Social Network Analysis Visualization Tools: A Comparative Review

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2020 IEEE 23rd International Multitopic Conference (INMIC) | 978-1-7281-9893-4/20/$31.00 ©2020 IEEE | DOI: 10.1109/INMIC50486.2020.9318162

***Abstract*—Social network analysis helps analysts to study the relationships among different nodes of a network and get valuable insights. The common output of social networks analysis is measuring the node's centrality and graphical visualization, which helps us to understand the degree and nature of relationships between different nodes of the network. Online Social networks produce data that provides tons of knowledge. But it is challenging to extract the data and get useful information through its analysis and visualization. Getting insights from small-scale networks is comparatively easy since they can be manually constructed and graphically represented. But it gets very time-consuming and hectic process as the network expands. Several social network analysis tools are available for this purpose. These tools also come with embedded techniques for analyzing social networks, reducing the overhead for the manual study of complex networks. The focus of this paper is on the analysis and comparison of popular tools that are often used by experts for analysis of large-scale data-sets. In this paper, we have addressed the various characteristics, functionalities, support comparison, strengths, and limitations of SNA tools based on a literature survey and expert opinions. This will help researchers and practitioners to choose a suitable tool for social network visualization and analysis.**

***Index Terms*—Social Networks Analysis and Visualization; SNA Tools Comparison; SNA Tools Characteristics; NodeXL, UCIENT; PAJEK; MuxViz; Gephi**

I. Introduction

The idea of social network analysis (SNA) is used loosely for over a century to denote complex relationships between the participants of social systems at each scale. SNA has now been moved to a more analytic approach and has developed its own methods, theoretical statements, and software. Social network analysts now either study the whole network or personal networks. To study the whole network, the analyst needs to gather the data of all the nodes present in that network while to study personal networks or egocentric network [8], the analysts need to consider the tied nodes only [4]. To carry out the social network analysis, the analysts first have to gather data about a network, they want to analyze. After gathering the data they can apply social networks analysis techniques on it. The most popular measures of social network analysis are Betweenness Centrality [9], Closeness, Cohesion, Degree, and Density [7]. These measures can be calculated manually for smaller networks but for the large complex networks, containing hundreds and even thousands of nodes, it is very difficult. Therefore different tools or softwares are built which not only calculate these values but also help us to visualize and analyze a social network [11].

The number of tools has been developed that get data from social networks and provide desired results after performing social network analysis. While dealing with current SNA tools researchers face several challenges including; the ability to automatically import data from social sites, big data analytics which is an open issue, sub-network extraction, and community detection which is essential in exploring networks and predicting connections that are difficult to see, user-friendliness as well as rich and enhanced features to represent data including support of multiple layouts and editing property, coverage, response time, open-source or propriety software, input/output data possibilities, algorithm support and computing centralities, network type support including temporal networks (network changing over the time), acyclic, multi-relational networks and platform dependency.

In earlier review articles of SNA tools, most authors have listed two or three best tools, but in our research paper, we have the best use-case of each tool which will enable researchers and practitioners to pick an appropriate tool that suits their purpose. Although there are many tools available for performing social network analysis, we will only analyze a few SNA tools, often used by experts to overcome the above-mentioned challenges and are must be supported by the Windows platform. We have conducted a survey and got expert's opinions about the SNA tools they used. Moreover, we have also consulted five famous scientific libraries including springer, IEEE, science direct, ACM, and Taylor, thus explored

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which tools are mostly used by researchers. After careful analysis of results from survey and expert opinions, we have selected five tools mostly preferred by experts which include the following: Node XL [30] [5] [6], GEPHI [17] [18] [19] [21], PAJEK [23] [24] [25] [26], UCINET [27] [28] [29] and MuxViz [20] [22].

II. SOCIAL NETWORK VISUALIZATION TOOLS

In this section, some of the state-of-the-art tools are discussed in detail along with supported functionality and graphical representation of the 9-11 terrorist network dataset(Noordin Top Network) to help researchers pick the right fit for them. We have considered both open source and proprietary software.

A. NodeXL

NodeXL commonly used to perform analysis on networks [1]. It is not standalone software; rather it is implemented as an add-in to Microsoft Excel. NodeXL enables the automation of data flow that primarily begins with the collection of network data. Different steps are performed to reach the desired network visualization and reports [2]. NodeXL gives the power to anyone who is familiar with Microsoft excel's basic features to generate network statistics very quickly.

NodeXL is proficient enough to analyze and visualize a social network. It can not only visualize the whole network in the form of a graph but can also plot graphs of different social network attributes such as Closeness Centrality, Betweenness Centrality, Vertex Degree, Vertex PageRank, etc.

1) Input/Output file formats suppoted by NodeXL:: NodeXL not only allows the user to paste the edge list data but also allows to fill the data manually. The users can import data from supported MS Excel formats (xls, xlsx and csv) or from a text (txt) file. Moreover, it can import data from PAJEK, UCINet, GraphML and social sites [10], like Facebook, and Twitter. NodeXL can save the output of processed data in a variety of formats as shown in Table 2.

2) Graphical Representation of Network in NodeXL:: NodeXL provides different types of options for graphical representation of networks. We have shown a graphical representation of the 9-11 terrorist network dataset also known as Noordin Top Network.

B. GEPHI

GEPHI is an open-source, standalone software used for the visual and network analysis [3]. Visualization is an important factor that gives humans a huge advantage of finding useful features in data or a network. GEPHI provides a variety of rich and enhanced features to represent data and text mining features using "Plugin Alchemy AP" which is of immense value. [16] The main advantage of using GEPHI for network analysis is its capability to work with large size data or networks. There are few downsides of GEPHI software that were experienced during its usage. It sometimes takes too long to respond to a very small task. Such as browsing a file takes a lot of time. But considering that GEPHI is standalone, open-source software, it supports many features.

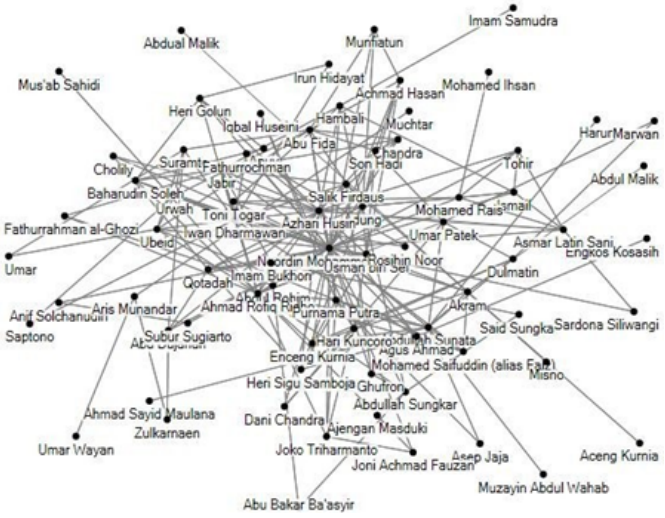

Fig. 1. Noordin Top Network representation using NodeXL

1) Input/Output file formats supported by GEPHI:: GEPHI can read data from a simple text file (txt), spreadsheet (CSV), and database. GEPHI can also take input from various other social network analysis tools as shown in Table 2.

2) Graphical Representation of Network in GEPHI:: It is very easy to represent a network in graphical format using GEPHI. GEPHI is capable of building network graphs and plots. Noordin Top Networkś Graphical representation with GEPHI is shown in Figure 2.

Fig. 2. Noordin Top Network representation using GEPHI

C. UCINet

UCINet is menu-driven software used for cultural domain analysis and social network analysis [13] [14]. UCINet is

standalone software. All the data is described in matrices in UCINet 6.0. UCINet 6.0 takes two types of input and two types of output. Input includes input parameters and input datasets whereas output includes output text and datasets. Spreadsheet editor is used for editing purposes, to enter new data, and to transform UCINet data to excel or SPSS. UCINet spreadsheet supports small networks. For larger datasets variety of data, formats are available which are accessible from an editor called dl editor.

1) Input/Output file formats supported by UCINet:: UCINet accepts ASCII text files as input and gives output in different formats as shown in Table 2. File with the extension (.##d) means actual data and the file with extensions (.##h) means information about actual data.

2) Graphical representation of Network in UCINet:: UCINet uses Netdraw to support network visualization. Netdraw support multiple layouts for visualization purpose. These include Isolates, components, subgroups, and centrality measures. Moreover, it provides functionalities like restore node, color scheme, hide reveal property, node size adjustment, etc. A graphical representation of the Noordin Top dataset is shown with the help of NETDRAW in figure 3.

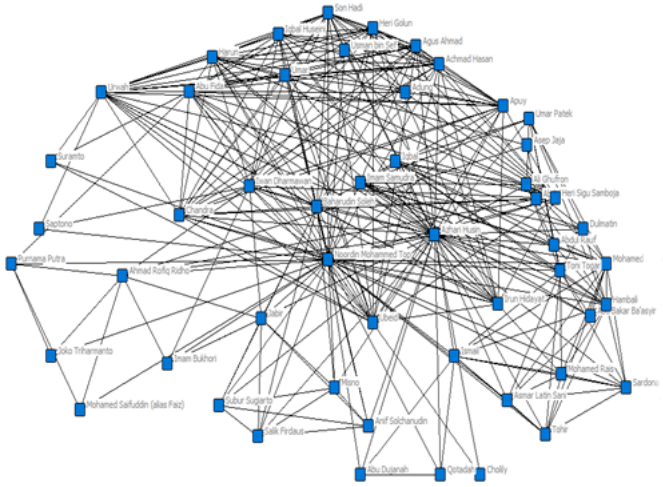

Fig. 3. Noordin Top Network representation using Netdraw

D. PAJEK

PAJEK is a software used for visualization and analysis of large social networks [14]. It can be used to calculate most of the centrality measures. Also to perform repetitive tasks macros can be recorded. Basic operations supported by PAJEK includes extracting sub-networks, shrinking selected parts of the network, looking for connected components(strong, weak, connected) looking for shortest paths, maximum flow, k-neighbors, computing centralities, centralization of the network (closeness, betweenness, and degree, etc.), fragment searching and, community detection. Moreover, results drawn by PAJEK can be further analyzed by excelR, and SPSS. PAJEK support two modes networks, temporal networks (network changing over the time), acyclic, and multi-relational networks (multiple relations defined on same vertices), signed networks (network with negative and positive lines). PAJEK also supports text mining algorithms of social network analysis.

1) Input/Output formats supported by PAJEK:: The input format GEDCOM is the standard format for genealogical data [12]. Ball and Stick (.bs), Mac Molecule (.mac), and MDL MOL(.mol) were developed mainly for chemistry. PAJEK supports 2D or 3D output formats like SVG, EPS, and X3D, VOSViewer, Mage).

2) Graphical representation of Network in PAJEK:: PAJEK gives a good visualization of big networks. It shows a clear visual view against the provided input network. Noordin Top networkś visualization is done using PAJEK in Figure 4.

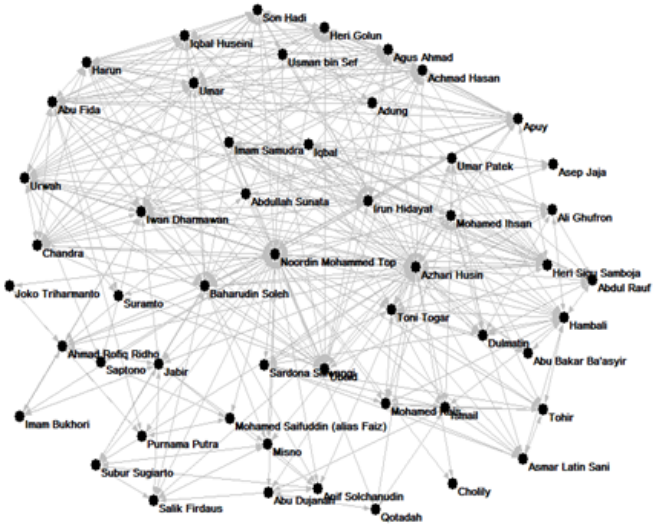

Fig. 4. Noordin Top Network representation using PAJEK

E. MuxViz (Visualization for Multilayer Social Network Analysis)

MuxViz is open-source software that provides the framework for the visualization and exploration of Multilayer social networks i.e. graphs where different nodes show multiple relationships simultaneously from different online social networks like Facebook, LinkedIn, and Instagram.[15]. A MuxViz tool is used in a large variety of systems in the engineering, biological, social, information, and physical sciences which can be described as multilayer networks.

1) Input/Output file formats supported by MuxViz: : Input/Output format supported by MuxViz are shown in Table 2.

2) Graphical Representation of Network in MuxViz::: MuxViz gives a good visualization tool for Multilayer social networks. Noordin Top networkś visualization is done using MuxViz in Figure 5.

III. COMPARATIVE ANALYSIS OF VISUALIZATION TOOLS

The data from social networks can not be overlooked in today's time. Fortunately, it's easy to access the data nowa-

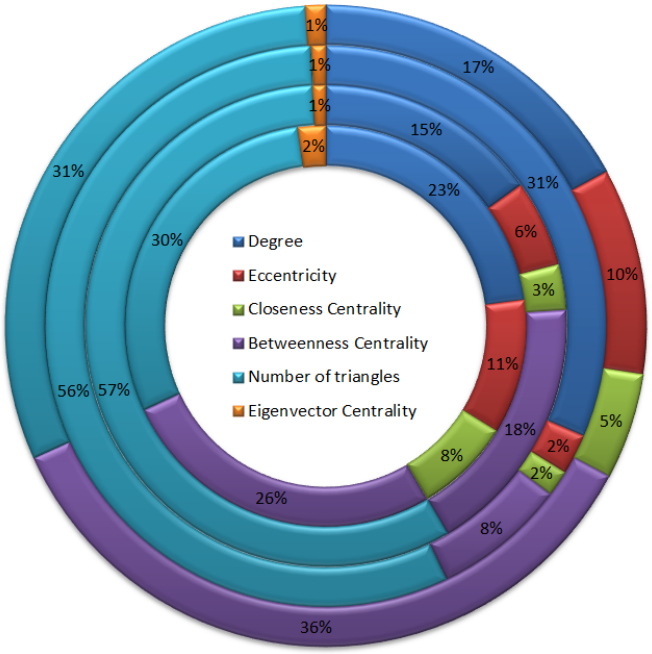

Fig. 5. Noordin Top Network representation using MuxViz

days, because there are different data collection and storage methods but analyzing that data is still challenging. Due to the rise in new technology and the increasing need to analyze social networks, numerous SNA tools have been developed. Such tools not only help to analyze the network in a technical way but also to depict it graphically.

This section describes the comparative analysis of SNA visualization tools in tabular format with a focus on general characteristics, representation, visualization, identification of weak and mature functionalities, and strength weakness analysis of SNA tools. Table 1 depicts the general characteristics of SNA tools. It covers the core functionality, coverage; analysis and visualization features, open-source/ proprietary, and supported platform of the tool. GEPHI and MuxViz are preferred as open-source tools. Moreover, Table 2 illustrates the input and output file formats of the visualization tools under discussion. Further, it also provides information about supported SNA tool's input and output files. All of the discussed software can handle .net format but data is mostly available in .txt format, thus tools like NodeXl and MuxViz are preferred in this regard. Table 3 provides information about features supported by the tools including visualization types, source code availability, indicators like node edge filtering, and status of tools (standalone/independent). The visualization types provided by the software are graphs, charts, and plots, etc. Additionally, functionalities (Mature/weak) and support comparison of SNA Visualization tools is represented in Table 4 whereas Table 5 shows the strengths and limitations of the discussed tools.

Furthermore, NodeXL input supports a wide range of formats. NodeXL is a very powerful tool but it still needs MS Excel to work which makes it a dependent software. It only supports the visualization of small and medium scale datasets and canńt handle large network datasets. Still, it is very easy to use and its processing speed is much faster and supports all the major social network analysis features.

Similarly, GEPHI also supports a wide range of input formats including input from a wide range of SNA tools and importing data from databases. It is an independent, standalone software but its features are very limited and it is mostly used for the visualization of the network. Though GEPHI seems good software for the network analysis but itś not good for large scale networks. Also it takes too much time to perform a specific task in GEPHI. One of the main reasons for not using GEPHI for Social Network Analysis is because of its limited set of features.

Furthermore, UCINet is also a very powerful tool and is available for free use but it is not open-source software. UCINet does not provide any graphical output or visualization of the network rather it relies on Netdraw to provide visual output of social network data.

Moreover, PAJEK supports 2D or 3D output formats. The input format which support genealogical and chemistry data are supported by PAJEK. Though PAJEK can process large amounts of data and it is available for free personal use. It is available as standalone software but it accepts only some specific type of input data and does not support any simple text format.

As far as MuxViz is concerned, it has an edge over other tools as it can analyze the multi-layered social networks. MuxViz also supports large scale input formats and it is open-source software but it is dependent on other third-party applications.

IV. CONCLUSION AND FUTURE WORK

As discussed in a research paper each visualization tool has its own specific set of features thus tools vary in how they address the challenge of visualizing and analyzing social networks. From the analysis of Node XL, PAJEK, GEPHI, UCINET, and, MUXVIZ. It was found that GEPHI is advised when visualization of the network is required rather than analyzing networks because it has the capability to calculate just a few common centrality metrics. This limitation is overcome by Node XL which does not possess the flexibility of GEPHI in terms of visualization but it can interface directly with the SNAP library to access efficient algorithms to compute centrality metrics. Also, its main strength lies in its data collection feature; it can interface with twitter API to do so. Moreover, PAJEK has its strength in having a number of layout algorithms which makes it ideal for exploration and pattern identification within social networks. Additionally, it can analyze large networks but still, it is weak on visualization. UCINET is most widely used in academic circles. It is recommended while analyzing any social network as it is strong on analytics with a large number of centrality metrics. MUXVIZ is used for the visualization of the multilayered social networks.

TABLE I
SNA VISUALIZATION TOOLS GENERAL CHARACTERISTICS

Tool Support	Core Functionality	Coverage	Open Source /Proprietary software	Platform
NodeXL	Overview and exploration of large scale social network (SN), clustering, automatically import data from social sites, Sentiment Analysis	Analysis + Visualization	Proprietary	Windows
GEPHI	Graphical exploration and manipulation of social network, Rich features for data representation, centrality metrics	Analysis + Visualization	Open source	Systems supporting Java 1.6 & Above + OpenGL
PAJEK	Analysis and visualization of large networks/ multi-layer social network/ temporal networks, centrality metrics, GUI packages, easier to learn, clustering, text mining, sub network extraction,	Analysis + Visualization	Proprietary, free for non-commercial use	Windows, Linux, Mac OS X
UCINet	Cultural domain analysis and social network analysis, clustering	Analysis + Visualization	Proprietary	Windows
MuxViz	Analysis and visualization of multilayer social network, clustering, automatically import data from social sites	Analysis + Visualization	Open source	Windows , Linux , Mac OS X

TABLE II
SNA VISUALIZATION TOOLS INPUT/OUTPUT CHARACTERISTICS

Tool Support	Supported Input Formats	Supported Output Formats	Supported SNA Tools Input Formats	SNA Tools Output Formats
NodeXL	.txt, .xls, .xltx, .csv	.txt, .xls, .xltx, .csv	PAJEK (.net), UCINet (.dl), GraphML	UCINet (.dl), GraphML
GEPHI	GEPHI (.gexf), Edge list (.csv), databases	GEPHI (.gexf), .svg, .png	GraphViz (.dot), GUESS (.gdf), Graphlet (.gml), LEDA (.gml), NetworkX (.graphml, .net), NodeXL (.graphml, .net), PAJEK (.net, .gml), Sonivis (.graphml), Tulip (.tlp, .dot), UCINet (.dl)	GUESS (.gdf)
PAJEK	SVG, text format (ASCII)	.net, xml(graphML)	PAJEK , network (.net, PAJEK matrix(.mat)), Vega, GEDCOM, UCINet DL files (.dat), Ball and Stick (.bs), Mac Molecule (.mac), and MDL MOL (.mol)	.net, .dat (UCINet), .paj, bs, .xml(graphML)
UCINet	ASCII text files	dl, Raw	UCINet (.##h .##d), VNA (.vna), DL (.d), PAJEK network (.net), PAJEK vector (.vec)	PAJEK(.net, .vec), Metis, Excel
MuxViz	.txt, .xls, .xltx, .csv, Edge list (.csv), databases files	.txt, .xls, .xltx, .csv, Edge list (.csv), databases files	GraphViz (.dot), PAJEK	(.net), UCINet (.dl) .net, GUESS (.gdf), Excel

TABLE III
SNA VISUALIZATION TOOLS FEATURES

Tool	Visualizations Types	Source Code Availability	Standalone/ Dependent	Node /Edge Filtering
NodeXL	Graphs, Plots	Yes(Only Basic Version)	Dependent	Yes
GEPHI	Graphs, Plots	Yes	Independent	Yes
PAJEK	Graphs	Yes	Independent	Yes
UCINet	Graphs, Plots	Yes	Independent	Yes
MuxViz	Graphs, Plots	Yes	Dependent	Yes

TABLE IV
FUNCTIONALITIES AND SUPPORT COMPARISON OF SNA VISUALIZATION TOOLS

	Node XL	GEPHI	PAJEK	|UCINet	MuxViz
Input/Output	MF	MF	MF	|MF	MF
Compute Centrality Metrics	MF	W	MF	|MF	MF
Visualization	MF	MF	W	|W	MF
Clustering	MF	W	MF	|MF	MF
Response Time	W	W	MF	|MF	MF

"Mature functionality" is represented by "MF" and "Not Available or Weak" functionality is represented by "W".

We have performed this comparison by using a limited number of SNA tools which are mostly used for network analysis. This research paper will help practitioners to select suitable tools for SNA, considering their expertise and requirements. In the future more tools can be analyzed to find out the best

TABLE V
ANALYSIS OF STRENGTH WEAKNESS OF SNA VISUALIZATION TOOLS

Tool	Strengths	Weakness
Node XL	Processing speed is much faster, also helps in data collection.	Supports the visualization of small and medium scale datasets and canŕ handle large network datasets. MAC users need excel to use it.
GEPHI	High quality visualizations. Does not require knowledge of programming languages and ability to handle large graphs	Take comparatively more time to perform specific task
PAJEK	Strong on analysis	Weak on visualization
UCINET	Strong on analytics with enormous centrality metrics	Weak on visualization, also require windows for installation
MUXVIZ	Strong analysis and strong visualization	Data pre-processing is weak

available SNA tool to overcome social network visualization and analysis challenges.

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