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Gaofeng Yan
chool of Economics and Management, Beijing Jiaotong University, China

Lei Huang
chool of Economics and Management, Beijing Jiaotong University, China

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Gaofeng Yan[1], *Lei Huang*[2]
[1]School of Economics and Management, Beijing Jiaotong University, China
[2]School of Economics and Management, Beijing Jiaotong University, China

Abstract: Visualization technology has been extensive used in various fields which makes the information presented in a visual way. Visualization directly improves the cognitive efficiency of information, greatly reduces the complexity of data understanding, and breaks through the limitation of the traditional statistical analysis method. The automatic placement of nodes and edges in the network graph has been an important part of visualization research, and the automatic layout algorithm based on force directed graph is a kind of method in this kind of research. An abstract data model of the port transport network is built and the force directed model is improved and applied to port transportation network in this paper.

Keywords: force directed model, visualization, port transportation network

1. INTRODUCTION

After years of informatization, the existing production business system has covered all aspects of production of the port. Statistical analysis system responsible for the annual inspection, statistical reporting, and other statements has basically covered all the branch companies. The current statistical analysis system is mainly to complete the task of reporting the national statistical report. But the application of the system in the management and decision support analysis is rather limited. Especially with the development of information technology and the increasingly fierce competition between different ports, the system cannot meet the demanding of the port development and a more understandable way to display data for the users is needed.

As a hot research topic the information visualization has attracted the attention of a lot of researchers in recent years. Information Visualization has become an independent branch of Visualization and has been discussed as a special session in many international conferences such as IEEE InfoVis and IEEE IV which have greatly promoted the development of Information Visualization [12]. In recent years, information visualization development has been presenting four trends：from Visualization research based on structure to study on visualization of dynamic properties of potential phenomena; Information visualization technology combined with statistical analysis ;transferring from data-oriented to user-oriented; more productized and commoditized [13]. At present some visualization systems based on virtual reality have be applied successfully in key operation domains of port such as monitoring truck operations and barge operations [14].

This paper will be divided into the following several parts. In the first part, the network graph visualization algorithm based on force directed graph is discussed. In the second part, the data model of port transportation complex network is established and the traditional force directed model is improved to adapt to the data model of port transportation network. In the third part, case analysis of port transportation network visualization is given.

2. FORCE DIRECTED MODEL

2.1 Basic Model Introduction

Force directed model (FDM) was first proposed by Eades Peter in 1984 to reduce edge crossing in network layout and keep lengths of edge consistent [15]. The basic idea to solve the problem of automatic layout of network graph is to use physical spring model. There are both attraction and repulsion exist in each node of the force directed model. The distance between nodes too close to each other gets farther and farther due to mutual exclusion and distance between nodes too far away from each other gets closer and closer. The entire layout eventually reached a stable dynamic equilibrium through constant iteration. The development of force directed model can be divided into three stages. The first stage is in late 1980s to the early 90's researchers proposed the AA model, KK model, FR model etc. The second stage is the late 1990s to around 2003 in which researcher focused on the deduction and improvement of mathematical formulas and then put forward a layout algorithm based on multidimensional scaling analysis (MDS). The third stage is from 2003, with the development of large-scale complex network research, how to make use of force directed model to draw graphics in a broad range of fields has become a research focus.

2.2 Several Improved Models

Peter Eades does not directly use Hooke law to calculate the force of the spring because it leads to the distance too large between the nodes. KamadaT and KawaiS improved the Hooke law and proposed the KK model. The concept of ideal distance is proposed by KK model [19]. The ideal distance is the ratio between the number of hops and the radius of the graph. The ideal distance formula can be expressed as $l_{ij} = L_0 / \max_{i<j}(d_{ij}) * d_{ij}$ in which L_0 is the length of the display area and d_{ij} is the distance between the nodes. As a result, the total energy of the spring system in the model proposed by KamadaT is defined as equation (1).

$$E = \sum \sum \frac{1}{2} k_{ij} (| a_i - a_j |) - l_{ij} \qquad (1)$$

In formula (1), k_{ij} is the elastic coefficient between nodes and $| a_i - a_j |$ is the distance between the node a_i and the node a_j. KK model can only solve the local minimization of energy but can not solve the global energy minimization.

FruchtermanT and Reigold improved basic force directed model and proposed the FR model. He introduced the electronic repulsion and defined the electronic repulsion between any two nodes as $F = G^2 / | a_i - a_j |$. The model can effectively solve the problem of node duplication and the algorithm converges more quickly.

In recent years, a new force directed model called LL model was proposed by NoackA when researching on complex network [22]. The model define the energy of the power system as the follow equation (2).

$$E = \sum (| a_i - a_j |) - \ln(| a_i - a_j |) \qquad (2)$$

In equation (2), $| a_i - a_j |$ is the distance between any two nodes. The first half of the formula represents the gravitational force between two connected nodes and the latter half of the formula represents the repulsion force between any node. NoackA then improved the model and put forward AR model [18] on the basis of previous research as equation (3):

$$E = \sum (k_{ij} \frac{| p_i - p_j |^{a+1}}{a+1} - k_i k_j \frac{| p_i - p_j |^{r+1}}{r+1}) \qquad (3)$$

In the formula given above, k_{ij} is the weight of the connection edge between the nodes p_i and p_j, k_i and k_j are the weights of node p_i and node p_j. a and r are parameters and different values are taken to represent the different force directed model.

3. FDM MODEL BASED ON PORT TRANSPORTATION NETWORK

3.1 Port Transportation Network

The port transportation system mainly includes transportation facilities, modes of transport and transportation management [20]. The transportation facilities usually refers to the highway, railway, port, warehouse, storage yard, etc. The modes of transport are mainly waterage, highway transportation, railroad ,etc. Transportation management refers to the transportation planning, organization and coordination. In the port transportation system. Collection transportation refers to transporting the goods from places designated by the shipper to the port and put the goods together in the dock or warehouse nearby. Dispersion transportation includes not only unloading the goods from the ship to the port and store the goods in warehouse in the dock or storage yard near the dock but also unloading the goods directly from the ship to the barge, train or car. Then the goods will be delivered to the consignee's designated destination through various means.

3.2 The establishment of data model

Port transportation network is a typical complex network, including a variety of transfer stations and different transportation modes. The basic network of the port transportation system consists of nodes and edges between each of the two nodes. The nodes are ports, ships, barges, trucks, train and docks of consignees. Each edge represents a way of transportation mainly including waterage, highway, railroad, belt conveyor and pipeline transportation. Business model as shown in Figure 1.

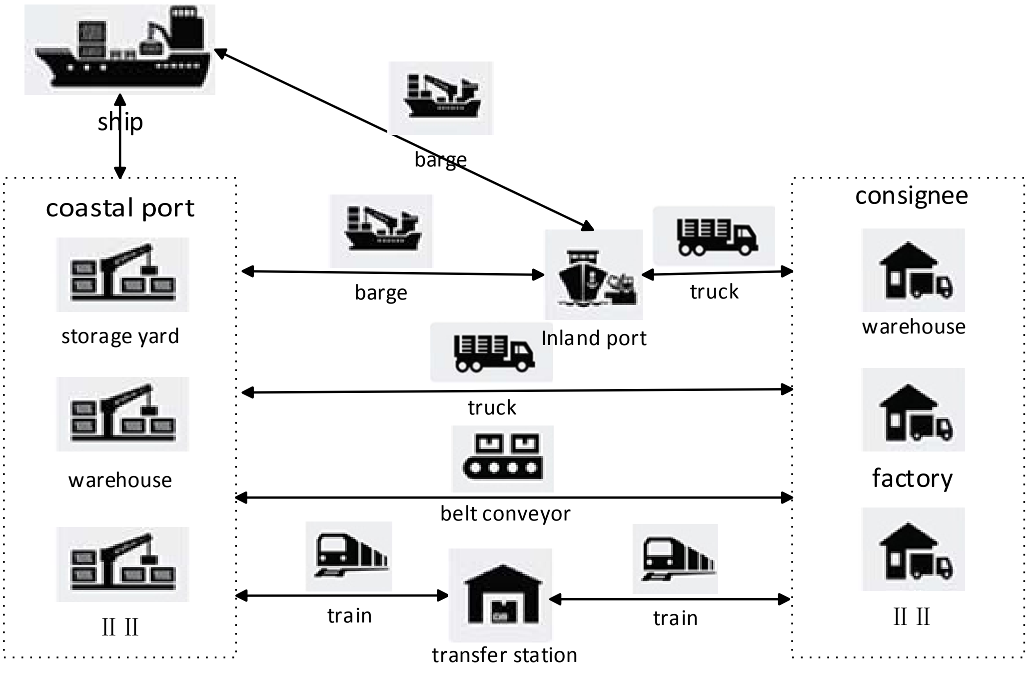

Figure 1. Business model of port transportation

Each port has a lot of storage yard, so there is no need to abstract each storage yard to node but rather to abstract all storage yards in one port to one node. Ship nodes are connected to port nodes and barge nodes, truck nodes, train nodes, belt nodes and other nodes are connected directly to corresponding ship nodes. This is different from the actual transport network but meets the needs of port users. The data structure model is in Figure 2.

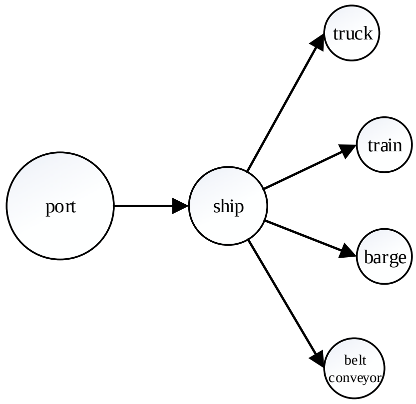

Figure 2. Data structure model of port transportation

3.3 Improvement and Application of FDM Model

There is a big difference between the nodes mentioned above because each node has different attributes. In this paper, we introduce the concept of uniform nodes and non-uniform nodes. Uniform nodes are nodes whose physical attributes can be ignored substantially such as shape and size. Non-uniform nodes are nodes whose physical attributes can not be ignored substantially such as shape and size. The physical attributes of non-uniform nodes usually have symbols of meaning or other uses. For example, in this paper, there are obvious differences between the port nodes, ship nodes, truck nodes, train nodes, barge nodes and other nodes. If we can show the important information of the node at a node itself it will be convenient for users to find the key nodes and then analyze. According to the actual situation of the port transportation network, the weights should not only show the node category, but also reflect the amount of port operations. In order to solve this problem, this paper improves the weights of the nodes in the AR model. The improved weight formula is as follow equation (4).

$$k_i = w_m + w_m^{'} \cdot \frac{v_i}{v_{\max}(m)} \tag{4}$$

First of all, we have to divide all nodes into M classes. In the above formula w_m and $w_m^{'}$ are classification weight and variable weight respectively. v_i is the natural weight of node p_i. For example, it represents the maximum of operation amount in this paper. $v_{\max}(m)$ represents the maximum of all nodes' natural weights in class m.

w_m and $w_m^{'}$ can be determined according to the user's choice. It is more targeted but may mislead the users if the classification is not clear enough. The weights can also be calculated dynamically based on the proportion of the natural weights of each class. It is aimless to do so and the overall layout may be a result of a large change due to the outliers. In addition to calculating the weight to determine the size of the nodes according to the method described above, color, shape, texture and other attributes can be combined to distinguish the nodes. In this paper, the node weights are as follows in Table 1.

Table 1. Information system levels

Serial Number	Node Type	Classification Weight	Variable Weight
1	Port	5	5
2	Ship	3	2
3	Barge	2	2
4	Train	1	1
5	Truck	1	1

The lengths of the edges in the traditional force directed layout will also be relatively consistent. Especially when the nodes generally have large degrees, in the center of the layout the nodes overlap each other and at the leaf nodes the edges cross each other. In this paper, the processing of the edge is similar to that of the node. The processing of the edges in this paper is similar to that of the nodes. If the weights changed, the nodes' size and length of edges will change and the force directed graph will be recalculated to reach a new equilibrium according to the weights changing.

4. CASE ANALYSIS OF PORT TRANSPORTATION NETWORK VISUALIZATION

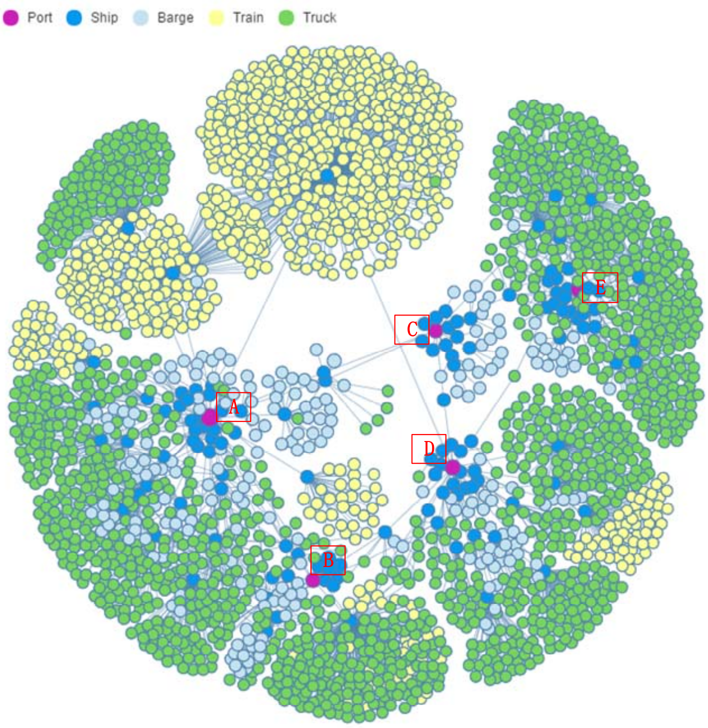

Figure 3. Port transportation network visualization

Figure 3 shows the force directed graph of transportation network of a port for a period of time. The nodes in the graph are divided into five types: the port nodes, the ship nodes, the barge nodes, the car nodes and the train nodes. Different types of nodes are distinguished by different colors. All nodes can be filtered according to legend. The situation of port operations of the branch companies A, B, C, D, E can be seen from the figure. The amount of A company's operations is the largest accounting for almost half of the total amount of the whole group's operations. Operations of B, D, E are similar and operations of C company are at least. A company's mode of transportation is more comprehensive, including trains, cars and barge. But the amount of A company's operations is very large compared to other companies. The mode of transportation of B company also includes barge, car and train. Different from the A company, B company's operations are mainly the operations in car. The mode of transportation of D company also includes barge, car and train. Different from the A company and B company, operations of the three ways are more balanced. The mode of transportation of C company only includes barge which is major and car which is minor. The mode of transportation of D company also only includes barge and car. Different from the C company, the amount of both two kinds of operations is relatively large.

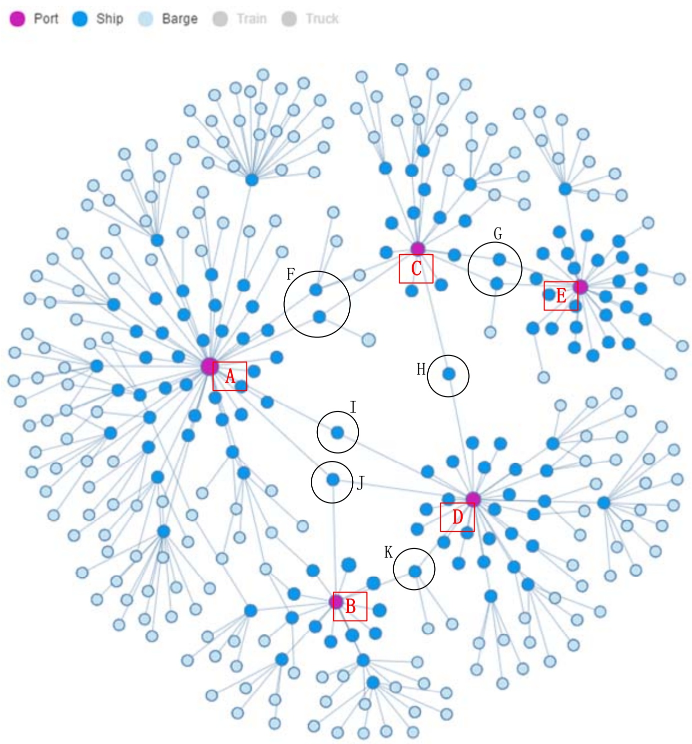

Figure 4. Water transport visualization

The water transportation of the whole transportation network is displayed on the screen after the car nodes and train nodes are filtered. It represents multi-port operation if a ship node which is called cooperative ship is connected to several port nodes. The ship of multi-port operation is refers to a ship which does not sail from the port of shipment to the port of destination directly, but sails to the port of destination after loading and unloading parts of the goods to the transshipment ports. The F, G, H, I, J, K marked in the Figure 4 are ship nodes of multi-port operations. Among them, F, G, H, I, K have one transport and J has two transport. It can be seen from the figure that there are more cooperations between A and B, C, D but E cooperates more with D. As mentioned above, two examples are given to analyze the results of the visualization of the port transportation network. It can be more intuitive to show the data for users through the visualization.

5. CONCLUSIONS

The port transportation business is complex and busy. The visualization of port transportation network helps to find problems in time to improve the operation efficiency and quality. The force directed model is improved according to the characteristics of the port's business and applied to the port transportation network based on correlated theory. The research of this paper has a certain reference value for the application of force directed graph in the port enterprises. How to combine the visualization technology and data analysis technology in order to achieve a better application effect is the key point of the next step.

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