

Towards Context-Sensitive, Visual Social Network Analysis: Case Wiki Co-Creation

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Abstract. Along social media and Web 2.0, the amount of data sources potentially available for social network analysis (SNA) has snowballed. Recent development on information visualisation technologies contribute to the availability of tools enabling SNA data visualisation. Yet, applying the tools in different usage contexts is often difficult. The data formats vary and many of the tools are platform-specific. Potential SNA tools each have their strengths but often a single tool is not sufficient for covering all the aspects of analysis. We apply the means of component-based visualisation to streamline visual SNA. Further, through our approach, we seek to narrow the gap between everyday knowledge work and visual social network analysis of the data that knowledge workers process. We acknowledge the need of programming skills in introducing SNA to different usage contexts but yet we see that teams of analysts can apply the approach when conducting network analysis in varying contexts. The main contributions of this article are the following: a description and an analysis of a streamlined social analysis process and a brief review of the related applications and tools, based on the idea of conceptual integration of SNA analysis and augmented browsing.

Keywords: information visualisation, social network analysis, social media analytics, knowledge federation, context-sensitivity, co-creation

1 Introduction

The use of graphic images to represent social configurations within a given social system is important because “[i]t allows investigators to gain new insights into the patterning of social connections, and it helps investigators to communicate their results to others” [6]. The era of Web 2.0 and social media sets up a context that seems perfect for conducting social network analysis (SNA), a research field that has been developed since 1930’s to support the study of the structure of networks of social actors. In Web 2.0, a plethora of potentially inter-connectable Web services are used for digitally mediated social interaction. Digital medium implies that the interactions may be recorded and thus serve, in principle, as an excellent data source for social network analysis. Further, Web feeds and Web APIs are in the core of Web 2.0 paradigm, enabling, at best, the “serendipitous

reuse” [18] of the resources in different usage contexts and applications possibly unthinkable to the publisher of the data.

However, many problems still hinder the development of visual social network analysis applications sharing light to the connections between wiki co-creators, actors of social networking platform or online collaborators in general. Due to various reasons, not all the systems provide easy access to the data within the system. In addition, several non-interoperable *de facto* formats are used to represent the data both in the source systems and the analysis tools. Despite the recent rapid development of visual tools useful in social network analysis including Gephi [2], NodeXL [9], Commetrix, Tulip, Orange, SocialAction, Vizster, Network Workbench and others, there is no single tool - silver bullet - that can be used to collect, manage and visualise the SNA data - an object envisioned by Freeman [5].

This all implies that a lot of manual work is needed to conduct the analysis. Instead of being able to concentrate to the analysis process *per se*, the analyst is often forced to solve problems, *e.g.*, related to data formatting or even character encoding. Moving the data between the different tools used for analysis is often done with various copy-and-paste operations that, when the skills of the analyst allow, are partly automated with sketchy scripts and batch processes. Many useful visualisation tools, particularly the ones falling to the category of Web mashups, require the exposure of the SNA data that is often sensitive by nature. Further, the analysis process is usually separate from the everyday workflow of modern knowledge workers.

In this article, we explore the means to streamline the development of visual social network analysis applications that aggregate SNA data from wikis, social networking engines, Web APIs and other sources to form sets of linked SNA data (cf. (cf. linked data in the context of the Semantic Web [3]), instantly visualise the data with mashup-like solutions that are based on Web technologies or, alternatively, export the data for further analysis to existing high-end SNA tools. Further, means to attach the visualisations and analysis functionalities to the systems where the SNA data originates from are described in the context of our work, *i.e.*, the *context-sensitive* aspects of visual SNA. Importantly, we take into account the often sensitive nature of SNA data throughout the proposed solution. The main contributions of this article are the following: a description and an analysis of a streamlined social analysis process and a brief review of the related applications and tools, based on the idea of conceptual integration of SNA analysis and augmented browsing.

2 Background for Visual Social Network Analysis

Visual *social network analysis* (SNA) is a powerful method enabling the analyst to gain insight into the structure of social networks and to communicate the findings to others [5]. The analysis of overall network structure, the different characteristics of the network, the roles of the network actors and the nuances of their interaction are of interest in many fields of research. Networks may be

characterised as random, small world and scale free [1] and have actors acting as hubs or connectors [1] transferring information within the network (cf. [12]). Phenomena such as homophily, reciprocity and transitivity (cf. [8]) shape the networks as they evolve. Density and cohesion [9] are additional examples of core network metrics.

Precise SNA metrics can be calculated both for the network as a whole and for its actors. Nodal degree representing the number of connections of a node is the most simple metric. Main categories for actor SNA metrics are centrality (betweenness centrality, actor degree centrality) and prestige (actor degree prestige, actor proximity prestige, rank prestige) [20]. Also metrics such as page rank [16] are applicable in SNA. Some of the metrics apply only for one-mode networks. These metrics can be calculated with different tools from Pajek to MATLAB and R. In addition, libraries enabling the implementation of the metrics are available for modern programming languages such as Python.

From the beginning of SNA and its precursor *sociometry*, visualisation has been a key part of the analysis process, cf. Moreno [15]:

“We have first to visualize [...] A process of charting has been devised by the sociometrists, the sociogram, which is more than merely a method of presentation. It is first of all a method of exploration. It makes possible the exploration of sociometric facts. The proper placement of every individual and of all interrelations of individuals can be shown on a sociogram. It is at present the only available scheme which makes structural analysis of a community possible.”

Wasserman and Faust [20] define *sociogram* as “a picture in which people (or more generally, any social units) are represented as points in two-dimensional space, and relationships among pairs of people are represented by lines linking the corresponding points”. In addition to the sociogram data *per se*, *actor attribute* [20] variables representing the properties of social units are in the core of SNA data.

While sociograms are usually visualised as (socio)graphs composed of nodes representing the social actors, and edges representing the connections between them, expressive complementing visualisation approaches exist. One of the most interesting alternative approaches for sociogram visualisation is geospatial social network visualisation in which graph nodes are laid out according to their geographical locations instead of an abstract graph layout algorithm such as Kamada-Kawai [13] or Fruchterman-Reingold [7] commonly used in different SNA tools. Freeman ([5]) points out an early example of overlaying social network data on a geographical map presented by Leonard and Loomis as early as in 1941. Although modern tools including Google Maps and Google Earth introduce means to visualise data on a geographical map, there are no general means to visualise large geospatial (social) networks.

Although targeting primarily for supporting visual SNA, our approach also eases the use of quantitative SNA. Whereas visualisations serve in providing an overview into the phenomena under analysis, different SNA metrics are useful in gaining understanding on the nuances of the structure of a given social construction. We aim to provide help for users of both tools from NodeXL offering

“potentially low-barrier-to-entry framework for teaching and learning SNA” [4] and Vizster [10] to specialised tools targeted for SNA experts such as StOCNET. Visual analysis is usually based on graphs and quantitative analysis on matrices [20]. A *sociomatrix* represents the interconnections between actors in matrix format.

While visualisations of network structures may not be sufficient for full analysis, they provide an approachable abstraction that can be used as a steppingstone for more detailed analysis. Also, once more detailed network metrics are uncovered, the visualisations can be enriched with these metrics as visual properties. For instance, proportional sizes of nodes in visualisation may be derived from node’s degree or centrality.

When modelling a dataset representing a phenomena in target to a sociogram, there are several options to take. First, network can be either one-mode or two-mode. In one-mode networks all the nodes are of same type, wiki contributors, for example. Connections between the nodes are formed, *e.g.*, on basis of friendship or, in wiki context, co-authorship. In two-mode networks, there are two types of nodes, say, wiki contributors and wiki pages. A contributor node is connected to each wiki page node she has contributed. Means to visualise two-mode networks include hypergraphs and bipartite graphs [6] (cf. [11]).

Further, the connections between the actors can be either valued or dichotomous. With valued connections, the strength of a connection can be expressed. In either case, the connections may be directed or undirected. A graph with directed connections is called a *digraph*.

An important aspect in visual SNA is utilisation of temporal data. With temporal data, insight to the evolution of a social network may be gained. Academic conference data visualisation related to IRIS (Information Systems Research Seminar in Scandinavia) conference [12] presents a profound example case of temporal analysis. To visualise the evolution of the social network of authors and the research topics of IRIS on a period from 1978 to 2006, data representing articles and their authors was collected manually from web pages, conference proceeding CDs and other sources and inserted into a database and a dynamic network visualisation tool Commetrix was used to visualise the data. The outputs of the work include animations of the evolution of IRIS co-authorship and of the diffusion of terms in IRIS community. In addition to solving the issues related to heterogenous sources of data, manual work was needed to identify the authors whose names or origins were written in various ways. In particular, Scandinavian letters (åäö, etc.) caused problems for data collectors since author names including such letters are expressed in various ways.

We approach social network analysis as an act of data-driven information visualisation and aim to close the gap between a) the systems where the SNA data originates and b) the tools that are used to conduct the analysis, thus we refer to data-driven, context-sensitive visual social network analysis. Historian Alfred Crosby (1997) has highlighted the power of visualisation by stating that visualisation and measurement are the two main factors enabling the explosive development of modern science (cf. [5]). Generally, the underlying objective of

information visualisation is to serve as an amplifier of the cognition of a user through expressive views giving insight on a certain phenomena represented by the data [19]. Interactive information visualisation “allows the user to implicitly form mental models of the correlations and relationships in the data, through recognition of patterns, marking or focusing in on those patterns, forming mental hypotheses and testing them, and so on” [14].

3 Analysis Process

Next, we walk through our approach to data-driven, visual, context-sensitive social network analysis. Our work is based on Wille Visualisation System, a framework developed in Hypermedia Laboratory at Tampere University of Technology for building visualisation applications. The objective of the latest generation of the system, Wille2, is to function as a component-based data pre-processing and visualisation system for distributed and peer-to-peer (P2P) environments. Wille provides a light-weight core that can be extended by creating and integrating components. By scripting pipelines of component execution, interactive views to data can be created.

We have developed Wille SNA Toolkit, a set of Wille visualisation components and applications, that enables the development of information visualisation applications that implement the different steps of the analysis process. The toolkit comes with a set of reusable, extendable and tailorable components for SNA data processing, visualisation and export. Further, through the component-based architecture of Wille, Wille SNA Toolkit can be extended either by integrating existing SNA software to be used as Wille components or by developing entirely new components as needed.

3.1 Data-Driven

We see that the availability of the data is the main driver behind the renaissance of social network analysis. Whereas SNA data has traditionally been collected with different manual means, the methods can now be used to process data that originates e.g. from an ecosystem of data sources.

Some or all of the following steps are involved in data-driven SNA processes:

1. Selecting a set of resources to be used as the sample (source of SNA data). A set of wiki pages, for example.
2. Crawling the resources to collect the source data. This may require for example logging in to the source system and scraping the data from representations targeted only for humans to use.
3. Creating a logical sociogram on basis of the source data.
4. Calculating different SNA metrics for the different nodes in the sociogram and for the sociogram as a network *per se*.
5. Visualising the sociogram and the related data with different visual means.
6. Transforming the data into various formats supported by the different SNA tools and exporting data for further analysis.

In some cases, an existing Web API may be used to access the data. Quite often, the data-crawling process is very slow as are some of the SN analysis processes as well. Thus, a local cache may be used speed up the process. While Wille SNA Toolkit enables the development of simple crawling and caching functionalities, more advanced crawling tools such as Scrapy can be used to complement the ones implemented in Wille. Spreadsheets and other types of documents can also be used as a source of SNA data.

3.2 Context-Sensitive

In addition to providing support for SNA data processing, Wille SNA Toolkit introduces means to deliver SNA tools to different contexts in Web from where the SNA data is originated or the actors within the data are appearing. A Wille application Visualise collects context information from the pages that the analyst is browsing the Web and notifies, in the spirit of *augmented browsing*, when SNA visualisations and usable SNA data is available. This enables the development of applications providing a “sneak peek” to the social whereabouts of a given document, user profile or other Web context. See Salonen and Huhtamäki [17] for a detailed description of the means to automatically collect context data when launching visualisations and to inject the visualisation tools to the source applications.

3.3 Visual

The main social network visualisation tool included in Wille SNA Toolkit enabling context-sensitive launch is Vizster [10], a tool for interaction-intensive visualisation of (online social) networks. Vizster was originally developed to support ethnographic research on the use of user profiles in social media. Due to its open licencing policy, support for importing SNA data in a dialect of GraphML, capability in managing thousands of nodes, Vizster is still a viable tool for visualising social networks in Web context. Further, we look forward to the progress of JavaScript InfoVis Toolkit and other Javascript-based graph visualisation tools that provide even more straightforward analysis process than using Vizster.

In addition to enabling the immediate visualisation of different social networks in the context in which the data originates from, SNA data can be exported in different formats to support the usage of different state-of-the-art SN analysis and visualisation tools. As a legacy format Pajek is still very popular and supported by tools including Orange and others, for example, Wille SNA Toolkit provides a component for serialising sociograms in Pajek format. In addition, data can be exported in GraphML and GEXF among other formats. This enables the use of Gephi, NodeXL, and other modern visual network analysis tools. New export formatters can be created as needed.

From information visualisation and contemporary mashup development point of view, graphs are just one of several options to create visual images of information. Wille SNA Toolkit can be used to serve data for visualisations such as heat

maps animated graphs and timelines to regular office graphics. Recent development on geospatial visualisation, i.e. visualising SNA data on a geographical map with tools including Google maps, Google Earth and Tulip.

3.4 Representing SNA Data

A lot of ground can be covered by two main data-representation natives, 1) social network (with user profile data) and 2) timeline representing a stream of actions in the SNA data source system. A sociogram including the attribute data of social network actors and the objects of their action is used as the core data model in Wille SNA Toolkit. To support temporal analysis, timestamps are used in data representing actions. When geospatial views are created, location data is needed. Additional data types may be introduced to the processing pipelines as needed.

Currently we are working with representation formats based on XML and JSON. As it often is desirable to aggregate social network data from several data sources and data formats, the idea of using RDF is very appealing. However, in practice, it is often sufficient to create individual data transformation components that use very simple data formats based on XML and JSON.

Some common formats for SNA data representation have also began to emerge. Pajek NET format, a legacy from Pajek tool, is a simple plain text format that is often supported by SNA tools.

4 Case knowledgefederation.org

A note to the reader: This section is under development; please note the sections marked with the TODO prefix. We are particularly interested in receiving comments and feedback on how to approach the case in a useful manner.

TODO: A diagram of the components and steps needed in the process. Discussion on which of the steps are wiki-specific, wiki-type-specific, phenomena-specific, etc.

To make the discussion concrete, we present an example on visual analysis of social structures within knowledgefederation.org. The current version of the federation is an instance of MediaWiki with the Semantic MediaWiki (SMW) extension enabling the use of added semantics (metadata) in wiki content. TODO: further introduction.

Due to the current size of the wiki, we are able to use the whole wiki content as a source for co-creation analysis. Component `wiki.mediawiki.pagehistory.collector` is used to collect the contribution history of the wiki pages. The component first uses `wiki.mediawiki.search` to collect a list of wiki pages, iterates through the list and collects the contribution (editing) history of each page using the `wiki.mediawiki.pagehistory` component that parses the HTML representation of each history page. In a MediaWiki, a list of pages is available on page `Special:AllPages` that Wille SNA Toolkit component `wiki.mediawiki.search`

uses to scrape the page list from. TODO: An example of collected contribution data is presented in Listing X.

TODO: An example of history aggregate. Importantly, SNA data is included in the sociogram.

Once an aggregate of all the contributions is ready, a logical sociogram is created. In Wille SNA Toolkit, a dedicated XML format is used to represent sociogram data. The format serves as means to harmonise different sources of SNA data: adapters format data from different sources into the sociogram format.

We have chosen bipartite two-mode networks as the default approach to represent the wiki contributions sociogram: wiki contributors and wiki pages are both represented as nodes and a contributor is connected to a pages if she has edited it at least once. Component `wiki.pagehistory2graph` implements this step. A component for creating one-mode representations of the contribution history could, of course, be implemented as well as needed.

TODO: Figure that shows an example of the social whereabouts of a wiki page (created with Gephi).

On basis of the abstract sociogram, different representations of the data can be created. Existing components such as `sna.graph2graphml`, `sna.graph2gefx`, `sna.graph2pajek`, and `sna.graph2evesim` enable analysis done with Vizster, Gephi, NodeXL, Pajek, EvESim and other appropriate tools. Moreover, data can be refined, e.g. the nodes can be geocoded with `sna.graph.geocode` if textual location data is available in the sources system. In `knowledgefedation.org`, however, this is not yet possible because there is no means to explicitly define user profiles.

A Wille application `sna-mediawiki` ties together the different components described above. For now, the location of the wiki system has to be configured manually to the application.

To enable context-specific analysis of `knowledgefedation.org`, Wille Visualise application is used to sense the location of the analyser in the wiki and to enable the launch of different visualisations and export utilities related to the context. TODO: is there room to explain how this is done? Vizster is an example of a tool that can be launched on a specific context, i.e., a specific wiki page open.

4.1 Discussion

Selecting the dataset to be used in analysis can be done in various ways in the context of wiki systems. In a wiki system targeted to a specific use such as `knowledgefedation.org`, the whole wiki can be crawled in a timely manner. Starting from recent changes is a valid approach when analysing wiki development in a real-time manner. Wiki categories may as well be used to define the dataset. The context-sensitive approach can be developed further: In a large wiki system, the crawling process can be started from a given context, for example. The content of a given page can be analysed for additional context information e.g. related people, locations or concepts and the possibility to view respective visualisations

can be offered to the user to enable having a “sneak peek” to the (social) whereabouts of a given page. In MediaWiki, for example, contributions of a given user can be listed, thus cliques of wiki editors can be traced also in large wikis.

As the size of the dataset (wiki, in this case) increases, the use of XML for representing SNA data challenges the performance of the system. Using lightweight databases such as Sqlite provide a more efficient option.

The absence of semantic HTML markup makes the parsing/scraping process very fragile. In some cases, scraping rules are based on stylesheet rules and thus break when the visual appearance of the wiki system is altered. A Web API would provide an even more stable solution for data access. The use of HTML Tidy (Wille component `tidy`) enables us to create a valid HTML representation of a Web page, thus we are able to process pages as XML documents, e.g. with XPath. More expressive data-scraping tools such as Scrapy may be applied as needed.

While e.g. the amount of editing times or even the change in the size of the page can be used to value the wiki contributor sociogram, developing a justified measure to the strength of the connection between a contributor and a wiki page requires always interpretation.

In knowledgefederation.org, wiki is used in a different manner than a more regular wiki system. Instead of editing the pages co-operatively, the authors are encouraged to use the Discussion pages to present their input. Due to this, the contributions in the Discussion pages may be included in the contributions of the actual page. This is, again, a matter of interpretation.

5 Conclusions

While Wille SNA Toolkit implements the core components of the SNA toolchain, it is not meant to replace the existing SNA tools. Instead, more expressive tools for data crawling, matrix algebra, SNA metrics calculations and other steps of the SNA-related can be used as components within the toolkit. Further, toolkit can be used to preprocess data for tools such as NodeXL, Gephi, and others providing more expressive functionalities to support visual social network analysis.

One of the main advantages of Wille SNA Toolkit is the fact that in its default configuration it is run on local machine. This gives the analyst the possibility to use also sensitive data as a source of analysis data. The analyst can, for example, manually log in to a source data system to collect the data to be processed with Wille or, when possible, use Wille to log into the source system to crawl the data automatically.

Many of the SNA data processing steps can be generalised in a way that reusable components can be created. The best possible modelling and interpretation solutions are, however, often context-specific and thus have to be implemented case by case. Keeping the number of data formats in use to a minimum offers means to harmonise different sources of data.

We acknowledge that developing new applications with the presented approach insists the availability of programming skills in the development team.

The benefits of the approach include means to easily reuse existing SNA components, add new data sources, create new processing components, and enable the use of new visualisation tools that are either launched directly from the browser or, alternatively, enable exporting SNA data for further analysis. This all promotes the incremental development of new SNA processing toolchains streamlining visual SNA.

Future work includes refining the strategies for crawling and processing to enable both sneak peeking the social structures around a given context as well as seeing the big picture of a social phenomena in a timely manner. More support for working with constantly evolving data sources in real-time are needed. We are also going to validate our approach through different case studies where visual, data-driven, context-sensitive social network analysis is applied and refined.

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