Social Network Analysis Layout Algorithm under Ontology Model

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***Abstract*—Social network analysis and visualization is an active area of study but good organizations of social network information are lacking. This paper proposes a domain ontologies model focusing on social network information, which abstracts the impersonal existences in social network information domain into some primary ontologies. The model is suitable for describing a wide variety of social network analysis and visualization methods. For overcoming the disadvantage of transitional force directed layout algorithms in social network structure analysis, we propose a Social Network Analysis Layout (SNAL) algorithm based on domain ontologies model. SNAL algorithm analyses the subgroups, the roles and the key attributes in social network. Then the results are used to improve the force directed layout algorithm, in both 2D and 3D visualization. Results with the case of terrorist information demonstrate its advantages in analyzing and displaying the structure of social network.**

***Index Terms*—social network, domain ontology, force directed layout algorithm, structure analysis, SNAL algorithm, subgroup analysis**

I. Introduction

Visualization is often used as a way of understanding the social network data in an exploratory manner, therefore help the process of social network analysis. In methods of visualizing network graphs, force directed layout algorithms(FDA) are the most popular one. They are straightforward to implement and provide satisfactory results for many different types of networks, including social networks. Recent research in multi-scale and multi-body algorithms[1] has made it possible to create node link layouts of graphs of tens of thousands of nodes in limited time. However, traditional force directed layout algorithms have two serious problems:

1. Social networks often have the "small world" property. Such graphs exhibit both small average path length compared to their size and a high degree of clustering compared to a random graph. For graphs with small diameter force directed layout algorithms often produce images where nodes clump together in the center of the screen, making it hard to discern structure and follow paths.

2. FDA considers the network as a system of forces and is related to little about social network information organization or analysis. Therefore, they can't contribute more for further needs of social network analysis.

A fine solution is to organize the social network information with domain ontology, and then develop layout algorithms based on the ontology model. The advantages of this means are:

1. Ontology is a formal explicit specification of a shared conceptualization[2]. With the help of domain Ontology, we can organize the information and standardize the definitions fine in the field of social network analysis and visualization.

2. Many kinds of methods of social network analysis can be used under the domain ontology model for initial analysis of layout algorithms.

3. For new needs of social network visualization or analysis, changes and improvements can be made easily under the domain ontology model.

In this paper, we propose a domain ontology model for field of social network visualization and analysis which abstract the impersonal existences in the field into four primary ontologies: actor, relation, social network and subgroup. To overcome the disadvantages of traditional force directed layout algorithms in analyzing and visualizing the structure of social network, we propose the Social Network Analysis Layout (SNAL) algorithm based on our domain ontology model. In SNAL algorithm, results of social network analysis are used to improve the traditional algorithms. Section 2 discusses related work of force directed layout algorithms and Ontologies used in social network visualization, while Section 3 describes the Ontology model for field of social network visualization and analysis. In Section 4 we outline the main idea of SNAL algorithm. In Section 5 we evaluate the method by consider the case of terrorist information. Finally, section 6 presents conclusions and recommendations for further work.

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II. RELATED WORK

Force directed layout algorithm was originally developed by Eades[3], 1984. It involved transforming the vertices and edges into a system of forces and finding the minimum energy state of the system. This algorithm was easy to understand and implement, but the time cost was a little bit too high. Thus a series of improvements have been made for it in past years. The ODL (OutDegree Layout) algorithm[4] simplified the layout problem by separating the nodes in the network into multiple hierarchical layers based on the outdegree of each node. The algorithm proposed by Quigley[5] was a fast algorithm for the drawing of large undirected graphs. This algorithm made space decomposition based on the structure of graph and used the ideas of multi-layer and cluster to accelerates the calculation. Moreover, the algorithm proposed by Ahmed[6] was fit for visualizing scale-free networks in three dimensions, produce graph visualizations with nodes constrained to lie on parallel planes or on the surface of spheres, while nodes placed in every plane or surface through fast force directed layout method[5]. For intensive comprehension of social network data was lacked, these force directed layout algorithms can hardly use the existing methods of social network analysis, therefore cause the difficulties of analysis and visualization of social network structure, etc. As Fig. 1 shows, dense clusters can recognized easily in graphs produced by force directed layout algorithms, but structural features can hardly be identified and the large number of nodes in a small space further aggravates the problem of overlapping edges.

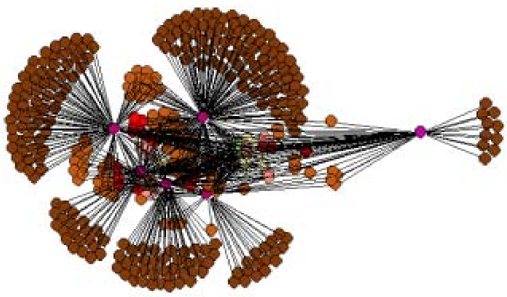

Figure 1. Layout graph of ODL algorithm[7] for a routing network

One existing approach which try to meet the needs of social network analysis better was to using an adjacency matrix representation[7][8][9]. Although adjacency matrices can deal with graphs of arbitrary density and can show internal clustering structure, they do not convey the internal connectivity structure of a graph well and are unsuitable for path finding.

There are some other attempts which organize and visualize social network information via Ontology models have been made. Jung's three layered model[10] involved social network, ontology network and the network between concepts occurring in these ontologies. This model used analysis techniques relying on network specificity and designed for analysis of social network and semantic network. Gilson proposed an approach[11] for automatic generation the visualizations graph from domain-specific data available on the web through ontology mapping and probabilistic reasoning techniques. With this approach, web data was first mapped to a Domain Ontology, and then was mapped to one or more Visual Representation Ontologies through Semantic Bridging Ontology. OntoVis[12] was a visual analytics tool for understanding large, heterogeneous social networks which proposed by Dr. Ma. This tool used both structural abstraction and filtering based on ontology information, which resulted in a dual-graph approach using both the semantic graph and its associated ontology graph to simplify the large social network. The terrorism network from the MIPT Terrorism Knowledge Base was used as a case of the tool. In these attempts, Ontology often be used for information organization of social network, not involves the further analysis theory of social network.

Therefore, we propose a domain ontology model for analysis and visualization of social network data. Under this model, a variety of social network analysis and visualization methods can be described or added easily thus supports applications of social network analysis well.

III. DOMAIN ONTOLOGY MODEL OF SOCIAL NETWORK ANALYSIS

From the sociology perspective, social network is the social actors and relations among them. In this definition, there are two key words: actors and relations. Social actors can be any social unit or entity, such as people, families, Internet social groups, corporate organizations, business partners, nations, etc. There is wide variety of relationships among actors, such as friend relationship among people, trade relationship among nations, distance relationship among cities, etc. The determination of actors and relations completely depends on the purpose of social network analysis. Thus, the actor and relation is the main impersonal existence in field of social network analysis.

Before propose the domain ontology, let's consider the main applications and methods in field of social network analysis. The main tasks list as following[13]:

1. Analyzing the basic characters of social network, such as the density or diameter of the network, the degree of actors, the distance among actors, etc.

2. Analyzing the centrality of the social network graph. The power of actors is judged through the analysis of points (represent actors) centrality and graph (represent social network) centrality.

3. Analyzing the subgroup (group of actors in which actors have the regular, close, active or direct relations) to achieve more structural information of the social network. For different purposes of analysis, subgroup can be cilques, n-cliques, n-clan, component, k-plex or k-core.

4. Analyzing the social role of actors through the research of its network position. In the graph of social network, the actors which have the similar network position quite possibly have the similar social role too. The equivalence (such as structural equivalence,

automorphic equivalence or regular equivalence) is often used to measure the similarity of network positions of actors.

Basing the analysis above, we propose a domain ontology model for the field of social network analysis, described as Fig. 2. This model contains four main ontologies: Actor, Relation, Social Network and Subgroup. In this model, the Relation is the core ontology, and there are some associations between ontologies. Among Actors there are some kinds of Relations, all these Actors and Relations form the Social Network, Subgroups are parts of Social Network, Actors in a Subgroup have some close Relations, etc.

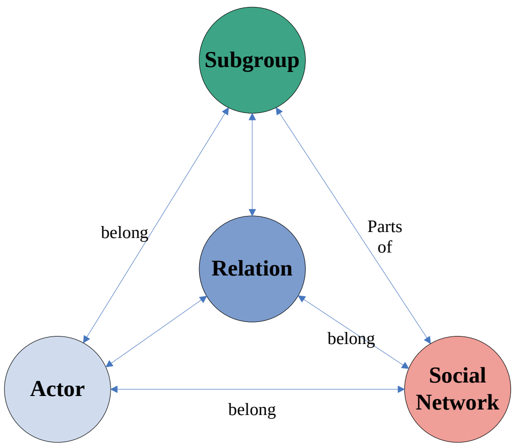

Figure 2. Domain ontology model of social network analysis

This domain ontology model is quite suitable for describing all kinds of applications of social network analysis, including the four main tasks mentioned above. Through this model, basic characters and the centrality can be calculated to actors and the whole network; subgroup analysis can be done to gain the structural information of social network and network positions of actors can be calculated for analysis of social roles. In addition to illustrating methods of social network analysis, this model is also suitable for describing the layout algorithms which is the crucial work of social network visualization. For example, the force directed layout algorithms try to find the minimum energy state of the system. We can define methods for Ontology Actor and Social Network to calculate their energy, and finally determine the positions of actors.

IV. SOCIAL NETWORK ANALYSIS LAYOUT ALGORITHM

In this paper, we present the social network analysis layout algorithm which takes advantages of our domain ontology model for better efforts of structural analysis and visualization of social network. In SNAL algorithm, social network analysis includes subgroup analysis, role analysis and key attribute analysis. Subgroup analysis is the basic task which plots out the subgroups in the network, and the similarity of subgroups then be calculated through the analysis of the actors' key attributes. The role analysis makes further analysis inside subgroups which resolves the "small world" problem fine. Finally, the results of social network analysis are used to improve the force directed layout algorithm for 2d and 3d visualization.

A. *Subgroup Identify*

In social network analysis field, subgroup means a set of actors in which actors have the strong, direct, close, regular or positive relationships and subgroup analysis is an important task which helps a lot for understanding the intentions of actors in social network. While there are many ways to calculate the dense clusters in the network by traditional force directed layout algorithms, we can use the methods of subgroup in social network analysis field to identify the subgroup under our domain ontology model. There are four important attributes in identify the subgroups: the linkage attributes, the accessibility attributes, the link densities of the members inside and outside the subgroup and the linkage attributes between subgroups. Through the social network analysis method, we can recognize the subgroups more easily and exactly.

B. *Key Attribute Analysis*

After the subgroup analysis, we get the probable division of subgroups. But there still may be some actors can't identify its subgroup accurately from the relationship perspective. To solve this problem and research the close degree between subgroups, we make further researches based on key attributes.

Researches from social network analysis indicate that there are always many common characters between actors within one subgroup. In other words, actors which have the same key attribute values quite possibly have close relations, therefore within one subgroup. Thus, we research the association between the key attributes of actors and the division of subgroups, assist in division of subgroups and calculation of the similarity between subgroups.

Throughout the paper, a same subgroup relationship matrix is defined as Q which element q_{ij} equals 1 when actor i、j belong one subgroup, otherwise 0. Similarly, for every key attribute of actors, a same attribute relationship matrix is defined as A which element a_{ij} equals 1 when actor i、j have the same key attribute value, otherwise 0. Therefore, we can use the QAP（Quadratic Assignment Procedure）method of social network analysis field for calculating the relativity between Q and A. Assume the key attributes of actors is independent, the probability of actor i belong to subgroup j is calculated by equation (1). In this equation, let q_m be the relativity between the same subgroup relationship matrix and the same attribute relationship matrix for attribute m and let f_m be the similarity of the actor i and the subgroup j in key attribute m.

$$bs = \max_{m=1}^{g} q_m f_m \tag{1}$$

Equation (1) also can be used for computing the similarity of two actors or two subgroups when let f_m be the similarity of the actors or the subgroups in key attribute *m*. If *bs* beyond a limit, such as 0.8, etc. It means that actor *i* or subgroup *i* should merge into subgroup *j*.

Exclude the attributes whose similarity with the division of subgroups are low, the similarity of subgroups is

$$sf = \sum_{m=1}^{g} q_m f_m / \sum_{m=1}^{g} q_m \tag{2}$$

From this value, we can estimate the close degree of subgroups.

C. Role Analysis Based on Regular Equivalence

Role analysis is another important task of social network analysis which tries to understand the roles and status of actors in the social network. Here we use it to further analysis internal structure of subgroups and the link attributes of actors inside subgroups.

Role analysis always means the analysis of network position of actors. In the graph of social network, the actors which have the similar network position quite possibly have the similar social roles too, it is the main idea of equivalence analysis. Here we choose the regular equivalence analysis for computing the similarity of network positions of actors. Therefore, the actors in the same regular equivalence group will have the same characters of group link.

When iterative computing the regular equivalence groups, first we divide the actors into several initial groups according to their degree. The initial regular equivalence values between actors, in the same group is 1, otherwise is 0. After every calculation cycle, the actors which regular equivalence values below a limit in one group will form a new regular equivalence group, this process continues until all the actors in their group have the regular equivalence values beyond the limit. Equation (3) calculate the regular equivalence values between actors *i* and *j* in cycle *i*+1.

$$M_{ij}^{t+1} = \frac{\sum_{k=1}^{g} \max_{m=1}^{g} M_{km}^{t} \times \min\left(x_{ik}, x_{jm}\right)}{\sum_{k=1}^{g} \max_{m=1}^{g} \max\left(x_{ik}, x_{jm}\right)} \tag{3}$$

In equation (3), the regular equivalence values between two actors measure by similar of their association with other actors. For every actor *k* in the all *g* actors, the member calculates the *jm* link which matches the *ik* link best. For the actor *k* and *m* not always equal under the regular equivalence rule, so multiple the M^t_{km} which present the regular equivalence values between km calculated in last cycle. The denominator presents the max value of link matching. The value calculated by this formula is a relative value which from zero to one.

In graphs produced by FDA algorithms, there is always large number of nodes and relations swarm in a small space inside a dense cluster. This causes the difficulty of discerning structure and paths. Use the results of equivalence analysis and role analysis, we can solve the problem of "small world" inside the subgroups well, as Fig. 3 shows.

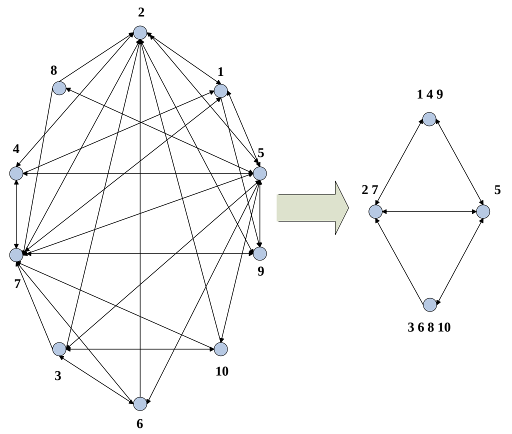

Figure 3. Extract subgroup via regular equivalence group

D. Planar Layout of SNAL Algorithm

Based on the analysis of subgroup, improvements made by SNAL algorithm are

1. For regular equivalence groups and subgroups are known through the analysis of subgroup, we separate the actors in the network into three hierarchical layers for reducing the complexity of the graph layout problem. In computational sequence, the layout objects are subgroups, regular equivalence groups and actors.

2. The similarity of subgroups can be used to estimate the close degree of subgroups. Then our visualization results include more social network information when the distance between subgroups reflect the similarity or close degree of subgroups in layout graph.

3. The actors which have same key attributes are quite probable have some relations, even such relations are unknown yet. Thus we consider the key attribute value of actors when decide the distance between actors in layout graph for facilitating the structural analysis from visualization result.

For the 2nd and 3rd purpose, we need adjust the distance between actors based on the result of subgroup analysis. In traditional force directed layout algorithm, Let d_{ij} be the shortest length path between actors *i* and *j* in the graph and L be the unit natural length, then the natural length of the spring between actor *i* and *j* is

$$l_{ij} = \mathrm{L} \times d_{ij} \tag{4}$$

In SNAL algorithm, l_{ij} decided by not only shortest length path, but also their key attributes values and the similarities of their subgroups. Then equation (4) turned to be equation (5), in which b_{ij} is the distance value decided by shortest length path between actors and similarity of subgroups and s_{ij} is the distance for key attributes.

$$l_{ij} = \mathrm{L} \times \left(b_{ij} + s_{ij}\right) \tag{5}$$

Usually, $d_{ij} \neq \infty$. Then b_{ij} equals to shortest length path add a distance between subgroups. Let sf_{ij} be the similarity of subgroups which actors *i* and *j* inside and *u* be the larger number of actors in the subgroups which actors i and j inside, therefore square root of u represent the value for the diameter of the subgroup and b_{ij} is

$$b_{ij} = d_{ij} + \sqrt{u} \times (1 - sf_{ij}) \quad d_{ij} \neq \infty \tag{6}$$

Specially, dij=∞. Then b_{ij} equals to an initial distance add a distance between subgroups. Let v be the total number of actors in the network, therefore square root of v used to estimate the diameter of the graph and b_{ij} is

$$b_{ij} = \sqrt{u} + \sqrt{v} \times (1 - sf_{ij}) \quad d_{ij} = \infty \tag{7}$$

The key attributes distance is the sum of all natural distances for every key attribute. Let S_m be the natural distances for key attribute m and a_{ij} be the same attribute relationship matrix for key attribute m, then s_{ij} is

$$s_{ij} = \sum_{m=1}^{g} a_{ij} S_m \tag{8}$$

These adjusts apply in calculation of every hierarchical layers.

E. 3D Layout of SNAL Algorithm

We get the clear layout of subgroups and key attributes in planar graph of SNAL algorithm. Furthermore, we extend this algorithm to 3d by changing height of actors according to their relative centralities. Therefore, the final 3D graph can indicate the actors influence inside its subgroup and the actors which play the key roles in the network are outstanding.

In the algorithm proposed by Ahmed[6], the only measure basis of layout is the degree of actors which defined as absolute centrality in social network analysis field. But valuing the importance and influence of actors according to the absolute centrality is not the best choice because absolute centrality considers just the local information (number of actors which have direct link with the target actor). Here we choose the relative centrality which defined as the ratio of absolute centrality of actor and the biggest possible degree of actor in the graph instead of absolute centrality. Furthermore, we define relative centrality inside subgroup as the ratio of absolute centrality of actor inside its subgroup and the biggest possible degree of actor inside its subgroup. This value used to estimate the importance and influence of an actor inside its subgroup. Let C_i be the degree of i inside its subgroup and m be the actor number of its subgroup, then the relative centrality inside subgroup of actor i is

$$C_i^{'} = (C_i - 1)/(m - 1) \tag{9}$$

The value range of result of equation (9) is from 0 to (m-2)/(m-1). Higher value indicates more important the actor is inside its subgroup. For relative centrality inside subgroup is a relative value involved with the subgroup, we should consider the diameter of the subgroup when using this relative value for deciding the actor's height. Let R be the planar diameter of the subgroup and constant D be the biggest possible gradient of the subgroup which below 90°, then the height of actor i is

$$h_i = \mathrm{tg}\left(\mathrm{D} \times C_i^{'}\right) \times R / 2 \tag{10}$$

After the 3D extension as above, every subgroup of social network displays as a mountain in the final visualization result. The characters of mountain inflect some social network information.

1. How dense are the nodes in the mountain indicate how close the relationships among actors in the subgroup. Because the layout algorithm consider about the value of key attributes, the denseness also indicate the similarity of actor's attributes inside the subgroup.

2. The number of main peaks in the mountain indicates the number of key actors in the subgroup because a main peak represents an actor who has the most relations in the subgroup.

3. The gradient of the mountain indicates the relative centrality inside subgroup of the actors. For example, the gradient of the mountain is low indicates that relations among actors inside the subgroup are few.

Therefore, users can analyse the structural character of the social network intuitively form the information visualization result of SNAL algorithm.

V. CONTRAST OF SNAL AND FDA ALGORITHM FOR TERRORIST INFORMATION

A. Describe Terrorist Information with Application Ontologies

Case study in this paper is terrorist information which comes from the MIPT Terrorism Knowledge Base. Through analysis of our domain ontology model, terrorist information describes as the terrorist organization, terrorist attack and terrorist in Fig. 4. These three application ontologies are derived from the domain ontology Actor, therefore inherit its methods and attributes. Besides, some attributes such as location, tactic, target, weapon of the terrorist attack are defined in this case. Terrorists can be the main members of an organization and terrorist organizations can be responsible for terrorist attack.

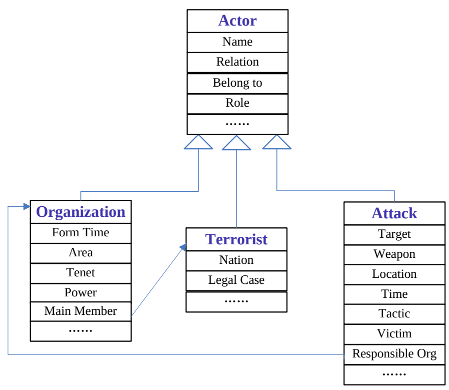

Figure 4. Domain ontology model of social network analysis

The OntoVis's ontology graph[12] classified the terrorism network into nine different types of nodes in Fig. 5. It just listed all key words in its ontology graph, lacking further analysis and hierarchical description, while application ontologies terrorist organization, terrorist attack and terrorist are derived from the domain ontology Actor in this paper and they have some important attributes for describing information or linking each other. These differences decide that OntoVis was fit for schematic displaying only, while method in this paper is suitable for not only visualization but also meticulous analysis. For example, the areas of terrorist organization and the locations of terrorist attack all described as Country_Area in OntoVis but different attributes of application ontologies in this paper, and we can even define different relation matrixes for further analysis.

B. Social Network Analysis of SNAL Algorithm for Terrorist Organizations Information

In process of subgroup analysis, first we find 22 regular equivalence groups and 9 subgroups based on role analysis. Main attributes of terrorist organizations are area, leader, form time, power, tenet and financial source etc. After computing the relativities for every attribute with the subgroups division by QAP method, we get rid of some attributes not quite important and finally left the key attributes area and tenet. Then we calculate the similarity of subgroups for these two attributes.

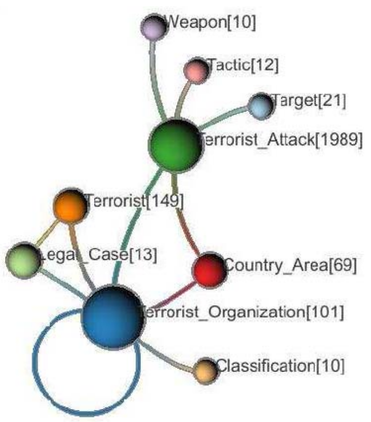

Figure 5. Ontology graph of OntoVis

C. Planar Layout of SNAL Algorithm for Terrist Organizations Information

Based on subgroup analysis, SNAL algorithm computes the graph layout in three hierarchical layers. The result of the first layer for terrorist organizations information shows as Fig. 6. In this figure, the main layout objects is the subgroups and the isolated terrorist organizations grouped by their key attributes values. After the calculation for three hierarchical layers, the final visualization result of terrorist organizations network shows as Fig. 7. The terrorist organization subgroup of al-Qaeda is in the center of the graph while the subgroup of Hamas is on the right hand of it and other terrorist organizations as CPN-M、IRA and LVF are all around them. The colors in Fig. 7 represent the tenet of terrorist organizations.

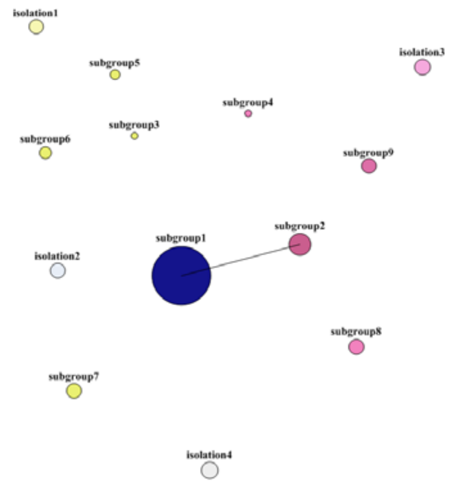

Figure 6. subgroups layout of SNAL algorithm

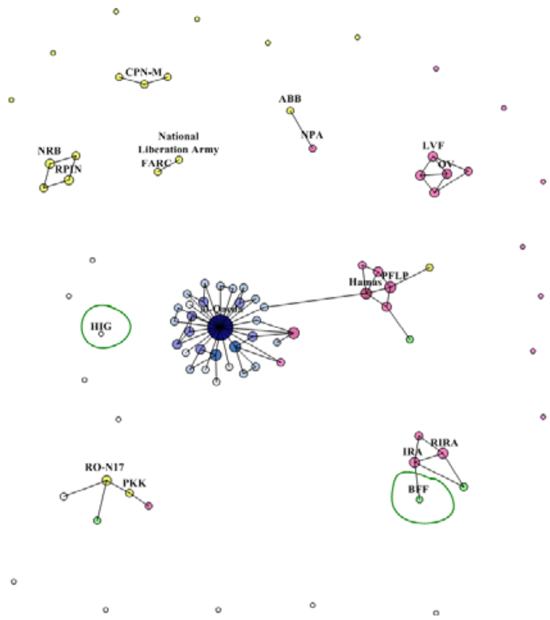

Figure 7. final layout of SNAL algorithm

The OntoVis[12] also used the case of terrorist organizations information, Fig. 8 shows the result graph.

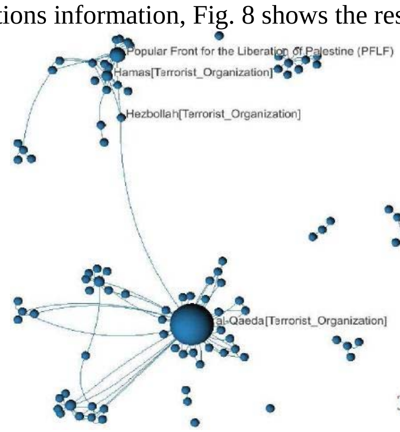

Figure 8. layout graph of OntoVis

Compare the results of two algorithms:

1. Same source data causes the result graphs are similar in some way. The main subgroups of al-Qaeda and Hamas can be recognized easily. However, the

distribution of subgroups is more regularly and legibly in graph of SNAL algorithm for the computation of subgroup distance.

2. In Fig. 7, the distance between subgroups is related to the similarity of subgroups. As a result, through the similarity computation based on key attributes, the similar subgroups are near while the subgroups not similar are far off in the graph. Specially, isolated actors always be placed at the most periphery in traditional force directed layout algorithms for the distances from them to other actors are infinite. But in SNAL algorithm, isolated actors are placed close to subgroups which have the similar key attributes values with them. For example, the HIG terrorist organization is a religious organization at Afghanistan and Pakistan, thus it's near the subgroup of al-Qaeda because similarity between them is high. The distance between subgroups or actors could be used for estimating the possibility of relations between them. For example, the HIG terrorist organization might have unknown relations with the subgroup of al-Qaeda for they are close in the visualization result.

3. In Fig. 7, the distances between actors reflect their similarities of key attributes. Therefore, the internal cohesion of subgroups can be concluded easily from the distribution of key attributes and the distances between actors. For example, most terrorist organizations in subgroup of al-Qaeda are religious (blue) organizations and they are near in Fig. 7, therefore we can get the conclusion that it is a steady team which internal cohesion is strong. There are nationalism (green) organizations and left (pink) organizations inside the subgroup of IRA and they are a little bit far from each other in Fig. 7, thus it should be a loose team. The BFF is different in area and tenet with all other organizations inside its subgroup and just have link with the IRA. It might be a departing organization of the subgroup.

4. In Fig. 7, the color depths and diameters of actors represent the network roles of nodes. As a result, the subgroup of al-Qaeda has four network roles and the deeper color indicates more important role in the subgroup, while just the al-Qaeda was outstanding and other nodes had no difference with each other in shape and color in Fig. 8. That's mean visualization results of SNAL algorithm is fit for displaying the distribution of social roles better.

D. 3D Layout of SNAL Algorithm for Terrist Organizations Information

In Ahmed's [6] method, the degree of actors were used as the crucial factor of deciding the importance of actors, then actors had different degree were placed in different planes. This method was fit for representing the property as "power-law" degree distribution of scale-free networks. The layout graph of terrorist organization network produced by Ahmed's algorithm shows as Fig. 9 while the graph produced by SNAL algorithm shows as Fig. 10.

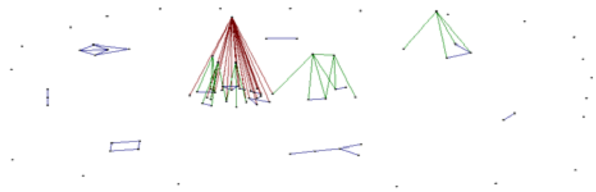

Figure 9. 3d layout of terrorist organization network by Ahmed's algorithm

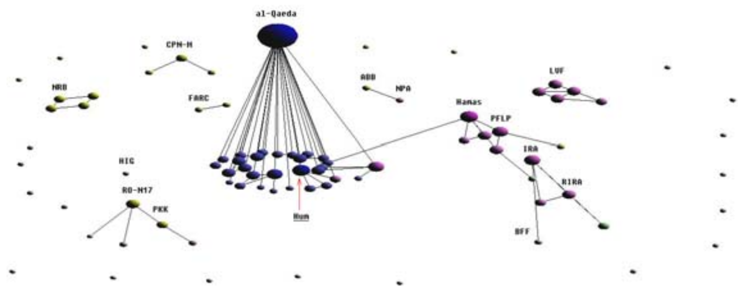

Figure 10. 3d layout of terrorist organization network by SNAL algorithm

Comparing these two images, we found that: 1. Fig. 10 legibly displays the distribution of terrorist organization subgroups and close degree between them for SNAL algorithm based on the subgroup analysis and considers the similarity between subgroups when calculating actor distance. 2. Fig. 10 intuitively displays the distribution of key attributes and internal cohesion of subgroups for distance between actors reflect the similarities of key attributes and colors are used for represent the tenet of terrorist organizations. 3. Fig. 10 legibly displays the distribution of network roles because SNAL algorithm analyzes the network role of actors and color depths and diameters are used for represent the roles of actors. 4. Degrees of actors are the crucial factor of deciding the importance of actors in Fig. 9, while Fig. 10 layouts the actors in height according their relative centralities inside subgroup. Therefore, Fig. 10 is more suitable for displaying the influence and importance of actors. For example, the actors with degree 5 are in the second plane in Fig. 9. But Hum in a subgroup which actor number is 31 while Hamas in a subgroup which actor number is 7, their importance in their subgroup and in the network are quite different. Fig. 10 represents this well while Fig. 9 can't do it.

VI. CONCLUSIONS AND FUTURE

The most popular algorithms for information visualization of social network are the force directed layout algorithms at present. These algorithms always calculate the layout by separate the actors in the network into layers or clusters. They are suitable for displaying the distribution of whole network but can't meet the needs of structural analysis and visualization. To solve this problem, we propose a domain ontology model for the field of social network analysis. Based on this model we propose the SNAL algorithm for planar and three dimension visualization. SNAL algorithm analysis the subgroups, roles and key attributes at first. Then the results are used to improve the force directed layout algorithm，include adjusting natural distance of actors and computing the layout in multilevel manner. So the actors can be layout according to their relative centralities in 3D visualization in the algorithm. SNAL algorithm overcomes the disadvantage of traditional force directed layout algorithm in analyzing and visualizing the structure of social network. It's suitable for legibly displaying layout of subgroup, reflecting degree of affinities between actors, displaying distribution of key attributes, intuitively displaying role distribution and influence of actors within subgroups. Results with the case of terrorist information demonstrate its advantages.

More applications should be done by the domain ontology model in this paper. We plan to analyze the relationships of multiple types of actors or the changes of relationships based on ontology model. For example, find how relations between the terrorist organizations affect the relations between the terrorist attacks is significative.

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REFERENCES

[1] S. Hachul and M. Junger, *An experimental comparison of fast algorithms for drawing large general graphs*, Proceedings of Graph Drawing 2005, 2005, pp. 235-250.

[2] T. R. Gruber, *A translation approach to portable ontology specifications*, Knowledge Acquisition, vol. 5, February 1993, pp. 199-220.

[3] P. Eades. *A heuristic for graph drawing*, Congressus Nutnerantiunt, vol. 42, 1984, pp. 149-160.

[4] D. S. Chan -M, K. S. Chua, C. Leckie, and A. Parhar, *Visualisation of Power-Law Network Topologies*, Proceedings of the Eleventh IEEE Internationa1 Conference on Networks, Sydney, 2003, pp. 69-74.

[5] A. Quigley and P. Eades. *FADE: Graph Drawing, Clustering, and Visual Abstraction*, Lecture Notes in Computer Science. Heidelberg: Springer, 2001, vol. 1984, pp. 77-80.

[6] A. Ahmed, T. Dywer, S. H. Hong, C. Murray, L. Song, and Y. X. Wu, *Visualisation and Analysis of Large and Complex Scale-free Networks*, Proceedings of Eurographics/IEEE VGTC Symposium on Visualization, Leeds, 2005, pp.1-8.

[7] N. Henry and J. D. Fekete, *MatrixExplorer: a dual-representation system to explore social networks*, IEEE Transactions on Visualization and Computer Graphics, vol. 12, May 2006, pp. 677-684.

[8] N. Henry, J. D. Fekete, and M. J. McGuffin. *NodeTrix: a hybrid visualization of social networks*, IEEE Transactions on Visualization and Computer Graphics, vol. 13, June 2007, pp. 1302-1309.

[9] N. Henry, A. Bezerianos, and J. D. Fekete, *Improving the readability of clustered social networks using node duplication*. IEEE Transactions on Visualization and Computer Graphics, vol. 14, June 2008, pp. 1317-1324.

[10] J. J. Jung and J. Euzenat. *Towards semantic social networks. Proceedings of the Semantic Web: Research and Applications*. Berlin: Springer, 2007, vol. 4519, pp. 267-280.

[11] O. Gilson, N. Silva, P. W. Grant, and M. Chen, *From web data to visualization via ontology mapping*, Eurographics/ IEEE-VGTC Symposium on Visualization, A. Vilanova, A. Telea, G. Scheuermann, and T. Moller, Eds. Eindhoven, vol. 27, March 2008, pp. 959-966.

[12] Z. Q. Shen, K. L. Ma, and T. Eliassi-Rad. *Visual analysis of large heterogeneous social networks by semantic and structural abstraction*, IEEE Transactions on Visualization and Computer Graphics, vol. 12, June 2006, pp. 1427-1439.

[13] J. Scott. *Social network analysis: a handbook*, 2nd ed, Sage Publications: 2006, pp. 6-25.

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