Analysis And Visualization Of Visibility Surfaces

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Biography

Physical Scientist, U.S. Army Engineer Research and Development Center, Topographic Engineering Center (1979-Present). Research interests in digital elevation models, cartographic modeling, cartography, and scientific visualization.

Introduction

Visibility assessment is a basic terrain analysis capability used in a wide variety of applications, from resource management and urban planning to crime mapping and military operational analysis. Current visibility products, including line-of-sight profiles and masked area plots, are limited in their ability to represent the overall visibility characteristics of the terrain. Line-of-sight profiles model point-to-point visibility, while masked area plots, also known as viewsheds, model point-to-area visibility. Neither line-of-sight profiles nor masked area plots provide information on the overall visibility characteristics of the terrain surface.

Researchers at the University of Edinburgh have expanded the suite of visibility analysis capabilities with the development of the Complete Intervisibility Database. The Complete Intervisibility Database stores masked area plot information for every point in a Digital Elevation Model, resulting in a sampling of information that characterizes visibility over the entire terrain surface. Details of the Complete Intervisibility Database computing architecture, construction process, and format are described in other publications (Mineter et. al., 2003; Mineter et.al., 2002a; and Mineter et.al. 2002b)

The Complete Intervisibility Database provides the source data for a suite of visibility surface analysis products. Descriptive measure products, such as cumulative visibility, cumulative visibility slope, fragmentation, core area visibility, and observer/neighborhood relations provide basic information about the visibility characteristics of the terrain. Tactical decision aids, such as, percent target visible and least/most visible route, go beyond basic measures to provide analyzed products for decision makers. Descriptive measure products and tactical decision aids are an initial attempt to characterize and analyze visibility surfaces.

Analysing And Visualizing Visibility Surfaces

The Complete Intervisibility Database aids researchers in developing a deeper understanding of the visibility characteristics of the terrain, as well as the relationships between terrain and intervisibility. Initial research has resulted in two classes of products, descriptive measure products and tactical decision aids.

Descriptive Measure Products

Descriptive measure products provide basic information on the characteristics of the terrain surface. Primary descriptive measures, such as cumulative visibility, fragmentation, and core area visibility are derived directly from an analysis of the Complete Intervisibility Database. Secondary measures, such as cumulative visibility slope and observer/neighborhood relations are derived from primary descriptive measure products.

Cumulative Visibility

Cumulative visibility records, for each point in the Digital Elevation Model, the total number of visible locations in the masked area plot associated with an observer at that point. The value can range from 1 to the total number of points in the Digital Elevation Model, with higher values indicating locations with greater visibility. Cumulative visibility is useful for rapidly identifying areas of low and high visibility and can be used as a cost surface for selecting most and least visible routes.

Cumulative Visibility Slope

Cumulative visibility slope measures, for each point in the Digital Elevation Model, the slope of the cumulative visibility values. The value can range from 0 to 90 if the slope is calculated in degrees, with higher values equaling steeper slopes. Cumulative visibility slope can be used to identify locations with sharp changes in visibility characteristics.

Fragmentation

Fragmentation records, for each point in the Digital Elevation Model, the total number of connected regions for the masked area plot at that point. Regions can be defined using 4-connected or 8-connected criteria. The lower value of this measure can equal, with higher values indicating locations with greater masked area plot fragmentation. Fragmentation provides an indication of the degree of connectedness of the masked area plots.

Core Area Visibility

Core area visibility records, for each point in the Digital Elevation Model, the total number of visible locations that are connected to the point. This core region can be defined using 4-connected or 8-connected criteria. The value can range from 1 to the total number of points in the Digital Elevation Model, with higher values indicating larger core areas. Core area visibility is used to measure the visible area extent adjacent to a location. Analysis of the result can identify locations where large areas can be

observed from the observer location, as well as areas with limited visibility from the observer location.

Observer/Neighborhood Relations
Observer/neighborhood relations characterize the similarity in coverage between each point in the Digital Elevation Model and its neighbors. The masked area plot for each point is compared against a masked area plot that represents the union of the masked area plots for its neighbors. Measures of the common visible area, area visible only from the point of interest, and areas visible only from the neighbors can be combined in a series of measures indicating similarity of coverage. One such measure is the ratio of the common visible area to the sum of the common visible area and the areas visible only from the neighbors. This gives a value between 0 and 1, where 0 represents no commonality and 1 represents complete overlap of the neighborhood visibility by the masked area plot of the point of interest.

Tactical Decision Aids

Tactical decision aids provide processed information that can be directly used by a decision maker. Production of a tactical decision aid may involve analysis of the Complete Intervisibility Database and/or use of a primary or secondary descriptive measure product, as well as additional user information.

Percent Target Visible
The percent target visible tactical decision aid calculates the percentage of a target feature that is visible from each point in the Digital Elevation Model. Point, line, or area target features can be modeled using a raster grid. The masked area plot for each point in the Digital Elevation Model is intersected with the target feature and the percentage of the target feature covered by the masked area plot is calculated. The values can range from 0 to 100, where 0 indicates that none of the target feature is visible, and 100 indicates that the entire target feature is visible. The percent target visible tactical decision aid is valuable for identifying optimal locations for viewing target features of differing sizes and shapes.

Least/Most Visible Route
The cumulative visibility surface can be used as a cost surface for determining the least or most visible route between two points. The least visible route can be calculated directly from the cumulative visibility surface, while the most visible route is calculated from a derived grid generated by subtracting the cumulative visibility at each point from the largest value in the cumulative visibility surface. The output of the route analysis is a grid with cells having a value of 1, if they are cells on the route, or 0, if they are cells not on the route.

Summary

The Complete Intervisibility Database extends the traditional visibility analysis models, line-of-sight profiles (point-to-point) and masked area plots (point-to-area), by storing masked area plots for every point in a Digital Elevation Model. This opens a new line of research related to visibility surface characteristics and properties.

The focus of the poster is on the descriptive measure products and tactical decision aids that exploit the Complete Intervisibility Database. The descriptive measure products provide basic measures of the visibility surface such as cumulative visibility, cumulative visibility slope, fragmentation, core area visibility, and observer/neighborhood relations. More sophisticated tactical decision aids, such as the percent target visible and least/most visible route, can be developed from the Complete Intervisibility Database and descriptive measure products. These products represent the beginning of a new generation research on visibility surfaces that will include the development of additional descriptive measures and tactical decision aids, as well as basic research into the relationship between terrain and visibility.

References

Caldwell, D., Mineter, M., Dowers, S., and Gittings, B. (2002) Explorations in Visibility Analysis: Applying ArcInfo in a Distributed Computing Environment. Poster, 22nd Annual ESRI User Conference.

Mineter, M., Dowers, S., Gittings, B., and Caldwell, D. (2003) High-Throughput Computing to Enhance Intervisibility Analysis. Submitted to GeoComputation 2003 for publication..

Mineter, M., Dowers, S., Gittings, B., and Caldwell, D. (2002a) A Multicomputing Software Environment for ArcInfo Intervisibility Analysis. Proceedings of the 22nd Annual ESRI User Conference. Redlands, ESRI.

Mineter, M., Dowers, S., and Gittings, B. (2002b) Software Infrastructure to Enable Parallel Spatial Data Handling: Final Technical Report. R&D 8707-EN-01 Contract N68171 00 M 5807. London: U.S. Army Research Office.