All Roads to Rome: Visualizing Mobility at Scale

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Abstract

The proverb 'all roads lead to Rome' is, by a closer look, a very interesting suggestive mobility statement. The goal of the 'Roads to Rome' was to find an automated way to visualize this saying. During the process of finding the right methods and approaches the authors encountered several inspiring further threads of ideas. The authors created maps using algorithms for routing from multiple starts to a single destination and also multiple destinations. The researchers also used the developed methodology on a small scale to visualize mobility network diagrams of selected cities. The resulting images are not only visually intriguing, but also allow conclusions about how road infrastructure reflects regional, political and geographical situations.

Keywords: Geographic/Geospatial Visualization, Graph/Network Data, Visualization for the Masses, Aesthetics in Visualization

1 Introduction & Thoughts

The internationally known proverb 'all roads lead to Rome' [1] itself is a very interesting suggestive mobility statement. For the authors, this was the initiator of 'Roads to Rome', which visualizes approx. 500.000 routes that lead to the Italian capital, Rome. Roads that are used more frequently are highlighted by line width. The authors refer to the maps (fig. 1-7) which had been created as 'data art'. The aim is to incorporate the aesthetics of art while basing on the principles of real world routing and large scale data processing.

Figure 1: Roads to Rome.

The proverb 'all roads lead to Rome' refers to a bronze monument built in 20 B.C. called Miliarium Aureum (lat. Golden Milestone). The Miliarium Aureum was used as a reference [2] mark (located in Rome) for travelling through the Roman empire. It was believed that all roads lead to this point [3].

In infrastructure planning names like 'arterial road' and 'bypass' suggest a kind of organic impression of mobility networks. Previous works have shown visualizations of street networks [4], travel times [5] and geological run-off regimes [6, 7] with similar aesthetics. For the authors these works have been a great inspiration for creating the unique figures shown in their project.

2 Project Goal & Approach

The goal of this project was to find an automated way to visualize the proverb. During the process of finding the right methods and approaches the authors encountered several findings inspiring further threads of ideas. Finding the right algorithm for multiple routes to a single location was finalized in the concept of 'Urban Mobility Fingerprint' and 'Street DNA' (fig. 5 & 6) - this will be elaborated later. Also, the fact that there is more than one city called Rome in the USA rose the question which principles of routing and visualization on maps can be used to show all routes to multiple destinations (fig. 2 & 4).

3 Tools & People Involved

Roads to Rome is based on several open source tools and resources, ranging from routing engines, street graphs to image rendering software. The project was realized by moovel lab, which is an interdisciplinary work environment exploring new approaches to mobility through various domains. The authors cover the disciplines geography, computer science and design supplementing the anticipated skills for the scope of this project.

4 Methods & Materials

The following part sheds light on the methods, tools and design decisions made in the course of the project. It is split in three parts elaborating on figure 1 & 3 as single destination visualizations, figure 2 & 4 as multiple destination visualizations and finally figure 5 & 6 as mobility network diagrams.

4.1 Single Destination

As pointed out above, the 'Golden Milestone' should resemble the endpoint of every calculated route leading to the city of Rome, Italy (fig. 1). The start point of these routes is determined by a grid covering the area that is supposed to be displayed, while each cell contains one starting point. Depending on the area covered in the calculation, the grid size varies between one and five kilometers. This decision was also a trade-off between route calculation time and actually reflecting all routes.

The ca. 500.000 routes leading to Rome (fig. 2) were calculated by a custom made batch process in graphhoper (an open source routing engine). The routing network used for all calculations in this project was based on the openstreetmap community. Routes were calculated as the fastest route by car.

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Figure 2: New Europe.

The line width of a single road segment depicts the frequency within the routing options, the thicker a line, the more routes run on the segment. The characteristic organic aesthetics was thus created by aggregating the frequency of each road segment and displaying it in respect to the total amount of segments. Several options for depicting the frequency had been evaluated by the authors. Line width was chosen because color was already occupied by service areas of multiple destinations (see section 4.2), additionally the authors aimed for organic aesthetics mentioned before.

All images were rendered primarily for online use. The resolution was kept at a level that also allows large poster prints. The routes itself have been created as vectors containing also frequency information. For creating the rendered images the vectors were projected on a subtle map background. Since the routes have been identified as central element of the images created, they were to be given clear focus in design hierarchy, thus only contours were chosen as a geographical reference.

4.2 Multiple Destination

For finding all routes from a multitude of origins to a multitude of destination, the algorithm used needed to be altered to routing to multiple locations. In this case cities with the name of Rome in the USA (fig. 4) were chosen, to support the narrative mentioned in section 1. The interesting territorial effects seen in figure 4 inspired the authors to further look into multiple destination mappings, which lead to figure 2 where destinations are the capital cities of Europe.

From each starting point, the fastest possible destination reached by car is determined. In the visualization (fig. 2 & 4) the routes to a given destination are color-coded. Color-coding routes to different destinations uses design principles of thematic maps. It emphasizes and reveals a territorial effect of 'service areas' of the given destination. The effects and interpretations that are derived out of this graph are explained in section 5.

4.3 Mobility Network Diagram

The 'Urban Mobility Fingerprint' and the 'Street DNA' are names the authors created for a diagram that evolved out of applying the principles of routing from multiple origins to a single destination to a far smaller area. The diagrams resulting out of this can be used as a tool for analysing urban mobility networks, for example on a city level. While colours were chosen to resemble geographical direction, the routes on the left side (map view) of the diagram show how far one will be able to travel in 15 minutes by car. Travelling without streets would result in a round 'Fingerprint' with straight lines to the outsides. The right part of the diagram displays the 'Street DNA', where color-coding also indicates the geographical direction. It shows the deviation of all routes from the direct connection after scaling them to an equal size. The further the coloured routes deviate from the beeline the more indirect is the connection. The direct connection thus uses travel time as scale (defined in the route calculation) and not distance/length.

The authors chose cities with different cultural backgrounds and city structures to apply the principle of creating mobility profiles which will be elaborated in the following section 5. On the project's website users are able to create a fingerprint and DNA for a given location. In the online tool, the mobility profiles can be viewed for different modes of transport: car, bike and walk [8].

5 Outcome & Evaluation

The different maps and figures being the result of 'Roads to Rome' show how mobility at scale can be visualized. Keeping in mind, that this project is a borderline case of 'data-art' it does allow interpretations, but should be handled with care when making decisions needing hard proof for example in infrastructure planning. Nevertheless, since closely connected to real datasets it can be seen as a great entry point for mobility discussions, especially concerning street networks, politics and geography.

Hierarchies already play a major role on the local planning scale and are manifested in programmatic papers (like European TEN-T [9]). This hierarchy can also be seen in the figures of this project, as traffic is routed on the fastest routes. Small roads quickly merge into large roads covering long distances more efficiently. This reflects the standard routing problem [10] of taking the path with least cost (time in this case) which is manifested in the built infrastructure of street hierarchies (residential roads vs. highways).

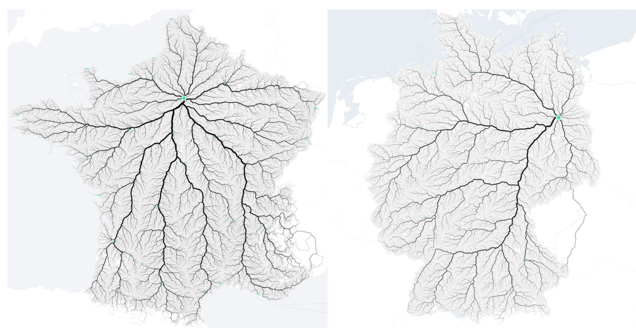

Figure 3: Roads to Paris vs. Roads to Berlin.

In a comparison of the maps in figure 3, the authors tried to find out if political systems can also be revealed out of the project's approach (in this case France and Germany). As mentioned before, programmatic papers play a role in political decision making concerning mobility infrastructure. In this comparison it is looked at if the general political system (centralism in France and federalism in Germany) are reflected in the bigger mobility picture. Routes in France seem to always lead to Paris rather directly with many heavily used roads. The situation in Germany suggests a rather broken down network of roads, before attaining Berlin. Another question that was raised was, what would happen, if the cities had a different location. Trying to simulate this by simply using another city is nearly impossible. Since infrastructure of a country is lead by political decisions, it inherits a large history of hierarchical decisions when building new streets etc.

Looking at the figures with multiple destinations one can see a territorial effect. By visualizing the service areas of the respective destinations using different colors (fig. 2 & 4) mobility could speculate on or suggest new, mobility optimized political borders (like in fig. 2). The speculative map of 'New Europe' shows big changes to the political borders as we know them today - assuming they corresponded with travel-time zones of a country's capital. Proposing these borders, a travel-time zone for every national capital of Europe had to be calculated. Hence every color-coded zone shows the area of which it would be fastest to reach the respective capital city. The authors chose to use the road network as medium for color coding, since it is essential for calculating travel time.

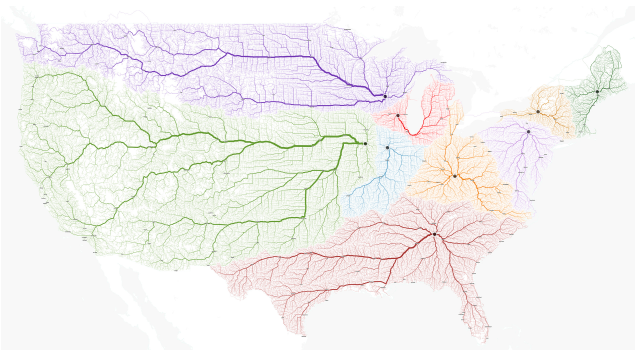

Figure 4: Roads to US-Romes.

The travel-time zones of some countries are comparable to their original borders, like Turkey, the UK, Denmark, Spain and Portugal. While small states like Andorra, Liechtenstein, Vatican and Monaco experience huge spatial growth, showing the importance of their infrastructural inclusion.

Looking at the countries of central Europe it can get very difficult to recognize any of the known political borders. Looking only at the travel-time zones, especially Germany, Switzerland and Italy amongst many others seem to lose their characteristic political borders. A possible conclusion of this could be that the unified European transit network planning decisions show effect on how connectivity within Europe is established. Concluding that political borders in Europe play a less important role than imposed by political maps. Looking at selected places (Alps, Highlands of Scotland or the isle of Corsica) it could even be argued that physical borders play a larger role the division of land, when only taking travel-time as criteria. It can easily be argued that simply looking at mobility for suggesting new political borders is somewhat limited, yet again a suitable way to open the discussion.

Other notable interpretations found in figure 4 (showing all routes to the nine Romes of the USA) are historical hints of the settlement of the United States and also topological influences on the road network. Historical elements can be found if compared to historical settlement maps [11, 12] segmented into ethical backgrounds. One can find a significant amount of Italian immigrants during the period of 1880-1930, matching this with the core settlement areas [11, 12] of these centuries the spatial similarity is remarkably matching. Other than mentioned above physical characteristics, in this case topology, also influences shapes and alignments of roads. Especially in the Cordillera (Rocky Mountains) road structure seems to be curvy and winded aligning to the natural form of present landscape. Contrary to this are the perpendicularly seeming road structures with north-south or east-west alignment found in the Great Plains. This is not exclusively visualized by the maps of this project, but can easily be derived because of emphasizing the information displayed solely on road networks.

In [12] a similar spatial pattern was created with a Voronoi diagram based only on Euclidian distance. The comparison is quite interesting, since space is partitioned in a similar way, using different principles. Since human mobility is mostly based on built infrastructure it can be argued, that using street networks leads to more precise results.

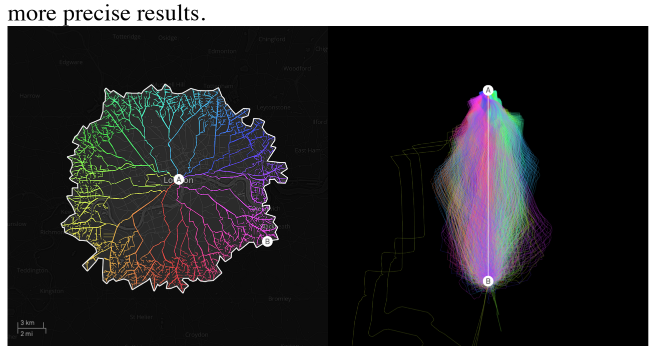

Figure 5: Mobility Fingerprint and Street DNA of London.

Interpreting the 'Urban Mobility Fingerprints' and 'Street DNA' of London and New York City (fig. 5, 6 & 7) a couple of things mentioned above reflect in the diagrams. Manhattan's street network is characterized by bottlenecks connecting it to other boroughs. Brooklyn Bridge, Battery Tunnel, Queensboro Bridge and other connecting paths create a very interesting Street DNA pattern.

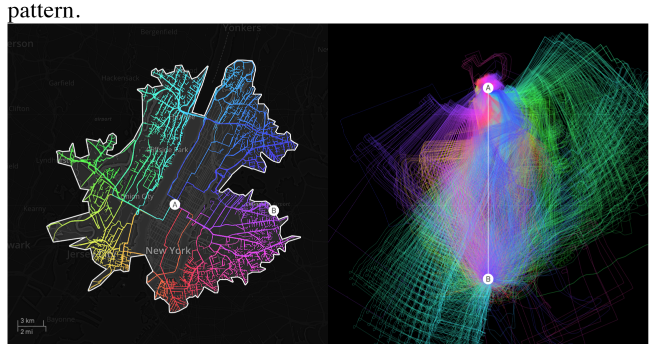

Figure 6: Mobility Fingerprint and Street DNA of New York City.

It is far from optimum but imposed to the natural landscape of the area. On the other hand, London as capital of the United Kingdom has been the largest city of the world in large parts of its urban history. London therefore inherited a nearly ideal 'Street DNA'. It shows very direct connections, created by a dense street network. Within the scope of this project, these mobility network diagrams have also been created for other cities. Like in the single and multiple destination mappings, similar tendencies in terms of topography and political structure are found in cities. Taking Jerusalem (fig. 7) as prime example: Strong deviation can be found due to topography and political separation (manifested by borders and mobility bottlenecks).

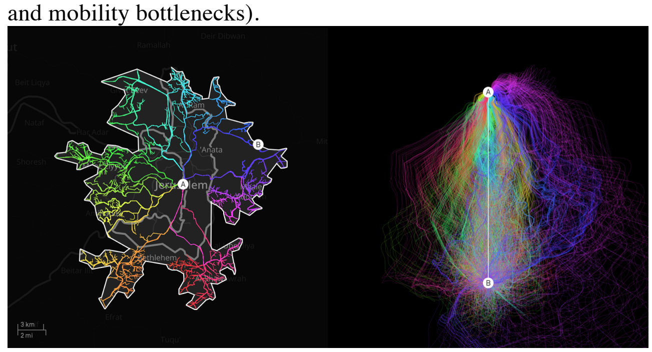

Figure 7: Mobility Fingerprint and Street DNA of Jerusalem.

6 OUTLOOK

Roads to Rome has gained great attention in a number of popular news media and blogs. The broad acceptance of the work showed that the rather emotionless topic of routing can be backed by public interest by displaying it in an accessible and tangible way. It can be seen as a door opener for discussions about the connection between mobility and infrastructure, politics, history and geography.

As an outlook it should also be considered to enhance the dataset with additional data sources. For example, using socio demographic data could supplement the route frequency with relevance for local population. Emphasizing the historic aspect of the project it would also be interesting how historical street graphs would change the images shown. Thus enhancing the images with various datasets can for example be interesting for history, sociology or particularly the emerging field of Digital Humanities. Projects [12] from this field also tend to touch upon spatial mobility questions.

The comparatively small scale of the mobility network diagrams could maybe compliment location analysis of urban planning processes or street infrastructure discussions. The diagrams often triggered the discussion of time as spatial scale unit. Previous works [13, 14] have shown that reprojecting geographical information on the basis of other parameters leads to interesting insights. Hence using time as scale could, especially for the mobility network diagrams, lead to images showing mobility optimized space.

7 REFERENCES

[1] Burns, P. (2016). International Translations of 'All roads lead to Rome'. http://holyrosarychurch.tripod.com/strade.html (Accessed: 24.06.2016)

[2] Richardson, L. jr. (2005). Milliarium Aureum. The Johns Hopkins University Press. Los Angeles. http://dlib.etc.ucla.edu/projects/Forum/resources/Richardson/Milliarium_Aureum (Accessed: 24.06.2016)

[3] Schaaf, P. (1867). Ante-Nicine Fathers. The Apostolic Fathers with Justin Martyr and Irenaeus. Vol. 1 http://www.ccel.org/ccel/schaff/anf01.ii.i.html (Accessed: 24.06.2016)

[4] Fry, B. (2008). All Streets. http://benfry.com/allstreets/map5.ht ml (24.06.2016)

[5] Gortana, F., Kaim, S., v. Lupin, M., Till Nagel, T. (2014). Isocscope. Mapping the time-varying extent of urban mobility. https://uclab.fh-potsdam.de/projects/isoscope/ (Accessed: 24.06.2016)

[6] Mayorga, E., M.G. Logsdon, M.V.R. Ballester, and J.E. Richey. (2012). LBA-ECO CD-06 Amazon River Basin Land and Stream Drainage Direction Maps. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. http://dx.doi.org/10.3334/ORNLDAAC/ 1086 (Accessed: 24.06.2016)

[7] Minar, N. (2013). Map of American Rivers. A vector tile demonstration and tutorial. Boston. https://github.com/NelsonMinar/vector-river-map (Accessed: 24.06.2016)

[8] Groß, B., Reimann, R., Schmitt, P. (2015): Roads to Rome / Explore. http://roadstorome.moovellab.com (Accessed: 28.08.2016)

[9] European Union (2011): WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. Brussels. http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52011DC0144&from=EN (Accessed: 24.06.2016)

[10] Eppstein, D. (1998): Finding the k Shortest Paths. SIAM J. Comput., 28(2), 652–673.

[11] Klett Perthes Verlag GmbH (2007): Nordamerika: Raumerschließung Haack Weltatlas. S. 192. Gotha. http://www2.klett.de/sixcms/list.php?page=infothek_artikel&extra=Haack%20Weltatlas-Online&artikel_id=261808&inhalt=klett71prod_1.c.139752.de (Accessed: 24.06.2016)

[12] Freitas F., Frank, Z., Spatial History Project: Terrain of History. http://web.stanford.edu/group/spatialhistory/cgi-bin/site/project.php?id=999 (Accessed: 28.08.2016)

[13] Laux, H. D., Thieme G. (2008): Einwanderung/Besiedlung USA – Bevölkerung. Dierke Weltatlas. Braunschweig. http://www.diercke.de/content/einwanderungbesiedlung-978-3-14-100700-8-194-1-0 (2 Accessed: 4.06.2016)

[14] Jacobs, F., All Roads Lead to Rome. (2016): http://bigthink.com/strange-maps/all-roads-lead-to-rome (Accessed: 28.08.2016)