MC2 - SUA: A Sensor Uncertainty Analysis Tool of Radiation Measurement Data (VAST Challenge 2019 Award - Integrated Tool with Rich Data Encodings)

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Figure 1: User interface of SUA.

Abstract

The effective analysis of data collected by mobile sensors and static sensors deployed in cities is a great challenge, due to the spatiotemporal characteristics and uncertainty. To meet the challenge of VAST 2019 Mini-Challenge 2, SUA, an interactive visual analysis tool with a novel uncertainty glyph is designed. The tool provides a clear understanding of conditions in the city by visualizing the trajectories, the measurements, as well as the uncertainty of the sensors, and supports an overview-to-detail visual reasoning process. The rich data encodings and interactions help users solve the questions effectively.

Keywords: Uncertainty, visual analysis, sensors, radiation measurements

1 Introduction

Mini Challenge 2 of the VAST Challenge 2019 presented researchers with a fictitious scenario that was surrounding a five-day nuclear radiation monitoring in an island country, St. Himarks, which was hit by an earthquake. The goal of the challenge was to give the St. Himarks emergency management team a better understanding of conditions in the city and to identify potential locations of contamination, with the help of radiation measurements provided by static sensors in the city and mobile sensors on vehicles. In addition to visualizing spatiotemporal trajectory data, the uncertainty of sensor measurements needs to be fully considered.

Motivated by the above goal, we designed SUA, an interactive visual analytics tool, to allow emergency management team to master conditions in the city quickly. The tool contains six views that are linked to each other, supporting an overview-to-detail reasoning process. The overall views clearly summarize the situation within five days from time and space perspectives, while detail views provide explanations for our findings. Particularly, a novel uncertainty glyph was designed to provide an intuitive visual assessment of the uncertainty for sensors or regions.

2 Visual Design

As shown in Figure. 1, SUA contains six major views. The Sensor Matrix View (Figure. 1C) gives an overview of measurement changes for all the sensors over time, by which users can discover events of interest. The Trajectory View (Figure. 1B) describes sensors in the spatial perspective with a map. The animation is added for exploring events in a range of time. The Grid Summarization View (Figure. 1A) provides an intuitive visual assessment of each region. Potentially regions of contamination can be clearly identified with simplified uncertainty glyphs and background colors. The Sensor Projection View (Figure. 1D) depicts the various patterns of the sensors, with the help of an improved MDS. The Temporal Variation View (Figure. 1E) provides a detail description of sen-

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sor measurements at finer time granularity. The Detail Inspection View (Figure. 1F) gives a comprehensive portrait of a sensor or a grid. Rich interactions connect these views together to supporting an overview-to-detail reasoning process.

2.1 Uncertainty Glyph

To measure uncertainty accurately, we divide both the time range and the space region. For the time range, a time interval is one hour. As for the space region, we introduce the grid to take the place of the administrative district. Subsequently, uncertainty can be measured on a smaller scale(e.g., one hour in a grid).

We introduce the uncertainty of sensors to determine whether a sensor has completed the task of measurement accurately within all the five days. This kind of uncertainty is quantified for two indicators: consistency and missing.

Consistency: Consistency is used to represent the difference in multiple measurements of the same sensor in a grid over a time interval. We model the difference with Gaussian distribution. Mean and standard deviation are extracted to measure uncertainty. High standard deviation means low consistency. Note that if a mobile sensor passes two grids in one hour, it can generate two Gaussian distribution, we average the mean and standard deviation of these two distributions.

Missing: Missing values are used extensively to measure sensor uncertainty. One sensor is usually considered to have high uncertainty if it is often missing. For the purpose of visualization, we use the number of measurements to represent the missing, which means the total number of sensor readings in an hour.

As for uncertainty of regions, we measure it by two similar indicators. The difference is that when constructing the Gaussian distribution, we use the measurements from all sensors in the region in an hour.

In order to provide a comprehensive uncertainty portrait for a sensor or a region, we designed a radial uncertainty glyph with rich visual encodings. Standard deviation, mean, number of measurements, and the distribution of measurements for each time step are represented by rings from the outside to the inside. Particularly, for the mobile sensor, cyan-blue borders are added to distinguish whether the sensor is moving.

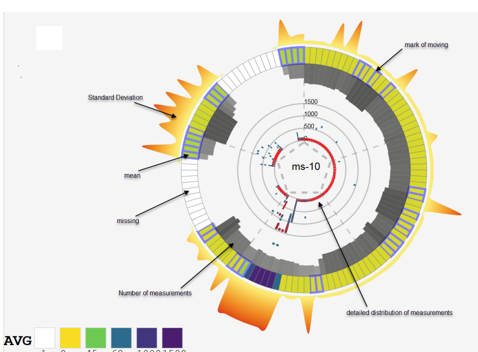

Figure 2: Uncertainty glyph.

2.2 Sensor Matrix View

This view in which each rectangle is colored according to the level of average measurements in an hour is designed for visualizing radiation measurements over time from both static and mobile sensors. Two visual enhancements are implemented to make the view expressively.

Layout: Instead of simply arranging the sensors in order of name on the vertical axis, we use MDS to project the 59 sensors to 1D, based on similarity in radiation measurements over time. We employ an improved distance function to calculate the similarity between sensors. We calculate the Euclidean distance of the mean if two sensors have measurements at a certain time step. But if one of the sensors is missing for an entire hour, we add a penalty for the distance. Missing is paid more attention by this distance function. Arranging similar sensors together helps to discover local features.

Statistics: We add a bar chart attached to the matrix view, which can provide an overview of the mean value for each row or column. Time steps or sensors with high radiation measurements can be captured clearly.

A range of time and a group of sensors can be selected by brushing, after which other views are linked for further exploration.

2.3 Grid Summarization View and Sensor Projection View

Both the two views provide intuitive visual assessments for the uncertainty using a simplified uncertainty glyph in which detailed distribution is omitted to reduce visual clutter. Grid Summarization View gives an effective contrast for grids in space, while Sensor Projection View focuses on the difference in timing of sensor measurements.

In Grid Summarization View, each Grid is described by a simplified uncertainty glyph. For the background, we use the max function as our aggregation criterion, which means the background of each cell is colored by the max measurements of all the 120 timesteps. The potential locations of contamination can then be quickly identified.

In Sensor Projection View, we employ a projection method similar to improved MDS in Sensor Matrix View,and the difference is that we project the sensor to 2D for a clearer visual expression. Static sensors and mobile sensors are represented as purple and black respectively. Some sensor patterns of interest can be identified taking into account both coordinates and uncertainty glyphs. Clicking can be performed for any grids or sensors, and other views will provide more detailed context information.

2.4 Trajectory View and Temporal Variation View

The main goal of these two views is to provide sufficient context information for the analysis process. Compared with other views, they have finer time granularity. Trajectory View shows the spatiotemporal characteristics of sensors with the help of animation. In this view, a circle represents a sensor, and the radius and color of the circle together indicate the magnitude of the measured value. After selecting a period of time by dragging the control bar or brushing in the Sensor Matrix View, users can have a clear understanding of conditions in the city, especially the movement of the sensors, such as the departure of the vehicles. Temporal Variation View employs polylines to show measurement changes for the selected sensors. Note that a grid is selected means that all sensors passing through this grid are selected. Demonstrating measurement changes over time of these sensors will help to understand the events of interest that occur in the region.

3 Conclusion

We develop an interactive visual analytics tool with a novel uncertainty glyph, which can give the emergency management team a clear understanding of conditions in the city by visualizing the trajectories, the measurements, and the uncertainty of the sensors. In future work, we will extend this tool to better handle the dynamic stream of data for identifying abnormalities quickly.

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