Visualizations for Mobility Policy Design

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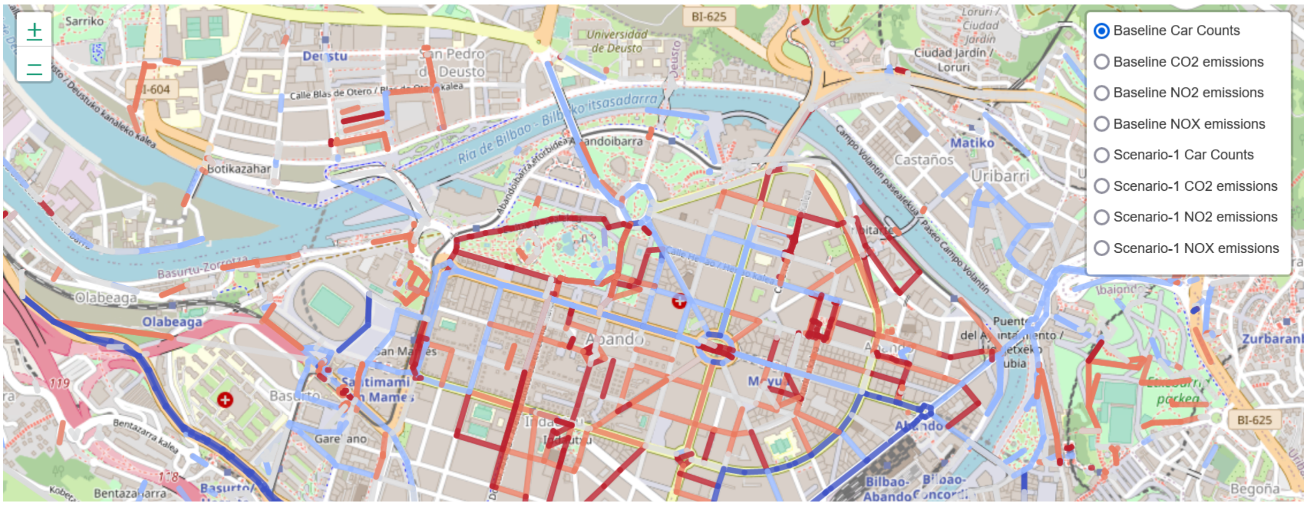

Figure 1: Visualization of simulated traffic flow intensity in center of Bilbao.

ABSTRACT

Cities around the world are rapidly gaining population as more people are moving to urban areas from the periphery. At the same time, novel urban mobility solutions are emerging such as e-cars and micro-mobility. Thus, urban traffic is getting heavier and more complex. To deal with these problems the H2020 URBANITE project is developing tools for city administrations including a data platform, mobility policy validation via traffic simulation, decision support for multi-attribute decision analysis and a visualizations module, described in this paper. We consider different types of visualizations in the domain of urban traffic and select most appropriate, implementing a module used for data visualizations for the system.

KEYWORDS

smart city, urban mobility, visualization

1 INTRODUCTION

Cities' mobility landscapes are rapidly changing due to the raising populations as well as new and disruptive mobility modes that are emerging. As the populations of cities are growing, so are occurrences of traffic congestions, air pollution and traffic noise in urban areas. At the same time, introduction of novel mobility modes both in the sector of micro-mobility (e-scooters, bike sharing etc) and sharing services in other sectors cause dynamics of the urban traffic to change [3]. This makes it increasingly difficult to model the growing complexity of the urban mobility as well as predict the effects of specific policies. This makes the prediction of possible effects of mobility policies more difficult but also more important. The importance of policy effects has been shown on the example of e-scooters [1]. They offer a clean and sustainable way of travelling the first and last kilometer of the trip but can also be very dangerous when not properly regulated.

We are developing a new AI assisted tool set for supporting the development and evaluation of urban mobility policies as part of the URBANITE H2020 project [7]. The project includes a mobility policy simulation, a recommendation system for policy design support, advanced visualization suite and a machine learning component for quick evaluation of expected policy results. This paper focuses on the visualizations of the traffic data, simulation results and decision analysis.

The end users of the tool set are city administrations (generally not technical personnel), urban mobility planners (experts on mobility) and interested citizens (laymen). These groups differ greatly with regards to their knowledge as well as the intent of interacting with the system. Citizens are interested in understanding the administration's actions but do not have a direct

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possibility to work with the system. Urban mobility planners are mostly already using traffic simulation tools and data analysis tools and require a highly detailed view of the data and analysis results. They are not limited by their knowledge and are used to working with complex tool sets. The city administrators however are similar to the citizens in that they are generally not experts on urban traffic and mobility, but are expected to make decisions about policies. The visualizations developed are primarily aimed at the city administrators with the goal to help them understands and interact with the data available, compare the results of different policy proposals and help with the interaction of the experts with the administrators. The second goal of the visualizations is to inform the public and democratize mobility planning. To achieve that the visualizations should be self explainable.

The paper is organized as follows: Section 2 overviews the common visualizations and their advantages and disadvantages, Section 3 covers the selection of visualization methods for first release and Section 4 describes the implementation of specific visualization methods.

2 VISUALIZATIONS IN THE TRAFFIC AND MOBILITY DOMAINS

This section overviews the common data types in the domains of traffic and mobility and the visualization methods commonly used to represent the data. The data types overviewed are traffic flows, air pollution and specific pollutant emissions, general tabular data, geo-spatial data and geo-temporal data.

2.1 Spatio-Temporal Data

In the domains of urban mobility and traffic spatial data is very common, since most of the data is related to specific roads or locations within the city. This category contains all such data, including the road networks (city maps), traffic flows on roads and streets, trips made and modal splits of traffic in specific locations, as well as population properties in different statistical districts of the cities, locations of important facilities such as hospitals and schools, parking lots and public parking garages and public transport lines. Some of these types of data are further discussed bellow in the section Traffic Data.

These data are best represented as interactive layers on a map. Each layer must be visually distinct from the underlaying map to ensure the visibility of the data. Often it is less important that the map itself is easily readable as it serves mostly as a spatial anchor that allows the easy recognition of general locations. To ensure the understandability of the geo-spatial visualizations data layers can be interatively selected so only the relevant data is shown at the same time.

To keep the data minimally cluttered and therefore more understandable we do not show details of the data on the map unless the user hovers the mouse over some part. In this case, a popup with the details of the selected locations are shown. This can be seen on the Figure **??**, where the demographic data is shown for each district. Generally one of the attributes is shown using a color scale on the map and other attributes are only shown when user hovers over a specific city district.

The most intuitive way to show time-dependant data is by animating the visualiziations. To simplify the interaction and thus reduce the mental overhead we show a timeline below the geo-spatial view. The user may select the time they are interested in or play the animation at different speeds. An example is not shown due to the limitations of printed media.

2.2 Traffic Data

Traffic data includes traffic counts, trips, and Origin-Destination (OD) matrices. There are multiple ways of visualizing these data. Following is a brief overview of common visualization methods used on these types of data.

2.2.1 Traffic counts. Traffic counts at a specific location are commonly shown via line charts where the horizontal axis represents time (usually one day) and the vertical axis represents number of vehicles passing the location. To compare data from several specific locations we can show multiple lines on the same chart using different colors.

To visualize the traffic counts all over the city simultaneously geo spatial map based visualizations are commonly used, either as point-based or line-based map layers. Point-based visualizations are best suited when the traffic counts are measured using existing sensing devices such as induction loops or smart cameras. Such sensing devices are usually not available on every road segment. In this case the points locate the sensors while the values measured are commonly color coded.

2.2.2 Traffic flows. Traffic flow is the amount of vehicles that pass a certain point on the road in a time slot. Traffic flows are commonly visualized using line-based map layers, where the traffic flow is represented either by line thickness or color. To specifically show the modal split of the traffic flows we can show them separately or at the same time. In the latter case it is best to use color codes to represent different types of vehicles and line thickness to represent the traffic flow.

2.2.3 OD matrices. OD matrices hold the information about number of people moving from parts of the city to other parts. Commonly the spatial resolution of the OD matrices matches statistical regions. OD matrices are commonly obtained using travel surveys, estimated using GPS traces of trips and public transit data.

Common method for visualizing the OD matrix data is to show the matrix as a heat map with rows and columns labeled with the name of the district. Such visualizations are hard to understand and under certain conditions can be cluttered, decreasing their readability.

Alternatively OD matrices can be shown on a map via connections between districts. The intensity of travel between two parts is commonly represented via the connection thickness, while color is typically used to distinct different connections. This method is easier to understand, but readability depends on the geographical positions of the districts.

2.3 Air pollution

Air pollution levels are usually visualized using heat map layers on top of the city map, and are therefore counted among the geo-spatial visualizations. Generally the most common method for visualizing air pollution is an air quality index heat map. Some of the advantages of visualizing air pollution as a heat map are high understandability and very low visual cluttering. A negative aspect of heat maps in this use case is that air pollution often does not spread equally in all directions due to air movements and buildings blocking the pollutants' paths. This is however not very important as the users are mostly interested in general pollution levels and in the case of the URBANITE project the levels of specific pollutant emissions.

3 SELECTION OF METHODS

The selection of methods to be implemented was based on the pilot city requirements, data availability and the available simulation outputs. In order to support comparing the measured data and the simulation results we are limited to using visualizations that are appropriate to both.

This section covers the visualization methods we have selected and is split by the type of data into traffic, air pollution, and other data visualizations and concludes with a brief discussion of the color maps chosen to represent the values.

3.1 Traffic data

The category of traffic data contains multiple different data types that have to visually represented using different methods. Some of the data that is shown using the methods for geo-spatial data visualization are:

- Traffic counts, shown either geo-spatially by aggregating the counts per day or geo-temporally by aggregation of the counts per specific time slot, commonly hours. Traffic counts at a specific location depends on time.
- Traffic flows, measures in vehicles per hour passing a road. The traffic flow at a specific location depends on time. The specific flows for different modes, such as public transport, heavy duty vehicles, bicycles and pedestrians are currently visualized separately.
- Congested roads. Simplest way of identifying problematic roads or junctions is to show the locations of congested traffic. We can detect congested traffic and traffic jams by searching for road segments with high traffic density and travel speed below the free-flow speed [8].

Some of the more detailed traffic data are better visualized using simpler charts. Traffic flows at specific locations over time are shown using a line chart. Traffic flow predictions at specific locations are shown using a line chart with the confidence interval included to inform the user that these are not exact. Modal splits of traffic at specific locations as well as city-wide aggregations of modal splits are visualized using area charts or stacked area charts.

3.2 Air pollution data

Due to the data available in pilot cities as well as the results of the traffic simulations we are not able to map the air quality index. Instead of air quality index, the data available includes levels of specific pollutants at existing measuring stations and the simulated levels of the same pollutants.

Therefore we show the available data: measurements at existing air quality monitoring stations are shown as a sparse heat map layer showing the levels of selected pollutant while the simulated pollutant emissions are shown as a layer over each road segment that shows the selected pollutant level.

4 IMPLEMENTATION

The visualization were implemented as part of the URBANITE user interface (UUI). We focus on the UUI modules used to analyse the simulation results and the comparison of two simulations.

The UUI is implemented using the Angular framework [4] mostly in TypeScript with some JavaScript parts. For ease of integration and to be able to package the UUI module as an Angular module we opted to use JavaScript libraries Leaflet.js [2] and echarts [5]. Leaflet.js is used for all geo-spatial and geo-temporal visualizations. It provides an interactive map and the functionality to add custom layers to the map. We use the library Echarts to implement any line charts and spider charts.

4.1 Map based visualizations

Multiple visualizations were developed to visualize certain geo-spatial data:

- Visualization of the traffic flows is shown on Figure 1. Each street is overlaid with a line, colored according to the traffic flow intensity. Less intensive flows are shown with blue hue and more intensive flows are shown in red. The color scale consists of a five color ramp selected for best visibility on the base map.
- Visualization of emissions of specific pollutants. Each street is overlaid with a line, colored according to the amount of selected pollutant. Streets with less emitted pollutants are shown in blue and streets with more are shown in red.

These visualizations are implemented using JavaScript and based on maps provided by the library Leaflet.js[2]. The overlays are generated from the simulation results by aggregating road network links by street name and summing the selected attribute for the day or per hour, thus enabling animated visualization of changes throughout the day or a static daily attribute visualization.

4.2 Color maps

We use one color map for all the visualizations that are based on the city map. The color map selected must be diverging in order to highlight best and worst values according to their desirability. The chosen map a diverging color map using red colors for undesired values and blue for desired values. The color map should also be appropriate for color blind users to avoid potential misunderstandings. With the requirements of the color map defined, we selected a color map named cold-warm [6] that fits our needs. The color map is shown on Figure 2 and is a a diverging color map that is colorblind safe. We have opted to use a five step color map instead of the full gradient to make the extreme values stand out more.

Figure 2: Color map used for overlays. Blue color is used for desired values and red color is used for undesired values.

4.3 Interactive charts

We use interactive charts implemented using the echarts library to implement line charts, histograms and spider charts. Line charts are used to analyse the modal splits on specific streets and the level of selected emitted pollutant (CO_2) using an overlaid area chart. These were made interactive to allow the user to zoom in and move the viewport around. Hovering over any of the lines shows the number of trips of the appropriate modes as well as the mode the line represents.

The same visualizations were also implemented as 3D line charts as shown on Figure 3. Lines are replaced with strips and instead of adding an area map to show the emitted pollutant levels they are color coded using the strip color. These allow more interactions such as panning and rotation.

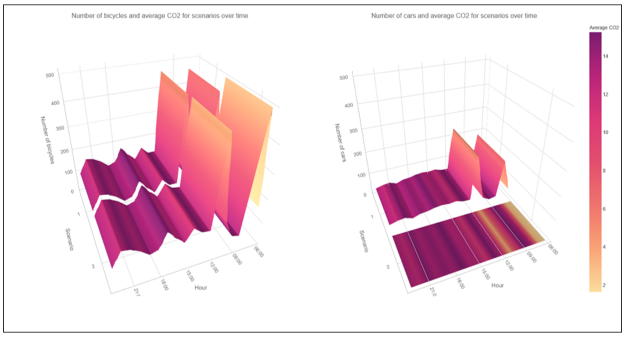

Figure 3: Visualization of the modal split between car and bicycle trips and the amount of the CO_2 emitted on the selected street The CO_2 levels are color coded.

A spider chart was implemented using the echarts library for multi-attribute comparison of different simulation results. This allows the user to recognize the dominant solution at a glance based on the size of the area that represents the simulations. On the other hand they allow us to show the detailed values of multiple, potentially competing attributes. Thus the user is able to understand the data at a glance on some level while also providing the details when the user hovers the mouse over axes of the spider chart or the line representing a single simulation result. An example of the spider chart can be seen on Figure 4.

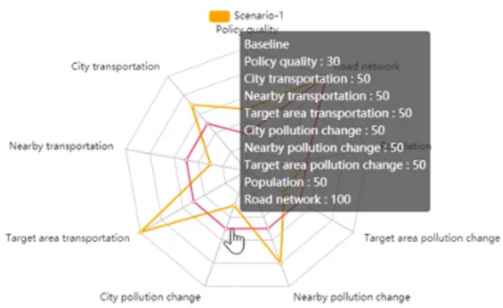

Figure 4: The spider chart shows the comparison of two different proposed mobility policies based on the simulation results. We can see the popup that shows values of all attributes of one of the simulations.

5 FUTURE WORK

There is a lot of room for improvement and the work is ongoing. Several visualization techniques covered are not yet finished, such as the geo-temporal visualizations and the heat maps. The next step is to finish the implementations of all the selected visualization types and to improve the visual appeal of the visualizations.

In order to compare the air quality measured with the results of simulations which provide estimations of the levels of emitted specific pollutants the data must first be transformed to an estimation of the air quality index. An alternative to this approach should it prove infeasible is to use the simulation results to estimate the measurements at the location of the measuring stations.

6 CONCLUSIONS

1 we overviewed the common methods of visualization of common traffic data

We have overviewed the mobility related open data-sets available in four major European cities and identified the most important for dealing with urban mobility policy. Several different sorts of data were analysed and appropriate visualizations were selected. Some of the visualizations are implemented, specifically traffic count, daily trips, and emitted air pollutant visualizations, among with some of visualizations of policy comparison.

The module implementing the visualizations supports the needs of the urban mobility analysis tool-set that we are developing. The visualization selection and implementation fits the needs of different users and will be further improved as we gather feedback from the pilots.

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