

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 other data analysis tools, specifically for maps.

ILWIS 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, 1989 (see Preface).

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 a single vector or raster map, 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 of 3x3 cells, which perform one calculation on a center raster cell and its eight neighbors. The result is stored in the central cell. Four types of 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.

Map Calculation can be used for many operations. Map Calculation will be treated as a 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:\ILWIS 3.0 Data\Users Guide\Chapter07, where the data files for this chapter are stored.



- Double-click the ILWIS icon on the desktop.
- Use the Navigator to go to the directory C:\ILWIS 3.0 Data\Users Guide\Chapter07.

7.1 Retrieval using the pixel information window

Data retrieval involves the (selective) search, manipulation and output of spatial data 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 2, the functionality of the pixel information window was already introduced to you.



- Open raster map FCC.
- In the map window open the File menu and choose Open Pixel Information.
- Open the Help menu in the pixel information window and select the command Help on this window. Click the hypertext word: Introduction.
- Close the Help window when you have finished reading the help on the pixel information 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, Geomorphology, Landuse, and Catchment (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.



- In the Catalog, select the polygon maps Geology, Geomorphology, Landuse and Catchment (hold down the Ctrl-key) and drag them to the pixel information window.
- When you move the mouse pointer in the map window, you will see information on these maps in the pixel information window.

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 will be explained in chapter 10.



- Also add the raster maps `Dem` and `Slope` to the pixel information window. You can do this for instance by using the `Add Map` command in the `File` menu of the pixel information window.
- Position the mouse pointer in the map 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 information 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.



- 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 (it says for the maps: ? outside map, and for attribute data: ?).

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 useful to display these maps on top of the false color composite.



- Select the four polygon maps `Geology`, `Geomorphology`, `Landuse`, and `Catchment` in the `Catalog` and drag them to the map window.
- When the `Display Options - Polygon Map` dialog boxes appear, specify:
`Boundaries Only` and choose for:
`Catchment (Boundary Color: White)`
`Geology (Boundary Color: Magenta)`
`Geomorphology (Boundary Color: Yellow)`
`Landuse (Boundary Color: Green)`.

For more information on how to manage data layers we refer to chapter 2 and to the ILWIS Help topic `Basic concepts: Layers in a map window`.

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



- In the Layer Management pane, clear the Show check boxes of the layers Geology, Geomorphology and Catchment.

Now you only see the green boundary lines of the land use polygons on top of the false color composite.



- Position the pixel information window and the map window in such a way on your screen that you can easily see both.
- Move the mouse pointer through the map, while keeping 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.
- Find the answer to the following question:
What is the predominant geological unit that 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.



- 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:



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



- Open table `Cityblock` and inspect the properties of the various columns, by double clicking the column titles. As you can see, the column `Landuse` has a class domain (`City_Landuse`), the column `District` has an ID domain (`District`), and the columns `Area`, `Population`, and `Population_Density` 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 `Cityblock`. Accept the defaults in the Display Options - Polygon Map dialog box and click OK.

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



- 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.
If you wish you can drag the Edit Attributes window into the map window, and dock it.

The polygon map window with the Edit Attributes pane docked into the map window is shown in Figure 7.1.

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.



- Close the Edit Attribute pane by clicking the cross in the upper-right.

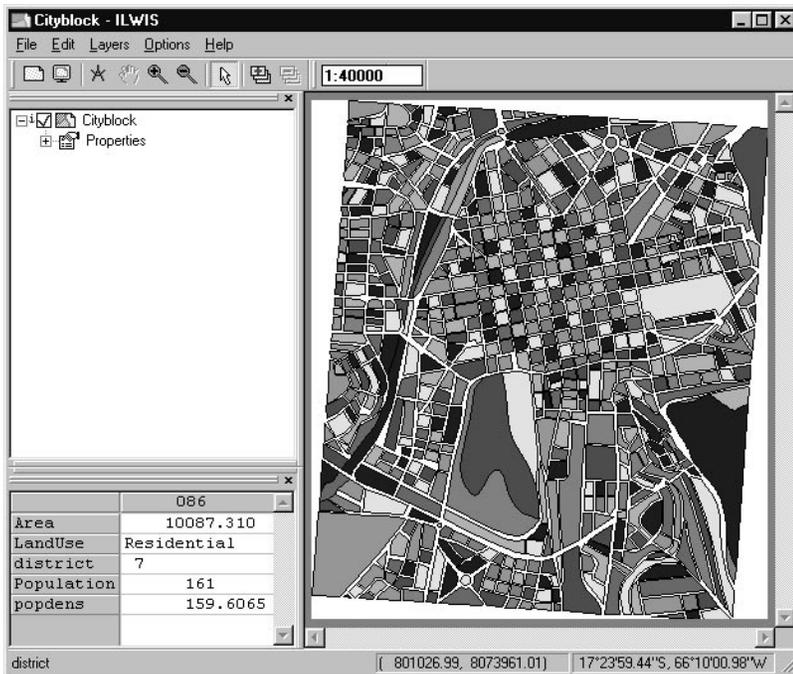


Figure 7.1: A polygon map window with both the Layer Management pane and the Edit Attribute pane docked in the map window.



- In the Layer Management pane of the map window, double-click the map Cityblock. The Display Options - Polygon Map dialog box is opened.
- In the Display Options - Polygon Map dialog box select the check box Attribute. Now a list box appears to the right of the word Attribute, containing columns of the attribute table Cityblock.
- Select the column Landuse. This column contains the dominant land use type of each cityblock.
- Select the option Representation. The representation City_Landuse will appear in the list box to the right of the word Representation.

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



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

The map Cityblock 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 City_Landuse.



- 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 `Cityblock` map: `District`. Each city block forms part of a cadastral district of the city. The `District` column uses an identifier domain.



- Click with the right mouse button while the mouse pointer is in the map window. Select `Display Options` from the context-sensitive menu and click on the polygon map name `Cityblock`.
- 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 `Cityblock` will be shown by the attribute population density. The column `Population_Density` uses a value domain



- Change the options in the `Display Options` dialog box in such a way that the attribute `Population_Density` 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` sheet 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 can 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`.



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

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 full names or codes you can use *wildcards*: the asterisk * to replace zero or more characters, and the question mark (?) to replace one character.



- 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 - Polygon Map 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.



- In the Catalog, double-click segment map Contour.
- In the Display Options - Segment Map 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 and click OK. Only the contour lines from 3000 to 3440 are displayed.
- Double-click the map Contour in the Layer Management pane.
- In the Display Options - Segment Map dialog box, select the check box Mask, and type the following search string in the appearing text box: ??00.
- Click OK in the Display Options - Segment Map dialog box. Only the hundred meter contour lines are displayed.
- Close the map window.

For more information about using wildcards in Mask, we refer to the ILWIS Help topic How to use masks.

Summary: retrieval operations

- In the previous exercises methods were shown that could be used to retrieve information from maps and from the connected attribute tables.
- In section 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 XY-coordinate that you point at with your mouse pointer.
- In section 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 domain, an identifier domain (ID domain) or the Unique ID 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 raster 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 7.2). The result of data retrieval using MapCalc is a new raster map.

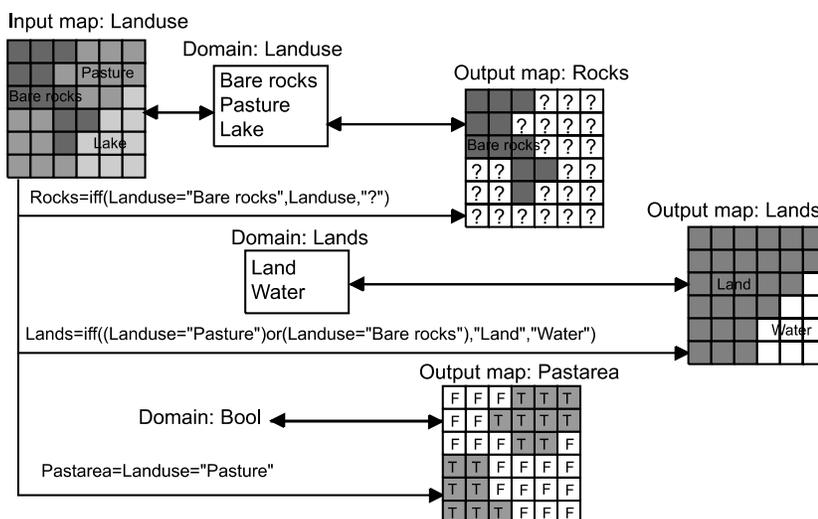


Figure 7.2: Examples of data retrieval and classification using different MapCalc formulas (see the following exercises for explanation).

Using a Map Calculation formula for data retrieval

In this exercise, 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.



- 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.

- ! MapCalc is not case-sensitive. On the Command line, it makes no difference if you type capitals or small letters.



- Press `↵` Enter after typing the formula. The Raster Map Definition dialog box is opened. Accept the defaults, and click Define.

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

The map `Rocks` is displayed on the screen. It only contains one unit: `Bare rock`. The rest of the map is undefined (?).



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

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.



- 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 7.2). 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).



- Type the following formula on the Command line of the 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 Show.
- Accept the defaults in the Display Options - Raster Map dialog box by clicking OK. 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 allows only two conditions: 1 (true) or 0 (false), but it doesn't allow undefined values.



- Close the map window.
- Repeat the calculation: Use the history of the Command line (Arrow Up or open the Command line list box) to retrieve the calculation on the Command line.
- Press Enter and answer the question Overwrite? with Yes. In the Raster Map Definition dialog box, select domain Bit.
- Display map Grass (now with the Bit domain), and close the map window when you have finished the exercise.

If you use the Bit domain, undefined values also become 0 (false). It is generally better to use the Bool domain.

Simple reclassification with a MapCalc formula

The previous 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 7.2), 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 class names (Land, Water) do not occur in domain Landuse.



- Type the following formula on the Command line of the Main window:
`Landwater=iff((Landuse="Lake")or(Landuse="Riverbed"),"Water","Land") ↵`
- 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.



- Click the Create button to the right of the Domain list box. The Create Domain dialog box is opened.
- Type the Domain Name `Landwater`. Click OK. Now the Domain Class editor is opened. Close the Domain Class editor. You are back in the Raster Map Definition dialog box. Click Show.
- The Merging domains dialog box appears, with the question: Add string 'Water' to domain 'Landwater'. Answer with Yes.
- The Merging domains dialog box appears, with the question: Add string 'Land' to domain 'Landwater'. Answer with Yes.
- The Display Options - Raster Map dialog box appears. Accept the defaults by clicking OK. The map `Landwater` is displayed.
- Change the colors of the units: double-click `Land` in the Layer Management pane. The Edit Repr. Item dialog box appears. Change the color to `Green`; double-click `Water` in the Layer Management pane and change the color to `Blue` in the Edit Repr. Item.
- 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 MapCalc formulas

The final example of the use of MapCalc 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).



- Double-click the MapCalculation item in the Operation-list. The Map Calculation dialog box is opened.

This is another way to work with MapCalc; of course you can also type the formula directly on the Command line of the Main window.



- 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.



- Type `Demclass` in the text box Output Raster Map.
- Click the Create Domain button next to the Domain list box. The Create Domain dialog box is opened. Type `Demclass` in the text box Domain Name.
- Accept the defaults by clicking the OK button in the dialog box. The Domain Class editor is opened. Close the Domain Class editor.
- Click Show in the Map Calculation dialog box.
- Accept to add the following items into domain `Demclass`: Low, Moderate and High.
- The Display Options - Raster Map dialog box is opened.
- Accept the defaults and click OK. The map is displayed. Click the units to find out their meaning.
- You can customize the colors in the same way as before.
- Close the map window when you are finished with the exercise.

We can draw the same conclusion as before: MapCalc 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 ID 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 MapCalc 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 raster 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 for vector maps is rather inefficient. The same information can be found easier by displaying the vector 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 section 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, Unique 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 in the table. In other words, a map linked to an attribute table can be reclassified by 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 7.3.

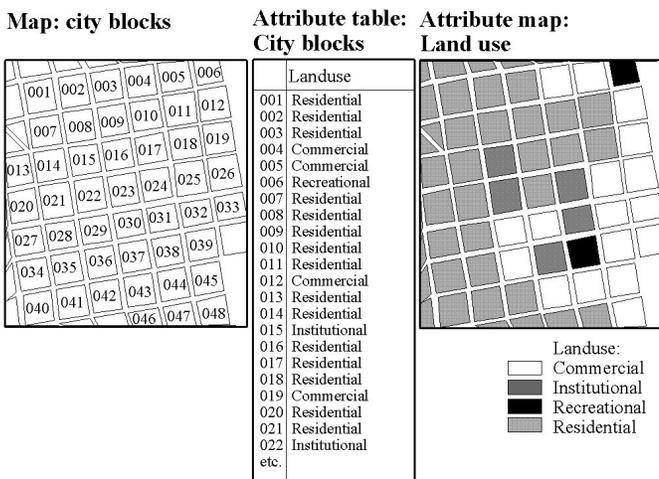


Figure 7.3: Example of a reclassification using an attribute table. The map city block (with a domain ID) is reclassified to the map Landuse (with a class domain) using the column Landuse from the attribute table.

In this exercise you will first use the polygon map `Cityblock` to create a new polygon map representing the land use of the city blocks of Cochabamba. The polygon map `Cityblock` 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 `Cityblock`. 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.



- Double-click Attribute Map of Polygon Map in the Operation-list.

The Attribute Map of Polygon Map dialog box is opened.



- Select polygon map `Cityblock` in the list box Polygon Map.
- Select column `Landuse` in the list box Attribute.
- Type `City_Landuse` in the text box Output Polygon Map.
- Type `Dominant land use` in the text box Description and click the Show button.
- In the Display Options - Polygon Map dialog box, accept the defaults by clicking the OK button.

The output map is displayed on the screen.



- Evaluate the contents 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 `Cityblock` by its attribute `Landuse`).
- Also generate a polygon attribute map `District`, by using the column `District` and the map `Cityblock`.

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`.



- In the map window, open the File menu, select Properties and click on the polygon map `District`. The Polygon Map Properties sheet 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 `Cityblock`, `City_Landuse` 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` raster 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:
`Landvalue=Landuse.Landvalue ↵`
- Click Show in the Raster Map Definition dialog box.
- Display the map `Landvalue` 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 section, 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 map 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 7.4). 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 Slicing dialog box; it lists the upper boundary values of the groups and the group names.

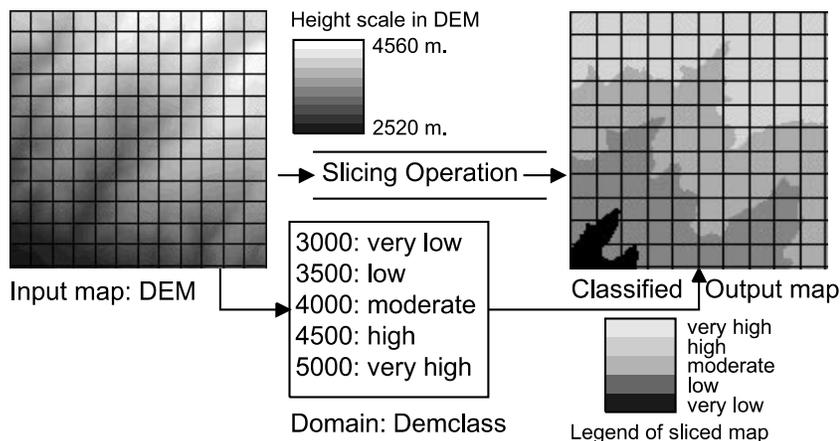


Figure 7.4: Process of the Slicing operation using DEM as an input map.

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 Demclass.

Upper boundary	Group name
3000	<3000 m
3500	3000-3500 m
4000	3500-4000 m
4500	4000-4500 m
5000	4500-5000 m

The raster map Dem has a domain type value in which pixel values refer to the height of the terrain.

Temporary classification for display options

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



- Double-click raster map Dem in the Catalog. The Display Options - Raster Map dialog box is opened. Click OK to display the map.
- In the Layer Management pane double-click the raster map Dem to open the Display Options - Raster Map dialog box again.
- In the dialog box click the Create button next to the Representation list box. The Create Representation dialog box is opened.
- Type for Representation Name: Demclass2. Accept the other defaults and click OK. The Representation Value editor is opened.
- Press the Insert Limit button in the toolbar. The Insert Limit dialog box is opened. Enter the limit 3000 and select the Color Red and click OK.
- Insert also the other limits shown in the Table 7.1 (3500, 4000, 4500) and select a color for each.
- Click the word Stretch between two limits. A list box appears.
- Click once more to open the list box and select Upper. Do this for all ranges in between limits.
- Close the Representation Value editor. You are back in the Display Options - Raster Map 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. Use the Redraw button in the map window, to redraw the map with the updated representation. This allows you to interactively select the best boundaries for the classification.

Permanent classification using the slicing operation

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



- Expand the Image Processing item in the Operation-tree and double-click the Slicing operation. The Slicing dialog box is opened.
- Select Dem in the Raster Map list box.
- Type `Classified_Dem` in the Output Raster Map text 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 `Classified_Dem` in the Domain name text box.
- Make sure to select the option Class and the check box Group.
- Click the OK button in the Create Domain dialog box. The Domain Group 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 Table 7.1, will be used in this exercise.



- Click the Add Item button in the toolbar of the editor. The Add Domain Item dialog box is opened.
- Type 3000 in the Upper Bound text box.
- Type `altitude <3000 m` in the Name text box. The use of a Code is optional. It will not be used now.
- Click OK.
- Click the Add Item button again, or 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, according to Table 7.1: 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 File menu in the Domain editor and select Open Representation. You can also click the Open Representation button in the toolbar.

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



- To edit colors of multiple classes (groups), select the first class, press the Shift-key and select the last class. Use the right mouse button and select Edit items from the context-sensitive menu.
- In the Edit Multiple Items dialog box, make sure the option Color Range is selected.
- Select two colors (e.g. White and Brown) for the color range between From Color (until 3000) and To Color (4500-5000) and click OK.

You can use the Variation check box when a random color variation should be used with a certain margin around the straight line between the specified From Color and To Color in the RGB color cube. Subsequently, specify a value between 1 and 255 for the maximum variation allowed. See also Figure 7.5.

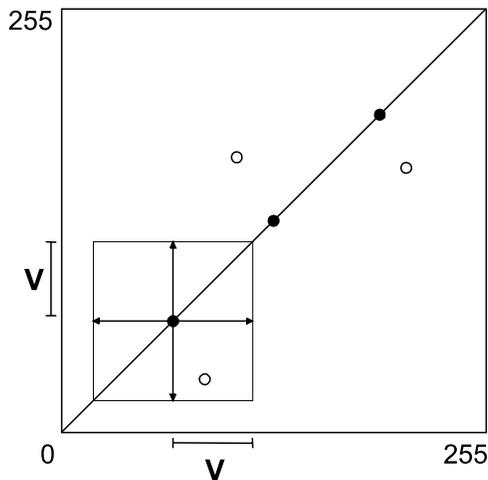


Figure 7.5: Two dimensional representation of a color range without variation (solid dots) and a color range with variation (open dots). In the Edit Multiple Items dialog box, you can select the option Variation to use a random color variation with a certain margin (V) in the Red, Green and Blue color cube.

To edit a color of a single class, double-click individual items in the Representation CLASS editor and either select a pre-defined color, choose a customized color or edit the color of the selected group by changing the amount of Red, Green and Blue.



- Close the Representation Class editor when you are satisfied with the colors.
- Close the Domain Group editor.
- Click the Show button in the Slicing dialog box. The Display Options - Raster Map dialog box is opened.
- Accept the defaults by clicking OK. The map and the legend are displayed on the screen.
- If you wish, you can change the colors again by double-clicking the word 'Legend' in the Layer Management pane. Press the Redraw button in the toolbar of the map window to apply the changes.
- Use the pixel information window to compare the values of the original map (Dem) with the names in the classified map (Classified_Dem).
- Close the pixel information window and the map window.

Permanent classification using the CLFY function in MapCalc

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 *Landvalue*, 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 *Landvalue* 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 *Landvalue_class*. Add three classes with the boundaries as given above. Use 1000 as Upper Bound for the third class.
- Close the Domain Group editor.
- Locate the mouse pointer on the Command line of the Main window and type the following command:
`Landvalue_class=CLFY(Landvalue, Landvalue_class) ↵`

The expression has the following structure:

```
OUTMAP = CLFY ( InputMapName, DomainGroup )
```

in which:

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



- Click Show in the Raster Map Definition dialog box.
- Edit the colors if you wish, e.g. Low = Yellow, Moderate = Orange, High = Red.
- Use the left mouse button in the map window to inspect the result.
- Close the map window when you finished the exercise.

Summary: Classifying a value map

- A value map cannot be reclassified from an attribute table.
- You can make a value map *appear* classified by creating a new representation value or gradual for it (temporary classification).
- A value map can be permanently classified with the Slicing operation. The operation requires a group domain. A group domain is a special class domain containing the names of the classes and the boundary values.
- To classify a map, you can also use the CLFY function and a group domain.
- 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 is different from the one of a value map. Both types are shown in section 7.9.

Measurement operations on point data

In this section 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, will be 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 is given in ILWIS Help, topic Point maps, Map calculation special: calculations on point data.

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 *Geomorphology*) will be applied first.



- Double-click the Polygons to Points operation in the Operation-list. The Polygons to Points dialog box appears.
- Select the Polygon Map *Geomorphology*. Type for the Output Point Map: *Geompoint*.
- Type the Description: *Center point of geomorphologic polygons*.
- Click *Show*. The point map is calculated and the *Display Options - Point Map* dialog box is opened.
- 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 (*Geomorphology*).



- Close the point map *Geompoint*.
- Click the point map *Geompoint* with the right mouse button.
- 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 *Geompoint*, this map is already shown as the Input Map. Click *Show*.

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



- In the table window, press the *New Graph* button on the toolbar. The *Graph* dialog box appears.
- In the *Graph* dialog box deselect the *X-column* check box and click *OK*. The *Graph Options* sheet is opened.
- On the *X-Axis* tab type for the *Axis Text*: *Geomorphologic unit*.
- On the *Y-Axis (left)* tab change the *Axis Text* to: *Number of points* and click *OK* in the *Graph Options* sheet. The *Bar graph* is displayed.
- Close the graph window and the table window.

Point density

Another measurement operation for points is *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 *Cochabamba*, 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 (*Geompoint*) as in the previous exercise will be used.



- Click the point map `Geompoint` with the right mouse button.
- 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 `Geompoint`, this map is already shown as the input `Point Map`. Defaults are available for the `Point Size` and the `Output Raster Map` name. Accept these defaults.
- Click the `Create` button next to the `Georeference` list box. The `Create GeoReference` dialog box is opened.
- Type for the `GeoReference Name`: `Cochabamba400`.
- Type for 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 `28`. Click `OK`. You return to the `Point Density` dialog box. Type the description: `Number of points within pixels of 400 meters`.
- Click `Show`. The map is calculated and the `Display Options – Raster Map` dialog box appears.
- Select the `Representation Pseudo` and click `OK`. The map is displayed.
- Press the left mouse button on a few pixels in the map. The points are widely spaced, even with a pixel size of `400 by 400` meters, we only get a maximum of `3` 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 may 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

With the distance tool distances and directions (angles) can be measured.



- Open point map `Geompoint`.
- Click the `Measure Distance` button  on the toolbar of the map window, or choose the `Measure Distance` command from the `Options` menu.
- Click a point of interest somewhere in the map (starting point), hold the left mouse button down, and release the left mouse button at another position (end point). The `Distance` message box appears.

The Distance message box will state:

From: the XY-coordinate of the point where you started measuring;

To: the XY-coordinate of the point where you ended measuring;

Distance on map: the distance in meters between starting point and end point calculated in a plane;

Azimuth on map: the angle in degrees between starting point and end point related to the grid North;

Ellipsoidal Distance: the distance between starting point and end point calculated over the ellipsoid;

Ellipsoidal Azimuth: the angle in degrees between starting point and end point related to the true North, i.e. direction related to the meridians (as visible in the graticule) of your projection.



- Click OK in the Distance message box.
- Close the map window afterwards.

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 *Geompoint* in the Catalog 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 two columns: *Coordinate* and *Name*. Now it is also possible to use table calculation expressions.
- If you do not see the *Command line* in the table window first open the *View* menu and choose *Command Line*.
- Type the following formula on the *Command line* of the table window:
`Geology=Mapvalue(Geology.mpa,Coordinate) ↵`

The *Mapvalue* function extracts thematic information from any map at a specific location. In this case, information is extracted from polygon map *Geology* (*Geology.mpa*) using the X and Y coordinates of the points in the current point map.



- 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 ILWIS Help topic *Table calculation: Special calculations*, for other useful functions to calculate 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 tool distances and directions (angles) can be measured. When the map uses a coordinate system of type *projection* with an ellipsoid and/or datum also the Ellipsoidal Distance and Ellipsoidal Azimuth are listed in the Distance message box. When the coordinate system uses a *sphere*, then the Spherical Distance (distance over the sphere) and the Spherical Azimuth are listed.
- A point map can be opened as table.
- The function Mapvalue allows the extraction of thematic information from a map at a specific location.

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 segment map `Faults`.
- Select Statistics, Histogram from the context-sensitive menu. The Calculate Histogram dialog box is opened.
- Click Show.

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. In the Statistics pane at the bottom of the table window you can find additional statistical information. You can open the Statistics pane by choosing the Statistics Pane command from the View menu.

It is also possible to calculate the length of every individual segment. In this case you need to convert the `Faults` 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 showing the segment histogram.
- Click with the right mouse button on segment map `Faults`.
- Select Vector Operations, Unique ID from the context-sensitive menu. The Unique ID dialog box is opened.
- Type `Nr.` for the Domain Prefix.
- Type the name of the Output Map: `Fault_ID` and click Show. The Display Options dialog box of the segment map is shown.
- In the Display Options - Segment Map dialog box 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.



- Close the map `Fault_ID` and open the table `Fault-ID`.

You can now find the most important faults. For example, the faults 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 `Fault_ID`. The Display Options - Segment Map dialog box is opened.
- Select the check box `Attribute`, select the column `Mainfault` and 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 calculated 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 Segment Direction Density.



- In the Catalog, click segment map `Faults` with the right mouse button.
- Select Statistics, Direction Histogram from the context-sensitive menu. The Segment 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`.
- Click Show. The table is shown.

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 Graphs menu and select the Rose Diagram command.
- In the Graph dialog box select `Direction` for the X-column, `Length` for the Y-column and click OK
- In the Graph Options - Direction x Length sheet, select Needle and click Show.

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 Graphs menu again and select the Rose Diagram command.
- In the Graph dialog box select `Direction` for the X-column, `NrLines` for the Y-column and click OK
- In the Graph Options - Direction x NrLines sheet, select Needle and click Show. 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 Segment Density. 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.



- In the Catalog 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 Cochabamba. Type the Description: Density of drainage lines per pixel.
- Click Show.

The drainage density is now being calculated. After that the Display Options - Raster Map dialog box is opened.



- Make sure the Representation Pseudo is selected.
- 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 layer. In the Add Data Layer dialog box select the segment map Drainage and click OK. The Display Options - Segment Map dialog box appears.
- Select the check box Mask and type Drainage in the text box.
- 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.
- Close the map window after finishing the exercise.

If the window is sufficiently enlarged, you can see the individual pixels and the red line of the drainage passing over it. The value of the pixel through which a line is passing indicates the length of that line within the pixel. The pixel size of the map is 20 by 20 meters (check this in the Properties sheet 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 (section 8.4).

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 *Geomorphology*, with a class domain, will be calculated as an example.



- Click polygon map *Geomorphology* with the right mouse button.
- Select Statistics, Histogram from the context-sensitive menu. The Calculate Histogram dialog box is opened.
- Click Show.

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 individual polygons, 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 already have a polygon map with unique IDs in the data set: the city block map *Cityblock*.



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

In an 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: Lists the values, which occurs 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.
- Npumpct: 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).

When you display the graph of the histogram (X-column: Value, Y-column: Npix) you see the frequency of occurring values in the maps.



- 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 Cochabamba.

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 Cochabamba.
- 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 $932 \times 637 = 593684$, 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 raster map Landuse.
- Calculate and display the histogram of 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 find out how many pixels have the undefined value by looking at the Additional Info, which can be displayed from the View menu.

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 a raster map and the other one calculated from its 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 wizard is opened.
- Select as Table the histogram of raster map Landuse. Select the Column: Area, click Next, and type the Output Column `Arearaster`.
- Click Finish.
- Click OK in the Column Properties dialog box.
- Make sure that the Command line is visible. Position the mouse pointer on the Command line of the table window and type the following formula:
`Area_difference=Area-Arearaster ↵`
- Click OK in the Column properties dialog box.

You can see from the values in column `Area_difference` that the Landuse area values as calculated from the raster map are quite different from those calculated

from the 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 the case, 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 `Area_difference`.

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 a 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 a value domain also show cumulative percentage and cumulative numbers.
- The number of pixels with undefined values are not shown in histograms. Column `Npixpct` gives the percentage of pixels in each class as part of all pixels in the map (including the undefined ones). Column `Pctnotund` gives the percentage of the pixels in each class as part of all defined pixels in the map (thus disregarding any undefined pixels).
- When calculating a histogram of a raster map, which is a rasterized polygon map, the calculated areas in the raster histogram have relatively slight errors due to the generalization effect, which occurs during rasterization.
- Histograms are dependent data objects: When the input map changes, the histogram will be recalculated.