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Uniform Graph Construction Based on Longitude-Latitude Mapping for Railway Network

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Abstract

In mathematics and computer science, graph theory is the study of graphs, which are mathematical structures used to model pair-wise relations between objects. A same graph can be drawn in different ways with different structures. The main emphasis has been given in minimizing the randomness of the structure of a graph to carry out many practical applications. A *novel* Uniform Graph Construction based on Longitude-Latitude Mapping is proposed for perfect visualization of traffic network particularly railway network. The objectives are, i) construction of uniform graphical image of a railway network without any randomness, and ii) making the graph positional by introducing a function that maps the longitude and latitude of a junction or important station into the graph. This will help to build intelligent network by integrating the communication mechanism with graph theory for controlling various railway operations that enables cooperative computation for local and instant decision making. The current work focuses on the implementation of uniform graph for Indian Railway Network that uses a longitude-latitude mapping function for sixteen zonal headquarters for perfect visualization.

Keywords

Perfect Visualization, Positional Graph, Traffic Network, Uniform Image

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1. Introduction

Many real-world situations can conveniently be described by means of a diagram consisting of a set of points together with lines joining certain pairs of these points. For example, the points could represent people, with line joining pair of friends; or the points might be communication centers, with lines representing communication links. Note that in such diagrams one is mainly interested in whether or not two given points are joined by a line; the manner in which they are joined is immaterial. A mathematical abstraction of situations of this type gives rise to the concept of a graph.

Graph drawing is an area of mathematics and computer science combining methods from geometric graph theory and information visualization to derive two-dimensional depictions of graphs arising from applications such as traffic network analysis, social network analysis, cartography, and bioinformatics [3, 4].

In mathematics and computer science, graph theory is the study of graphs, which are mathematical structures used to model pair-wise relations between objects. A graph is basically a set of vertices and edges connected between them [1]. A same graph can be drawn in different ways with different structures. The main emphasis has been given in minimizing the randomness of the structure of a graph to carry out many practical applications. The goal is to represent a graph in a meaningful way and which is not variable. A graph with certain vertices and edges connecting between them can be displayed in a meaningful way to have many

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practical applications.

A drawing of a graph or network diagram is a pictorial representation of the vertices and edges of a graph. This drawing should not be confused with the graph itself: very different layouts can correspond to the same graph. In the abstract, all that matters is which pairs of vertices are connected by edges. In the concrete, however, the arrangement of these vertices and edges within a drawing affects its understandability, usability, fabrication cost, and aesthetics. The problem gets worse, if the graph changes over time by adding or deleting edges (dynamic graph drawing [5]), and the goal is to preserve the user's mental map.

A. Contribution

The novel uniform graph construction mechanism uses a longitude-latitude mapping of a junction or important station into a graph for perfect visualization of a railway network. We consider the sixteen zonal headquarters of Indian Railway Network as the vertices of the graph. We take the longitude and latitude of each zonal headquarter and position them as the vertices of the graph by introducing a mapping function. This function is used to convert the longitude and latitude of the places into the x and y coordinate of the console respectively. This provides proper positioning of the vertices in the graph so that anyone can visualize the arrangement of these vertices uniformly. After plotting the vertices we compare our graph with the random graph which is generated without considering any mapping function. Here the edges of the graph are not considered at all as the proper positioning of the vertices alone can give us the perfect desired visualization of the graph.

The structure of the paper is: Section II discusses the basic graph theory concepts. Section III presents our novel uniform graph construction theory. In Section IV we apply our concept to the Indian Railway Network. Section V compares different graphs which are made without and with considering proper positioning of the vertices. Section VI concludes with future scopes of research.

2. Concept of Graph Theory

Mainly a graph consists of two components: the set of the vertices denoted by V (sometimes it is also called the node or point) and the set of edges denoted by E. i.e. when we join the pair of vertices, then a line joining the points is called the edge (sometimes it is also called arc or single line) [1]. If a graph G has set of vertices 'V' and set of edges 'E', then the graph is represented as

$$\text{Graph } G = (V, E).$$

If in a graph, each edge is associated with unordered pair of vertices, then the graph is known as *undirected graph*. A graph is called the *directed graph* if each edge is associated with ordered pair of vertices. A graph is known as a *mixed graph* if some of the edges in a graph are directed and some are undirected [1]. A graph in which all the vertices are isolated then it is known as a *null graph* i.e. a graph has no edges, only vertices called the null graph. In a graph, if there is at least one path between every pair of vertices, then a graph is known as a *connected graph* else it is a *disconnected graph*.

A. Representation of Graph

The two mostly used representations of a graph are *adjacency matrix* and *adjacency list* [2].

Adjacency matrix is a 2D array of size V x V where V is the number of vertices in a graph. Let the 2D array be adj[][], a slot adj[i][j] = 1 indicates that there is an edge from vertex i to vertex j, otherwise it becomes 0. Adjacency matrix for undirected graph is always symmetric. In case of directed graph, we can use 1 for the edge (i, j) and -1 for (j, i) in case the edge is directed from vertex i to vertex j. Adjacency matrix is also used to represent weighted graphs. If adj[i][j] = w, then there is an edge from vertex i to vertex j with weight w. Here the representation is easier to implement and follow. Removing an edge takes O(1) time. Queries like whether there is an edge from vertex i to vertex j are efficient and can be done in O(1). But it consumes more space O(V^2). Adding a vertex takes O(V^2) time.

Adjacency list uses an array of linked lists. Size of the array is equal to number of vertices. An array[i] represents the linked list of vertices adjacent to the i^{th} vertex. This representation can also be used to represent a weighted graph. The weights of edges can be stored in the nodes of the linked lists. It saves space O(|V|+|E|). Adding a vertex is easier. Queries like whether there is an edge from vertex i to vertex j are not efficient and can be done in O(V).

3. Uniform Graph Construction

The novel uniform graph construction procedure uses a longitude-latitude mapping function of a junction or important station into a graph for perfect visualization of a railway network. We take the longitude range in x-coordinate and latitude range in y-coordinate for a particular country. Let, x_1 and x_2 are the two extreme longitudes ($x_2 > x_1$) and y_1 and y_2 are the two extreme latitudes ($y_2 > y_1$) of a country. All the junctions or important stations of that country can be recognized by their corresponding longitudes and latitudes which are within the given range. In general, both the coordinate values increase with respective longitudes and latitudes. When these ranges are mapped into the console, no problem arises in case of x-coordinate as it gradually increases from left to right. But y-coordinate increases gradually from top to bottom, because origin of the console resides at the top left corner. Also, we have to consider the resolutions of the console, e.g. 640 X 480 for taking into account the multiplication factor. So, to plot a particular station into the console the following mapping function is proposed.

$$x\_con = (x - x_1) * (C_x / (x_2 - x_1)) \text{ and}$$

$$y\_con = (y_2 - y) * (C_y / (y_2 - y_1))$$

where, x and y are the longitude and latitude of a station respectively,

x_con and y_con are the x-coordinate and y-coordinate of that station at console respectively,

C_x and C_y are the resolutions of the console (C_x X C_y).

4. Application to Indian Railway Network

We take Indian Railway Network as our example for the following reasons. Indian Railways (IR) is a state-owned enterprise, owned and operated by the Government of India through the Ministry of Railways. It is one of the world's largest railway networks comprising 115,000 km of track over a route of 65,000 km and 7,500 stations [6]. IR is divided into sixteen zones and sixty eight divisions. People employed in IR are about 1.6 million and it runs about 14,300 trains daily [7].

We consider the sixteen zonal headquarters of Indian Railway Network as the vertices of the graph. Among them fourteen are plotted in the five graphs (see Fig. 1 to Fig. 5) as Mumbai and Kolkata both are the headquarters of two different zones (see Table 1). Longitude range of India is about 68^0E to 98^0E and latitude range is about 8^0N to 38^0N [9]. For example, the longitude and latitude of New Delhi, which is the zonal headquarter of Northern Railway, is 77.22^0E and 28.63^0N respectively. For 640 X 480 console resolution, the coordinates of New Delhi is (196.69, 149.92) using our proposed mapping function. Similarly, we take the longitude and latitude of each zonal headquarter and position them as the vertices of the graph by our proposed mapping function (see Fig. 5).

5. Comparison

The sixteen zonal headquarters of IR [8] with their corresponding longitude and latitude [10] are given in the following Table 1.

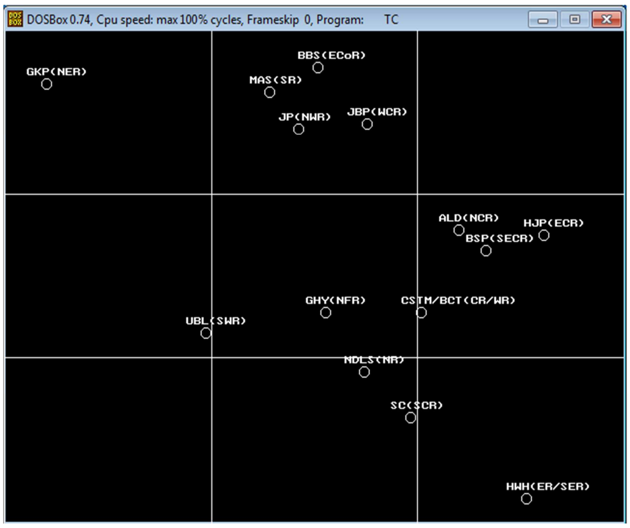

Fig. 1. 1st instance of Random graph.

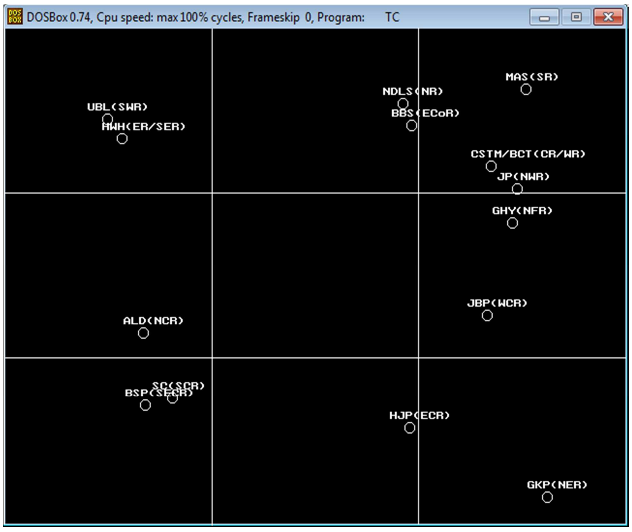

Fig. 2. 2nd instance of Random graph.

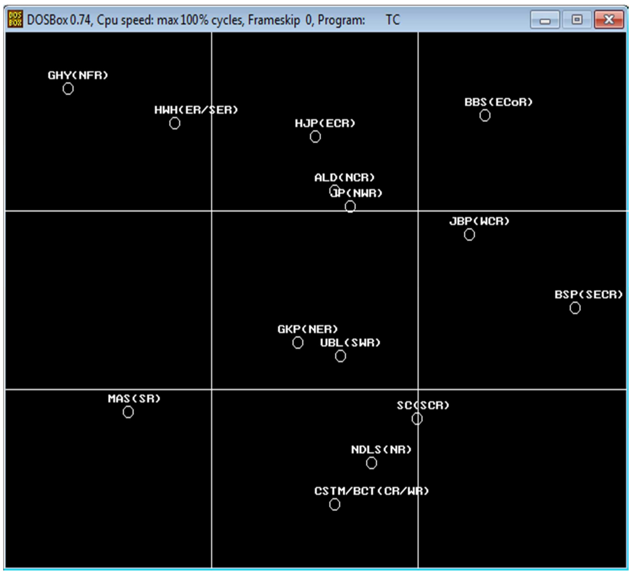

Fig. 3. 3rd instance of Random graph.

Fig. 1, 2, 3 and 4 present four instances of graphs by considering random longitude and latitude values of the fourteen zonal headquarters of IR. Each figure is divided into nine equal regions to identify the positions of the vertices given in Table 2. The x-axis regions are left, middle and right and the y-axis regions are top, middle and bottom.

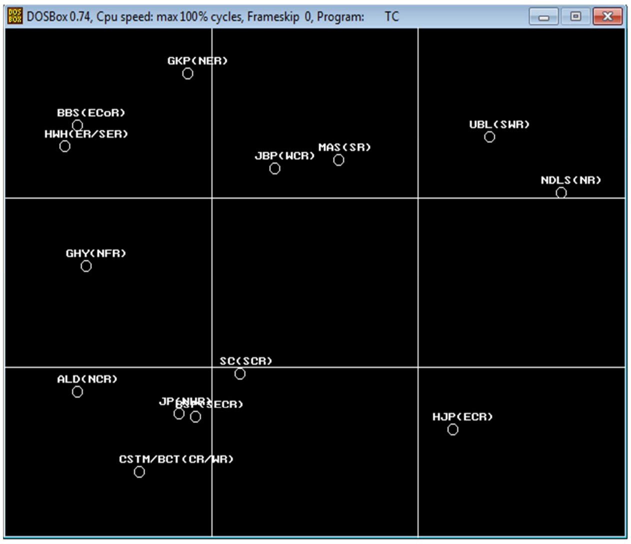

Fig. 4. 4th instance of Random graph.

Fig. 5 presents the uniform graph with the actual longitude and latitude values of the zonal headquarters of IR. We get the uniform graph each time by considering the same data given in Table 1. For the four random graphs, each time we get different positions of vertices, i.e. the graphs are not uniform. So, perfect visualization of the graph is not possible without using our proposed mapping function.

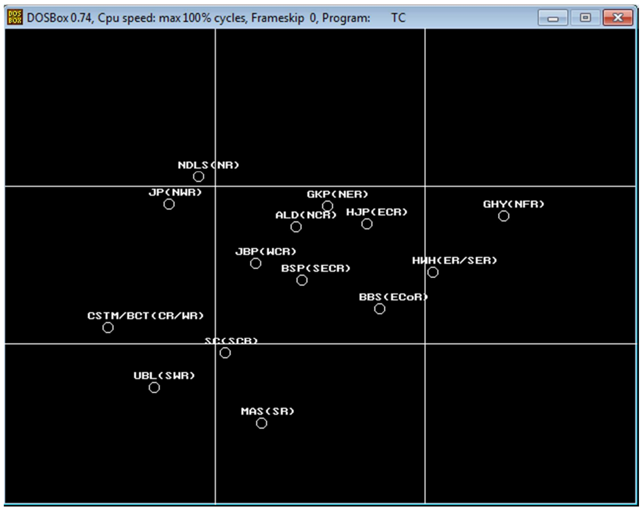

Fig. 5. Uniform graph using mapping function.

Table 1. Longitude and Latitude of Zonal Headquarters of Indian Railway.

Station Code with Zone	Zonal Headquarter	Zone Name	Longitude	Latitude
CSTM/BCT(CR/WR)	Mumbai	Central/Western Railway	72.88	19.08
HWH(ER/SER)	Kolkata	Eastern/South Eastern Railway	88.36	22.57
NDLS(NR)	NewDelhi	Northern Railway	77.22	28.63
GKP(NER)	Gorakhpur	North Eastern Railway	83.37	26.76
GHY(NFR)	Guwahati	North Frontier Railway	91.74	26.14
MAS(SR)	Chennai	Southern Railway	80.21	13.05
SC(SCR)	Secunderabad	South Central Railway	78.50	17.44
HJP(ECR)	Hajipur	East Central Railway	85.22	25.68
BBS(ECoR)	Bhubaneshwar	East Coast Railway	85.82	20.30
ALD(NCR)	Allahabad	North Central Railway	81.85	25.44
JP(NWR)	Jaipur	North Western Railway	75.79	26.91
BSP(SECR)	Bilaspur	South East Central Railway	82.14	22.08
UBL(SWR)	Hubli	South Western Railway	75.12	15.26
JBP(WCR)	Jabalpur	West Central Railway	79.93	23.17

Table 2. Positions of the vertices in the random & uniform graphs.

Headquarter	Position in Fig. 1 (random)	Position in Fig. 2 (random)	Position in Fig. 3 (random)	Position in Fig. 4 (random)	Position in Fig. 5 (uniform)
CSTM/BCT(CR/WR)	Middle-Right	Top-Right	Bottom-Middle	Bottom-Left	Middle-Left
HWH(ER/SER)	Bottom-Right	Top-Left	Top-Left	Top-Left	Middle-Right
NDLS(NR)	Bottom-Middle	Top-Middle	Bottom-Middle	Top-Right	Top-Left
GKP(NER)	Top-Left	Bottom-Right	Middle	Top-Left	Middle
GHY(NFR)	Middle	Middle-Right	Top-Left	Middle-Left	Middle-Right
MAS(SR)	Top-Middle	Top-Right	Bottom-Left	Top-Middle	Bottom-Middle
SC(SCR)	Bottom-Middle	Bottom-Left	Bottom-Middle	Bottom-Middle	Bottom-Middle
HJP(ECR)	Middle-Right	Bottom-Middle	Top-Middle	Bottom-Right	Middle
BBS(ECoR)	Top-Middle	Top-Middle	Top-Right	Top-Left	Middle
ALD(NCR)	Middle-Right	Middle-Left	Top-Middle	Bottom-Left	Middle
JP(NWR)	Top-Middle	Top-Right	Top-Middle	Bottom-Left	Middle-Left
BSP(SECR)	Middle-Right	Bottom-Left	Middle-Right	Bottom-Left	Middle
UBL(SWR)	Middle-Left	Top-Left	Middle	Top-Right	Bottom-Left
JBP(WCR)	Top-Middle	Middle-Right	Middle-Right	Top-Middle	Middle

6. Conclusion

Basically, all the vertices are isolated in all the graphs, i.e. they are null graphs having no edges, only vertices. We only emphasize on the proper positioning of the vertices, without considering any edges for the perfect uniform visualization of the graph. In this paper, we only consider the zonal headquarters of IR. Our proposed mapping function can be used to plot the divisions, junctions, stations and so on. Also, the same mapping function can be applied to any railway network of any country as well as any traffic network. Our uniform graph construction concept will help to expand the railway network.

In future, we will connect the edges by taking into account the distance between the vertices based on the railway network. For introducing a new train, the routes from source to destination will be automatically generated on priority basis by considering the shortest path as well as other issues, e.g. political factors, revenue of railway, importance of places etc. Each node will capable of cooperative computation through communication which will help to take intelligent decisions like automatic rescheduling of running trains, optimization of time table, instant message passing for any local incidents etc. These will introduce the concept of dynamic graph.

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