RRAMEN: An Interactive Tool for Evaluating Choices and Changes in Transportation Networks

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ABSTRACT

This demonstration paper focuses on transportation-related queries within a city that go beyond simple routing and that are of interest to different types of users. For instance, individual users could be interested in which modes of transport are more effective to reach a set of alternative locations at a given time of the day, whereas urban planners could be interested in the effect that adding/removing a bus line would have in connecting regions of a city, e.g., a residential neighborhood and downtown. Given that context and using real data from the city of Berlin, we introduce RRAMEN, an interactive tool which is well equipped to support different city-scale mobility-related queries by different types of users.

1 MOTIVATION

Mobility within a city is both an important problem from an individual point of view as well as a higher level concern from a planning perspective. In sync with the current efforts towards mitigating climate change, we believe that there should be, whenever possible, a concerted effort to incentivize the use of public transportation systems. A few of the many worthy goals that can be accomplished with better public transportation systems are reducing traffic, therefore gas consumption, pollution and noise, reducing the need to dedicate large spaces for parking, thus creating more space for people, reducing costs associated with road maintenance, etc. Hence, there is a clear need for better (or complementary) tools that can support/promote a shift from using private vehicles on a regular basis towards public transit. This is the context that implicitly motivates our discussions and contributions in this paper. Also, in keeping with the above and for the purpose of this demonstration, but without loss of generality, we constrain ourselves to two modes of transport, public transit and private vehicles, and two types of users, individuals and urban planners.

Individual users are likely familiar with mobile routing solutions, e.g., Google Maps[1]. Those apps are typically designed for end-to-end routing (possibly setting some intermediate points, between origin and destination). Some of these apps also allow users to compare the efficiency of different modes of transport, e.g., public transit, private cars, bike and walking. However, as we will discuss shortly, comparing modes of transport is a use-case that is not easily contemplated by current apps but which is

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[1]https://www.google.com/maps

nonetheless of practical interest to individuals in the sense that it can, even if in a subtle manner, persuade them towards using public transportation. Additionally, we consider the role of urban planners. These individuals are interested in transportation from a collective rather than individual perspective and could make use of tools that help them in that respect.

Many existing systems, e.g., SANET [5], TransCad[2], and ISOGA [4], provide algorithmic solutions that enable the evaluation of public transportation systems through accessibility and/or reachability analysis [2, 8]. Another common approach employed by systems such as TRANSIMS [7], is the analysis of transportation systems through simulation. While the aforementioned systems can provide insight for the design and evaluation of transportation networks, they also come with the shortcoming of examining modes of transport in *isolation*. In many real-world scenarios though, users are more interested in the efficiency of a mode of transport in comparison to other available ones.

Towards the goal of investigating the compromises between different modes of transport from different perspectives, we recently proposed the notion of Relative Reachability [3]:

> Given a set of modes of transport and a source location, the *Relative Reachability* (RR) determines the mode of transport which minimizes arrival time at a given destination location. (As we shall discuss later, this concept can be extend to multiple destinations and/or regions.)

Given this context, our main goal in this demonstration paper is to present RRAMEN[3], a web-based tool which leverages on the RR concept in order to support different types of users with different needs. Towards this goal, in what follows, we discuss the data model underneath RRAMEN, along with its potential users and queries of interest. Next, we discuss in more detail a few queries reflecting the motivation above, while at the same time illustrating how RRAMEN can be used to answer these queries.

2 OVERVIEW OF RRAMEN

RRAMEN is a tool for Relative Reachability Analysis on Multi-modal NEtworks that enables users to process a variety of RR queries and visualize the results. Our system is implemented in Python using the NetworkX[4] package for modelling the network, uses PostGIS[5] to store road and public transportation network data, and employs Mapbox[6] to display the map and visualize results. Figure 1 shows RRAMEN's interface. On the top left-hand side the user can define the source(s) and the destination(s), which
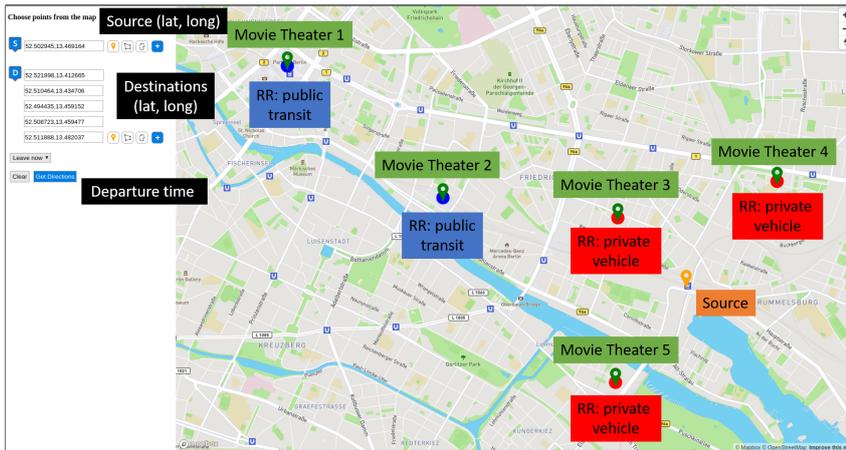
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[2]https://www.caliper.com/tcovu.htm
[3]https://github.com/camilaferc/rramen
[4]https://networkx.github.io
[5]http://postgis.net
[6]https://www.mapbox.com

Figure 1: Illustration of RRAMEN's interface as well as the scenario discussed in Section 3.1.

Figure 2: Speed over an edge during the day as %-age of maximum speed.

Figure 3: Stop with three routes, R_1, R_2 and R_3, and a parent node P connected to the road network.

can be either a single location, multiple locations or a region. The user can easily select these by clicking on the map. We note that while the processing of some queries is a computationally interesting topic, this paper focuses on discussing their applicability and on how RRAMEN can be used in practice.

In order to answer the queries supported by RRAMEN, we first obtain the road network (including footpaths) from Open Street Map (OSM)[7]. A PostGIS table is created to store the road networks' edges with their length, maximum speed, allowed transportation modes and geometry. To mimic how traffic fluctuates during a day, we assign to each edge of the network a speed distribution similar to the one illustrated in Figure 2. To compute such a distribution, we obtain the maximum allowed speed for each edge from OSM, split the day into a fixed number of time intervals (twenty four) and introduce a penalty that reduces the maximum speed during rush hour. Naturally, this assumption is orthogonal to RRAMEN's operation, i.e., should one have the actual speed distribution for each edge of the network, that could be easily integrated into RRAMEN.

Next, we obtain public transit data from GTFS[8] feeds, which include transit information such as stops, routes, trips and schedules. Such information is stored in a set of relational tables in PostGIS. For each route, we first extract the stop sequence covered by it. Then, for each existing route-stop pair, we create a node and add it to the public transit network. For instance, consider the stop shown in Figure 3 represented by a dotted box. There are three routes, R_1, R_2 and R_3, passing through the stop and, consequently, three nodes are created for that stop. Moreover, all nodes within a stop are directly connected to each other through an edge, the cost of which is given by the time to transfer from one route to another. Such a transfer time is extracted from the GTFS feed whenever available or set to 0 otherwise. Next, consecutive stops of a route are connected through an edge which is associated with a timetable containing the departure/arrival times for the corresponding route represented by that edge.

Finally, we build a multimodal network following the time-dependent model [6]. To connect the public transit network with the road network we create links from each stop to its closest
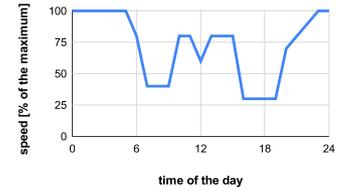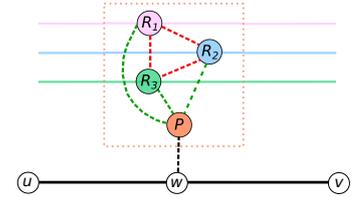
road edge, as shown in Figure 3. More specifically, we first create a parent node P for each stop that acts as an entrance point, and we connect all route nodes within the stop to P with zero-cost edges. Then we look for the closest road edge (u, v) to P. If the closest point to P is u (or v), we add a link edge from P to u (or v). Otherwise, a new node w is created along with two new edges (u, w) and (w, v) and a link edge is added from P to w. The cost of the link edge is given by the travel time on foot.

To process RR queries, RRAMEN employs variants of Barrett's algorithm for the language constrained shortest path [1]. We note that RRAMEN can build routes that use a combination of public transit modes, i.e., bus, train or tram, and walking, as well as driving and walking. In the latter case, we assume that a user can walk to where his/her car is parked, drive and possibly walk again to the destination. Due to lack of more fine-grained data, we make the optimistic assumption that when using a private car one parks as close as possible to the source location and to the destination.

RRAMEN can support a variety of types of users and queries. Table 1 shows two types of users and queries that would be well supported by RRAMEN. Note that while many of the requirements of individual users can also be addressed using existing route planning systems by executing multiple (independent) queries, RRAMEN makes the exploration and the decision making process much easier. Furthermore, while it is true that some users will choose a transportation mode regardless of the RR of the destination, we believe that allowing one to make such choices quickly and easily is of practical value. In particular, it may incentivize one to make choices that favour the use of public transit.

3 DEMONSTRATION SCENARIOS

In this section, we use real data from the city of Berlin to demonstrate how RRAMEN can be used in practice by individual users as well as urban planners. Note that while in the following discussion each query is associated with a particular type of user, RRAMEN imposes no such binding by design.

3.1 Individual users

Single source-multiple destinations. Consider a user who is at home and wishes to watch a movie which is showing in a

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Users		Queries (location-wise)	
Individual Users	**Urban Planners**	**One-to-many / Many-to-one**	**Many-to-many**
Can use RRAMEN to find easily reachable facilities within a city, or to make decisions related to their commute.	Can study transportation systems and the impact of changes on them.	Queries from a single source to multiple destinations or from multiple sources to a single destination.	Queries from multiple sources to multiple destinations (which can also model regions).

number of movie theatres. The choice of theatre could be based on how convenient it would be to reach that theatre w.r.t. the means of transportation considered. Figure 1 illustrates this type of one-to-many scenario, where the source is denoted by an orange marker and the destinations are denoted by green markers. The result of this query reveals that the two locations on the left half of the map (denoted by blue dots) have an arrival time earlier by public transportation than by car. Likewise, the other three possible destinations have an earlier arrival time by car.

In addition to determining the RRs for all destinations, the user may be interested in the actual arrival time at a given destination (using either means of transportation). For that he/she would simply click on the destination which would cause not only the arrival times to be displayed but also the actual suggested routes. This is illustrated in Figure 4 where we "zoom in" on the map in order to show only the relevant part of the interface[9].

Figure 4: Arrival times for Movie Theatre 3, along with the routes by both public transit and private car.

Now, one may ask, what is the practical relevance of such a query? Naturally, there are trade-offs to be considered. For instance, if a user measures convenience by not having to look and (very likely) pay for parking and/or being able to have a drink or two after watching the movie, he/she would choose to go to some movie theatre using public transit regardless of its RR. Also, if a movie theatre that can be reached faster by public transit is far away, the user may choose a closer one to be reached by car, even with the associated overhead. Either way, RRAMEN empowers the user to consider such tradeoffs by him/herself.

Multiple sources-single destination. Let us now consider a scenario that is sort of the "reverse" of the one above. Consider a user that is moving to a city to work at a certain location and is looking for a place to rent. One criterion to choose where to live may be how convenient it would be for him/her to reach his/her workplace by public transit whenever his/her working shift starts. In this case, it would be useful to see the RRs of different rental units. An important difference of this scenario w.r.t. the previous one, is that in the previous scenario the RRs are computed w.r.t. the destinations (which theatre would be more convenient to reach from home), whereas now the RRs are computed w.r.t. the sources (from which potential apartment it would be more convenient to reach the workplace).

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[9]Due to limited space, in what follows we show just the map part of the interface.

Figures 5 and 6 show the RRs of five apartments (orange markers) w.r.t. the working place of the user (green marker) at two different times, 7:30am and 5:30pm, respectively. By comparing the two figures we observe that the RR of all apartments but #4 remain the same. That is, if the user is interested in using public transportation, then apartments #3 and #5 are the best choices. We can imagine the case where apartment #4 may be a good choice if one is typically carpooling in the morning but riding a bus in the afternoon. The main point here is that, again, a single query returns the best available options to the user, leaving the final decision to him/herself.
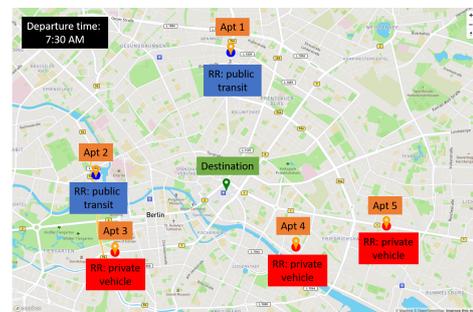

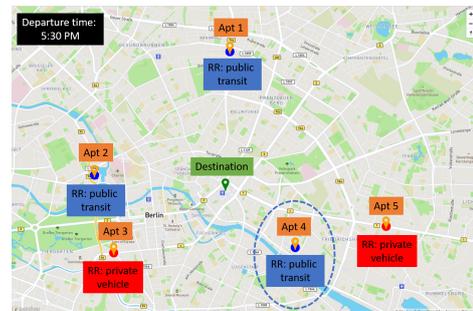**Figure 5: RR for apartments early in the morning.**

Figure 6: RR for apartments late in the afternoon. Note that Apartment #4's RR is different from earlier in the day.

Single source-region destination. Similar to the example above, one may want to consider living in a neighborhood that offers good transportation options towards a region on weekends. Figure 7 shows such a scenario at 8am, where the source is denoted by the orange marker and the destination region (say, the entertainment district) is determined by a polygon drawn by the user. We note that, besides selecting one or more destination points or sources as done in the scenarios above, RRAMEN allows the user to draw a region or select from a pre-determined set of regions, e.g., municipalities. As one can see in Figure 7, each point (node in the network) is either coloured blue or red (depending on whether the arrival time is earlier by public transit or
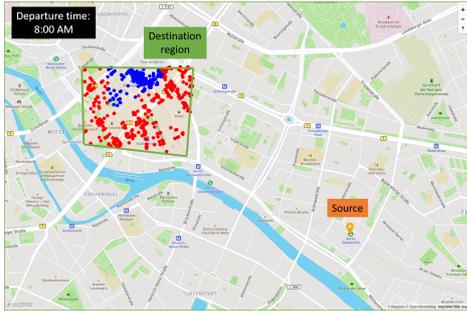
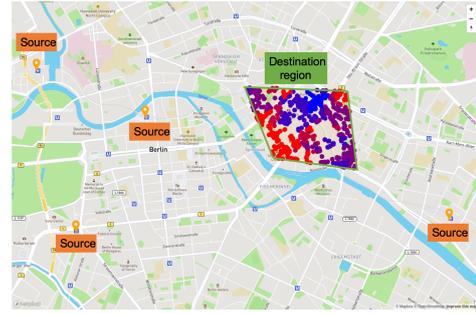**Figure 7: RR of points in a region w.r.t. a single source location at 8am.**

Figure 8: Same scenario of Figure 7 for 8am and 5pm. The dotted circles highlight the changed RRs.

Figure 9: RR of all points within a region w.r.t. multiple source locations

Current RRs (i.e., before adding the new train line)   Resulting RRs <u>after</u> adding the new train line
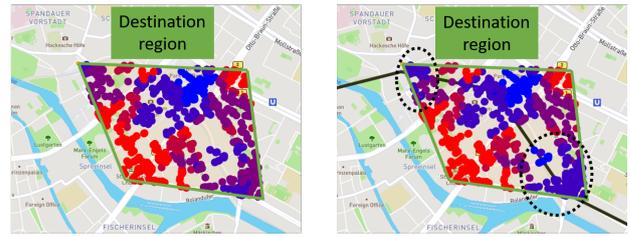
Figure 10: Detailed view before and after adding a new train line. The dotted circles highlight the changed RRs.

car, respectively). Interestingly, if the departure time were to be set to 5pm, the RRs within the destination region change quite a lot, as shown in Figure 8. Once again, by changing a single parameter in RRAMEN's interface the user can be better informed before making his/her decision.

3.2 Urban Planner

Multiple sources-region destination. Here we envision a scenario where a planner would select a number of representative points in the city, e.g., shopping malls, and identify their RR w.r.t. a region, e.g., downtown. While on the surface this may seem similar to the multiple sources-single destination query discussed earlier, there is a fundamental difference. For the earlier query each source location had its own RR, whereas for the current query, the RR for each one of the potential destination locations within the target region reflects an average over the RRs computed from all different source locations. Figure 9 illustrates this scenario, where the colors of each point reflect how much more likely it is for a transportation mode to be the most efficient w.r.t. the source locations. That is, the closer to red (or blue) the more likely it is, over the set of source locations, that private cars (or public transit) reach that point earlier.

Multiple sources-region destination before-after analysis. The following discussion is a natural follow-up from the previous one and depicts a scenario that may reflect best the usefulness of RRAMEN for an urban planner. What would happen if more resources were allocated to the public transportation system? For example, what would happen if one new train line was added? Figure 10 illustrates such a before-after comparison. One can clearly see that the northwest and southwest corners of the region in the figure on the right have more blue points than in the figure on the left. That is, by adding one additional train line, the RR of some locations would "flip" towards public transit, which we

believe should be one of the goals of an urban planner. A similar analysis can be done in case one removes transit lines and/or removes (or adds) thoroughfares for private cars.

4 CONCLUSION

We presented RRAMEN, a web-based tool based on the concept of Relative Reachability, the main goal of which is to aid individual users and urban planners (among others) in making informed choices and evaluating changes w.r.t. a city's transportation network. There are a few interesting directions for further work, such as taking into account the demographics of a city when evaluating how changes impact a city's population at large. From a computational aspect, it would be also interesting to consider incremental and parallel/distributed computation models to scale up the overall efficiency of the the tool.

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