GeoDec : A Multi-Layered Query Processing Framework for Spatio-Temporal Data (Demo Paper)

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ABSTRACT
Harnessing the potential of today's ever growing and dynamic geospatial data requires the development of novel visual analysis interfaces, tools and technologies. In this paper, we present and demonstrate *GeoDec*, a generic framework capable of supporting queries and visualizations of real-world geospatial data sets. We show, for various locations and applications, how our innovative *Query Driven Design* enhances the visual analysis of geospatial data through the interactive manipulation of queries and query results.

Categories and Subject Descriptors
H.4 [**Information Systems Applications**]: Miscellaneous; D.2.8 [**Software Engineering**]: Metrics—*complexity measures, performance measures*

General Terms
Geospatial data, visual analysis, spatio-temporal interface.

Keywords
Geospatial, temporal, query, interface, architecture.

1. INTRODUCTION
A critical review of existing geospatial systems, reveals that none of the current designs is capabale of supporting the creation, formulation and execution of queries on currently available spatio-temporal data. It further appears, that to realize these capabilities, one needs 1) to advance how we ask sophisticated questions about spatio-temporal objects, and 2) how we design and architect these systems to handle and scale with existing static and dynamic data sets. In this paper we propose concrete solutions to these challenges by demonstrating 1) how to incorporate the temporal dependency of geospatial data in the application design, 2) how to define a geospatial *Visual Query Formulation* interface from a set of building blocks and 3) how to define a generic query workflow specifically adapted to geospatial data by adopting a *Query Driven Design*.

2. RELATED WORK
Current geospatial visualization systems fall in three main categories: i) Earth visualization (EV) platforms, as first envisioned by Al Gore [3], like Microsoft Virtual Earth or Google Earth that display geo-realistic 3D worlds created from aerial imagery, ii) Game-based systems, such as Half-Life 2 [4], SimCity [11] or Spore [12] that excell at rendering realistic simulated functional urban environments where *fictional data* analysis supports the game-play and iii) Geographic Information Systems (GIS), such as the ESRI family of products, that offer mostly query and analysis of static worlds. Geospatial visualization research projects specialize in specific areas: UrbanSim [14, 1] focuses on socio-economic modeling for city planning, the GeoVISTA Center [2] develops geo-visualization tools for decision making, and UCI RESCUE [13] targets crisis-response management. These systems propose targeted solutions that require specific software solutions to be created based on domain experts guidance. No one system has studied the fundamental ways of asking questions about the real world in space and time, and visualize the responses, in an effective and comprehensive way. The Infolab [10, 6] has developed a spatio-temporal information visualization and management system, dubbed *GeoDec*[1] (for Geospatial Decision-Making) [9]. In this paper we demonstrate a transformative evolution of GeoDec resulting in a generic system fully capable of dealing with spatio-temporal dynamic data.

3. GEODEC FRAMEWORK
3.1 Architecture
GeoDec adopts a three-tier architecture that makes the interface independent of the inherent data model and facilitates scalability by allowing several visualization components to specify queries and receive the results back in a *uniform language* hiding the source of information. We have named the three tiers as follows: *Negaah* is the Presentation Tier (see Figure 2) and includes the client applications,

[1] *GeoDec* includes large-scale sources of static and dynamic multimodal data: U.S. road network provided by NAVTEQ [8] with more than 15 layers of point data (e.g., transportation hubs, hospitals, etc.), satellite imagery, road vector data, maps, static and moving objects point data, 3D models, textures, video streams, etc.). Information on these databases and web-services is publicly available [5, 7].

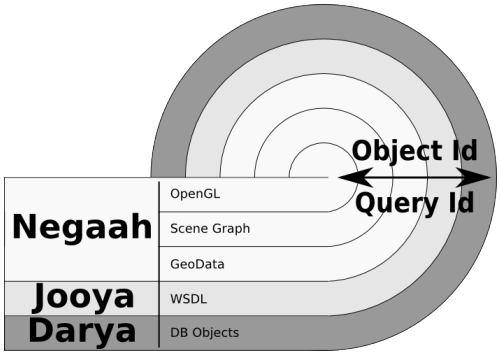

Figure 1: Query Encapsulation.

Jooya is the Web Services Tier and *Darya* is the Database Tier. Communication among the three layers in *GeoDec* is done through *Query Encapsulation* as shown in Figure 1: the data structures of present in Figure 1 are essential to support query interactivity as they allow to consistently map data to visualizations.

3.2 Query Creation and Manipulation

To define the visual query interface (2 in Figure 2) we rely heavily on the universal space and time coordinates to derive relevance between our objects. Therefore, our building blocks allow a user to ask a question about geospatial bounds and/or temporal intervals in a natural manner. Specifically, the formulation of a query involves determining five building blocks, namely Data Types, Query Type, Spatial Bounds, Temporal Bounds, and optionally Query Scheduling. There is no special order in this process as the user interface maintains consistency. Subsequently, we allow the user to interact further with the query result and formulate more queries. In particular, every object that is visualized in the system is selectable and can be used in new queries. Queries can be customized and merged in the *Query Result Panel* (3 in Figure 2). To support re-use of routinely used queries and promote collaboration user's queries are stored. To enable temporal navigation of query results GeoDec temporally tags all rendered objects and features a timeline (4 in Figure 2) designed by borrowing features found in current consumer and professional editing software. The timeline allows to visualize multiple query results at once by providing in context time clipping and time zooming capabilities.

4. DEMONSTRATION

The GeoDec demonstration presents live and recorded interactive sessions showcasing query operations of interest to various domains including security and sustainable architecture. Multiple geographical areas are featured including the USC Campus, downtown Los Angeles and part of the Shanghai Jiao Tong University campus.

5. CONCLUSIONS

In this paper have presented and demonstrated GeoDec, a framework that is able to consistently support geospatial queries on a virtualized location. We have described the benefits of our new *Query Driven Design* and discussed *GeoDec*'s architecture. We intend to pursue this work with

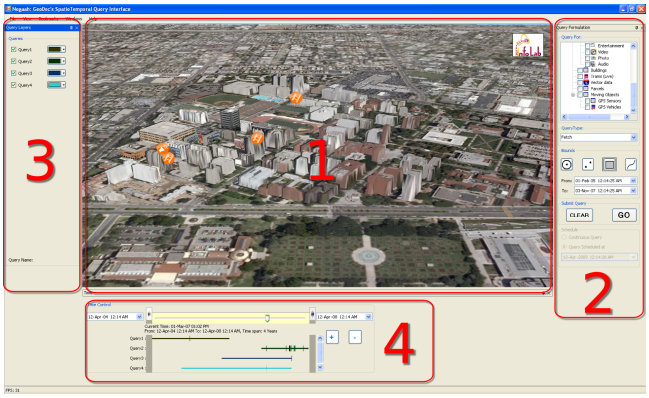

Figure 2: GeoDec's user interface: 1) rendering area, 2) query creation panel, 3) query results panel and 4) temporal navigation panel.

formal evaluations, investigate GeoDec's use in collaborative settings, and port it to mobile devices.

6. ACKNOWLEDGMENTS

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