A Graph Theoretical Analysis of the Streets of South Berkeley

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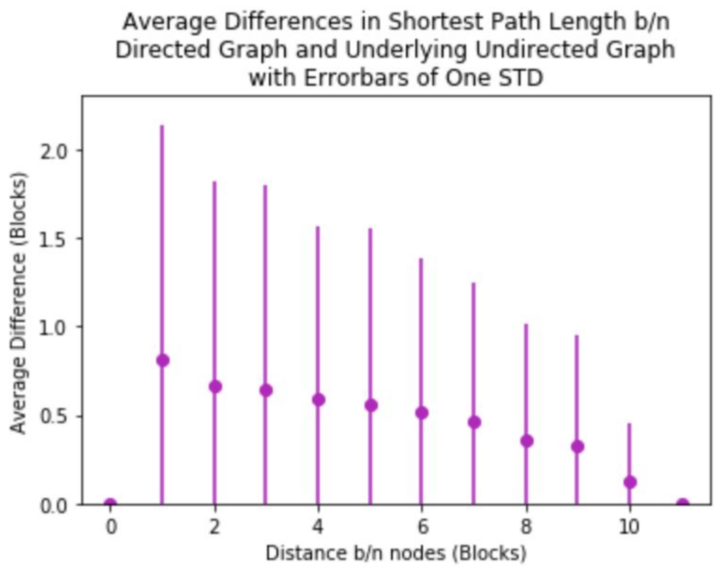
As anyone who has ever driven them will attest, the streets of Berkeley' so-called Southside are a veritable rabbit's warren of one way streets. One can hardly drive a block without getting lost at a left turn they can't make. This is actually a fairly common situation in cities across the United States. In fact, many have recently called into question the efficacy of systems of one-way streets, mostly for reasons of livability and friendliness to outsiders. However, some have also questioned whether systems of two-way streets might be more efficient as well as more conducive to outsiders and business. This is the question I seek to answer in relation to the streets of Berkeley's Southside by means of Graph theory. Using the python module NetworkX, I have created a directed graph representing the street network of South Berkeley (fig. 1), with nodes representing intersections and edges representing streets, which I compare with the underlying undirected graph. A comprehensive analysis of this relationship reveals that, while the undirected system is marginally more effective at short distances, the difference is not extreme. Therefore, the only reason to propose a remediation of Berkeley's street network would be for reasons of livability.

The first tool I employed to analyze the street system of South Berkeley is the concept of shortest simple paths, which is directly associated with the connectivity of the graph. The shortest simple path between two nodes is the group of consecutive edges and nodes which begins with the first and ends with the second and which contains the least possible edges. I used NetworkX to determine the shortest path between every pair of nodes in the directed graph and the underlying undirected graph. To be clear, this means that for all 42 nodes I computed the shortest path between node i and all other nodes. I then graphed the average, maximum, and standard deviation of the difference between the shortest paths in the directed graph and the



shortest paths in the underlying undirected graph (figs 2, 3). I graphed this against the raw distance between the the two nodes, i.e. the distance between them in the undirected graph. This comparison reveals two important facts: the average difference is less than 0.8 for distance classes and as the raw distance increases, the difference increases. There are some nuances to this, of course, especially in the standard deviation. The standard deviation is quite large, especially for the shorter raw distances. While the small average differences imply that the difference in efficiency is not large, the standard deviation suggests that for many pairs the difference is as high as 1.5 or even 2.0 blocks at short raw distances. Of course, most people do not drive such short distances anyways—they walk. In this way, the larger raw distances are the most significant in regards to actual efficiency, and in those cases the average difference is only about a half block. Therefore, there does not seem to be a significant difference in the efficiency of the one-way street network and the two-way street network.

The other comparison between the two networks I made was their vulnerability. First, the directed graph is strongly connected, so you can reach any other node from every node. I determined how many vertices would need to be removed such that this is no longer true. In a similar manner to the previous analysis, for every pair of nodes I computed the minimum number of edges that would need to be removed from the graph until there no longer exists a path between them. I then averaged these numbers and compared the figures for the directed graph and the underlying undirected graph. On average, 1.83 edges would need to be removed from the directed graph, as opposed to 2.99 from the undirected graph. Note that since the out-degree of every node—the number of edges leading from the node—is between one and four, the greatest possible value for this number is 4.00 and the least possible is 1.00. In this context, the directed graph is more vulnerable to edge removal by more than one whole edge. This suggests an significantly more vulnerable system to accidents. Of course, it is questionable how often the exact two streets would actually go down in reality, but since in some cases only one street has to be removed, it is significant nonetheless.

In the end, it does not seem that system of one-way streets in South Berkeley is significantly less efficient than a hypothetical two-way network, although it may be more vulnerable to accidents. The main caveat to this analysis is that the street system of Berkeley's Southside is actually but a single component in a larger overall system. In this way, many of the described paths are not the actual paths drivers take: many paths merely pass through the Southside. In addition, when accidents occur, detours are usually created to avoid that stretch, so the issue of vulnerability is not so great as it might seem. In the end, the main driving force for changing the street system of Berkeley's Southside should be issues of livability, not of efficiency.

Appendix

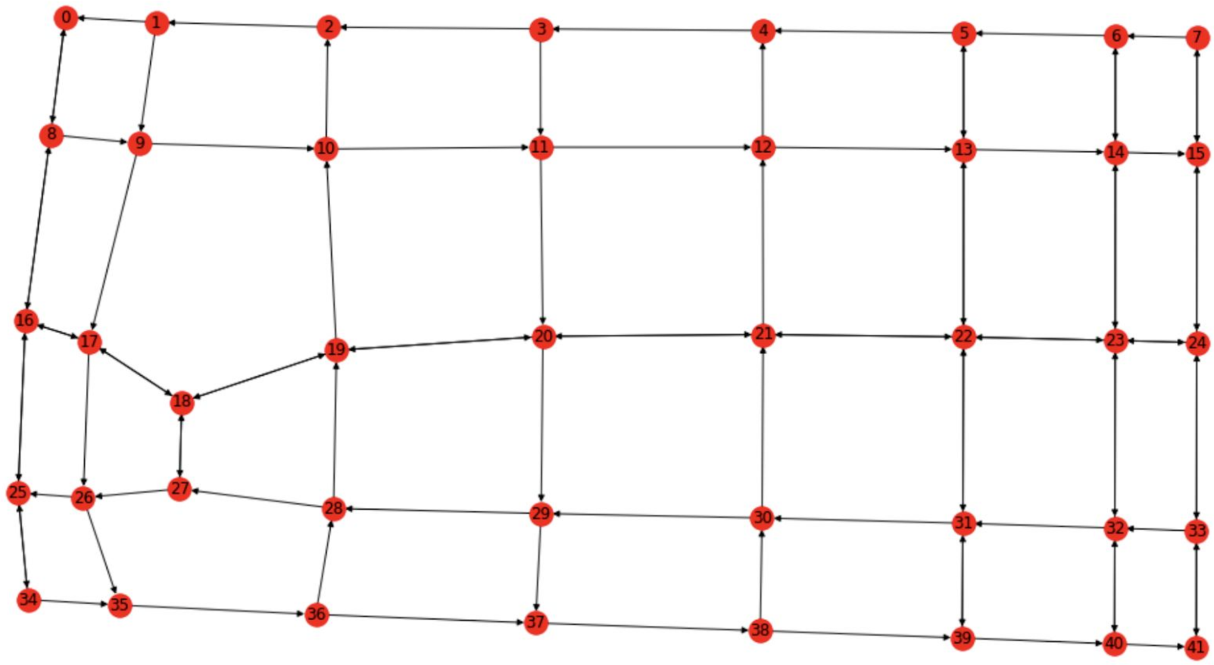


Figure 1. “Graph of Street System of South Berkeley.”

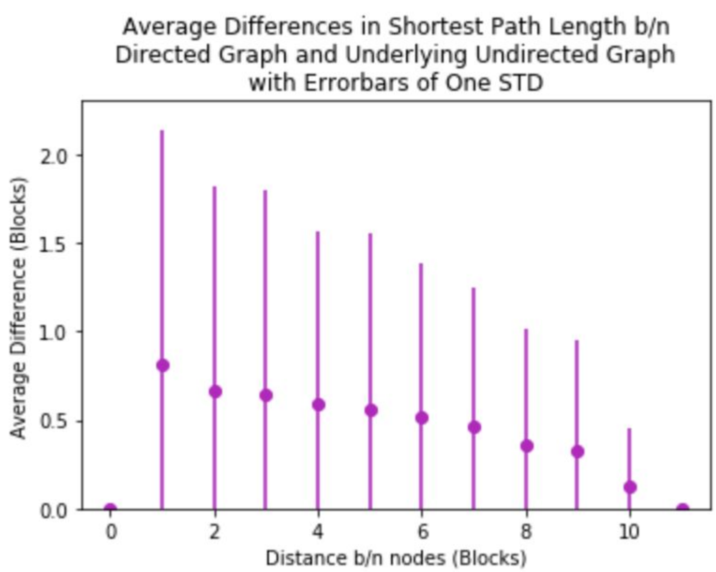


Figure 2.

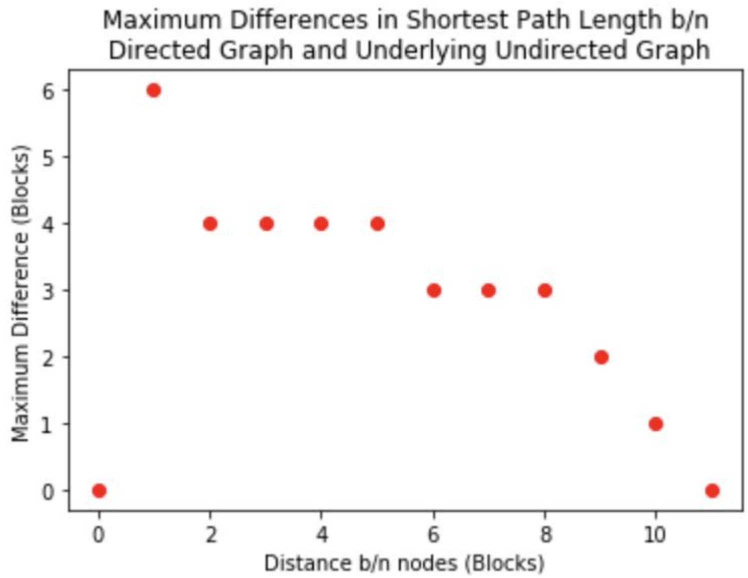

Maximum Differences in Shortest Path Length b/n
Directed Graph and Underlying Undirected Graph
Maximum Difference (Blocks)
Distance b/n nodes (Blocks)
0
1
2
3
4
5
6
0
2
4
6
8
10

Figure 3.

Bibliography

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