Where Can I Go From Here? Drawing Contextual Navigation Maps of the London Underground

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ABSTRACT

Network administrators often wish to ascertain where network attackers are located; therefore it would be useful to display the network map from the context of either the attacker's potential location or the attacked host. As part of a bigger project we are investigating how to best visualize contextual network data. We use a dataset of station adjacencies with journey times as edge weights, to explore which visualization design is most suitable, and also ascertain the best network shortest-path metric. This short paper presents our initial findings, and a visualization for Contextual Navigation using circular, centered-phylogram projections of the network. Our visualizations are interactive allowing users to explore different scenarios and observe relative distances in the data.

Keywords: Contextual Navigation, Phylogram

Index Terms: C.2.1 [Computer-communication Networks]: Network Architectue and Design—Network topology; E.1 [Data Structures]: Graphs and networks

1 INTRODUCTION

Several researchers and many hobbyists have created visualizations of the Internet [2]. Because the underpinning data is huge, these visual depictions are often complex. They often look like neuron visualizations or birds nests. Consequently they are often difficult to understand and use for network administrators. In fact, network administrators want tools that both demonstrate the complexity of the networks, but also make it simple to control. This would enable then to (say) locate and block security threats, and gain insights into the vulnerability of their network.

Our hypothesis is that contextual visualizations can reduce the complexity and integrate domain-specific knowledge, allowing navigation of the information in a timely manner. We can ascertain routes and visualize paths between different locations and 'here', instead of presenting a 'universal' projection. As an alternative to working with Internet connection data, that many find too complex to conceptualize, we have been exploring the concept using the London Underground as a model. This provides us with a proof-of-concept of a context-driven approach in visualizing complex (albeit smaller) networks.

Visualizing complex networks has been the focus of various research efforts; for instance with regards to communications [1], social [6] and transport networks [8]. Some of those efforts have resulted in iconic representations, such as Beck's London Underground [4] or Burch's and Cheswick's Internet depiction [1]. However, these representations are constructed to present simple links or available routes, without considering the location and context of the user.

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Our goal is therefore to visualize all possible routes from a particular starting point. Inevitably, for road networks this is virtually impossible, due to the large number of possible destinations. However, in a train network, where the destinations are finite and unambiguously defined as locations, it may be possible. In Internet traffic, there are 'preferred routes'; but even if the network reconfigures, we should be able to visualize alternative routes, add in route ownership data, highlight the most typical route and include different ownership and payment structures in the network. Thus to simplify the network we focus on the London Underground dataset.

2 RELATED WORK

Many researchers have visualized public-transport data. In particular, train, tube/underground and metro maps have often been the focus of researchers, either as data/content to be visualized, or as a metaphor for visualizing data in other domains. Beck's abstract London Underground map [4] has inspired many map designs [10]. E.g., Nesbitt [7] uses the tube metaphor to depict 'trains of thought', whereas Stott et al. [13] use it for displaying project plans. While several researchers have created algorithms that mimic Beck's design. E.g., Nöllenburg and Wolff [8] use mixed-integer programming to solve layout and labelling problems of tube maps; Fink et al. [3] presenting curvilinear maps using Bézier curves. We refer readers to [8, 5, 12]. Of particular inspiration to our use-case is *Isochrone* (i.e., equal-time) maps [9]. These are useful to answer spatial questions such as "where can I go, from 'here', within a given time-frame?". Zeng et al. [14] present public transport network isochrone and *isotime-flow* visualizations in terms of passenger mobility, thus deviating, somewhat, from merely displaying network topologies and employing journey information and context.

3 OUR USE-CASE

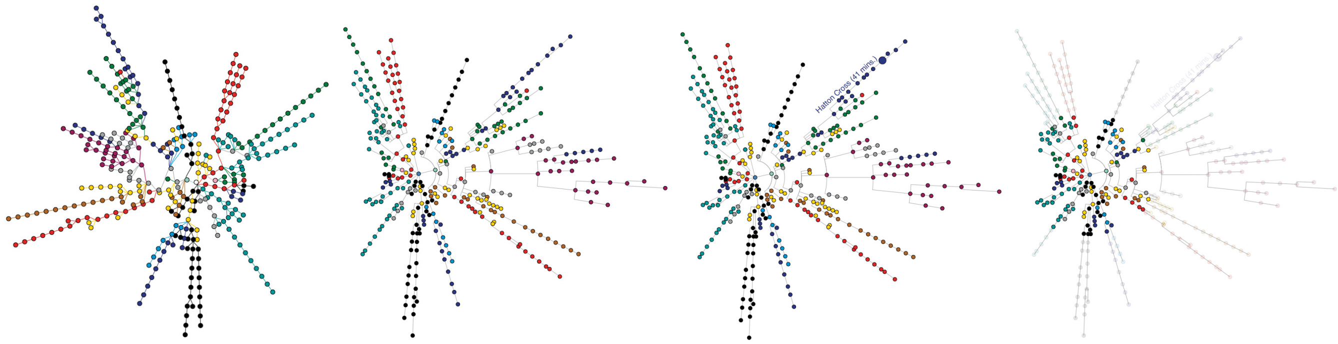
To use the London Underground data effectively, we construct a fictional scenario, for which we wish to built a context-driven transport-network visualization. A suspect is chased by the police into an underground station. Given knowledge of the time of their entrance in a station, where should the police be sent to intervene? In order to apprehend them, some elements of predictive planning must be considered. The perpetrator's strategy may be:

- avoid changes,
- erratic movement (most changes),
- shortest journey (fewest stations),
- longest journey (most stations),
- any combination of these two spectra.

Based on the strategy, we can explore different pathways through the network. These behaviours are simulated by different routing algorithms. Unlike traditional routing problems, there is no fixed destination. For this reason, traditional approaches to cartography do not provide the necessary location-based emphasis.

4 ALGORITHM AND VISUALIZATION DESIGN

Our visualizations were created using D3.js and the Five Design Sheet methodology [11]. Their evolution began with a traditional



(a) (b) (c) (d)

Figure 1: Visualization Evolution: The first image (a) shows the projection for Bank station using the original Reingold-Tilford Tree; (b) is the Radial Phylogram projection, again for Bank station. Sub-figure (c) highlights a destination station, Hatton Cross. The final image shows the temporal ‘dimming’ feature, fading all but stations within a user-set journey time.

Reingold-Tilford tree (see Fig.1a). However, this was abandoned as too many edges overlapped and relative distances of the links are not included. Early experiments also varied the colours of the links, representing the lines the travel takes place on. Whichever ordering/selection was chosen, it introduced confusion around major intersections; e.g. where the incoming and outgoing lines are different, what should the station node be be coloured?

Our final version uses the phylogram metaphor. The user chooses the originating station (compulsory), a destination (optional), and a time window in minutes (optional). The resulting concentric circles are effectively stations within a given travel time (similar to isochrones) (see Fig.1b). Each node is a London Underground station, coloured using the same colours as in Becks’ map. For stations where more than one line intersects we use the colour of the incoming line. The user may request a specific destination which is depicted with a pulsing circular node twice the size of the others. Station labels, including numerical notation of the travel time are displayed when hovering over each node. The filtering functionality dims stations beyond the requested time window (see Fig.1d).

Producing the visualizations requires some form of routing algorithm to convert the Station Adjacency data into a directed acyclic graph (DAG). When designing for a transport network there are three main options. First, a Prioritized Breadth First Search (PBFS). This algorithm spreads to the widest possible set of destinations at each step but selects paths that remain on the incoming line when possible, otherwise examines other stations in the order they were found. This combination means that a compromise of the shortest distance (to the destination) and the fewest number of train/line changes is found. Second, a standard Depth First Search (DFS). This algorithm searches each line to its end before branching off. DFS produces the fewest number of changes, however the resulting path may be sub-optimal (longer). Last, a standard Breadth First Search (BFS). BFS finds the widest range of stations, however paths are generated in the order in which they were found. This means that the absolute shortest path can be found, but the number of changes is sub-optimal.

In terms of the scenario: BFS gives the maximal set of stations to search, DFS the minimal set and PBFS the most likely set of stations. Depending on the nature of the policing operation, any one of these sets will be viable. E.g., to minimise public panic the DFS set could be used, to evacuate all from affected stations the BFS set would be suitable and to capture a suspect the PBFS set should be used.

5 Conclusion

Motivated by finding new ways to contextually visualize the Internet we studied a conceptually simpler analog, the London Underground network. We present a phylogram-based visualization as a proof-of-concept of a context-driven approach, using an imaginary police intervention scenario. We have also explored different routing algorithms that will eventually be useful for a network security task. We have started to visualize the security data, and have feedback from an analyst who was encouraging of the concept. By applying the Contextual Navigation concept to the generalized Internet problem we can begin to explore that data more interactively.

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