Visualizing the Los Angeles Metro Bikeshare System

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Abstract— Bike sharing systems are gaining immense popularity as an alternative or complementary mode of urban transport. Bike sharing can provide an alternative to traditional modes of transport or, more likely a complementary service for solving the "last mile problem" of getting from a public transportation stop to the final destination. Furthermore, bike sharing systems may help mitigate automobile congestion and reduce pollution, although relatively little research has been done to asses their actual impact in these areas. Visualizing and analyzing the current operations can assist in getting a better grasp on the performance of the system. In this paper, a data visualization approach is used to identify important factors related to the bike-sharing system. We analyzed the bike-sharing system such that we were able to group the bike renting trends, locate the busiest stations in the locality and number of monthly or flex passes taken by the customers for different time granularity. We have mined the Metro Bike Share, Los Angeles data and discussed the findings of this data set. Using this publicly available data, we conducted some experiments combining data filters and visualizations, potentially analyzing the sustainability of the bike sharing system. For this milestone, we have expanded on our progress from the fourth milestone. One of the major tasks was to conduct evaluations by showing our visualization to other people who aren't from visualization domain and get their feedback and the other part was to present our visualization in the class and get the feedback from fellow students. The evaluation results and analysis will be further discussed in the evaluation section.

Index Terms—Bike-Share, Visualization, Clustering, Data Mining.

1 Overview

Bike share schemes are an increasingly prevalent mode of intra-city transportation. The concept of bike sharing systems was introduced in 1965 Amsterdam. A bike sharing program is a system of supplying bikes for hire for point-to-point transportation. This program enables convenient active transportation as people have an option to ride between two stations in a defined geographical area. Since the introduction of bike-sharing systems, much research has been dedicated to different aspects of these systems. The benefits of bikes in urban areas, where travel distance is short, and the parking prices are high, has caused the demand for bike-sharing systems to increase. Bike share systems may help mitigate automobile congestion and reduce pollution, although relatively little research has been done to assess their actual impact in these areas. Benefits to users include potentially reduced commute times by perhaps as much as 10% [5] and a healthier lifestyle to lead.

Besides visualizing bike sharing systems as a new means of public transportation, such community shared programs offer a new way to look into the dynamics of movements inside a city, and more generally into its activity. In a sense, it provides digital footprints that reveal the activity of people in the city over time and space and makes possible their analysis. Different issues motivate the study of such a system. Some questions are about the usage patterns of this kind of transport, with reference to social or economic studies of transportation, while others are about the system itself: does the service work correctly? Can it be optimized? Can one regulate the availability of bikes? Some of the studies related to this system are descriptive and mine the data to get a better understanding of the operations.

Data Visualization and analysis of the current operations can assist in getting a better grasp on the performance of the system. Data visualization, which is defined as the effort of placing data in a visual context, can assist in better understanding the problem. When we have many data points, the visualization of the data becomes challenging. The purpose of this study is to analyze the bike-sharing system by applying filters like renting trends. We have mined the Metro Bike Share, Los Angeles data and discussed the findings of this data set. We have examined the bike-share system during different quarters of the year, therefore potentially analyzing the sustainability of the bike sharing system. This study also helped us in gaining a better understanding of the urban mobility of Los Angeles residents. In terms of visualizations, our project does not develop a novel visualization but uses prevalent methods of visualizing data to try and find trends of a certain behavior from this dataset. We have analyzed various types of visualizations and brought together several ideas to form an interactive and easy-to-use interface that helps users navigate through the bike-sharing data in a more ordered and systematic way. Our choice of visualization holds ground with the design practices that make an effective visualization and also takes into consideration some design techniques that further enhance the user experience.

The following progress has been made for this milestone:

- **Presentation**: We presented our visualization on November 21st, 2018 to the class and received their feedback.
- **Evaluation**: We performed evaluations of our visualization over a period of time with a group of different people. Subsequently, we received results from these users and analyzed the results in the evaluation section.

2 Visualization Progress

Not Applicable.

3 Evaluation

Our project can be put under the category of an application based visualization project. We used open-source data to create visualizations that help users identify trends and patterns in the way bike-share systems are being used in the city of Los Angeles. Keeping this in mind, we had planned our evaluation process to be primarily aimed at user test surveys. The volunteers for user surveys can be one among the following:

1. Mechanical Turks
2. A group of people who can be considered as laymen in the field of data visualization
3. A group of people with a considerable amount of idea and experience in the field of visualization design.

Our evaluation approach included the last two groups of people from the list above. We decided not to move forward with performing

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SN	Age	Gender(M/F)	Race	Occupation	Familiarity with domain
1	22	M	Asian	Student	Medium
2	24	M	Asian	Student	Medium
3	24	M	Asian	Student	High
4	30	M	Asian	Technical Consultant	Medium
5	27	F	Asian	Software Developer	Medium
6	26	F	Asian	Homemaker	Low

Fig. 1: Overview of Surveyor Demographic

evaluations on mechanical turks because we felt that for a project of our scale, being moderately complex and not too detailed, using the last two groups of people would suffice to come to a strong evaluation result. We explain each form of evaluation through the following sub-sections.

3.1 Survey Users Q&A

This evaluation was based on asking our test users a number of questions with varying level of depth and accessing their answers in a qualitative and quantitative measure.

3.1.1 Design

As mentioned above, the user Q&A session was primarily based on providing our test users with our visualization, making them study it in detail and then following it up with a number of questions. First off, we had to select the test users for our survey. Since this Q&A session was aimed for laymen in the field of visualization, we selected friends who were not well acquainted with this subject matter as our test surveys. Our choice for only selecting laymen users was because the class presentation peer review would consist of review from a group of experienced data visualization users. To balance the selection, each project member selected two test subjects adding upto a total of six surveyors.
Then, we decided on method our survey. Each user was assigned to view and navigate through our visualization for 2 minutes. After this duration, the visualization was removed and they were handed a paper with a list of questionnaires. We wanted to see if our visualization design also had a sense of remembrance to it and by making the users answer questions by first removing the visualization we were able to test that to some extent. The questions were primarily of two kinds: open-ended and close-ended.
The open-ended question pertained to the volunteers answering what they inferred from the overall visualization. This gave us a high-level feedback as to whether our choice of visualization fulfilled its initial objective. The close-ended questions will be more detailed and looked into whether the users were able to derive data and trends from the visualization. The rationale behind selecting these questions was to evaluate our design from both a high-level scenario and a detailed pattern finding scenario, which is ultimately the goal of the design. Some of the questions asked for each kind of questionnaire is listed below. A complete list of all the questions can be found in the **Evaluation** directory.

1. Open-Ended Questions
    - What can you infer from the visualization at a first glance?
    - What do you think this visualization is trying to achieve?
    - Does the visualization look appealing to you when you first see it?
2. Close-Ended Questions
    - Which area of LA has more bike stations?
    - How are the bike rents distributed across a certain area of bike stations?
    - What overall trend can be inferred from the bike rent data?

Finally we asked each test subject which of the two visualizations they preferred. We opted for comprehensive questions instead of multiple-answer questions which could ask subjects to answer from a list of 5 options ranging from 'Strongly Agree' to 'Strongly Disagree'. We decided on this because in addition to receiving positive/negative feedback, we also wanted feedback that would help us improve our design and add to it for future work. A simple multiple choice question would only provide us with a discrete result set for generalization.
For each user the question-answer session was completed in 5 minutes after which the answers were collected and analyzed. The answers from all test subjects were tallied and categorized broadly into two bins: positive and negative. The details from the answers were noted down which served well for our lessons learned and future work sections.

3.1.2 Results

The overall results from the user Q&A session was positive. This section will talk about the summary of the observations and the responses received for the visualization design.
Almost all the open-ended questions received positive responses. It could be concluded that the high-level goal was met by our visualization design. Out of the 6 participants, 5 answered positively on questions like "*What do you think this visualization is trying to achieve?*". This gives us a success rate of 83.3%. However, the reactions were a bit mixed towards the initial appeal of the visualization. Only 3 out of the 6 subjects positively responded towards the initial appeal and design. This makes up for 50% of the subject population.
Some comments about the design were directed towards the layout and look of the time histogram. We received feedback to make it more visually appealing and a single subject mentioned that the prevailing bug on our design was a negative factor while the remaining did not bring it up on the Q&A session.
As for the close-ended questions, they were answered with relative ease. Tasks such as finding busiest bike stations and station distribution was done quickly and almost all the test subjects were able to determine the trend of bike rents. All the subjects were successful in finding the trend of bike rents through time which is an accuracy of 100%. We also tested the idea of remembrance to check how much of the visualization they still remember and received positive results as 5 out of 6 subjects agreed to remembering every detail of the visualization (83.3%).
As mentioned before, all the answers of the questionnaire can be viewed in the **Evaluation** directory.

3.2 Visualization Comparison

This evaluation method is closely linked with the first method because it was performed at the same time one after the other.

3.2.1 Design

In addition to finding out how our visualization design fared on its own (in terms of fulfilling its primary objectives), we also wanted to see how it compared to other visualizations that performed similar tasks as our design. Comparing two things which perform similar if not the same tasks is always a good way to check for effectiveness and efficiency. This test would expand our evaluation coverage in such a way that we could get more ideas and feedback about possible changes/addition to our design.
Following from the first evaluation technique, we presented the test

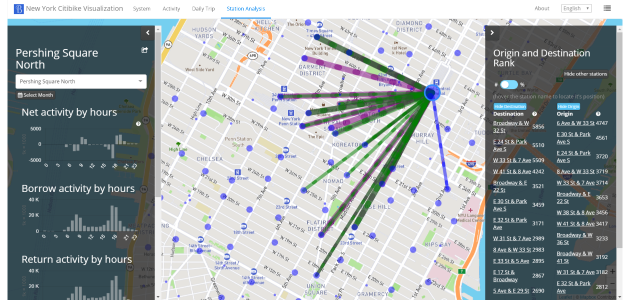

Fig. 2: New York CitiBike Visualization

subjects with another visualization design. We chose the **Bike Visualization** website which contains the visualization of bike shares for a large number of locations. This design implements more interactions than our visualization and is much more complex than our system. So for the sake of equality in comparison, we decided to test this for the same tasks as that were performed on our visualization. We chose the **New York Citibike Visualization** where we asked our test users the same questions as before after letting them view and interact with the visualization for 2 minutes. In this case, we focused more on the close-ended questions since we wanted to compare trend finding and location finding tasks between the two visualizations.

3.2.2 Results

The results from the visualization comparison came out somewhat expected. The New York Citibike visualization had more features and interactions, making it more favored than our visualization. 5 out of the 6 test subjects leaned towards this visualization approach (83.3%). The open-ended questions provided similar results as well, both in terms of answer type and time to answer. These visualizations were built by a team of experts who had experience in the field of data visualization and hence the design choices made by them was sound and just. This makes the visualization look appealing and obtains the overall objective as well. All 6 out of 6 people liked the initial appeal of the visualization producing a success rate of 100%. The same accuracy was obtained for questions like "*What do you think this visualization is trying to achieve?*".
Similarly, the close-ended questions did not vary as much from the answers of our visualization. The only noticeable difference was in the speed of answering. The test subjects seemed to take less time to find trends and locate items/places in the map compared to our visualization. This could be because of faster data processing and a smoother filtration process by the New York CitiBike visualization compared to our design. In terms of remembrance of the graph, the users did not seem to remember all the details with exact accuracy. Though they defined the maps, they could not explain the various bar graphs on the left side of the visualization.
Overall, the visualization comparison resulted in test subjects favoring the New York CitiBike visualization over our visualization design.

3.3 Class Peer Review

This is the part of the evaluation where our visualization was reviewed by a group of students experienced in the field of data visualization.

3.3.1 Design

As part of our class project, we presented our visualization design to the class of CSC 544 - Advanced Data Visualization. There were 5 students and Professor Katherine Isaacs attending our presentation. During the presentation, we talked about the overview of our project, explained the methodology ranging from task and data abstraction to the design rationale. We explained our visualization design to the class along with a small demo. After the presentation, there was a round of Q&A session where the students asked us a number of questions related to the project and also provided feedback. The students were then assigned to anonymously fill up a questionnaire designed by the Professor. The questionnaire was in the form of a Google Form and contained the following questions:

1. What is the goal of this project? What problem is it trying to solve and why is that problem important?

2. What are the strengths of the solution?

3. What in the solution could be improved and how? (Do not repeat what the presenter has already said.)

The answers from the questionnaire were then used to form our evaluation result.

3.4 Results

The answers to the questionnaires were analyzed and the following conclusions were drawn for each question:

1. For the first question, all of the five reviewers accurately described the goal of the project including the problem its trying to solve and the importance of it. The responses matched our project goal to visualize the LA bike share system. For the importance of the problem, the responses varied from helping users see bike share trends to planning the distribution of bike shares from a commercial standpoint. All these responses do fall in the scope of importance of the problem.

2. Our visualization received a number of positive reviews in terms of strengths. What was interesting was how varied the responses were between the five reviewers. This goes to show the advantage of using visualization experts for evaluation. Below are some of the strengths of the visualization as mentioned in the reviews:

    - Good data source with large possibility for future design additions
    - Smooth interactions in the visualization
    - Trends were displayed in a pronounced and preattentive manner
    - Low learning curve giving an intuitive sense to the visualization
    - Detailed data and task abstraction
    - Good and in-depth design rationale
    - Detailed evaluation plan, especially the visualization comparison section

    These reviews supported the positive feedback received from the previous two methods of evaluation.

3. Along with the strengths, there were a number of areas of improvements that were mentioned. These points were noted on the reviews but were also discussed in the Q&A session after the presentation. Some of the future areas of improvements are listed below:

    - When zoomed out, the circles get large and end up overlapping and crowding each other. A better representation, maybe a Voronoi diagram would be useful.
    - The opacity of the circles are not low enough to not occlude the background so decreasing the opacity might be helpful in that.
    - Adding a title to the visualization and labels to the graphs would be helpful.
    - Adding a 'Play Button' animation that automatically cycles through each month of the time period to show the visualization would be a good design addition.
    - Showing the destination when the source is clicked.
    - Adding a button to reset the view of the map and center is back to the original location would be helpful in viewers to start over.
    - Since this is a large project with good data source, using more attributes such as destination and trip route information to show more trends would add to the current progress.
    - Showing the information of all the months at once using various color/color scales for each month might help in comparing the data between months.
    - Being able to handle data with a longer time frame than the current two year frame.

    The above ideas and recommendations for future improvements of the project matched with some of the future plans that we had as well.

3.5 Discussion

Here, we talk about the results from our evaluations and how it shapes our current visualization and any future direction of it. In a nutshell, our visualization project was conceived in a very positive manner in terms of the problem it was trying to solve and the method implemented to solve it but it fell behind in terms of features and designs compared to other visualizations that perform the same task.

Starting with the strengths, the results of the evaluation resulted showed that both the general audience as well as the experienced reviewers liked the implementation of the visualization design. The use of circles of varying radius to show different bike stations over the map of a city might not be the best design choice but served our purpose well enough and the rationale behind the color/opacity of the marks was also received well. Most of the test subjects being able to answer both the open-ended high level questions and well as the close-ended trend finding questions added to the conclusion that the chosen design rationale suited well for the task performed. In addition to the design, our data/task abstraction and evaluation approach was also well received by the peer reviewers which in a resulted in our design choices being well-defined. Coming to the improvements, our visualization seemed to have large room for improvements and many possibilities for future work. This was evident from the visualization comparison and the peer reviews received from the presentation. The project idea we took on and the problem we tried to solve through it is of a large domain. Through the background research, we were aware of the variety of tasks and interactions that could be performed to solve this problem by using the raw data available to us. Our primary goal for this project was to design a visualization layout to solve the problem of finding the bike share trends and how it changed with respect to time. There are a number of areas where our design can be improved to better portray the information. Some of the more urgent improvements seem to be adding titles and labels to inform users about what is being visualized and modifying the way in which the data is mapped when zoomed out so that the circles don't crowd over each other.

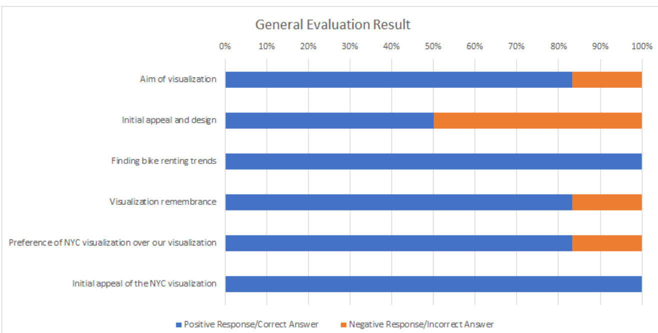

Fig. 3: General Overview of the Evaluation Results

In addition to this, we have improvements of our own which were part of our milestone but could not be achieved in time. These include fixing some bugs related to data mapping and implementing a brush over the time histogram in order to select multiple months at a time. The results from the visualization comparison show that our data handling and processing could be improved to speed up the visualization and interactions. One way of doing this would be to load the data to a server and read through it instead of reading the data locally. This would also provide options for scalability which is another area of improvement. The New York CitiBike visualization shows us that there a number of attributes that can be mapped into the visualization to show more trends and make the analysis process more richer. Other improvements include making the interaction smoother and more user-friendly by adding automatic animations and map view reset buttons. These are great ideas that can be added to our visualization to improve user experience.

In summary, the results from the evaluations show that our visualization project performs its intended task with high accuracy but at the same time needs improvements on its designs along with integration of other attributes to expand the data and trend analysis of the bike share system.

3.6 Limitations

While our evaluation approach produced acceptable results that concurred with the results from the peer review, there were a few limitations to our approach. First, the questions asked to the test subjects were of a kind that did not produce detailed answers. The questions were more focused upon whether someone understood the problem and the task being performed in the visualization and if a user could easily perform said task. While these questions are important in order to properly evaluate the effectiveness of the visualization design, questions similar to the ones asked in the peer review section would have helped us gain insights about what could be improved from a layman's perspective. Even though design suggestions from a visualization expert will always be more detailed, taking suggestions from these test subjects would have been beneficial. This is because they form a part of the demographic population who despite mostly being laymen in the field of visualization will be the largest proportion of consumers of this visualization. Even if their suggestions might be in the simple scope of improvements, they will directly be targeted towards improving the user experience. So, questions that ask the users about possible improvements and suggestions on the design will help in better directing the future efforts of the project.

Another limitation was the ineffective implementation of quantitative evaluation. During our initial evaluation phase, we intended to time the users while they were answering the trend finding and data localization questions. Our aim was to compare the time taken by each user and get a general sense of the time it takes for them to solve these tasks. Then we had planned on timing them for the same tasks on the New York CitiBike visualization and comparing these two sets of data. Our method of having the test subjects first go through the visualization and then answer the question separately posed a problem in terms of timing them. This is because the amount of time spent by the users on answering the questions now also relied on how well they remembered the visualization itself. We wanted the time to be independent of this factor and only depend on how effective the visualization itself is. Though the first few evaluations were timed, we later discarded this approach and relied on a general sense of how long people took to answer the questions.

One way of adding quantitative evaluation to our approach would be to having the users solve some task or find some data while they are navigating the visualization. This way the timing data obtained would be a factor of the effectiveness of the visualization design alone. We think this would result in more accurate data and hence obtain a better evaluation result.

Similarly, the method of evaluation itself could have been improved and made more streamlined by taking the evaluation session online. In some ways the live evaluation session did not seem smooth enough and having the test subject recite the answers while we noted them down felt cumbersome.

Finally, our choice of visualization to compare with our project might was not the best source for comparison. While we map the stations of Metro Bike Share stations over LA, there might very well be other bike share providers installing stations at other locations in the city. This is why the clustering appears only on 3 areas in the city. On the other hand, the New York CitiBike maps all the stations on the city irrespective of the service provider. This is why the stations are spread out all over the city. This information needs to be kept in mind before making any assumptions about the implementation of bike share service in LA.

4 Lessons Learned

In the duration of developing this visualization and analyzing the data for visualization we have learned few noticeable things as follows:

- The most important lesson we have learned in designing our visualization is deciding early-on in the project about how the visualization shouldn't look and how it should look. We have had many brain storming discussions in this area with the team members and realized that it is always better to iterate over multiple possible designs and decide on one early in the timeline.

- Focus on identifying and understanding the problem you'll be solving. It is not feasible to solve all problems on a single course project. So picking one problem that is most relatable and important for the users viewing the visualization and focusing on solving that effectively will fare better for the project than trying to solve all problems at once which might only result in mediocre solutions for each one of the problems.

- A user-centered design approach can result in an intuitive interface, which, in turn, can open up new possibilities. In our visualization, the appropriate user interface can open new possibilities by providing a big picture of operation and information within the metro bike share system.

- It is always important to focus and invest time on the initial data and task abstraction before starting off with designing the visualization. Properly defining the problem and iteratively coming up with tasks to solve this problem along with design choices that best help in this task ultimately help in creating a visualization that is most effective in terms of solving the stated problem.

- Our visualization provides a customized display of information. It shows the graphical representations of bike renting trends in Los Angleles area. They can also quickly identify correlations, and illustrate trends. All of these features combine to help in making better-informed decisions about the sustainability of the bike sharing system.

- The most important practice to follow when designing a visualization is to find out who the information consumers are directing our design decision accordingly.

- Visualizations should contain title fields and labels that clearly define what the visualization is about and what information it is visualizing. A person without any prior information to the visualization should be able to know straight out what the visualization is about and what it is mapping.

- It is advantageous to have the interactive parts perform more than one function, and allow interactive parts to be interacted (click/hover) for more information. Clicking a bar in the histogram, for example, could display more current bike renting numbers. When deciding on the appropriate interactions, we should careful to select the interaction type that best conveys the information being displayed.

- When designing geographic map visualizations, it is always useful to allow users to jump back to a designated starting location in a case that they move astray. A common example of this is being able to jump back to the current GPS location on Google Maps.

- Data may be missing, incomplete, inaccurate, duplicated, or use different standards. We need to cleanse and pre-process the data properly before we start the visualization such that our model can easily ingest it.

- In order to take into account the possibility of larger data sources, scalability can be achieved by hosting the data over a server instead of ingesting it locally, which not only makes the visualization slower but also reduces portability. Reading data online through a database will be much faster, scalable, safer and portable.

- Engage the right people for evaluation, as we need a diverse range of perspectives and experiences to uncover problems and co-create solutions.

5 Project Summary

Here we summarize our project as our whole, describing the tasks we performed in developing this project and the contributions presented in this milestone and the ones before this.

5.1 Project Summary

Bike sharing systems are gaining immense popularity as an alternative or complementary mode of urban transport. Bike sharing can act like complementary service for solving the "last mile problem" of getting from a public transportation stop to the final destination. The whole project is aimed at shedding light on how well the bike sharing model is working in the LA metropolitan area. In order to do this, the project focuses on visualizing the bike share rentals across different bike stations and filtering this data with respect to time in an effort to find trends in the use of these bike share systems.

5.2 Project Implementation

We started with the data provided by Kaggle and eventually shifted to the open source data from Metro Bike Share. This data was richer in attributes and contained information for a larger time frame. The initial structure of the data was in CSV format, from which after primary data cleaning in python, we converted it to GeoJson format. We divided our tasks according to Shneiderman's Task taxonomy which also conforms to our project goal.
After detailed data and task abstraction, we used our design rationales to create the visualization. Our work was to create a geographic map detailing every station according to their longitude and latitude; along with the numbers of rentals from each of those stations. We used the Leaflet library to generate the geographic map supporting various interactions. Then, we mapped the bike rentals (pick-ups) over this map and encoded the frequency of rentals for each station. Using circles as marks and circle radius as the encoding for rental frequency, our visualization depicted busier stations with larger circles. Additionally, we added few interactions like hovering tooltips to these data points. We also added a time histogram for every month from July 2016 to September 2018, which were used to filter the rental data in the map for that particular timeframe.
Apart from the visualization design, for this project we also performed a detailed evaluation study of our visualization that helped us determine our visualization's effectiveness and also gave us suggestions for improvements and future directions.

5.3 Current Milestone Contributions

In this milestone, our major focus was towards the evaluation of our visualization. So, for this purpose, we presented our visualization to a group of twelve people with some open-ended and close-ended questions. We also made a comparison of our visualization with another visualization with a somewhat equivalent goal. And in the end, we made a presentation in front of our class which was entirely comprised of people from visualization background and collected feedback from them. This feedback also served another form of evaluation for our project.

5.4 Previous Milestones Contributions

In the previous milestones, our work was focused towards the collection of the data and making the visualization design. Milestone 1 was about the proposal of the project which contained the problem statement, impact of the visualization, plan for evaluation, etc. Our contribution in this included getting everything ready to start the project. This included performing initial research, deciding on the technology to be used and creating an overall timeline for the project.
In milestone 2 we primarily worked on doing extensive background research on related work, data and task abstraction for the visualization and coming up with preliminary designs for the project. After deciding on the visualization to proceed with, we also started with initial data cleaning and pre-processing for our visualization.
In next milestone, we created our initial skeleton of the geographical map and mapped some initial data over it. This way we achieved more technical progress. Finally, in milestone 4 we fine-tuned the map, along

with designing the tooltips. We also created the time histogram for data filtering. We implemented our design rationales and related them back to the data and task abstractions discussed in the previous milestones. In this milestone, we completed almost all the planned visualization design.

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