3D modeling in GIS

Lecture notes on the masters course ITM-E3DM E at the

Eötvös Loránd University – Faculty of Informatics

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Introduction

This subject is aimed for those students, who are already familiar with GIS applications like ArcGIS, Grass or QGIS. **The aim of the subject is to get acquainted with the GIS base of 3D modeling and to put this knowledge in practice**. This aim is targeted with both theoretical and practical classes during the semester.

The theory and the practice together tightly fit into 1.5 hour classes in weekly schedules of one semester. The theoretical topics are focusing on a general approach to 3D modeling. Since 3D modeling tasks can be extremely different from each-other, modeling projects are discussed as series of tasks in many different digital environments. Usually in a real-life task the case is like this: one gets a bunch of very different data, and a deadline to create something in 3D. If the connection between these data-sources is not established, the system will not work.

The exercises are focusing on the use of a simple GIS tool (Global Mapper), a surface modeling tool (Surfer) and a 3D modeling tool (Jewel Suite). In general the exercises contain step-by-step guides for the tasks. This way using these notes, students can practice and explore the discussed tools on their own if they missed one of the classes.

The course material is designed for 10 demonstrative classes and two, or three guided classes. The demonstrative classes contain theoretical parts, but gradually the emphasis shifts to the exercises towards the second part of the semester. On the guided classes students should work on a special modeling task, which simulates a real-life problem. Their work is monitored and if it is necessary, help is given to them to proceed.

Themes of the semester

- Weeks 1–2: Concepts and theoretic base of 3D modeling. Types and the “scale” of 3D models. Data and objects in the model. Types of different modeling applications, and the usage of 3D models in the Earth sciences.
- Weeks 3–4: Hierarchical data management. Data management systems of the 3D model and their functionalities. The source and the management of primary data. Converting raster into vector and further into numerical data or converting raster directly into numerical data. The structure of GIS databases.
- Weeks 5–6: The 2D GIS base of the 3D model. GIS topology types. Connection between the sub-systems. Data mining, data classification and data analysis.

- Weeks 7–9: The modeling procedure. Classification of 3D modeling methods. Comparison of the regular and irregular data-model. Simple and complicated irregular models. The concept of tessellation.
- Weeks 10–11: Simple and complicated regular models. Processing and storing grid data. Calculation of grid point values. The concept of scalar-space and vector-space. The medium and the requirements of the visualization. The conceptual 3D model. Models in the virtual space. Tools for visualization and querying.
- Week 12-13: Own work, practice, consulting.

The following material was edited according to the sequence of the above mentioned topics. Theoretical parts are represented as slides of presentations, while the practical parts – usually following the theoretical slides – contain detailed instructions for the students how to use certain GIS tools and modeling applications (Global Mapper, Surfer and Jewel Suite). The practical parts contain references to sample files which can be accessed from the server of the Eötvös Loránd University, at each time this course is advertised.

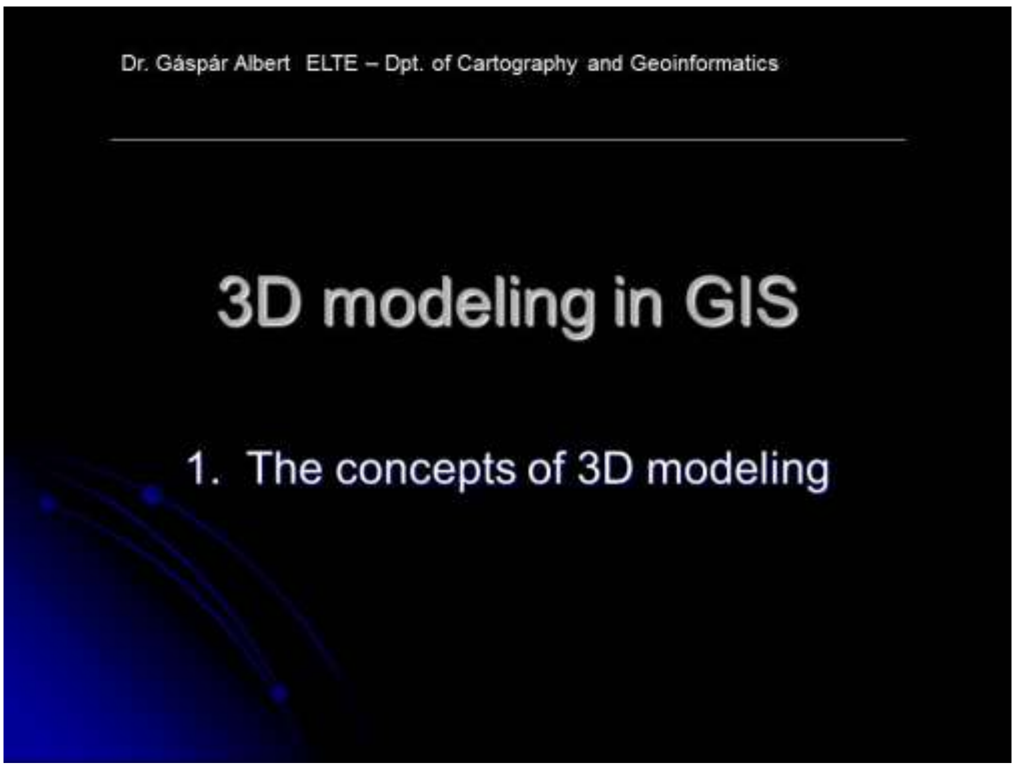
Lesson 1.

The topics of this class are the followings:

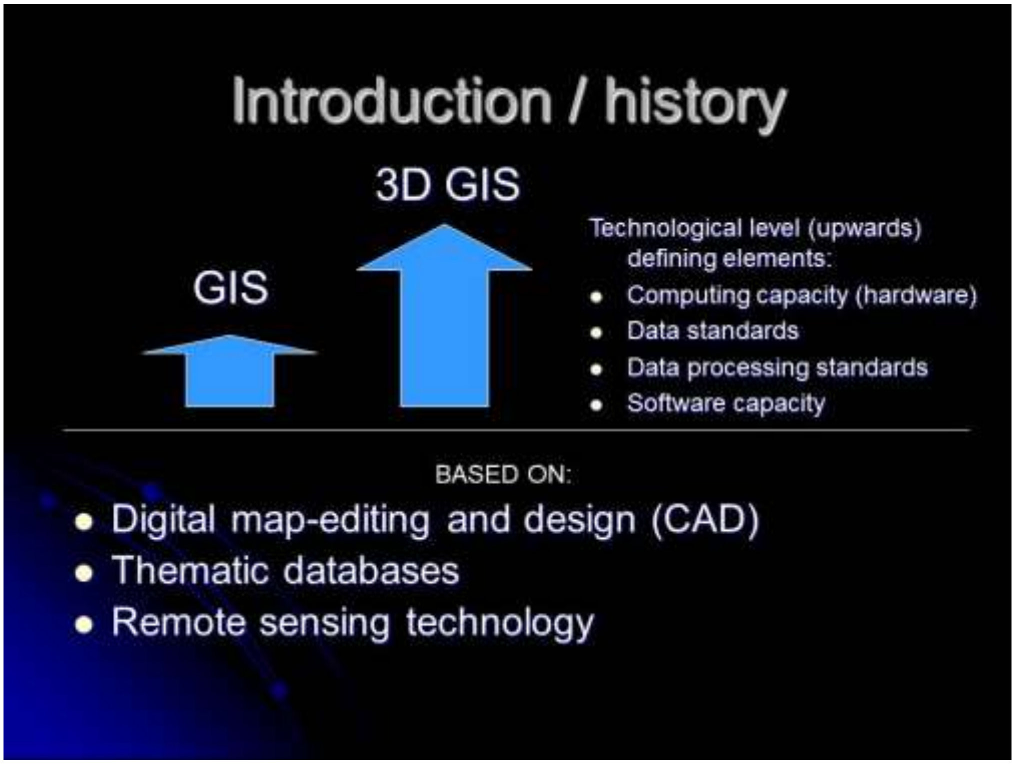
- Concepts of 3D modeling (definition of a model, mockup, modeling, 3D or 2.5D or 4D models).
- When do we construct models?
- Models before the IT age.
- Practical use of 3D models.

Practice: Types of 3D models. 2D components of 3D models. The use of Global Mapper – data I/O. working with SRTM data.

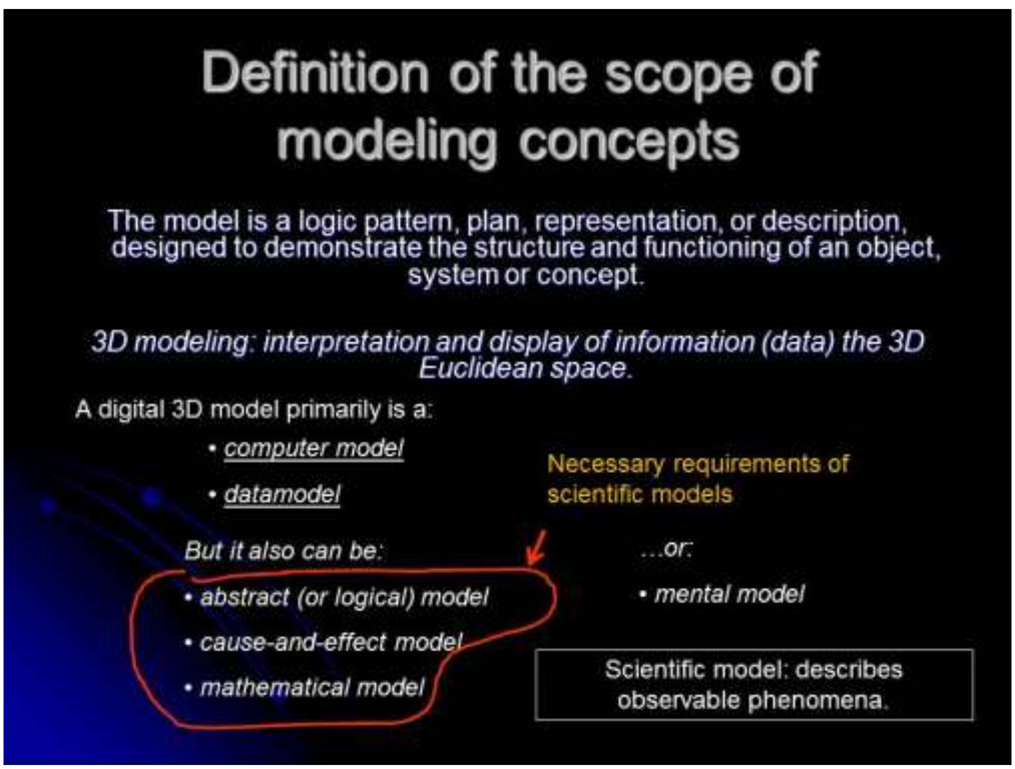
Concepts of 3D modeling



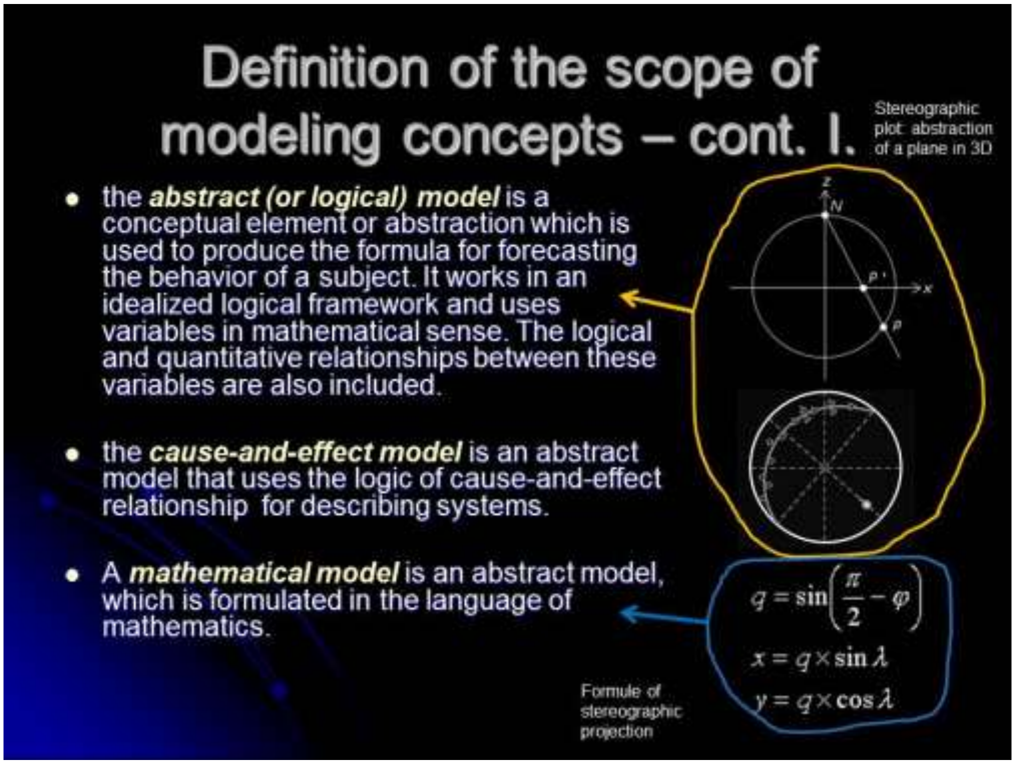
Slide 1 Welcome slide of the first theoretical class



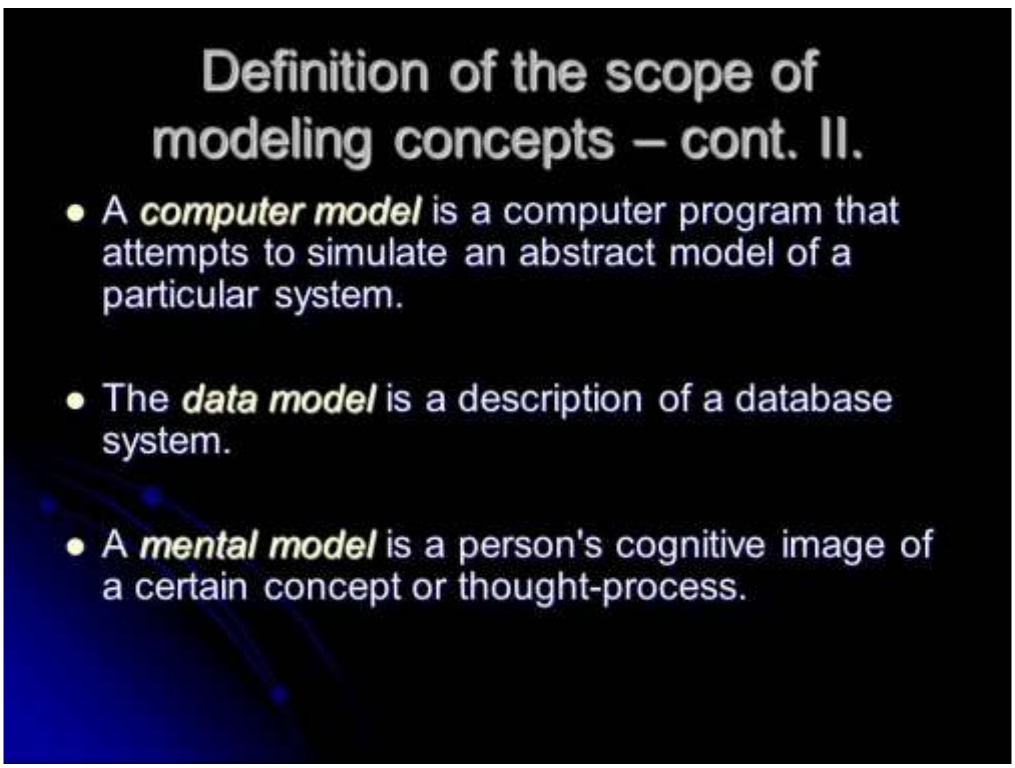
Slide 2 Overview of the evolution of 3D GIS mentioning the base technologies.



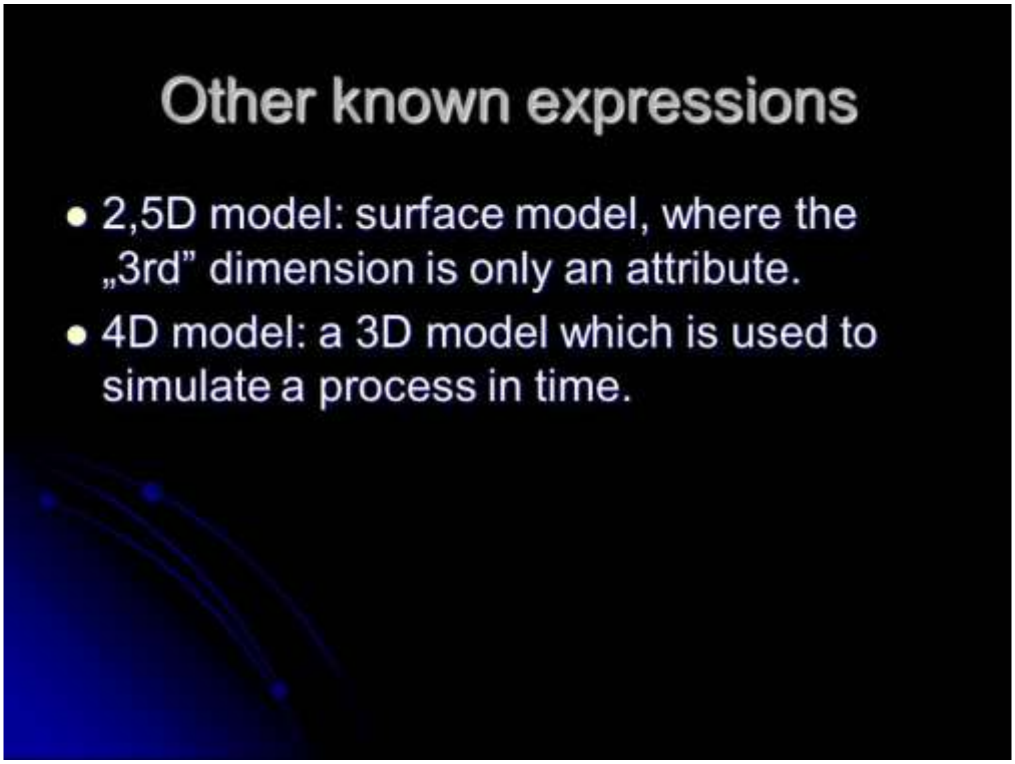
Slide 3 Defining the concept of modeling, with an emphasis on "scientific models"



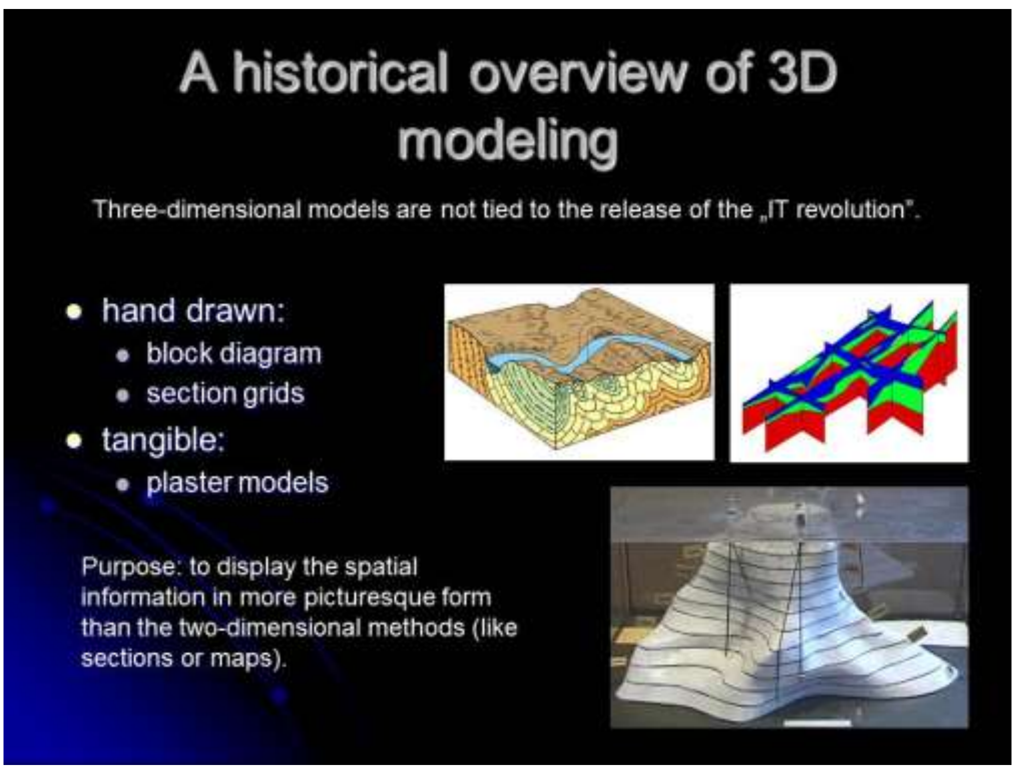
Slide 4 Definition of the abstract, the cause-and-effect, and the mathematical models with samples



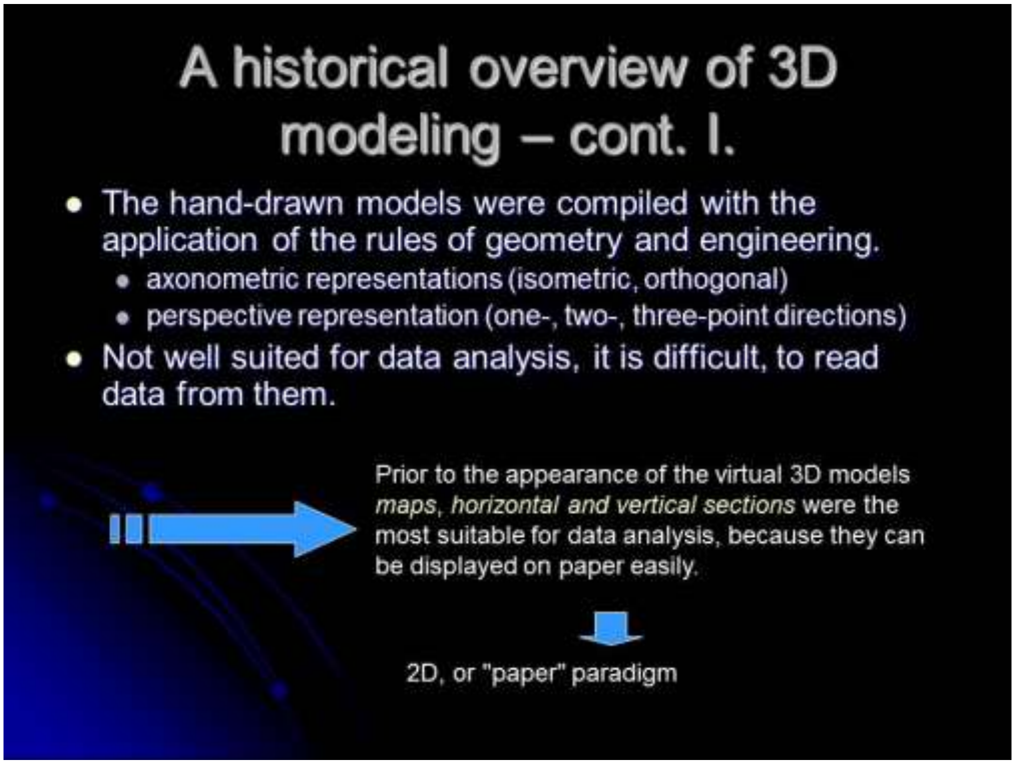
Slide 5 Definition of the computer model, the datamodel, and the mental model



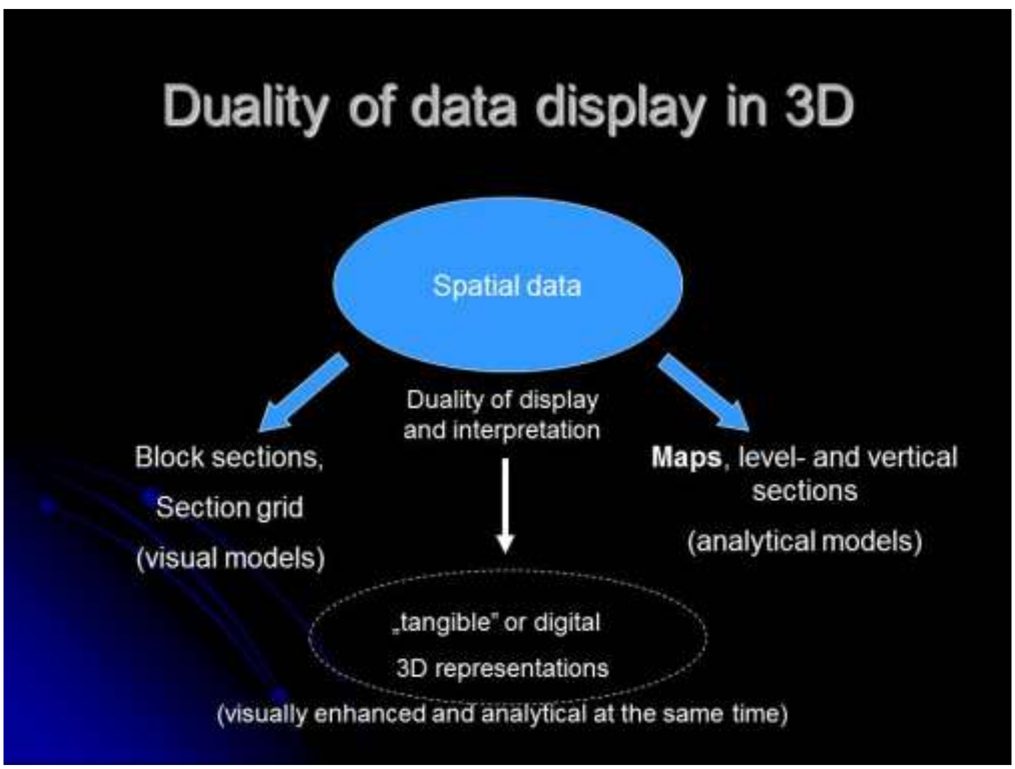
Slide 6 Definition of common expressions like 2.5D and 4D models



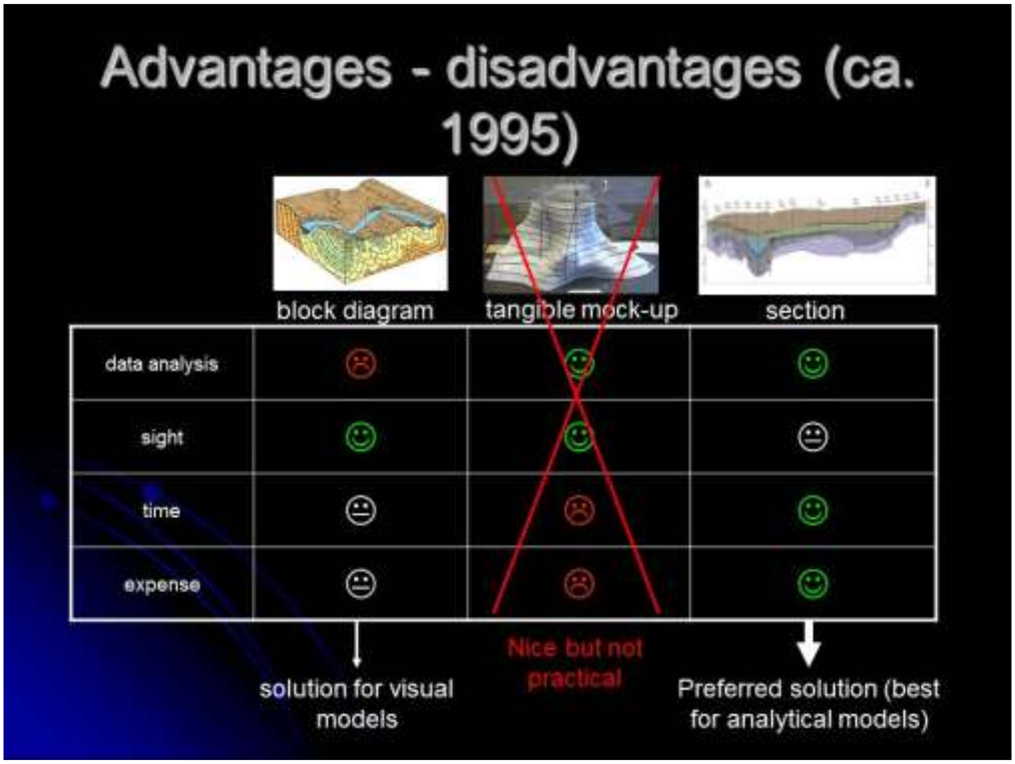
Slide 7 Hand drawn and tangible models before the digital era



Slide 8 Introducing the data reading difficulties of spatial representations

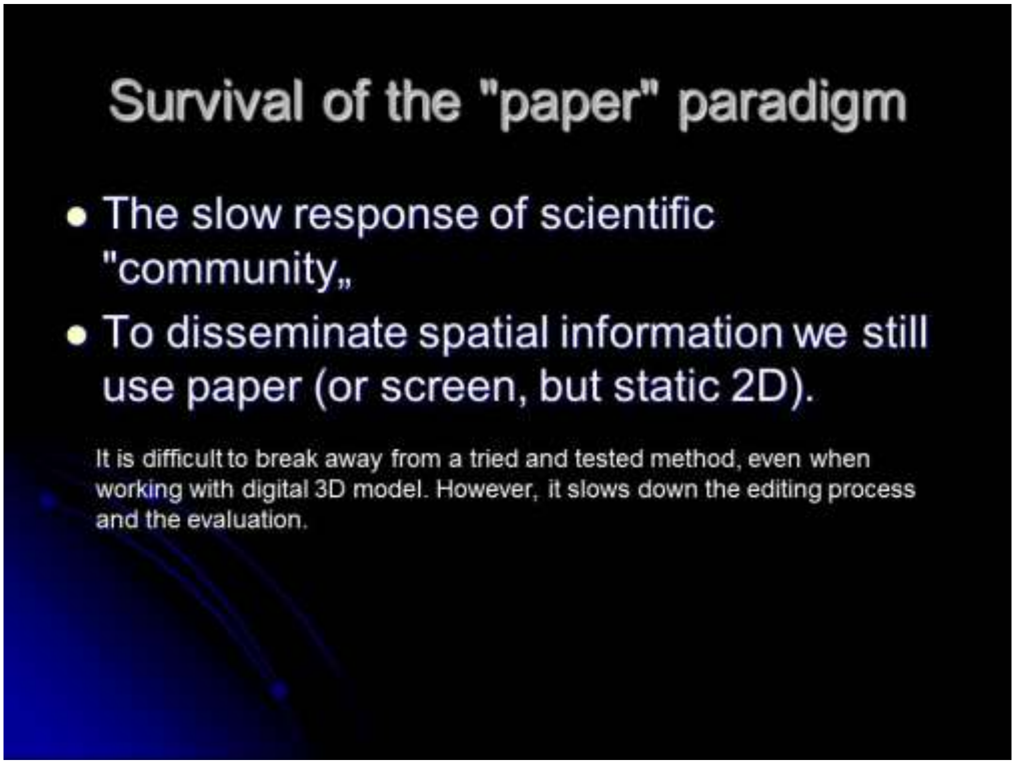


Slide 9 The duality of data display in 3D

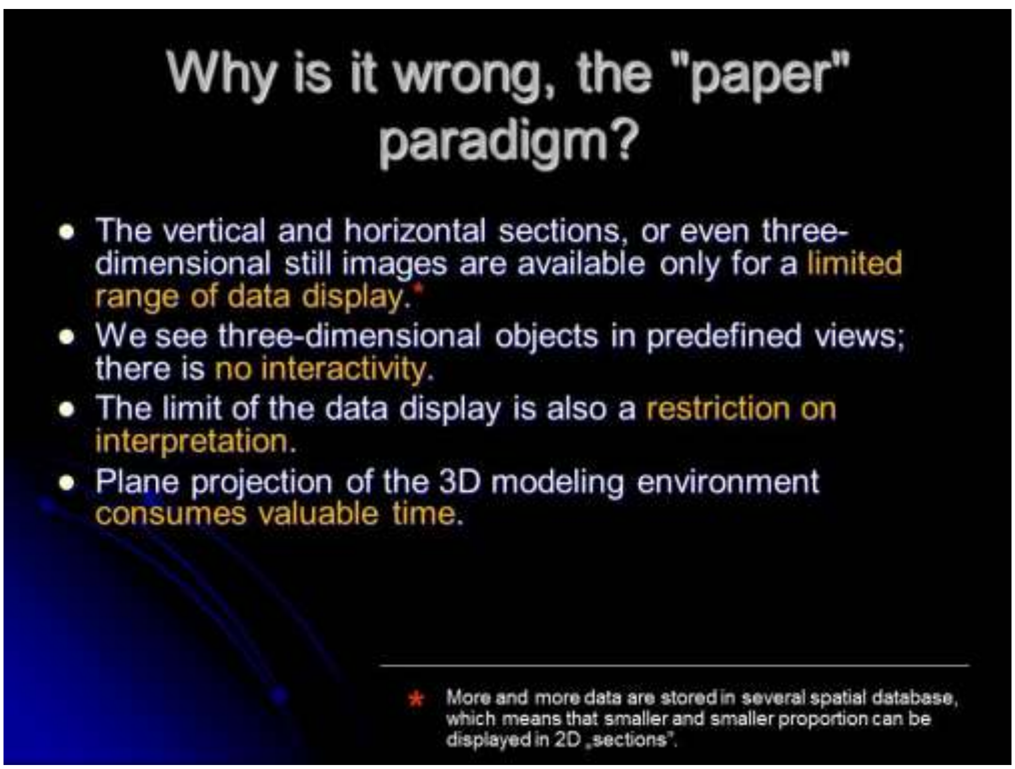


Slide 10 Advantages and disadvantages of the block diagrams, mock-ups and 2D sections

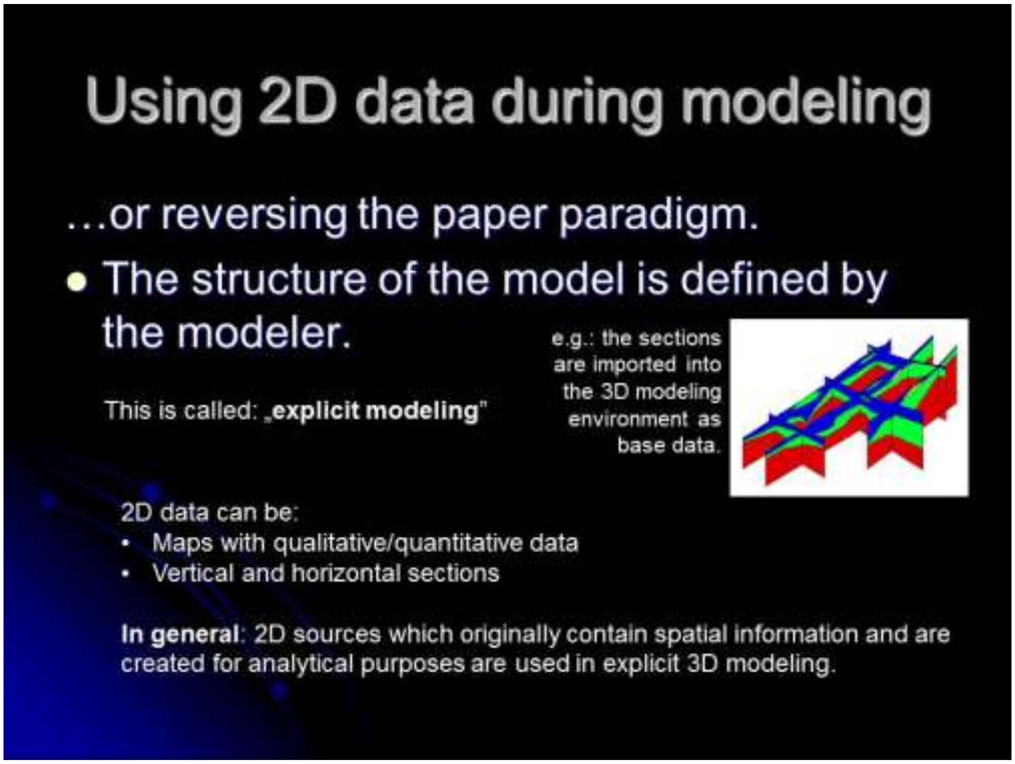
Slide 11 Comparison of the block diagram, digital 3D model and a 2D section from different aspects (utilization refers to the possibility to use the model for different purposes).



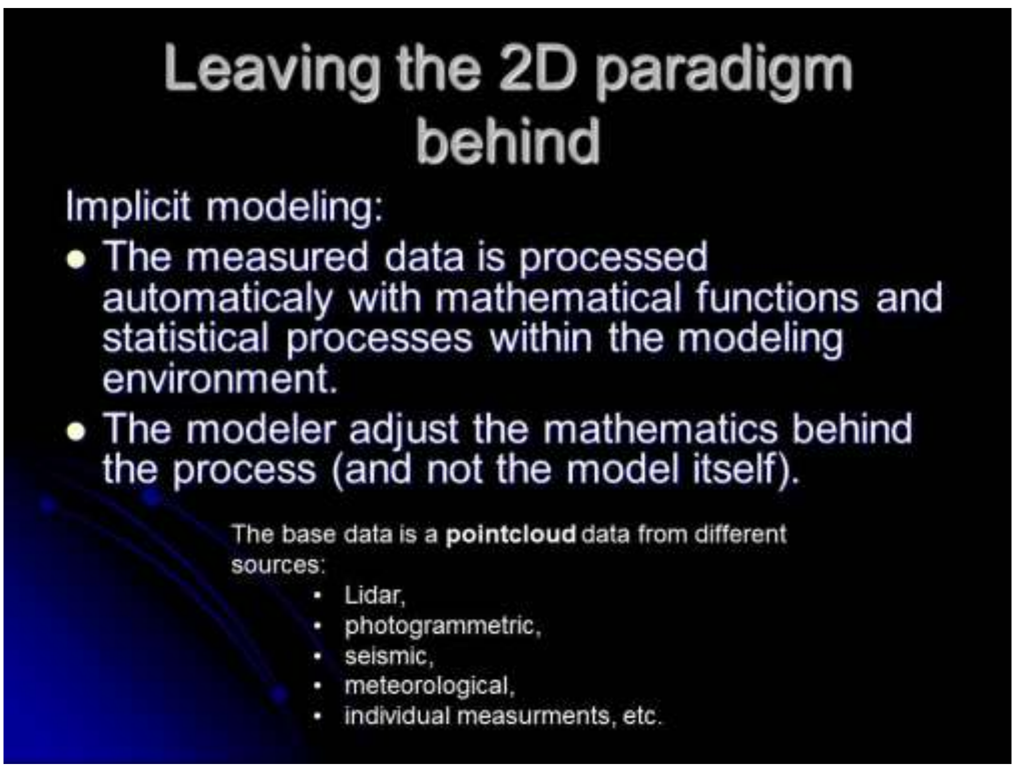
Slide 12 Reasons for the survival of the “paper paradigm” today



Slide 13 Reasons why we should abandon the “paper paradigm”



Slide 14 Introducing the basic model-building methods – the explicit modeling



Slide 15 The implicit method

Practical part of lesson 1 – the use of Global Mapper (part 1.)

The topics and exercises of the first practical class are listed below. The level of details of the discussion concerning each topic depends on the experience of the students.

1. Locate the webpage of SRTM (Shuttle Radar Topography Mission) on the Internet and download data from it.
2. Read the readme file before opening the downloaded data.
3. Import the data into Global Mapper.
   During opening: Why GM is good for us? – Overview of file formats in the import menu.
4. Reviewing the File menu items:
   File-Open, Unload, Catalogue, Download online data (Landsat), Workspace, Script (online help), Export, Combine Layers, Generate contours, Rectify
5. Reviewing the Tools menu (try out each of them)

Data traffic I-O:

6. Cut an area from the workspace (export raster to kml/kmz with defined bounds), then open it with Google Earth.
7. Draw polygons, polylines, and points in GE and export them to kml-files.

Transformation of data from kml to different formats (without GM i.e.: http://www.zonums.com)

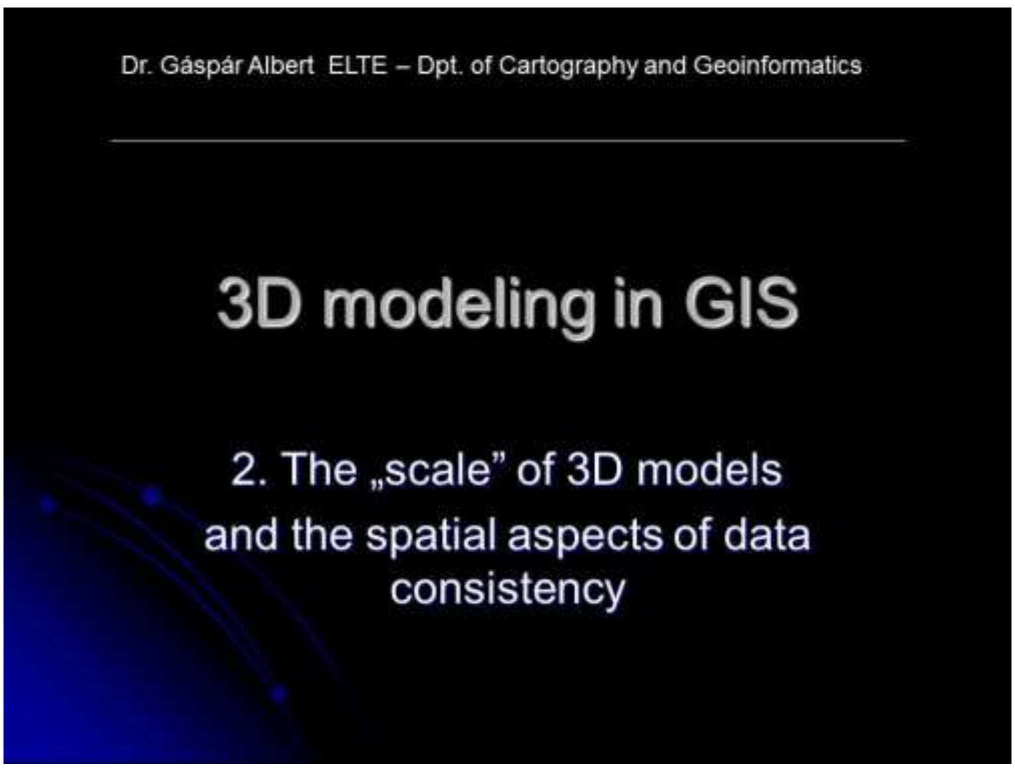
Lesson 2.

The topics of this class are the followings:

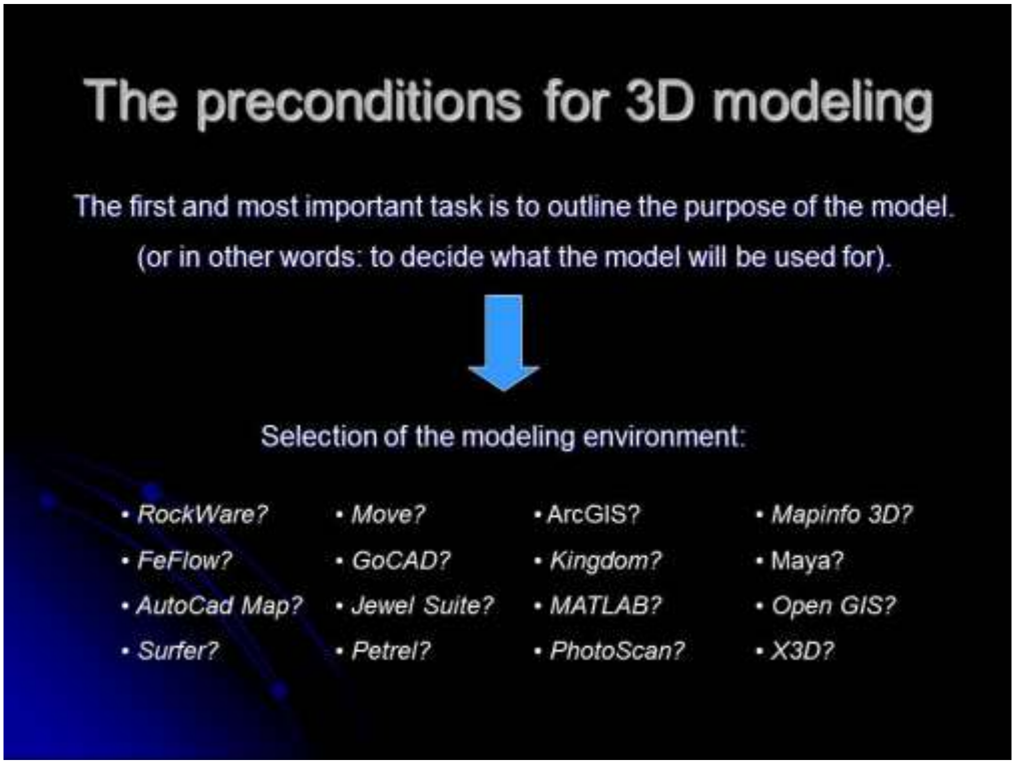
- The scale of 3D models (resolution, the concept of thematic scale/resolution).
- The coherence of data (mashup of measurements in one system).
- Objects in the model (point, line, polyline, plane, surface, polyface mesh, solid).

Practice: overview of different modeling software for earth sciences (Surfer, Rockworks, Modflow, Petrel, JewelSuite, Move, Vulcan, etc.). Working with GlobalMapper – definition and analysis of the data structure (new features, adding attributes), composition of cross-sections and extracting elevation data from surface models (file export).

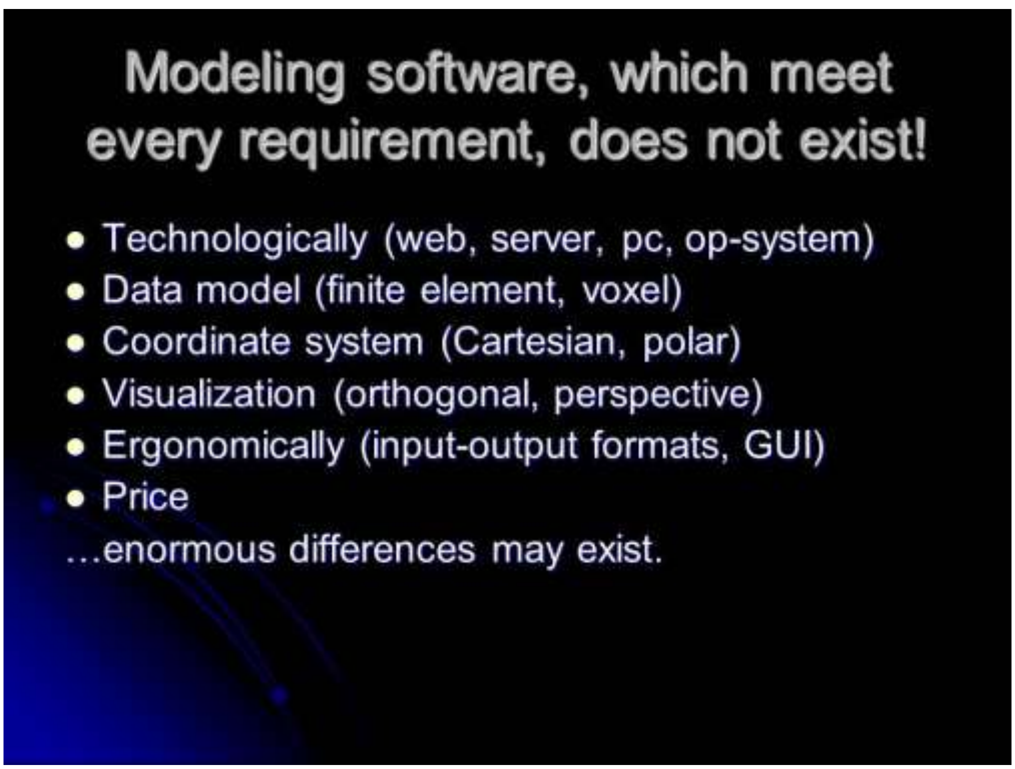
The „scale" of 3D models and the spatial aspects of data consistency



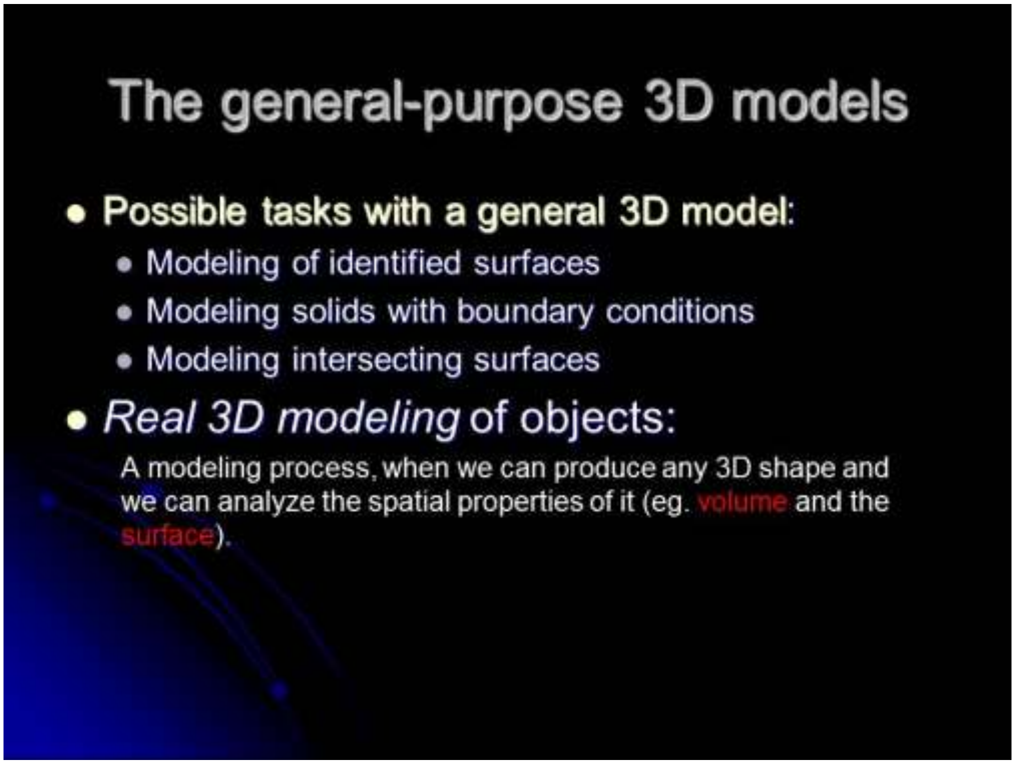
Slide 16 Welcome slide of the theoretical presentation



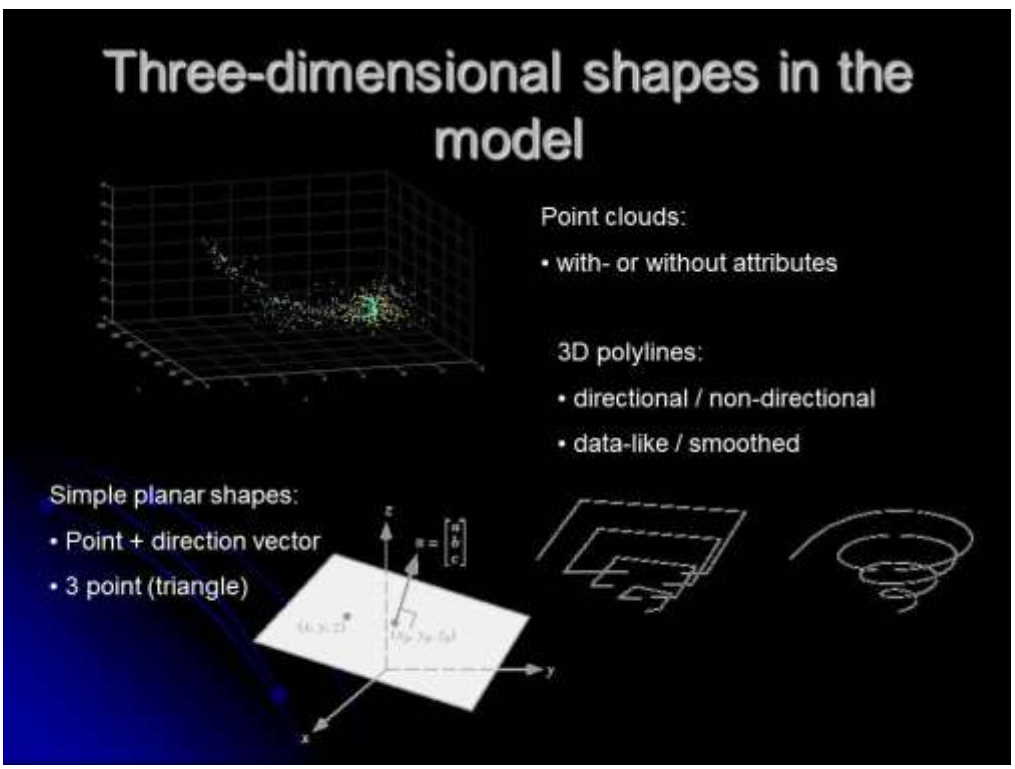
Slide 17 Start the modeling with defining the purpose of the model



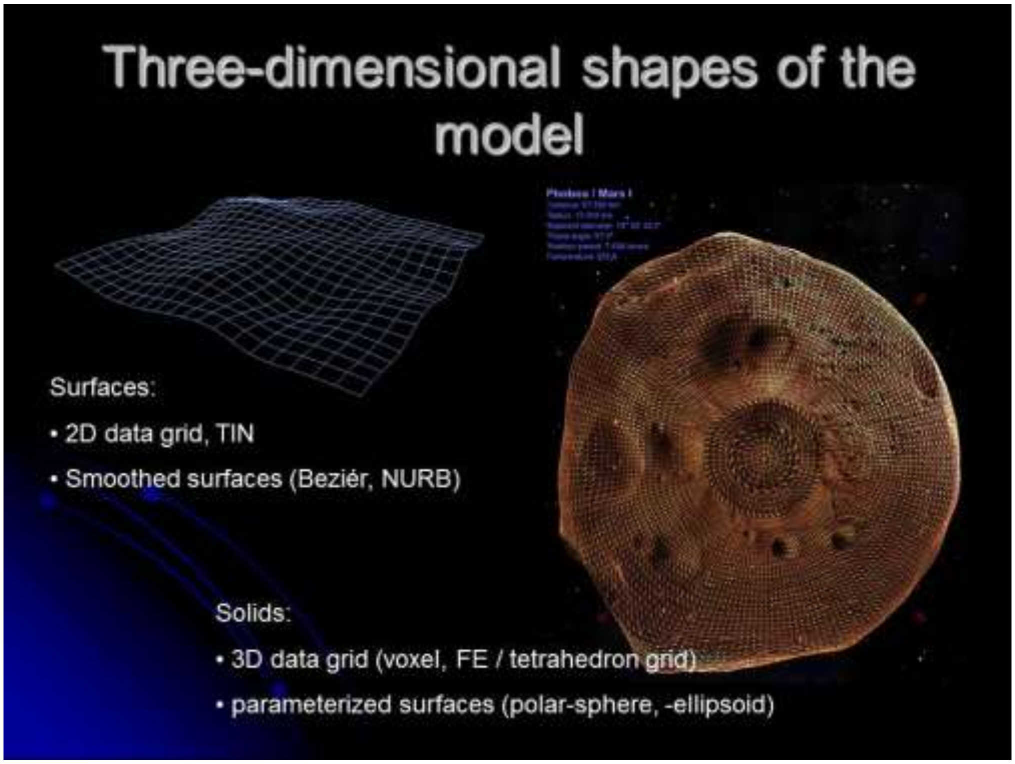
Slide 18 Keep our expectations in bounds: tools for all purposes are dreams!



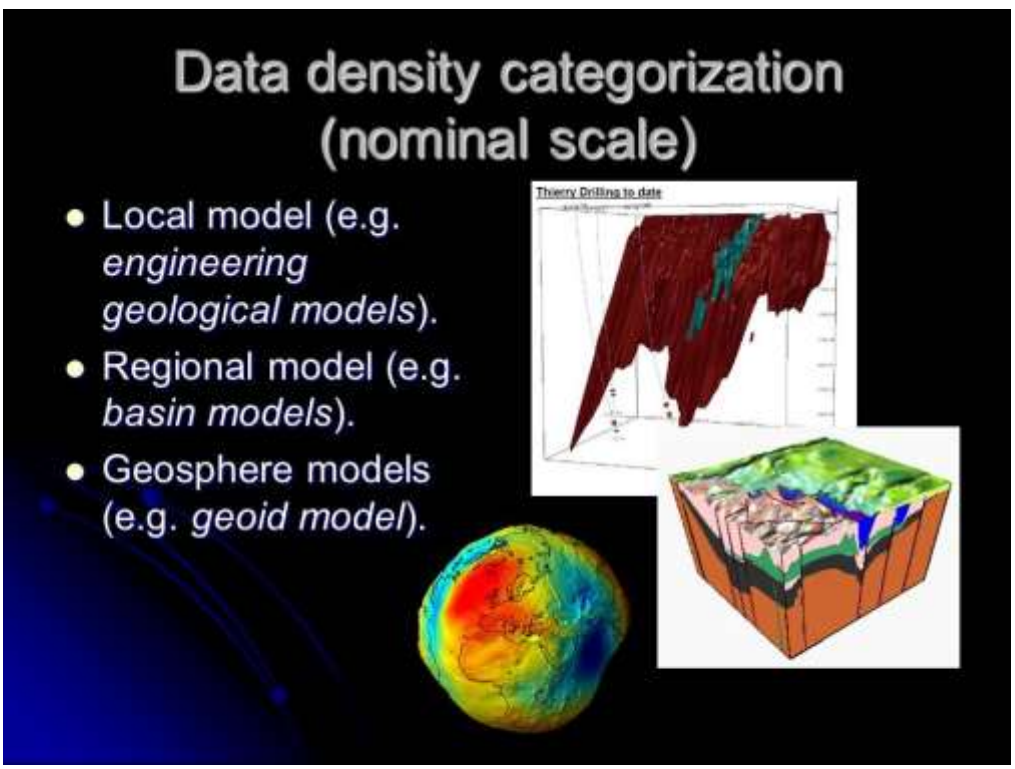
Slide 19 The general purposes of 3D models and the “real 3D modeling”



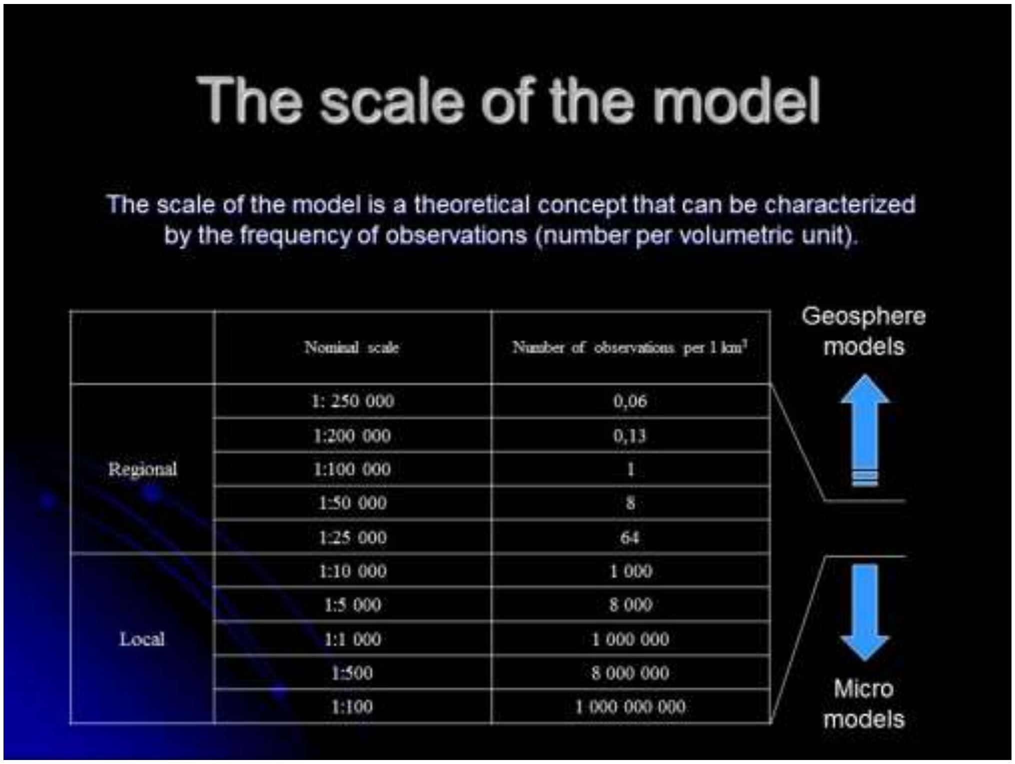
Slide 20 Object and shapes in a 3D model – point clouds, lines, polylines, planes



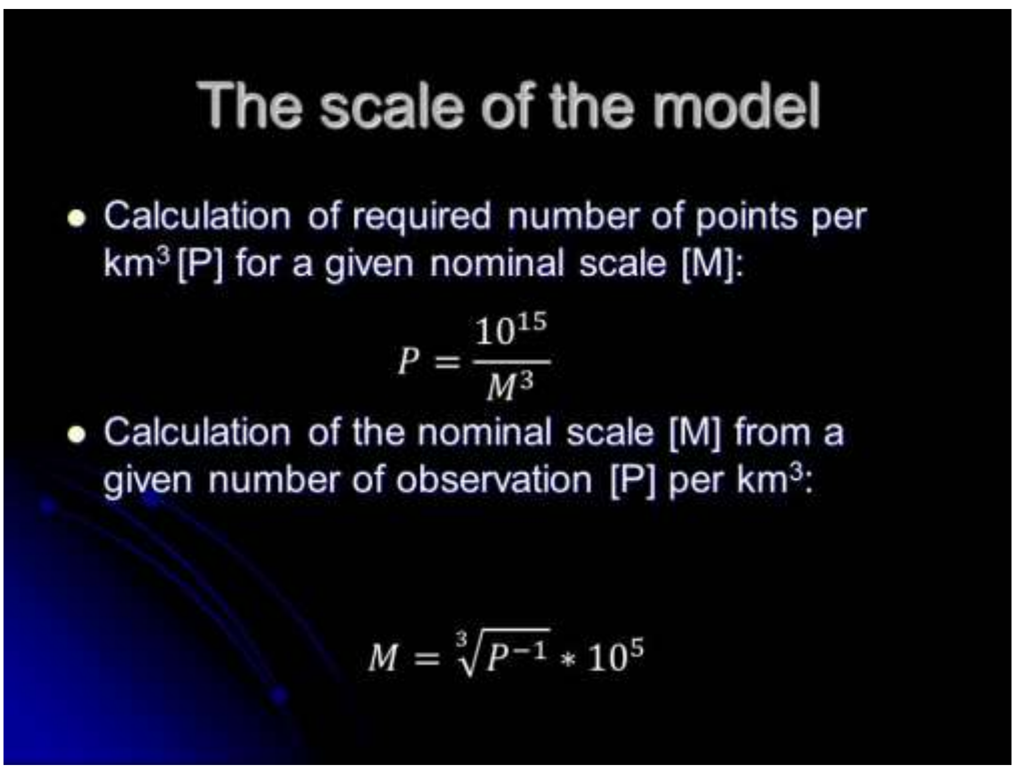
Slide 21 Object and shapes in a 3D model – surfaces, solids



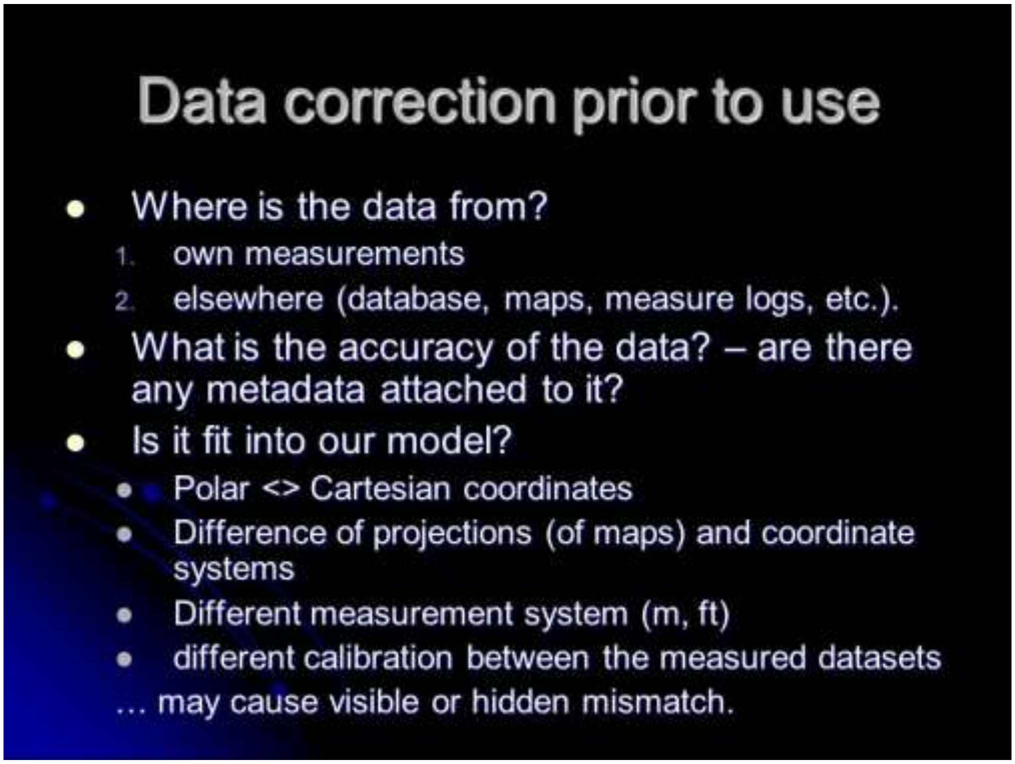
Slide 22 The different (nominal) scales of the models demonstrated with geological models



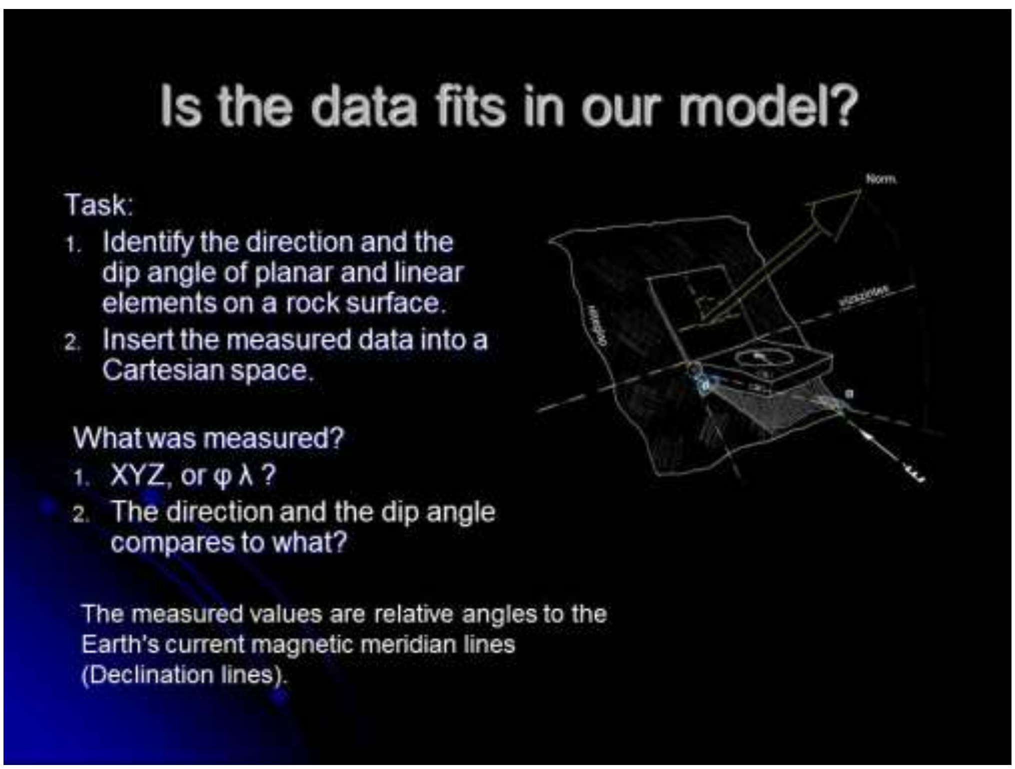
Slide 23 Definition for the different nominal scale categories



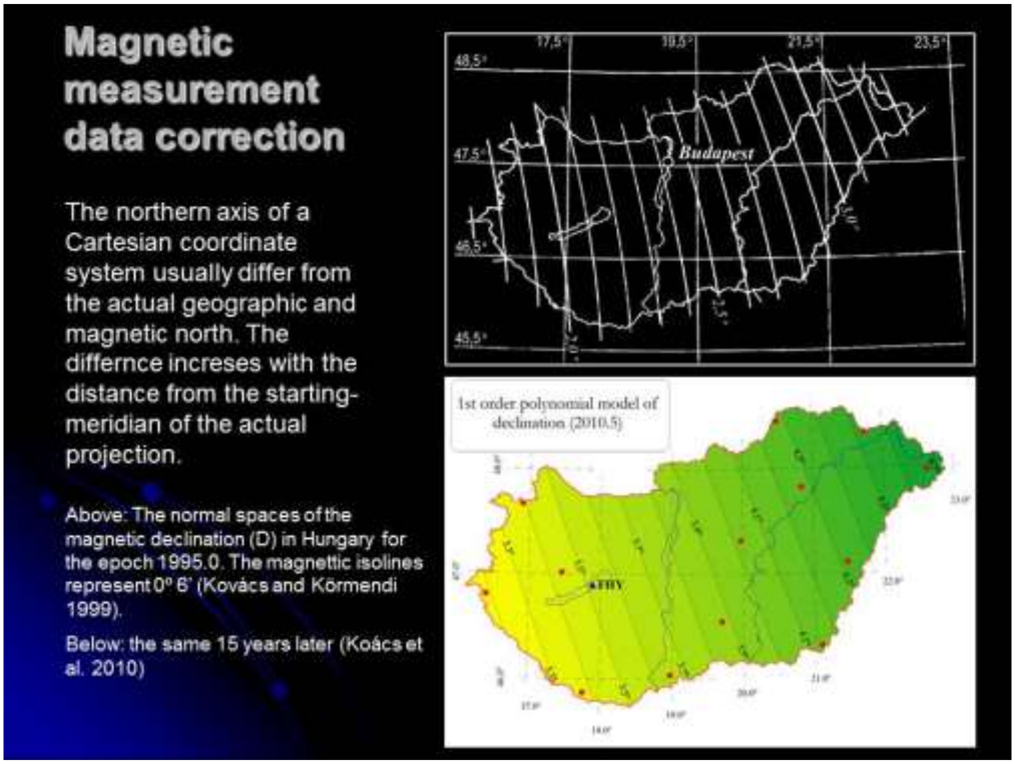
Slide 24 Calculations of the nominal scale from the number of data points and the required number of data for a given scale.



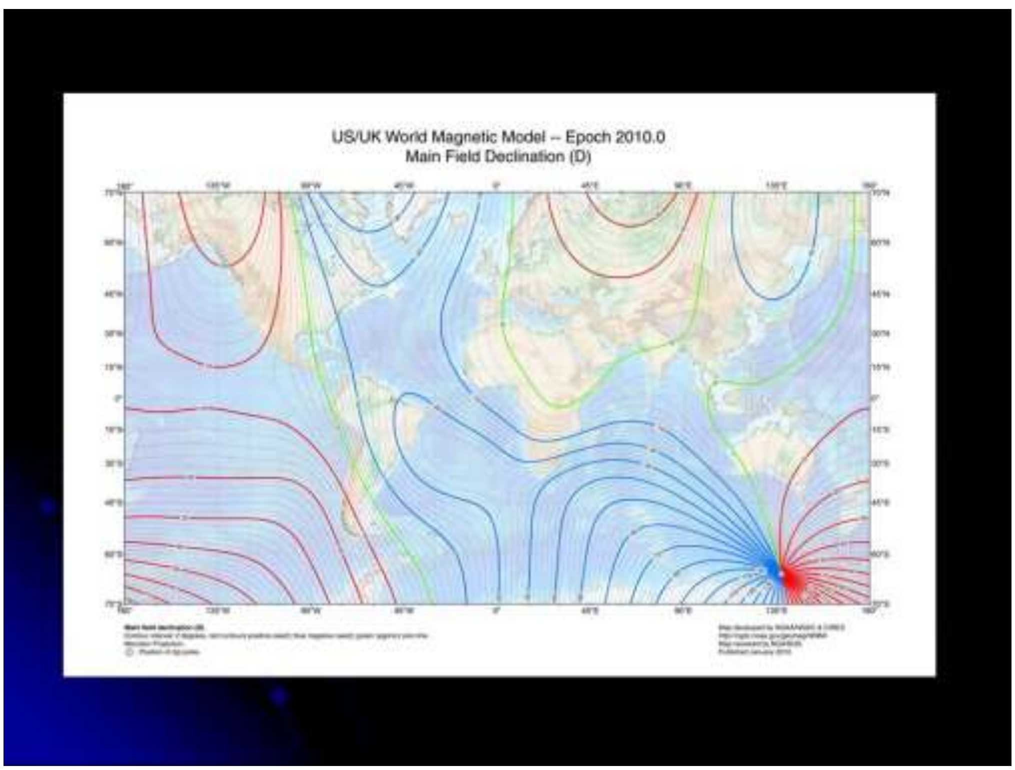
Slide 25 Data correction prior to use.



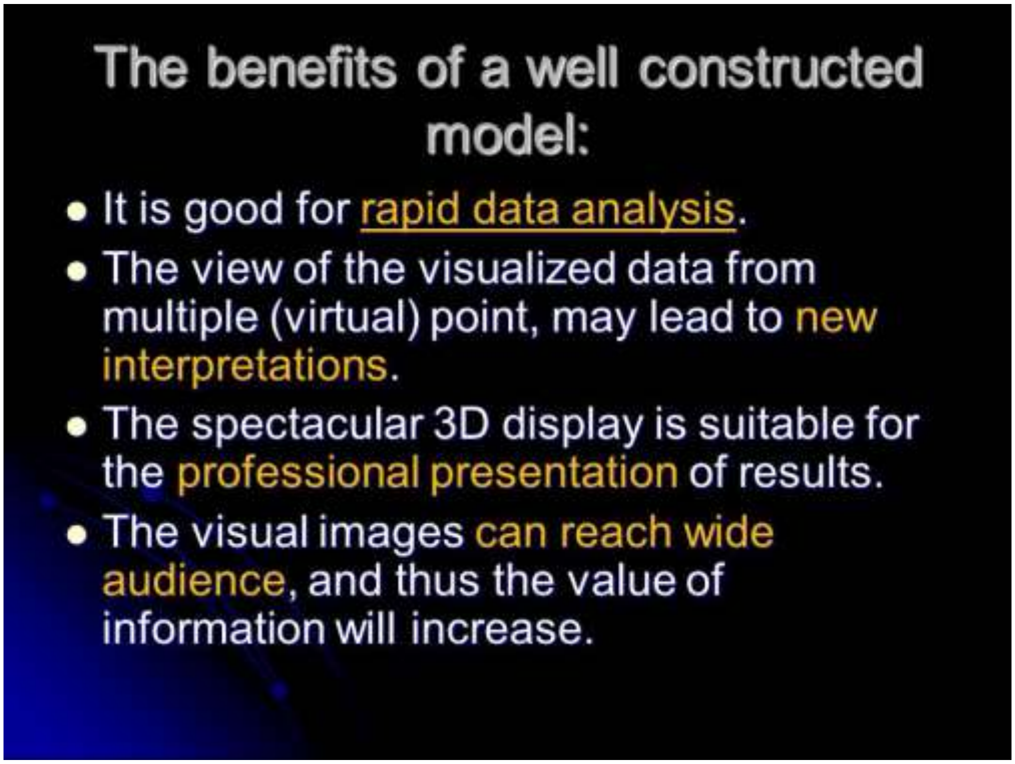
Slide 26 Introducing the problem of data import into a modeling environment



Slide 27 A discrepancy in the coherence of data may originate from the different time of magnetic measurements because the magnetic declination is continuously changing.



Slide 28 The source of magnetic data in recently used navigation systems is the WMM (Word Magnetic Model)



Slide 29 The possible benefits of a well-constructed model

References in the slides:

Kovács, P., Körmendi, A. 1999: Geomagnetic repeat station survey in Hungary during 1994–1995 and the secular variation of the field between 1950 and 1995. – Geophysical Transactions, 42 (3-4) pp. 107–132.

Kovács, P., Csontos, A., Heilig, B., Koppán, A. 2012: Hungarian repeat station survey, 2010 – ANNALS OF GEOPHYSICS, 55, 6, 2012

Mihályi Sz. 1995: The descriptive catalog of the Hungarian geodetic related projection systems - 4. ed – Institute of Geodesy, Cartography and Remote Sensing, Budapest

Practical part of lesson 2 – the use of Global Mapper (part 2.)

The aim of the class is to get familiar with the general file formats describing points, lines, polylines, and to study the attributing capacity of these formats.

Importing raster map into the GIS environment

1. Load a raster map (open->All supported raster types). If the file isn't georeferenced, then: rectify (select a coordinate system, add 4 points).
   Find the 74_423.jpg file; say yes to the popup question. An Image Rectifier window appears. On the lower part of the panel set the Ground Control Point (GCP) Projection to Hungarian National Grid and press OK. Set the coordinates of the four corner points according to the following table:

	Easting	Northing
Upper left	612 000	268 000
Upper right	618 000	268 000
Lower right	618 000	264 000
Lower Left	612 000	264 000

   Press OK when finished.

Digitization

2. Configure the attribute to be added to the line type (*Tools-Configuration, Line Styles panel*). Choose the line type you want to use, or create a new one, then clicking on the *Attributes* button, specify the attribute you want to add to the line during digitization – create an ELEVATION attribute (you can also set default values, if you choose). On the *Vector display* panel you can set that only those types of lines be selectable, what you had used.
3. Digitize some contour lines as for an exercise. Give descriptive name to the objects (try to add identical names, see if it is allowed).
   Attention! In the database, managed by the GM in the background, the identity of the names is not a problem, because the objects aren't identified on this basis. GM creates its own unique identifier field in its database! The name is only an attribute assigned to the object.
4. Look at the information of the lines with the query *Feature info tool*. We can see that the geometric data of the program is also stored in the background database (number of vertices, length), and we can look into the stored data pressing the *Vertices* button.
5. Select vertices in the *Feature Vertex List* window and see that the selected vertices are highlighted in the map window. Press the *Edit position* button to relocate the selected vertex. Press the *Add Elevation* button to create a new ELEVATION field in the Feature vertex table (Note that you can also modify the elevation values, although in the map view this will not change anything!).

6. Rename the created feature in the *Control Center* (push the right mouse button – Edit the selected Layer's description).

Output formats

7. Export the overlay into different vector formats (ascii), and see how they look like in notepad.
   File formats: xyz (Simple Ascii text); bln (Surfer line); dxf (Autocad); kml/kmz (Google Earth); gpx (GPS Exchange).
   Look at the content of the file! Notice how coordinates are written, what the name of each line is, what the file structure look like, etc…

Important observation! Which file type can store attributes and how it is formulated? To start working in a modelling environment, one has to know how to convert data into the proper format.

Differences of data structures

8. Open the AG001.kml in Global Mapper, and inspect the point with the *Feature info tool.* Do the same with the AG001_Global.kml.
9. Open both files in Google Earth, and inspect the points with clicking on them.
10. In Notepad we can compare the structure of the two kmls.

Questions concerning the study-kmls:

- Are these kmls database?
- What is the purpose of each?

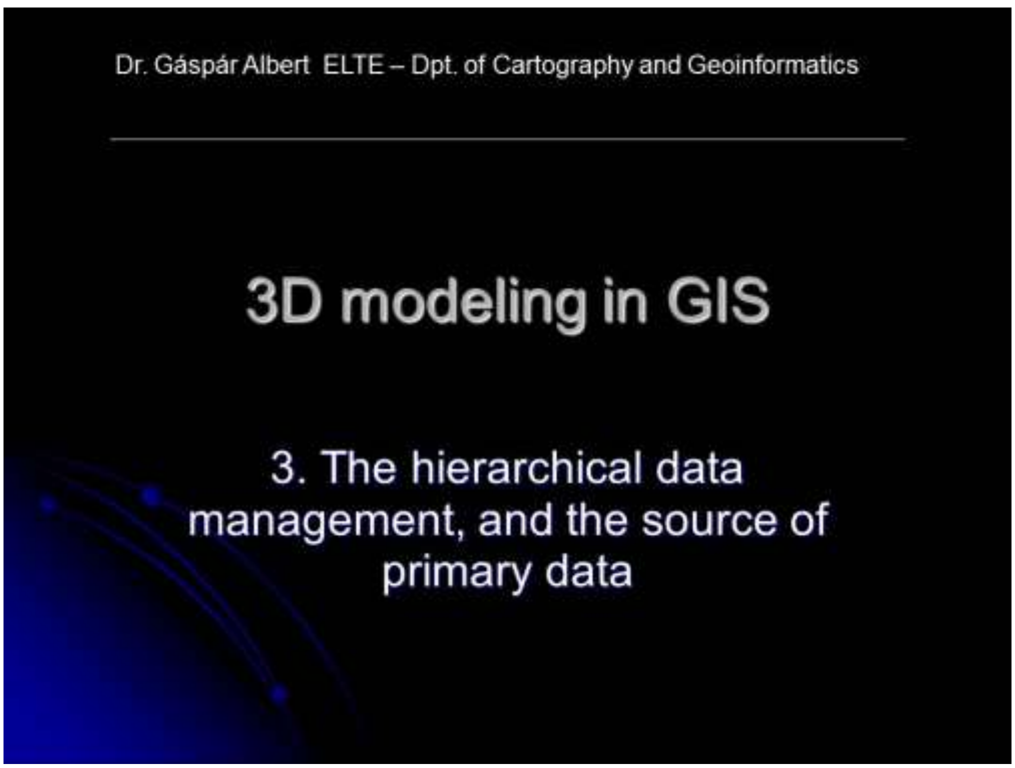
Lesson 3.

The topics of this class are the followings:

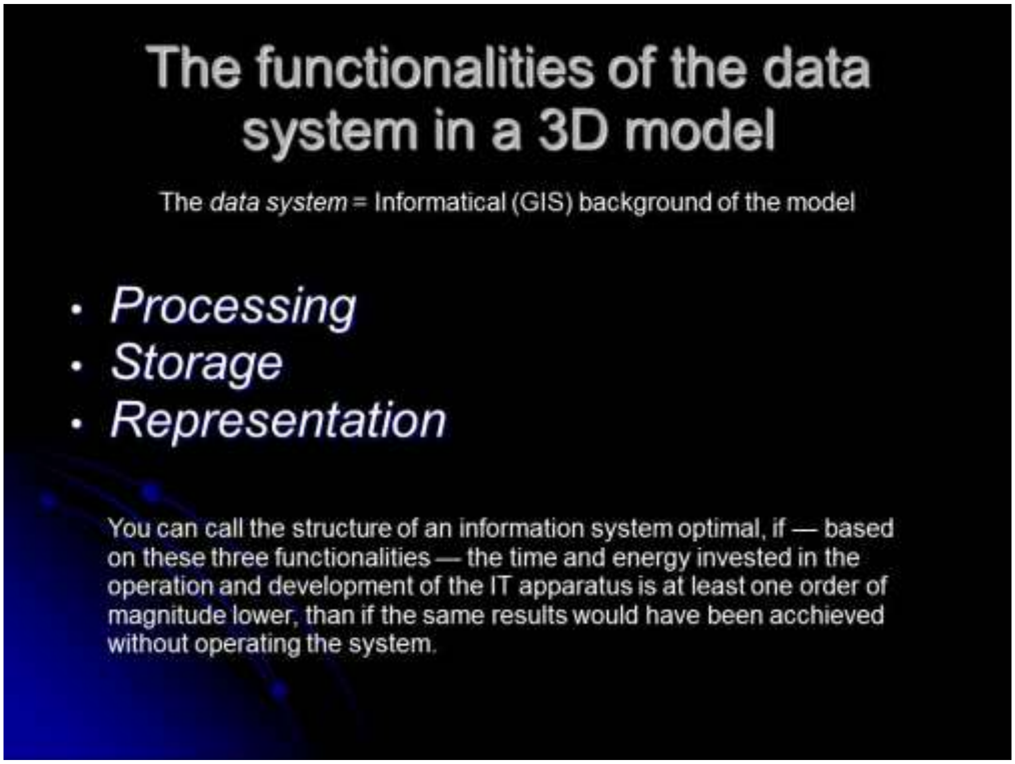
- Hierarchical management of data (primary-, or base data, secondary-, or compiled data)
- Data system of 3D models (connecting completely different subsystems into one, management of the data system).
- The functionalities of the data system (processing, storing, analysis and visualization).
- The source of primary data (maps, notes, log files, measurements in air/ on surface/ underground).

Practice: Constructing surface models from Excel. The use of Surfer – data input (points/lines/surfaces), and the parameterization of the modelling process.

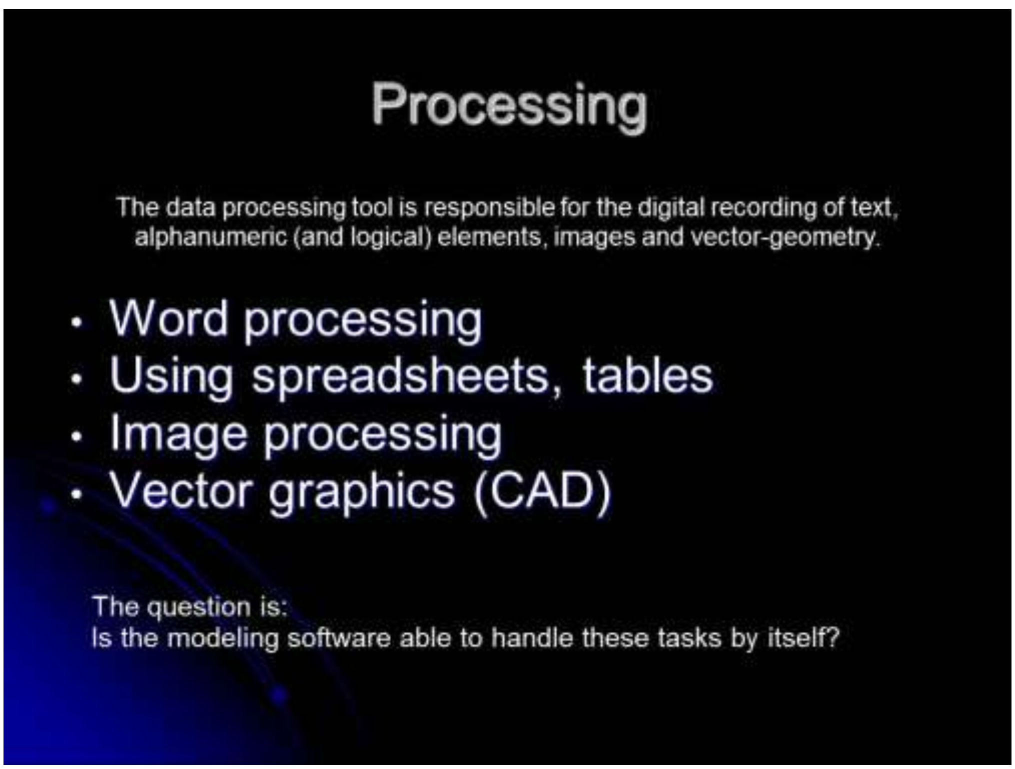
The hierarchical data management, and the source of primary data



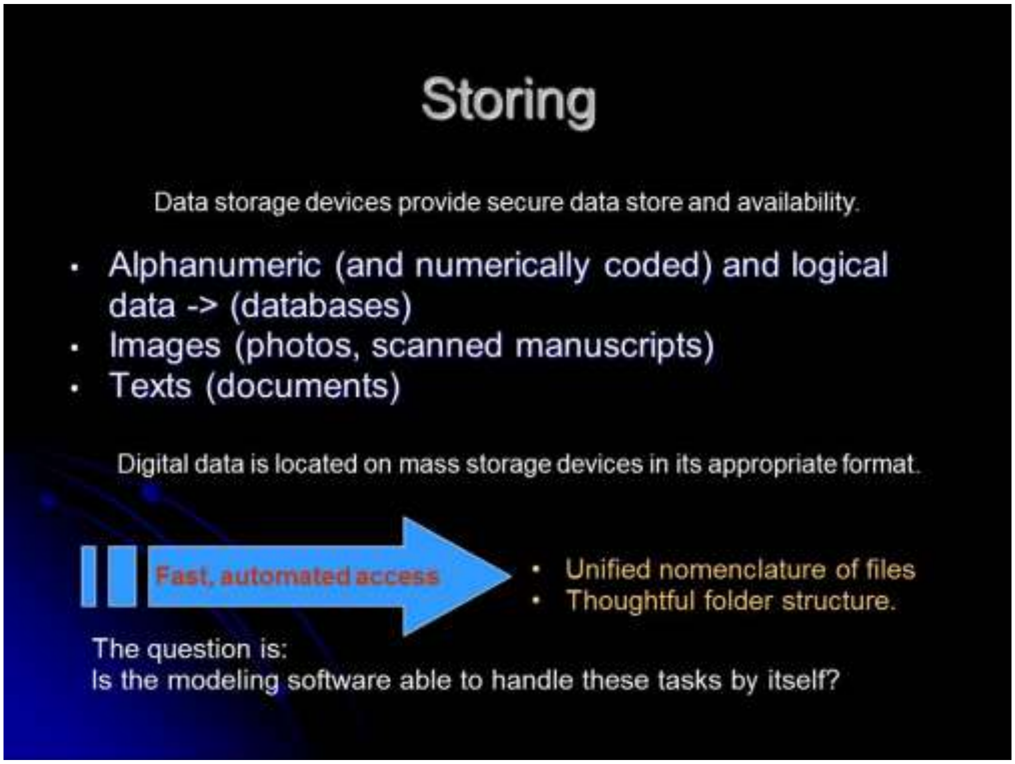
Slide 30 Welcome slide of theoretical class No. 3.



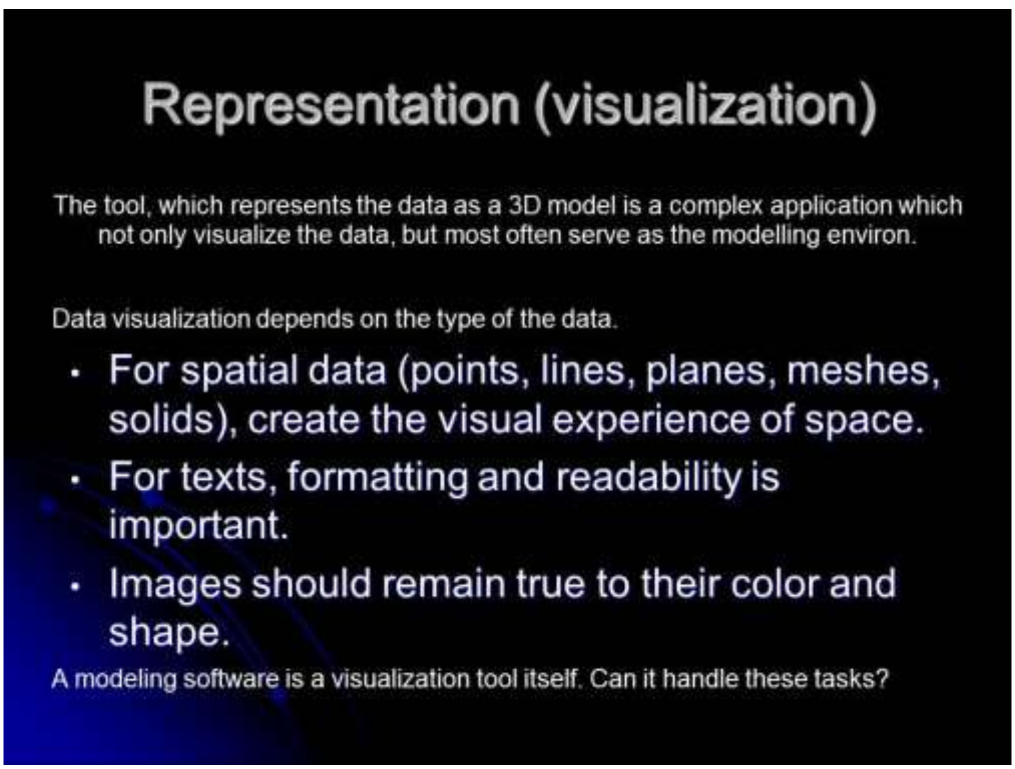
Slide 31 Basic functionalities of the data system of a 3D modeling project



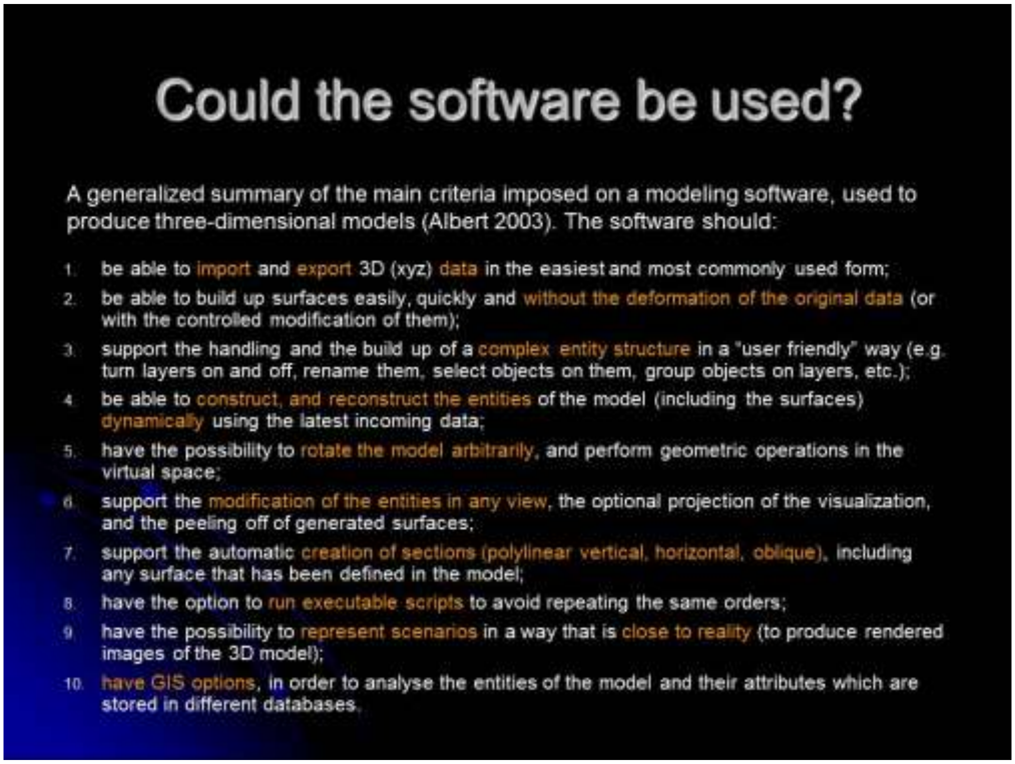
Slide 32 Usual types of the processed information in a 3D modelling task



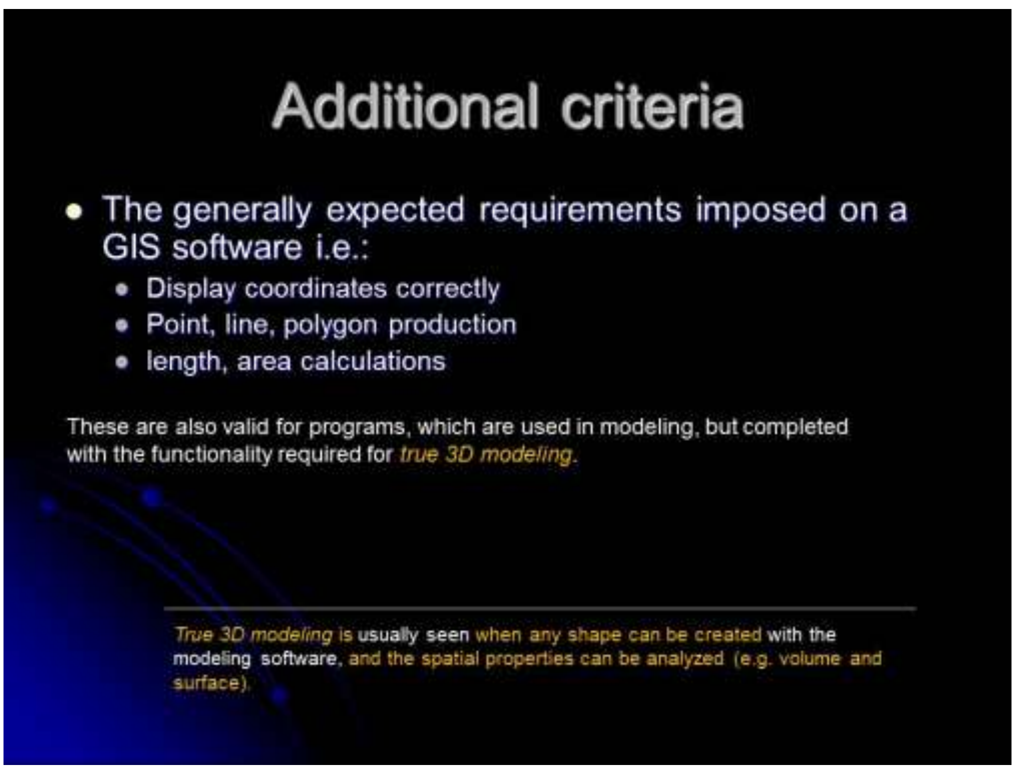
Slide 33 The aspects of data storing



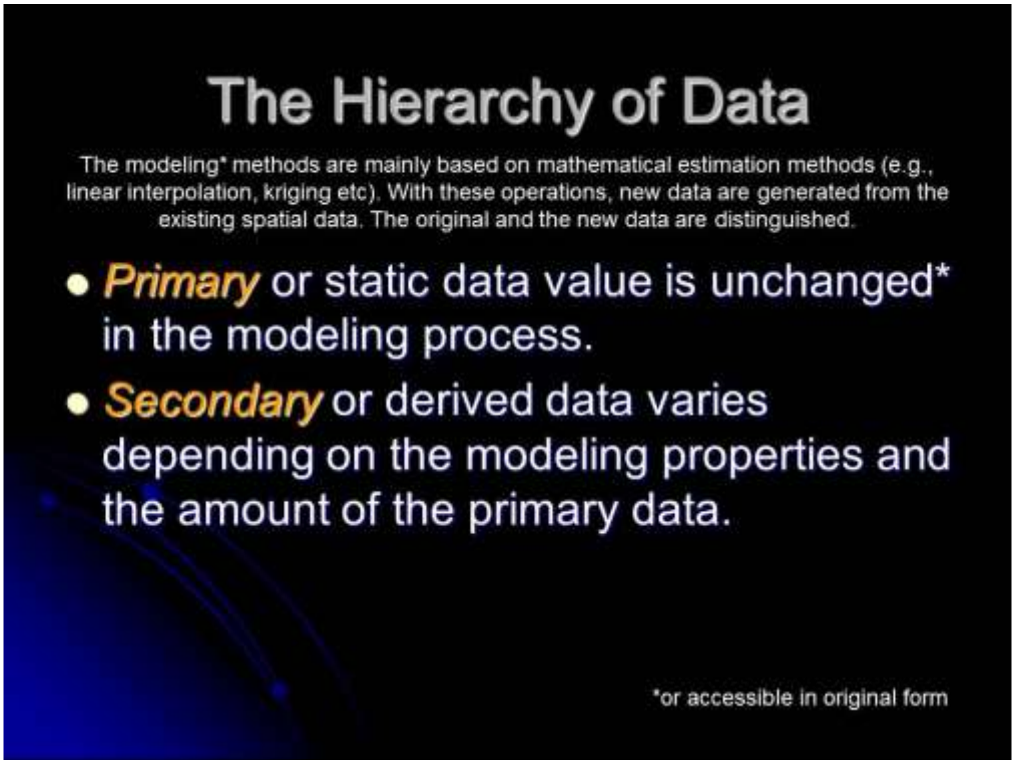
Slide 34 The aspects of data representation (visualization)



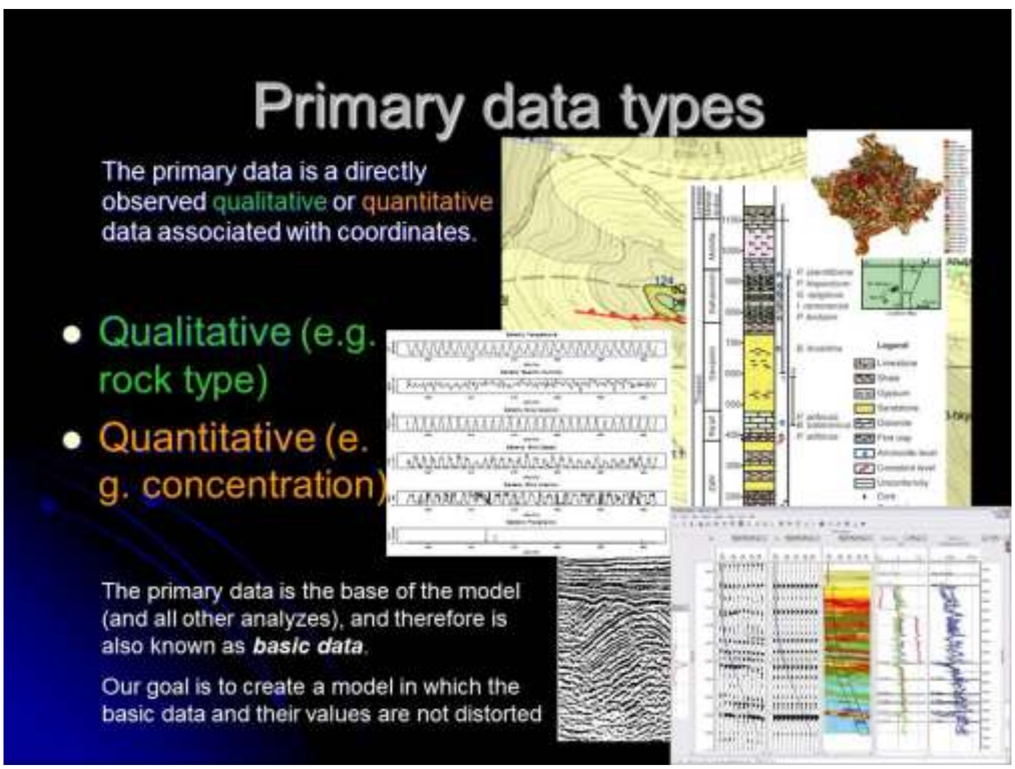
Slide 35 Criteria for the usability of any software from the aspect of 3D modeling



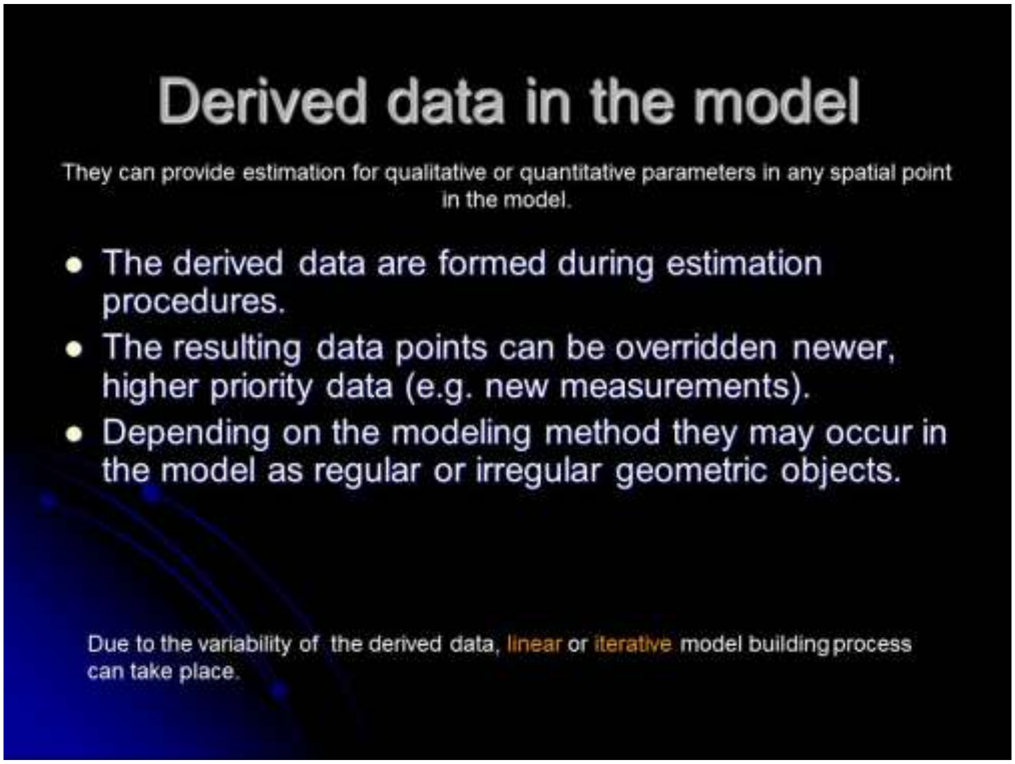
Slide 36 Criteria for any software, which is used for GIS purposes



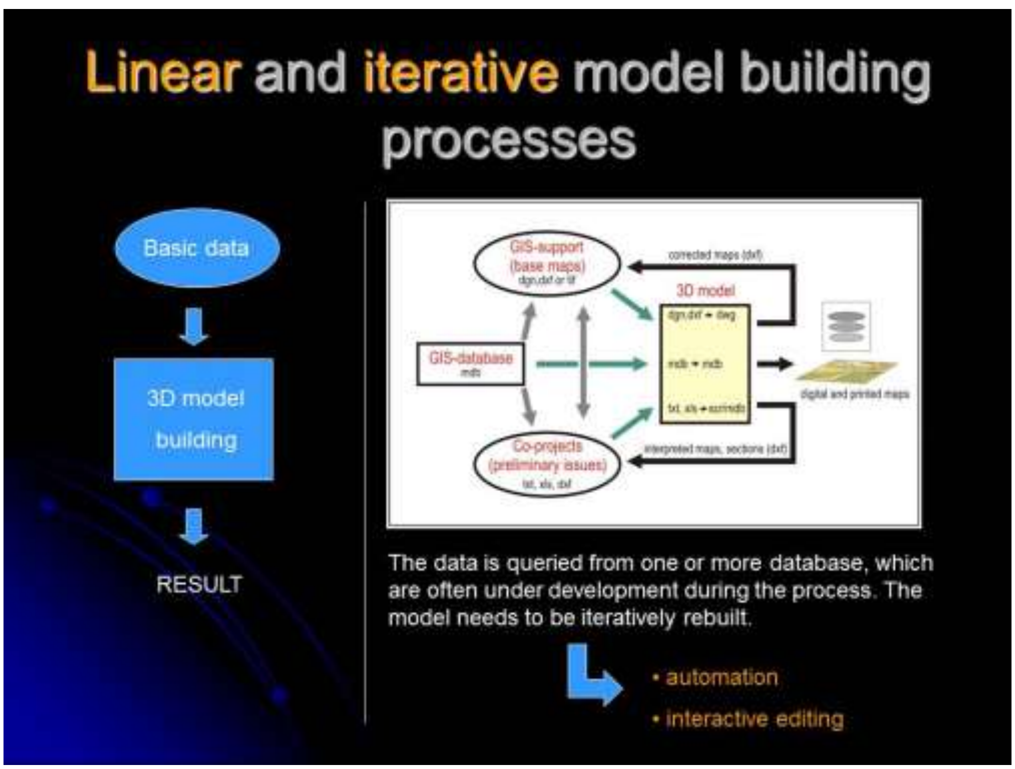
Slide 37 Definition of primary and secondary data



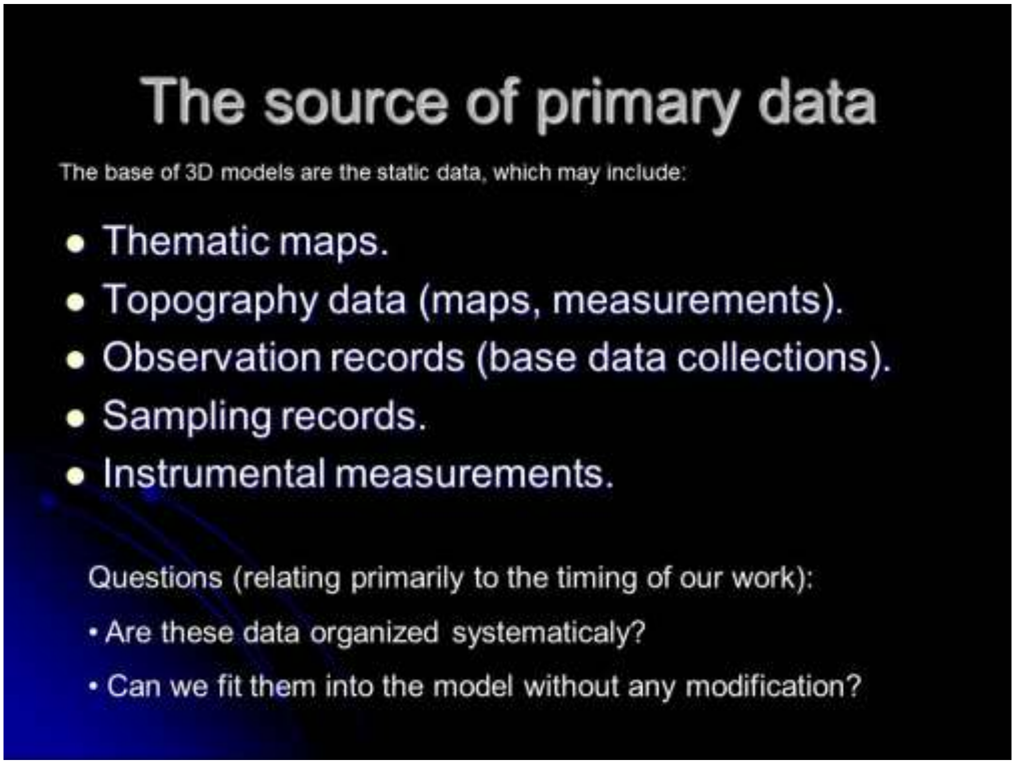
Slide 38 Types of primary data (differentiating quantitative and qualitative)



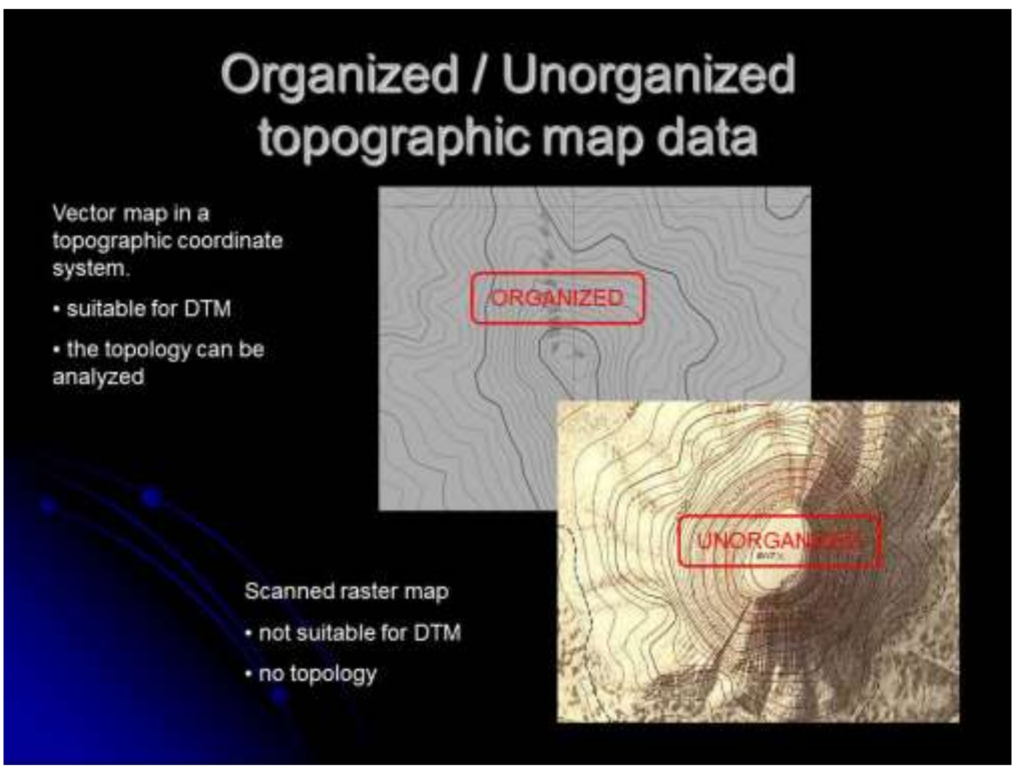
Slide 39 Derived data in the model



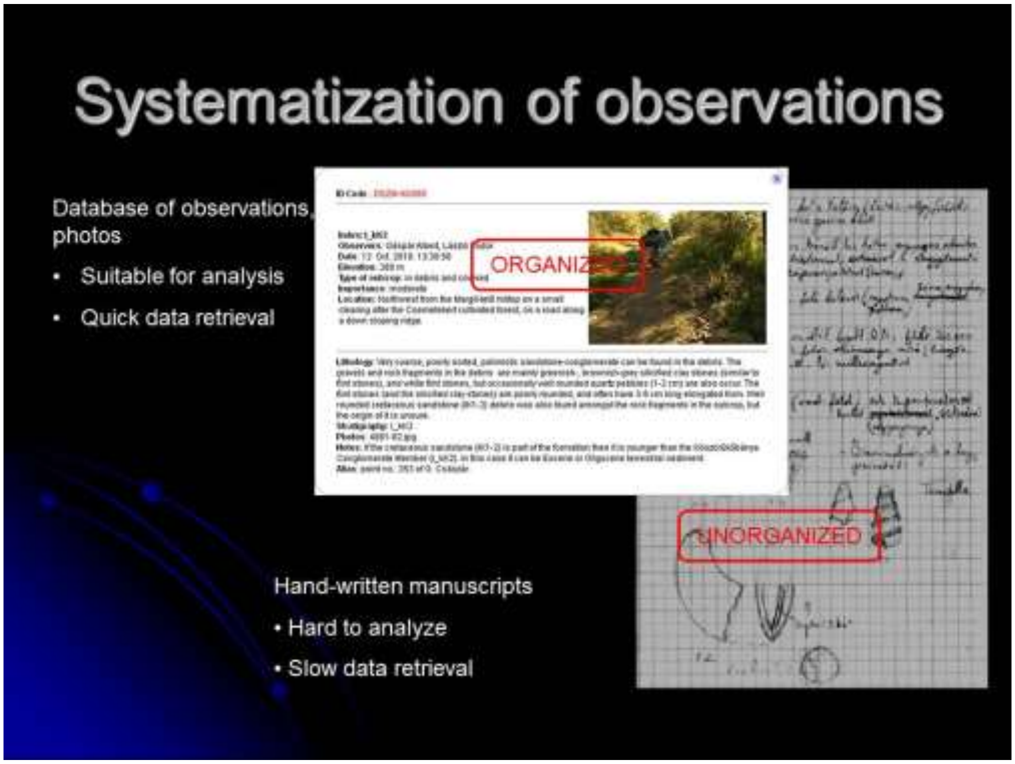
Slide 40 Linear and iterative model building processes



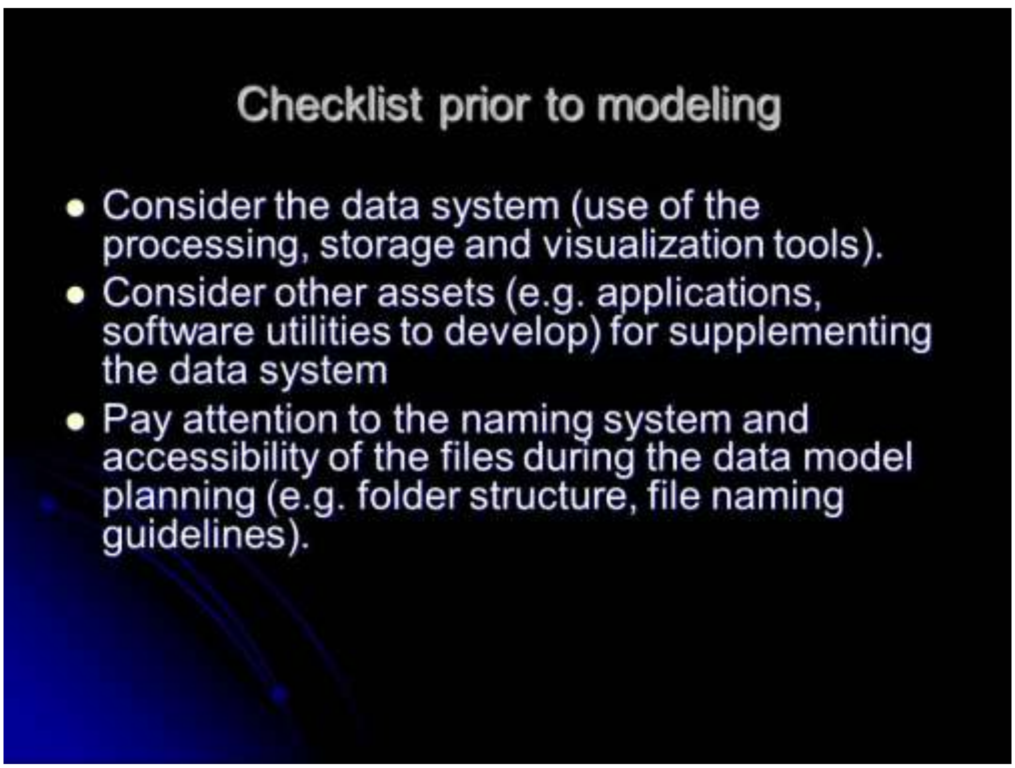
Slide 41 Different sources of primary data



Slide 42 Maps as primary data sources, and the aspects of data acquisition from them (organized/unorganized map data)



Slide 43 Organized and unorganized primary data stored in digital and analogue "databases"



Slide 44 Important considerations prior to the modeling

References in the slides:

Albert G. 2003: Modelling of subsurface geological structures on a future disposal site of low- and intermediate-level radioactive wastes. – European Geologist. Journal of the European Federation of Geologists, Dec. 2003, pp. 23–26.

Elek I. 2006: Introduction to geoinformatics – ELTE Eötvös Kiadó, Budapest, 2006.

Practical part of lesson 3 – Use of Surfer (part 1)

Surfer is a GIS tool with 2.5D modelling capacity.

Aim of the class is to compile maps using Surfer 10 from point data. Use the available Excel table (*Peldaadatok.xls*).

1. Available items in the Map menu:

    a. *Base Map* – load one map (dxf, shp, bln file) from the working region.

Go back to the *Grid* menu and cut the grid with the *Blank* menu option.

    b. *Contour Map* (New, Labels, Export)

    c. *Post Map* (post point names and texts from a database or a map file onto a map as a new object).

    d. *Image Map* convert the grid values into 0-255 greyscale raster on a given resolution (TIF-files can be created).

    e. *Shaded relief* (creates shades on the surface according to the elevation)

    f. *Vector map* (shows the direction and the rate of the difference between data points in the grid as a vector on the map). Two grids can be also combined.

    g. *Wireframe* (3D view wireframe)

    h. *Surface* (3D view colour)

In the next subchapters exercises with these menu items are described.

Creating point maps

2. Map – New – Post map (select *Peldaadatok.xls* worksheet: Munka1). In the Object manager (upper left panel) select the “Post” object from the tree structure. In the property manager (lower left panel) set the X and Y coordinates to LAT and LON (say yes to the popup message).

Set the sizing method to “proportional” and press the “scaling” button. In the popup window, select the column F for “worksheet column containing height”. Try different symbol styles in the “marker properties”.

3. Export the post map into a kml (File – Export); in the popup window, select the kml/kmz panel and turn on the “render marker symbols” option. Open the file with Google Earth and look at the “object IDs” of the points (the IDs were assigned to the objects by the Surfer and the original IDs were not used).

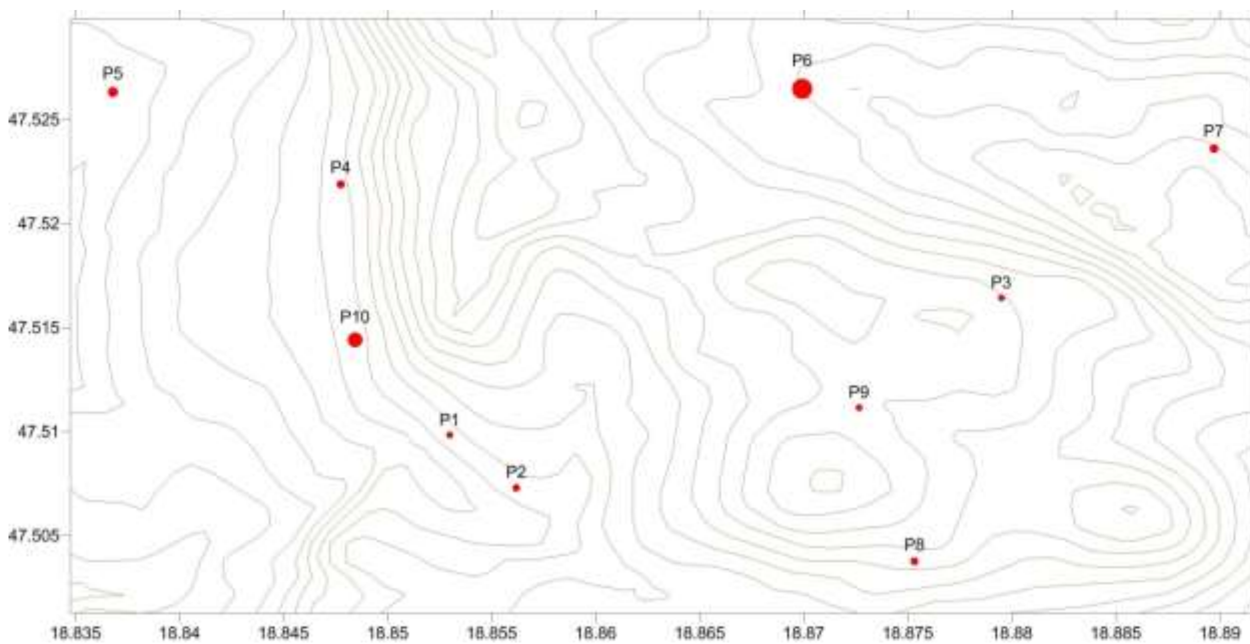


Figure 1 The layout of the post map overlay (Peldaadatok.xls) and the base map (contours.dxf) overlay

Creating line maps

4. Map – Add – Base map (select contours.dxf) and press ok for the popup questions. In the Object manager the “Base” base map will occur. Slowly double-click on it and rename to: “dxf contours”. Expanding the + sign the objects (polylines) will be listed.

5. Map – Add – Base map (select landsat rgb.tif) and press ok for the popup questions.

Creating surfaces

6. Grid – Data… menu (importing the table); specify the parameters of the grid, select the interpolation method, specify the output file name. [This method will be discussed in details in the next lesson]

Interpolation in Surfer:

Yang, C.-S., Kao, S.-P., Lee, F.-B., & Hung, P.-S. (2004). Twelve different interpolation methods: a case study of Surfer 8.0. Paper presented at the XXth ISPRS Congress Technical Commission II, Istanbul, Turkey. http://www.isprs.org/proceedings/xxxv/congress/comm2/papers/231.pdf

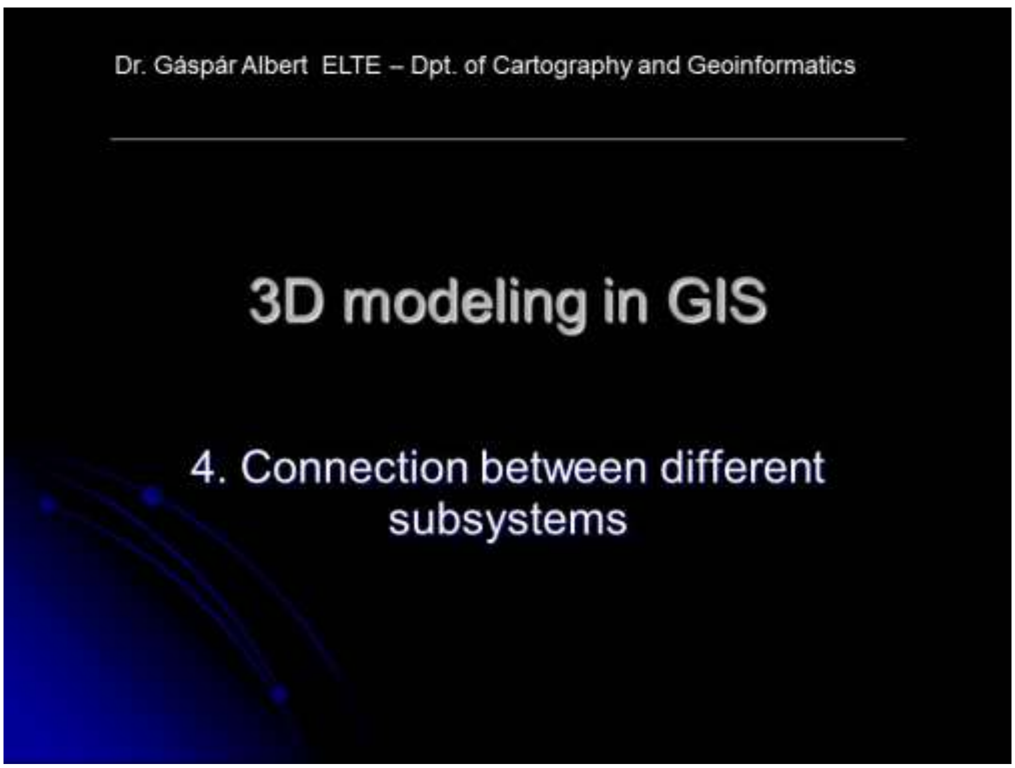
Lesson 4.

The topics of this class are the followings:

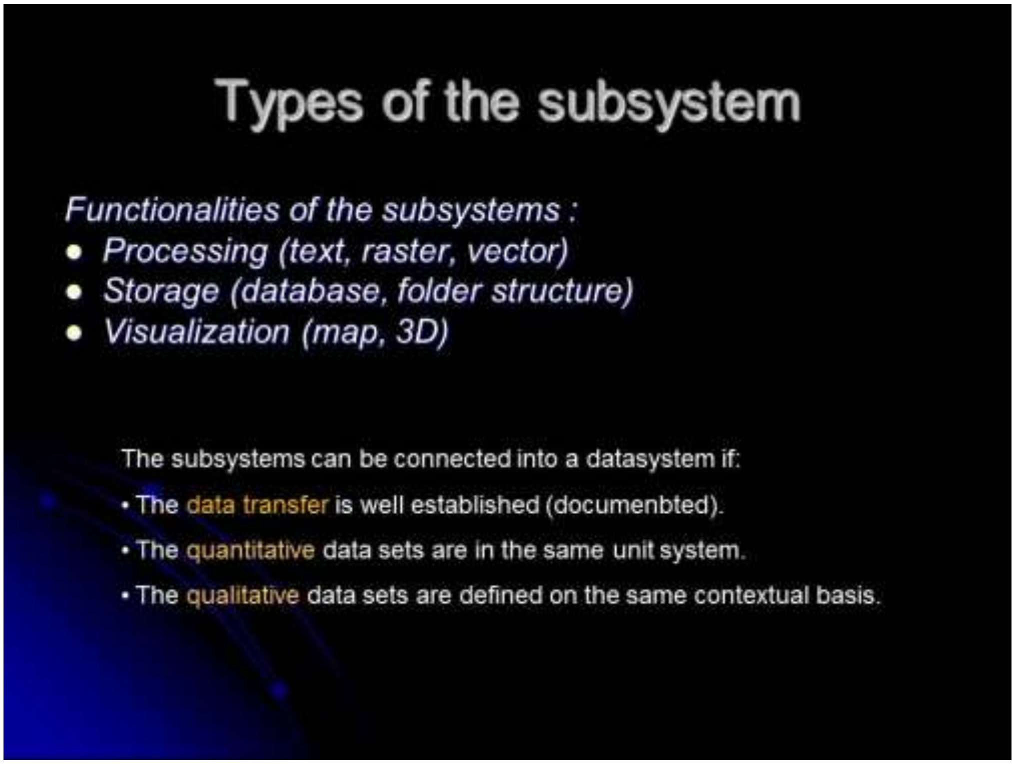
- Connection between the different subsystems in the *data system* (3D measurements linked to GIS).
- Management of primary data (definition of the structure of the data: i.e. predefinition/post-process revision).

Practice: The use of Surfer – data analysis and visualization. Different output file types for different applications (e.g. for AutoCad/Global Mapper/JewelSuite/ArcGIS).

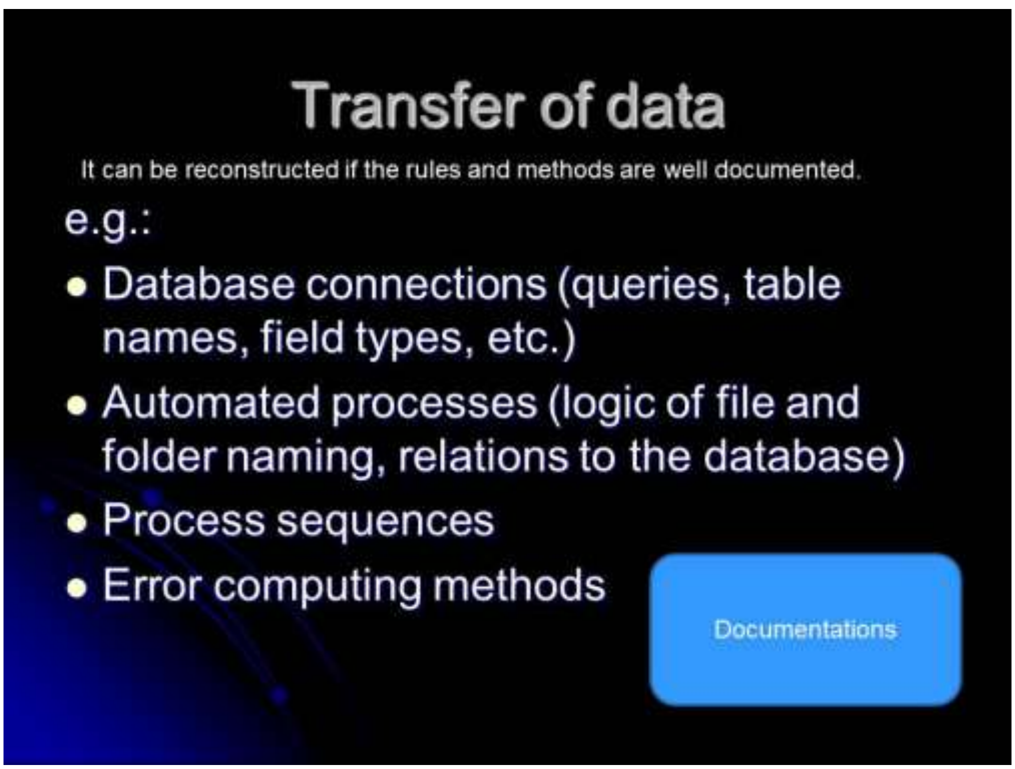
Connection between different subsystems



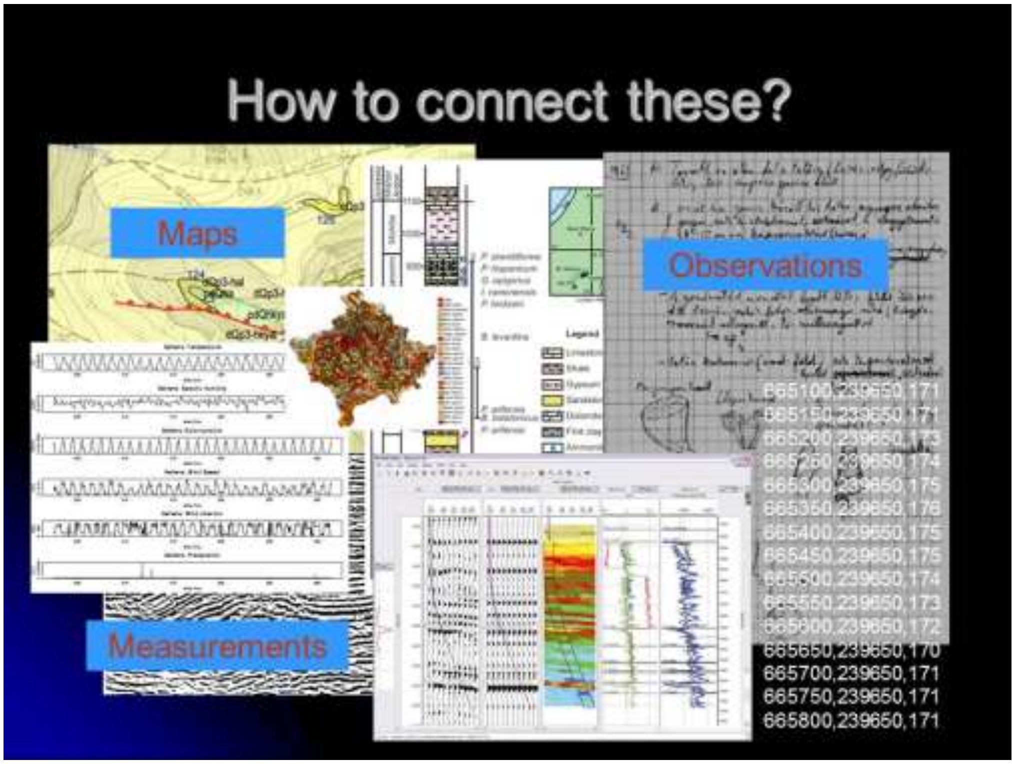
Slide 45 Title slide of the 4th theoretical class



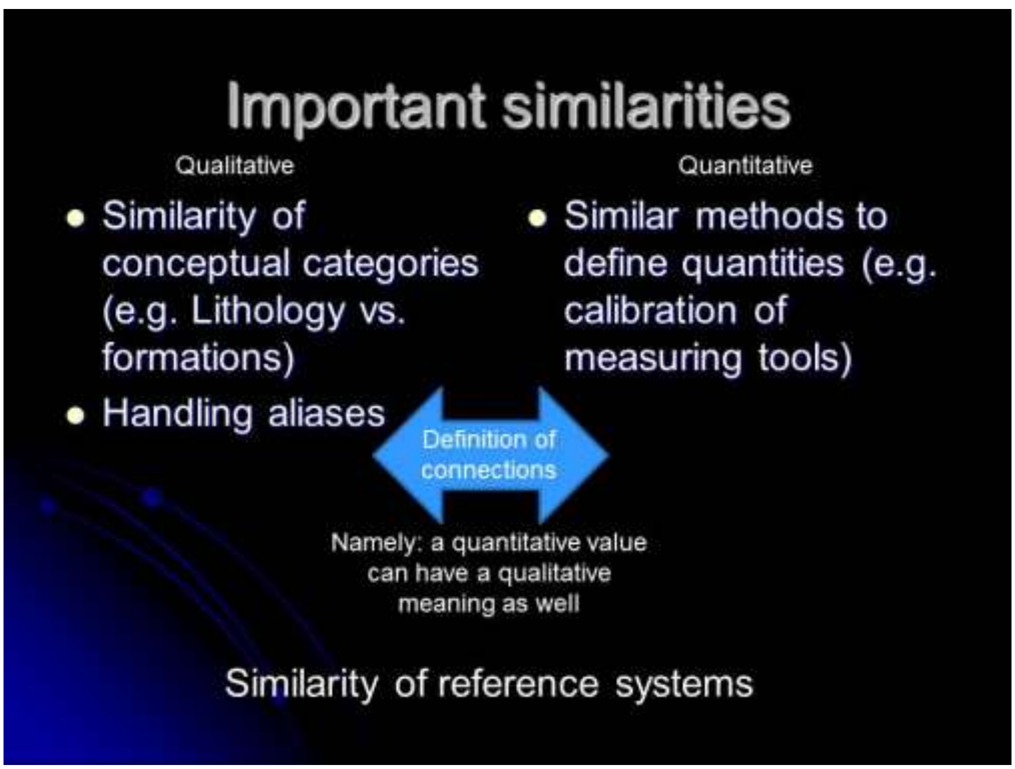
Slide 46 Main prerequisites of connected sub-systems in a modeling project



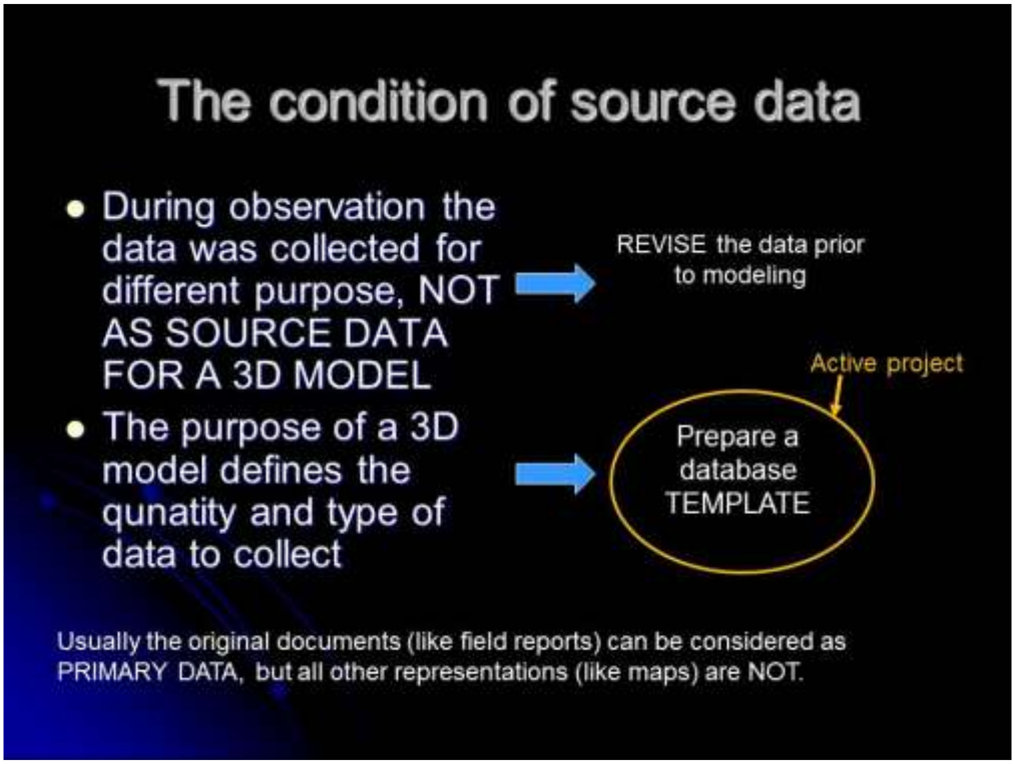
Slide 47 Important aspects of the data transfer between the sub-systems in a modeling project.



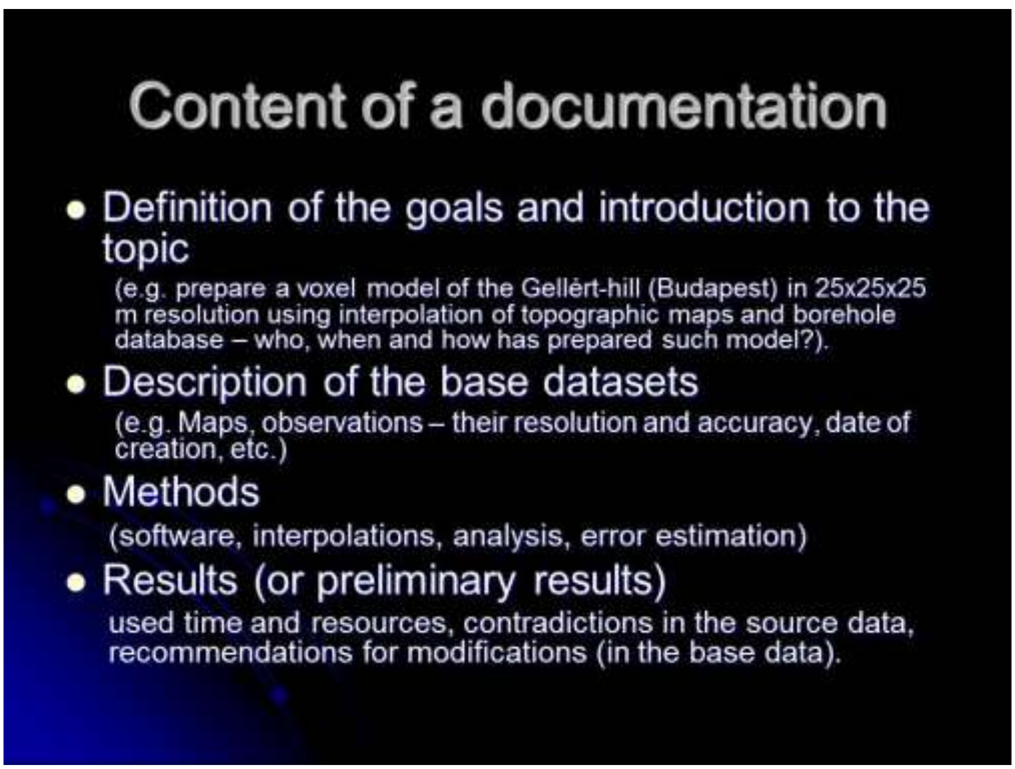
Slide 48 Illustrating very different data types, which may be gathered into one system



Slide 49 Similarities in different types of quantitative and qualitative data sets: conceptual categories and aliases in the first case, measuring methods and quantities in the second case. In both case the reference system must be the same.



Slide 50 Management of the primary data: predefinition or post-process revision



Slide 51 The content of a documentation file about the modeling process.

Practical part of lesson 4 – Use of Surfer (part 2.)

The goal is to create interpolated surfaces with different interpolation methods, compare the results, and learn to calculate the error of the used methods.

Load the 3D GIS class 03.srf file into Surfer 10. This workspace file contains the results from the previous class (No. 03).

Creating surfaces:

- Load the *Peldaadatok_VAL_Surf_krig1.grd* interpolated surface into the workspace (Map – New – Contour map), and rename it to “krig1”.
- Using the data of the *Peldaadatok.xls Munka1* sheet to create a different map from the previous one with the Triangulation method! Method: Grid – Data… menu (importing the table). You can specify the parameters of the grid by selecting the LAT, LON and VAL_SURF columns as X,Y and Z. Select the “Triangulation with Linear interpolation” method from the dropdown list as the gridding method, and specify the output file name *Peldaadatok_VAL_Surf_TIN1.grd*.
- Load the result (Map – Add – Contour map) to the workspace rename it to “TIN1” and compare it with the other interpolated surface (krig1).

NOTE: both the TIN1 and the krig1 were created from the same point set, but with different methods. Thus, the two grids will be different.

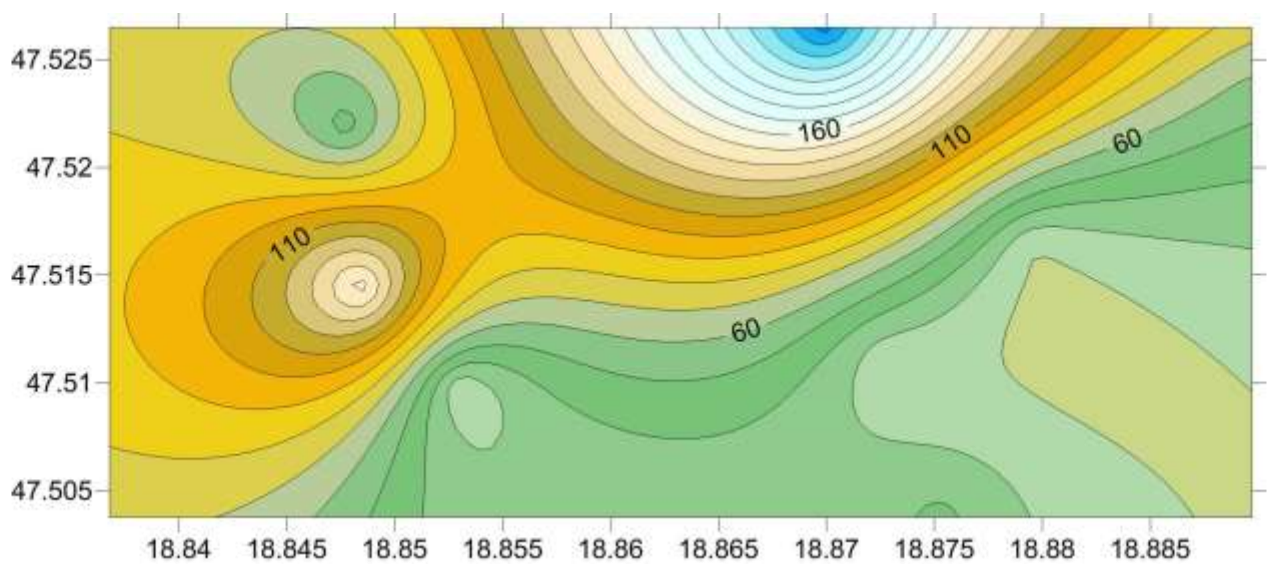


Figure 2 Contour map from the the *Peldaadatok_VAL_Surf_krig1.grd* file

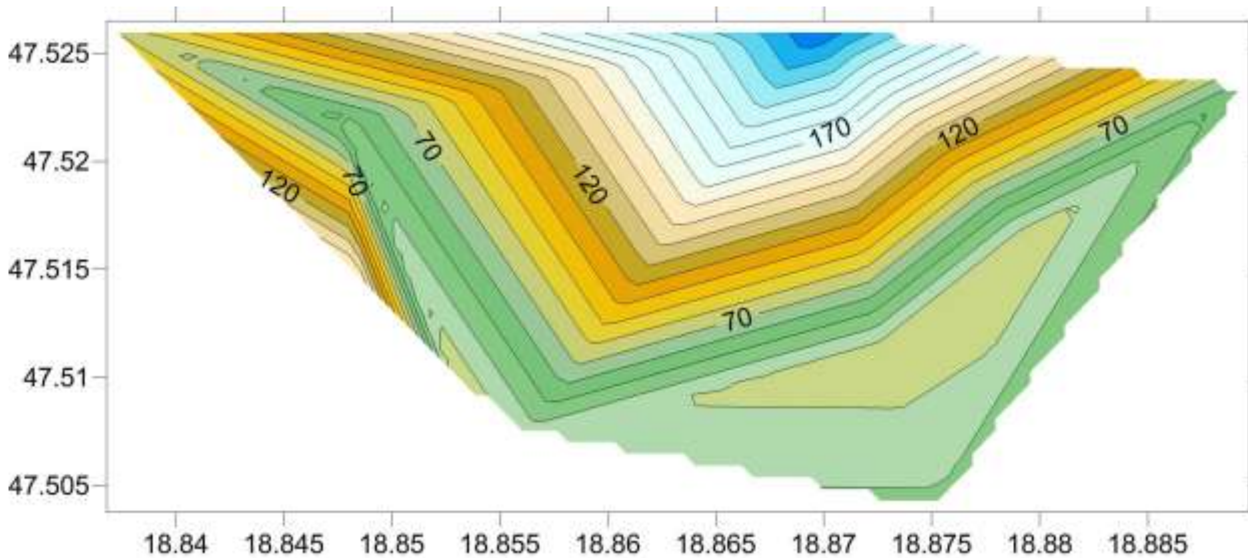


Figure 3 Contour map from the *Peldaadatok_VAL_Surf_TIN1.grd* file

Comparison of surfaces

7. Using the Grid – Math menu point select the two interpolated surface: *Peldaadatok_VAL_Surf_krig1.grd* as A and *Peldaadatok_VAL_Surf_TIN1.grd* as B. Define a function A-B and create a new grid as *Krig1-TIN1.grd*. Add this new file to your workspace as a contour layer. Observe the result, which represents the difference between the two modelling methods (kriging and linear interpolation).

NOTE: This is a relative comparison and both methods have their own error.

Error checking (cross validation)

8. During modelling the methods have errors on those points, where there is no primary data. To estimate the error of the method chose the same dataset (Peldaadatok.xls, sheet: munka1) and carry out the initial steps of the gridding procedure (Grid – Data, specify the X,Y and Z fields). Select the kriging method and press the cross validate button.

Given the known values at N observation locations in the original data set, cross validation allows you to assess the relative quality of the grid by computing and investigating the gridding errors. In Surfer, these errors are calculated by removing the first observation from the data set, and using the remaining data and the specified algorithm to interpolate a value at the first observation location. [error = interpolated value, minus the observed value]. Then, the first observation is put back into the data set and the second observation is removed from the data set (and so on until the Nth data). In the case of *Peldaadatok.xls* we have only 10 points.

9. In the cross validate window leave the preset parameters as they are, and specify the output filename as *PeldaadatokXV-Krig.dat* click Ok.

10. Open the *PeldaadatokXV-Krig.dat* in surfer or Notepad. The “Estimate” column contains the interpolated value at the specified point calculated from the remaining 9 data. The “Residual” value is the absolute error at that point.

NOTE: the residuals in our case are extremely larges, which means that the dataset is too small to execute sound geostatistics on it. Thus, in this case the method will have very low confidence, although it is mathematically correct. The Report file (see: *CrossValidationReport-PeldaadatokXV-krig1.rtf*) contains information about the cross validation process. Consulting these reports help us to decide whether our method is acceptable or has too much error in it (see the yellow rows in the file).

11. Add the *PeldaadatokXV-Krig.dat* to the workspace in Surfer as a Classed Post map (Map – Add – classed post map), and display the Residual column (Classes –Edit classes –Load – residuals.cls in the Property Manager).

12. Check the “show legend” checkbox in the “General” panel of the Property manager to display the legend. Manage the appearance of the legend object (click on it in the Object manager and adjust its properties in the Property manager) to create a nice layout.

13. Compare the two post maps (the original *Peldaadatok.xls* VAL_SURF column and the *PeldaadatokXV-Krig.dat* Residual column).

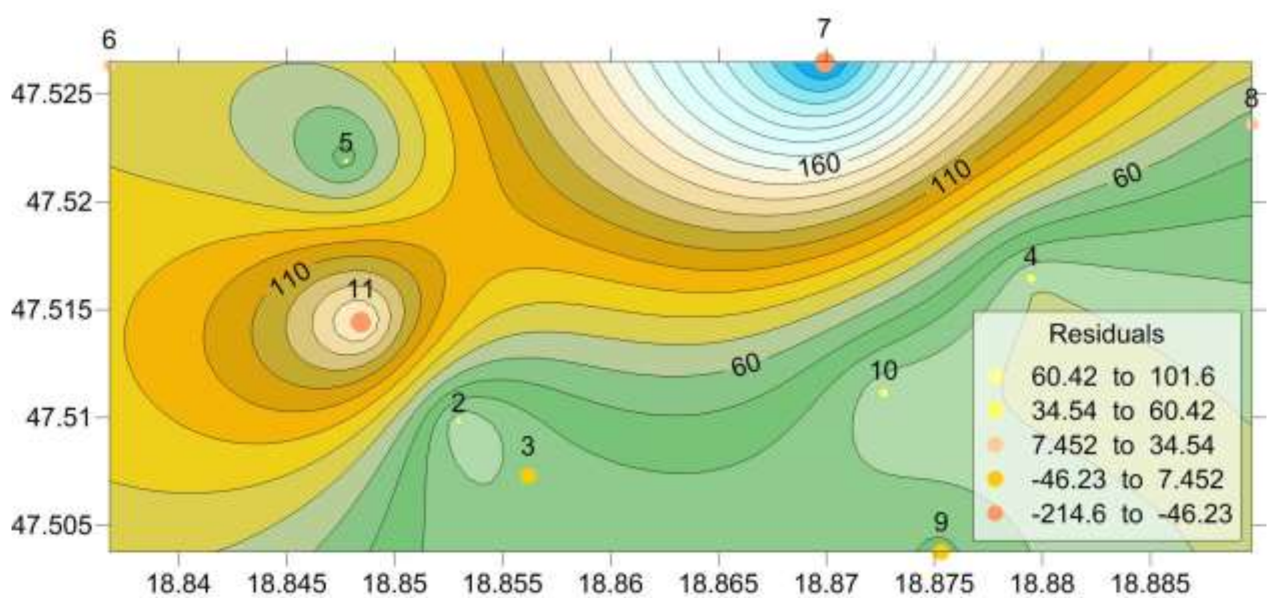


Figure 4 Layout with the classed post map of the estimated error (PeldaadatokXV-Krig.dat)

Creating slices (cross sections).

Slices are used to study the variability of the data in a 3rd dimension (z) along a line, which is defined in 2D (x,y plane).

1. Select one of the maps (e.g. *Post*) in the Object Manager and digitize a new polyline in the coordinate system of this map (Map – Digitize) from the P5 through the P4 and P9 to the P8 data point. A popup window appears with its own menus and the list of the digitized points. After P8 save the polyline in bln (AscII text) format "*digitized_sectionP5-P8.bln*".
2. Create a slice of the selected surface (grid) by selecting the Grid – Slice menu point. In the file selection window specify the grid what you want to slice (*Peldaadatok_VAL_Surf_krig1.grd*) at first, and the line-file (*digitized_sectionP5-P8.bln)* at second.
3. Two different files will be created:
    a. The first will be a polyline (in .bln format), but it will contain all the points where the digitized line crossed the gridlines. Save this with a descriptive name (e.g. *sliced sectionP5-P8.bln*).
    b. The second is a database table (dat file e.g. name it *section_VAL_SURF_Krig1_P5-P8.dat*) which is an extended version of the previous polyline file. It contains the distances of each points along the line from the starting point. The measure unit of this distance will be the same as the measure units of the coordinate system.

WARNING! The here presented sample files are in geographic coordinates, thus, the created dat-file will contain length distorted data in the 4th column.

4. Open the file *sliced sectionP5-P8.bln* in Notepad and compare it with the digitized version. Open it with Surfer as an added base map (Map – Add – Base map).
5. Open the file section_VAL_SURF_Krig1_P5-P8.dat in Surfer (or Notepad), and compare it with the simple sliced section file. Note that the 5th column contains only "1". This is the ID number of the polyline which produced the slice (It means that bln files with more polylines can be used to slice a grid).

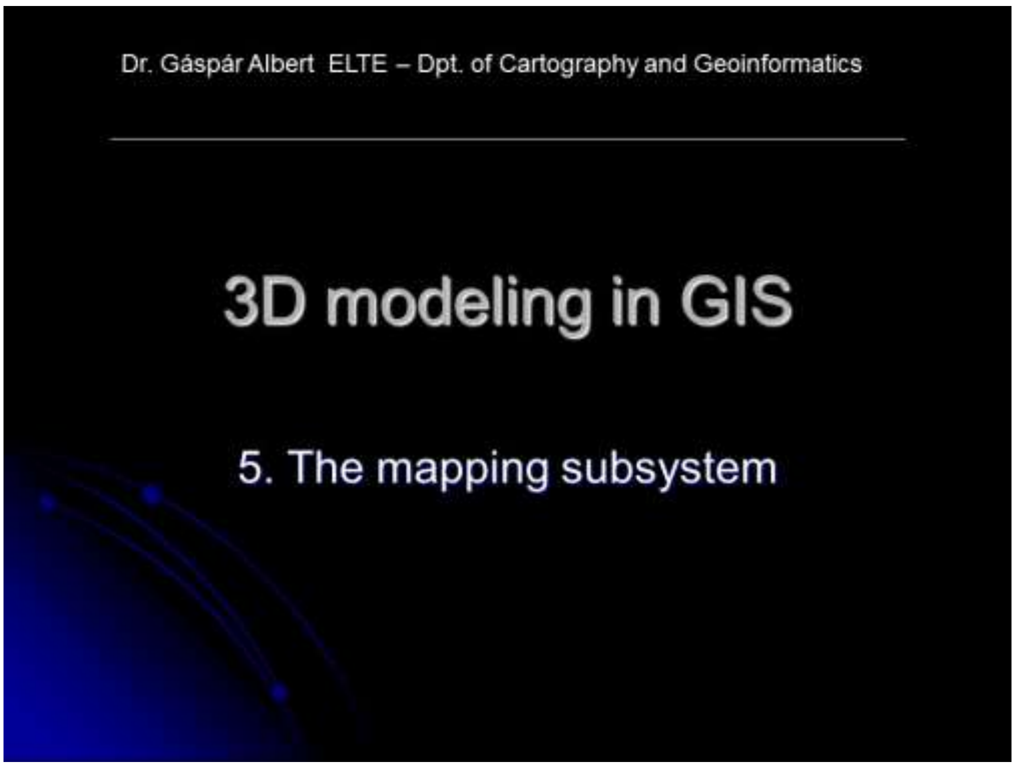
Lesson 5.

The topics of this class are the followings:

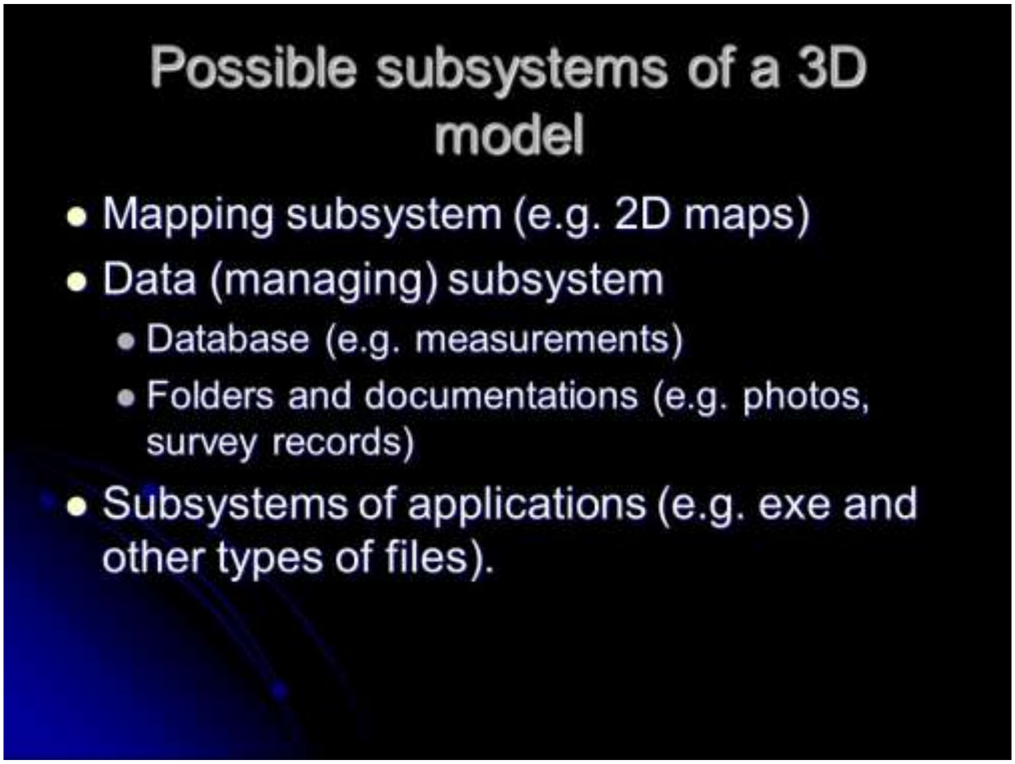
- Creating maps for the data system (revision/correction/topology).
- Topology types in GIS.
- The use of topographic data.

Practice: Spatial representation of the data in a 3D modeling environment (and 3D models). The use of Jewel Suite – data creation, visualization, data model, and importing points.

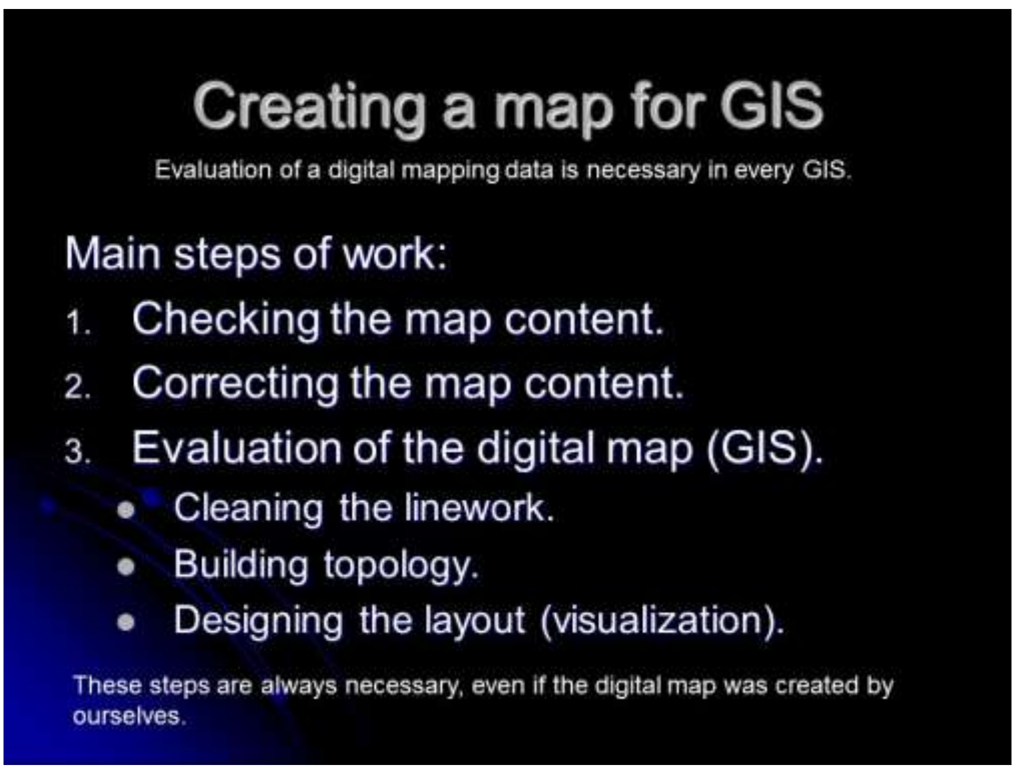
Creating maps for GIS – the mapping subsystem



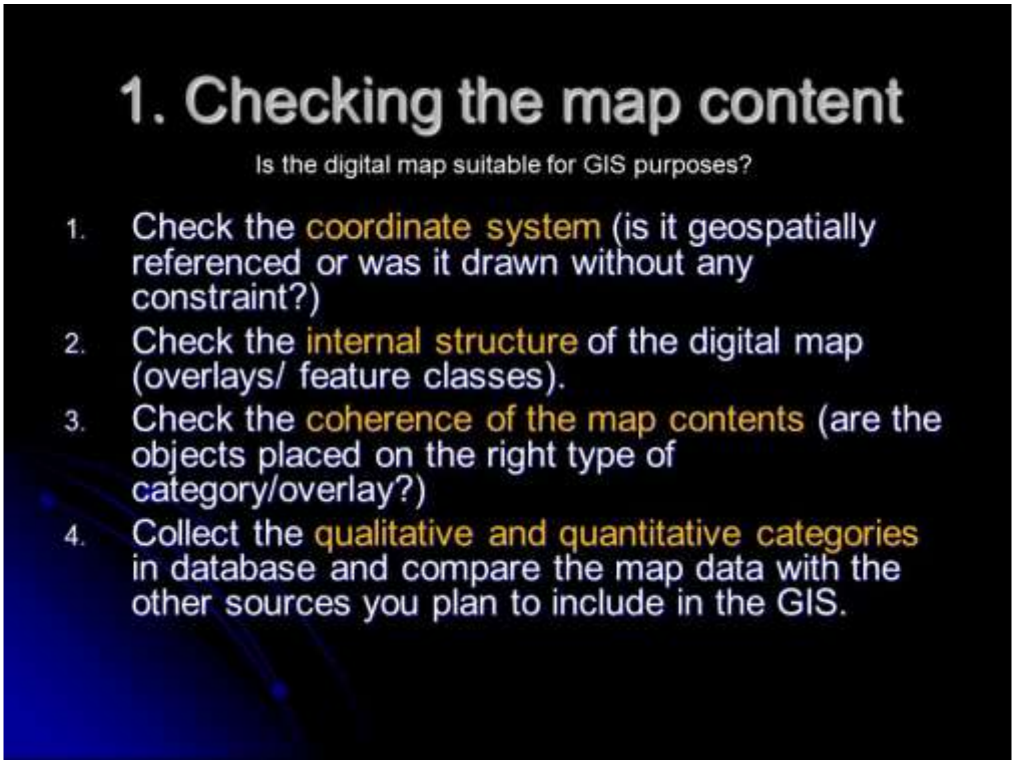
Slide 52 The welcome slide of the 5th thematic class.



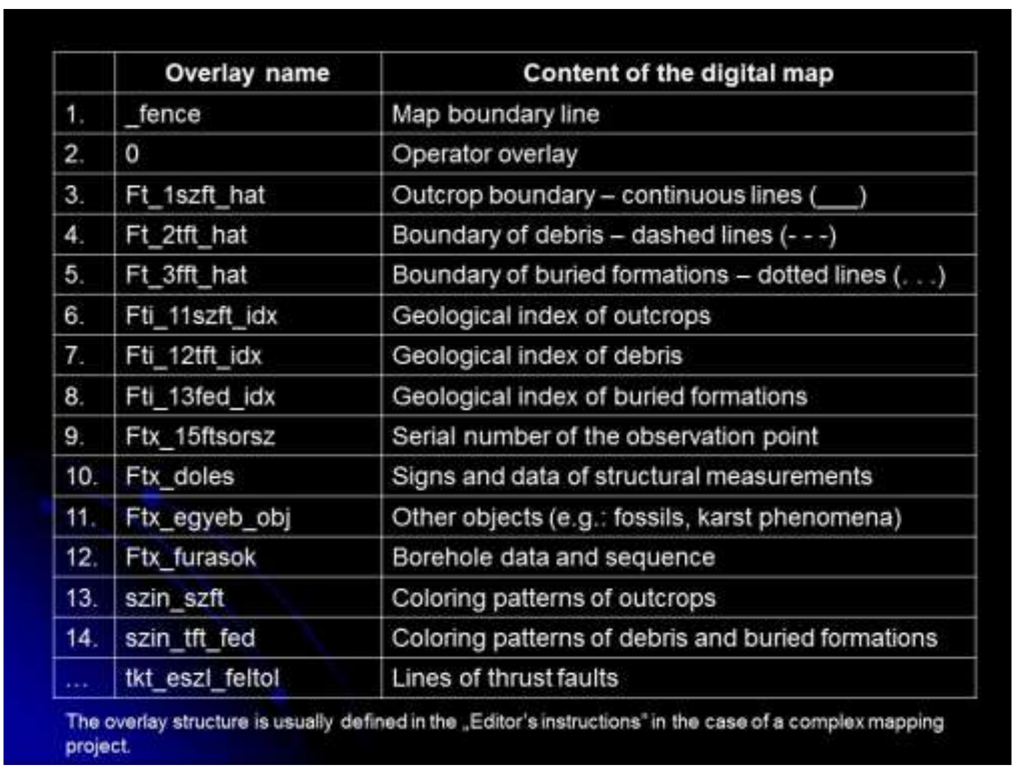
Slide 53 Possible subsystems of a 3D modeling project.



Slide 54 Main steps of creating maps for GIS purposes.

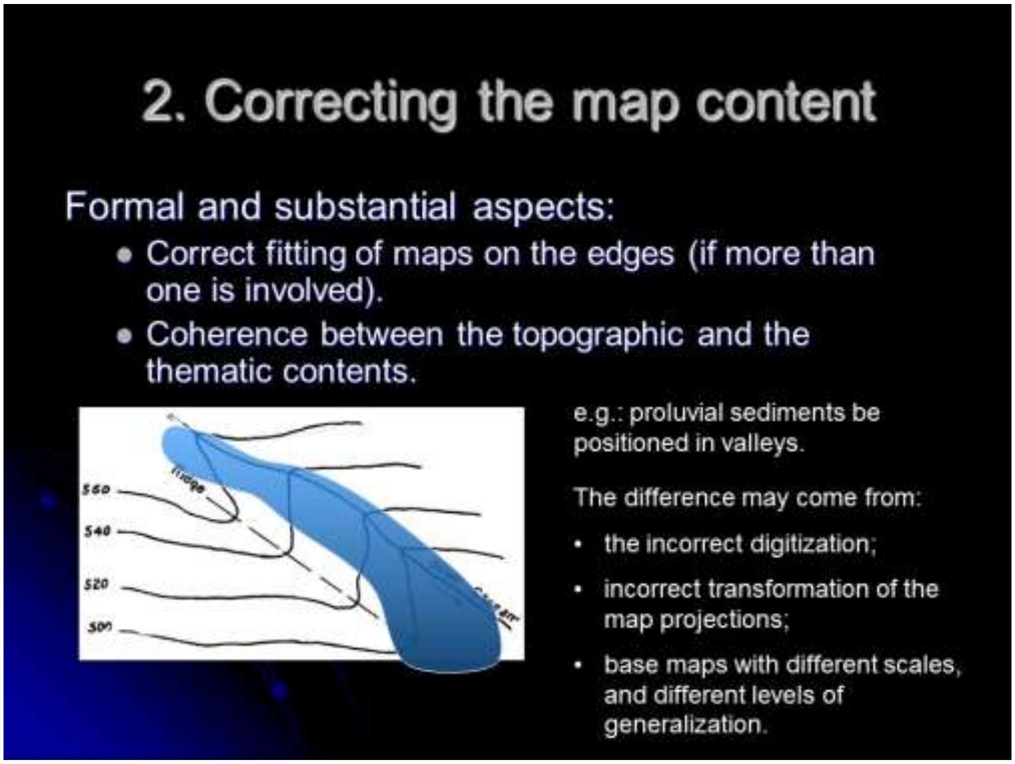


Slide 55 The first step: checking the map content.

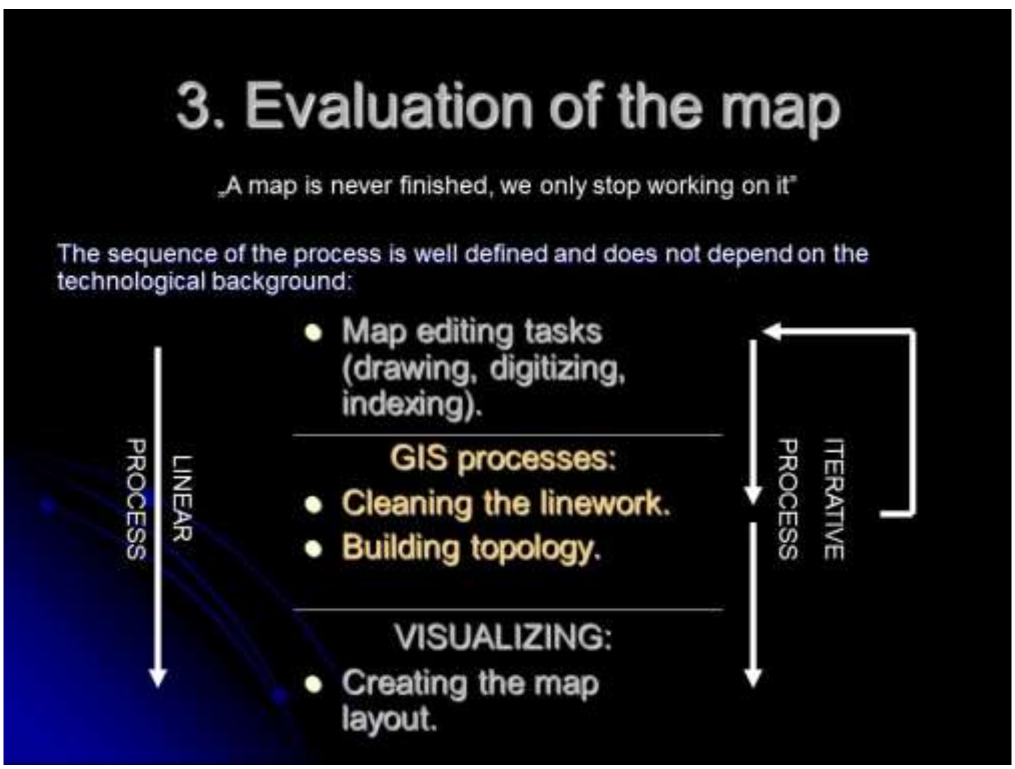


	Overlay name	Content of the digital map
1.	_fence	Map boundary line
2.	0	Operator overlay
3.	Ft_1szft_hat	Outcrop boundary – continuous lines (___)
4.	Ft_2tft_hat	Boundary of debris – dashed lines (- - -)
5.	Ft_3fft_hat	Boundary of buried formations – dotted lines (. . .)
6.	Fti_11szft_idx	Geological index of outcrops
7.	Fti_12tft_idx	Geological index of debris
8.	Fti_13fed_idx	Geological index of buried formations
9.	Ftx_15ftsorsz	Serial number of the observation point
10.	Ftx_doles	Signs and data of structural measurements
11.	Ftx_egyeb_obj	Other objects (e.g.: fossils, karst phenomena)
12.	Ftx_furasok	Borehole data and sequence
13.	szin_szft	Coloring patterns of outcrops
14.	szin_tft_fed	Coloring patterns of debris and buried formations
…	tkt_eszl_feltol	Lines of thrust faults

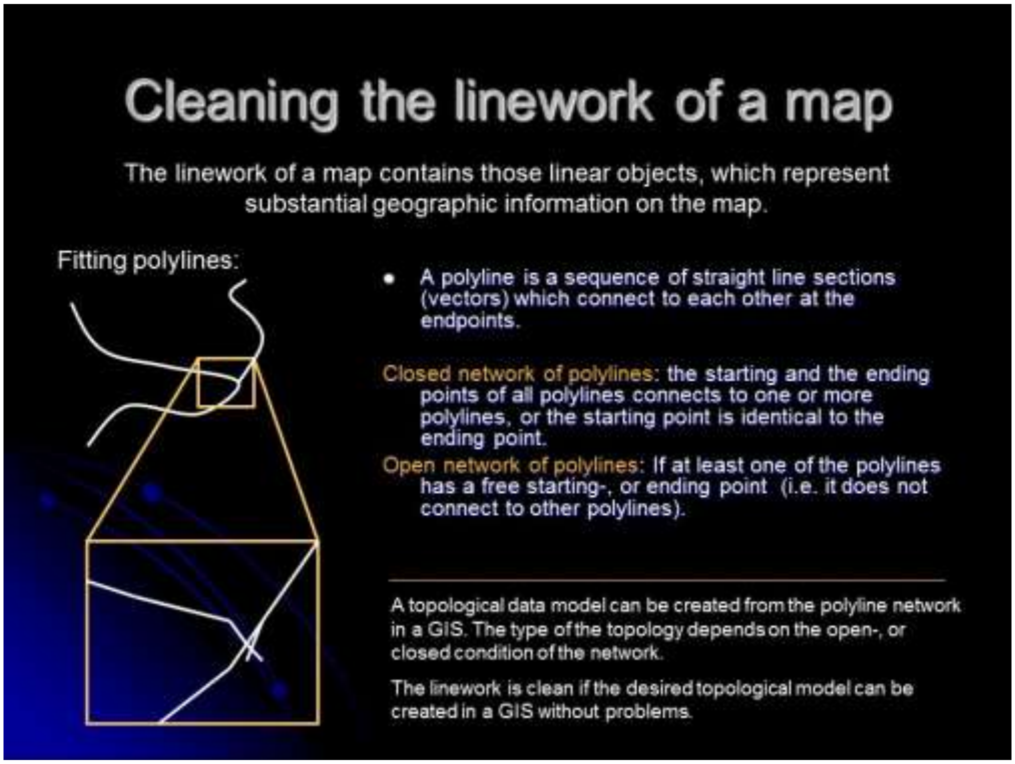
Slide 56 A CAD overlay structure defined in the "Editor's instruction" at the Geological Institute of Hungary.



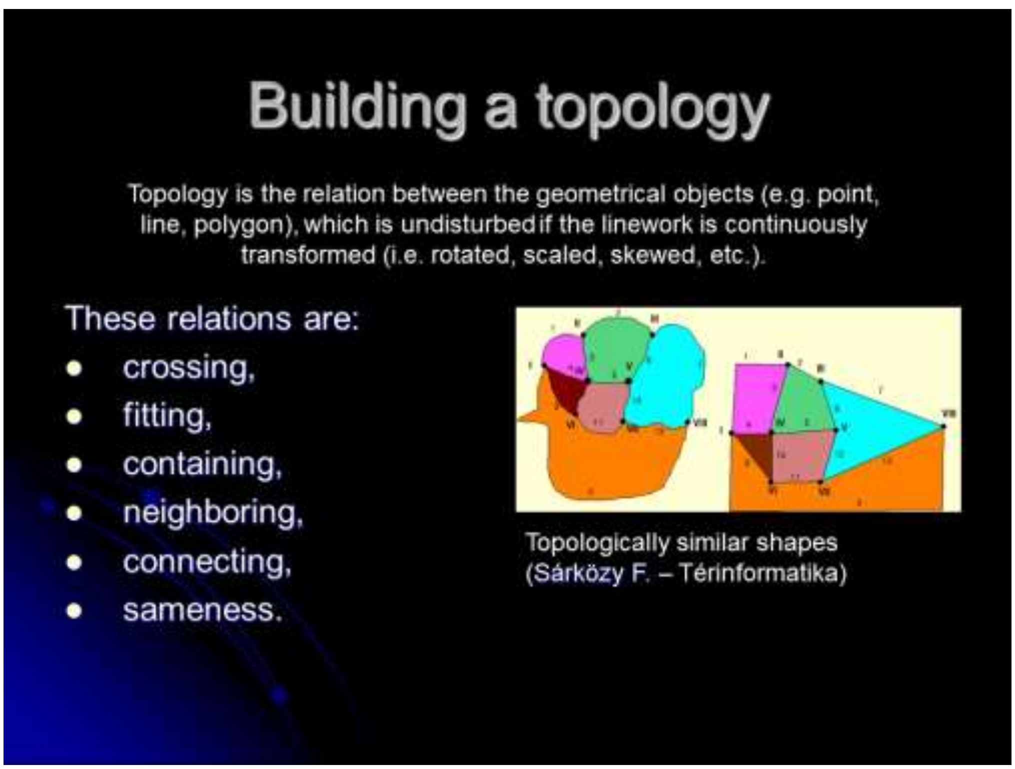
Slide 57 Step 2: Correcting the map content



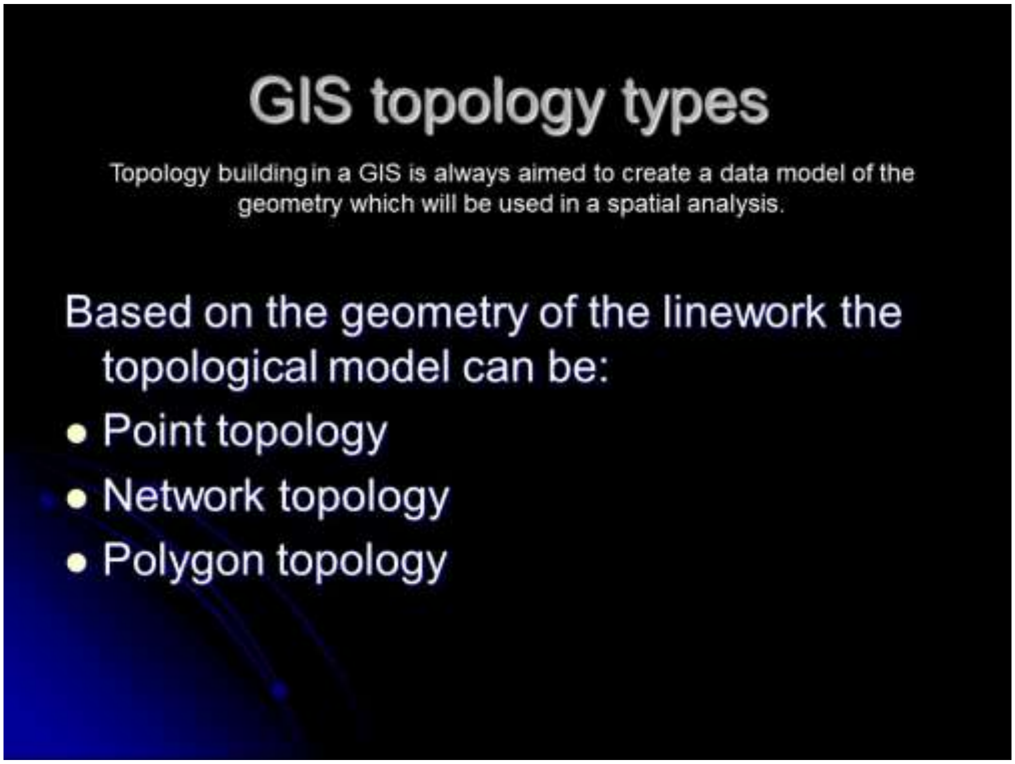
Slide 58 Step 3: evaluation of the map.



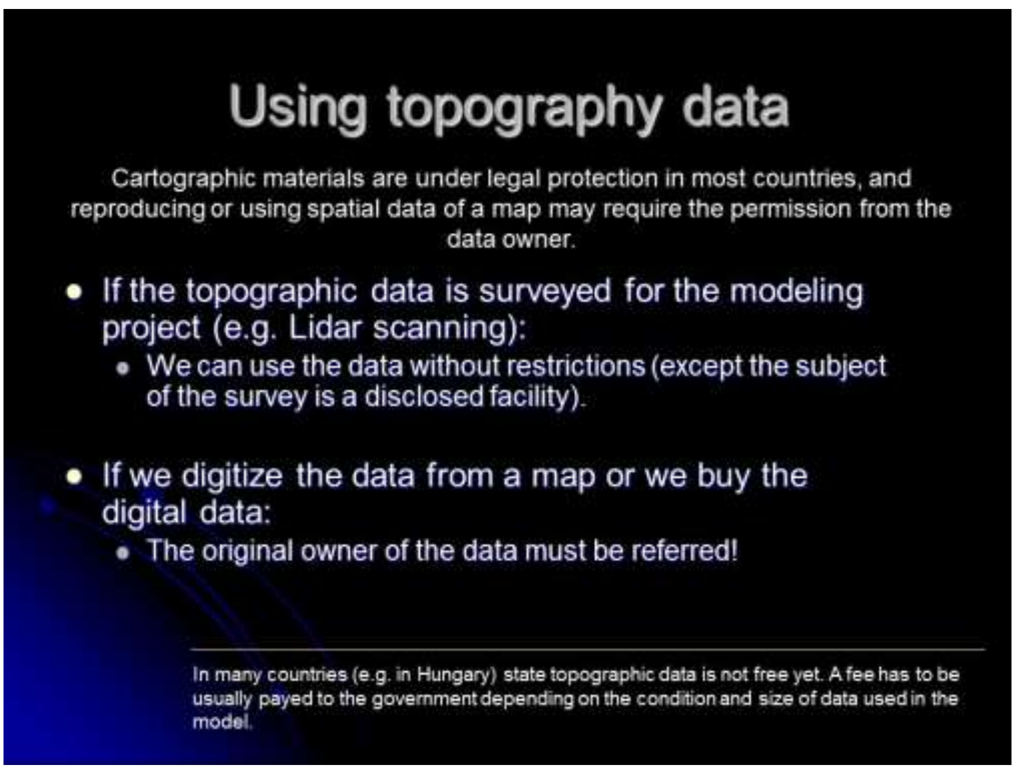
Slide 59 Definitions for linework, polyline, closed, and open network of polylines.



Slide 60 Definition for topology.



Slide 61 GIS topology types.



Slide 62 Aspect of using topographic data.

Practical part of lesson 5 – Use of Jewel Suite (part 1.)

This software is a full workflow framework that supports and describes every step which is needed to build complex 3D voxel models. The files are called "solutions" as they represent only one solution of a problem (like where can I find water below the surface?). When you start a new project in Jewel, you will create and save a project file with an extension *.jewel*. This file contains all Jewel settings associated with a given project, and when you open a *.jewel* solution file, you have access to all the geometric data in a database form too. To see what type of models can be built with Jewel, load the *Wells_TOC.jewel* file into Jewel Suite 13. This workspace file contains an interpolated voxel model based on the data of the *Wells_TOCvalues.xls* table. In Jewel only one solution file can be opened at a time, but several models can be defined in one file.

NOTE: the Z-axis in the modelling environment points downward and is called **tvss** (true vertical subsea depth).

The basic functionalities (New Solution):

1. Window – New window – Start Page: select the New Solution icon. This will unload the *Wells_TOC.jewel* project. An empty 3D View panel (in the middle of the screen) show up.

2. The settings of the user interface can be changed (Tools – Options – User Preferences). Layout changes to the JewelSuite user interface are stored per user and will be used when starting JewelSuite. This allows you to customize the JewelSuite user interface for each user. Select the "User Preferences" panel in the "Options" dialogue window and with pressing the "select default unit system" button set the unit system to metric.

Try other settings in the options dialogue, and explore the tree structure of the user preferences panel.

3. On the right side of the screen there is a Workflow Guide. All of your work is outlined as a set of workflows in the Workflow Guide. The main **processes** are written in bold characters (e.g. **Data Import**). The processes are divided into several *panels* (e.g. Point Set Data). The sequence of the processes is the usual sequence of a workflow in 3D modelling.

Data creation

This exercise is aimed to illustrate the database structure of the software, and to demonstrate the active connection between data tables and 3D objects.

4. During modelling the database of your project can be accessed and edited. To get familiar with it, try the **Data Creator** process, Create Objects Control panel. A new *viewer* panel will appear next to the 3D View panel in the middle of the screen where you can create different data objects using the manual process. Each object type has its own *sheet*. Select the "Point Set" sheet and create a New point set with the name: "locations". The Type should be "Undefined" for now. You can type data in the table rows and pressing the Create button the Point Set will be created.

5. For real data Open the *Wells_TOCvalues.xls* and type the Northing, Easting, and Tvss coordinates of points P1-P10. After finishing this, press the Create (or Update) button and change the view panel to the 3D View.

NOTE: All the spreadsheet views in the Create Objects View support Copy and Paste functionality. This is useful when you have your data available in a spreadsheet format such as an Excel table. Make sure the data is in the correct format, and in the proper columns!

6. The “locations” Point Set is created and it can be selected in the Solution Explorer (The Solution Explorer is a window to view all data objects and properties that you have created or imported). Right-clicking on the data object, a popup menu appears where you can set parameters and execute processes.

7. Select the “locations” Pont Set – right click – execute the *Triangulate* process. A new data object (a Tri-mesh = TIN surface) is created with the same name.

8. Change the view panel to Create Objects Control and select the Trimesh sheet. Here the created “locations” tri-mesh can be selected as an existing data object.

9. There are two tables: 1) on the left a 4-columned one containing all the nodes (with an automatically created ID); 2) on the right a 3-columned table which lists the individual triangles and the node IDs of each of them.

10. Try to modify the Tvss value of node No. 9 from -229.61 to 0. Press “Update” and go back to the 3D View and see what happened. To practice this functionality creates new nodes and triangles manually.

NOTE: this exercise demonstrates that the database structure is a RDB (Relational Database), and the 3D View is only a visualization of the data (NOT a model!).

Visualization

11. Select the “locations” tri-mesh in the Solution Explorer (or by left clicking on it in the 3D View). Right click (popup menu) – Properties – Depth – Depth (double definition means: several other depth-type property can be defined additionally). The tri-mesh will be coloured according to a colour-scale. Note that the Azimuth, Dip and Smoothness properties are also selectable (try them). These are automatically-created properties.

12. Right click (on the tri-mesh) – Solid > change this to “Solid and mesh”. The TIN structure appears.

13. Right click (on the tri-mesh) again – check “Contours”. Contour lines appear (a hypsometric colouring is the result).

14. To enhance the vertical differences between the nodes on the tri-mesh you can increase the vertical scale using the General View Toolbar below the 3D View (up-and-down arrow and a textbox).

15. Here in the General View Toolbar you can set pre-defined views, or change the cursor into a measuring tool (all functionalities are explained when the cursor is moved over a toolbar icon).

Data Import

This exercise focuses on the workflow of importing a simple point database, originally stored in Excel.

16. Remove the point sets (Solution Explorer – select the Point sets – right click – Remove all Point sets).

17. In the Workflow Guide go to the **Data Import** process, and then select the **Point Set Data** panel. A dialog window appears where you can define the file where the Point set data is stored. In the file type list, select the “User-defined Formatting for Column Files” and select the *Wells_TOCvalues.txt* in the 05 folder.

18. In the next window each column can be defined separately. Check all columns to be in use except the first. Below the first line of the table there are 3 dropdown lists in each column: the first dropdown list contains the selectable types, the second contains the methods and the third the measure units. Set the second column to Easting/Distance/meter; the third to Northing/Distance/meter; and the fourth to Tvss/Depth/meter. On the left side of the dialogue window, set the “Start import at line” to 2, select only the ‘Tab’ as a delimiter (uncheck the “space” if checked). At the “columns” sector check, and set the “Properties from col” to 6, and the “Names from line” to 1. Press Next.

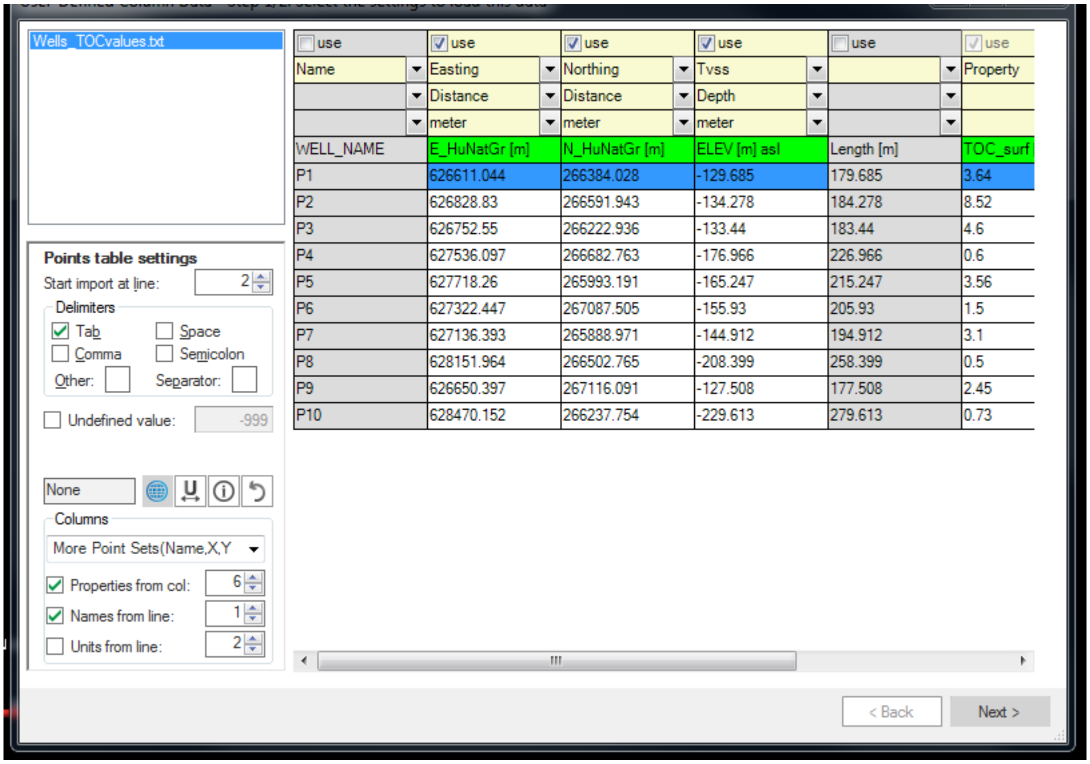


Figure 5 Dialogue window for defining the fields of the imported database in Jewel Suite 13

NOTE: when importing points into Jewel as point clouds, the names of the individual points are indifferent. Thus, we ignore the name column in the above exercise, and we will create a point set object which will be defined with one single name.

19. In the next window there are two tables. The upper one shows the data objects ant its parameters (in this case there is only one line in the table, because all the points are handled as one entity: a point-set). Change the name to “Wells_TOC_surf”. The lower table contains the list of imported properties. Check only the first one (TOC_surf [%]) and set its “Template name” (second column) to “Ratio” and the “Unit” (third column) to percent. Press Finish.

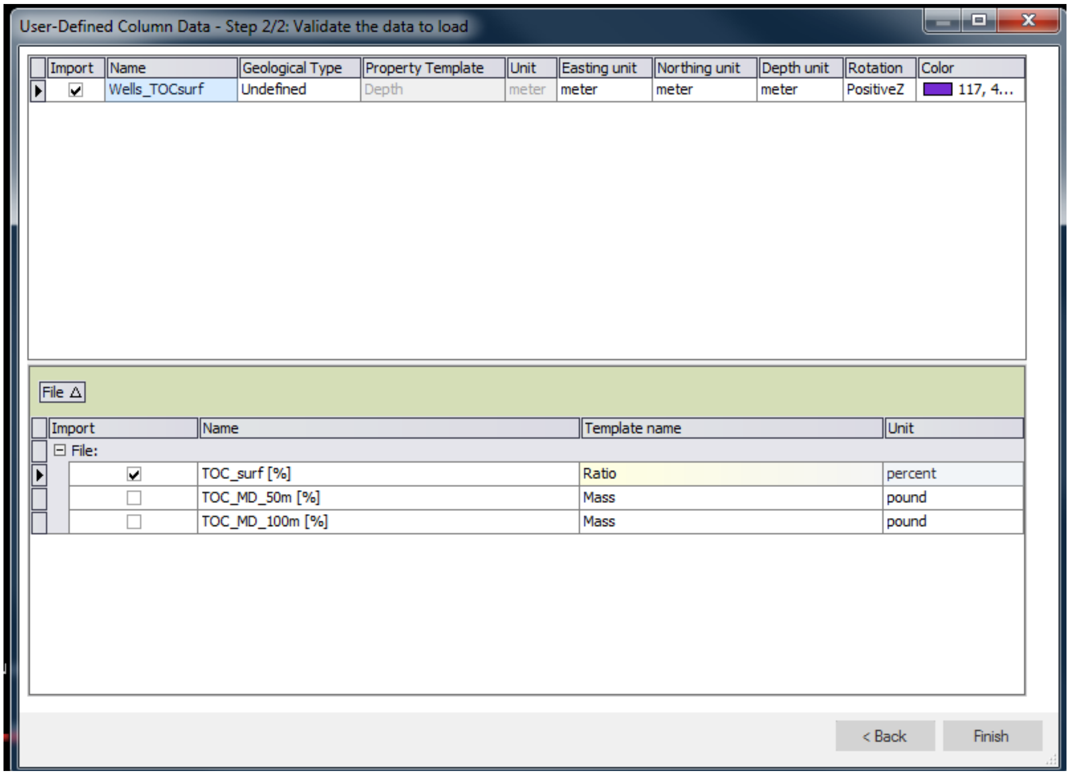


Figure 6 Validation dialogue window to properly define the type of the imported data

20. In the Solution Explorer the point set object appears. Explore the properties of the created point set (press the + sign next to the name). Check the TOC_surf [%] property to visualize the different values.

NOTE: this exercise demonstrates that you can import several attribute data into the modelling GIS environment using Point sets.

21. However, in the Create Objects Control panel these properties are not accessible to modify (only the X, Y, Z coordinates). Once you imported the property data, it remains the same.

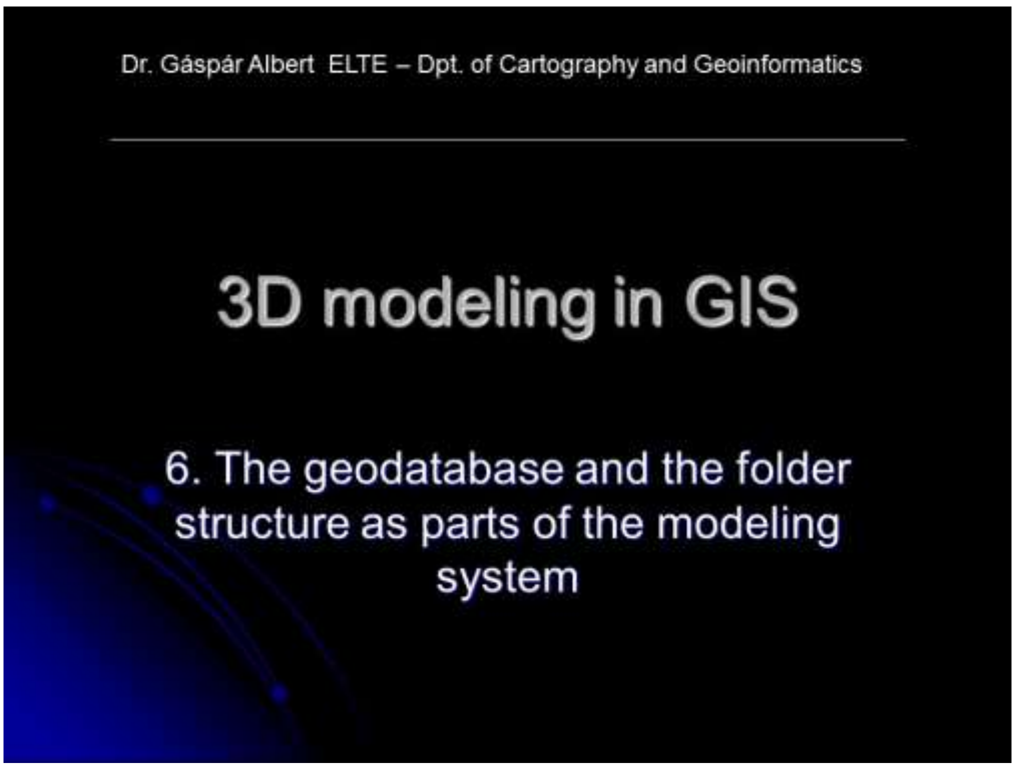
Lesson 6.

The topics of this class are the followings:

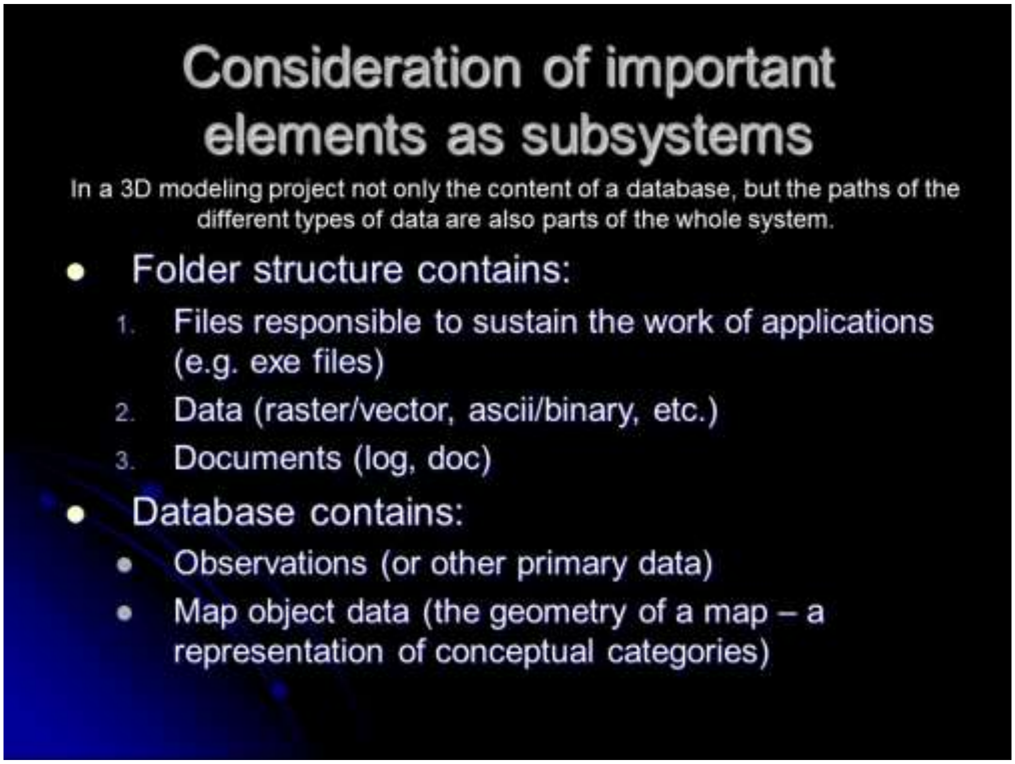
- Folders and files as database systems (e.g.: doc, xls, txt, dxf, xml).
- Data mining for GIS purposes.

Practice: The use of Jewel Suite – importing point clouds, creating and editing simple surfaces, importing grid surfaces, and creating cross-sections.

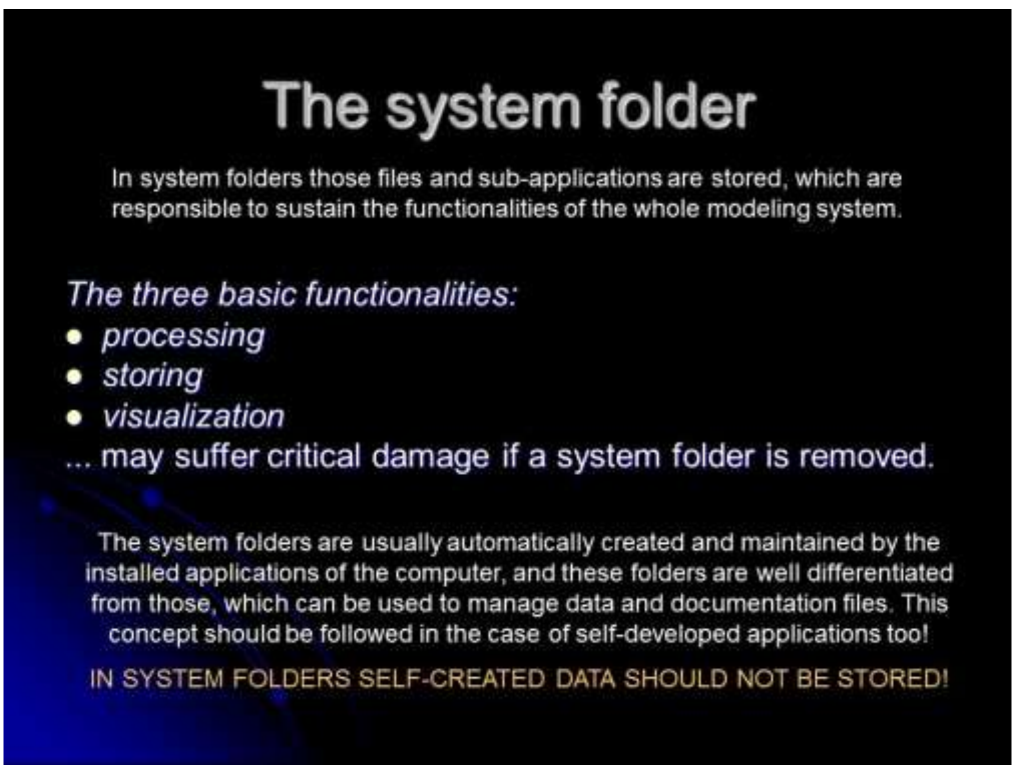
The geodatabase and the folder structure as parts of the modeling system



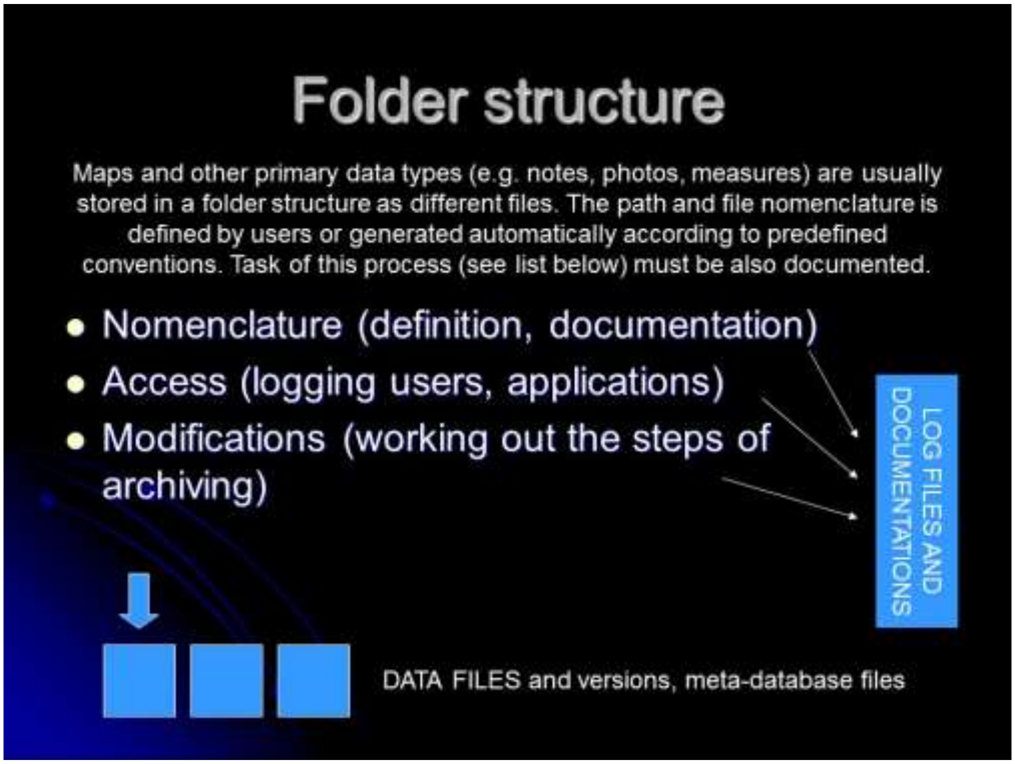
Slide 63 Welcome slide of class 6.



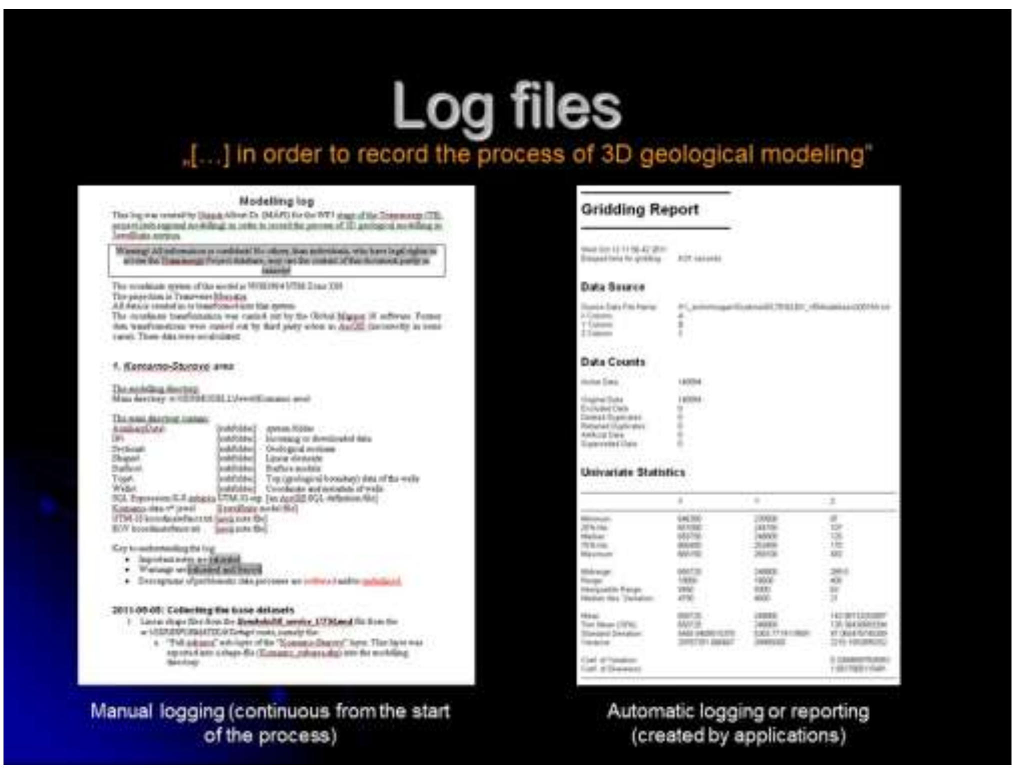
Slide 64 Elements of the subsystems: folder structure, observations and map object data.



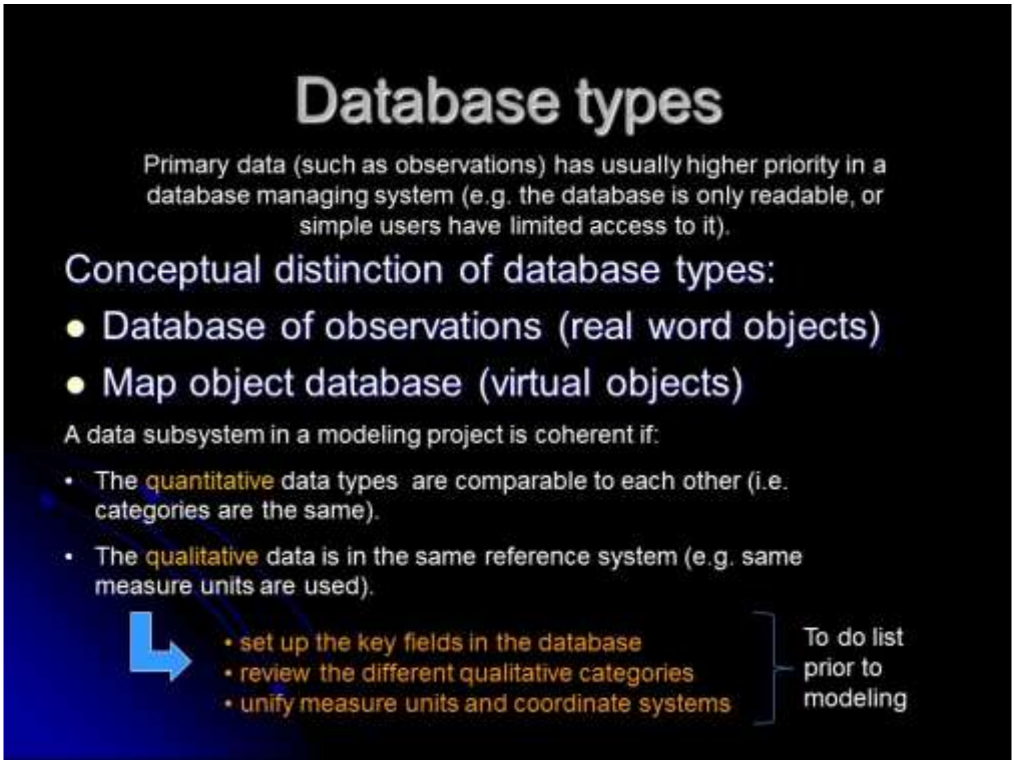
Slide 65 The system folder.



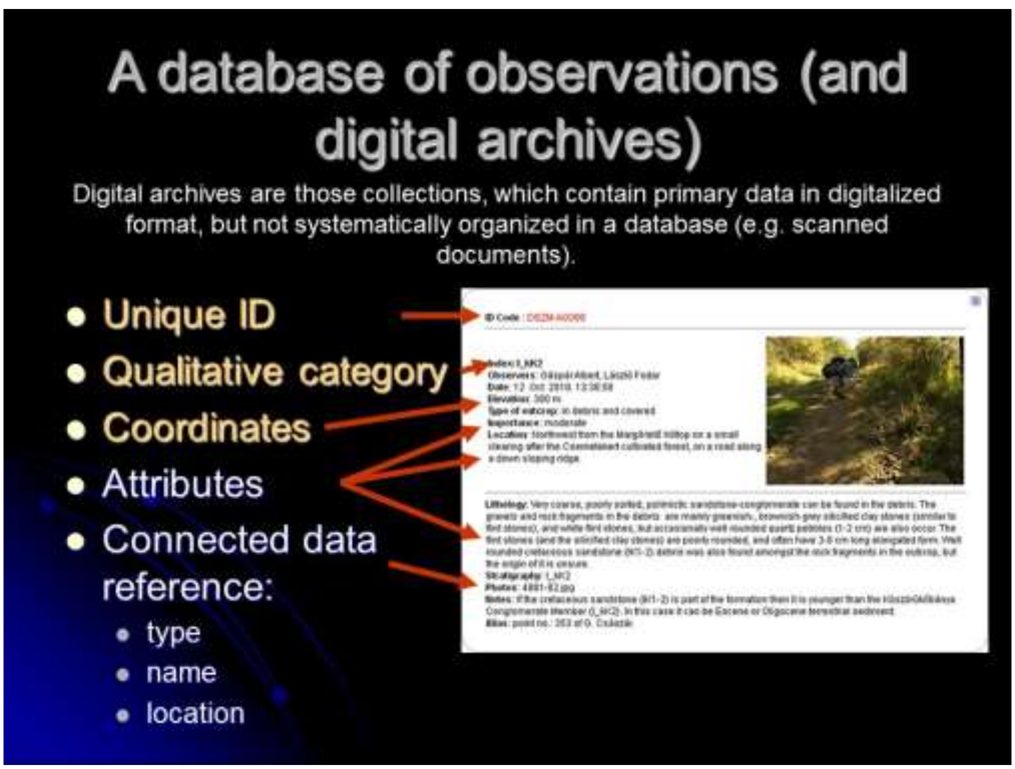
Slide 66. Folder structure and the importance of documentation.



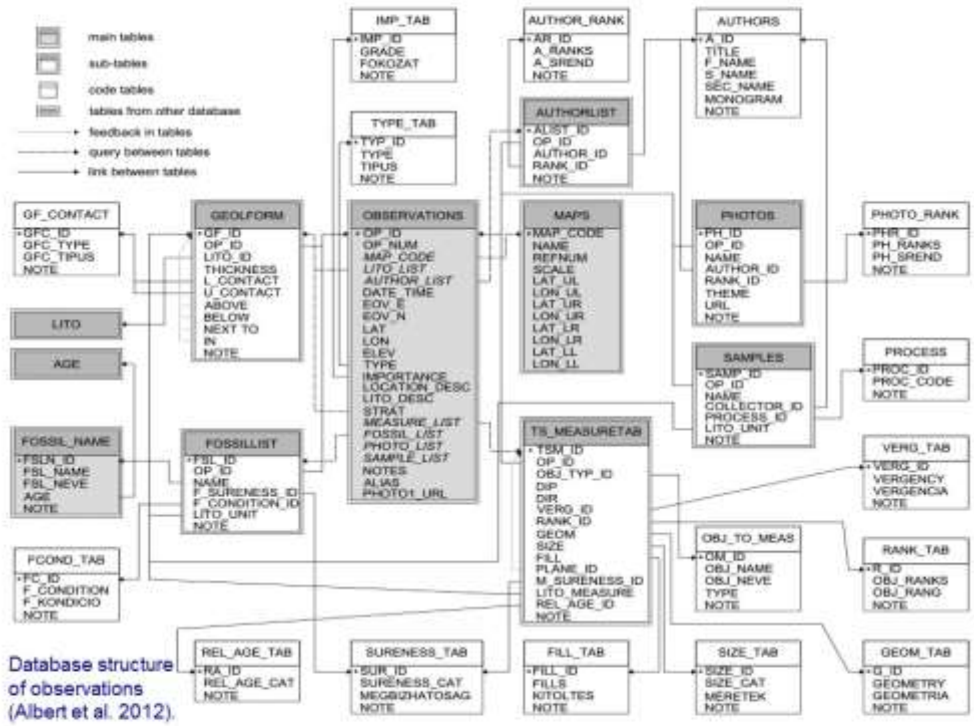
Slide 67 Manual and automatic log files.



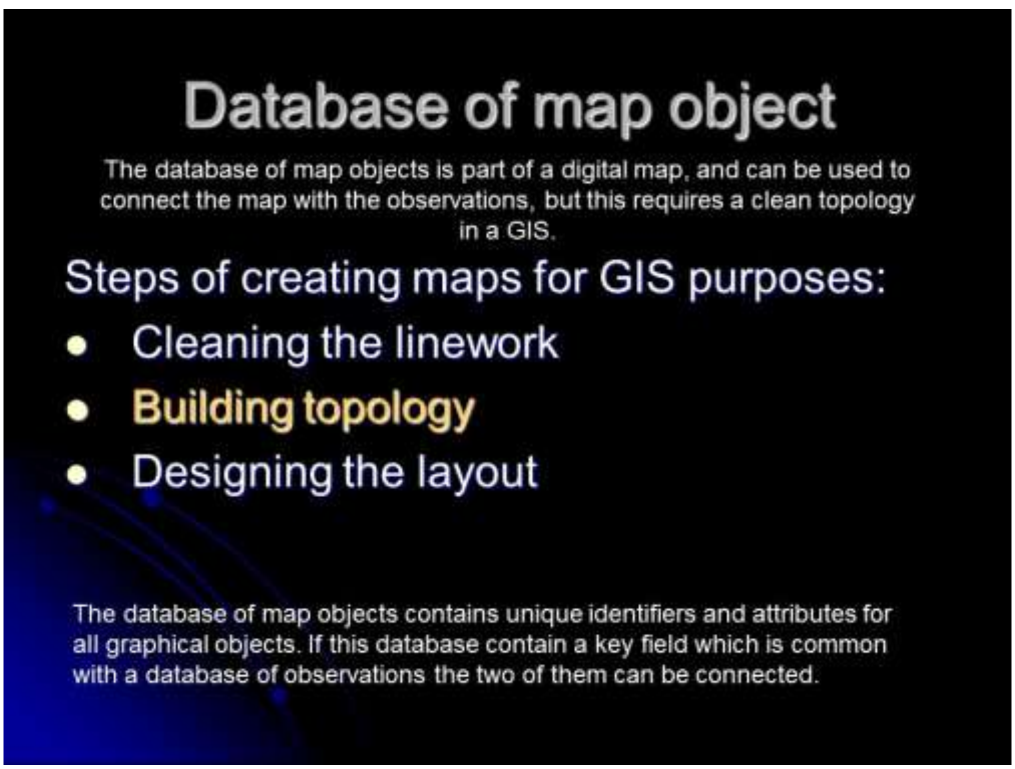
Slide 68. Database types and the "to do list" prior to modeling.



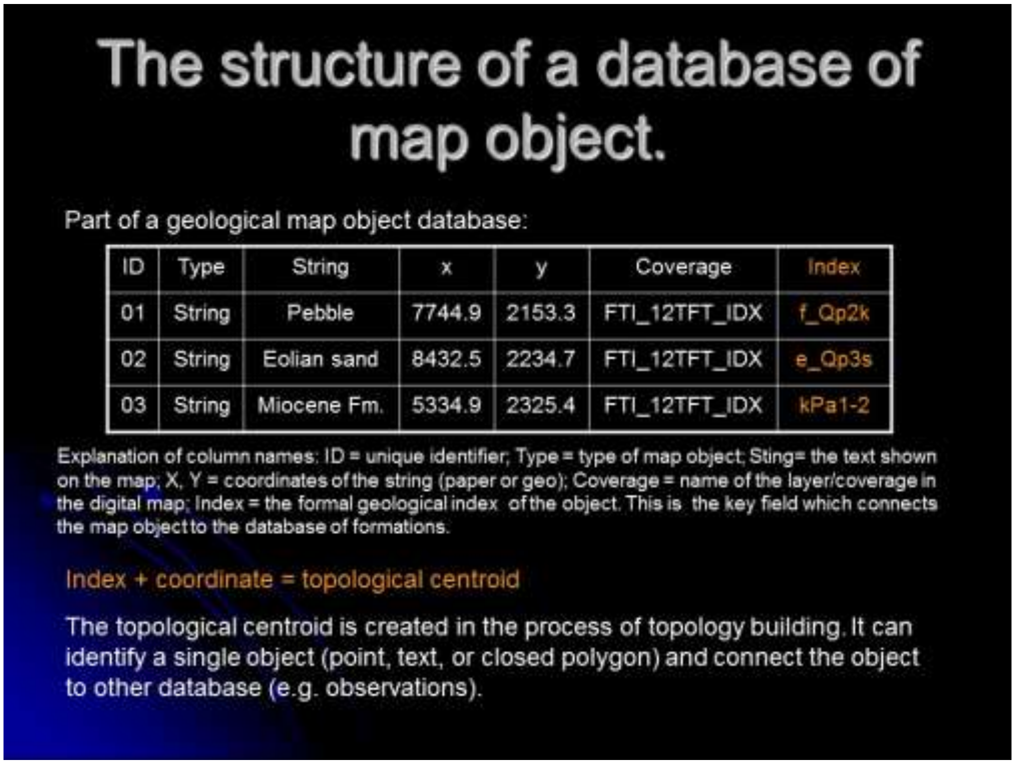
Slide 69 A sample for the database of observations.



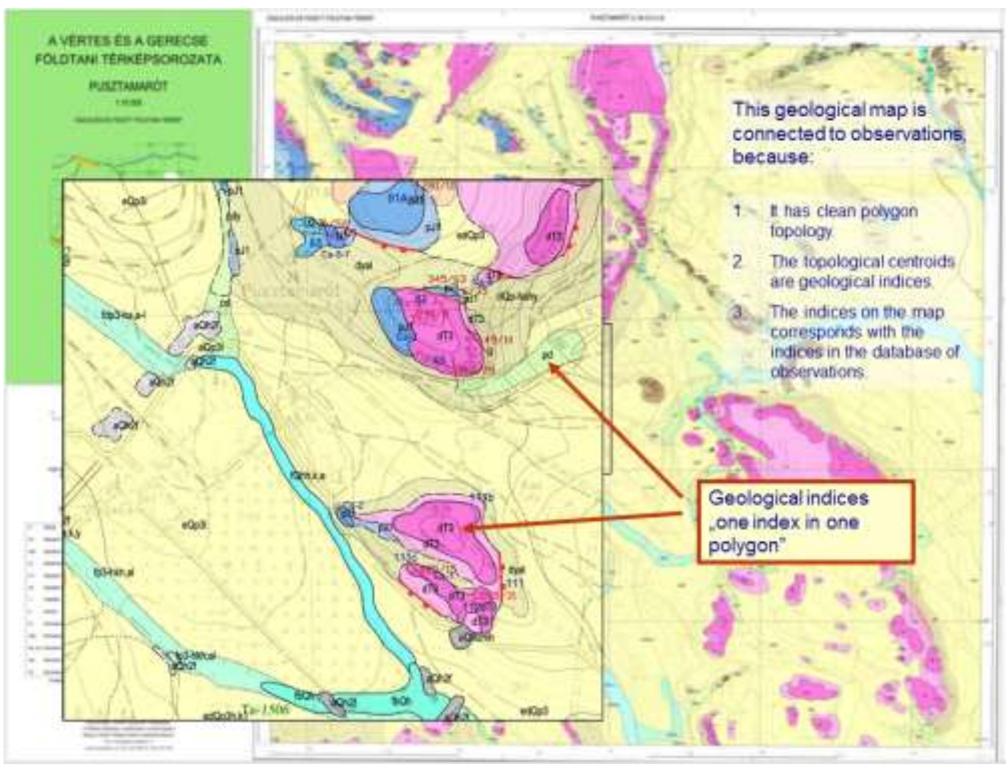
Slide 70 A relational database structure for geological field observations (Albert et al. 2012).



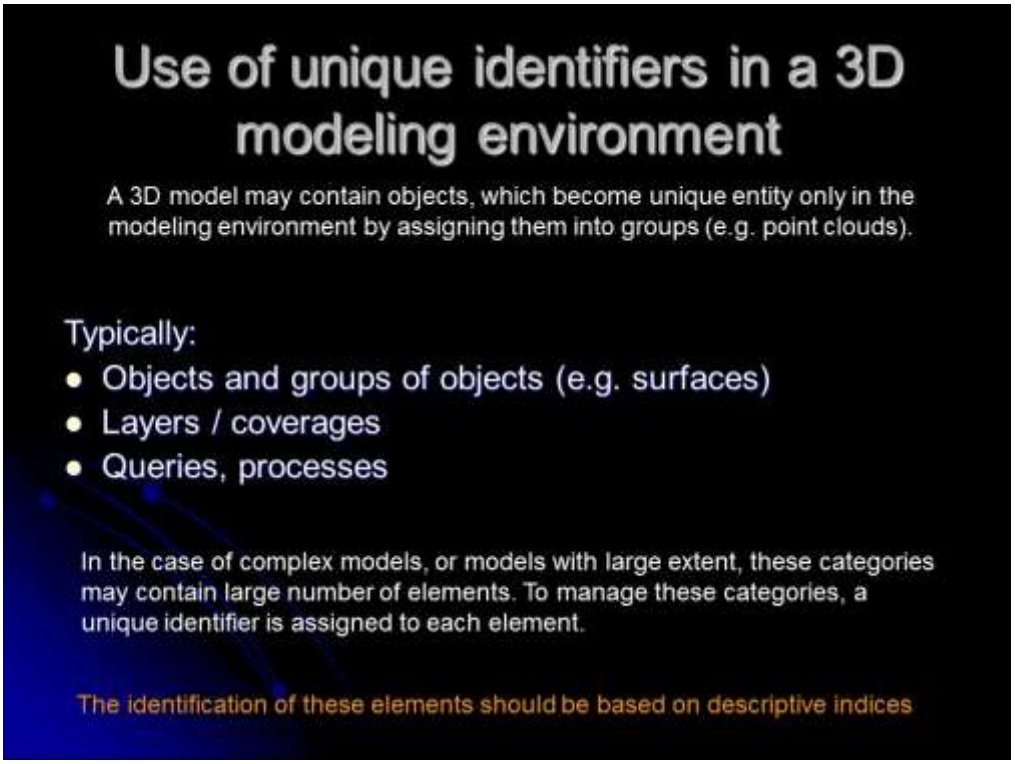
Slide 71 The database of map objects.



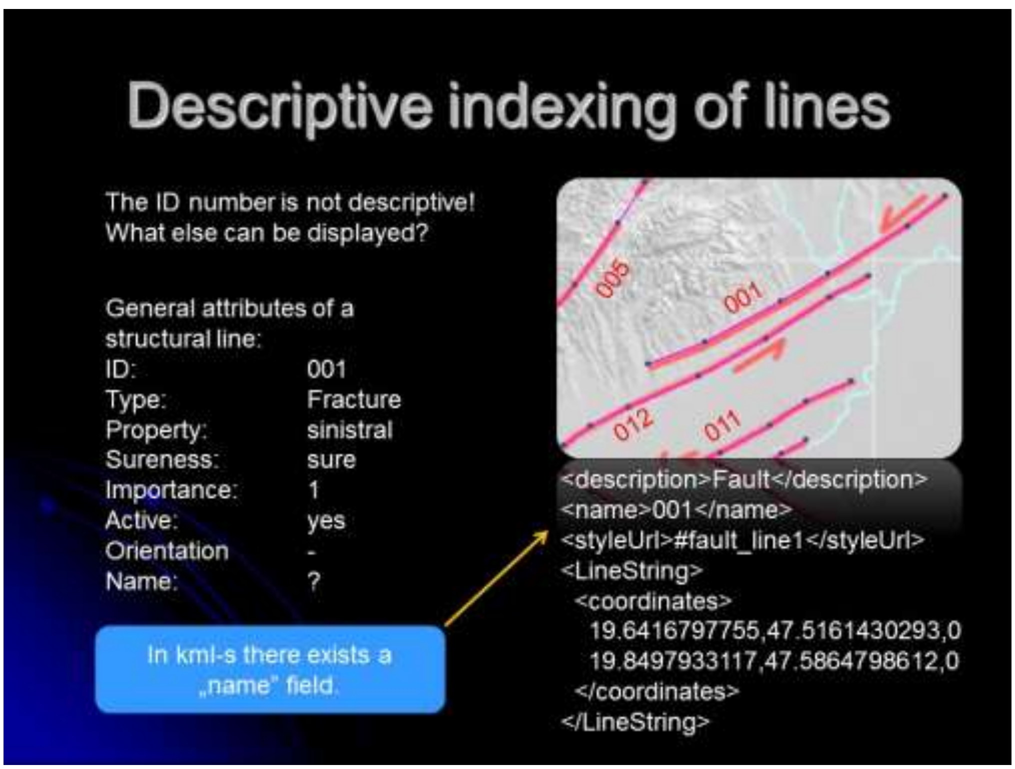
Slide 72. The structure of a map object database and the explanation of a topological centroid.



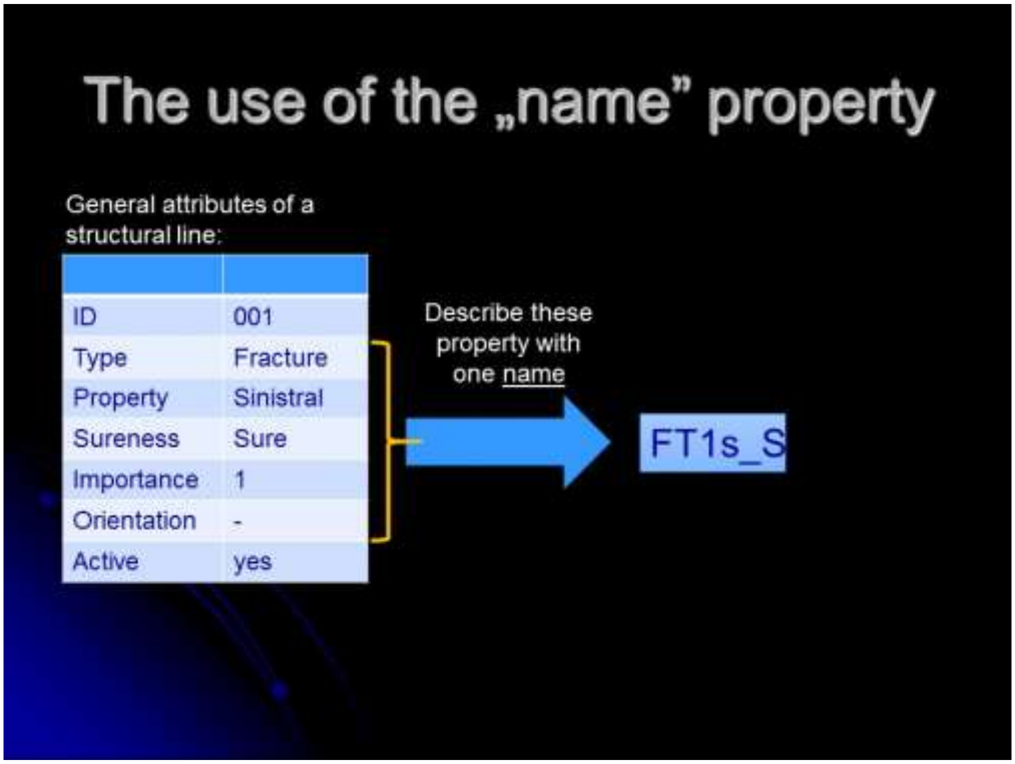
Slide 73 A sample map which is connected to a database through topological centroids.



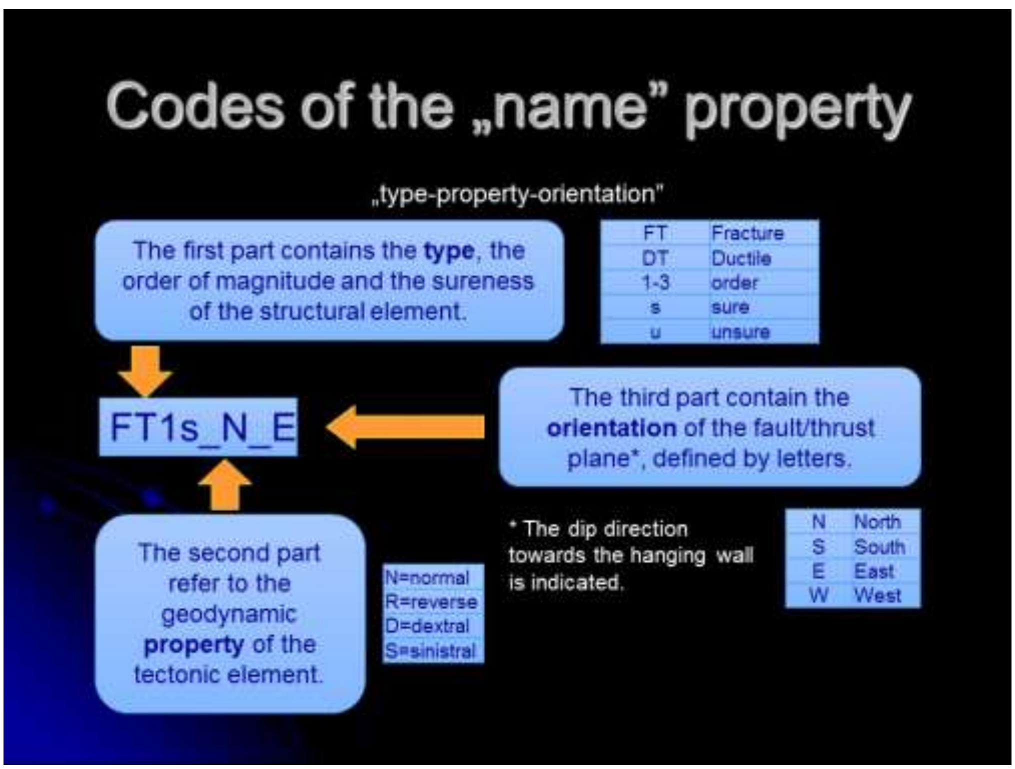
Slide 74 The use of unique identifiers in a 3D modeling environment.



Slide 75 demonstrating the descriptive indexing of lines – a structural geological sample (Albert 2014).



Slide 76 The use of the name property in the kml, as an index.



Slide 77 Descriptive codes (indices) of the "name" property of a kml which contain structural lines. The method – besides the benefit of comprehensive naming – can be used in structural geological modeling, to automatically process linear objects, which are stored in a geodatabase.

Reference in the slides

Albert G, Csillag G, Fodor L, Zentai L. 2012: Visualization of geological observations on web 2.0 based maps – In: Zentai L, Reyes Nunez J (eds.): Maps for the future – Springer.

Albert G. 2009: Digital processing/archiving of geological field maps – Annual Report of the Geological Institute of Hungary 2007, pp. 45–53.

Albert G. 2014: Inventorizing tectonic elements in geological maps and 3D models – Problems, Concepts, Solutions - In: Beqiraj A, Ionescu C, Christofides G, Uta A, Beqiraj Goga E, Marku S (eds.) Proceedings XX Congress of the Carpathian-Balkan Geological Association. Tirana: p. 459.

Use of Jewel Suite (part 2. – Explicit Data Modeling)

This class is about the explicit model building in the modelling environment. Load the *class05_pointsets_from_wellsTOC.jewel* to continue your work where you left it in the previous class, or repeat the steps of the Data Import as an exercise (see steps 17-21 in Lesson 5.).

Importing the point properties from the 50 and 100 m depths

The *Wells_TOCvalues_ext.txt* table contains TOC values from three different depths: 1) zero depth (surface); 2) 50 m below the surface; 3) 100 m below the surface. The horizontal positions of the points are valid for all the three, but the vertical positions are calculated from the "ELEV [m] tvss" column values for each points. These are the ELEV-50 and ELEV-100 columns containing the height data of the measured points.

1. Using the *Wells_TOCvalues_ext.txt* repeat the importing process (2-4) to create two additional point sets containing the attributes: TOC_MD_50m [%] and TOC_MD_100m [%] respectively. Name the new point sets as Wells_TOC_MD50 and Wells_TOC_MD100.

IMPORTANT! The *Wells_TOCvalues_ext.txt* contains elevation data as height above sea level! Since Jewel works with depth data, these **a.s.l.** values must be converted to **tvss** values in step 3, where the upper table of the upcoming dialogue window contains a "Rotation" column. Left click on it and select the "Negative z" from the dropdown list to convert a.s.l. to tvss.

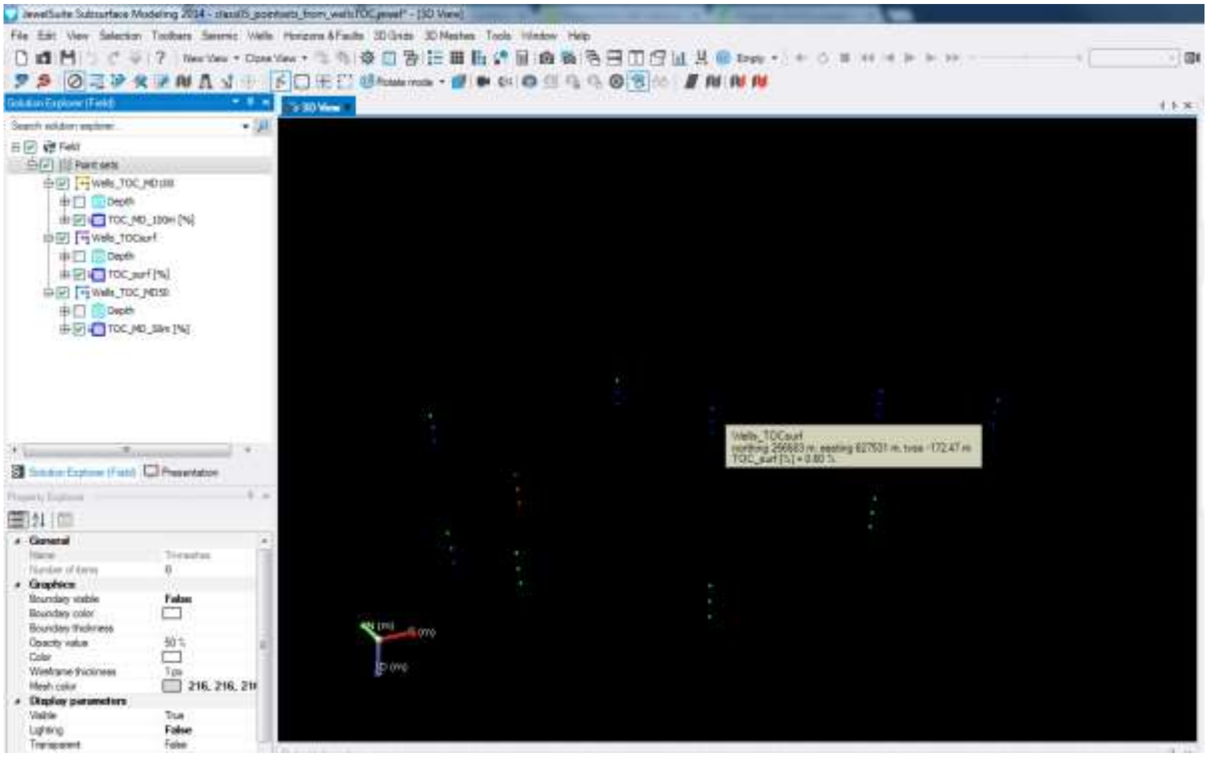


Figure 7 Point sets of the different levels (imported from the Wells_TOCvalues_ext.txt) in Jewel Suite 13

Creating triangulated surfaces

2. Either in the Solution Explorer, or in the 3D view select the "Wells_TOC_surf" Point Set – right click – execute the "Triangulate" process. A new data object (a Tri-mesh = TIN surface) is created with the same name.

3. Modify the visualization with right clicking on it, and selecting "Solid and mesh" from the pop-up menu (clicking on the default "Solid" menu object).

Editing tools

4. In the picking Toolbar select the hammer and pencil icon (Enable picking for the editing tools). A popup window and a new toolbar (Editing Tools Toolbar) appear. Minimize the popup window (but do not close it!). All icons in the new toolbar are explained with a cursor message, if the cursor is moved above them.

5. At first try the "Add triangle" tool (a grey triangle icon). To activate it, click on it once with the left mouse button, and the cursor will change to a combined arrow - triangle symbol. Complete the shape of the Wells_TOCsurf to a convex polygon with this tool. To add a triangle click on the

existing surface near 3 corner-points (a green ball appears if a point is selected). To deactivate this tool click on the icon once again.

6. Check the result in the Trimesh sheet of the Data Creator View panel selecting the Existing Wells_TOCsurf object. A new row appears in the database of the triangles.
7. Save a copy of this tri-mesh by clicking on it and selecting the “Create a copy” pop-up menu item. With the copied TIN try more editing tools which are about triangles or tri-meshes (avoid the use of polyline editing tools on TINs, because it may cause malfunctions!).

Importing terrain surface into the modelling environment

Digital terrain data can be accessed from SRTM datasets. The downloaded free access data of the area is in the *srtm_40_03_original.zip* file, but it is too big for the Wells_TOC project area and uses geographic coordinate system instead of Hungarian National Grid. To convert the data into the right format use Global Mapper (GM).

8. From the start view of GM, open the *srtm_40_03_original.zip* file. This file is in Geographic (Lat/Lon) coordinates and the datum is WGS84. Because of this the whole GM workspace will be in this coordinate system.
9. Import the point file *Wells_TOCvalues.txt* as a “point set data”. Prior to this, check the file structure in a text viewer (e.g. Notepad), and observe the sequence of the columns.
    a. In the “Generic AscII text file import options” dialogue window, check the “Point Only” as import type, and the “X/Easintg/Longitude Coordinate First” radio buttons. Type 1 to the “Fields to skip at Start of Line” textbox. Check the “Include attributes from lines with coordinate data” and the “Column headers in the first row of file” check boxes. Press OK.
    b. Select the Hungarian National Grid and the Hungarian Datum 1972 as the projection and the datum for the *Wells_TOCvalues.txt* coordinate data. The automatic coordinate conversion will be performed during the import, and the points will be displayed in Geogaphic (Lat/Lon) coordinates in the workspace.
10. In the Tools – Configurations menu convert the projection of the whole workspace into Hungarian National Grid (HD 72 datum). Check the cursor coordinates in the lower right corner of the window.

11. Export the SRTM as a **surfer 6 binary grid** (File – Export – Elevation Grid Format). In the "Surfer Grid Export Options" dialogue window set the resolution to 25 by 25 m in the "Sample Spacing" region of the "General" panel. In the "Export Bounds Panel" check the "Global Projections" radio button and define the export boundary using the following values: North: 267150; West: 626575; South: 265850; East: 628475. Save the file as *wells_TOC_topography.grd.*

Import the *wells_TOC_topography.grd* file in the Jewel modelling environment. Switch to the active Jewel solution (or open the solution, you left at point 7).

12. In the Workflow Guide go to the **Data Import** process, and then select the 2D Grid Data panel. Select the file created in step 11.
13. In the "Import as" dialogue window specify the file type as "**Surfer 6** Grid Files". Don't forget to switch the z-axis in the "Data Import Validation" window (Rotation column)!
14. Modify the appearance of the surface by clicking on it with right mouse button and

Definition of cross sections

15. Select the "Add planar section" tool in the "Cross Sections Toolbar" and define a cross section between two arbitrarily defined points. Notice that the section expands until it cuts the whole extent of the imported surface!
16. Click on the cross section with right mouse button, and press the "show cross section view" menu point. A new main window appears.
17. In this view select the visualized planar section in the Solution explorer. Scroll down in the Property Explorer to the "Geometry" section and modify the value of the "Data points projection distance" to 200 m. The data points in the buffer zone of the section are displayed.
18. In the picking Toolbar select the hammer and pencil icon (Enable picking for the editing tools). A popup window and a new toolbar (Editing Tools Toolbar) appear. Minimize the popup window (but do not close it!).
19. Press the "Add polyline" tool once, and draw a polyline on the cross section. To finish a polyline, use double clicks with the left mouse button.
20. Switch back to the 3D view to see the 3D polyline.

This tool will be used in later exercises to demonstrate the digitization method of explicit models.

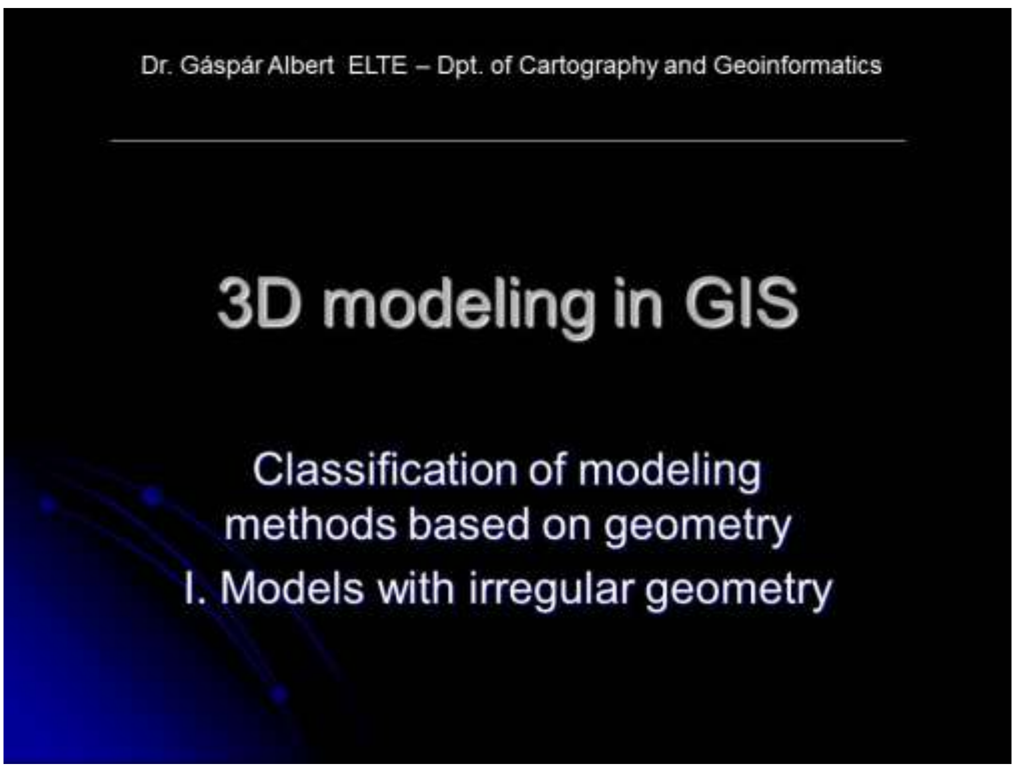
Lesson 7.

The topics of this class are the followings:

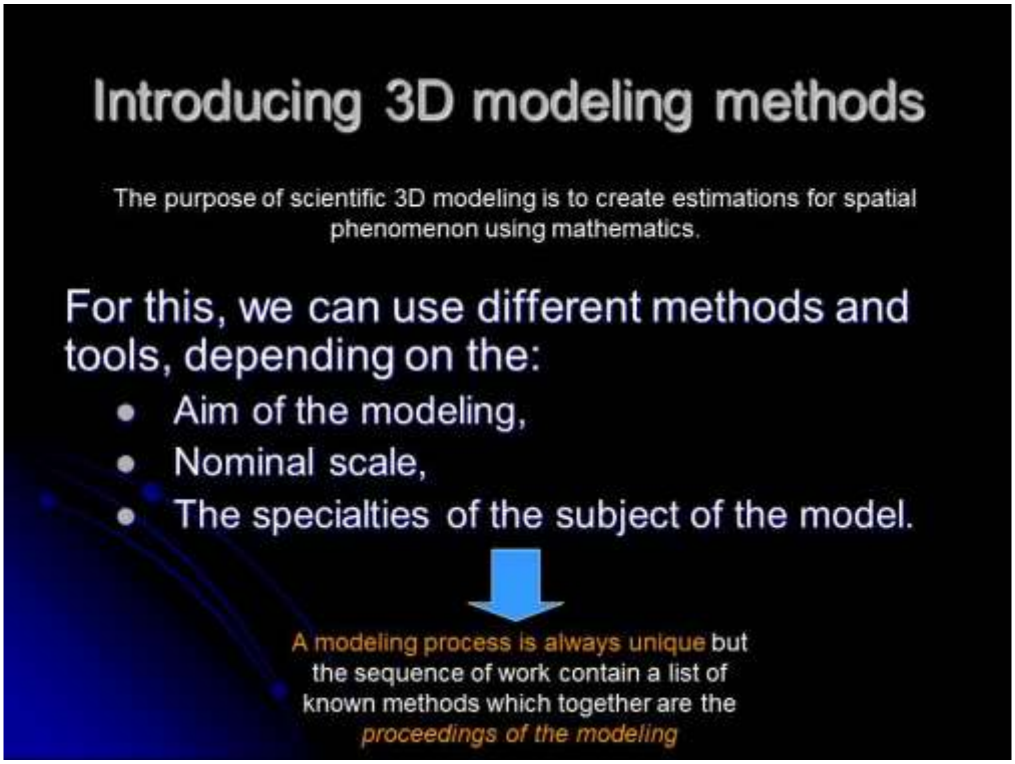
- Modeling process: the concept (mathematics, step-by-step definition).
- Classification of 3D modeling methods based on geometry.
- Comparison of the regular and irregular models.
- Irregular models 1: point-cloud, parametric point-clouds, TIN surfaces.
- Delaunay triangulation and voronoi-polygons.
- Irregular-shaped solids, and irregular tetrahedron-mesh (tessellation of voronoi polyhedrons)

Practice: use of Jewel Suite – importing shapes, data manipulation in Jewel, Spatial querying, importing images for explicit modeling

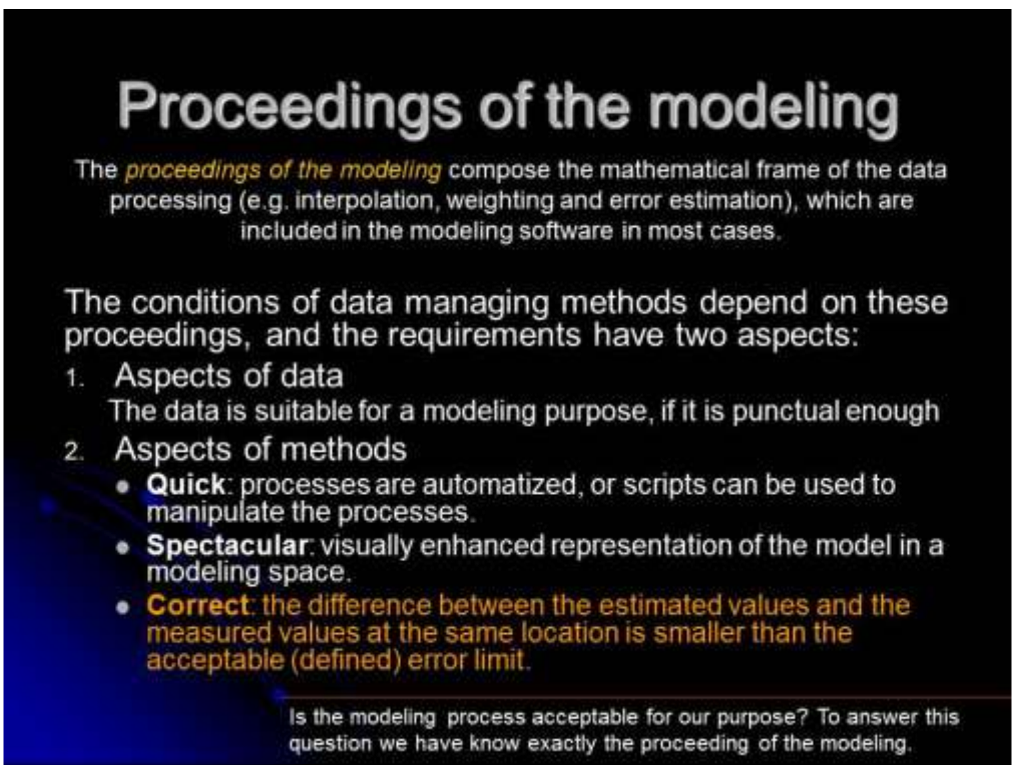
Classification of modeling methods based on geometry – I. Models with irregular geometry



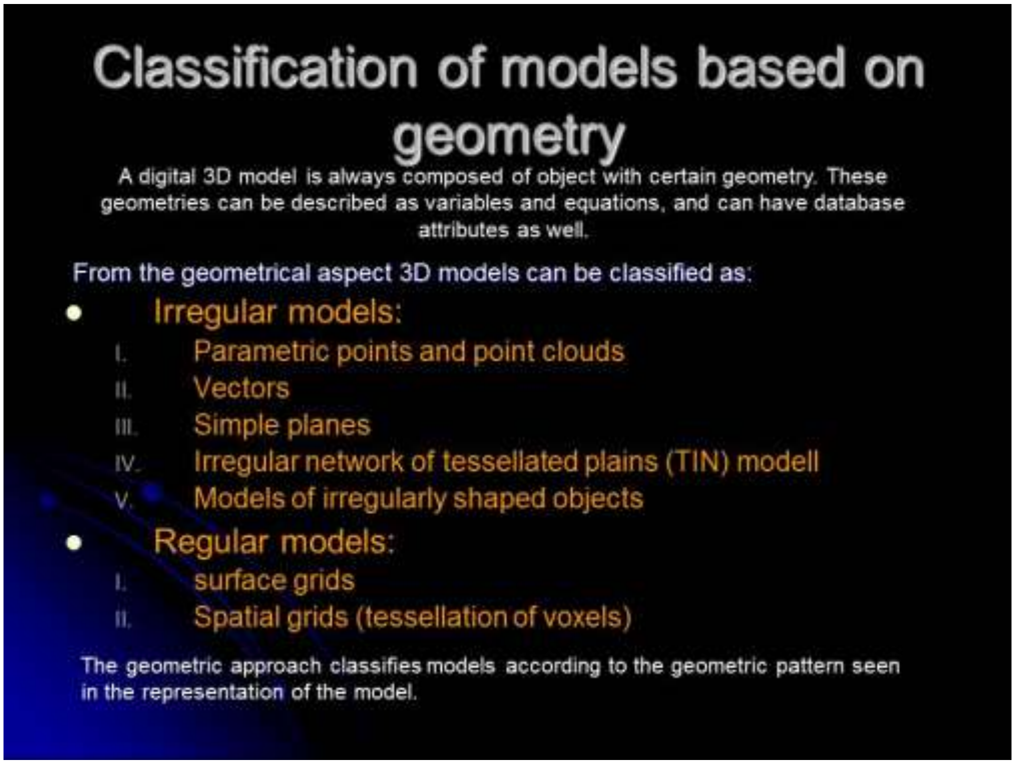
Slide 78 Welcome slide of the 7th class.



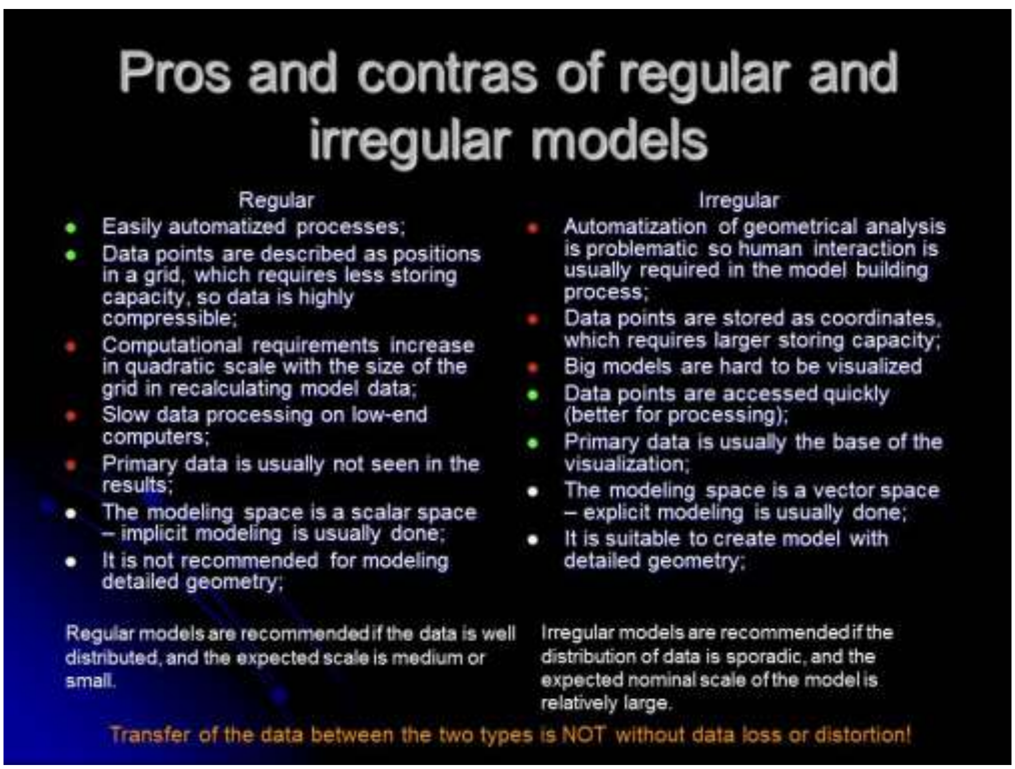
Slide 79 The Uniqueness of a modelling process, despite of the use of well-known methods.



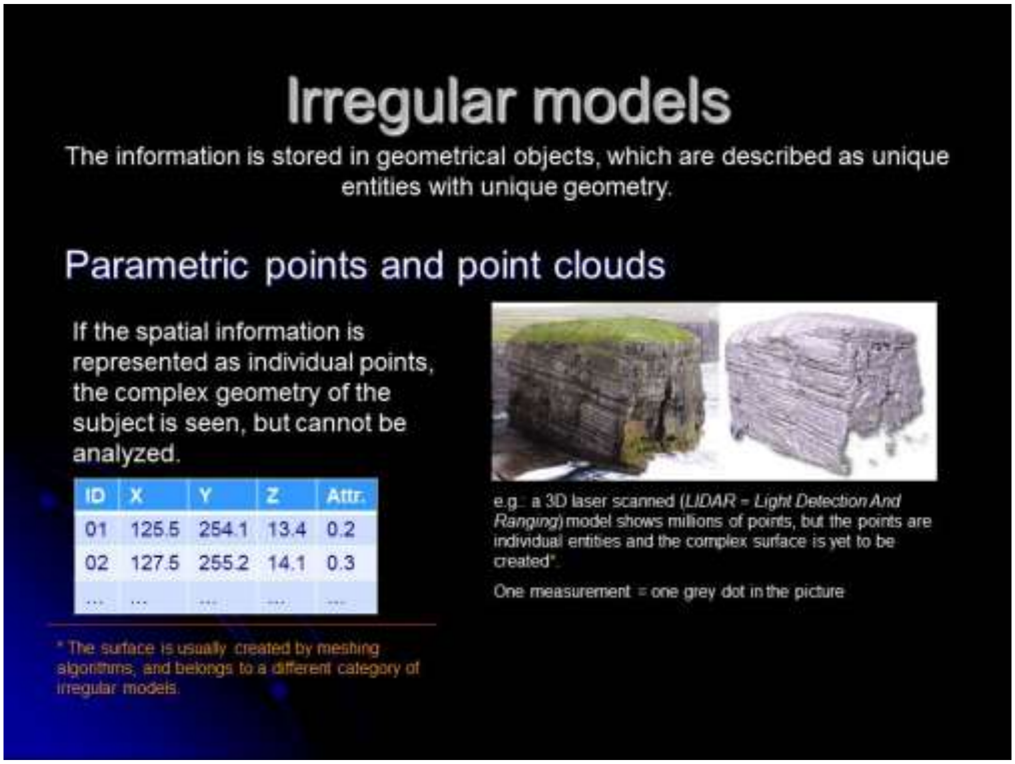
Slide 80 Definition of the "proceedings of a modeling".



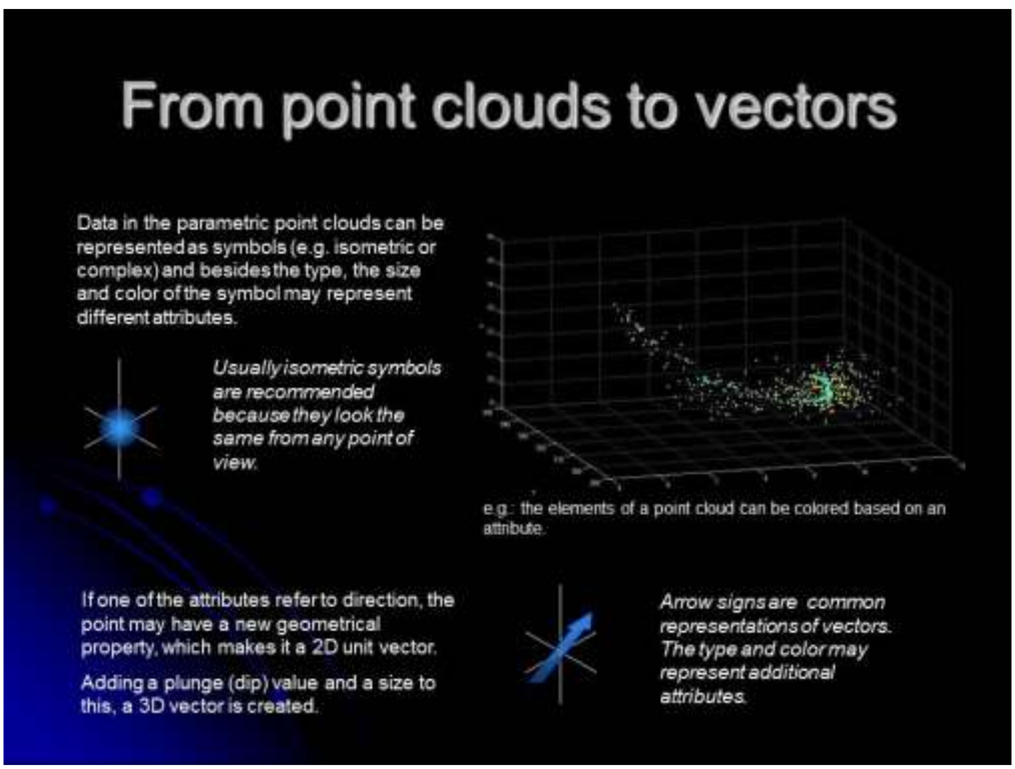
Slide 81 Classification of models based on geometry.



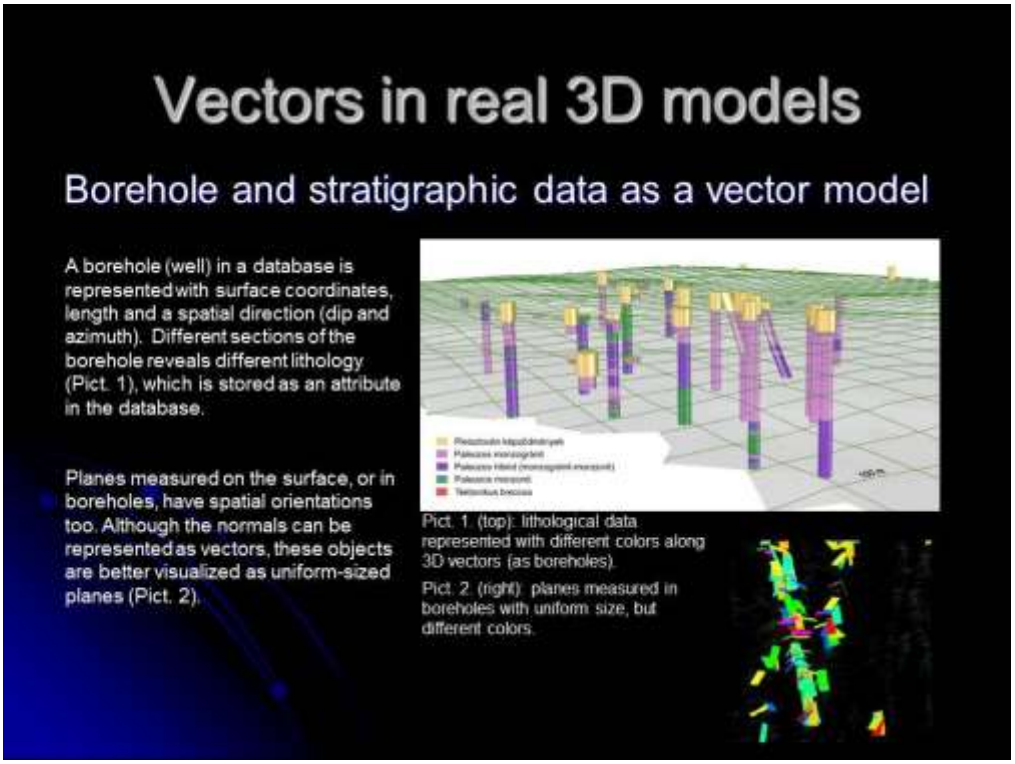
Slide 82 Comparison of regular and irregular models.



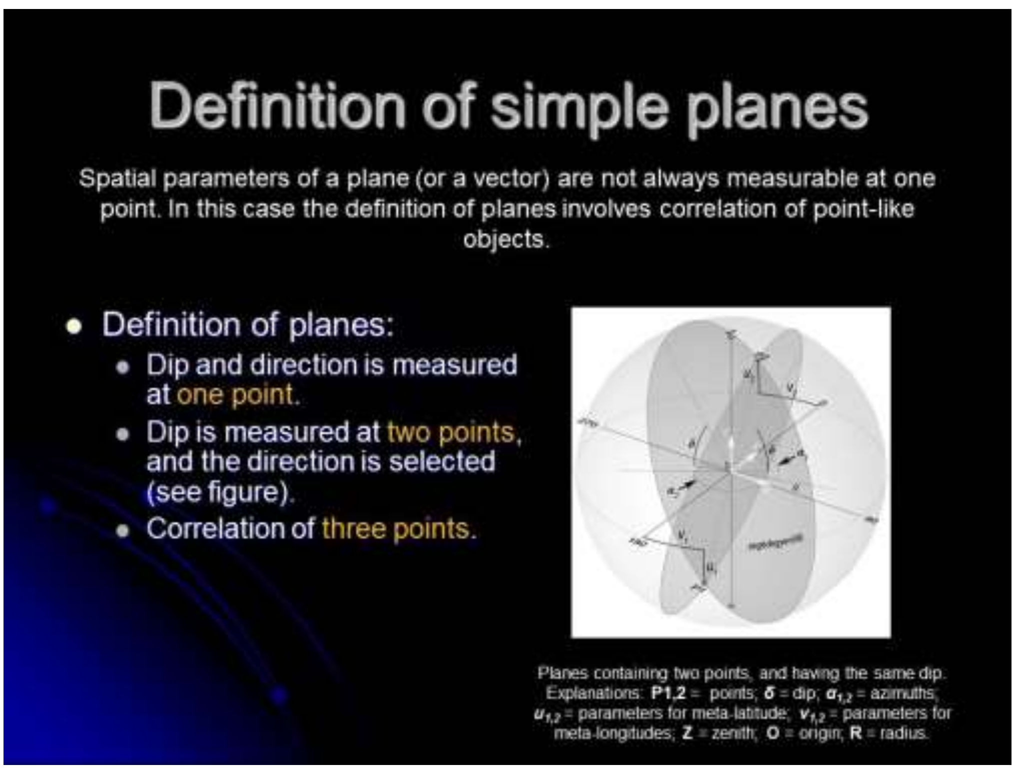
Slide 83 Simple irregular models – points and point-clouds.



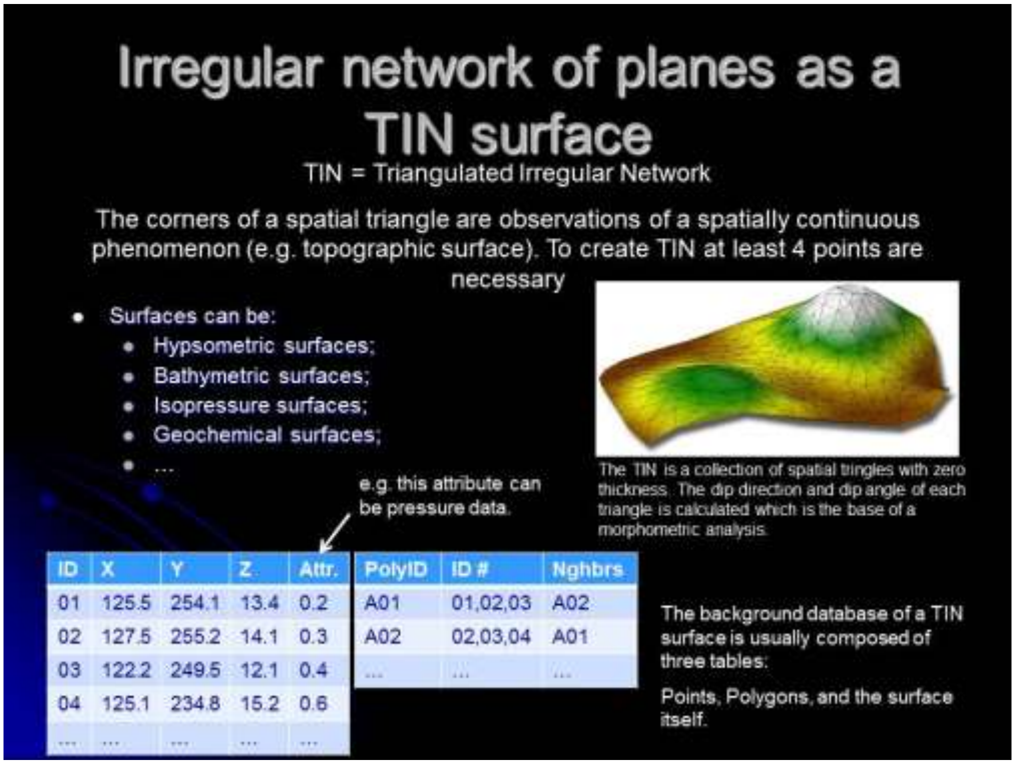
Slide 84 transition between points and vectors in the data model.



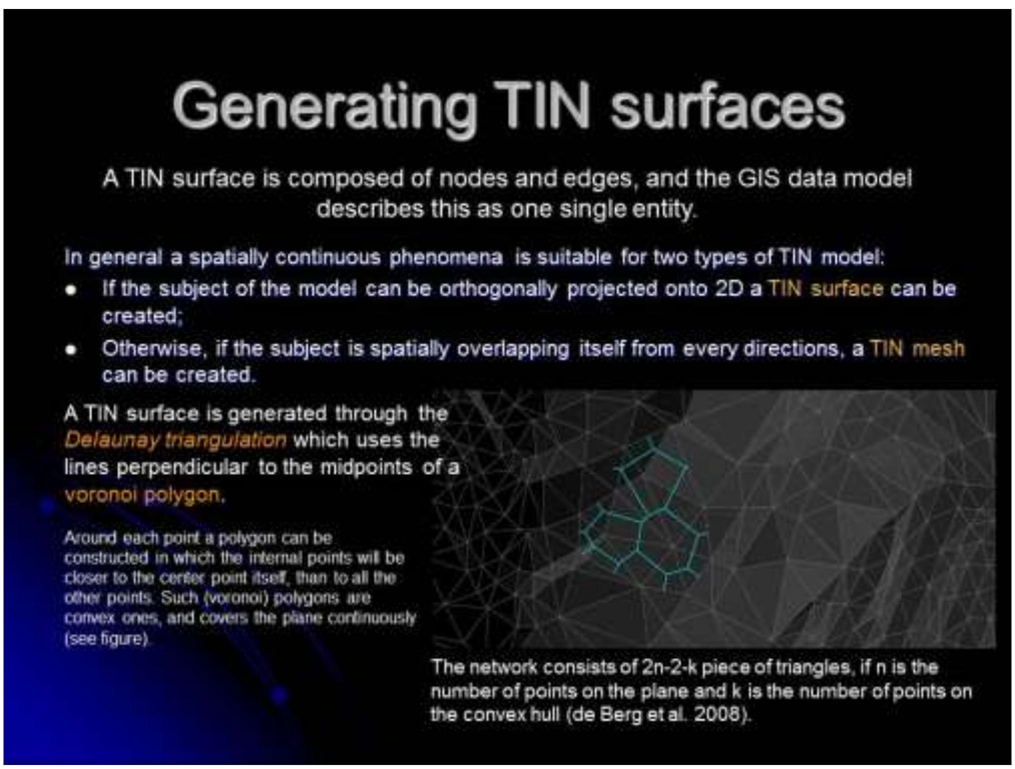
Slide 85 Vectors in real 3D models – Borehole and stratigraphic data as a vector model.



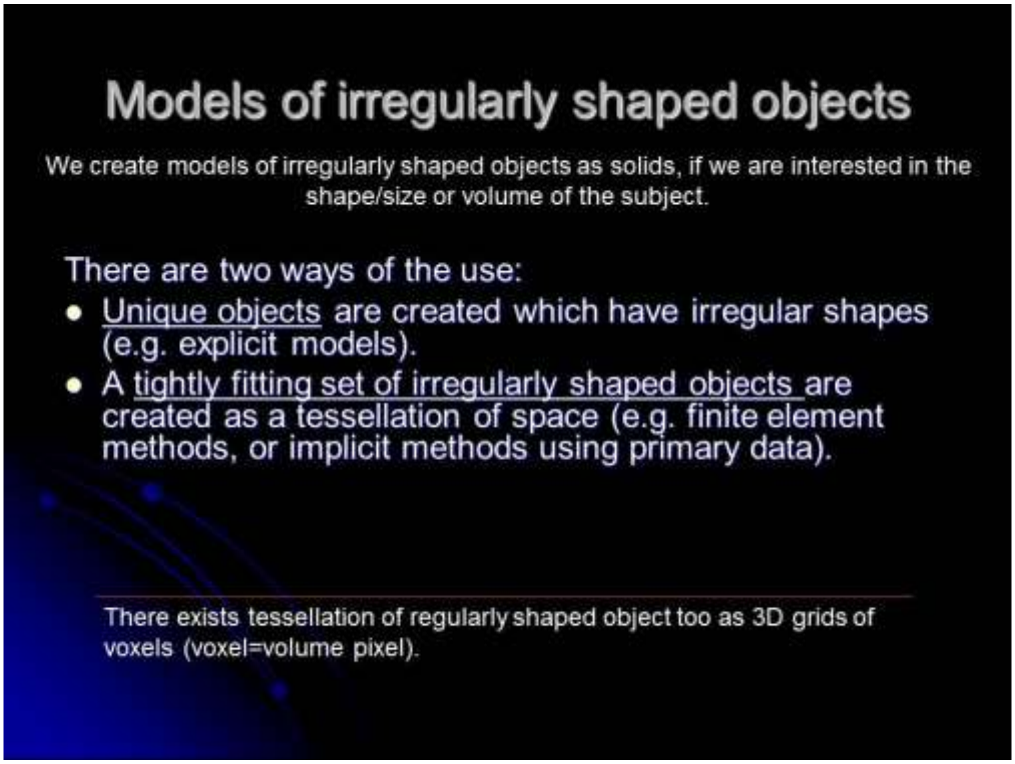
Slide 86 Definition of simple planes.



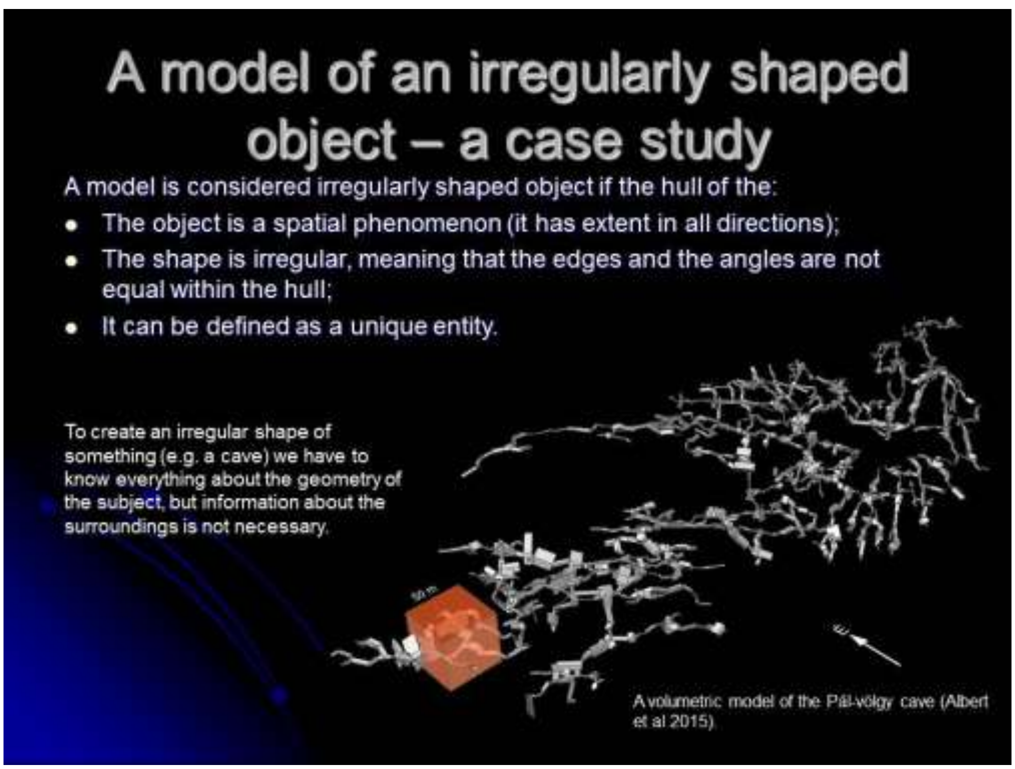
Slide 87 Irregular network of planes as a TIN surface.



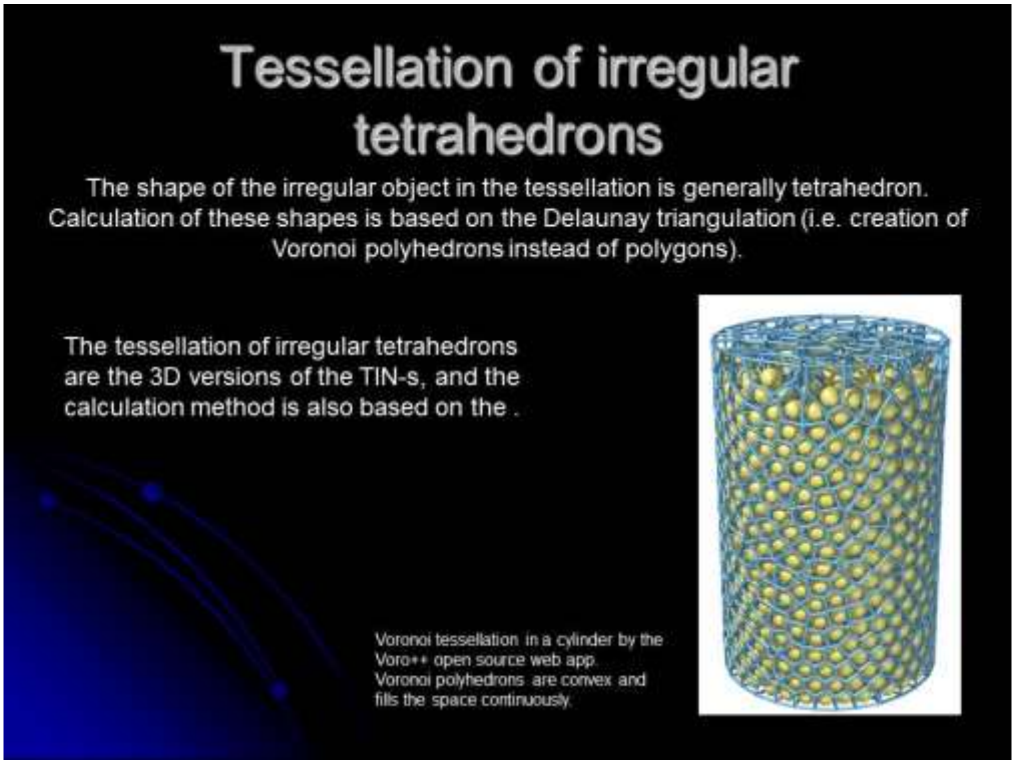
Slide 88 Generating TIN surfaces or TIN meshes.



Slide 89 Models of irregularly shaped objects – the ways of use.



Slide 90 A model of an irregularly shaped object – a case study of the Pál-völgy cave (Albert et al. 2015).



Slide 91 Tessellation of irregular tetrahedrons. Both the tetrahedrons and the polyhedrons may serve as the base geometry of the model.

References for the slides

Albert G., Virág M., Erőss A. 2015: Karst porosity estimations from archive cave surveys - Studies in the Buda Thermal Karst System (Hungary) – International Journal of Speleology, 44 (2):151-165. Tampa, FL (USA)

Bellian, J.A., Kerans, C. and Jennette, D.C. (2005) Digital outcrop models: Applications of terrestrial scanning LIDAR technology in stratigraphic modelling. Journal of Sedimentary Research, 75, 166-176.

Gold C. M. 1991: Problems with handling spatial data - the Voronoi approach. CISM Journal ACSGC. Vol. 45, No. 1. Springer 1991. pp. 65-80.

Kidner, D., Dorey, M., Smith, D. 1999: What's the point? Interpolation and extrapolation with a regular grid DEM. – IV International Conference on GeoComputation, Fredericksburg, VA, USA – http://www.geovista.psu.edu/sites/geocomp99/Gc99/082/gc_082.htm

de Berg, Mark; Otfried Cheong; Marc van Kreveld; Mark Overmars 2008. Computational Geometry: Algorithms and Applications. Springer-Verlag.

Voro++ open source web application, http://math.lbl.gov/voro++/about.html

Use of Jewel Suite (part 3.)

The explicit method of model building may include the import of polylines, images and (in case of geological modelling) borehole data. This class is aimed to practice the import of shape files and images in the workflow.

Data Import

1. In the Workflow Guide go to the **Data Import** process, and then select the Shape Data panel. A dialog window appears where you can define the file where the shape file is stored and select the *outcrop_bdn.shp* in the 07 folder. Notice that the shape is positioned on the 0 tvss level.

Data manipulation in Jewel

Shapes in Jewel can have multifunctional use. A shape can represent a mapped line on the surface, but it can be considered as a trace line of a cross section. In the first case it usually needed to create a 3D polyline set in the modelling environment which is draped on the surface. However, this can be achieved in several ways. The following exercise demonstrates two of them.

2. In the solution Explorer right click on the “otcrop_bdn” object which has a 0 at the end (referring to the vertical position).
3. Select the “create vertical arbitrary section” sub menu. A “outcrop_bdn 0 Section” object is created in the Solution Explorer. And a grey vertical section object is displayed in the 3D view.
4. Right click on this object and press the “Show cross section view”. A new main window appears showing the planar view of the curved plane. The section line of the *wells_TOC_topography* surface is displayed.
5. Click on this section line with right mouse button and select the “Create – intersection with cross section” sub item in the popup menu. A polyline set is created with a name similar to the surface of which it was created from.

NOTE: the same is achieved if you click on the *wells_TOC_topography* surface object in the Solution Explorer with the right mouse button.

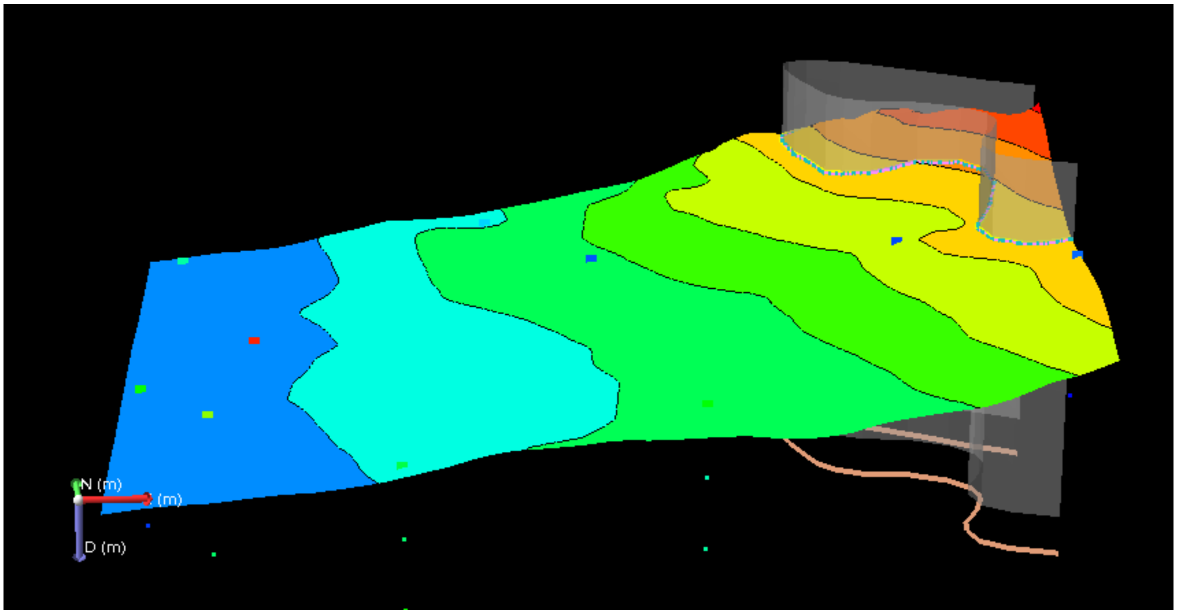


Figure 8 The surface model with the imported shape at zero elevation (lower right), and the grey transparent vertical-section surface, which was used to project the shape-line onto the surface.

Although this is a quick way to create the 3D polylines draped on the surface, it is problematic if we are working with a shape, which consists of several polylines. The other way to create a draped polyline set is to transfer the depth property of the surface to the vertices of the shape entity.

6. Right click on the "outcrop_bdn 0" shape object. A new polyline set with the same name appears. Select this object in the Solution Explorer
7. Click on the "open calculator" icon in the "window toolbar" The "Property Calculator" sub application appears, which is a database querying and manipulating tool in Jewel.
8. In the Functions panel (left part of the window) explore the "Property extraction" and select the function: PropertyExtraction… with double clicks.
9. A new window appears where we can define the type of the object from which we want to extract the properties. Select the "2D grids" from the dropdown list.
10. The *wells_TOC_topography* surface is listed. Check the checkbox next to it (if not checked), and select the "depth" property from the dropdown list below the list of objects.
11. Explore the available interpolation methods in the dropdown list. For now select the nearest neighbour method and check the vertical projection radio button.
12. Press OK. A query expression appears.

NOTE: this query method has nothing common with the usual SQL language but builds on the "if, then, else" logic.

13. In the right side of the window change the Property name to depth, and press "Update Property" in the lower right corner. Close the Property Calculator.
14. Observe the result in the 3D view. Compare the two polyline sets! Check the database structure of the two of them in the "Data Creator View". Explain the difference!

Importing images

15. In the Workflow Guide go to the **Data Import** process, and then select the Image Data panel. A dialog window appears where you can define the file where the image file is stored and select the *P3-P8 cross section.jpg* in the 07 folder.
16. In the next dialogue select the simple image type.
17. In the next window you have to define the insertion point, the orientation and the size of the image. Insertion point: is the P3 well (Easting: 626752.550; Northing: 266222.936), bearing -11.5 degree (azimuth)[1] and 1 pixel=1 meter. Set the inclination to 90 (vertical) and the tvss to 250.
18. In the "Picking Toolbar" select the hammer and pencil icon (Enable picking for the editing tools). A popup window and a new toolbar (Editing Tools Toolbar) appear. Select the "Add polyline" tool icon in the toolbar and the list of the available polylines appears in the popup window. Select one of the existing polyline sets.
19. In the 3D view, digitize the bottom line of the "Oligocene Sandstone" with this tool. To finish digitizing double click on the last point.
20. Close the toolbar with clicking once again on the hammer and pencil icon (Enable picking for the editing tools).

[1] Although in Jewel it is called like this, in reality this value is not azimuth because it represents a counter clockwise rotation angle from the easting axis, while azimuth represents a clockwise rotation angle from the North axis.

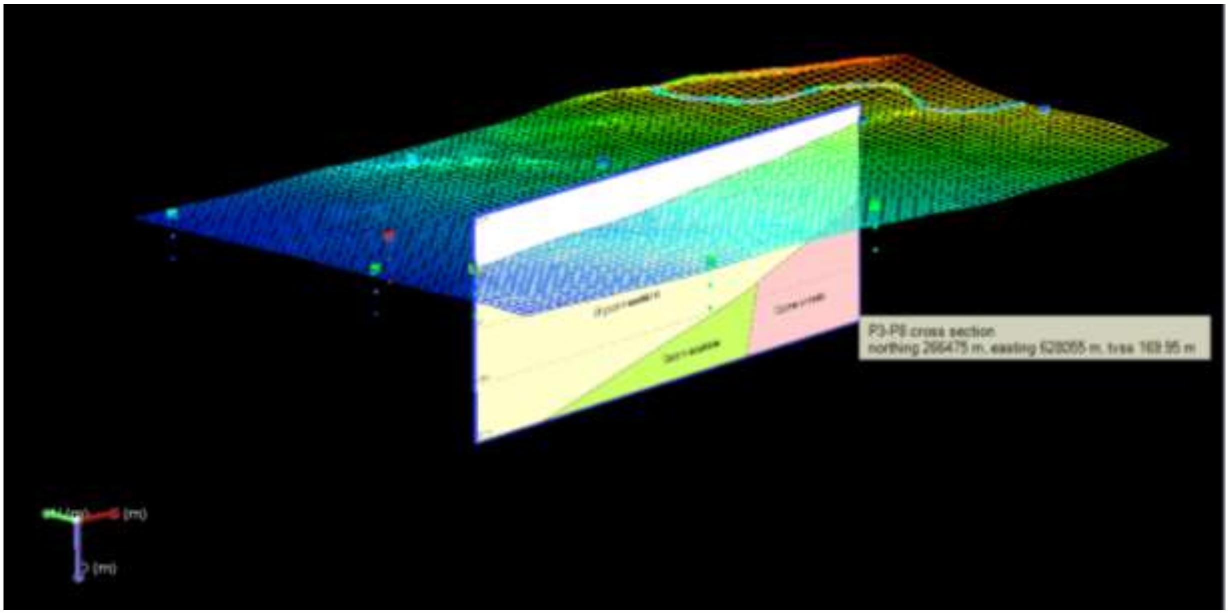


Figure 9 Image file (*P3-P8 cross section.jpg*) of a geological cross-section after modifying the angle and the dip value to place it in a geographically correct position in the modelling space.

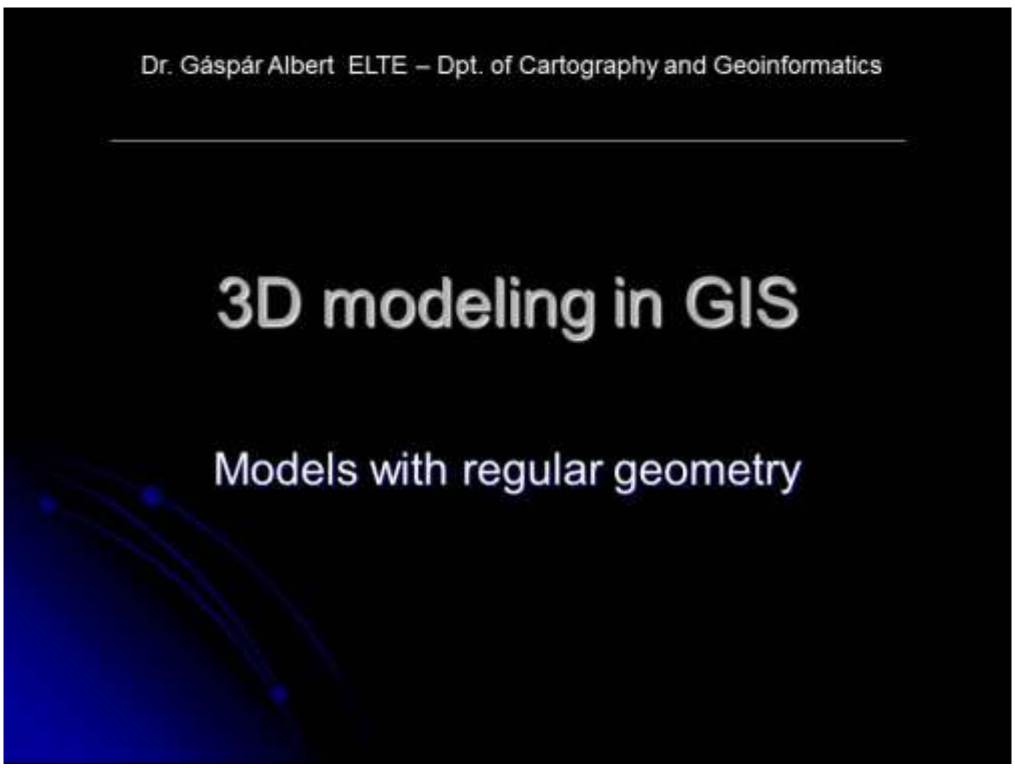
Lesson 8.

The topics of this class are the followings:

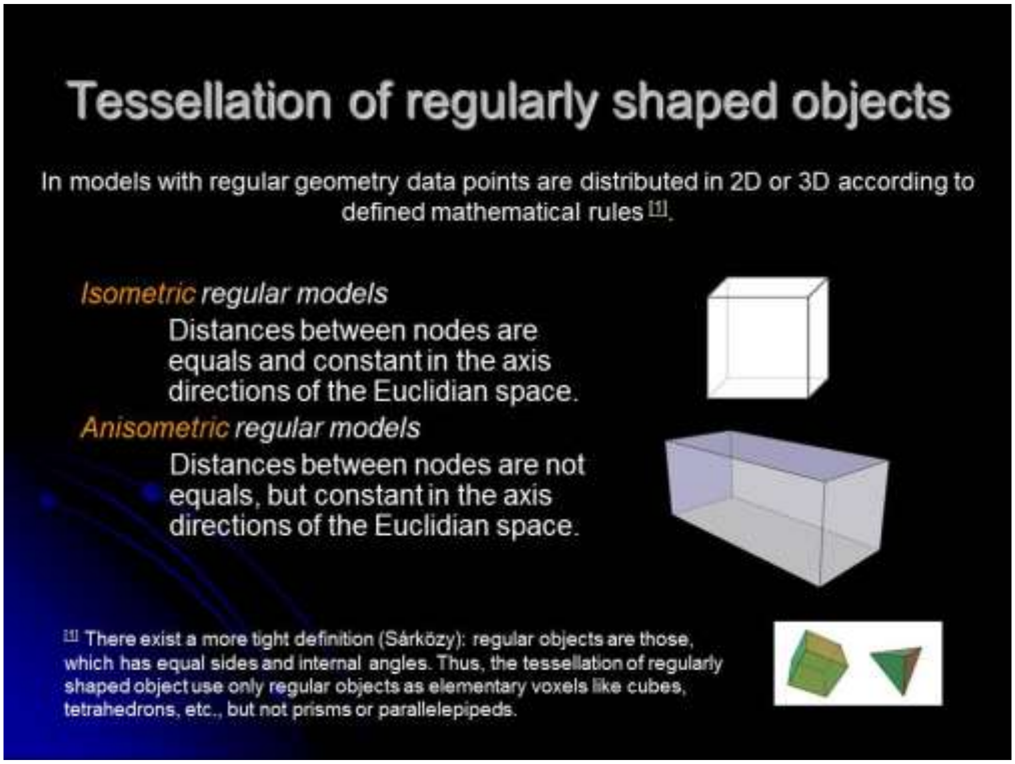
- Tessellation of regular polyhedrons (isometric-anisometric; isotropic-anisotropic).
- 2D grids (the nature of grids: primary or compiled data?);
- Processing and storing grid data.
- 3D grids (types of voxels)

Practice: spatial modeling (creating voxel models from different input data). Quantitative 3D modeling from sample point-cloud data.

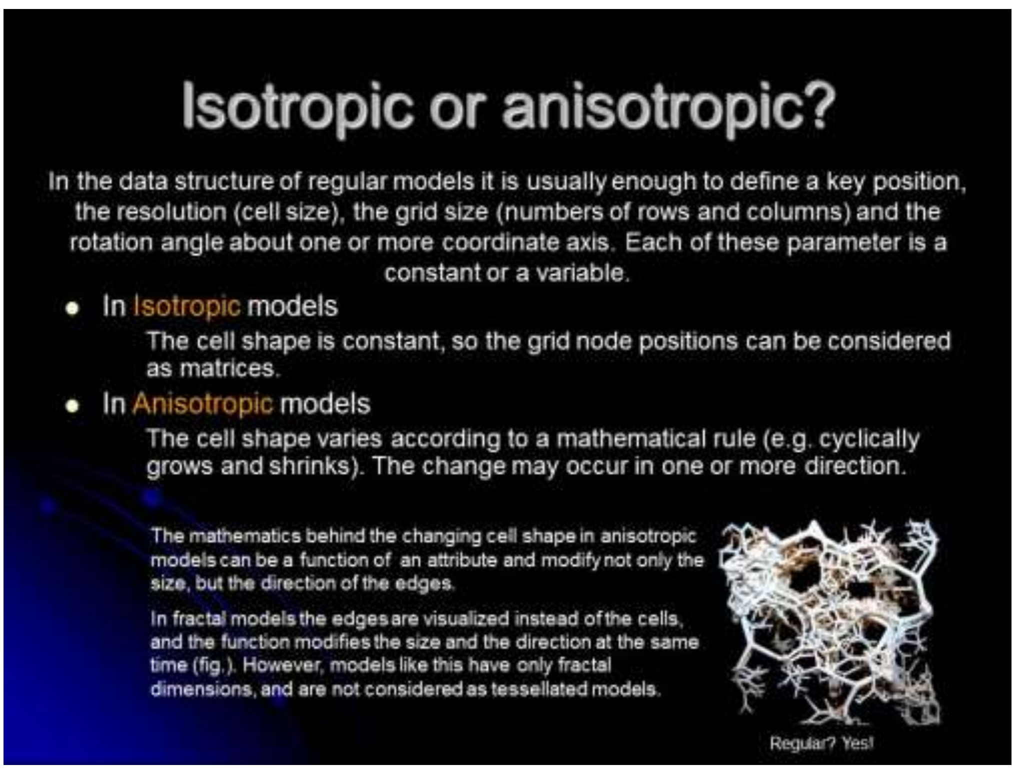
Models with regular geometry



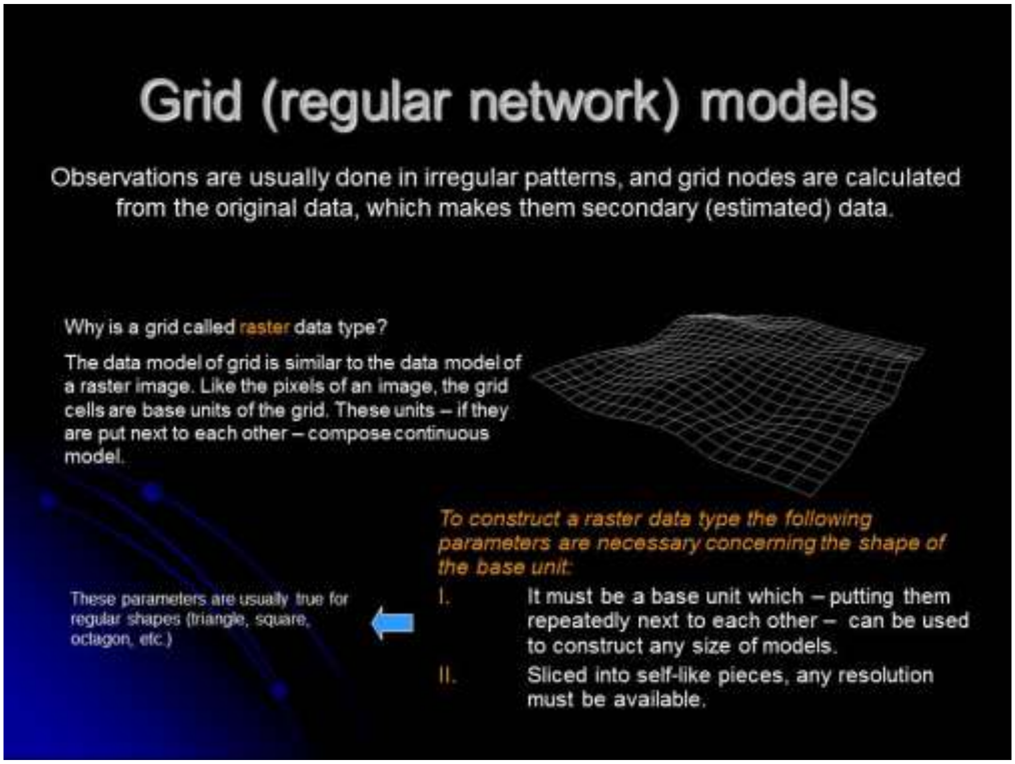
Slide 92 Welcome slide of the 8th theoretical class.



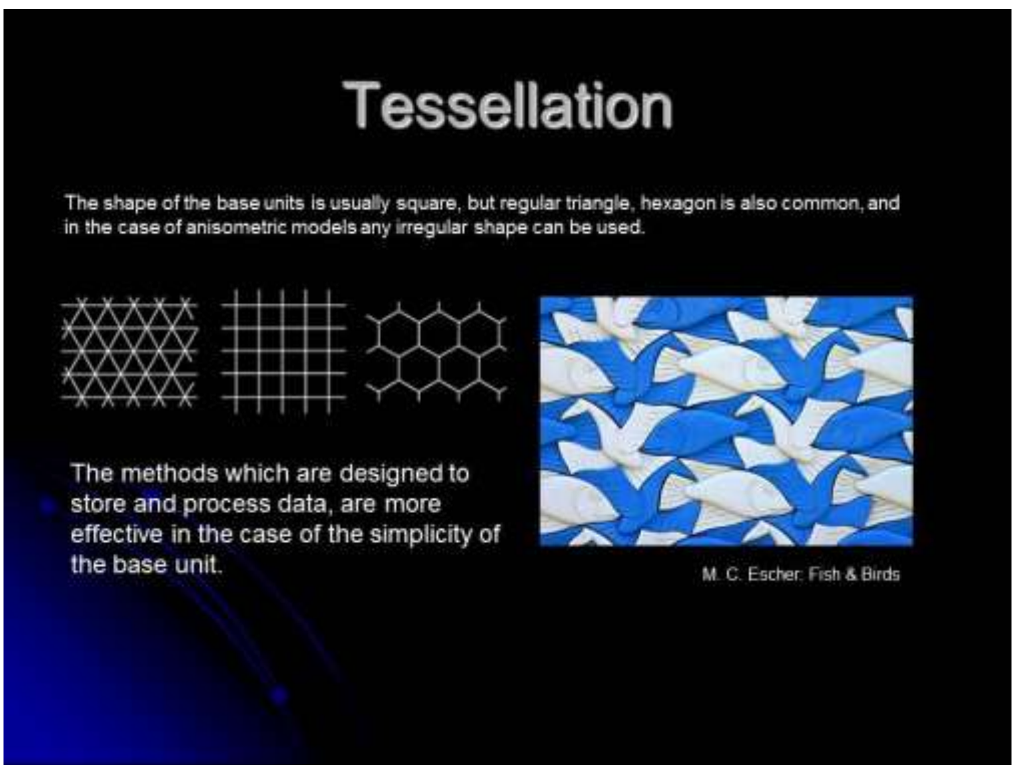
Slide 93 Isometric and anisometric grids



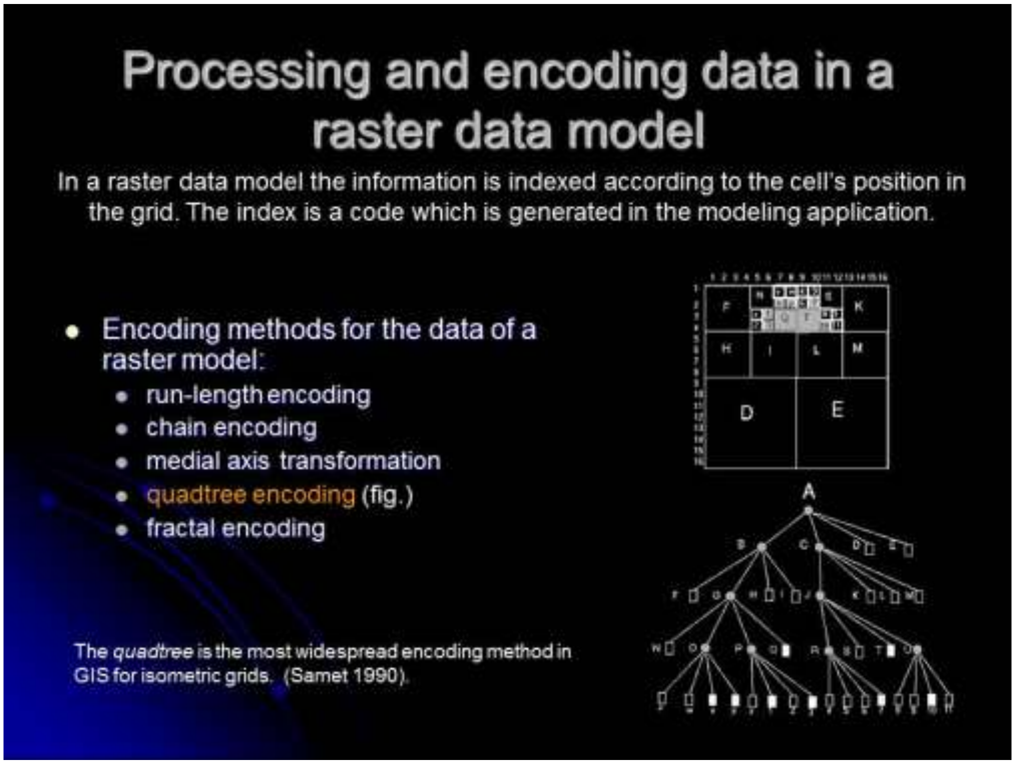
Slide 94 Isotropic and anisotropic models



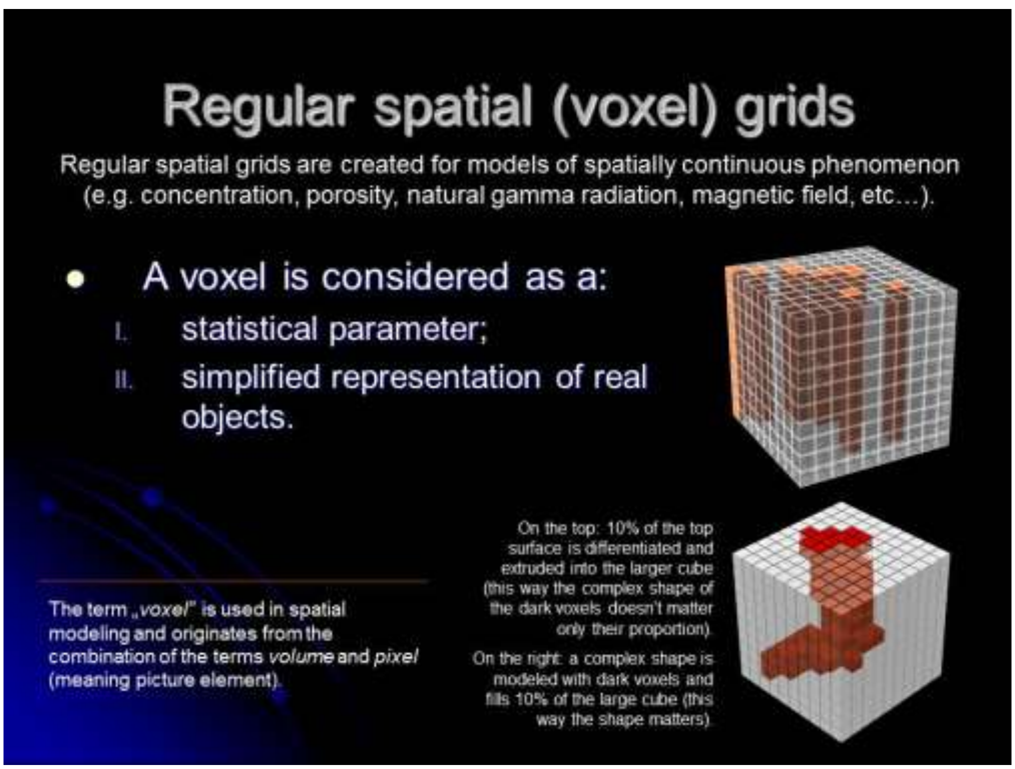
Slide 95 grid models as surfaces



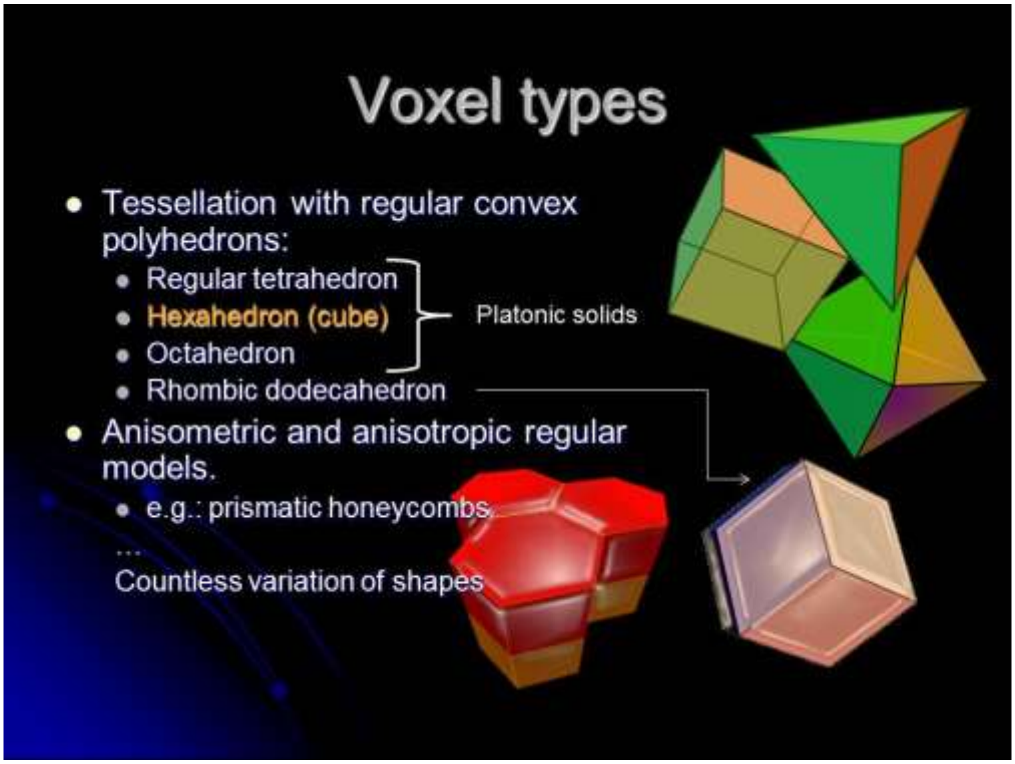
Slide 96 what is a tessellation?



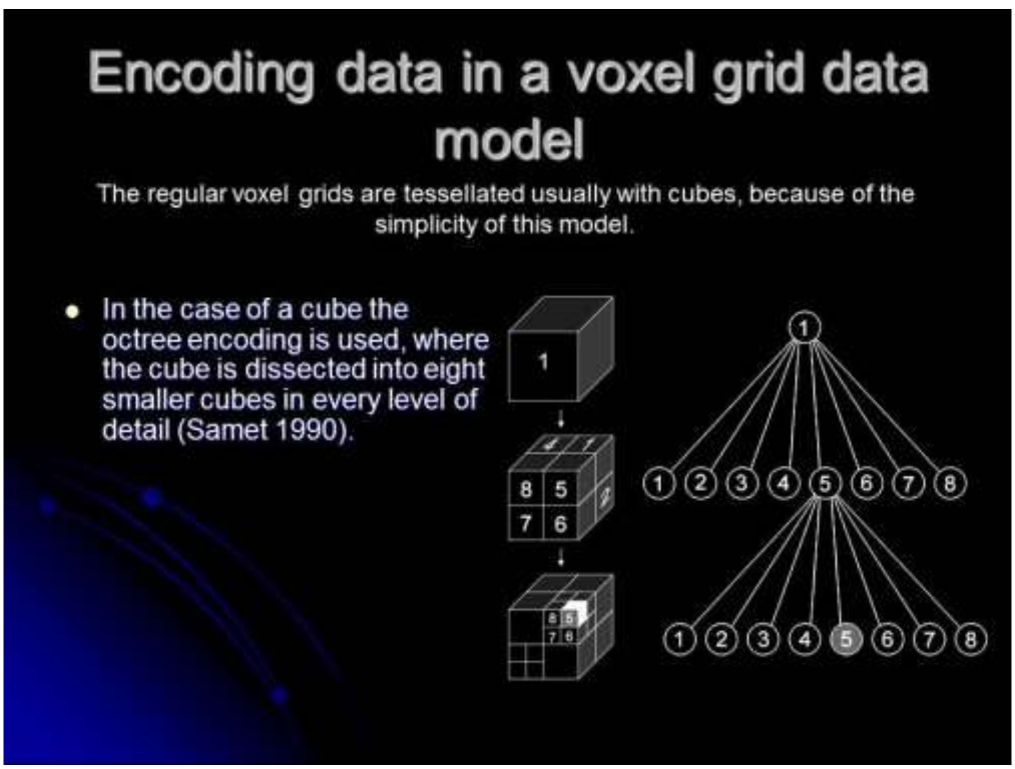
Slide 97 Data encoding in a grid – the quadtree method.



Slide 98 The different meanings of a voxel in a model.



Slide 99 Voxel types (convex polyhedrons).



Slide 100 The octree encoding (Samet 1990).

References for the slides

Samet H. 1990: The design and analysis of spatial data structures – Addison-Wesley Publishing Company, Inc. 1990.

Use of Jewel Suite (part 4. – Implicit Data Modelling)

In this class a 3D voxel grid modeling is demonstrated by importing quantitative data into the modeling environment and defining the model parameters and calculation methods.

Window – New window – Start Page: select the New Solution icon. This will start an empty project with the default settings. An empty 3D View panel (in the middle of the screen) show up.

Import point set and surface data:

1. In the Workflow Guide go to the **Data Import** process, and then select the Point Set Data panel. A dialog window appears where you can define the file where the Point set data is stored. Select the Wells_TOCsurf.joapointset file.
2. Repeat the import process with the Wells_TOC_MD100.joapointset and Wells_TOC_MD50.joapointset files.
3. Import the wells_TOC_topography.grd file as a 2D grid. Be prepared to rotate the Z axis during the process!

Model Area definition

To create a model first we have to define an area where the application will calculate the secondary data from the original ones.

4. In the **Model Definition** workflow process select the Model Area Definition panel.
5. In step 1 define the name of the modelling area (e.g. TotalArea), and press the “Create” button. A grey outline of a 3D regular block appears in the 3D view. Notice that a new object type appears in the Solution Explorer.
6. Try to modify the extent of this block by holding the Ctrl button and dragging the sides of the block with the left mouse button.
7. In step 2. select the “Calculate from model data” and press the “Calculate” button.

8. In step 3 set the location to 626575 (E) and 265850 (N), the size to 50x50 m and press update in step 5.
9. Modify the Tvss value to -300 and the Length to 300 in step 4.

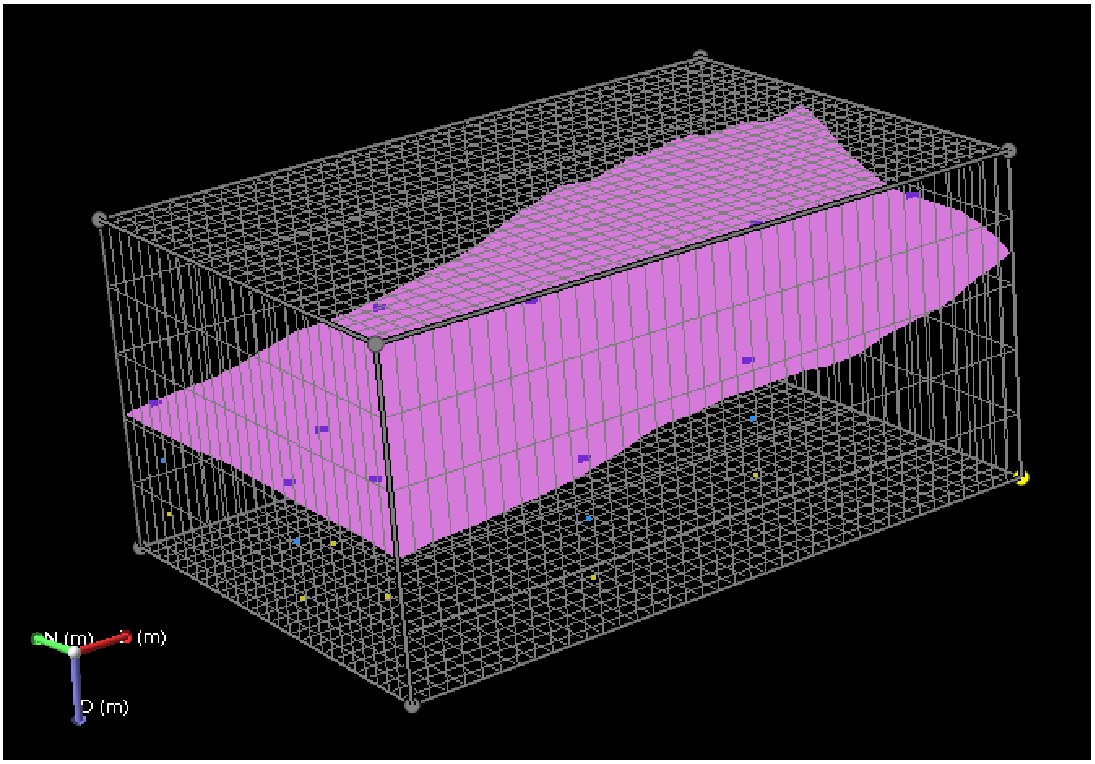


Figure 10 setting the modeling area (represented with a white “cage”)

Set the scale in depth value to 3 in the General View Toolbar to see this display.

Model Layer definition

The modelling process is partly based on an idealized vertical sequence of entities (surfaces, point- and polyline sets, etc.). This sequence must be true in all parts of the model. However, it is possible that one or more elements are not present at every position (i.e. certain layers are missing in one area of the model, while they are present at other locations). This is usually called the “**layer cake**” modelling method, and it can produce surface entities which are not folded under themselves.

10. In the **3D Gridding** workflow process select the Model Layer Definition panel.
11. In step 1 (Show the model layer definition) press the Show button. A new main window appears. This window shows the idealized sequence of the model layers from bottom to top.

12. In this window left click on the grey rectangle (Reservoir) and select the “Set internal layers” submenu. In the popup dialogue type 8, and press OK.
13. In step 5 rename the main object from Reservoir to Oligocene Sandstone, and set the Thickness value to 400.
14. Set the Top surface with selecting the wells_TOC_topography 2D grid object from the dropdown list. Since no other surface is created at this point, the base surface cannot be defined. Set the Conform type to “proportional” and the Conform direction to “Top”.
15. Press the home icon (or the “close workflow panel” link).

3D gridding

In this exercise a **voxel model** is created using the bounding parameters of the previous steps.

16. In the **3D Gridding** workflow process select the Jewel Gridding panel.
17. In step 1 create a new 3D grid object with the name: TotalGrid. In step 3 select the existing TotalArea as the active Area (if not selected).
18. In step 5 check only the “insert stratigraphic surfaces”, and press Execute.
19. Switch back to the 3D view and observe the result.

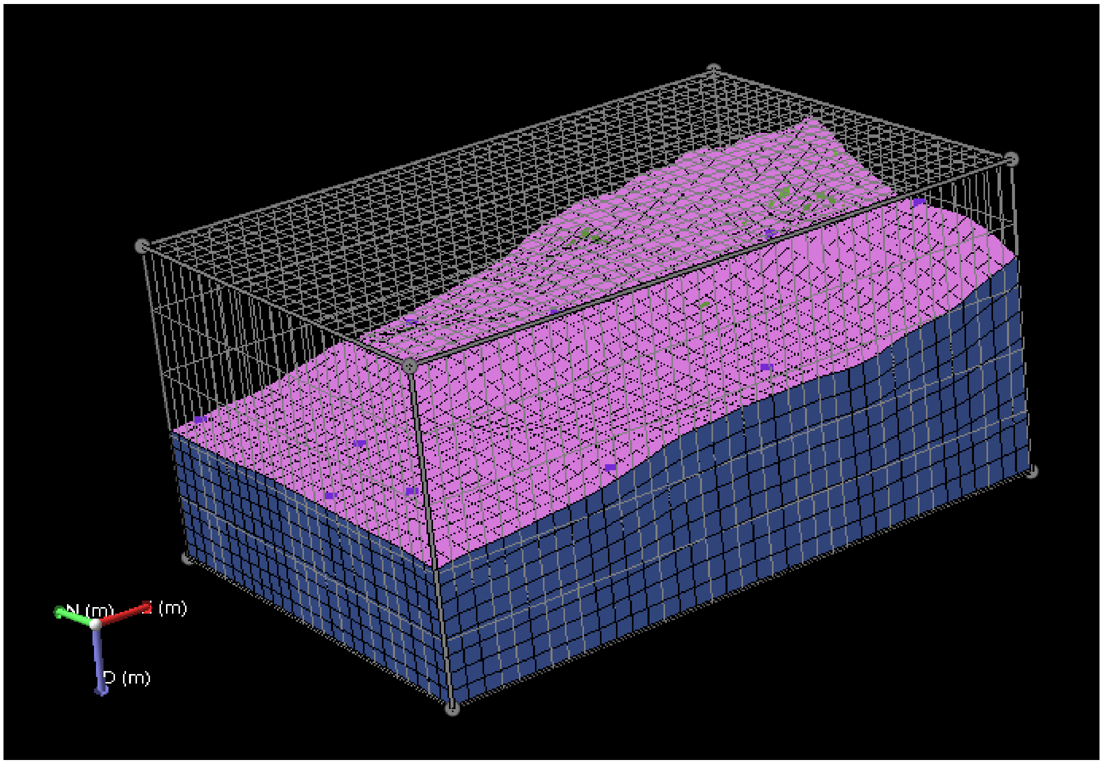


Figure 11 The Jewel model of an eight-layered rock body – further modification of the geometry is possible with modifying the type and direction of stratigraphic conformity in the "3D Gridding" panel.

In the Solution Explorer a new object appears which the voxel model is. The created model is bounded by the modelling area and the topographic surface. It contains 8 sublayers which follow smoothly both the top and the bottom bounds. It is because in step 14 of this exercise the Conform type and directions were defined to behave like this.

20. Open the Model Layer Definition panel again and change the Conform type to "Conform" and the Conform direction to "Bottom". Close this workflow panel and open the Jewel Gridding panel. In step 5 press "Execute". Say "Yes" to the popup questions.

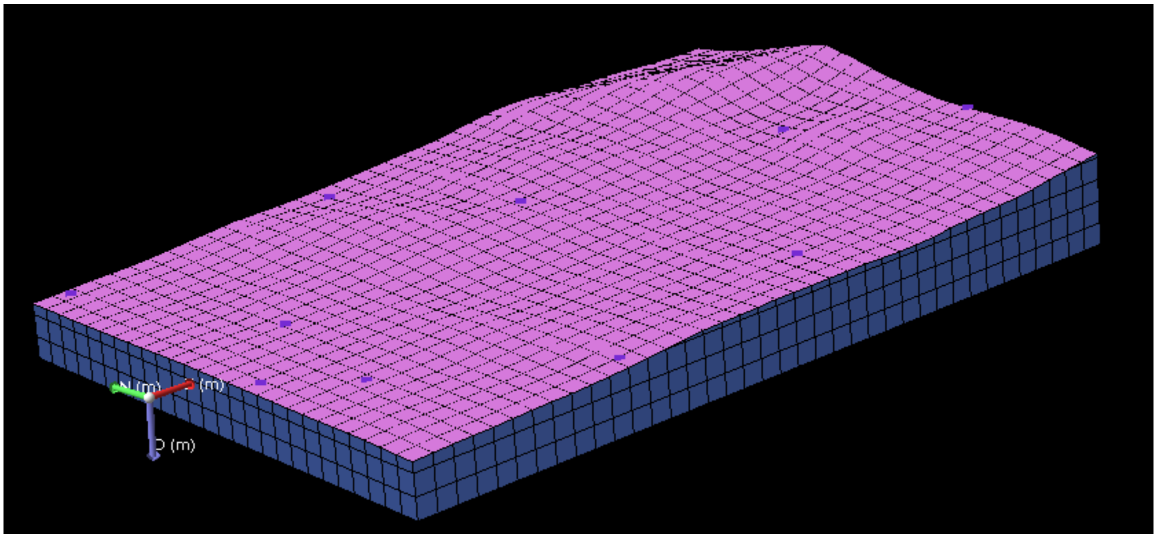


Figure 12 A 3D model having uniformed 3d cells (voxels=volume pixels).

This new pattern represents a voxel grid with the resolution of 50x50x50 m (see step 12 and 13 of this exercise: 400 m divided by 8), but the topmost voxels are cut by the topography. Set the scale in depth value to 1 in the General View Toolbar to see this display.

Extracting property data from the point clouds

The property modelling is the final step of an implicit modelling method. Using the original data, new secondary data is created on those spatial positions, where originally no information was available.

21. In the 3D view or in the Property Explorer select the TotalGrid object. Open the "Property Calculator" sub application (click on the "open calculator" icon in the "window toolbar").
22. In the Functions panel (left part of the window) explore the "Property extraction" and select the function: PropertyExtraction… with double clicks.
23. A new window appears where we can define the type of the object from which we want to extract the properties. Select the "Point sets" from the dropdown list, and check all the listed point sets.
24. Select the "TOC" property from the dropdown list below the list of point sets.
25. Explore the available interpolation methods in the dropdown list. For now select the inverse distance weighted method and check the without projection radio button.

26. Press OK. A query expression appears.
27. In the right side of the window change the Property name to TOC (if not listed type it in), and press “Create Property” in the lower right corner. Close the Property Calculator.
28. Observe the result in the 3D view.

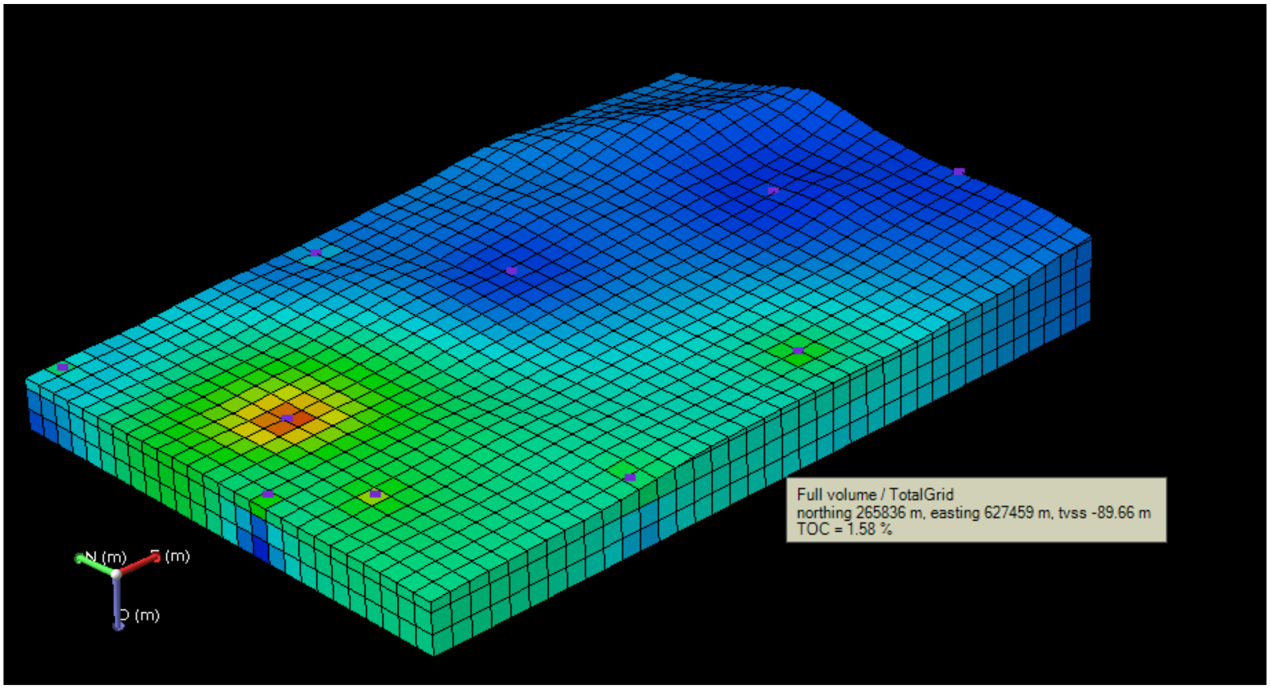


Figure 13 Interpolated TOC values are generated for each cells (voxels) in the 3D grid. The 3D interpolation method used the original measurement data from the imported point cloud.

Try other interpolation methods (e.g. nearest neighbour and kriging) in the Property Calculator.

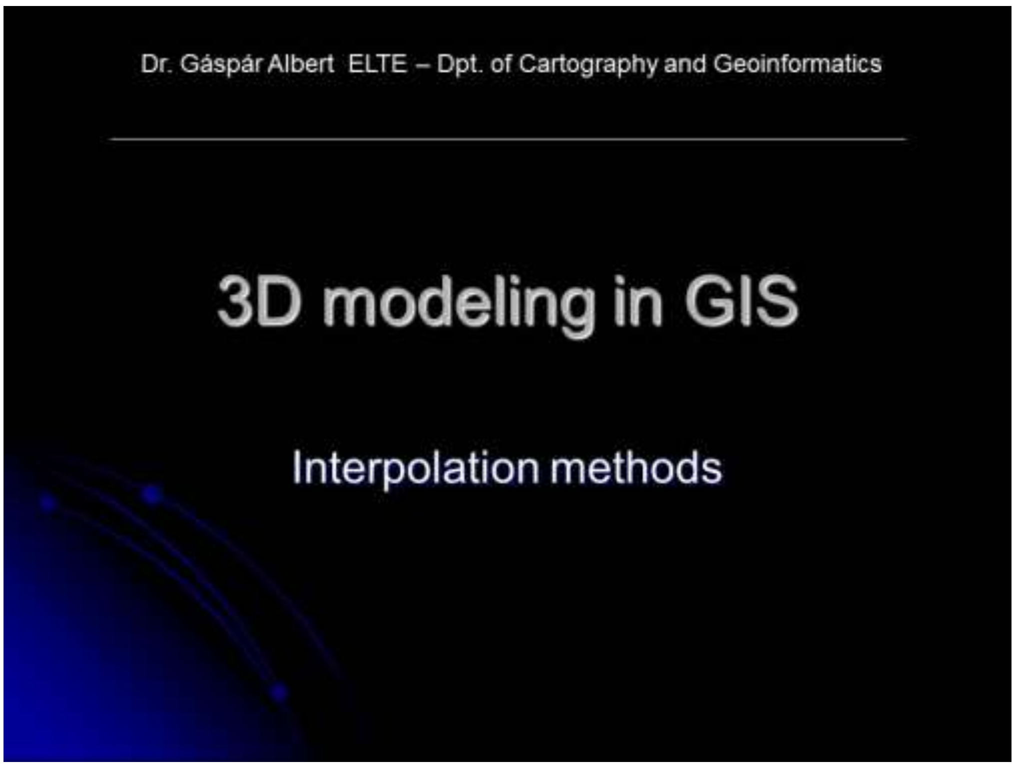
Lesson 9.

The topics of this class are the followings:

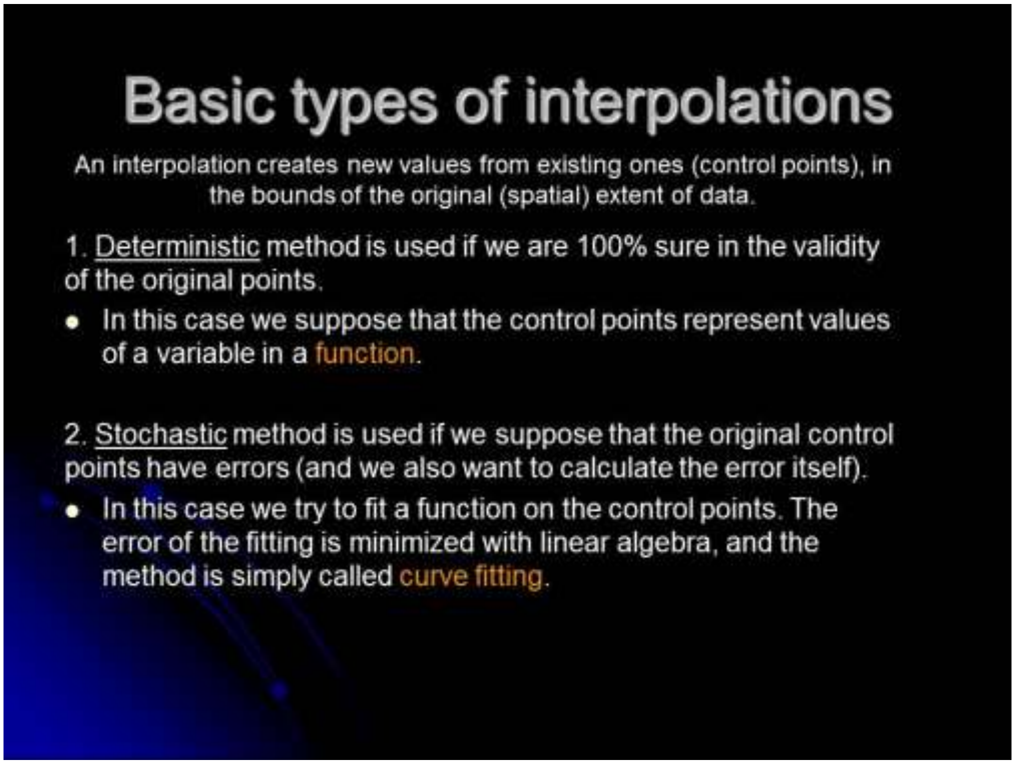
- Calculation methods of grid-point values (interpolation and spatial statistics).

Practice: Converting TIN-s into grids and vice-versa. Draping and rectifying image files into the model. Extracting data from a 3D model. Working with extracted data

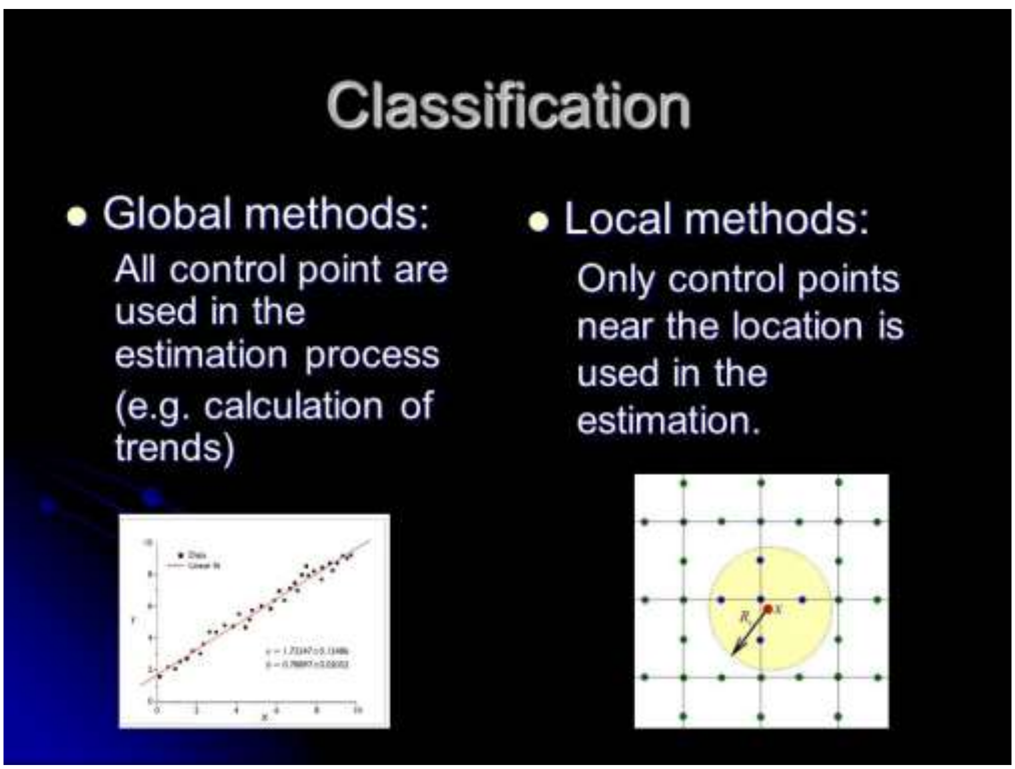
Interpolation methods



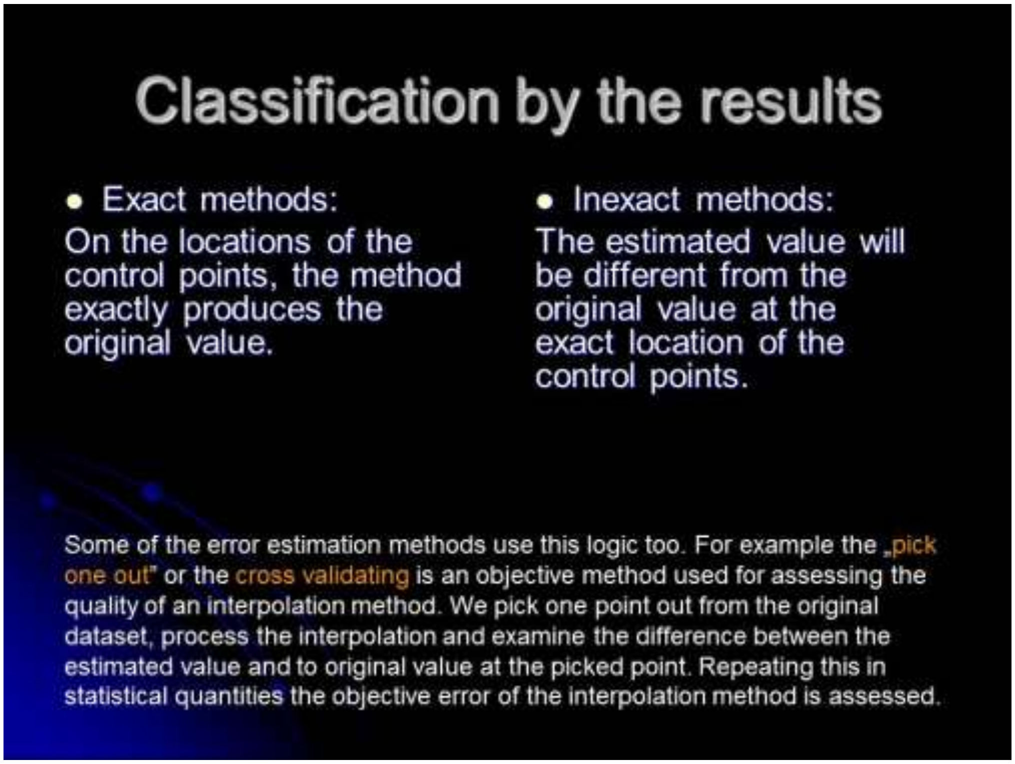
Slide 101 Welcome slide of the 9th theoretical class – interpolation methods.



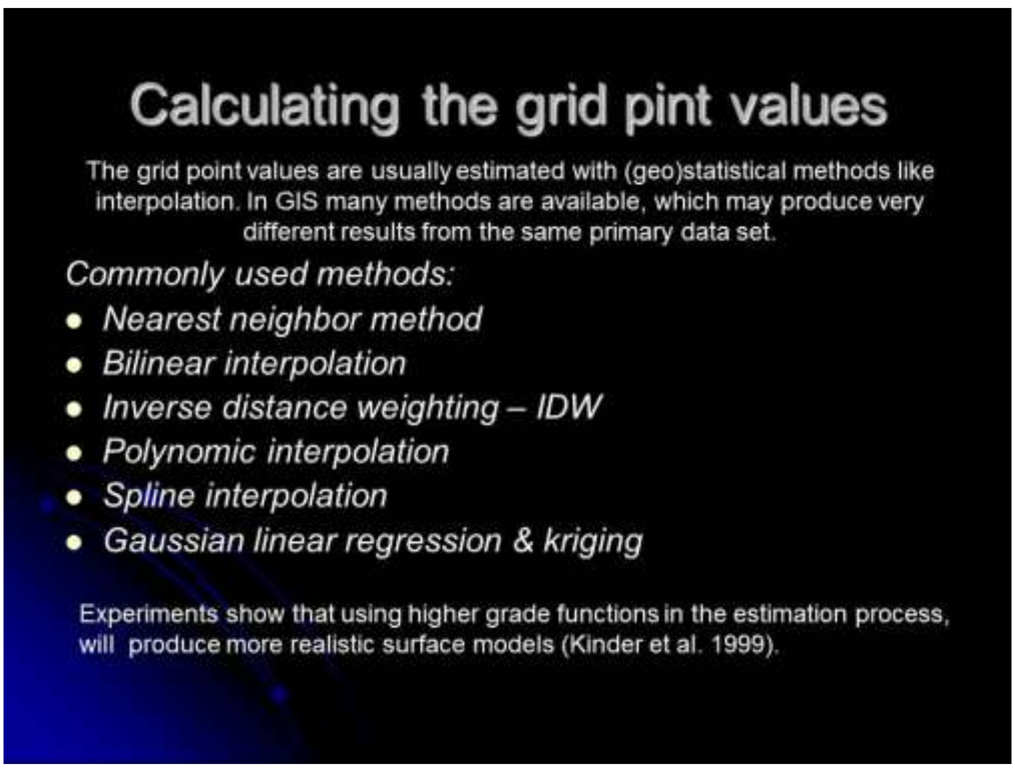
Slide 102 Types of interpolation– deterministic and stochastic methods.



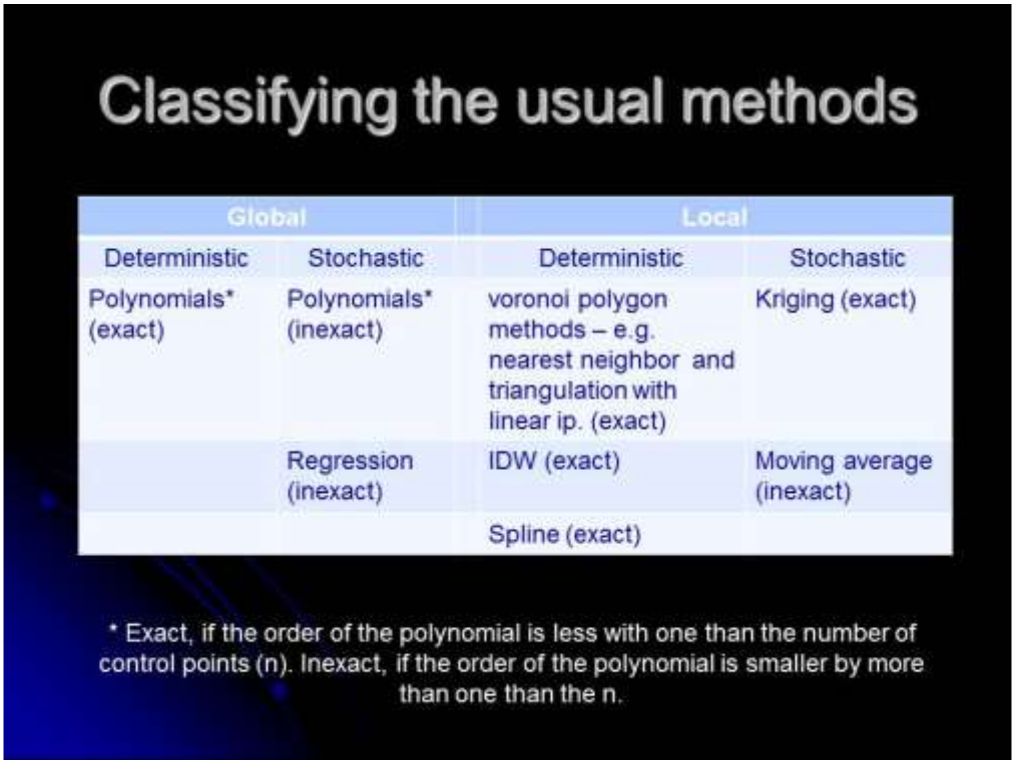
Slide 103 Classifying interpolations – global and local methods.



Slide 104 Classifying interpolations by the return values (results) – exact methods and inexact methods.



Slide 105 Commonly used calculation methods.

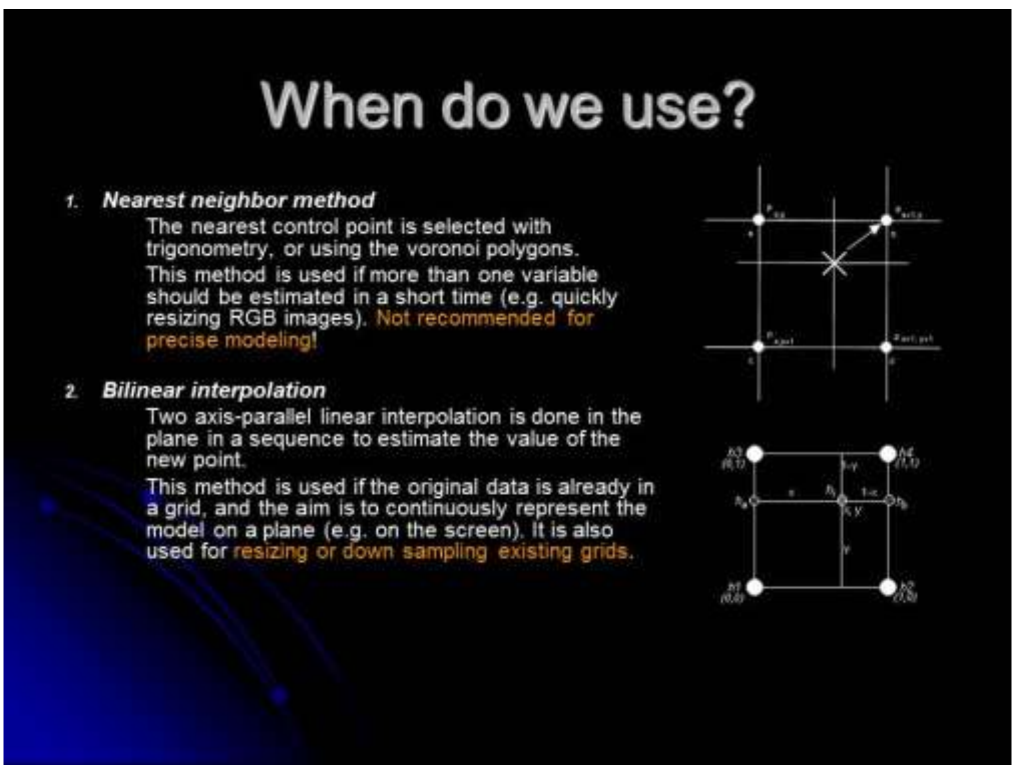


Classifying the usual methods

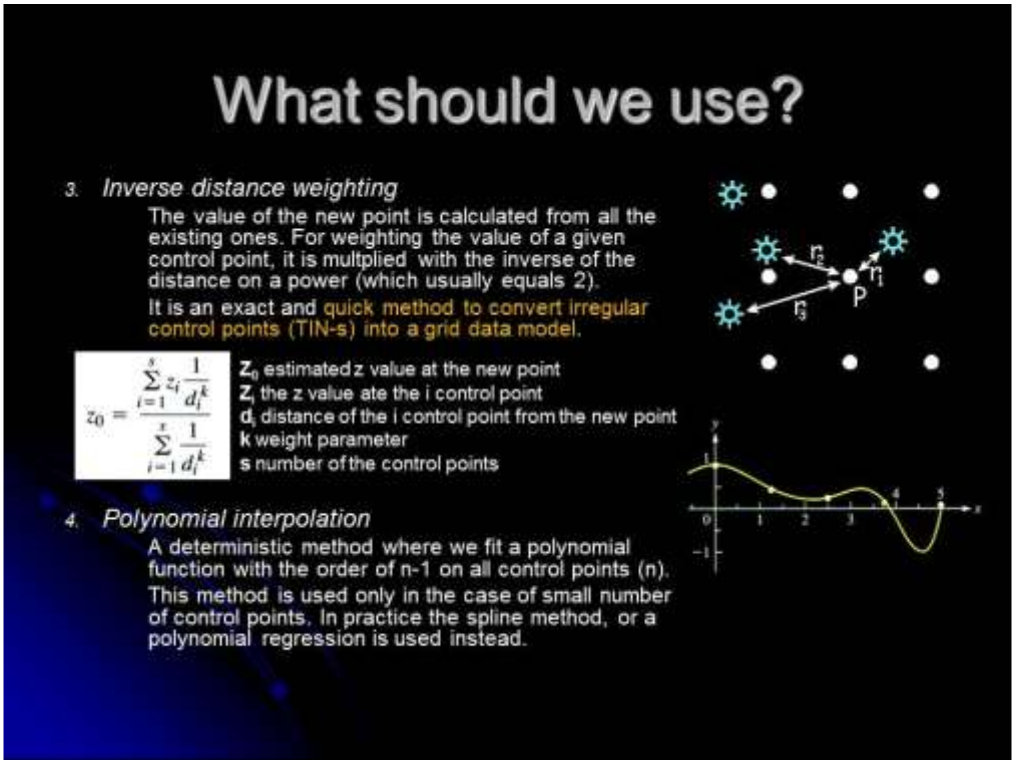
Global		Local	
Deterministic	Stochastic	Deterministic	Stochastic
Polynomials* (exact)	Polynomials* (inexact)	voronoi polygon methods – e.g. nearest neighbor and triangulation with linear ip. (exact)	Kriging (exact)
	Regression (inexact)	IDW (exact)	Moving average (inexact)
		Spline (exact)	

* Exact, if the order of the polynomial is less with one than the number of control points (n). Inexact, if the order of the polynomial is smaller by more than one than the n.

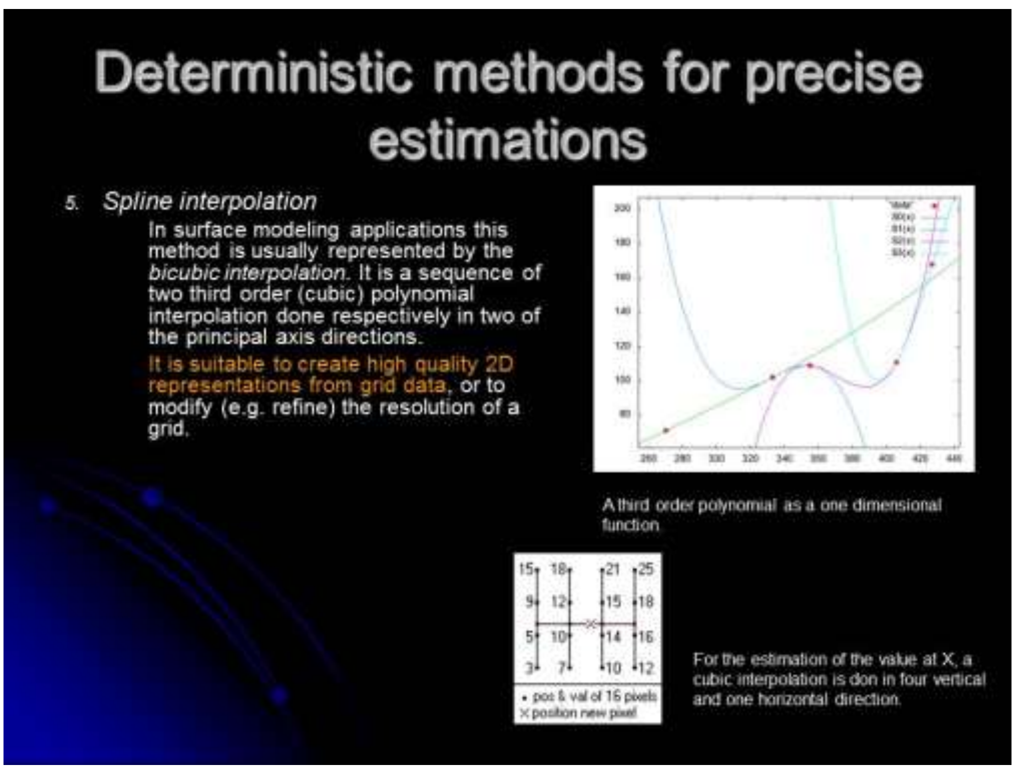
Slide 106 Classification of the commonly used interpolation methods.



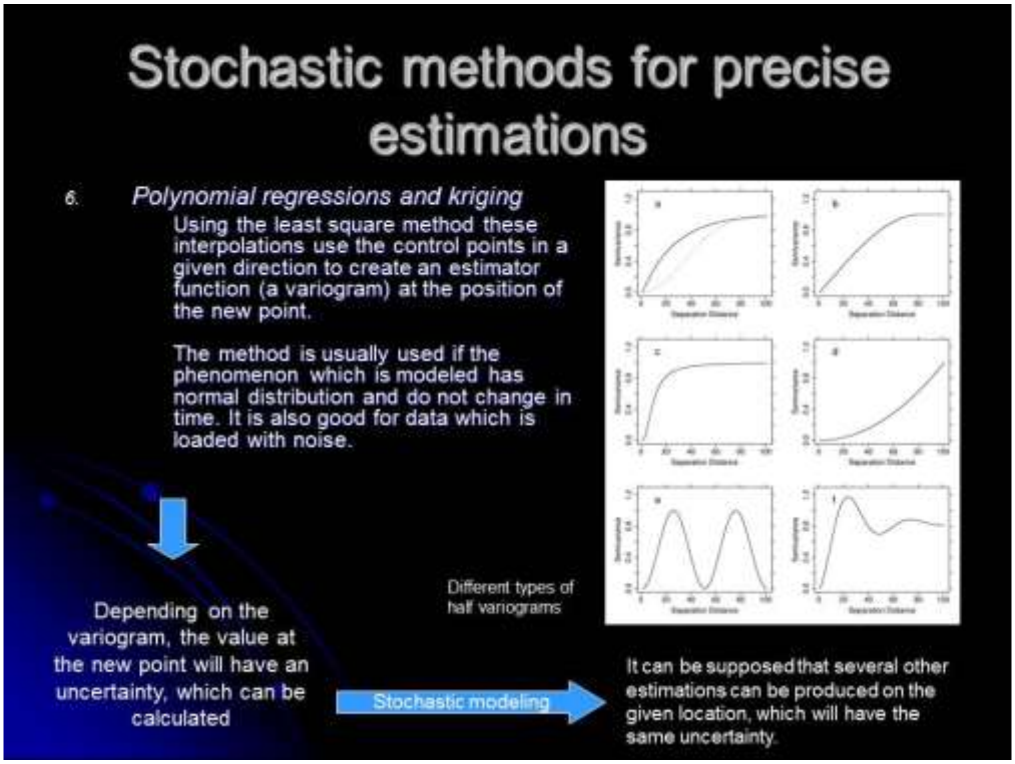
Slide 107 The use of the nearest neighbor and bilinear methods.



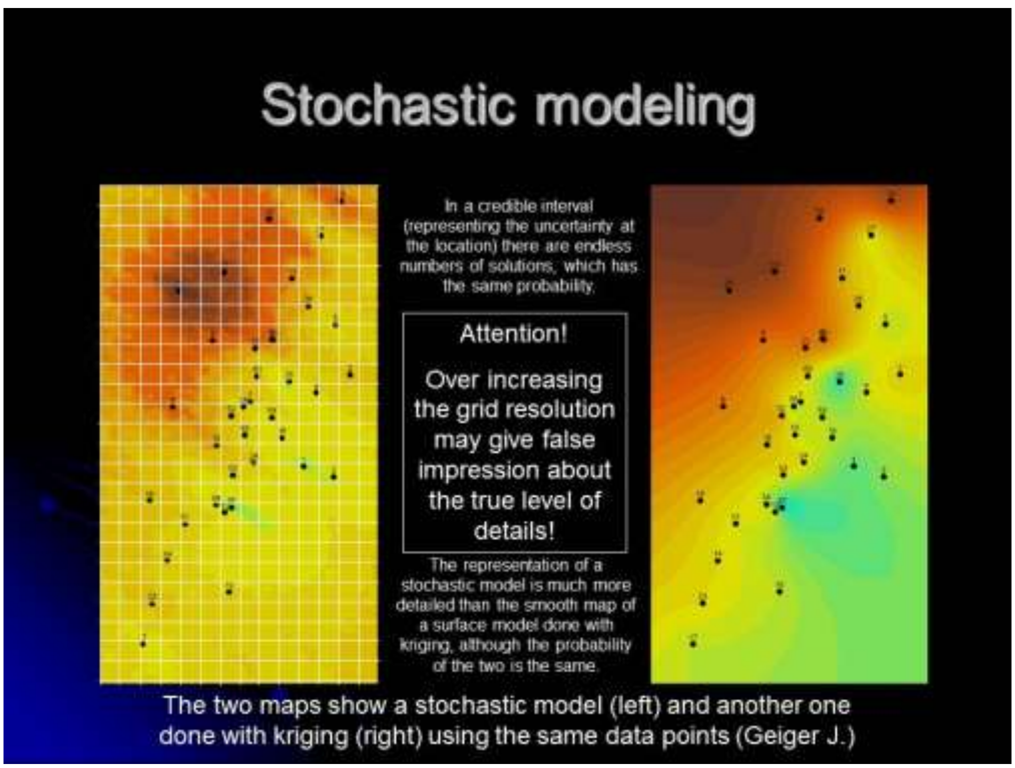
Slide 108 The use of the inverse distance (IDW) and the polynomial methods.



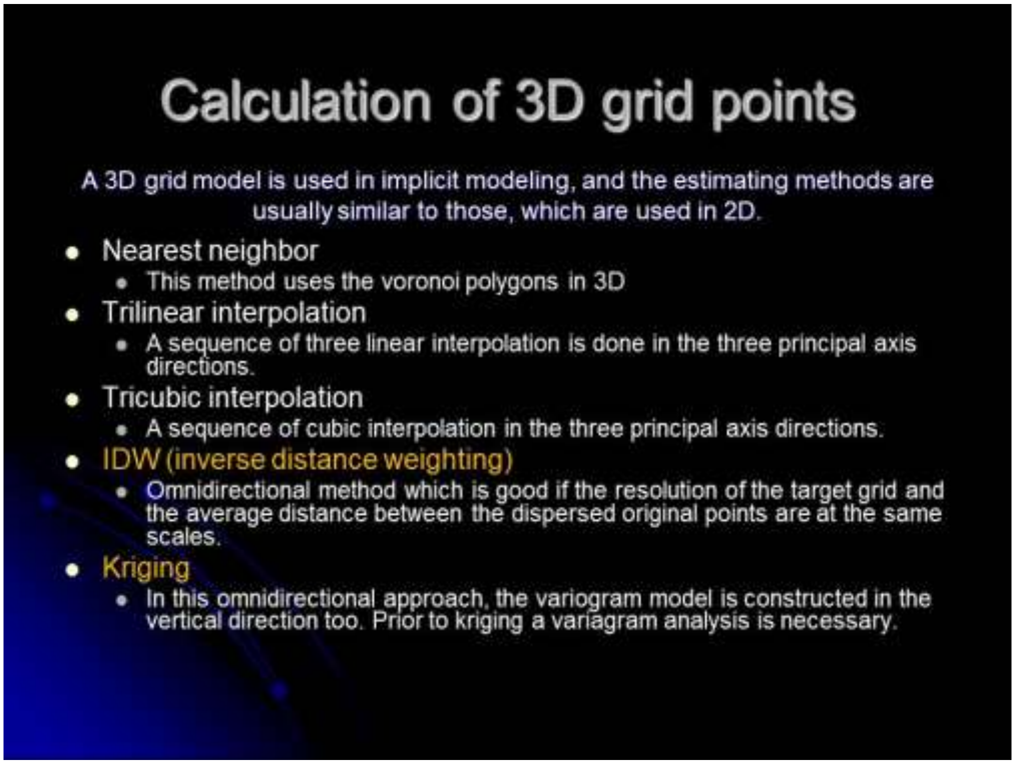
Slide 109 Deterministic method for precise estimations – the spline interpolation.



Slide 110 Stochastic methods for precise estimations – polynomial regression and kriging.



Slide 111 Stochastic modeling.



Slide 112 Calculation methods in 3D grids.

References for the slides

Kidner, D., Dorey, M., Smith, D. 1999: What's the point? Interpolation and extrapolation with a regular grid DEM. – IV International Conference on GeoComputation, Fredericksburg, VA, USA – http://www.geovista.psu.edu/sites/geocomp99/Gc99/082/gc_082.htm

KN Zelenika, T Malvić 2011: Stochastic simulations of dependent geological variables in sandstone reservoirs of Neogene age: A case study of the Kloštar Field, Sava Depression – Geologia Croatica 64/2, Zagreb, Croatia, pp. 173-783.

Use of Jewel Suite (part 5. - Extracting data from the 3D model)

In this class a secondary data from a 3D voxel grid model will be extracted in different formats.

Window – New window – Start Page: select the New Solution icon. This will start an empty project with the default settings. An empty 3D View panel (in the middle of the screen) show up.

Import point set surface and 3D grid data:

1. In the Workflow Guide go to the **Data Import** process, and then select the 3D Grid Data panel and import the *TotalGrid.joasgridset* file as a 3D grid data.

Extracting data from the grid

Property

- Extract property values from the whole grid as point set, then export the point set to an xyz file.
- Extract property values from a horizontal (K) segment of the grid as point set, then export the point set to an asci point set (txt) file.
- Extract property values from a vertical (I or J) segment of the grid as point set, then export the point set to an asci point set (txt) file.
- Create a point set with one point at one given coordinate and use the property calculator
- Create a well at an x, y coordinate and create a log
- Create a well (X1) at the position:

EASTING [m]	NORTHING [m]	TVSS [m]	MD [m]	INCLINATION [deg]	AZIMUTH [deg]
627002	266311	-144.0	300	0	0

- With the calculator, extract the TOC and the vertical thickness property from the TotalGrid into the well X1.
- Export the logs of the X1 into an AscII file.

Geometry

- Modify the model (or a copy of the model) to be conform from the top and create a horizon tri-mesh at the K=3 level. Create a 2D grid from this and export it as a surfer grid.

View

- Copy the view content to window
- Save the view content to a file.

Working with extracted data

- Filter the extracted point cloud data (TotalGrid_Full volume.txt) with excel and keep only those points, which have TOC values between 1.4% and 1.5%. Save this as a new txt, and import it back into Jewel (using the "user defined formatting…" method). During the import process define the geological type of the point set as "Horizon".

- In the **Model Definition** process, add the new point set to the model in the "Model Data Selection" panel.
- In the **Structural Framework Modeling** select the Triangulation and create a Tri-mesh from an aspect, different from the top view (see step 4 in the workflow manager).
- Open the extracted property values from a horizontal (K) segment of the grid as an Excel sheet and modify the sequence of the rows E, N, TOC be the first 3.
- Open the text table with Global Mapper as an elevation data file
- Extract the result as a kmz and open it with Google Earth.

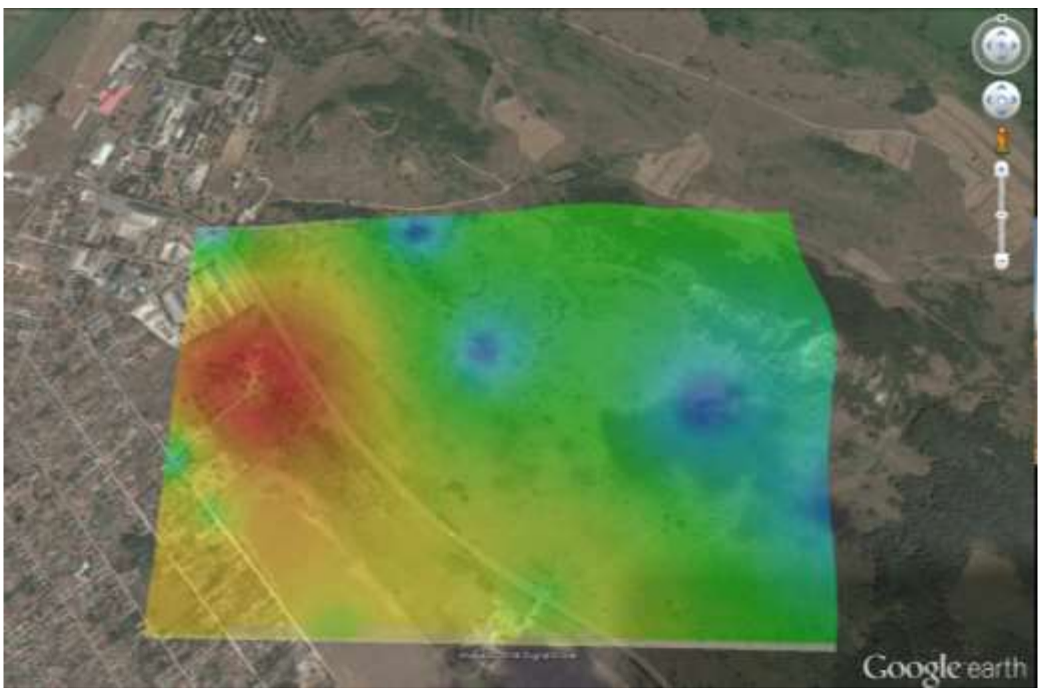


Figure 14 The extracted horizontal level of the Jewel grid can be displayed in Google Earth after some preparation in a GIS software (e.g. Global Mapper)

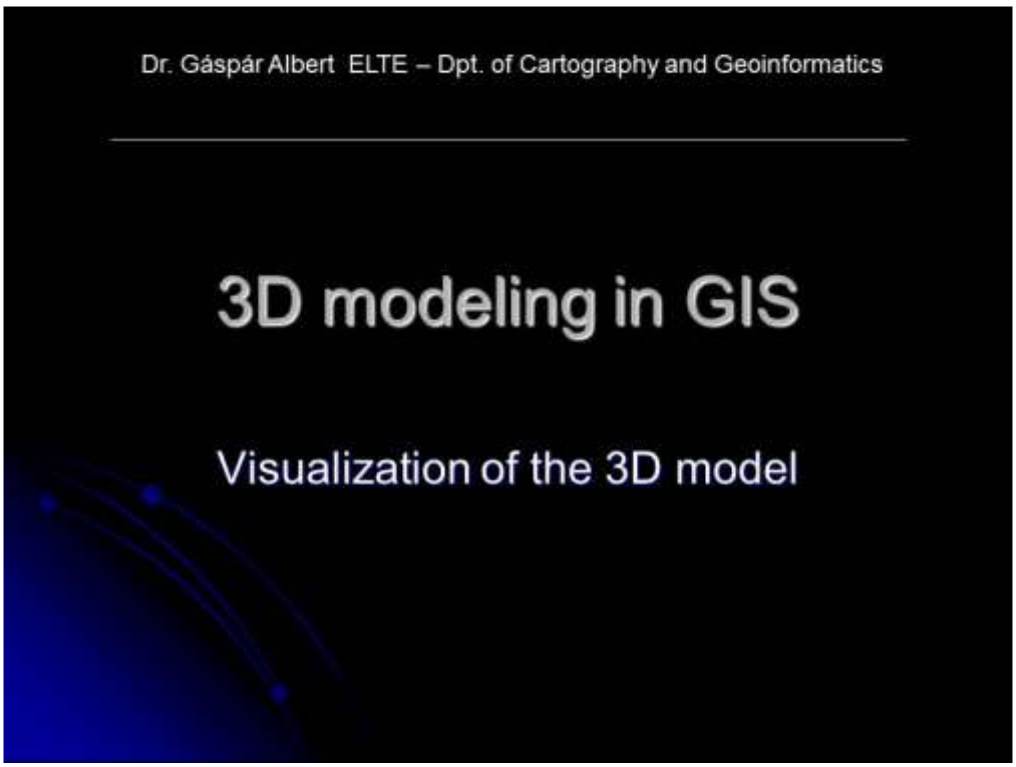
Lesson 10.

The topics of this class are the followings:

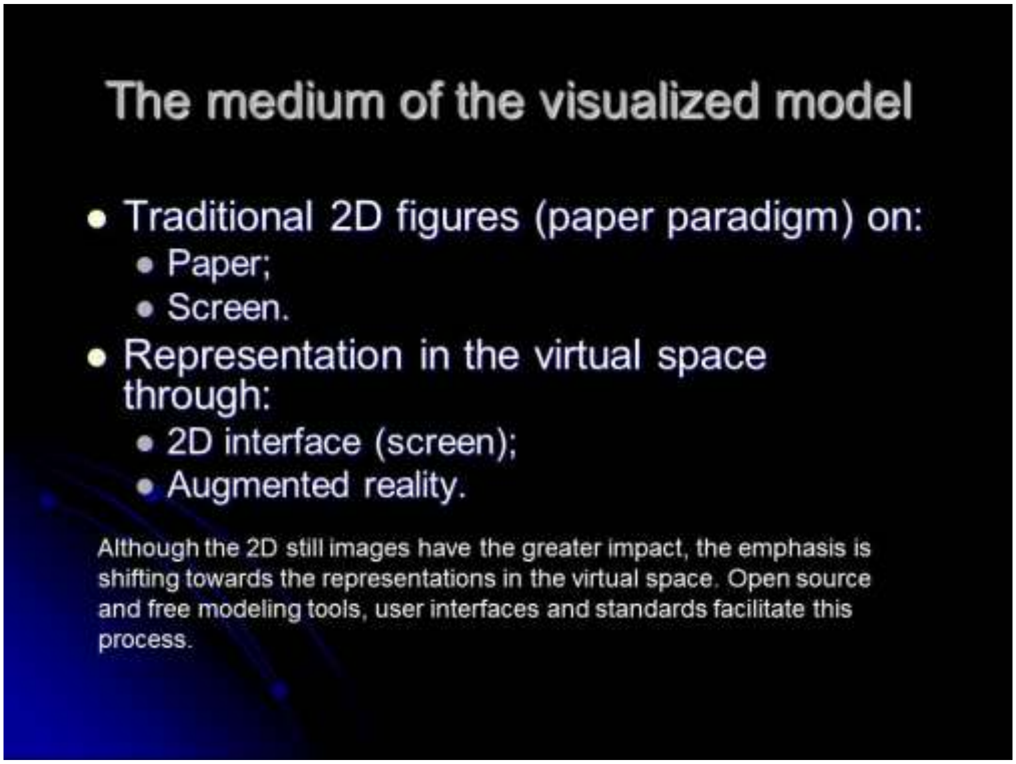
- The media of the 3D visualization (paper/screen).
- Visual requirements of the model in 2D, 2.5D and 3D (perspective/orthogonal/vertical exaggeration).
- The conceptual 3D model.
- Models in the virtual space (when do we really see models?).
- Viewers and query tools.

Practice: Modeling without a 3D modeling software. The modeling log and the modeling report.

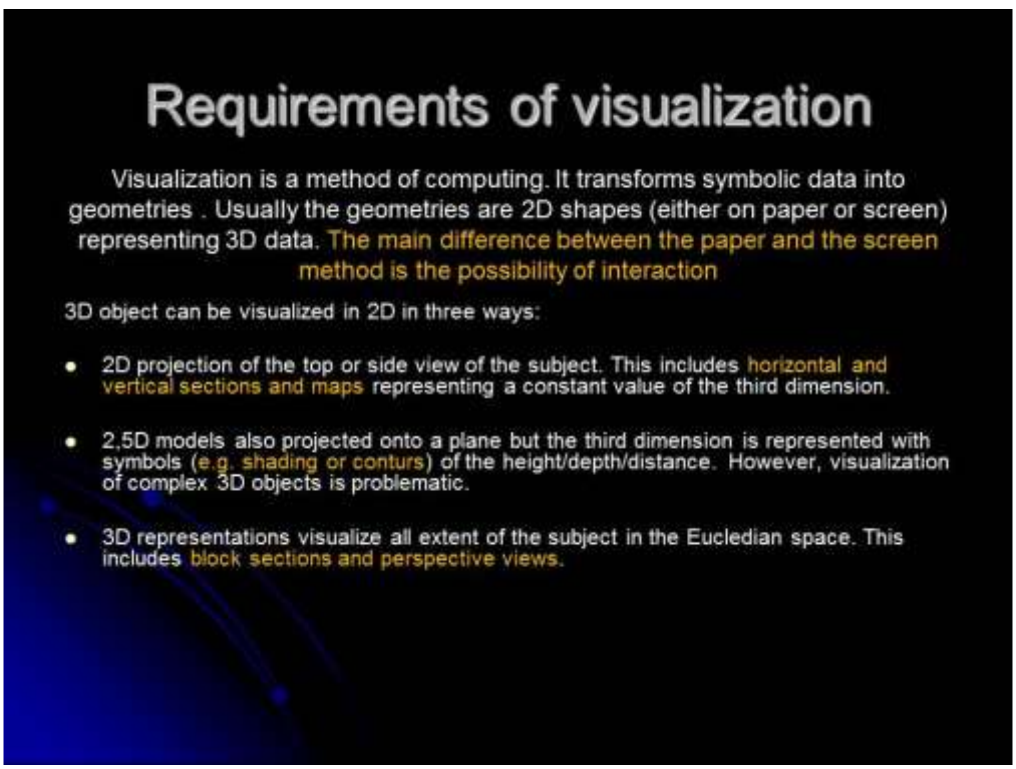
Visualization of the 3D model



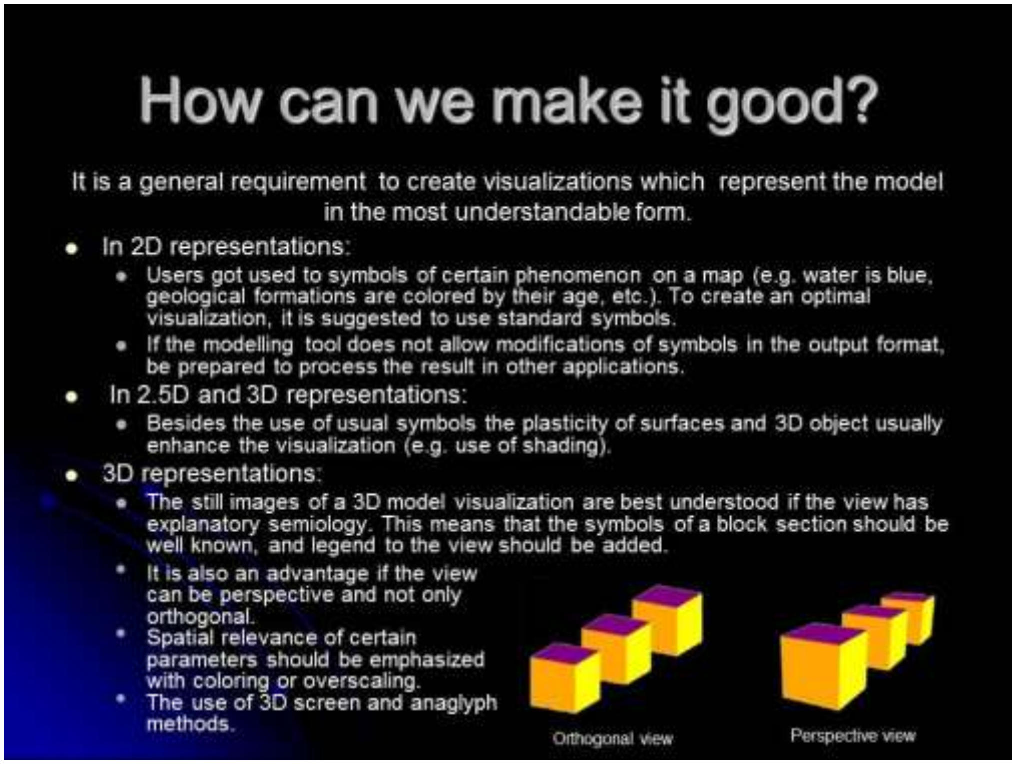
Slide 113 Welcome slide of the 10th theoretical class – Visualization.



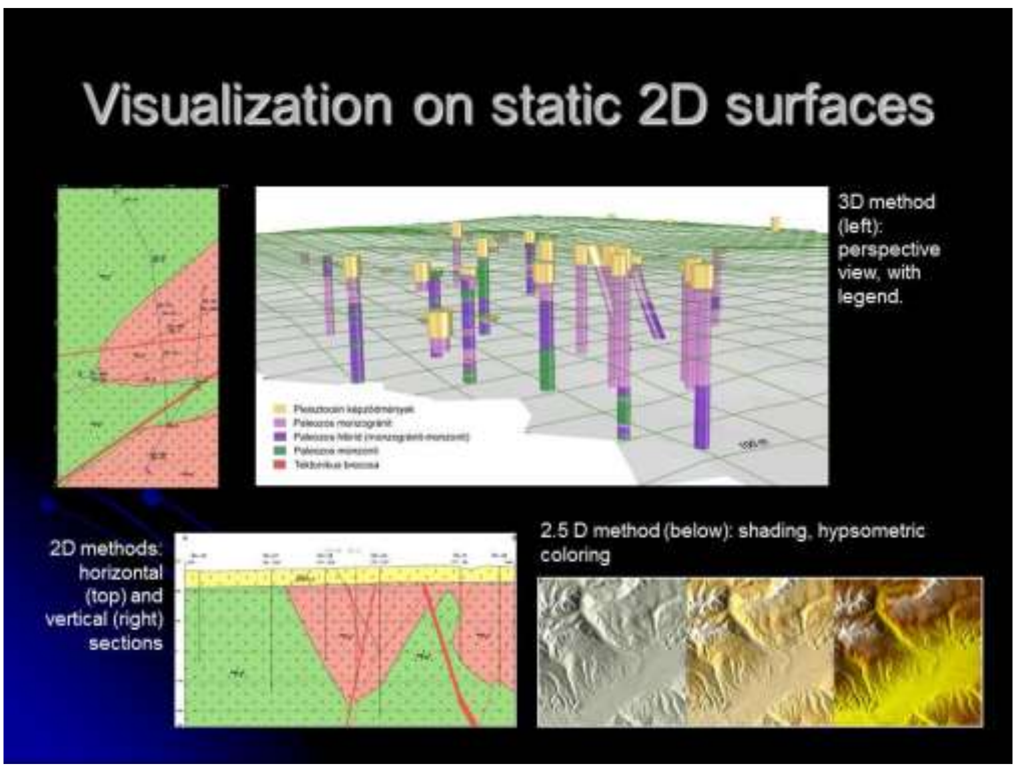
Slide 114 The medium of the visualized model: paper, screen, virtual reality.



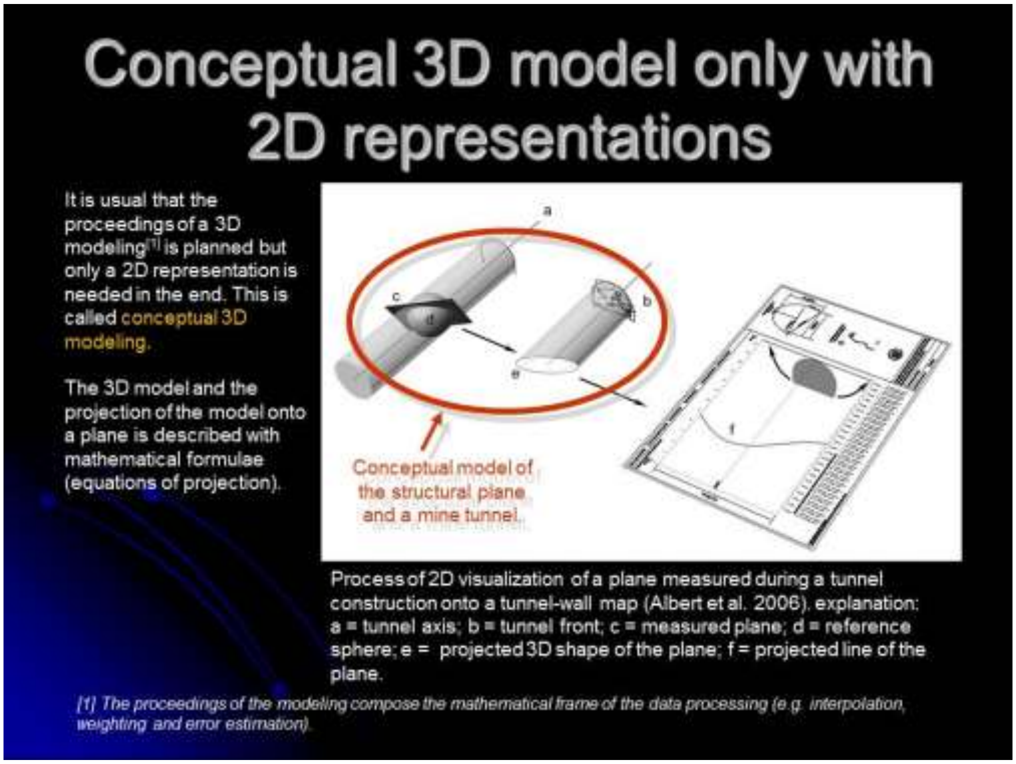
Slide 115 Requirements of visualization.



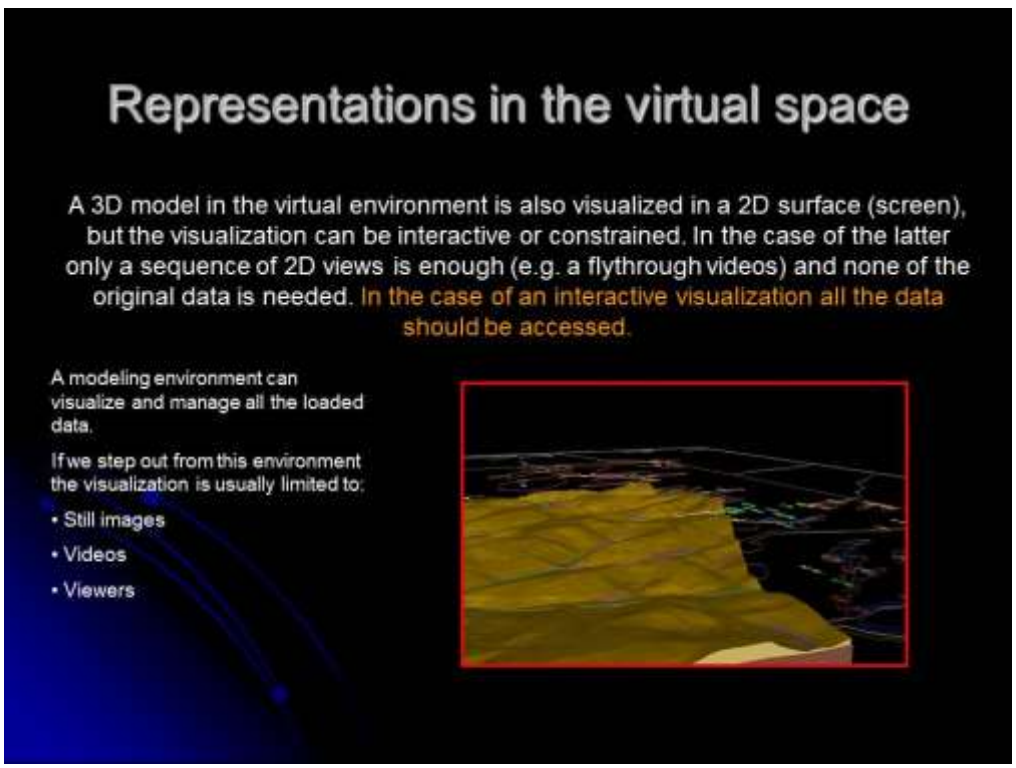
Slide 116 How can we make good visualizations? General requirements of 2D, 2.5D and 3D representations.



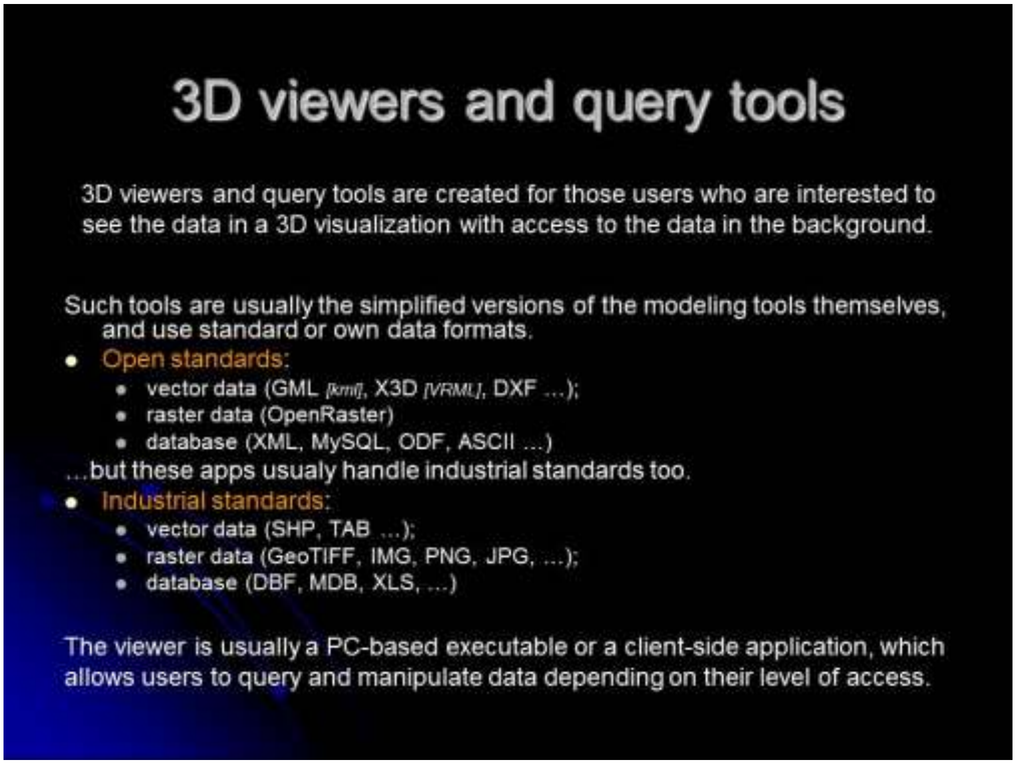
Slide 117 Visualization on static surface (still images on paper or screen).



Slide 118 The conceptual 3D model.



Slide 119 Model representations in virtual space – a viewer or a video?



Slide 120 3D Viewers and query tools.

References for the slides

Albert G., Orosz L., Gyalog L. 2006: Cartographic representation of geological information, observed on tunnel walls and fronts – *Proceedings of the 5th European Congress on Regional Geoscientific Carthography and Information Systems (Earth and Water), Barcelona, Spain 13–16/06/2006,* Vol. II. pp. 89–91.

Müller, H., Curtis, E. 2005: Extending 2D interoperability frameworks to 3D – Snowflake Software Ltd., http://www.snowflakesoftware.co.uk/news/papers/3DFrameworkPaper.pdf

Vries, M. de, Zlatanova S. 2004: Interoperability on the web: The case of 3D data. – Delft University of Technology, http://www.gdmc.nl/zlatanova/thesis/html/refer/ps/Mv_sz_esociety.pdf

McCormick, B.H., DeFanti, T.A., Brown, M.D. 1987: Visualization in Scientific Computing – a synopsis. 1987. IEEE Computer Graphics 21, 6. ACM SIGGraph, New York

Modeling without 3D modeling software

In this class a 3D modelling is demonstrated by creating a series of horizontal 2D models and cutting them with a section line, where the data is extracted. This extracted data subsequently is used to create a vertical 2D model. The compilation of 2D distribution maps (surface, horizontal, and vertical) with Surfer can produce the same result what we can calculate in a 3D modelling environment.

Interpolating horizontal sections.

1. The "*Peldaadatok2.xls*" Excel sheet contains fictional Fe-ion concentration of 10 observation wells in several a.s.l. levels (surface, +200, +100, sea level, -100, -200 m). Use the interpolation methods (see class 03 and 04) in Surfer to compile a distribution map for each level.

Grid-> Data menu (importing data from the excel sheet); set the resolution of the grid; select the interpolation method; define the output file.

Creating cross sections from the horizontal maps either with Surfer or Global Mapper

Stay in Surfer.	Import the created output grid-files in Global Mapper (GM). Be aware of the coordinate settings!
Create a post map for each level stack using the "*Peldaadatok2.xls*" sheet.	Import the well locations with point name into GM. The well coordinates are in the "*Peldaadatok2.xls*" Excel sheet. Convert the data into the right syntax if necessary (i.e. simple text file)
Use the Map – Digitize tool to digitize two points P4 and P3 and save it as *sectionP4-P3.bln*. For correct coordinate data use the *Peldaadatok2.xls* file.	Draw a line feature (name it as *section-P4-P3*) across a wells P4-P3 in GM which will represent the line of a cross-section.
Create a cross section for each level along the *section-P4-P3* line (using the *sectionP4-P3.bln)* with the "*Grid-Slice*" tool in Surfer.	Create a cross section for each level along the *section- P4-P3* line using the "*Path Profile/Line Of Sight*" tool in GM.

Two types of file are created in each step: a bln file and a dat file. Name the files descriptively (e.g. *section_VAL_100_Krig1_P4-P3.dat)*!	In the Options menu of the PP/LOS window select the "Set Sample Count/Spacing Distance" and set the value to fixed 100 m.
Since the level maps are concentration maps, the dat files contain concentration data at a given elevation (e.g. 100 m a.s.l.).	For each level, create a data export (*File->Save Distance/Elevation file*) from the cross section to get the interpolated distribution values along the *section-1* line.
	Name the export file clearly (like: section-P4-P3_level0.xy). The created xy-files are simple texts and contain two columns of data: The first column of the xy-files is the distance along the section line, and the second column is the interpolated concentration value on the level.
	On the surface level, the elevation values can be captured from the SRTM using the same method.

Assigning elevation value to the linear sections

1. Open the section (dat or the xy) files in Excel and assign the proper elevation value in an additional column in each of them. The elevation value should be given according to the level of the grid, of which the section-file was created. For example: if we created a section file from the level 100, the elevation in the third column should be 100. Save each file with a new name (i.e. section-P4-P3_level-100_elev100.txt).

2. Create a mash up table (*section-P4-P3_mashup.xls*) from the created files. It can be done in Excel by opening each of them, and with selecting the whole content copying them below each-other in the first three columns.

3. Compile an interpolated distribution map in the vertical plane of the cross section in Surfer from the *section- P4-P3_mashup.xls*. Be aware of the order of the columns during data import!

Deliverables at the end of the semester

Starting from class 11, students should work on their own task. The final marks for each student will be calculated from their work progress, the result (the model file) and the quality of documentation (report file). All these three aspects worth one mark [1-5]. The average of these three will be the final mark of the student.

The progress of the work is continuously monitored, while the model files and the report should be delivered at the end of the semester.

General comments

The report is a scientific text. Write simple sentences, and take care of the exact formulation and the use of technical terms. The report aims to present the results of the modeling in the most meaningful way, so it is recommended to compose data in tables and separate the equations from the paragraph text. It is also recommended to illustrate the report with snapshots of the work. The images and tables must always have captions and cross-references in the text!

Report Template

Author

Date

Participants and their tasks

[optional] List of the participants and their responsibilities in the project (in the exam report for the 3D modelling in GIS subject, this chapter can be omitted).

Introduction

Write about the general summary of the circumstances and the aim of the project. Introduce the prerequisites and prior projects. [max. 200 words]

Base data

Make a list of the base data of the project. Include the type, source, name and owner (if applicable).

Methods

Describe the applied methods clearly. Use the exact terminus for specific methods and details (like primary and secondary data instead of data, interpolating a surface instead of making a surface, etc.). [max. 400 words]

Results and discussion

Write about the results of the project, and refer to the aims (you achieved/ failed to ansver the proposed questions). Discuss the results (write about the error of your methods). [approximately 200 words]

References

[optional] list of papers which were cited in the introduction.

Recommended readings

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