The Wireframe Model—Showing 3D Structure with Open Space

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Abstract

This research examines use of the wireframe model for showing three dimensional subsurface structure. Three questions were posed: First, how can subsurface structure be portrayed using a graphics technique dominated by open space? Second, what engineering graphics techniques can be used to show quantitative information? Third, how can the wireframe model be incorporated into existing coursework?

To answer these questions, existing mapping for three oil fields was digitized for use in wireframe modeling. Different engineering graphics techniques were tested for gridding, shading and contouring. Wireframe modeling then was introduced into existing exercises in two university-level courses and student outcomes examined.

In response to question one, open space in the wireframe can be advantageous for showing major trends while omitting extraneous detail. Graphically, the angular appearance of the wireframe can be softened using a dense gridding algorithm that is subsequently thinned.

To address the second question, graphic techniques for shading, contouring, and vectoring were tested for showing quantitative data. Shading is enhanced by using heavy line weights and by constraining the shading by contours. Vectors are effective, but potentially confusing.

The third question was answered by integrating a wireframe modeling exercise into existing surveying and estimating courses at Murray State. Integration was into the surveying course was relatively seamless because of student knowledge of basic engineering graphics. Extension of a wireframe modeling exercise into the estimating course was more difficult, but for reasons other than those posed by the graphics component of the assignment involved.

Introduction

The wireframe model is a method of three dimensional subsurface mapping commonly employed for the preparation of digital elevation models in surveying, hydrology, geology, and mining. The wireframe model maps a set of points having known triaxial (x,y,z) Cartesian coordinates. Prior to plotting, a gridding routine is used to place randomly located field data in a regular grid with spacing selected by the drafter. Wireframe plotting results in an open (x,y) grid with the height of each grid node corresponding to the z coordinate at that point.

The wireframe model has a number of advantages over other 3D modeling methods. These include simplicity of presentation, flexibility in the use of color, and high impact value as a presentation tool. Inclusion of a wireframe model employing a multichromatic color scheme on a black background can convey the image of thorough analysis and a detailed examination.

Despite these advantages, use of the wireframe incurs some limitations. A widely spaced grid is desirable for the wireframe model, but such a grid generally produces an angular and unattractive wireframe model. Conversely, a closely spaced grid may more accurately represent subsurface structure, but the corresponding wireframe may plot as an amorphous solid. Further, the multichromatic color scheme frequently used for wireframe models in technical presentations may hinder or even mislead interpretation. Even when carefully selected to support interpretation, colors may appear washed out, flat, or patchy.

From the above discussion, it is apparent that use of a 3D wireframe model requires careful attention to basic principles of engineering graphics for accurate data presentation and thoughtful communication of technical information. Because of this, it is necessary to examine techniques that minimize limitations inherent in this method if the wireframe model is to be used as a general method in engineering graphics.

Further, drawing and modeling using the wireframe model is rarely taught in undergraduate courses. Its use, if addressed at all, is taught by integration into courses in surveying, hydrology, geology or other coursework. Because of this, it is important to determine whether and how to effectively integrate wireframe modeling into instruction or if such is to be done at all. Consequently, this research poses the following questions:

(1) How can subsurface structure be portrayed accurately with a graphics technique that is dominated by open space?
(2) What techniques can be employed with the wireframe model to convey quantitative information?
(3) By what means can the use of the wireframe model be effectively incorporated into existing technical coursework?

Previous Work

This paper will adopt the HSV convention of hue (color), saturation (shade), and value (intensity) as terminology for describing color. The use of color in mapping is summarized by Madej (2001) who develops basic rules for color use in modeling. He suggests the use of a dark colors for the figure with a light background color, and he proposes variation in saturation as a means of showing changes in magnitude of a feature. While the use of standard patterns for different types of rock is common in subsurface mapping, this is precluded in wireframe modeling because of the significant percentage of open space.

McEachren (1995) summarizes cartographic use of color and the association of specific colors with the features being mapped (blue for water; tan, buff or yellow for dry or unvegetated areas; brown for landforms). He notes the use of a polychromatic color scheme (grading from blues for lowlands to reds for highlands) for use in 3D modeling.

Barnes and Lisle (2004) suggest that the color used in mapping match the color of the formation being mapped. Kellie et al. (2007) selected color to match specific strata in 3D geotechnical models (e.g., gray for clay, tan for sand, etc.). In later work, Kellie (2010) stated that while the use of a polychromatic color scheme for showing height provides a very impressive graphic, a polychromatic color scheme might hinder or mislead interpretation because the colors used do not accurately represent the strata mapped.

Procedure and Results

Based on the work above, three dimensional wire frame mapping was done for three subsurface study areas in order to address the questions posed at the beginning of this paper. Study area one was the 600 foot aquifer of western Kentucky mapped by Davis, Plebuch, and Whitman (1974). Study area two was the Reed East Oil Field, Henderson County, Kentucky mapped by Turner (1988). Study area three was the Hanson Oil Field, Hopkins County, Kentucky described by Nuttall (1968). Following the general procedure described by Kellie (2009), existing structure or isopach (thickness) maps for each study area were digitized using Didger software and a CalComp digitizing table (Golden Software, 2001). All digitizing was based on the Kentucky State Plane Coordinate System (South Zone). For each study area, a datafile of the x,y,z coordinates and a graphic file of isopachs or contours digitized were exported to the Surfer (Golden Software, 2002) modeling program. To ensure model quality, the datafile from each study area was gridded and contoured using Surfer. The resulting structure or isopach map was then checked for congruence with the graphic file resulting from digitizing.

To address the first question posed in this research, wireframe models were generated for study areas one and two. The grid size used on each area was adjusted by either densifying or thinning the default grid. Densifying the default grid generally produced a smoother wireframe and a more realistic looking surface. A very dense grid results in a almost solid surface. Thinning the grid restored the wireframe but left a smooth surface when the wireframe was plotted. Because the differences in scale of the study areas used in this project, acceptable grid sizes were determine by trial and error.

Figure 1 shows two wireframes resulting from modeling of an aquifer on study area 1. Both models are plotted with the black background preferred for technical presentations. Figure 1a shows a traditional wireframe model with a polychromatic color scheme. Color change with thickness is shown by use of a color scale. Figure 1b shows the same model with blanked areas in blue and the surface of the model in light tan and yellow. The effect of color on interpretation is evident from the graphics. Typical barrier island morphology is obvious in figure 1b, but is somewhat hidden in the traditional polychromatic wireframe model shown in figure 1a.

Examination of figure 1b suggests that one advantage of a wireframe is the simplicity of the model that results. To understand some structures, it may be advantageous to portray the shape of the object being investigated at its most general or fundamental level so that features otherwise obscured by detail can be visualized. For this, the wireframe seems well suited.

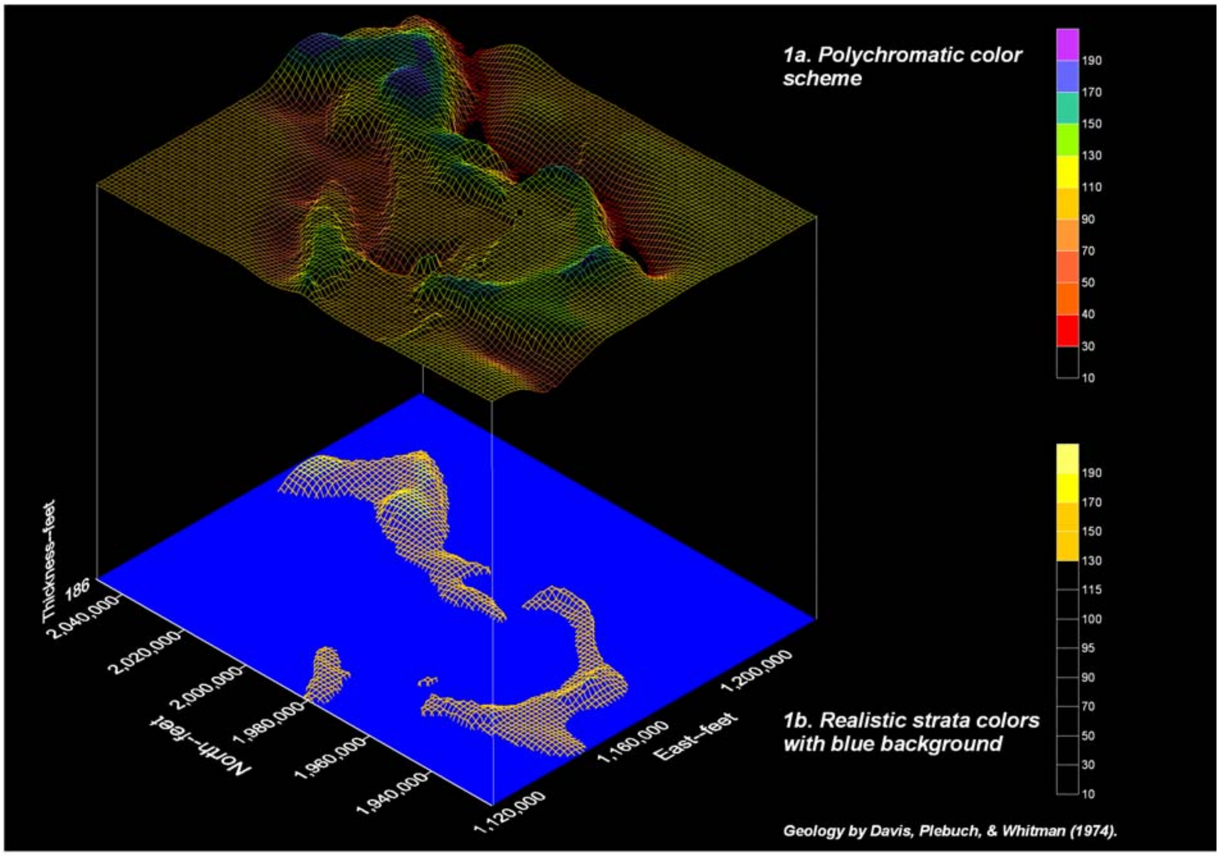

Figure 1. Polychromatic and natural color schemes applied to a wireframe model of sandstone isopachs in the 600 foot aquifer, western coal field region, Kentucky.

Further examination of the use of color in wireframe modeling is shown in figure 2, which shows the results at the Reed East Oil Field. Both wireframe models in figure 2 are plotted with the traditional black background. Figure 2a uses a polychromatic color scheme where different hues (colors) are used to show different thicknesses. Figure 2b shows the same model, but employs a graduated color scale, matched to drilling data, to show thickness differences.

The line weight used for the models in figure 2 is heavier than the line weight used for the models in figure 1. The result is a textured appearance for the model. It must be noted that the model of the Reed East Oil Field shows a structure that is significantly simpler than the aquifer modeled in figure 1. Examination of either figure 2a or figure 2b discloses a series of distributary channels the morphology of which is evident from either color scheme. The line weight used for the models in figure 2 is heavier than the line weight used for the models in figure 1. The result is a textured appearance for the model.

To address the second question posed in this research, use of wireframe models as the basis for quantitative information was examined. For much subsurface mapping, engineering graphics techniques employed must be capable of communicating the magnitude and direction of slope. Two methods of doing this using wireframe models were examined in this research.

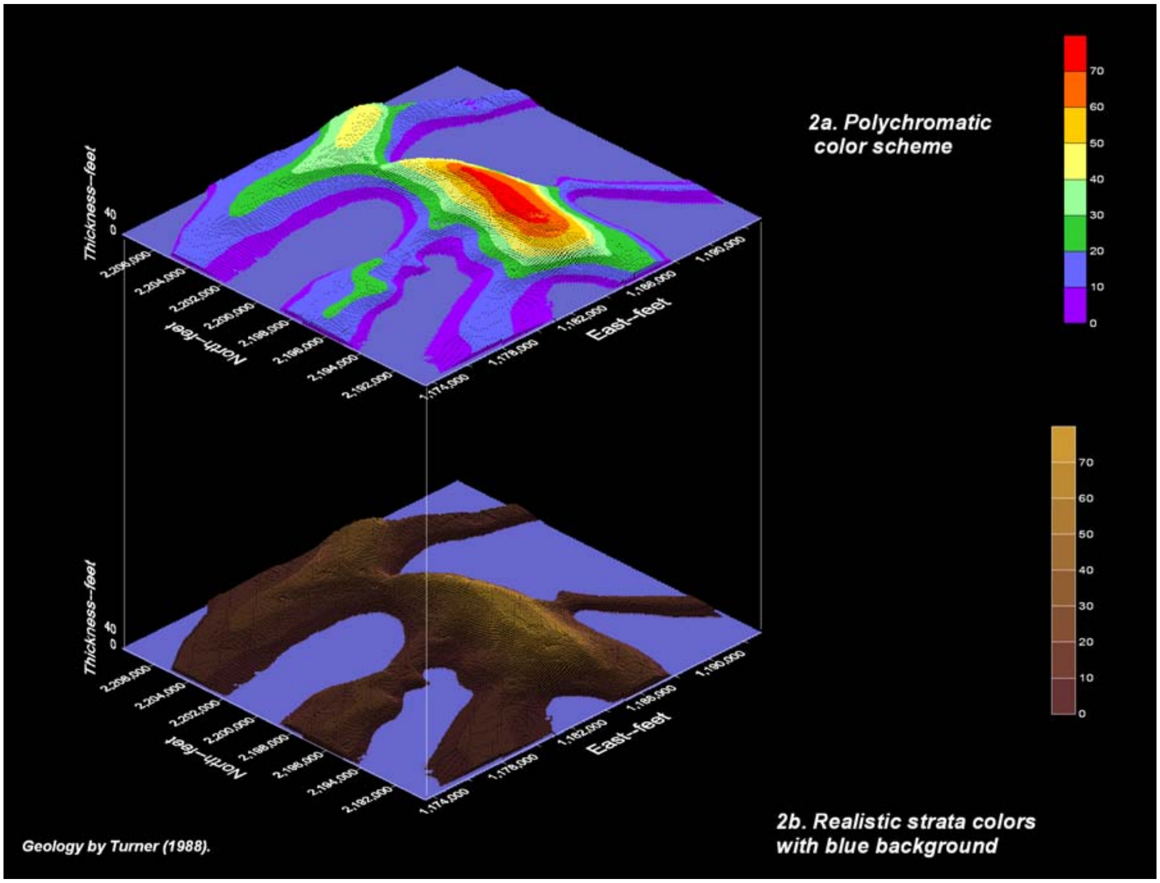

Figure 2. Polychromatic and natural color schemes applied to a wireframe model of the Reed East Oil Field, Henderson County, Kentucky.

On study area one, the direction and magnitude of the slope of the aquifer are important for predicting ground-water flow. Figure 3 shows slope by use of graduated colors and by use of reference vectors. The wireframe model used as a base for the vectors has been colored using a graduated color scheme in which specific saturation (shade) is employed for showing elevation. The colors used were purposely selected to match the color of the sandstone that comprises the aquifer.

In addition, reference vectors show the direction and magnitude of slope. Vector orientation shows slope, and vector size shows magnitude. Figure 3 uses a neutral gray background that is intended to recede from the map user. The width of the grid lines in the wireframe model was increased to minimize the amount of open space in the model and to facilitate use of the graduated color scheme.

In addition to the quantitative techniques discussed above, both a wireframe model and a solid surface model were used as a basis for contouring on study area 3. Figure 4a shows structural contours draped over a wireframe model; figure 4b shows structural contours draped over a surface model. Both models are shown against a neutral gray background, and realistic colors have been used for the sandstone in the field shown.

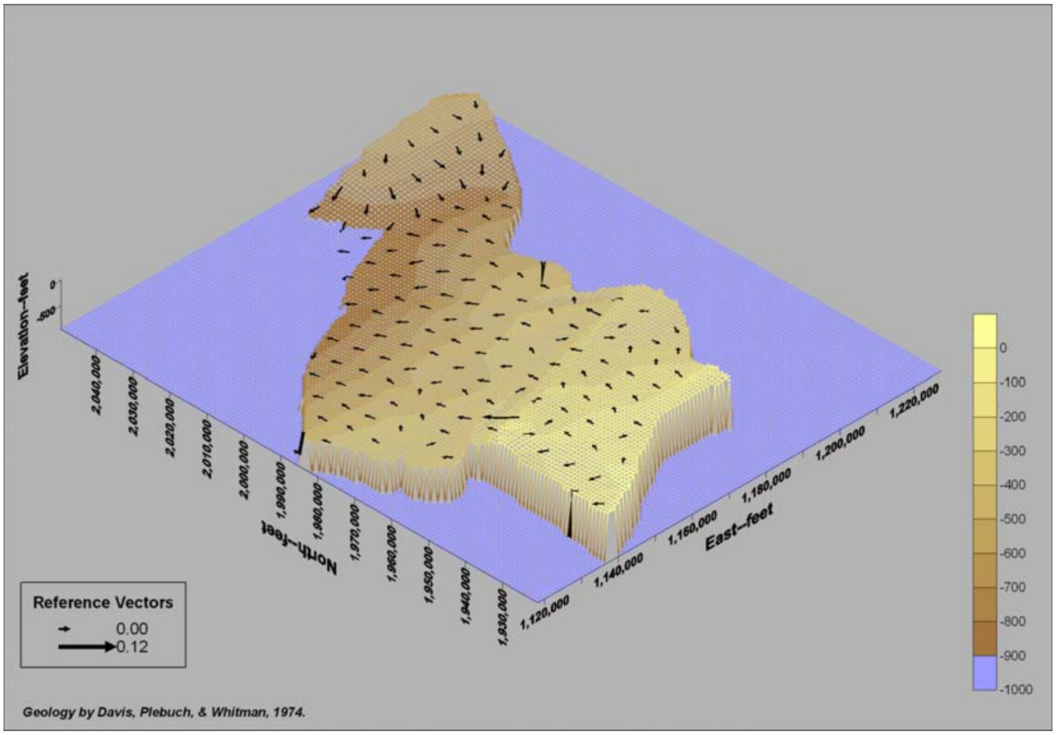

Figure 3. Structural wireframe model of the 600 foot aquifer, western coal field region, Kentucky showing surface structure and slope vectors.

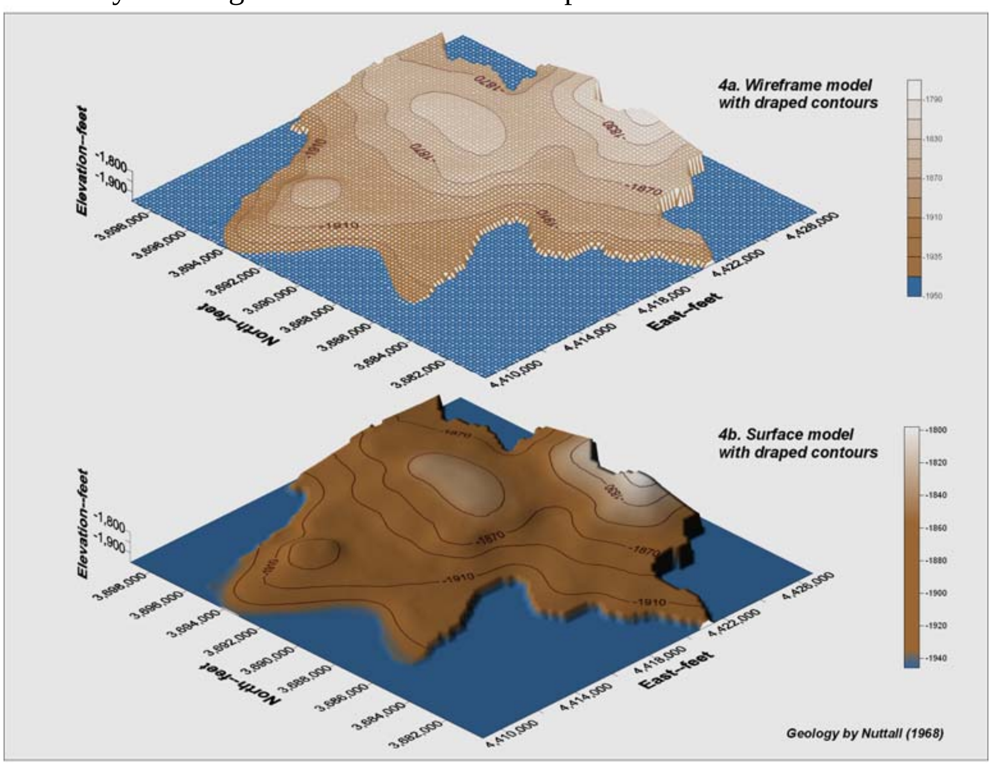

Figure 4. Contour-draped wireframe and surface models of the Hanson Oil Field, Hopkins County, Kentucky.

In comparing the two models in figure 4, it is recognized that the wireframe model clearly shows surface structure and forms a quite acceptable base for contouring. Including contours lines in figure 4a appears to make the elevation of the surface more apparent, as would be expected from using a sharp line to define a boundary. The surface model in figure 4b still appears to retain an advantage, however, because the illumination of the surface model can be controlled in both altitude and azimuth. Illumination isn't employed with the wireframe (figure 4a) because of the open space in the model.

The final question in this research involved whether wireframe modeling should be integrated into existing coursework, and if so, how. Whether the technique is a necessary component of a potential graduate's ability in engineering graphics depends on the student's potential career path as well as industrial and professional expectations. For students planning a career in surveying, mining, or construction, there are obvious applications of the specific technique involved in wireframe modeling. Specific applications include the use of wireframe modeling in site planning, digital elevation modeling, and earthwork volume computation. Quite apart from the practical application, however, wireframe modeling provides the student additional opportunity to develop ability to visualize surfaces in three dimensions.

Wireframe modeling has been integrated into two traditional engineering technology courses at Murray State University during the past two years. In surveying, development of a wireframe model is simply done as part of an existing topographic mapping exercise. The same field data and software are used for both topographic mapping and the development of a wireframe model. Students already are familiar with graphics conventions and topographic mapping from the basic engineering graphics course. The only additional instruction required is how to generate the wireframe. This instruction is normally provided on a small group basis. Students appear to see the use of color and 3D projection as novel, seem interested in the work, and often export the maps generated to their personal folders as *.jpg files. A follow-up homework assignment requires the student to submit wireframe models showing the change in the ground surface at different dates at a surface mine.

The use of wireframe modeling also has been introduced into the heavy construction cost estimating class as a means of computing earthwork quantities. Existing and proposed surfaces on a construction site typically are shown using separate sets of contours. Wireframe models generated from the same data set used to draw the contours show the existing and proposed surfaces as a 3D model. The volume of cut or fill is, of course, the difference between the two surfaces, and this is calculated by the same software (Surfer) used to generate the wireframe models. The current earthwork estimating project provides the student with topographic data sets for both the existing and proposed surfaces. The student is then required to generate two wireframe models and to estimate earthwork quantities (cut and fill) on the site. Despite a significant amount of instructional effort, this exercise has been less than completely successful. There are probably a number of reasons for this: a relatively high student/instructor ratio, student difficulty in visualizing the 3D volume to be computed, and student frustration with the need to adjust volume computations for material shrinkage and swell.

Conclusions

The first question posed in this paper was, "How can subsurface structure be portrayed accurately with a graphics technique that is dominated by open space?" The answer to this question involves limiting the amount of space that is open. This is done by limiting controlling grid size and line thickness. However, it is also possible to use wireframe open space to provide a simplified model of complex structure. Thoughtful selection of wireframe and background colors also can enhance model presentation.

The second question posed herein was, "What techniques can be employed with the wireframe model to convey quantitative information?" This paper demonstrated three methods for conveying quantitative information: elevation shading, draped contours, and use of vectors. To correctly follow cartographic convention, elevation shading should employ changes in saturation (shading) rather than changes in hue (color). The use of contours (or isopachs) when draped over a shaded wireframe model appears to clarifiy slope information.

The third question asked in this work was, "By what means can the use of the wireframe model be effectively incorporated into existing technical coursework?" Two suggestions are: integration of wireframe modeling into surveying coursework, and inclusion of wireframes in earthwork volume estimating. Integration of wireframe modeling within a typical surveying course is neither difficult nor time-consuming and adds a 3D component to instruction. Including wireframe modeling into earthwork estimating does simplify otherwise tedious computation; however, the extent to which it improves visualization of pre- and post-construction surfaces is undetermined.

In conclusion, the integration of 3D wireframe modeling in undergraduate instruction extends student ability in basic engineering graphics and provides the student with a tool for 3D visualization and volume computation. Use of wireframe modeling provides the student the opportunity to explore the use of color and the concept of space.

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