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Data Visualization for Urban Planning and Modeling

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1. Introduction and Problem Definition

As an ever-growing field since the 1950s, computer-based data visualization is multidisciplinary in nature and its development has been driven by a variety of factors. In the 1950s, these factors are the exploratory data analysis (EDA) advocated by John W. Tukey, the monumental book *Semiologie graphique* published by Jacques Bertin and the introduction of computers into statistical data processing (Friendly, 2008). In the 1980s, the factors like the digitalization of data in both pubic and private sectors, the emergence of Internet, and the rise of Geographical Information Science (GIS) stimulated the rise of information visualization and geovisualization. After entering the new millennium, the field of visualization becomes increasingly diverse, as evidenced by the pop-ups of new tools, new platforms, new ways of data representation and the applications in miscellaneous respects of our daily lives.

Data visualization techniques have been playing an important role in the context of urban planning and modeling. It will become increasingly so when the researchers and planners start to be challenged by rapidly accumulated spatiotemporal information, more complicated modeling process (e.g. activity based modeling), and a growing demand for the involvement of stakeholder at the different stages of planning process. What types of visualization techniques or tools are needed to address these domain specific challenges? How can the complex data (e.g. spatial-temporal data, network data, etc) be presented to facilitate exploratory analysis and decision making? What roles will the selected visualization tools play in the process of planning and modeling in terms of analytical reasoning, knowledge discovery and dissemination, as well as communication and collaboration among stakeholders? These are the questions I intend to investigate in my research.

2. Theories

For the community of visualization, one of the major unsolved problems is the lack of a systematic theoretical foundation (Johnson, 2004). The theories used to support visualization are mostly from other disciplines, ranging from the cognitive science to semiology, from computer graphics to cartography. Here, I briefly touch on several theories form the perspectives of visual cognition and information visualization.

2.1 Visual cognition

To understand the function or the importance of visualization, one should first have a sense on how human process visual signals to derive meaning. According to the cognitive experimentalists, human eyes perceive the sensory input and temporarily store the visual information in a place called iconic memory for a very short time. Part of the information is then selectively passed to working memory, which is a short-term memory responsible for linking incoming information with the domain knowledge saved in the long-term memory to interrogate the information and derive meaning from it (Zhu and Chen, 2008). Ware (2002) argued that visualization is able to augment working memory in two ways: memory extension and visual cognition extension. Because the working memory can load visual input at the same speed as loading internal memory (Kieras and Meyer, 1997), visualized information does not need to be stored in the working memory in the process of problem solving. Meanwhile, visualization facilitates the perception process by reducing the load of reasoning and mental image construction, which enables brain to focus on querying domain knowledge and generating solution.

Further, there are two main psychological theories explain the perceptual process of visual signals. The preattentive processing theory illustrates the type of visual features that can be effectively processed. The Gestalt theory describes some principles used by our brain to understand an image (Ware, 2002). These theories provide important guidelines for visualization interface design and human-machine interaction.

2.2 Information theory

Information visualization developers are more concerned with how to effectively convey information embedded in data to observers. Purchase et al (2008) advocated the predictive data-centered theory, which aimed at establishing a framework matching pattern typology that users are potentially interested to various types and structures of data. For example, for a temporal dataset, it may contain linear, fluctuated or cyclical patterns. Besides, users may also be interested in the properties like peak, valley, stability and trend. Establishing a pattern-by-data typology like this not only help users to select the right visualization tools for their data, but also facilitate tool designers to understand the type of analysis that users will conduct.

In attempt to compare and evaluate visualization tools, Purchase et al (2008) also proposed to employ concepts from the theories of data communication to quantify the amount of information transferred or lost at all stages of the visualization process. They suggested this approach will be especially useful if the visualization process involves data reduction techniques like clustering or distortion techniques like cartogram by making explicit about the tradeoff among the speed of rendering, the accuracy of representation and visual clarity. However, they also acknowledged the difficulty in distinguishing the part of data that are more informative from those that are featureless to the observers since the information been perceived is very specific to each individual observer.

3. GIS based Visualizations of Activity-travel Patterns

One barrier to the activity-travel study is that the abundant information contained in new data source like GPS traces or smart card, and the intertwining relationships of multi-facets of activity-travel patterns prevent the data and modeling results being examined thoroughly. Therefore, there is an urgent need for effective exploration tools to assist in understanding daily activity-travel patterns and interpret the spatiotemporal associations among activities, trips and urban forms.

Ideally, exploratory visualization tools should not only provide an overview of the data, but also allow exploration at a variety of geographical and temporal scales, because both the overall urban dynamics at the city level as well as the built environment at the neighborhood level are important for comprehending the decision making process of individuals. In addition, the tools should be equipped with the functions of filtering and querying, which facilitate drilling down into the data and exploring details on demand. More specifically, the visualization tools must present individuals' activity trajectories together with the concrete built environment information such as land use and transportation network as well as the socio-economic attributes of the individuals like employment status and income level. In this context, the challenges are not just on the presentation of spatiotemporal information, but also on the management and processing of big data, as well as the usability and interaction forms of the tools.

4. Readings and Discussion Questions

Readings:

Batty, M. P. Steadman, P. and Xie, Y. (2006) Visualization in Spatial Modeling. In J. Portugali (ed.) *Complex Artificial Environments*, Springer, Berlin, 49-70.

Daniel Keim, Gennady Andrienko, Jean-Daniel Fekete, Carst
on. Visual analytics: Definition, process, and challenges information visualization. In Andreas Kerren, John Stasko, Jean-Daniel Fekete, and Chris North, editors, *Information Visualization*, volume 4950 of Lecture Notes in Computer Science, chapter 7, pages 154–175. Springer Berlin / Heidelberg, Berlin, Heidelberg, 2008.

Optional Reading:

Cheshire J, Batty M, 2012, "Visualization tools for understanding big data" Environment and Planning B: Planning and Design 39(3) 413 – 415

Discussion Questions:

1). According to the authors of "Visualization in Spatial Modeling", what are the benefits of using visualization in spatial modeling? What types of visualization tools do you use in your research or work? Which aspects (features) of the visualization tools are most helpful to you?

2). Urban planning is a data rich field and increasingly become so as new data sources like urban sensing and crowdsourcing start to be exploited. This trend my help to reveal the functioning or cities at a finer spatial-temporal level but also may bring the problem of information overload. What is the opportunity of visualization in this research frontier? Among the following three ways of representing spatiotemporal data, which one do you think is more suitable for the exploration and analytical reasoning purpose:

a. 3D cube: in additional to the 2D map, time is represented as a third dimension in the geographical space

b. Multiviews: multiple maps with one map corresponding to one discrete time step

c. Animation

5. Other References

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Friendly, Michael. A Brief History of Data Visualization. Handbook of Data Visualization. Editors: Chen, Chun-houh, Härdle, Wolfgang, Unwin, Antony. 2008. Springer Berlin Heidelberg

Jean-Daniel Fekete, Jarke J. Wijk, John T. Stasko, and Chris North. 2008. The Value of Information Visualization. In *Information Visualization*, Andreas Kerren, John T. Stasko, Jean-Daniel Fekete, and Chris North (Eds.). Lecture Notes In Computer Science, Vol. 4950. Springer-Verlag, Berlin, Heidelberg 1-18.

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MacEachren, A.M.; Gahegan, M.; Pike, W.; Brewer, I.; Cai, G.; Lengerich, E.; Hardistry, F.; "Geovisualization for knowledge construction and decision support," Computer Graphics and Applications, IEEE , vol.24, no.1, pp.13-17, Jan.-Feb. 2004

Nahum Gershon, Stephen G. Eick, and Stuart Card. 1998. Information visualization. *interactions* 5, 2 (March 1998), 9-15. DOI=10.1145/274430.274432

Purchase, H.C., Andrienko, N., Jankun-Kelly, T.J., and Ward, M. (2008) *Theoretical foundations of information visualization.* In: Kerren, A., Statsko, J.T., Fekete, J.D. and North, C. (eds.) Information Visualization: Human-Centered Issues and Perspectives. Series: Lecture notes in computer science (4950). Springer, pp. 46-64.

Ware, Colin. Information Visualization: Perception for Design. Second Ed. Morgan Kaufmann. 2002.

Zhu, Bin and Hsinchun Chen. Information Visualization for Decision Support. Handbook on Decision Support Systems 2 International Handbooks on Information Systems, 2008, X, 699-722, DOI: 10.1007/978-3-540-48716-6_32