Viewing Spatial Data from the 3-D Perspective

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Abstract

Humans walk erect and view the world accordingly. We know where we are by reconciling what we "see" with what we know. However, if I am not able to reconcile the two, I am "lost" until I am able to recognize some feature or landmark. A map is a pictorial representation of features on the earth and can be enormously helpful in learning more about where we are. Typically, maps are two-dimensional (2-D) and, because we walk erect on a "flat" earth, we equate knowing where we are with horizontal position. While it is true that a topographic map shows the third dimension (3-D) with contour lines, there is a long history of using 2-D maps in many applications.

But, the world is not flat and cartographers understand the challenge of depicting a curved earth on a flat map. Wouldn't it be nice if we could use a 3-D map that portrays an undistorted view of the world? Such a dream is called virtual reality and already exists in cyberspace. Data visualization programs are quite sophisticated and permit the user to "fly through" a 3-D database. However, there is an enormous amount of work to be done (both literal and conceptual) to make the transition from cyberspace to a 3-D database of our physical world. Part of that challenge is helping students gain a better understanding of spatial relationships and providing them with better models and tools for handling 3-D spatial data.

Modern measurement systems collect and store 3-D spatial data. Given the evolution from analog to digital during the past 50 years {1} and the convergence of three technologies - the global positioning system (GPS), geographic information systems (GIS), and the world-wide web (www) - the challenge for surveyors and others who use spatial data is to exploit the capabilities of modern technology to satisfy the growing demand for reliable 3-D digital spatial data. This presentation will include a brief description of the 3-D global spatial data model (GSDM) and discuss how it can be used to facilitate the transition from cyberspace to physical reality.

Introduction

Many people associate surveying with the image of someone standing behind a tripod in the middle (or along side) of a busy road peering through a telescope. Admitting some truth in that perception, modern surveying involves much more. Surveying has become an exciting profession involving diverse talents of many people. It is true, many surveyors work outdoors on construction sites and in other fascinating places. But surveyors also work with (or are) attorneys, engineers, planners, photogrammetrists, scientists, researchers, teachers, programmers, bureaucrats, business owners, and corporate executives. And, typical surveying activities are just as diverse as our talents: distances and angles are measured electronically; maps are made from aerial photographs; images of the earth are obtained from satellites; tedious computations formerly taking hours are now performed with lightening speed on a computer; a position almost anywhere on the earth is readily available to anyone with a GPS unit; and massive amounts of geospatial data are being collected and stored in GIS's. In many parts of the U.S. and around the world, "geomatics" is a word being used to describe the expanded scope of surveying and many disciplines work with spatial data. But, regardless of the expanded scope or the image associated with surveying, the on-going challenge for the NMSU Surveying Engineering Department is to help our students grow in their maturity and understanding of spatial relationships and to gain practice working with 3-D digital spatial data.

During the past 50 years the use of spatial data has evolved from the analog map and photograph to digital data stored in GIS databases. And, with satellites taking pictures of (imaging) the earth 24 hours a day, 7 days a week, enormous quantities of digital spatial data are being collected and stored in "electronic silos." In a speech on "The Digital Earth" {2} given in 1998 by then Vice President, Al Gore, he said, "The hard part of taking advantage of this flood of geo-spatial information will be making sense of it – turning raw data into understandable information." The use of numerous datums around the world and the practice of referencing geo-spatial data to disparate origins (latitude/longitude for horizontal and sea level for vertical) are obstacles to that process. Part of the solution will be implementing an integrated 3-D global spatial data model (GSDM) that has a single origin for spatial data and that includes both a functional model for geometrical relationships and a stochastic model for spatial data uncertainties.

Goals

The goals of this presentation are to:

- Consider ways to develop a better understanding of spatial data and relationships. This will involve visualizing both the local "flat earth" as well as looking at the global nature of spatial data. An important subcomponent is helping students learn to ask better questions about what they see and experience.

- Provide information about the GSDM and show how standardized procedures can be used to handle spatial data more efficiently – both locally and around the world.

- Suggest that the GSDM can be used:

  1. As a bridge to carry the powerful concepts of 3-D data visualization and analysis from cyberspace to reality, i.e. to connect 3-D spatial data to the physical world.

  2. As a common reference by two groups of people - those persons and professions devoted to generating spatial data (engineers, photogrammetrists, manufacturers, mappers, programmers, etc) and those using spatial data (planners, spatial data analysts, mappers, navigation, fleet dispatch, etc). Enormous economic benefits can

be realized to the extent spatial data users exchange spatial data in accordance with a standard having a single origin for 3-D spatial data.

Definitions

The following definitions are used:

Science is the process of organizing knowledge in such a way that conclusions are consistent with beginning assumptions and subsequent observations. Depending upon ones perspective and/or objective, science can be exciting or frustrating when inconsistencies are identified. An example is the grid/ground distance difference when using a 2-D map projection.

The **spatial data primitive** is taken to be the distance between endpoints of a line in Euclidean space. Although a line could be considered the path of a moving point, the definition of a point is meaningless unless one knows its location – typically described by distances. Such a distance can be along a curved line (latitude/longitude coordinates) or along a straight line (rectangular coordinates). An alternative might be to use Euclid's definitions {3 - Appendix I} given as, "A point is that which has no part." and "A line is breadthless length."

Geo-spatial data are those spatial data connected to or referenced to the physical earth.

A **mathematical model** is an abstract representation of the real world using numbers, geometrical elements and equations. A spatial data model gives relevance and meaning to concepts of location. The goal is to find and use the simplest model that is at the same time appropriate {4}.

The Global Spatial Data Model (GSDM)

Traditional models for spatial data include separate horizontal and vertical datums. The underlying problem is that horizontal is referenced to a mathematical ellipsoid which has its ultimate origin located at the earth's center of mass. But the third dimension, vertical (or elevation), is referenced to the geoid, an origin described simply as "mean sea level." Those two origins are incompatible in that there is no unique mathematical expression that can be used to relate the two. Geoid modeling is used to relate elevation with ellipsoid height and enormous progress has been made in the recent past. But, the GSDM utilizes the earth-center earth-fixed (ECEF) coordinate system as designed by the U.S. Department of Defense {5} and provides a solid geometry computational environment that obviates the need for geoid modeling in many cases {6}.

Modern concepts include the fact that spatial data are now predominately digital. As such, the details of data manipulation become increasingly important as data are moved from one reference (coordinate) system to another and as users in various disciplines attempt to share compatible spatial data. The GSDM provides a simple 3-D rectangular coordinate system that is common to all users (there is only one set of equations for the whole world). But each user, agency, or organization also has the flexibility of converting the standard ECEF coordinate values into any well-defined coordinate system. Since the rules of coordinate conversion are bi-directional, each user can work in the system of choice while exchanging spatial data with others in a standard 3-D format. But, since the GSDM represents the world the way humans see it (the user selects a local origin), it is also expected that many users will choose to work with the local perspective view of the stored ECEF values – in which case the grid/ground distance dilemma becomes moot.

Spatial data accuracy is another very important issue. As described by Burkholder {7} and {8} the GSDM provides specific unambiguous procedures for establishing, tracking and using standard deviations to describe spatial data accuracy, component by component. Current definitions of "local accuracy" and "network accuracy" {9} are somewhat vague and little information is provided as to how spatial data accuracies are computed. The spatial data user community deserves to have clear concise mathematical definitions of spatial data accuracy such as that provided by the GSDM. Meta data are currently used to provide data about data and meta data will remain important. But the use of meta data will be diminished to the extent that reliable numerical filters as provided by the GSDM are used instead. Such numerical filters can be applied to any component and the filter size is selected at the discretion of the user.

As described in the defining document {10}, the GSDM includes a functional model of geometrical relationships and a stochastic model for describing the spatial data accuracy of any point in any direction. There is no "new" science in the elements or equations included in the GSDM. But what is "new" is building a 3-D database and subsequent computations on the assumption of a single origin for spatial data. Once a competent 3-D position of a point is defined, 1-D and 2-D operations with that point are fully supported by the GSDM. Regretfully, the reverse is not true. It is difficult, if not impossible, to build a true 3-D database by combining 2-D and 1-D data based upon disparate origins – unless, of course, unrealistically large standard deviations are assigned to the vertical component.

Conclusions

- The technology is in place and the transition to digital is all but complete. The GSDM is already defined and operational. Using the GSDM is essentially a matter of deciding to do so.

- NMSU has an excellent reputation for engineering research and applications. Is it possible NMSU will become a player in the implementation of the GSDM? The spatial data segment of the global economy is significant – measured in billions of dollars per year.

- The crux of the 3-D issue is the definition of the spatial data primitive and using a single origin for 3-D spatial data. The paradigm shift issue described by Kuhn {11} should be considered carefully. The transition could take years to achieve.

- The NMSU Surveying Engineering Department is a small but talented department. The opportunities to team-up with professionals in related spatial data endeavors need to be explored. The potential benefits are enormous and the work will be exciting.

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Biographical Sketch

Earl F. Burkholder earned his BSCE from the University of Michigan in 1973 and, after working 5 years for an international consulting engineering firm, got his MS from Purdue University in 1980. He taught at Oregon's Institute of Technology from 1980 to 1993 and in 1990/1991 spent sabbatical time at the University of Maine. In the 1980's and 90's he served two separate four-year terms as Editor of the ASCE Journal of Surveying Engineering and was self-employed from 1993 to 1998. He joined the faculty of the NMSU Surveying Engineering Department in August 1998 and was Chair of the ABET Applied Science Accreditation Commission during 2000-2001.