Learning from the Users for Spatio-Temporal Data Visualization Explorations on Social Events

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Abstract. The amount of volunteered geographic information is on the rise through geo-tagged data on social media. While this growth opens new paths for designers and developers to form new geographical visualizations and interactive geographic tools, it also engenders new design and visualization problems. We now can turn any kind of data into daily useful information to be used during our daily lives. This paper is about exploration of novel visualization methods for spatio-temporal data related to what is happening in the city, planned or unplanned. We, hereby evaluate design students' works on visualizing social events in the city and share the results as design implications. Yet we contribute by presenting intuitive visualization ideas for social events, for the use of interactive media designers and developers who are developing map based interactive tools.

Keywords: Geographical information visualization · Volunteered geographical information · Event-maps · Spatio-temporal data · Interaction · Visualization · Design ethnography

1 Introduction

Volunteered geographical data opened cartographers and mapmakers a path of many possibilities of creating meaning out of different datasets from different sources [1]. Now, with the help of social media applications like Foursquare or Facebook, we can reach the metadata of events' location, time and topic, volume of the event that is happening in the city or comment and media of them with Twitter or Instagram. And since we can also reach the data from remote sources like weather data or traffic data, now it is the time that new questions arise. How can we visualize all this multi-layered live data in a legible way so that people can read them together, to create meaning for public to make decisions, plan, act or react about any kind of activity in the city?

The amount of spatio-temporal data has raised, causing the only field that is related to visualize spatio-temporal data, cartography, to evolve into something more inter-disciplinary, mapmaking. This new field has its roots from cartography, but with the common use of interactive maps, it is now more interdisciplinary including disciplines like interactive media design, graphic design and software development, city planning.

It is now an open area for more people to create new meanings and new ways to present this widely available spatio-temporal data.

Now we are at a point in time where we try to represent new types of data that we would not achieve before, using the old ways to visualize. This might cause the map makers to create maps that are less engaging and harder to read. This paper is our way of exploring spatio-temporal data visualization ideas and intuitive visual patterns for spatial movement and event data. Presenting movement and event data in the city in a legible way might be a very challenging task for a designer. Yet, it also can be highly useful for supporting daily decision making processes of public (Fig. 1).
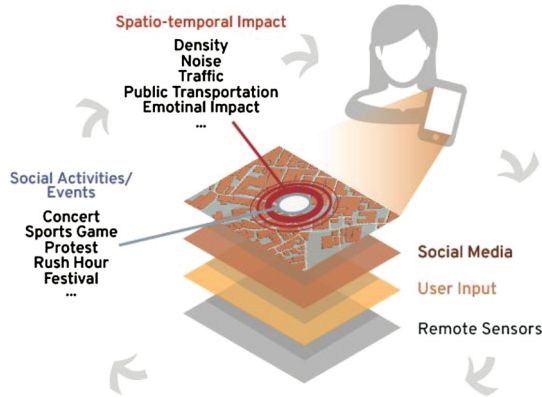

Fig. 1. Diagram of our motivation, sources and visualization layers of a hypothetical interactive tool

In our research, we had two goals; (1) finding interesting visualization ideas and (2) intuitive visualization patterns for representing movement and spatio temporal event data in a multi-layered format. To achieve this, we used an exploratory design research method, a participatory design workshop as a part of the basic design class. Then we evaluated the outcomes, using analysis criteria that we borrowed from the information design field.

2 Literature Review

In this section, we briefly summarize related work on event-based data visualization, spatio-temporal data visualization, participatory design methods, and the use of cultural probes as an ethnographic research tool in this context.

Location based data is an increasingly critical topic which has been studied in detail under the field of geographical information systems (GIS). As MacEachren [2] suggests, most of the digital data we produce, comes with geospatial information like coordinates, postal codes. When we add every other geo-tagged data like photos, videos from social media applications or when we semantically analyze the content of messages and their relation with location, we can understand the potential of spatial

information analysis in terms of decision making. Today, every specific coordinate in the cities holds a lot of valuable data which can be turned into useful information. Bertrand et al. [3] argues that the increasing amount of measurable public sentiment, allows more of the timely and geographically precise data.

Studies on visualizing geo-spatial information include static, animated and interactive visualizations. O'Madadhain [4] expresses that research on data analysis is very much focused on static visuals. Geo-visualization has also its roots coming from semiology of cartographic visualization studies. Bertin [5] classified and identified the visual elements and diagrams that are used in the cartography field which forms a basis for geographical visualizations. While learning from Bertin is crucial, there is a need for researching modern animated and interactive geo-visualization methods for a case like urban event-maps. Accordingly, Eccles et al. [6] uses story as an element in visualization to represent time varying information or Ferrari et al. [7] presents urban patterns using the data of social networks in their studies. In another study, Tominski [8] solves the complexity of the case with a flexible method for user-driven event-based concepts for visualization by not selecting a case event, but a more general event definition and its representation. Quercia et al. [9] suggests a route-planning service model that includes qualitative and emotional opinions by making use of crowd-sourced data. However they use the data for proposing routes according to the user preferences, instead of displaying this multi-layered data.

While such recent research studies, question the information architecture and visualization issues for interaction with the event-based spatio-temporal data, we can also see some relevant event-based social networks such as Plancast or Meetup [10, 11] for the end-user, but none of these use a geographical visualization approach but a list based interface design. Yet, it is obvious that there is still need for research in the field for novel, effective and sophisticated representation and interaction methods.

3   Methodology

This research study is a part of an ongoing wide research interest on exploring novel ways of visualizing and interacting with the multi-layered urban data. We have been making use of several different ethnographic methods and user research studies. However, this paper is concentrated on spatio-temporal data visualization explorations on event-based urban data. Here, in this section, we present our process of previous studies related to event-based urban data visualization, and how we conducted the whole iterative process (Fig. 2).

3.1   Previous Studies on Spatio-Temporal Data Visualization

We started this research by conducting a set of participatory design workshops about spatio-temporal data visualization and we also conducted a diary study. Our goal in these studies was to find qualitative user needs by discussing through participatory design and finding novel spatio-temporal visualization explorations which has been previously presented [12]. Below we briefly explain how the previous studies are related to this paper.
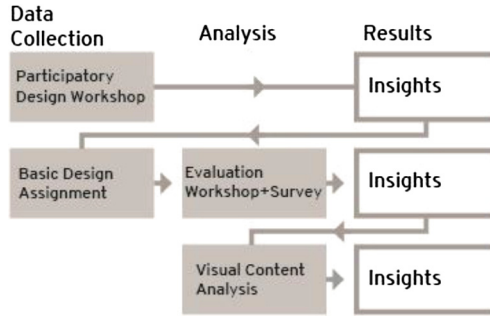
Fig. 2. Diagram showing the connection between our previous studies

After the first PD workshop and the diary studies, we conducted a more focused workshop on the specific topic of visualizing events in the city. We developed user scenarios based on the user needs from previous studies. In this workshop, our first aim was to find patterns on what types of information users choose to visualize and how they visualize them, which would lead us to understand user needs of a hypothetical interactive event map while a second aim was to explore novel visualization ideas in the context of social events. The PD workshop was held on a Saturday for a total of 8 h. It required volunteered participation by the people who were interested in the topic of spatio-temporal visualization and living in the same city. We sent an invitation to the network of people who attended at least one of our previous studies and are interested in the topic. The workshop had 10 participants who were mainly senior design students from interactive media design department and media and visual arts department. In the workshop, we presented them the scenarios we prepared and asked participants to visualize the activities and possible data that would have been created in such a scenario. Later on, the visualizations were presented by participants and we closed the session.

Basic Design Lecture and Assignment. Building up on our previous experience with the diary and the workshops, we decided that we needed a more structured visualization user research for collecting intuitive and creative ideas. With this perspective in mind, we prepared a presentation and gave an assignment to the basic design students of a media and visual arts department, two terms in a row. The basic design course is a one term class about the foundations of art and design. It is an introductory course to the principles and elements of design. Interdisciplinary seminars and discussions are held with a wide range of issues about art and design, design thinking, visual arts, plastic arts, moving image, photography, interdisciplinary relations with philosophy, psychology, and math. This study of giving spatio-temporal data visualization as an assignment to the students in the basic design course is a valuable idea because throughout the term, students learn the fundamental elements (line, shape, direction, size, texture, color) and principles (balance, proximity, alignment, repetition, contrast and space) of design and the assignment provides a challenging task that requires students' to apply the skills they gained.

Our study consists of two parts. The first part is the lecture on spatio-temporal data visualization within the course structure of the basic design course. And the second part is the assignment we gave to the students after the class, for the following week. The participants are university students who took basic design course at spring 2015 and fall 2016 terms. Both at spring 2015 and fall 2016, 60 students took the class. These students come from various fields mainly from media and visual arts, engineering and social sciences. A total of 120 students from various fields, attended to the lecture and made the assignment.

Presentation. Before we gave the assignment, we made a lecture about information design and spatio-temporal information design. We started this lecture with the basic principles of information design and then later on started discussing about what spatio-temporal data is, how it can be an asset in our daily lives for observing, understanding or planning needs.

Assignment. After the lecture, we gave an assignment to the students. We asked the students to visualize a social event or an incident they observe or experience in the city from bird's eye view, in an abstract way. They can use color. And we informed them that it is important that their work should be original, different than existing examples, and intuitive. One other thing that is important for the works is which data types they will include in their visualizations. We briefed them that the data types could include, but are not limited to: (1) time (date/time/duration); (2) movement (i.e. people/vehicle); (3) population (i.e. people/vehicle); (4) important elements about the space; (5) other data types you think are relevant with the event/incident (i.e. weather, sound). They are free to decide on the scale, whether it will be a city, region, or neighborhood. They had 2 weeks to finish the assignment.

Analysis and Evaluation. In this process, first we collected the assignments and separated the ones that were off brief and we scanned all the assignments and created a visual board using Pinterest [13] (Fig. 3). Later on, we went through an iterative analysis process. As a first iteration, we prepared a survey with quantitative and qualitative items and organized an analysis workshop where participants completed the surveys individually and evaluated the works through group discussion, explained below. But not feeling content about the outcomes of this first iteration, we then we conducted content analysis to code the visual data as a second and final iteration, of which we share the results below Sect. (4.2).

Survey and Analysis Workshop. We prepared a survey to evaluate the works. In the survey, we borrowed design analysis criteria from the cartography field, to evaluate how well the students' works fitted basic cartography design principles. These principles are, visual contrast, legibility, figure-ground organization, hierarchical organization and balance. [14] We used a likert scale from 1 to 5 for the items. Next section included three open ended questions and one multiple choice question. First question asked the users the types of data that they can read from the visualization. Second question asked if they can locate the main subject (locator) on the visualization and where is it. Third question asked if the viewer can see the effects of the environment through the event and how was it visualized. The last multiple choice question consists of two parts, first part asked the participants if the visualization is overall intuitive or
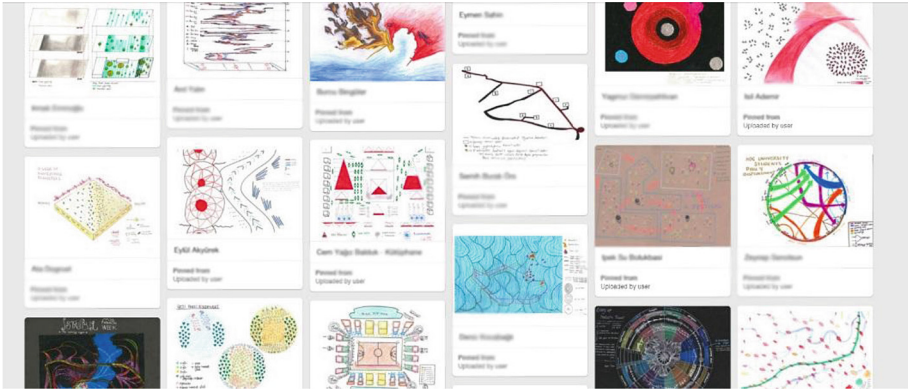
Fig. 3. Examples from student works

mediated, the second part asked if the visualization overall is interesting or ordinary. At the final part of the analysis, there is a section where we wanted the participants to redraw the interesting visual elements individually and write the data type they think it represents.

We announced the evaluation workshop to our network of participants who have participated in previous workshops. The workshop had 5 participants. (Fig. 4) 3 from various design backgrounds and 2 senior interactive media design students. The workshop lasted for 5 h. First we briefed the participants on the aim and structure of the workshop and we went through the survey structure. The participants selected works from our visual board and completed the evaluation survey individually. After this, they did a group discussion on each work.

Visual Content Analysis. The experience we had through the analysis workshop led us to revise our analysis method. One of the main problems with the workshop was that, participants had to select works to analyze, since there was insufficient time to analyze all of the results. Another problem was that, most of the student visualizations were too abstract to be evaluated as maps. This caused us to eliminate the set of criteria that we

Fig. 4. A photo from the analysis workshop and survey

borrowed from the cartography field. We added another set of criteria from literature regarding how engaging and informative each visualization was, using likert scale from 1 to 5 [15]. Two experienced designers rated 80 visualizations according to the revised criteria we used in the analysis workshop. Raters qualitatively coded the visual representations in each work. For the coding of representations, raters used keywords of basic shapes like dot, arrow, and spiral and they noted down the data type they think the visual element represents. After the analysis finished, we used inter-rater reliability check.

4   Results

Finally here, we share our insights throughout the whole design research process starting from our previous studies, followed by our data collection and analysis methodology and our insights from the process.

4.1   Previous Studies

As mentioned about, we started with a series of participatory design workshops and a diary study in combination. Since the time and effort the participants spent on the study was very limited, the visualization results were unsophisticated. Even though we can say that these methods were successful in terms of collecting user needs, they were insufficient for us to make a visual content analysis in terms of quantity. We leave the results of this study to another paper.

4.2   Data Collection

For collecting visual data, we conducted two studies, design workshop and assignment. The main reason that led us to use the assignments (student works) for data collection in this paper rather than design workshop, was that volunteered participants of design workshop had limited time to execute their ideas. This caused the workshop results to be unsophisticated and less detailed while this research interest is all about detail. This led us to change our method and try a data collection method that could have more detail in the visual data. The differences between basic design assignment and the workshops that might lead the assignments to be more successful are;

- Time: The workshop's time span was limited to 8 h, while the students had two weeks to finish their assignments.
- Discussion: After the lecture prior to the assignments, we spent enough time discussing on visualization examples so that students were able to create more original results.
- Motivation: The grading motivation in the basic design course assignment created a more limited space for the participants of the study. Students' previous studies on visual representation, ways of seeing and observation studies provided a background for the hard problem of visualizing complex information.

4.3 Analysis

Our process of analyzing the results was an iterative process and had several challenges. Through the process we realized that some of the analysis criteria did not serve our purposes related to the context and we revised the criteria. As mentioned before, we started off by borrowing design analysis criteria from related fields like cartography and information design literature. We realized that most of the results were too abstract to be evaluated as maps and all of them were hypothetical maps, in terms of the data they represent.

The first method to analyze the results, the analysis workshop was ineffective in a couple of ways. We planned the workshop in a way that participants both analyzed each work individually via analysis survey and made a group discussion at the end of survey, on each work. This caused the analysis process to be very slow. Therefore, only some selected works were analyzed through workshop. Another obstacle that we realized during the workshop was that, some of the works had metaphorical expressions like icons, while the brief told the students to use abstractions. This caused us to eliminate the works that were off brief and left us with 80 works. Among these 80 works that we will discuss, some had a more abstract language while others didn't had. So for the visual content analysis, we added an abstraction criteria, and raters rated the level of abstraction from 1 to 5. In this rating 1 is more metaphorical and using more concrete geographical elements and 5 is less metaphorical and visually most abstract. In the last analysis section where raters coded the data types that they recognize, we added another item regarding how many data types can raters recognize to understand how having more data together in one work effected other parameters.

4.4 Evaluation and Discussion

In this section, we will share our insights on event visualization. We conducted a content analysis study on spatio-temporal data visualizations created by basic design students to find out what they prefer to include on these maps, how they visualize them, patterns on what kind of visual elements are used for which information and criteria such as engaging, informative, abstract, intuitive/mediated. According to the content analysis, we reached the following results that we will present in three sections, first one is the visual representation patterns that we encountered in the works. Second one is the relationship of abstraction and other elements. Third one is about how the amount of data types effects other parameters.

Common Data Types. Here we will present two outcomes. First one is the most encountered data types from the works. (Fig. 5) 40 % of the students chose to visualize people individually (Person) when describing an event visually. 30 % visualized the movement path of people or vehicles (Path). 14 % visualized direction of moving elements (Direction). 12.5 % visualized moods or feelings (Mood). The works we wanted from students were static, so most of the works were showing a certain point in time when visualizing an event, but 10 % of the students, still visualized time in different ways. 7.5 % of the students represented people not individually, but as a whole.
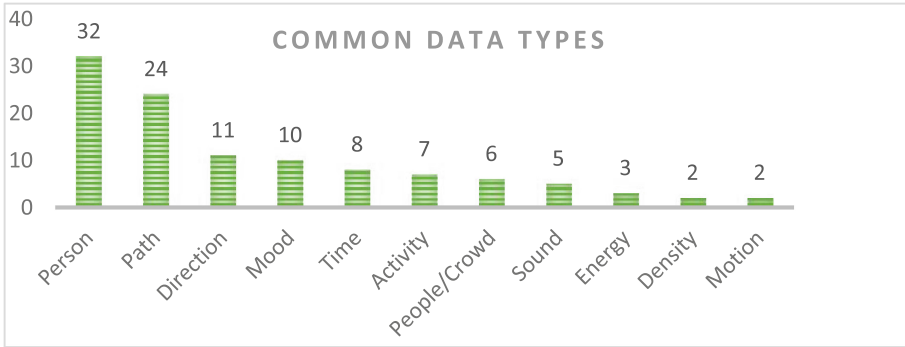
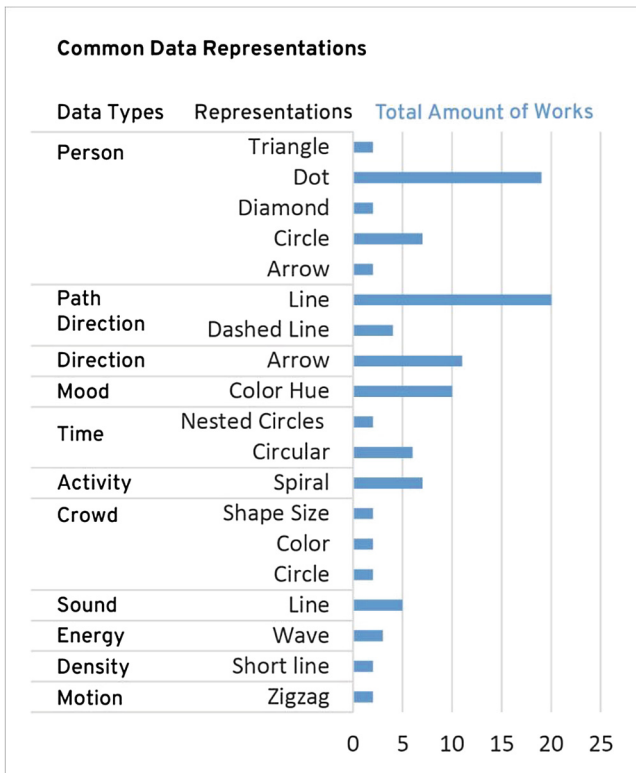**Fig. 5.** Common data types that students chose to represent on their works

Fig. 6. Common data representation patterns on each data type

Visual Representation Patterns for Event Maps. Our second outcome is about the visual element that were used while visualizing the data types above. (Fig. 6) 59 % of the students who visualized people individually, used dot while others used circle, diamond, arrow and triangle. 83 % of the student who visualized path used line including curved or
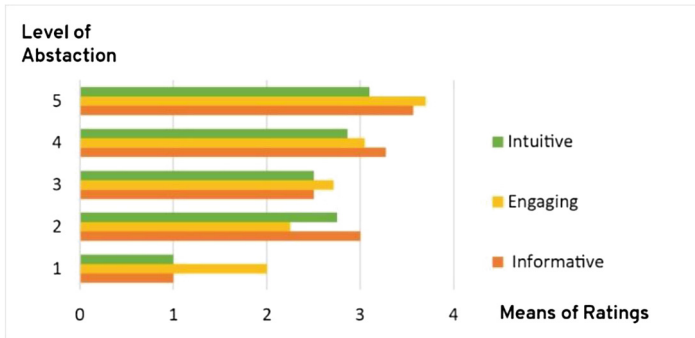
Fig. 7. Relationship between level of abstraction and intuitiveness, engaging and informative (Color figure online)

straight lines and the rest used dashed lines. Students used arrow to visualize direction, color hue to visualize feelings or mood. The students who wanted to represent a period of time, used clock-like circular shapes while others used nested circles.

Abstraction. We are interested in how the level of abstraction effected other parameters like engaging, informative and intuitiveness. To see the relationships more clearly, we compared means of four parameters which were rated from 1 to 5 (level of abstraction, informative, engaging, and intuitive) (Fig. 7). Even though we cannot say that we see a consistent correlation between abstraction and intuitiveness or abstraction and informative, but the ratings show that as the level of abstraction increases, the visual works become more engaging. This relationship might help designers in early design stages, keeping in mind that this is a case study related to visualizing events in the city and might not be applicable for every other design case.

Multi-layerability. Even though we told the students that they are free to combine as many type of data as they choose, most of them chose to have fewer data types on their work. 35 % of the students had one type of dominant visual representation. 31.25 % had two, 27.5 % had three and only 5 % of the students had four type of data representations in one work. This downside prevents us from interpreting how having more data type effect other criteria in a visualization.

5   Conclusion

Here in this paper, we share our preliminary insights from our exploratory user studies on how people visually represent event-based urban stories or situations in an intuitive way. This is a part of an ongoing study, where we are exploring novel ways of providing interactions between the things happening in a city and its dwellers. We envision bringing together different (both needed and also unexpected) urban data in a crowd-sourced event-based interactive tool. The way how these complex, unrelated, live data can come together on such a multi-layered tool while still being self-expressive, is still an open research question. With this motivation, we first conducted participatory

design workshops and a diary study to collect intuitive data and visualization ideas from the users which in this case is any mobile device user city dweller. However, our preliminary studies lacked profound visualization ideas due to the users' weak motivation on using the probes regularly during their daily life. We then decided to implement the idea into a basic design course, as an assignment, where we asked to students to visualize events happening around them. This worked out, and we collected valuable data from the students. We share our preliminary insights from this study while we still continue collecting this ethnographic data regularly, which grows the data we have.

Looking at the data we collected, we learned about (1) what kinds of data users prefer to see; (2) with which visual elements they intuitively represent these data types; (3) some creative visual elements and representations to be used; (4) and some criteria (such as abstraction, intuitiveness, engagement) that teaches us about each visual element – data matching. Even though these are very valuable feedbacks for our ongoing research, we haven't yet reached significant information regarding the multi-layerability of the data types and how an interactive tool would benefit from the use of which types of visualization methods in terms of multi-layerability. While starting to work on the design of the visualization, based on the findings of this study, we will continue collecting intuitive user data to further learn how different layers can be brought together in an easy to read manner.

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