Drawing an Intersecting Clustered Graph by Force-directed Placement

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The classical methods for graph drawing so far has been investigated to nicely draw rather simple classes of graphs such as a tree, planar graph, directed graph, undirected graph and so on. Recently the research in this area tends to draw more complicated graphs called clustered graphs or compound graphs which consist of clusters as well as adjacencies among vertices.

In this paper we introduce a new class of graphs called an intersecting clustered graph and study how to draw it. In an intersecting clustered graph, vertices can belong to different clusters while any cluster should be disjoint each other in a clustered graph. The intersecting clustered graph often appears in KJ diagrams and in structure maps of object oriented language.

Our drawing method is based on simulations of virtual physical systems which are well-known techniques called force-directed placement. As one of the early works of the force-directed placement, Eades presented an algorithm based upon the spring model. In the model, vertices are replaced with steel rings and each edge with a spring to form a mechanical system, and repulsive and attractive forces are defined among rings. But this model need not reflect the physical reality like Hook's law, rather can use a virtual physical laws. The rings are placed in an initial layout and moved iteratively according to the forces so that the system reaches a locally stable state. Finally, rings are drawn as points or small circles, and each edge as a straight line segment between a pair of rings connected by the edge. This spring model has been extended to control orientations of edges by Sugiyama et al. which is called the magnetic spring model. One of graph drawing by force-directed, Luders etal has controlled that the objects(Vertices, Clusters) size change to different size by force-directed placement according to the law of Boyle and Charles.

Our algorithm basically depends on Eades' spring model. Eades' method models two type of forces, whereas our method utilizes six types of spring forces: four types of forces are used for controlling distances between neighbors and two types of forces are used for clustering vertices and forming intersection areas. We also use another type of forces, Coulomb forces, which are in direct proportion to the product of a value of electric charge and in inverse proportion to the square of a distance between electric charges. They work to place shared vertices within intersection areas and to avoid clusters overlapping and vertices overlapping. This model is called the Electric spring model. In the model, vertices and clusters are replaced with electric charge, and repulsive and attractive forces are defined among electric charges to form a electro-magnetic field system. The electric charges are placed in an initial layout and moved iteratively according to the forces so that system reaches a locally stable state. But this model also need not reflect the physical reality like Coulomb's law, rather can use a virtual physical laws.

We have performed experiments to evaluate the performance of our method. In experiments we defined three difference typed of clustering patterns which may correspond to difficulties for clustering and then tested the performance of clustering for various cases. As the result of experiments we have the followings:

1) The average success rate of placement of vertices is 93.9%.
2) The average rate of overlapping clusters is 2.5%.
3) Our algorithm can completely form an intersection area.

It is concluded that our drawing method have useful possibility in representing of more complicated knowledge structures.