A Real-Time 3D Visualization Framework for Multimedia Data Management, Simulation, and Prediction: Case Study in Geospatial-Temporal Biomedical Disease Surveillance Networks

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ABSTRACT

Geographic Information Systems (GISs), which map spatiotemporal event data on geographical maps, have proven to be useful in many applications. Time-based Geographic Information Systems (GISs) allow practitioners to visualize collected data in an intuitive way. However, while current GIS systems have proven to be useful in post hoc analysis and provide simple two-dimensional geographic visualizations, their design typically lacks the features necessary for highly targeted real-time surveillance with the goal of spread prevention. This paper outlines the design, implementation, and usage of a 3D framework for real-time geospatial temporal visualization. In this case study, using livestock movements, the authors show that the framework is capable of tracking and simulating the spread of epidemic diseases. Although the application discussed in this paper relates to livestock disease, the proposed framework can be used to manage and visualize other types of high-dimensional multimedia data as well.

Keywords: Biomedical Multimedia Simulation and Prediction, Geographic Information Systems (GISs), Multimedia Data Management and Visualization, Multimedia Forensics, Social Network Analysis

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INTRODUCTION

Multimedia data streams used in real world applications have been growing at an astonishing rate. Often, cross data streams are collected from different sources without obvious correlations. Integration typically generates data of high dimensionality, which needs further processing to be useful. Although computer systems and artificial intelligence techniques can assist data processing and, to a certain extent, replace human intensive procedural tasks, incomplete data records and insufficient input from domain experts still pose challenges and make it impossible to implement a fully automatic simulation and prediction system. The goal of our visualization framework is to present cross data streams collected from multiple sources in an interactive and intuitive format, so that domain experts can navigate within the visualization space and identify trends that would not have been discovered using traditional analysis techniques. As a result, data record irregularities can be rectified and important expert input can be built in as system parameters, so that sophisticated machine learning and data mining algorithms can be applied.

In addition to simulating, tracking, and predicting diseases, our framework can be applied to analyze financial data, e.g., currency and interest rate movements, which have important impacts on economies. In this case, the visualization network parameters include the flows of import and export, national and domestic consumer indices. The duration of political instability, natural and seasonal disasters, e.g., hurricanes and other storms can be additional factors affecting the network flows. Another example would be tracking the source-destination and responsiveness of message exchanges in social webs. The visualization framework can also be used to improve traffic movements, and thus city planning. Traffic patterns, which can be denoted by the number of vehicles passing a certain bottleneck, can be plotted along a time scale. The time of the day and day of the week, as well as holiday seasons, can be used as filtering parameters to visualize selected data sets. Residential dispersion can be used to refine the analysis further. Consumer preferences and purchasing patterns are important analytic criteria in grocery chains. Identifying associations between product sale quantities and other factors, such as weather, holiday seasons, pay days, etc., helps stocking and pricing. In general, the proposed framework is useful in modeling flows over geographical areas, communication networks, business networks and human disease spread. Note that one common characteristic among these applications is that data or information flows can be modeled using nodes and edges, and a value can be assigned to each edge to reflect the probability of occurrence.

Although we use geospatial-temporal biomedical disease surveillance in our case study, the visualization framework can be applied in many applications. Visualization helps the understanding of data by making use of our human visual system’s highly tuned ability and visual encoding, e.g., position, size, shape and color; to recognize patterns, identify trends, and discriminate exceptions, as well as making data more appealing to engage a larger audience in exploration and analysis (Heer, Bostock, & Ogievetsky, 2010). Observation and simulation of flows and trends are keys for proving scientific theories and discovering facts that the human brain would otherwise never imagine (Ailamaki, Kantere, & Dash, 2010). In response to these application demands, constant improvements of observational instruments and simulation mechanisms such as our visualization framework are launched in scientific research.

The rest of the paper is structured as follows: the Related Works Section reviews visualization and network analysis techniques; the Background Section introduces our case study and disease surveillance; the Design Section and the Implementation Section describe the challenges and technical details, as well as feedback from a case study. The final sections include the conclusion and describe future work.
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