

Isoline Engine: A Digital Assistant for Surface Mapping

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Abstract

In many scientific disciplines, isoline maps are by far the most widely used cartographic device. Their appearance and utility are controlled by large number of design parameters related to both data processing and display. Standard packages, though flexible, do little to assist users in obtaining a good design. Here we report on a software “brewer” that allows for easy and rapid experimentation with a variety of isoline map parameters, such as interpolation method, contour interval, coloring, data focusing, etc. Our goal was to provide a tool that cartographers will find useful in testing various possibilities before committing to a final design. In addition, we believe the interactive features of the brewer make it useful in teaching introductory cartography, particularly in lecture settings where standard packages are too cumbersome for use. (www.isolineengine.org)

Keywords: isarithmic maps, contouring, interpolation, map brewer, expert system.

Introduction

The large majority of maps today are made by people who would not call themselves cartographers: They work in urban planning, environmental consulting, real-estate development, travel and tourism, advertising, and anywhere else where the growing collection of geospatial data is needed to solve problems and communicate. Like many authors (Rød et al. 2001; Kumar 2000; Forrest 1999; Morrison 1994), we view this ever-increasing democratization of cartography as a positive development. However, while the non-specialist map maker now has easy access to both geospatial data and mapping software, what remains elusive is the knowledge of how to make the most of these tools and produce effective maps (Muller 1983, Weibel and Buttenfield 1992, Green and Horbach 1998). This is not a criticism of the non-specialist; rather, it is a critique of mapping software that provides little guidance on how to make maps. Worse yet, we fear the prevalence of default settings in software seldom encourages deeper learning or experimentation with alternative approaches. Software help systems, when present, usually fail to do more than tell users what buttons to push in the provided interface for the desired action (what could be termed low-level knowledge), not *why* a particular choice is preferable or *how* to make effective maps independently of a particular software (high-level knowledge). An analogy would be the difference between knowing how to use a word processor and how to write. Furthermore, traditional sources for design assistance, such as cartography textbooks and class-based instruction, are not practical ways to reach today’s diffuse map-making public (who may lack either the time or money). What is needed, therefore, are ways to bridge the gap between expert know-how and public need.

This paper reports on Isoline Engine (www.isolineengine.org), an interactive Web-based mapping system, or “map brewer” (see below), that helps both specialists and non-specialists explore issues in creating isarithmic maps (also known as contour¹ or surface maps). Built in Flash, Isoline Engine is free to use and requires nothing more than a web browser and an Internet connection. This paper provides an overview of Isoline Engine, its functionality, and outlines the rationale behind its development. Like the other map brewers that have been developed to date (Harrower and Brewer 2003, Schnabel 2005, Sheesley 2006), Isoline Engine encourages users to “test drive” their design choices in a relatively simple viewer and to learn more about the impact these choices have on the map (and ultimately the map reader). Also like other map brewers, Isoline Engine does not make the map for the user—it is not mapping software in the traditional sense—rather, our goal is to help the user to think through the process of making an isarithmic map and to preview their choices quickly before actual map creation.

Isarithmic maps are a highly flexible and elegant map form used to depict continuous data surfaces. While the use of isolines dates back more than 350 years (Robison and Hsu 1976), it was not until the development of computerized cartography that they became easy to make. In the past 30 years, dozens (perhaps hundreds) of software packages have been written to create isarithmic maps, in part because this is a classic computational problem (i.e., formalizable and repeatable). Today’s scientific visualization and mapping programs provide a wide array of spatial interpolation and display options of mapping continuous surfaces. Such programs, when used in concert with professional illustration software, can produce maps of the highest quality. While some of this software is domain-independent and intended to work broadly (e.g., ArcGIS and Surfer being two currently popular packages), most advanced contouring software available today serves specific domains such as hydrology, meteorology, and geology. In most cases, the mapping and visualization capabilities of this software are impressive (as is the price). However, after using this software we have identified the following common problems:

- (1) Little or no design guidance is provided for the correct selection of isoline parameters and display options (e.g. contour interval, interpolation method, the relative merits of continuous versus discrete color ramps, animated versus static depictions, and so on).
- (2) Changing these parameters in the software can be difficult or sometimes impossible (see example below), inhibiting real-time visual editing and exploration.

Almost 15 years ago Weibel and Bittenfield (1992) outlined these same limitations with commercial GIS packages and suggested that one potential solution could be better help systems that use embedded learning modules and “amplified intelligence” software. As they note, “weak of ineffective map design restricts the communication of information, and may communicate false ideas about the facts contained in the data that are displayed.” (p. 223). It is this challenge that Isoline Engine was primarily designed to address. A second motivation for this work is educational; there is an obvious lack of software that can be easily used for teaching and visualizing basic concepts surrounding interpolation, gridding, and contouring. As a result, classroom teaching is typically restricted to term definitions and a series of static maps, neither of which translates easily to the world of practicing cartographers. Isoline Engine dynamically updates the isoline display when particular parameters are adjusted, allowing for interactive classroom participation and a better understanding of the role of each parameter in the generation of the isoline surface.

¹ Cartographers prefer to reserve the name ‘contour’ to isolines of elevation (Robinson et al. 1995)

What is a “Map Brewer”?

Named for researcher and cartographer Cynthia Brewer, the map brewer is a new kind of mapping support system, focused on helping map makers with one particular aspect of the map design process. To date, available map brewers include ColorBrewer (Harrower and Brewer 2003), Symbol Brewer (Schnabel 2005), and TypeBrewer (Sheesley 2006). Brewers are different from other forms of online help such as wizards, tutorials, forums, agents, and documentation because they do not steer the user to a single solution, nor do they try to do the work for the user (e.g., auto-complete in Microsoft Word). Rather, they present the user with a range of “good” solutions (given the task at hand) and encourage exploration of these options so that the user can begin to think about the problem as an expert does. This is done in two ways: (1) embedded “learn more” mini tutorials, and (2) tools for critical evaluation of alternatives (e.g., visual quizzes). The danger with a system that only “fixes” mistakes for you (e.g., spelling corrections) is that users may never develop better habits and simply become lazy. In contrast, brewers can be characterized as “digital teaching assistants,” offering important background theory, yet challenging the user to find his or her own solution.

As outlined by Brewer (2003), brewers have a number of unique characteristics. They should:

- Focus on a specific cartographic design challenge (i.e., not a general lesson)
- Organize design choices around a set of established mapping principles
- Offer only suitable choices (i.e., nothing too extreme or irrelevant)
- Encourage learning about design choices
- Not be software-specific
- Only require basic skills with mapping software
- Offer tips on the suitability of choices
- Encourage users to be critical of their choices through an interactive, graphical display

Two of the most popular commercial isolining software products, ESRI’s ArcGIS Suite (using the 3D Analyst extension) and Golden Software’s Surfer, lack many of the essential brewer characteristics. While Surfer focuses specifically on isolining and surface generation, the isolining functionality of ArcGIS is but a small part of the mapping system, and both nest the selection of isoline parameters deeply in option windows (which perhaps explains the dedication of much of the help tool towards explaining which series of buttons to press). Such nesting of functionality distributes the position of important isoline parameters among multiple option windows, increasing amount of time it takes to generate the map image as well as making it difficult to determine how the parameters interact in the creation of this image. In both systems, the appropriate choices are not limited to those that are suitable to the quality of the data and the application at hand (e.g. an interval of .01°C can inappropriately be used when the precision of the underlying data is at a full degree).

The most glaring brewer characteristic omitted by ArcGIS and Surfer is the ability to immediately update the graphical display when parameters are altered. The extreme of this final point is found in ArcMap, where the change of isoline parameters creates an entire new spatial file, rather than updating an image. The computer processing time necessary for this complete isoline recreation likely discourages parameter exploration and increases reliance on default values. In ArcMap’s defense, the function of the software is for the creation of linework, not the visualization or

education of how and why the linework is created. It is instead the role of a brewer to allow the user to first experiment with possible parameter choices, learning about their appropriate use in the process, and then translate these parameter choices to the isolining software for generation of the final map.

Isoline Engine Overview

The intent of the Isoline Engine application is to address the need of a map brewer for the creation of isoline maps. In its present form Isoline Engine displays isolines for the mean daily air temperature for North America (Figure-1). Because it is continuous across space and changes smoothly, air temperature is a prime candidate for isarithmic mapping (in this case producing isotherms). Future versions of the application could include additional datasets and also have the ability to accept user-provided data. Isoline Engine provides insight into both data processing issues (e.g., interpolation method, number of control points) *and* cartographic display issues (colors, number of lines, etc.) because we see these as interrelated issues. In other words, what is done to the data is not independent of the ultimate look of the map.

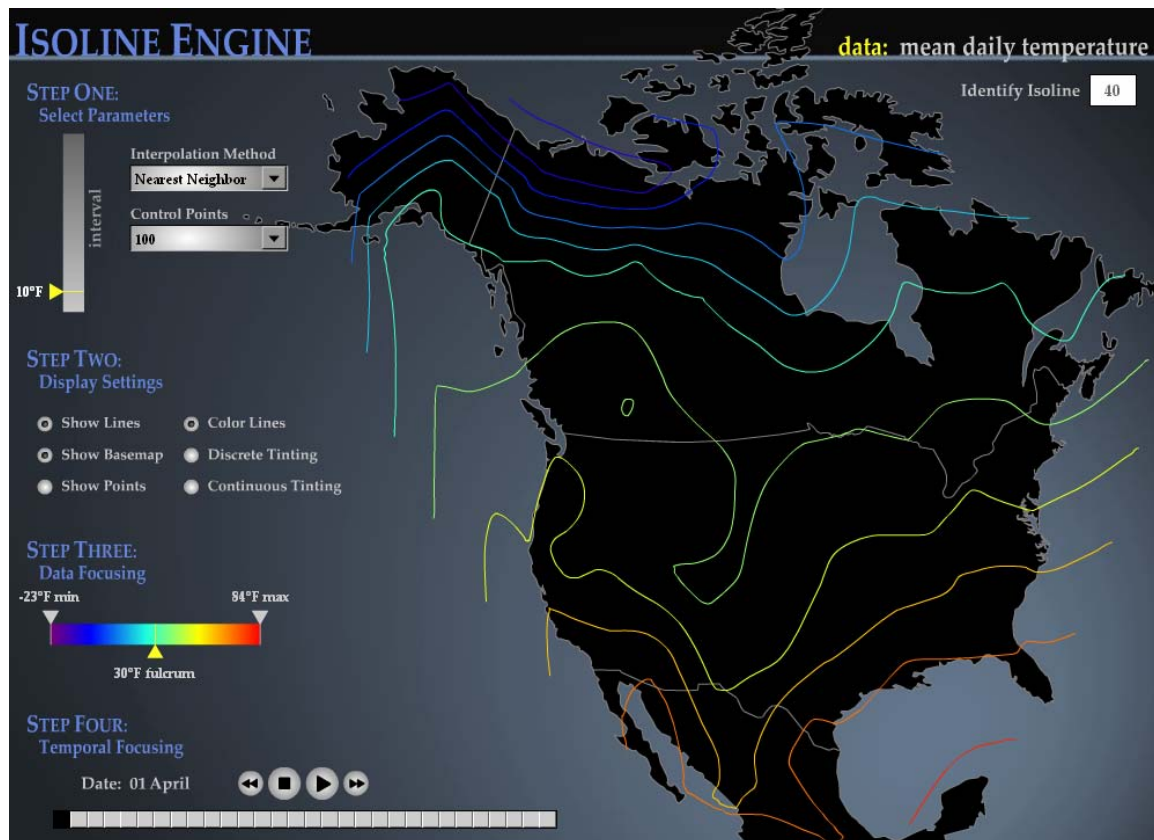


Figure 1: The Isoline Engine interface.

MacEachren and Dvidson (1987) identify five factors in the accuracy of isoline mapping: (1) data measurement accuracy, (2) control point density, (3) spatial distribution of sample points, (4) intermediate value estimation procedures, and (5) the spatial variability of the surface represented. These elements can be equated to the basic data processing issues important to the creation of isoline maps. To interrogate the first element, the location of control points, the actual weather station points used to create the isoline maps can be shown in Isoline Engine. Because

there are many fewer stations in the arctic regions of Northern Canada compared to the coastal areas of the United States, users will be able to visually assess the differences of isoline placement in sparsely versus clustered areas of control points. The second element, the gradient assumed, is determined by the interpolation method used. Users will have the ability to quickly toggle between several of the most common interpolation methods, including Thiessen polygon nearest neighbor, inverse-distance weighting (IDW), TIN-based linear, smoothing splines, and kriging, to see how the interpolation method influences the lines that are drawn (e.g. multiple islands with nearest neighbor, values above control points with kriging, etc.). Information on the pros and cons will be provided, as well as when each method should be used. For the more complex methods, additional information on how to use specific method parameters will be provided, although these parameters will not be interactive in Isoline Engine itself. The final element, the number of control points, will also be an interactive parameter in which the user can toggle between several dataset sizes (100, 500, and 1000 points).

Isoline Engine also provides direct interaction with the most common ways to cartographically symbolize isolines. The first parameter in this category is the isoline interval to be used, determining how many lines will be symbolized on the map. Because it has been shown that it is difficult to determine the gradient and aspect of slopes when varying intervals are used on isarithmic maps (Robinson et al. 1995), only equal intervals are provided (one example of how the brewer restricts the design choices of the user). The isoline interval has been identified as one of the key parameters affecting the look of the map, as “An interval that provides too many isolines generally results in a map that looks ‘too accurate’” while, “A wide interval appears too generalized and reveals little” (Dent 1999). Alteration of the interval value using a slider bar immediately updates the map, encouraging exploration for an interval that appropriately represents the surface. Other symbolization of the isoline surface includes the ability to add colored isolines, filled isoline ranges or discrete hypsometric tinting, and continuous hypsometric tinting. Again, the user is notified of the relative pros and cons of each symbolization technique

Additional Functionality for Classroom Education

Our second goal with Isoline Engine is the creation of an interactive tool for the classroom education of isoline mapping. Such a tool would provide educators with dynamic examples of lecture material to help illustrate cartographic theory. Beyond the explanation and exemplification of the above data processing and cartographic display issues, Isoline Engine also can aid with the following topics:

(1) Illustrate the uncertainty involved in isoline maps due to interpolation

Much of the literature on interpolation and isolining involves the explanation of error computation in the generated surface. It is important to convey the point to students that interpolations are only representations of reality, and should only be thought of as “the GIS version of intelligent guesswork” (Longley et al. 2005). This point should be easily illustrated by toggling through multiple representations of the same dataset using different methods to reveal how the placement of lines the same value can be highly variable.

(2) Demonstrate the importance of a fulcrum value

A fulcrum value (also called a base value or critical value) is the dividing point around which the isoline interval is added. ColorBrewer places a similar importance on such a fulcrum value by the inclusion of diverging color schemes. Temperature data is a good example of the importance of a fulcrum value since the freezing point of water is a “critical value” and it may not be directly shown if the isoline interval skips over it. We chose to show the temperature in degrees

Fahrenheit rather than Celsius to emphasize the role of the fulcrum value because the user must adjust this to 32°F (as in most cases not specifying a fulcrum value places it at 0°C by default). Dent (1999) explains the influence of this value on the look of the map and that when selecting the fulcrum value, “no universal rules apply,” making exploration important.

(3) *Provide an example of data focusing*

Data focusing is the selection of a subset of values within a numeric range (Slocum et al. 2005). An advantage of digital maps is that only certain sections of the dataset can be made visible at a given time, allowing for much more involved interaction with the dataset. Isoline Engine provides the ability to demonstrate both attribute focusing (e.g. values from 50-70 degrees) and temporal focusing (e.g. April 10-12).

(4) *Provide an example of isoline animation*

Finally, Isoline Engine is an example of cartographic animation, as the nearest neighbor interpolation method can be animated daily over the month of April. Isoline maps animated well because the movement of the isolines creates a fluid animation, resembling that way in which cartoon lines are animated over time. In isoline maps this fluidity is magnified because similar line values are always found next to each other. The animation of choropleth maps, for example, keeps the enumeration boundaries uniform while changing the color fill, often making for a visually disjointed, “speckled” animation. Isoline Engine also includes the full set of temporal controls (e.g. play, stop, rewind, etc.) as well as temporal focusing.

Conclusion

Isoline maps enjoy widespread use in many disciplines. They are an essential item in every cartographer’s toolbox, and--it is probably safe to say--they are covered in every introductory cartography course. A relatively large number of interacting parameters enter the design of such maps, such as data density and distribution, interpolation method, isoline interval, etc. Recognizing deficiencies in existing software, we have developed a web-based program for easy and rapid exploration of the isoline map design space. Reflecting the map brewer style, our program exposes numerous controls to encourage experimentation, restricts choices to sensible combinations, and provides expert guidance and explanation. We believe the software, called Isoline Engine, will prove useful to professional production cartographers wishing to test various design alternatives before committing to a final map look. In addition, we believe Isoline Engine will find a place in teaching introductory cartography, where its interaction and speed will be particularly appreciated.

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