A collaborative large spatio-temporal data visual analytics architecture for emergence response

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Abstract. The unconventional emergency, usually outbreaks more suddenly, and is diffused more quickly, but causes more secondary damage and derives more disaster than what it is usually expected. The data volume and urgency of emergency exceeds the capacity of current emergency management systems. In this paper, we propose a three-tier collaborative spatio-temporal visual analysis architecture to support emergency management. The prototype system, based on cloud computation environment, supports aggregation of massive unstructured and semi-structured data, integration of various computing model sand algorithms; collaborative visualization and visual analytics among users with a diversity of backgrounds. The distributed data in 100TB scale is integrated in a unified platform and shared with thousands of experts and government agencies by nearly 100 models. The users explore, visualize and analyse the big data and make a collaborative countermeasure to emergencies.

1. Introduction

With the development of obtainment measures of spatial data in a long duration, the amount of data volume, variety and velocity exceed the processing capacity of single computer and a single person. Collaborative visualization, the conflux of two growing areas of technology collaboration and visualization, provides people opportunity to easily connect and collaborate with one another through distributed networked computers, across mobile devices, or using shared displays such as interactive walls and table top surfaces [1, 2]. More and more scientific research and application are needed to deal more effectively with large amounts of spatio-temporal information while interactive visualizations allow users to explore the underlying data. In these applica- tions, spatial and temporal information is accessed by multiple people distrib- uted in different places in order to share information, to view it together, to interpret it solely, to analyse it, or to make decisions.

Unconventional emergencies are the disasters which lack sufficient omen, but produce potential secondary and derived harm to the physical world and human society [3-5]. Typical unconventional emergencies include natural disasters, production safety accidents, public health incidents and social security events. Unconventional emergency usually takes place in a burst and evolves in no time so as to make it difficult to be solved in real time. Massive heterogeneous information, which is involved with different specific domains and distributed in different geographical location, is produced in the evolution [6]. To deal with unconventional emergency efficiently and make quick re- sponse effectively, it is needed to process and manage massive data in different format from distributed organization in a short time. The increasing vol- ume, variation and velocity of emergency management data make the traditional visualization system fail to make timely response to
unconventional emergency. For example, more than 146 thousand people from 31 province and overseas were involved in searching and rescue in 5.12 earthquake of Wenchuan in 2008. The volume of geographic information data only provided by Shaanxi Survey and Mapping Bureau exceeded 1.2 TB.

In this paper, we propose collaborative visualization architecture oriented to unconventional emergency management (UEM). The remained section is arranged as below: after related works introduction in the second section, section 3 describes technologies of the newly collaborative visualization architecture. A application scenario implemented in UEM-cloud can be found in section 4 before a short conclusion in section 5.

2. Related works

Traditional visualization and visual analytics tools are typically designed for a single user interacting with a visualization application on a standard desktop computer [2]. As the problems that analysts face in the real world are becom-ing increasingly large and complex, not to mention uncertain, ill-defined, and broadly scoped, collaboration has been one of solution to the grand challenges for visualization and visual analytics. For a single analyst, it is not feasible to tackle the immense datasets that are now commonplace in the real world, where realistic problems often require broad expertise, diverse perspectives, and a number of dedicated people to solve. In addition, interaction with digital information is becoming a social activity, especially on the social web or on large interactive display technologies in public spaces.[7] From the perspective of application, the character of collaborative should include: 1) to bring together many experts so that each can contribute toward the common goal of the understanding of the object, phenomenon, or data under investigation[8]; 2) to control over parameters or products of the scientific visualization process is shared [9]; 3) to allow geographically separated users to access a shared virtual environment to visualize and manipulate datasets for problem solving with out physical travel[10]. In the latest years, distributed web-based information visualization applications have emerged with a focus on making information visualization accessible to an internet user.

![Figure 1 Three-tier collaborative visualization for emergency management](image)

3. Collaborative spatio-temporal data visualization platform

The traditional visualization system, usually being built in stand-alone system, integrated data model and representation into a single computer. This architecture works well when the data size is small; the computation complexity is low; and there is no need to integrate with multi data source to implement complex comparative analysis. In the cloud computing era, software is often encapsulated as a service. Service-oriented architecture provides a set of principles and methodologies for
designing and developing software in the form of interoperable services. In this paper, we design a three-tier services-oriented collaborative visualization architecture oriented to UEM based on Chinese Academy of Sciences. (Figure 1) Collaborative visualization benefits from three-tier architecture at least three aspects below: 1) Loose coupling among three parts makes it possible to distribute different visualization parts, like data storing, data modeling and data visualization, into different computer. Data can be distributed to different computation nodes; and distributed data can be visualized in the same visualization application. Loosely coupling architecture makes it feasible to use data throughput cluster to decrease the cost of disk I/O. 2) Visualization algorithms can be packed as web processing services and form a model library pools. That makes it feasible to make comparative visualization applications conveniently. 3) Independence from data storage and computation make the representation can be remotely deployed in different environment and support collaborative decision making.

3.1. Data tier of multi data source
Data tier is composed of data access services for multiple data sources (Figure 2). The key one is geographic data including basic geographic vector map and remote sensing images. The sequence data, which is from various sensors, provides the real time status of position where sensors locate. Social network reflect the dynamic of public sentiment when hazard outbreak. Textual data, which are used to transfer report, command and other broadcast information, can be viewed in collaborative visualization system after they are geocoded and transform to spatio-temporal events.

Figure 2 The structure of data tier
3.2. Model tier of model lib pool
As the diversity of visualization analytics algorithms and the result being produced by different algorithms show diversity from different perspectives. It is often needed to make comparative analytics using the same datasets. For single user, it is difficult to implement all the related visualization algorithms, even if some source code can be downloaded freely. Due to the structure of GPU and CPU, the same algorithm performs sharply differently in the two computation structure. The hybrid computation environment provides an option for user to choose the appropriate computation schema.

3.3. Represent tier with variant users of collaborative visualization
In collaborative visualization system, data and model sharing by different user is not the only goal (Figure 3). Collaborative working from distributed sites for the same task is more important. The collaboration takes place among users in at least three aspects: 1) users can view the visualization or analysis result produced by others; 2) users can control the same map view synchronously; 3) users can transfer textual command in the platform to specific person, unspecific person who visit specific location, or to all the users.

Figure 3 Variation of dataset and users with progress of earthquake scenario
4. Implementation in UEM cloud

Due to the demand of unconventional emergency management, we build a spatio-temporal collaborative visualization and analytics platform in UEM-cloud environment. We take big earthquake simulation as an implementation scenario (Figure 3). Due to shift of the most urgent task in different stage, the datasets and government departments involved in STCVAP change accordingly. For example, in the early stage of survey and assessment, aerial or sat-elite image of variant resolution and band is the main data processed in STCVAP. The key task of STCVAP is to process and visualize those data to provide remote experts of the Earthquake Administration Bureau to assess and make collaborative decision. But in the reconstruction stage, with the main task turn to help victims rebuild their home, the majority data in STCVAP shift to geological map for geological experts to determine suitable reconstruction sites. We simulate more than 1000 users visual analyse about 100 TB data to make collaborative decision simultaneously by employing nearly 100 models in a hybrid CPU and GPU environment deploying in UEM-cloud.

5. Conclusion

The collaborative visualization system shows larger and scalable capacity in data processing and user interaction, and support collaborative visual analytic for decision support to UEM.

Acknowledgments

The work is partially supported by China NSF under Grant 91224006, the Strategic Priority Research Program of CAS under Grant No. XDA06010202, "Twelfth Five-Year" Plan for Science & Technology Support under Grant No. 2012BAK17B01-1, the Special Project of Informatization of CAS in the Twelfth Five-Year Plan under Grant No. XXH12504

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