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Assessment of an Exploratory Spatial-Temporal data method: hypothesis finding of electric vehicle charging patterns

Abstract

Over the last decade several researchers developed software tools to explore spatio-temporal data. However, current Exploratory Spatio-temporal Data Analysis (ESDA) tools show limitations: they often use aggregated data, static time frames, visualize only one or two attributes and they anonymize space. Improving human visual-cognitive and analytical capacities in the exploratory phase, we develop an ESDA tool which enables the user to interactively explore by a dynamic multivariate visualization of spatio-temporal point data. The tool combines the plotKML R package and the Google Earth (GE) interface environment. The assessment used the electric vehicle (EV) charge session data from the municipality of Amsterdam, the Netherlands. Users of the ESDA tool were asked to generate hypotheses on *"why there?"* and *"why then?"* by using this ESDA tool. Results showed that users were able to generate such hypotheses. The ability of the GE interface to visualize day-night transitions is unique and proved very useful. The assessment showed some limitations of the methodology, such as time constraints and the need for an aggregated (over)view. Since the amount of spatio-temporal data is expected to grow in the future, the current geo-visualization need additions like roll-up and drill-down options to allow the user to switch from the more general (over)views to more individual EV charging objects.

Key words: *exploratory spatial data analysis, geo-visualization, spatio-temporal data, plotKML, Google Earth, electric vehicle charging.*

1 Introduction

Much of the research that applies mapping as a tool follow the same steps: map (visualize), explore (look), discover patterns (see), relate findings to the spatial environment (link) and formulate hypotheses (think). Over the years, the way we explore and interact with spatial data has changed, transitioning from paper maps to mapping in the digital environment (Roth, 2012). This transition increased the range of possibilities enormously.

1.1 Exploratory Spatial Data Analysis

Exploratory Spatial Data Analysis (ESDA) combines the techniques of Exploratory Data Analysis (EDA) with spatially referenced data (Carr et al., 2005). It combines the power of computers and GIS with the visual analytical strength of humans in order to highlight spatial similarities or spatial heterogeneity (Andrienko et al., 2003). More recently, researchers have tried to integrate the temporal dimension of spatial data in these ESDA's, such as time sliders (Pebesma, 2012).

1.2 Problem definition

Current ESDA's on spatio-temporal point data have certain limitations with regard to the exploration of this data: (1) Spatio-temporal point data is often aggregated; (2) the number of object attributes that can be visually explored simultaneously in space and time are often limited to one or two and (3) they anonymize the spatial dimension, which removes the analyst's capabilities to recognize the detailed characteristics of the physical environment.

1.3 Objective

The thesis research describes the development and assessment of a new ESDA method that makes better use of human visual-cognitive and analytical capacities in the exploratory phase of data analysis. An ESDA method was developed, which enabled the user to interactively explore a dynamic multivariate geo-visualization of spatio-temporal point data; visualized in a highly detailed and information rich spatial environment.

2 Methodology

An ESDA tool was developed based on criteria formulated scientific literature on exploratory (spatial) data analysis. As case study data for the assessment of the new ESDA method, this research uses the electric vehicle charge session data of Amsterdam, the Netherlands, of January 2013. An asynchronous online group session was held to test the ESDA tool. The resulting hypotheses -derived from the geo-visualisation- were compared to the actual charge session data. Furthermore the hypotheses were crosschecked with experts in the field of EV charge infrastructure. This gave an indication of the potential of the ESDA tool to generate hypotheses on spatio=temporal phenomena.

3 Results

3.1 The ESDA tool

Google Earth (GE) functioned as the graphical user interface (GUI) for the ESDA. GE has a huge quantity of geographical data (place names, street names, borders and commercial places of interest) and has rich interactive features (time slider, day and night visualization, the adaptation of the viewpoint, the selection and extraction of data, Street View). This allow the user "to relate the phenomenon being studied to the specific geographic area and related features" (Compieta, 2007).

With building blocks from the plotKML package (Roudier & Beaudette, 2015a) a function was created function that did the data pre-processing and parameters setting in one. The charge session dataset used for this research shows public charge point data from the municipality of Amsterdam. The combination of the geo-visualisation and the GE user interface will be referred to as the ESDA tool.

3.2 Hypothesis finding

Looking at the user hypotheses, the last step in Roth's Stages of Interaction model was rarely made. Most hypotheses were based on the perception of the state of the geo-visualization (*seeing that)* and rarely on the interpretation of the state of the geo-visualization (*reasoning why*). Looking at the content of the hypotheses, the hypotheses can be described as observations. Only a few students related their observations to the spatial context information of GE.

The tool allowed the user to select the representation of the data by sliding through time and disabling/enabling layers to display. The danger occurs that not all users are aware which layers are visualized when they generate their hypotheses. Analysis of the results showed that in some cases potential proof for the hypotheses cannot be found in the dataset as a whole, but can be found in some individual weeks. E.g. the hypothesis that on Saturdays many efficient charge sessions occur, was observed by multiple users. This could be found in the data of certain weeks, but is not confirmed by the data of the whole month. It is unclear whether the user was consciously aware of which data was visualized in the ESDA and which data was not, when he/she came up with the hypothesis.

4 Conclusion and discussion

The combination of a geo-visualization of spatio-temporal data and the GE virtual globe environment has a high potential to become a successful ESDA method in the field of scientific geo-visualization. From feedback by the users it was concluded that the tool needs semantic zoom options (roll- up/drill-down) and query possibilities in order for the user to more specifically identify and compare spatio-temporal map objects. The users frequently wanted to compare space (just two charge stations), a particular time interval (every morning of every day) or a certain variable (sessions larger than 10 kWh). The representation of individual charge sessions provided a visual overload of information for some of the users. With the growth of EV charging in mind, semantic zoom and query options need be added in order to still be able to visually execute the exploratory tasks of identifying and comparing map objects, like EV charging poles,, as defined by Andrienko et al. (2003).

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