dialog box. Now the column length is added, and you have the length for each segment.

You could now pick out the most important faults. For example, those with a length more than 5 km.

☞

- Locate the mouse pointer on the command line of the table window, and type the following formula:

  Mainfault=(Faults="Fault")and(length>5000)↵

- The formula can either be true or false. This is called a Boolean statement, and it results in a column with the domain bool. Click OK in the Column Properties dialog box. The new column contains the words True and False.

- Close the table window.

- In the Catalog, double-click segment map Faultid. The Display Options dialog box is opened. Select the check box Attribute, and select the column Mainfault. Select "white" as false color.

- Click OK. Only the main faults are shown.

- Close the map window.

Segment histogram of value maps

A segment histogram for segment maps with a value domain looks slightly different. Take for example the value map `contour`.

☞

- Calculate the histogram of the segment map `contour`.

The histogram table for segment maps with a value domain contains more columns:

- `Value`: the altitude of the contour lines, which have this value code. So the lowest contour line is 2520 meters and the highest is 4560.
- `NrSeg`: the number of segments occurring for each value.
- `NrSegCum`: the cumulative number of segments. For each altitude value the number of segments of all the contour lines with a lower or equal altitude is indicated.
- `Length`: the length of all segments with the same value.
- `LengthCum`: the cumulative length of segments. For each altitude value the total length of all the contour lines with a lower or equal altitude is shown.

☞

- Close the table window.

Segment directions and Rose diagrams

Another useful measurement operation on segment maps, especially for Geological applications, is called SegmentDensity (HistSegDir).

☞

- In the Catalog, click with the right mouse button on segment map `Faults.`
- Select Statistics, Direction histogram from the context-sensitive menu. The Direction histogram dialog box is opened. Since you used the context-sensitive menu on segment map `Faults`, this map is shown already as the Input Map. Type the name of the output table: `Faults`. Select the check box Show.
- Click OK. The table is shown after a while.

The table shows 180 records; one for each degree of the northern part of the geological compass. Record 1 shows the east-west direction. Record 91 shows the north-south direction. It is possible to display the directional data in the form of a Rose diagram.

☞

- In the table window, open the Options menu and select the Rose diagram command.

- Select for the Angle: `Direction`, and for the Value: `Length`. Click OK.

This Rose diagram shows in which direction faults have the largest length.

It is also possible to display the number of segments instead of the length.

☞

- Close the Rose diagram.

- Open the Options menu again and select the Rose diagram command.

- Select for the Angle: `Direction`, and for the Value: `NrLines`. Click OK.

  The rose diagram now shows the number of segments for the different directions.

- Close the Rose diagram and the table window.

Calculating segment density

In many applications it may be useful to know the density of segments within certain units. For example, the drainage density per catchment is often required in hydrologic models, or the density of faults in certain geological units for geological applications. With ILWIS we can generate a segment density map with the operation SegDensity. This operation generates a raster map from a segment map, in which for each pixel the length of certain segments is indicated.

This is demonstrated for the segment map `Drainage`.

☞

- Click with the right mouse button on segment map `Drainage.`

- Select Rasterize, Segment density from the context-sensitive menu. The Segment density dialog box is opened.

- Select the check box Mask and type the mask `Drainage.`

> - Select the Georeference `Cochabam`. Select **Show**. Type the description: `Density of drainage lines per pixel`.
> - Click **OK**.

The drainage density is now being calculated. This will take some time. After that the Display Options dialog box is opened.

> ☞
>
> - Select the representation: `pseudo`.
> - Click **OK**. The map is displayed. You will see a number of colored lines within a blue map.
> - Zoom in on one of these lines so that you can see only about 20 individual pixels. Click a few pixels to read the values.
> - Open the Layers menu and select Add data layer and Segment map. Select the segment map `Drainage`. Click **OK**. The Display Options dialog box appears.
> - Select the check box Mask and type: `Drainage`.
> - Select the option Single color and choose the color `Red`.
> - Click **OK**. The segment map `Drainage` is displayed on top of the drainage density map.

If the window is sufficiently enlarged, you can see the individual pixels, with the red line of the drainage passing over it. The value of the pixel through which a line is passing indicates what is the length of that line within the pixel. The pixel size of the map is 20 by 20 meters (check this in the Properties dialog box of the raster map). So if the drainage is crossing the pixel in an exact North-South or East -West direction, the length of the line in the pixel is also 20 meters. If the line is oriented in NW-SE or in NE-SW direction, it crosses the pixel diagonally. In that case the length of the segment in the pixel is 28.28 meters (Pythagoras rule). So this is also the maximum possible length of a segment in the pixel, unless you have two segments in the same pixel.

The segment density map by itself is not so useful. It is just showing the length of segments covering each pixel. It is, however, an important input map for calculating the segment density of another thematic map, such as a catchment map. In order to know the drainage density of the different catchments, we need to overlay the raster map of the catchments with the segment density map that we have just created, using the Cross operation. This will be demonstrated when we deal with the Cross operation in the next chapter.

Summary: measurement operations on segment maps

– A segment histogram for a segment map with a class or ID domain, shows the number and the length of segments having the same class or ID.

– A segment histogram for a segment map with a value domain, shows the number, and the length of segments with the same value, as well as the cumulative number and cumulative length of segments (all segments with the same value or a smaller value).

– A directional histogram shows the number and the length of segments oriented between West and East.

– The data from a directional histogram can be displayed in the form of a Rose diagram.

– The Segment Density operation calculates the length of segments per pixel. It is useful when you want to overlay this map with another thematic raster map (having a class or ID domain) in order to calculate the segment density for each mapping unit, using the Cross operation.

7.8 Measurement operations on polygon maps

For polygon maps we can also calculate histograms. In this case we are most interested in the area of the polygons belonging to the same mapping unit, as well as the number of these polygons. Besides we can also obtain information on the length of the boundary line around each polygon, called the *perimeter*.

A histogram of the geomorphologic map (Geom), with a class domain, will be calculated as an example.

☞

- Click with the right mouse button on polygon map Geom.

- Select Statistics, Histogram from the context-sensitive menu. The Calculate Histogram dialog box is opened. Click OK.

A polygon histogram table contains the following columns:

− NrPol: The number of polygons belonging to each class of the domain.

− Perimeter: The total length of the boundary lines of all polygons belonging to the same class. The values in this column are in meters if the coordinates used in the coordinate system are also in meters (which is nearly always the case).

− Area: The total area of all polygons belonging to the same class. The values in this column are in square meters.

If you need to know the area and the perimeter of each individual polygon, you need to convert the map to unique identifiers, with the operation Unique ID, in a similar procedure as explained in the previous section for segment maps. We do have a unique ID polygon map in the data set: the city block map (Citybl).

☞

- Close the table window.
- Calculate and display the histogram for the polygon map Citybl.

In a unique ID map, the column showing the number of polygons (NrPol) is obsolete, since all polygons have a unique identifier and therefore each code occurs only once.

7.9 Measurement operations on raster maps

Finally, you will look at the histogram of raster maps. In the chapter on Image processing you have been working extensively with histograms made from raster maps with an image domain. As an image domain is a special type of value domain, the same type of histogram is used for all raster maps with a value domain.

Let us have a look at the histogram of a value map: Dem (the digital elevation model).

☞

- Calculate and display the histogram of raster map Dem.

The histogram table shows the following columns:

- Value: It contains each value occurring in the map.
- Npix: The number of pixels with a certain value.
- Npixpct: The percentage of the number of pixels with the same value as part of the total number of pixels (that are not undefined) in the map.
- Npixcum: The cumulative number of pixels with the same or a smaller value.
- Npcumpct: The cumulative percentage of pixels with the same or a smaller value as part of the total number of pixels (that are not undefined) in the map.
- Area: The area of pixels with the same value. This is obtained by multiplying the number of pixels with the pixel area (npix * pixel size * pixel size).

☞

- Scroll to the last record of the table.

The value 593684 in column Npixcum represents the total number of pixels in the map (provided that there are no undefined pixels, which are not used in the histogram calculation). Let's check this.

☞

- Close the table window.
- Open georeference Cochabam.

The georeference determines the pixel size and the minimum and maximum X and Y coordinates in the map. These determine the number of lines and columns in the map. As you can see we have 932 lines and 637 columns.

☞

- Close georeference Cochabam.
- Type the following pocket line calculation on the command line of the main window:

    ?932*637

As we have 932 lines and 637 columns., the total number of pixels is 932*637 = 593684, which is the same as the number we have just seen.

Let us now look at the histogram of a raster map with a class domain: Landuse.

☞

- Open raster map Landuse.
- Click on the white area in the upper right corner of the map and read the information.

Part of the raster map Landuse contains question marks (?). These are *undefined* values for which no land use information is available.

☞

- Close the raster map Landuse.
- Calculate and display the histogram of the raster map Landuse.

The histogram table shows the following columns:

- Npix: The number of pixels with the same land use type.
- Npixpct: The percentage of the number of pixels with the same land use type as part of the total number of pixels in the map (so as a percentage of 593684).
- Pctnotund: The percentage of the number of pixels with the same land use type as part of the total number of pixels in the map that are not undefined.
- Area: The area of pixels with the same land use type.

We can know how many pixels there are with undefined values by looking at the difference between 593684 and the cumulative number of pixels in column Npix.

☞

- Position the mouse pointer on the command line of the table window and type the following formula:

    Npcumnotund:=cum(npix)↵

> - Click OK in the Column properties dialog box.

The last value in this column gives the number of pixels within one of the land use classes (554000). So the difference between the total number of pixels (593684) and this value is the number of pixels with undefined values.

☞

> - Type the following pocket line calculation to find out the number of undefined pixels:
>
>   ?593684-554000
>
> - Close the table window.

There is one more thing to know about the histogram of a raster map: The areas calculated from a raster map are less accurate than those of a polygon map. We will compare the areas of the same land use units, one calculated from the raster map and the other one calculated from the polygon map.

☞

> - Calculate and display the histogram of the polygon map Landuse.
>
> - In the table window, open the Columns menu and select the Join command. The Join dialog box is opened.
>
> - Select as the Table: The histogram of the raster map Landuse. Select the column: Area, and type the output column: Arearaster.
>
> - Click OK.
>
> - Click Ok in the Column properties dialog box.
>
> - Position the mouse pointer on the Command line of the table window and type the following formula:
>
>   Difarea=Area-Arearaster ↵
>
> - Click OK in the Column properties dialog box.

You can see from the values in column Difarea that the Landuse area values as calculated from a raster map are quite different from those calculated from a polygon map. This is caused by the fact that a pixel in a raster map can only belong to one land use type. During the rasterization, the program will look whether more than 50 percent of a pixel is occupied by a certain land use type (for example: forest). If that is so, then the pixel is classified as forest. If the pixel was actually covered 51 percent by forest and 49 percent by shrubs, this means that the actual

area of the shrubs is less in the raster map than in the polygon map. For forest it is the reverse. The combined effect of all these underestimations and overestimations of the area will result in the differences that are shown in column `Difarea`.

So, when all the raster maps that you are using are derived from polygon maps it is more accurate to use the areas of the polygon maps instead of the raster maps. However, if some of the maps were not derived from polygon maps (for example the map `Dem`), then it is better to use raster map histograms for all maps.

Summary: Histogram calculation on polygon and raster maps

– Histograms for polygon maps with a class or ID domain give the number of pixels within each class, the perimeter and the area.

– Histograms for raster maps with class or ID domain show the number of pixels, the percentage of the total number of pixels (with or without the undefined ones) and the area for each class.

– Histograms for raster maps with value domain also show cumulative percentage and cumulative numbers.

– The number of pixels with undefined values are not shown in histograms. However, there is one column that gives information on the percentage of pixels in each class as part of all pixels in the map (including the undefined ones).

– When calculating a histogram for a raster map, which is a rasterized polygon map, the calculated areas in the raster histogram have slight errors due to the generalization effect which occurs during the process of rasterization.

– Histograms are dependent data objects: When the input map changes, the histogram will be recalculated.