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Visualizing the Modal Split in Public Transportation Networks

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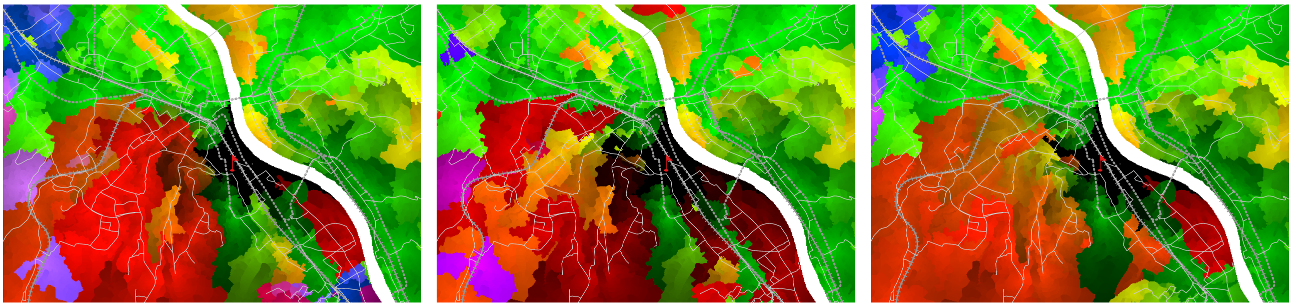

Figure 1. Accessibility computed for each mode of transport and mixed together as a color (red: bus, green: tram, blue: train, brightness: walking) for starting times: 1.00pm (left), 4.00pm (center) and 6.00pm (right). The white stripe represents the Rhine river. See Figure 2 for a legend.

Abstract:

Public transport constitutes the backbone of urban and sub-urban mobility in densely populated areas. Public transport systems are comprised of different modes of transportation that are fixed to routes and timetables such as railway, tram and bus. When using a public transportation system, a user usually not only spends time inside of these specific modes, but also on transferring between modes or on walking to his start and destination stations. Visualizing the modes of transport used to access a region is an important aspect for public transport planning and decision making. Such a visualization succinctly reveals deficits in existing infrastructures and triggers a redesign towards sustainable forms of urban transportation. In this work, we present an approach that uses an efficient color mixing method to visualize the combination of public transport modes that serve a region given a starting location and starting time. In specific, we overlay the region with a colored raster surface where the different color channels encode time spent in different modes of transport when traveling to this location from a given starting location and starting time.

We use two data sets: public transport timetable data as provided by many public transport companies as open data and road network data acquired from OpenStreetMap[1], the latter is only used for walking. In order to calculate travel times in this network, we use the multimodal routing model as described by Forsch et al. (2021). In specific, we set up a routing graph $G = (V, E)$, where every edge $e \in E$ is annotated with the mode of transportation and we use the time $t(e)$ it takes to travel along e as its cost. The vertex set V consists of two vertex types: the vertices V_r of the road network which represent the geometry of the road network and the vertices V_p of the public transport.

We start by computing a single source shortest path tree starting at the vertex v_s corresponding to the specified start location and departure time. We continue by computing, for every vertex $v \in V_\mathrm{r}$, the time spent in the different modes of transport including the times spent walking or waiting for transfers to reach v. We do this by iterating through the arcs on the shortest path from v_s to v and for every mode m in the set of modes M cumulatively summing the time $t_m(v)$ spent in m during the trip. Given the total time $t(v)$ to travel to v, we then compute the ratios $r_m(v)$ spent in the different modes.

From the computed ratios we generate uniform raster surfaces for each mode of transport. For this, we assume that each vertex $v \in V_\mathrm{r}$ is a point-wise observation and has influence around its neighboring region. We perform inverse distance weighted spatial interpolation (IDW) to get a continuous surface-based visualization. The interpolated ratios are then layer-stacked to generate a composite of the three main modes of transport with the red channel being the bus ratio r_B, the green channel being the tram ratio r_T and the blue channel being the train ratio r_R. We optimize the brightness while maintaining the coloring pattern in order to achieve a raster image of high quality. For this, we apply Maxwell's color triangle optimization by scaling the RGB values of each pixel by the largest value among the three channels (cf. Figure 2).

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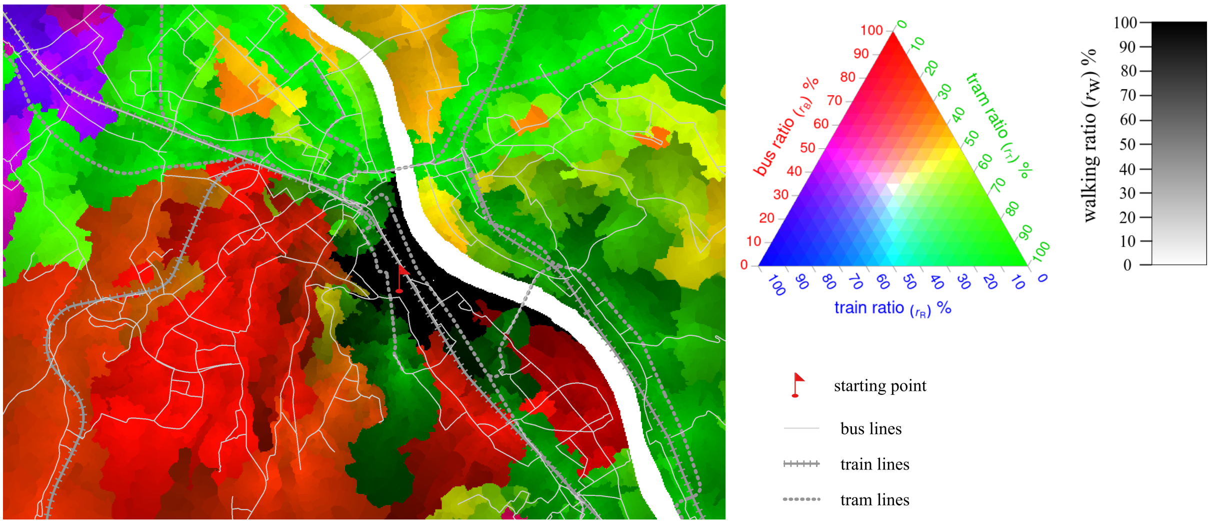

Figure 2. Surface showing public transport coverage for the city of Bonn, starting at the main station at 10.00 am. Red represents bus, green tram and blue train. The darker the color the more walking is involved. The visualization reveals interesting patterns in the transport system: the region right of the Rhine is mainly served by tram while the region to the left in mainly served by bus. The train only gains influence at larger distances (see purple region in the top left).

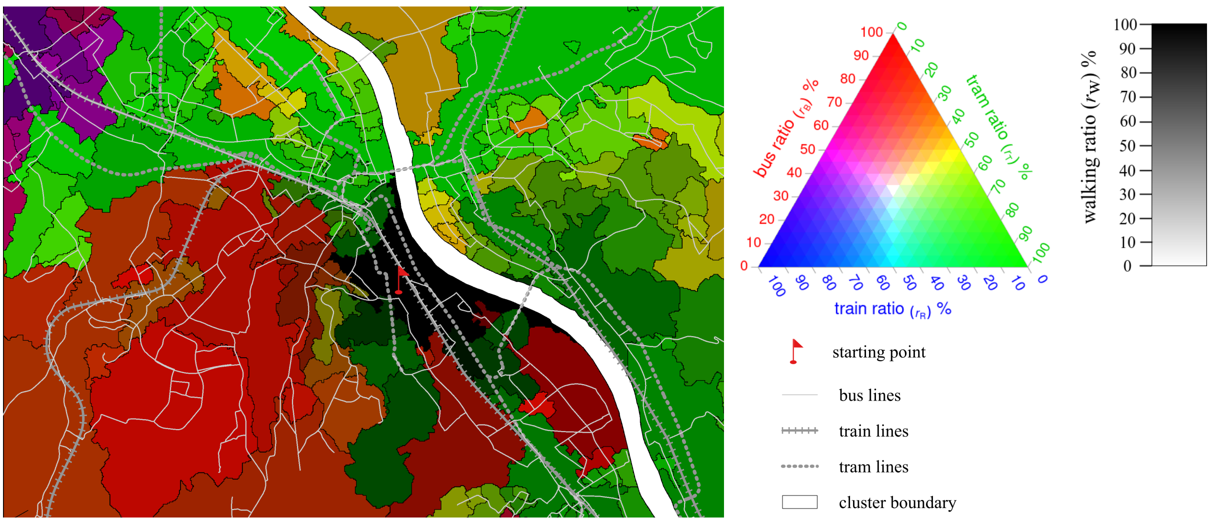

Figure 3. Segmented surface showing public transport coverage for the city of Bonn, starting at Bonn main station at 10.00 am. Each cluster represents a region that is reachable by a specific combination of modes of transport.

To this end, we have encoded three travel-time ratios in our visualization: the ratios spent in bus r_B, tram r_T and train r_R respectively. The relative amount of time spent walking r_W is not represented yet. However, this ratio a crucial element in individual trips. To encode this value, we incorporate the brightness of the colors. The Maxwell's color triangle optimization provides colors with maximum brightness. Hence, the brightness can be used as an additional degree of freedom to visualize walking ratios. To this end, we scale the RGB channels by the inverse of the walking ratio r_W. That way, locations that are reachable with less walking appear brighter than locations that require a lot of time in this mode as can be shown in Figure 2. Lastly, we improve our visualization by grouping pixels of similar color in clusters using mean shift image segmentation algorithm. This results in a homogeneous clustering of pixels as shown in Fig. 3 where each cluster can be interpreted as a region that is reachable by a specific combination of modes of transport.

For now, the visualization shows the modal split that is used to access a region. Absolute travel times are not visualized. This is a subject of ongoing and future research by incorporating isochrones to the visualization. Additionally, the visualization of the public transport network can be reduced to only display the connections on the shortest path tree. Last but not least, animating the visualization over the course of a day helps in identifying deficits in the public transport timetable.

References

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