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Transport network modelling on hexagonal discrete global grid system

Anastasia Shurygina[a,*], Matvey Bogolyubov[a]

[a] *Lomonosov Moscow State University, ashurygina@geogr.msu.ru, geoshur13@gmail.com*

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Abstract:

Reality models allow the representation of geographical space in formalized manner. They associated to the sets of techniques, developed to analyze spatial data. Thus, transport system like bus routes or simply pedestrian roads are usually considered network models. There are typical problems that are solved with spatial networks in most cases through the use of graph theory. The examples are traveling salesman problem, closest facility problem, travel cost or isochrone drawing (Barthelemy (2022)).

Although graph methods have proved their effectiveness, their bottleneck is performance. It is hardly possible to develop and maintain a routing service written in a high-level programming language, e.g. Python, for any extensive city, due to the large number of edges and nodes required for presenting inner network system. A still unsolved question is whether it is possible to simplify a spatial network to such an extent that it has better performance, but does not lose its properties as a model? Previous studies have focused on structural transformations of graphs such as removing circles, dead ends, loops, redundant nodes (Liu et al. (2009)). We propose to involve another model of reality, discrete global grid. Regular grids have been used to solve the problem of the optimum path determination in space (Stefanakis, Kavouras (1995)).

Following the idea, we presented the pedestrian and road networks of the experimental city as several levels of H3 (https://h3geo.org/) discrete global grid system (DGGS). It was done as following: a. covering the city road network with defined level of H3 grid; b. extracting central points of resulting grid cells; c. for each couple of adjacent cells' centroids — calculating the shortest path time as if we were moving on the graph representing the network; d. creation of new, DGGS-based graph, where H3 indexes of cells, which centroids were used, are nodes, segments between adjacent cells centroids are edges and calculated travel time is the weight of each segment. Then, any graph method could be applied to the resulting DGGS-based graph. However, in this case we do not have to store coordinates of the spatial graph entities as H3 indexes serve for georeferencing. What is more, this technique potentially reduces the number of nodes and edges, thus, increases the performance.

During the study we obtained 6 DGGS-based graphs for the experimental city: 3 pedestrian and 3 road network graphs. For each kind H3 grids of levels 10, 9 and 8 were involved. We compared DGGS-based graphs with corresponding conventional spatial network graph by several parameters: a. general parameters values (centralities, node degrees, betweenness and so on); b. results of solving shortest path and isochrone problems; c. time spend on problems solving.

The results show, that it is possible to find the DGGS level so that the DGGS-based graph would save the most of the initial transport network characteristics and the size of selected grid would be enough to generalize the network and increase its performance. The results of solving graph problems are similar, but obviously depend on the grid granularity. Although, DGGS have shown promising results in transport networks analysis, the step of DGGS-based graph construction could be time-consuming. Moreover, future work should consider using DGGS-only functions, like finding neighbors by indexes, in networks analysis.

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