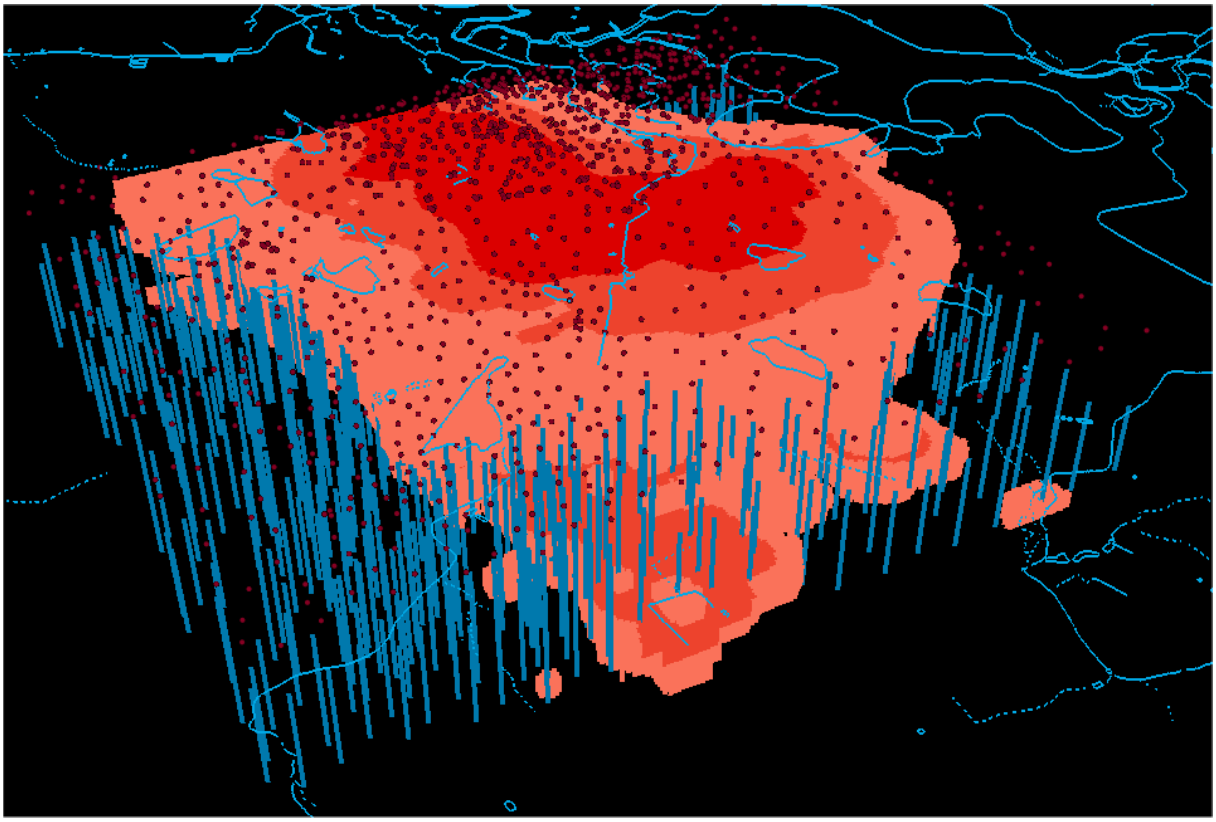
3D interpolation and visualization with ArcView 9.x



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1 Abstract

This manual describes a stepwise application of techniques implemented in ArcView 9.x for a 3D interpolation of irregularly spaced 3D data. The interpolation techniques are optimized for geological purposes but have to be evaluated for each case study. In the example dataset the results of a modelling approach were taken so that the density of information is quite high. The ArcView 9.x components involved in this approach include ArcMap, ArcCatalog, ArcToolbox and the extensions 3D Analyst and Spatial Analyst. For the 3D interpolation several VBA scripts and ArcView "models" were written that have to be included and carried out for the exercises.

2 Introduction

Since nearly 10 years the Department of Hydrogeology and Environmental Geology is active in the field of application of geological modelling systems for several investigation areas. Many projects are documented on the homepage http://umweltgeologie.geologie.uni-halle.de and http://www.3d-geology.de. The dataset for the tutorial is derived from one of these projects in the Bitterfeld area which has been documented in several publications. The data are an export of a model run concerning the distribution of an ideal tracer for a certain time step, so it's a mixture of fictive and real data.

3D interpolation methods are described and implemented e.g. in the GSLIB (Deutsch & Journel 1998), in SADA (University of Tennessee Research Corporation 2009) and FIELDS (US EPA 2009) and in EVS/MVS (CTECH 2009). In this case the interpolation results are mostly poor due to a lack of data. The dataset for the tutorial of the course solves this problem by interpolating a subset of a model result so here the database is sufficient to use also these tools.

GIS are typically 2D oriented tools which have been enhanced in 2.5D and 3D capabilities in the last years. Most of the new tools are visualization tools but especially the 2.5D interpolation has made profit from recent developments.

In ArcView 9.x the extensions Spatial Analyst and Geostatistical Analyst provide a set of interpolation functions and the 3D Analyst is used for visualization.

For the 3D interpolation as implemented here, a special technique has been developed. The problem of sparse data is on the one hand overcome by using a suitable database. On the other hand the interpolation technique itself can help a bit in the Z direction.

The irregularly spaced data are first interpolated by the IDW method in Z direction and afterwards a horizontal interpolation is carried out with any of the standard techniques (IDW, spline or kriging). Thus a better database for each slice of the 3D interpolation is reached because for each sampling point in each interpolation slice a value is given. In case of avoiding an interpolation in Z direction, additional data points have to be set to restrict this method.

The result of the 3D interpolation is visualized in block diagrams, isosurfaces or cross sections together with the fictive boreholes/the database itself.

This tutorial is a step by step manual of 3D interpolation with GIS tools using ESRI ArcView 9.x including Spatial Analyst and 3D Analyst and some scripts.

After finishing the exercises/labs you will be able to create fence diagrams, block diagrams and isosurfaces including the database and additional GIS layers.

You have to be familiar with ArcView 9.x, an introduction to digitizing etc. is not given.

3 Tutorial data

The dataset for the tutorial is derived from the results of a numerical groundwater transport model in the Bitterfeld area. The 3D data are distributed irregularly but not severely clustered. It is an unsorted list with X, Y, Z and Value data that can also be generated from a database.
In environmental geology and hydrogeology this area is of very high interest because of a wide spectrum of groundwater contaminants and a very heterogeneous geology with glacial sands, tills and tertiary coal and sandy aquifer material.

4 Manual

This manual will lead you step by step through three main steps of a 3D interpolation and visualization:

- Visualize the database
- Interpolate to a distribution in 3D
- Visualize the results

The data used for this manual are samples saved in an X, Y, Z, Value file that can be derived from a database via SQL statements or in some other way. The data don't have to be sorted, a script will do that occasionally.

4.1 Visualize the sampling locations

To get access to the scripts open the project file (.mxd) of the tutorial and add the data "data_red.shp". This shapefile can also be generated via a text file import and conversion to a shapefile or via a database export and subsequent conversion to a geodatabase.
Visualize the unsorted data in ArcMap to get an overview.
If the project file (.mxd) doesn't work because you don't have ArcView version 9.3 installed on your computer, then please load via "Alt"+"F11" or in the menu bar "Tools", "Macros" and "Visual Basic Editor" the Modul1.bas and the 4 forms via "File", "Import file".

4.2 Interpolation to a 3D distribution

To get a 3D distribution two big steps have to be connected: First an interpolation in Z direction along the boreholes and second the 2.5D interpolation in horizontal slices.

- To get started with the scripts load your database, add an empty point shapefile and create a raster file with the desired dimensions and resolutions. These files are needed by the scripts. The list in the TOC of ArcMap should be top-down: 1. Empty point shapefile, 2. point database, 3. raster file.
- Start the macro "select_datasource" either via *Tools -> Macros -> Macros -> select_datasource* or directly via the VisualBasic Editor. If you use the scripts often you can also connect them with a button either in the menu or within a toolbar.
- In the subsequent forms choose first, if you want to work with a sorted or unsorted database file and after that choose the shapefile and the correct attributes.
- After clicking OK the sorting algorithm starts in case of an unsorted file and this will take some time (only poor algorithm).

- Another form asks for the vertical dimensions and resolutions for which the interpolation should be carried out.
- The result of this first step is an additional shapefile with a vertically interpolated value for each location and each 3D slice. This file is created by ArcObjects and has in the actual version one mistake: The extent is not defined. Therefore the locations have to be selected (without the first one which holds 0 in X and Y) and saved in a table. Afterwards this table has to be imported and the locations can be visualized via the X and Y coordinates. The temporary layer should be saved as a shapefile with which you can work on.
- This shapefile can be used for a visualization of the locations and dimensions of the input in 3D via ArcScene. To do this, open ArcScene either from *Start -> Programs -> ArcGIS -> ArcScene* or by starting the 3D Analyst and choosing ArcScene.
- Load the shapefile you created via the scripts.
- With a right mouse click on the shapefile and choosing *Properties* the tab *Base Heights* is opened and the *Height* can be set by the small *calculator* to "Bottom".
- In this tab also set the exaggeration to 15 in the field *Z Unit Conversion*.
- After that the tab *Extrusion* has to be selected and the extrusion should be set via the small calculator to Top – Bottom.

Congratulations! You visualized your boreholes in 3D!

The second big step is as easy as the first one.

- Back in ArcMap organize your layers in the TOC so that the prepared raster layer is directly below the layer with the (newly created) locations. The locations layer should be activated.
- Then choose *Tools -> Macros -> Macros -> interpolate_slices* to create the previously defined number of raster layers (one for each slice). The predefined interpolation method is kriging wit a spherical variogram. The variogram itself can not be visualized with the Spatial Analyst (and therefore also not with the corresponding ArcObjects) and the variogram parameters are set automatically.
- Have a look at the interpolation results, it is quite important to identify mistakes and perhaps choose another interpolation method.
- If everything is ok, make all your rasters permanent and convert them to point features. This can be done by right-clicking on each of the rasters and choosing *Data -> Make Permanent* (and afterwards setting the location).
- When all raster layers are permanent they have to be reclassified via *Spatial Analyst -> Reclassify*. The problem is that only integer values are accepted for the necessary conversion to features. The best way for a reclassification is to create a table with reasonable values for the first layer and load this table afterwards also for the other raster layers, but be sure to cover the whole range of interpolated values. Additionally the possibility of a logarithmic scale (e.g. logarithm of 2) should be taken into account in some cases. With predefined tables the problem is the format: .dbf files are read but normally don't fit to the layout of the table in the form. The best way is to use *classify* and the subsequent form to create a table once, afterwards *save* it and *load* it for the other raster layers.

- The reclassified raster layer has to be exported via *Spatial Analyst* -> *Convert* -> *Raster to Features* as point shapefile. This can be used in ArcScene for a 3D visualization.
- To visualize your results switch to ArcScene again and load all the point shapefiles.
- With right mouse click open the Properties and choose the tab *Base Heights* so that the *Height* can be set by the small *calculator* to the adequate bottom height of the slice. Don't forget to set the exaggeration to 15.
- With the tab *Extrusion* the thickness of the slice can be set.
- The last two steps have to be repeated for all slices.
- The *Symbology* tab is needed to give all slices the same colour table. If you set the values lower than the cutoff (or threshold) to no colour, you will get the layout of isosurfaces.

Congratulations! 3D visualization as block diagrams and isosurfaces are complete.

Try to find out, how to create cross sections, there are several ways to do it.

5 Summary and discussion

The interpolation and visualization tools of ArcView 9.x (and extensions) are not very sophisticated but to a certain extent effective. Especially familiarity with the standard tools themselves makes it easier to work through all the steps. Some important tasks have to be solved by VBA programming, but once they are developed it is possible to use them in every project. With these scripts no additional third party software is needed. Additionally to the scripts written for this course, some of the repeated tasks can be done with the help of the ModelBuilder, a nice tool to develop visually and carry out routine tasks in the ArcToolbox.
The terms 3D interpolation and 3D visualization have been used here for convenience. In the end, this is a piling up of 2.5D interpolated data. The significant differences between 2D, 2.5D and 3D are not described here and also not clear in the GIS literature. ArcView 9.x is not capable of real 3D data, their calculation in form of volumes and representation of geological heterogeneity, and of a real 3D visualization with real cross sections, virtual boreholes, fence diagrams, isosurfaces etc.