Web 2.0 Geospatial Visual Analytics for Improved Urban Flooding Situational Awareness and Assessment

Yong Liu, David Hill, Luigi Marini, Rob Kooper, Alejandro Rodriguez, Jim Myers
National Center for Supercomputing Applications (NCSA)
University of Illinois at Urbana-Champaign
1205 W Clark St., Urbana, IL 61801
{yongliu, djhill1, lmarini, kooper, alejandr, jimmyers@ncsa.illinois.edu}

ABSTRACT
Situational awareness of urban flooding during storm events is important for disaster and emergency management. However, no general purpose tools yet exist for rendering rainfall accumulations in real-time at the resolution of hydrologic units used for modeling. This demonstration will exhibit a novel web 2.0 visual analytical approach for understanding and adaptively managing urban flooding issues. The approach generates a geospatial-temporal map of rainfall within urban hydrologic units (sewer-sheds) in real-time. The polygon-averaged rainfall data is generated using virtual sensors which provide customized real-time data products derived from National Weather Service weather radar data using NCSA’s workflow tools. Time-series KML (Keyhole Markup Language) layers are generated, where each KML layer represents a particular slice of the geospatial color-coded sewer-shed map. Such time-aware KML can be replayed as a movie in the web-based Google Earth environment. This geospatial visual analytic approach can provide decision markers and communities a powerful resource for assessment of neighborhood flooding issues. We will demonstrate our technology using historical and real-time rainfall data in the metropolitan Chicago area to show the effectiveness of such approach. Future work by combining additional ground-truth flooding data will allow us move towards real-time improved decision support for flooding and stormwater management.

Categories and Subject Descriptors
H.5.1 [Multimedia Information Systems]: Animation; H.4.2 [Types of Systems]: Decision support

General Terms
Design

Keywords
Web 2.0, Geospatial visual analytics, virtual sensor, animation, Keyhole markup language, workflow, rainfall, NEXRAD

1. INTRODUCTION
Urban flooding is responsible for the loss of life and property as well as the release of pathogens and other pollutants into the environment. Situational awareness during urban flood events can help focus emergency services and management to mitigate these effects. Several studies have shown that spatial distribution of intense rainfall significantly impacts the triggering and behavior of urban flooding [e.g. 1]. However, no general purpose tools yet exist for rendering rainfall accumulations in real-time at the resolution of hydrologic units used for analyzing urban flooding. This demonstration will show a new visual analytics tool that renders rainfall data from the NEXRAD weather radar system at the sewer-shed (i.e. urban hydrologic unit) scale in real time.

Geospatial visual analytics [2] holds great promise to provide useful tools for improved awareness and assessment during storm and flood events, and to support decision making for emergency management. In this paper, we introduce a lightweight Web 2.0 approach which takes advantages of scientific workflow management and publishing capability developed at NCSA, streaming data-aware semantic content management repository, web-based Google Earth/Map and time-aware KML (Keyhole Markup Language) to render and animate the rainfall accumulation at the sewer-shed level.

2. BACKGROUND AND RELATED WORK
Previously, we demonstrated the derivation of rainfall accumulations at specified point locations from NEXRAD radar image streams using point-based virtual sensors [3]. However, in order to render rainfall at the sewer-shed scale, it is necessary to extract the NEXRAD radar pixels that compose the geospatial polygons representing the sewer-sheds. This is done through a series of spatial, temporal and thematic transformations, which are implemented as workflows, to derive the polygon-based virtual sensor which computes sewer-shed-averaged rainfall measurements from raw NEXRAD reflectivity measurements.

Due to the complexity and heterogeneity of spatiotemporal dynamic systems, visualizing spatiotemporal data and managing the model-based transformation and synthesis is not satisfying. This was well acknowledged in [4]: “there is no GIS software capable of end-to-end support of spatiotemporal analysis and modeling for general purposes.” Geospatial visual analytics is an emerging multidisciplinary area which supports analytical reasoning and decision-making through interactive visual interfaces (such as maps and other visual artifacts) that are linked to computational methods [2]. Such approach has not been previously applied to improve near-real-time rainfall accumulation estimation and visualization at the sewer-shed scale.

3. SYSTEM IMPLEMENTATION
This geospatial visual analytics system is built on top of NCSA’s Digital Synthesis Framework for Virtual Observatory. Most im-
portantly, we use streaming data or historic data from a stream-oriented semantic repository, multiple coordinated workflows running on a Virtual Machine farm and a web 2.0 front-end displaying time-aware KML data using Google map/earth. Such general, lightweight and loosely-coupled framework is a major advantage of this system implementation.

3.1 Streaming Data and Stream-oriented Semantic Repository

Streaming data is managed and indexed by NCSA’s streaming middleware toolkit\(^1\), which can continuously fetch the near real-time NEXRAD Level II data from the LDM (Local Data Manager)\(^2\) distributor at the University of Illinois. The semantic repository is managed by the Tupelo\(^3\) semantic content middleware.

3.2 Multiple Coordinated Workflows

A set of scientific workflows are implemented using NCSA Cyberinteg\(^4\)r\(^5\) workflow system. These workflows run the online spatial, temporal and thematic transformations using the NEXRAD radar data to derive polygon-based virtual precipitation sensor defined by the sewersheds. The published workflows are accessible through RESTful (Representational state transfer) web services, through which on-demand generation of time-aware KML animation is possible. The entire system is hosted on a Linux-based virtual machine farm. A rolling purge is used to dispose of data older than four weeks to preserve storage capacity.

3.3 Time-aware KML Animation

There are many popular mapping formats (e.g. shapefiles), but few support the concept of time. GML (Geography Markup Language) supports various time concepts, but is not suitable for our visualization purpose. Open Geospatial Consortium’s KML\(^6\) standard supports time stamp, time span and network link updates for time-based geospatial annotation and animation. It is a considerably lightweight approach to present the status of the rainfall accumulation in the sewersheds as well as the animation. A major advantage of time-aware KML is that it does not demand the animation time interval be equidistant.

Figure 1. A Geospatial Visual Analytics for exploratory analysis of precipitation accumulation at the sewersheds level in the greater metropolitan Chicago region. Different color represents different level of rainfall accumulation for each polygon-based sewershed.

4. A DEMONSTRATION CASE

The demonstration of our geospatial visual analytics prototype is shown for a use case where different stakeholders need to have a better understanding of rainfall distribution at the sewershed scale in the Chicago metropolitan area. The polygons that delineate the sewersheds in the system are defined by a KML file that has been provided by the City of Chicago Department of Water. When a user comes to this web site, he/she will be able to see the latest and most up-to-date color-coded rainfall accumulation map for the sewersheds (see Figure 1). There is also an option for users to view an animation of the past several hours (in accelerated time) which will illustrate the rainfall dynamics in space and time.

5. CONCLUSIONS

This paper demonstrates a prototype geospatial visual analytics system for urban rainfall accumulation mapping and animation using polygon-based virtual sensor data stream derived from near-real-time NEXRAD radar data. By using a Web 2.0 mashup and lightweight time-aware KML at the visualization layer, combining with the backend stream-oriented scientific workflow management and publishing capability and computational power, we allow users to visually interpret how much rain has fallen in a particular neighborhood during a storm event in near real-time, a necessary first step towards supporting decision making for flooding and emergency management. We envision future work will allow other ground-based geo-referenced data sources such as basement flooding events and combined sewer overflow events data to be co-presented in such geospatial context, further demonstrating the power of geospatial visual analytics and improving the urban stormwater management.

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7. REFERENCES


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