Map Stylization for Tile-based Representation

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The Black Arcs, Inc. is a company focused on putting people at the center of land-use planning using a lightweight simulation of citizen mobility that lets users change the layout of a city to explore the impacts on transportation and GHG emissions.

The simulation runs on a map generated from the road network of actual cities. The current test case, Sackville, NB, is shown below in the simulator.

Figure 1: CitiSketch simulation of Sackville, NB

A key part of using this simulation to portray the effects of land-use changes is the communication of information as efficiently as possible. Maps contain a large amount of information and can be difficult to process at a glance, so some adjustment is needed. The approach taken by Massimo Vignelli when designing his enduring map of the New York Subway system, shown below, was to sacrifice some geographical accuracy in the interest of clarity of communication.

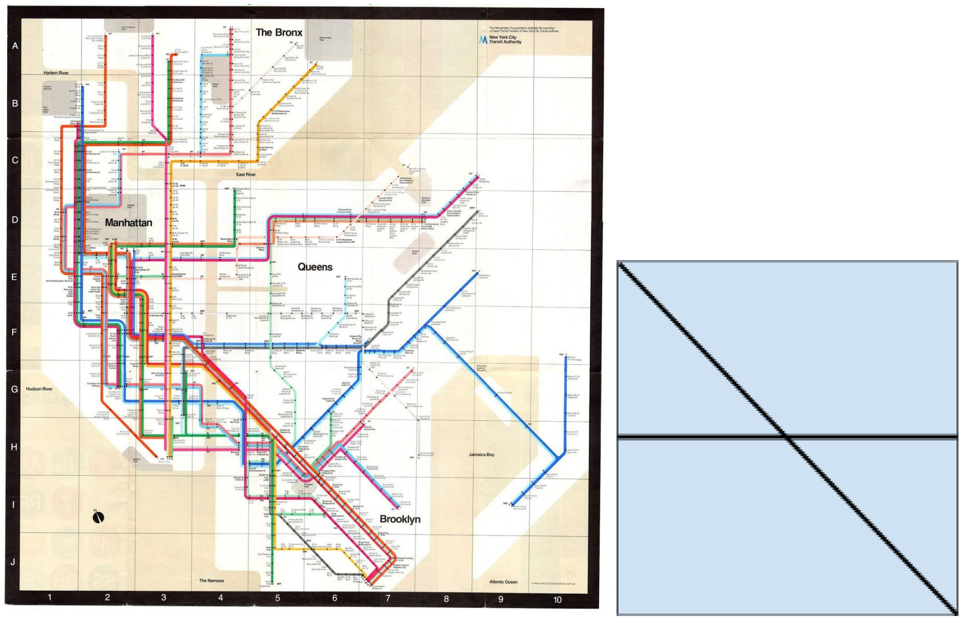

Figure 2: Massimo Vignelli map of New York City subway from the New York Times[1] (left) and a stylized map tile showing 45° connections (right).

This type of design can be applied to our simulator independently of the mobility simulation. To pursue greater efficiency in the future and to improve the visual appeal of our data-visualization, an algorithm is required to transform a real-world map into a stylized representation comparable to the design aesthetic of Vignelli's map, although with some variation.

Vignelli's map can be thought of as series of "tiles" illustrating connecting nodes between subway routes, such as the one shown on the right side of figure 2 above. Note that all tiles in the above map use angles of either 0°, 45°, or 90°. Our stylized map would use angles of 0°, 22.5°, 45°, 67.5°, 90°. If we assume that all lines pass through the center of a tile, and that a tile can have any number of these options (or no lines at all), we get 2^5 combinations of lines. In other words, 32 possible tiles.

The challenge, then, is to generate an algorithm to transform the road network of our test community into a series of interconnected tiles, with all connecting nodes represented by angles of 0°, 22.5°, 45°, 67.5°, or 90° using the minimal number of unique tiles possible. Changes to distances and road lengths can be corrected by the simulation software independently. This algorithm can then be deployed to serve a variety of different communities.

This challenge is, at its core, an optimization problem. Given a limited number of tile possibilities, we must find the optimal number and arrangement of each tile so that it most closely approximates a given arrangement of lines (i.e. a map). A possible approach to solving this problem is a *genetic algorithm* (GA).

GAs are a powerful and widely applicable approach to complex optimization problems[2]. A GA is an iterative, evolutionary algorithm that starts with a randomly generated population of individual solutions (a “generation”) and evaluates each solution for “fitness” by means of an objective function. The more “fit” solutions are carried on to a new generation and stochastically mutated into a new set of solutions.

Formatting this problem to be solved by a GA has two main requirements. First, a potential solution (i.e. a particular combination of tiles) must be represented via a *genetic representation.* This usually means converting a solution to an array of bits suitable for digital processing. This particular problem has an extra caveat in that not only must the arrangement of a group of tiles be represented, a set of tiles must be generated for each solution.

After establishing a genetic representation of possible solutions, a *fitness function* must be defined to evaluate each solution domain. Definition of an effective fitness function is a critical part of designing an effective GA, and will likely be the main challenge in applying a GA to this problem.

Of course, there are many other approaches to solving optimization problems. Perhaps treating the map as an arrangement of lines and applying computational geometry will offer more efficient solutions than a GA. Can this be reduced to purely combinatorics problem, or can combinatorics be applied in tandem with another optimization technique? Can small areas of the map be analyzed with a technique that can then be recursively swept across the entire grid?

To allow for a tiered approach and multiple stages of validation in pursuit of a widely applicable solution, we will be providing a number of maps for analysis, with increasing levels of complexity. Data will be provided in the form of a visual representation of a map, and digital representation of the map as a series of edges and vertices.

References:

1. Rawsthorne, Alice. “The Subway Map that Rattled New Yorkers.” *New York Times* 5 Aug. 2012. Web. 5 Mar. 2018.

2. Gwee, B.H. & Lim, M.H. Comput Optim Applic (1996) 6: 273. https://doi.org/10.1007/BF00247795