HOLISTIC GEOGRAPHICAL VISUALIZATION OF SPATIAL DATA WITH APPLICATIONS IN AVALANCHE FORECASTING

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ABSTRACT: Avalanche forecasters face ever increasing pressure to make more informed decisions and accurate predictions. Decisions often are made very quickly and face criticism from many different parties. Therefore, forecasters need a means to synthesize data efficiently and effectively. The development of a better support system for decision makers and avalanche forecasters by incorporating new methodology into time honored and proven methods is the goal of this research.

With the vast amount of data being produced, visualization is an improved and effective method for organizing, analyzing, and communicating complex data. This finding is supported by studies showing that the human mind assimilates complex information better when displayed graphically versus text-based or numerical representations. Effective visualization is presented in a manner that is consistent with the cognitive, perceptual, and response-based mental representations of the user.

This research develops a new method to visualize multiple spatial data sets that are factors in determining snow pack stability in an intelligible holistic form that maintains the contribution of each data set. The spatial visualization model synthesizes multiple qualitative and quantitative spatial data sets into a single, clear, more comprehensible representation without losing important information. The visualization method allows the user to drill down deeper or drill up to analyze individual data sets. In addition, a comparison technique is developed to compare a set of chosen parameters with historic data in order to determine similar historic analogs. The result is an intuitive software program that allows users to analyze multiple complex datasets through a graphical user interface. The success of this visualization model is based upon whether it provides any benefit to the avalanche forecasting process.

KEYWORDS: geographic visualization, avalanche forecasting, spatial decision support system

1. INTRODUCTION

Today, decision makers are faced with ever increasing pressure to make accurate predictions and informed decisions. This is especially true when forecasting natural hazards such as floods, fires, and avalanches. Natural hazards have a large potential economic impact and may be life threatening. Natural hazards forecasting require prompt decisions and face scrutiny from many different areas. These decisions are based upon data that is collected and presented in many different forms (i.e. text, tables, graphs, maps). In order to make sound decisions, decision makers need to synthesize data efficiently and effectively.

Accurate predictions are made by individuals who fully understand and comprehend the factors that contribute to the process being evaluated. Often, decision makers are presented with only a select subset of factors that someone else has determined as the most influential. In addition, these factors are usually presented in many different forms to the decision makers. For example, data presentations include text, tables, graphics, maps or even verbally. The human brain has difficulty assimilating large data sets from many different sources and at varying spatial scales. This research concentrates on developing a visualization method for spatial data that incorporates all of the factors considered in the decision making

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process in order to create a more holistic representation of the modeled process.

Avalanche forecasting is the chosen application area for the development of this visualization method. Creating a holistic visualization of the avalanche risk level will provide avalanche forecasters with a more complete and robust model of the snow pack. The hope is that forecasters will have the opportunity to make better decisions by offering an alternative method that is more holistic than current methods. This can potentially minimize the potential loss of life and economic impact involved in avalanche forecasting.

This research develops a method to visualize multiple spatial data sets that are factors in determining the avalanche risk of an area in an elegant holistic form that maintains the contribution of each data set. The spatial visualization model addresses and incorporates the following three scientific questions:

1. How are multiple qualitative and quantitative spatial data sets synthesized into a single, clear, more elegant representation without losing important information?

2. How are multiple spatial data sets presented in a holistic elegant form that also allow the user to drill down deeper or drill up if they choose?

3. How are the current conditions most accurately compared to historic conditions in order to present a historic perspective?

This paper presents a background for the research in Section 2. A description of the Little Cottonwood Canyon, Utah study area is included in Section 3 followed by the methodology used in the development of the holistic spatial visualization model in Section 4. And finally the paper concludes with a look at the expected results and contributions of this research.

2. BACKGROUND

One of the most effective ways to communicate data is through the use of visualization techniques within a spatial decision support system. Three distinct subfields, scientific, information, and geographic visualization, are at the forefront of computational science research. Scientific visualization is the interactive visual representation of scientific data to amplify cognition whereas information visualization is the visual representation of abstract data to amplify cognition (Card et al., 1999). Geographic visualization represents the interface between scientific visualization and cartography (MacEachren and Monmonier, 1992). Employing a combination of visualization techniques within a spatial decision support system provides decision makers with one of the most important and powerful tools needed to assist them in their decision making process. Not only is the data presented to them in a more cognitively compatible way, but they have the ability to explore and choose between a number of different alternative policies and plans.

Numerous visualization models display static information. A majority of these models visualize the final effect and do not include the individual factors that contribute to the change. Bermudez et al (2000) developed a new cutting edge visualization model to display physiological data in real-time while simultaneously providing a holistic view of the data set. In the model all the variables and the overall health of the person are visualized together.

Bermudez et al (2000) stressed simplicity in the design of the visualization model. Due to data set size, the level of graphic intensity, interactivity, real-time processing, and the desire to use the model on a PC platform required that a simplistic design be maintained in order for success. The use of geometric primitives and abstractions related to the fundamental laws of human perception allowed the design to remain simplistic in nature. The results from using this new visualization system have proven statistically significant over the use of traditional methods. By employing three dimensional data representation architecture to monitor the health of a patient, the user's recognition time of critical events is improved. Users are able to physically see variable interactions that they knew existed, but had not witness previously. In addition, several undocumented interactions were discovered through the use of the model (Bermudez et al, 2000).

Bermudez's model is very successful in providing a comprehensive understanding of physiologic states. However, when quantitative and detailed data is necessary, the model is less successful. The authors' assessment is that the model performed very well for rapidly detecting and diagnosing problems, but needs improvement when dealing with situations where quantitative information is necessary (Bermudez et al, 2000).

The research presented concentrates on extending the Bermudez research group's model by developing a visualization method for spatial data that incorporates many of the various forms of data being considered in the avalanche forecasting decision making process in order to create a more holistic representation of the modeled process.

3. STUDY AREA

The selected study area is located in Little Cottonwood Canyon of the Wasatch Mountains in Utah. Little Cottonwood Canyon is among the most active avalanche areas in North America. The Wasatch Mountains are in the intermountain climatic zone. This area combines the cold dry continental region of the Rockies and the warmer wet maritime zone of the Sierra Nevada and Cascade mountain ranges. This zone receives cold dry snow similar to the continental climate and deep snow depths typically associated with the maritime climate (Adams, 1996). This combination makes the area prone to high avalanche activity.

Avalanche control work in Little Cottonwood Canyon is carried out by three primary entities, Alta Ski Patrol, Snowbird Ski Patrol, and the Utah Department of Transportation (UDOT), and one secondary group, the Wasatch Powderbird Guides. The ski resorts, Alta and Snowbird, and the helicopter guide service, Wasatch Powderbird Guides, are located in the upper reaches of the canyon. The Wasatch Powderbird Guides are responsible for control work in the areas they are operating; this varies on a daily basis. Alta and Snowbird are the primary avalanche controllers on the south side of Utah State Road 210 (U-210), which runs up the center of the canyon. On the north side of U-210, there are thirty-six main avalanche slide paths that have the potential to hit the road (UDOT, 1987). Avalanche control work on the north side of U-210 is the responsibility of UDOT. In addition, there is consistent communication and interaction between the different avalanche control groups. The canyons high use by tourists, recreationists, skiers, snowboarders and backcountry enthusiasts makes the decisions by these groups even more important.

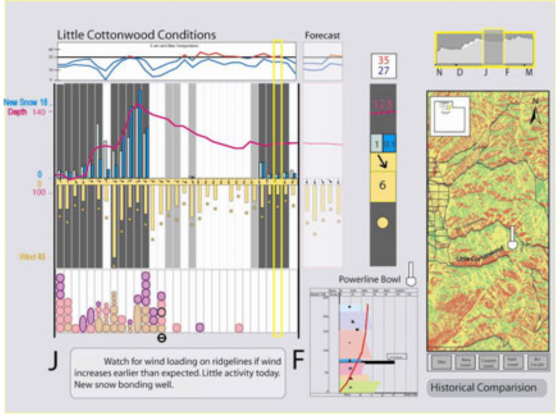
4. METHODOLOGY

4.1 *Data*

In avalanche forecasting there are a large number of variables that contribute to the overall stability of the snow pack. These variables are grouped into four basic categories: terrain, meteorological, snow pit, and avalanche occurrence data. Terrain factors include elevation, slope, aspect, and ground cover. Temperature, relative humidity, solar radiation, wind speed and direction, amount of precipitation, and total snow depth comprise the meteorological factors. The snow pit data set consists of the location, hardness, temperature, crystal type, density, and strength of each of the individual layers within the snow pack. The type, class, trigger, and the location of each individual avalanche combine to make up the avalanche occurrence data. All four data sets are stored in a third normalized form relational spatial database to prevent the replication of data, to eliminate inconsistent dependency, and ensure the integrity of the data sets.

4.2 *Holistic View of Current Conditions*

The holistic view is created by displaying each of the data variables as a unique feature. These unique features consist of geometric shapes, colors, and textures, which are easily differentiated by the forecaster in one holistic image. The holistic representation dynamically displays the changing data. The unique features assigned to the variables deform or "morph" depending on their measurement. The "morphing" of the features include changes in shape, position, or color. For example, a circle becoming more elongated along one of its axis with an increase in measurement or a rough texture may become smoother as its measurement decreases (Bermudez, 2000). By assigning features to the data variables, forecasters may view thirty days worth of daily data, as well as, get an overview of the entire winter in one image (see Figure 1). They can also get more detailed data for the selected day, maps of the area and the predicted avalanche risk.



Watch for wind loading on ridgelines if wind increases earlier than expected. Little activity today. New snow bonding well.

Figure 1: Example of Holistic View of Avalanche Forecasting

The visualization representing the holistic view of the current conditions provides an interactive interface to allow the forecaster to examine each individual variable, analyze the avalanche risk level, and to change the resolution of the data being displayed. This interactivity provides the forecaster a means to further examine the data that was highlighted in the holistic visualization.

4.3 Comparison of Current Conditions with Historical Data

A three-step approach is utilized in order to compare the current conditions with the historical data. Step One allows the user to select the number of days and rank the variables in order of importance for comparison. Step Two, the factors are entered into a nearest neighbor model, which selects the historical analogs that have the closest parameters to the current conditions. Lastly, the selected analogs are displayed visually along with the current conditions for the avalanche forecaster to review.

Step One:
To begin the historical comparison, users select the specific set of days they are interested in for comparison, between one and ten days. The user then ranks the variables for comparison from highest priority to lowest based upon what he/she is most interested in. For example, one could rank the factors wind direction, wind speed, new snow precipitation, and temperature from high to low. This selection would give wind direction the highest priority in finding similar days followed by wind speed and so forth.

Step Two:
The second step in the comparison process is to perform a nearest neighbor analysis using the days and factors identified by the user. The nearest neighbor method calculates the metric distance between the same variable in different analogs. The analogs that are considered the nearest neighbors are those with the shortest metric distance from the given analog. For this analysis, the variables are weighted according to their priority ranking as determined in the previous step. By weighting the variables, the nearest neighbor analysis is guided to return the cases with the closest values in the higher priority variables instead of returning cases which match very closely in lesser ranked variables. This provides a means for combining a number of variables in the nearest neighbor calculations. The nearest neighbors are then computed utilizing the entire database.

Step Three:
Visualization of the analogs is the final step in the comparison of current conditions to historical data. Following the nearest neighbor calculations, a user defined number of the closest analogs are displayed. The current analog and the selected returned analogs are displayed for the forecaster to visually compare and analyze. In addition, a visual scale indicates how close each of the variables within the returned analogs is to the current analog. This visual scale decreases the amount of time needed for the forecaster to analyze the different variables and provides a standard level of comparison for all the variables regardless of the weight assigned.

4.4 User Evaluation

At the time of paper submission, the user evaluation for the visualization model is not complete. Due to the University of Utah's close proximity to a large number of avalanche forecasters, the goal is to include many different forecasting groups in this evaluation. The model test will include back country users with varying levels of avalanche knowledge, as well as professional forecasters.

The user evaluation is three-fold. First, a standard form is created that addresses different aspects of the model. The objective of this form is to provide a baseline for comparison between the different evaluators. Forecasters complete the form and submit personal comments concerning the usability, graphical user interfaces, display methods, and the potential role of the model in their decision making and forecasting. The second part of the evaluation uses case scenarios where the forecaster uses traditional methods with and without the use of the visualization model. This will demonstrate whether or not the visualization model improved, degraded, or did not contribute to the forecaster's decision making. Thirdly, personal interviews with the forecasters are conducted. During these interviews, the forecasters will have the opportunity to identify their likes and dislikes of the model, and suggest improvements to or additional functionality desired in the model. The results of the user evaluations are analyzed to identify the potential contribution of the model in avalanche forecasting and decision making.

5. EXPECTED RESULTS AND CONTRIBUTIONS

As the effect of natural hazards increases with the rise in population, decision makers are increasingly faced with making difficult and controversial decisions. In order to make better predictions and decisions, an efficient and effective means to analyze data is needed. The goal of this research is to develop a new model for displaying spatial data that provides decision makers with a more comprehensive and holistic view of the situation.

Current avalanche forecasting practices incorporate large numbers of datasets in many different forms and locations when estimating present and future snow pack conditions. By creating a more holistic approach to forecasting, this model combines individual factors with historical data to present an objective view of the snow pack. The holistic approach reduces heavy reliance on the forecasters' experience and ability to synthesize large amounts of data. The model interface enables forecasters to see each factor, overall avalanche risk, and access the original raw data for additional in depth analysis.

To help development of a better support system for decision makers and avalanche forecasters, incorporation of new methodology into time honored and proven methods is the goal of this research. The determination of success for this research is based upon whether the avalanche forecasting process benefits by the use of this visualization model.

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7. REFERENCES CITED

Adams, R.J., 1996. Application of a Geographic Information System for the Modeling of Snow Avalanche Dynamics, unpublished M.S., thesis, Department of Geography, University of Idaho.

Bermudez et al, 2000. Data Representation Architecture. Visualization Design Methods,Theory and Technology Applied to Anesthesiology, *Proceedings of ACADIA 2000*, Washington DC.

Card et al, 1999. *Readings in Information Visualization: Using Vision To Think*, Morgan Kaufmann Publishers, Inc., San Francisco, CA.

MacEachren, A. M. and M. Monmonier. 1992. Geographic Visualization: Introduction. *Cartography and Geographic Information Systems* 19(4): 197-200.

UDOT – District Two, 1987. *Snow Avalanche Atlas: Little Cottonwood Canyon – U210*, UDOT, Utah.