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Interactive Visualization for Real-time Public Transport Journey Planning

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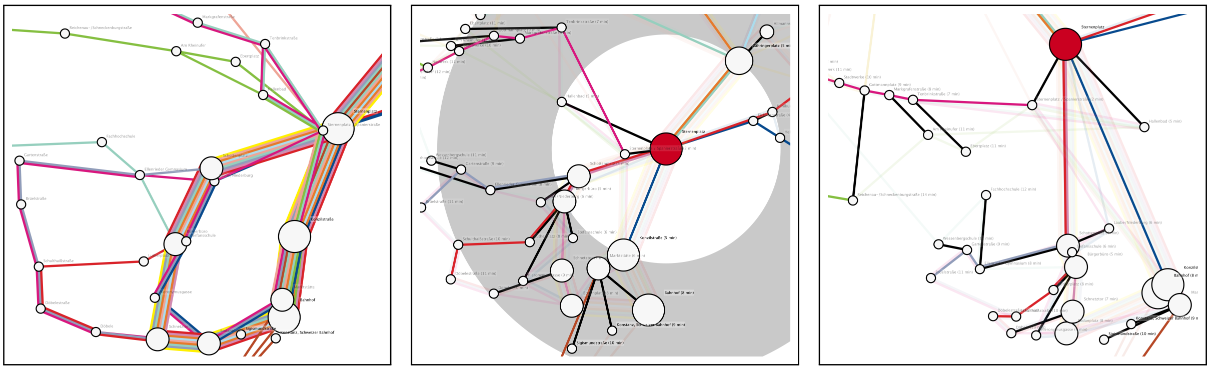

Figure 1: *Visualization of the bus transportation system of Konstanz (Germany) created with* BusVis*. Left: Geographical layout. Center: Radial layout. Right: Stress-majorization layout.*

Abstract

On-line journey planners encourage the use of public transport systems by easing the task of finding "optimal" routes between start and destination locations. Most of the tools lack the flexibility of comparing journeys that end at different (but maybe nearby) destinations. In this paper, we propose a novel visualization tool for public transport journey planning that integrates graph layout techniques to allow visual comparison of travel time and journey directions. Our tool uses data from the bus system of Konstanz. Taking this data as example, use cases describe the tool's applicability to trip planning with route alternatives.

1. Introduction

The motivation of using public transport is often hindered by inflexibility in journey planning. Without careful planning a traveler might end up wasting a lot of time waiting for the next connection or walking a long distance to reach another station. To solve this problem much effort has been devoted to develop on-line journey planning tools, for example, the Transport for London journey planner [Lon], the Public Transport Victoria journey planner [PTV], or the Rail travel planner Europe [Rai]. Most of these systems allow the user to enter a starting point and destination of a planned journey to find optimal routes between them. Some systems additionally allow for setting preferences (e.g., change times or types of vehicles) to refine results accordingly. However, most of them lack the ability to set multiple destinations to compare different journeys.

In this paper we propose a novel visualization system that provides overviews of a transport system in terms of distance and travel time, as well as easy comparisons between different routes and journeys. We exemplify our approach by showing our tool, *BusVis*, for planning bus journeys within the city of Konstanz, Germany. The system focuses on visualizing travel time between different locations and supports comparison of multiple destinations. Two modes of visualization display travel time with focus on a position selected by the user.

2. Related Work

Map drawing is a well established discipline ranging from prominent examples like Beck's map [Gar94] to recent techniques allowing automatic creation of metro map layouts [SRMOW11, NW11]. While being a generally broad topic, we want to focus strongly on related approaches for journey planning.

Early evidence for superior efficiency of using spatial maps over tabular data for choosing bus routes has been given by Bartram [Bar80]. Bogen *et al.* [BBZ10] analyze map examples, both historic and current, to open up space for innovative map designs, blending art history and computer science. In this context, the authors propose distortion and details-on-demand techniques to help the user focus on relevant areas rather than the complete map. Böttger *et al.* [BBDZ08] use such a technique to warp maps. A semantic zoom provides the possibility to explore the nearby area of a station without distortion while the overview is warped to represent the schematic map.

Hoar [Hoa08] proposed a web based geographic information system that displays schedule times of buses. The user can interactively query the system by entering bus stops or geographic locations and see the optimal route highlighted. Visualizing network lines on top of a geographic map has advantages in reflecting distances between stations. In crowded central areas of a map lines may be occluded. Wang and Chi [WC11] addressed this occlusion problem and proposed a focus and context technique that allows highlighting of routes while the remaining context is deformed. In contrast to standard focus lens techniques their deformation method is guided by Beck's map constraints. Both approaches, like many existing on-line journey planners, allow only planning of one-start-to-one-end connections.

Our system was encouraged by a visualization of the London Underground by Tom Carden [Car12]. His system allows to focus on a station and recalculate travel time from this station to other stations. Time is projected as distance to the selected station and angles reflect directions on the original map. One drawback of the system is that it uses time independent routing which ignores the schedule and possible waiting times.

3. Application

We design *BusVis* as interactive visualization tool for journey planning in transit systems exemplified on the bus network of the city of Konstanz, Germany. Our goal is to provide a flexible system that allows travelers to search for optimal routes between locations while still being able to compare different routes. The example data set consists of 123 bus stations, 18 bus lines and 16,088 edges between stations with departure times and travel duration. Based on this, the system finds fastest routes from one starting location to multiple destinations and maps travel time to visual distance. Visualization

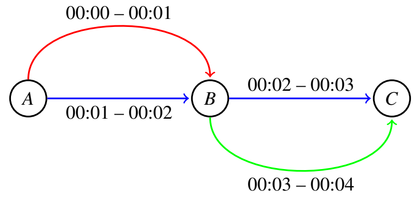

Figure 2: *Change times allow suboptimal intermediate steps to result in an optimal solution. From station A the fastest path to B is the red line. Considering a change time of two minutes, it is impossible to catch the blue line at B. Therefore the green line has to be taken. However, when a traveler takes the blue line at A he reaches B later than with the red line but arrives earlier at C.*

techniques are applied to show query results in a way that allows intuitive understanding, interaction, and comparison between different routes.

BusVis provides an interactive graphical user interface to support dynamic queries and shows the results visualized in a dynamic node-link diagram where nodes represent stations, edges show connections between them, and the size of a node depicts the number of lines. This allows rapid interpretation of overall connectivity and easier path tracing than adjacency matrices such as regular bus plans [GFC04, Bar80]. Edges of bus lines connecting same stations are drawn next to each other distinguished by line color. Walking edges are drawn in black when used for traveling. The interface allows the user to set a starting location and starting time, optional destinations of a planned journey, maximal tolerated walking time, and an estimated duration of changing bus lines. Automatic selection of the current time allows real-time updates. The results are shown in two different visualizations that allow either local correctness or global stress minimization for the distance mapping. Transitions are smoothly animated and the initial layout shows the geographic positions to retain the mental map [MELS95]. The schematic overview plan in the top left of Figure 3 provides a stable layout for easy station localization. Semantic zooming adaptively adds or removes station labels to make the visualizations less cluttered.

4. Routing

The travel time between two stations may vary throughout the day because of waiting periods and irregularities of the schedule. We modified the Dijkstra algorithm [Dij59] in order to determine routes on a graph with time dependent edge weights. Starting on a node at time t the optimal travel time lies in the interval $[t, t + w(t)]$ where w is the edge weight function. Using the partial periodicity of the schedule, bus lines can be split up into tours, which can be defined as an identification of a bus in its line. Later tours can be omitted because using a later bus of the same line never leads to a

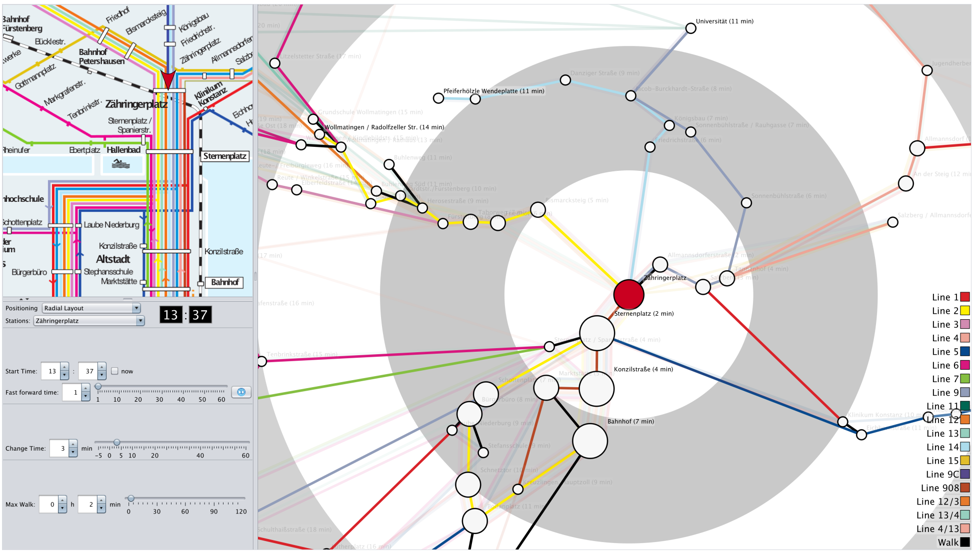

Figure 3: *The* BusVis *graphical user interface. Note the preservation of the geographic relations in the radial layout (center), as seen on the schematic overview (top left). The start location is indicated red and a color legend for bus lines is provided in the bottom right corner. The distance of a node to the origin is mapped to the travel time needed to reach the station.*

faster route. Changing bus lines requires time so that suboptimal intermediate steps can still lead to an optimal route. In Figure 2 the optimal route from A to C uses a suboptimal edge to B when assuming a change time of two minutes. Keeping track of the complete route from the starting location avoids this problem and also allows to reconstruct the final route. The worst-case runtime is similar to Dijkstra's algorithm although practically below, because most of the edges are not considered.

5. Visualization Techniques

We display the routing results in two different layouts. The radial layout (Figure 3) arranges stations concentric around the starting location while visual distance between any station and the center exactly reflects the fastest travel time to reach the station. To preserve the mental map we chose the direction to align with the geographic positioning. Concentric rings represent five-minute intervals and help the user compare distances in different directions. Resulting overlaps may occlude information and make the visualization less visually appealing. We resolved this by slightly changing the direction of overlapping nodes which does not affect visual distances. However, visible edges between two stations do not necessarily show the time needed to travel on them because only distances to the center are correct.

The stress-majorization layout reflects distances between all stations by finding an optimum in which every edge approximately has the length proportional to the time it takes to travel on it. This is an optimization problem which does not result in an exact solution. We used the *SMACOF* algorithm [dL77] to minimize the global stress function. Geographic positions of the stations are chosen as initial layout in order to roughly maintain the shape of the bus network. While travel times along edges are represented more accurately than in the radial layout, the mental map is not as well preserved. Overlaps cannot be resolved since node movements result in higher stress. However, stations connected by the same bus line can easily be identified as seen in Figure 4.

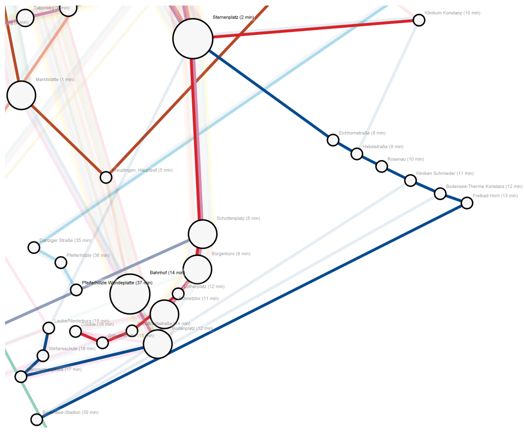

Figure 4: *Stress-majorization layout. The edge lengths between stations approximately represent travel time. Stations connected by the same line are lined up and can easily be identified (blue and red line).*

6. Use Cases

Our tool is useful for different user groups. Bus schedule planners can use the radial layout to get an overview of how well stations are connected throughout the day. To identify long waiting times when changing bus lines on a route, the stress-majorization layout can be used. Also frequent walk suggestions or outlier stations in one of the layouts indicate bad reachability.

The system can also be used to easily compare travel times. For example in the city of Konstanz, the bus stations *Universität* and *Egg* are geographically very close despite having no connecting street and therefore no bus connection. This raises the question when it is rewarding to chose one destination over the other. The user can simply choose the station that is closer to the center in the radial layout. Figure 5 shows that the optimal choice can change throughout the day. A similar scenario would be to find the fastest reachable restaurant for dinner from the current position. The corresponding stations could be integrated into the system. Another task is for citizens to find a flat with fast access to basic needs like grocery stores, doctors, and workplaces. The possibility to experiment with different times enables the user to check how the reachability of those places changes throughout the day.

A physical display at stations is thinkable as public time table. This display would use the radial layout with the station as starting point and the current time to help travelers at the station plan their routes, find out the arrival time, and get an estimation of needed waiting times.

7. Conclusion

We presented a novel visualization tool that allows the user to plan bus journeys within a city by exploring the shortest routes in the transportation network at a given starting time. The user can navigate the visualization and modify parameters with instant feedback via an interactive interface. Two graph layout techniques are integrated to visualize routing query results. The radial layout is especially useful at transit stations, where the starting point of the layout is the transit station itself. The tool is easily adaptable to support journey planning in other cities and networks with different means of transportation, only the data at the back-end has to be exchanged. We demonstrated the usefulness of the tool by a number of use cases that involve different tasks and user groups. As future work we want to show applicability of our approach on larger, more complex data sets.

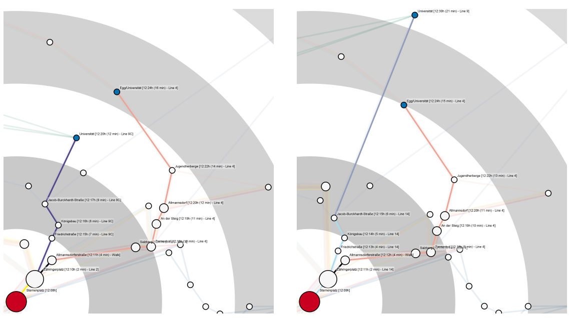

Figure 5: *Routes from* Sternenplatz *(big red dot) to* Universität *and* Egg *(small blue dots) at different times. On the left* Universität *(blue line) is closer than* Egg *(orange line), vice versa on the right.*

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