Context-Driven Social Network Visualisation: Case Wiki Co-Creation

Jukka Huhtamäki, Jaakko Salonen, Jarno Marttila, and Ossi Nykänen

Hypermedia Laboratory at Tampere University of Technology,
Korkeakoulunkatu 1, FI-33720 Tampere, Finland
{jukka.huhtamaki,jaakko.salonen,jarno.marttila,ossi.nykanen}@tut.fi
http://www.tut.fi/hypermedia

Abstract. Along social media and Web 2.0, the amount of data sources potentially available for social network visualisation has snowballed. Recent development on information visualisation technologies contribute to the availability of tools enabling visualisation of social media data. Yet, applying the tools in different usage contexts is often difficult. The data formats vary and many of the tools are platform-specific. Potential tools each have their strengths but often a single tool is not sufficient for covering all the aspects of analysis. In this paper, we describe the means of applying component-based information visualisation to streamline social network visualisation. 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 the visualisations 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 network visual analysis process and a brief review of the related applications and tools, based on the idea of conceptual integration of visual social network analysis and augmented browsing.

Keywords: information visualisation, social network 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" [7]. With support of the visualisations of the emerging social connections and their change over time, users are at best able to uncover "rabbit holes" "leading into new and unexpected information landscapes, to both discover unknown members with complementing interests and find unknown interests of already known members, and, in all, to become a working part of a community" [12].

The era of Web 2.0 and social media sets up a context that seems perfect for conducting social network analysis (SNA), a research method 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 the Web 2.0 paradigm, enabling, at best, the "serendipitous reuse" [21] 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 [10], Commetrix, Tulip, Orange, SocialAction, Vizster, Network Workbench and others, there is no single tool, no silver bullet, that can be used to collect, manage and visualise the SNA data – an object envisioned by Freeman [6].

This all implies that a lot of manual work is needed to create views for insights on different social structures and to conduct networks analysis. Instead of being able to concentrate to the visualisation and process *per se*, the investigator is often forced to solve problems, for example, 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 investigator allow, are partly automated with sketchy scripts and batch processes. Many useful visualisation tools, particularly the ones falling into the category of Web mashups, require the exposure of the SNA data that is often sensitive by nature. Further, the investigation process is usually separate from the everyday workflow of knowledge workers.

In this article, we explore the means to streamline the development of social network visualisation applications that aggregate SNA data from wikis, social networking platforms, Web APIs and other sources to form sets of linked SNA data (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 to existing high-end SNA tools for further investigation. Further, means to attach the visualisations and analysis functionalities to the systems where the SNA data originates from, i.e. the *context-sensitive* aspects of visual SNA, are described in the context of our work. 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 Social Network Visualisation

Visual *social network analysis* (SNA) is a powerful method enabling the analyst to gain insight on the structure of social networks and to communicate the findings to others [7]. The visualisation of the 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. [14]). Phenomena such as homophily, reciprocity and transitivity (cf. [9]) shape the networks as they evolve. Density and cohesion [10] are additional examples of core network metrics.

Precise SNA metrics can be calculated both for the network as a whole and for its individual actors. Node 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) [23]. Also more advanced metrics such as page rank [19] and HITS [16] are applicable in SNA. Some of the metrics apply only for one-mode networks while others are applicable also for networks of two or more modes. The metrics can be calculated with different tools from Pajek to MATLAB and R. In addition, software libraries enabling the utilisation of the metrics, e.g., in algorithm development 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 [18]:

"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 [23] 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* [23] 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 [15] or Fruchterman-Reingold [8] commonly in use in different SNA tools. Freeman ([6]) 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.

Even though our approach is primarily targeted for supporting visual SNA, it also eases the use of (number-based) quantitative SNA. Whereas visualisations serve in providing an overview of a 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 [11] to specialised tools targeted for SNA experts such as StOCNET. Visual analysis is usually based on graphs and quantitative analysis on matrices [23]; a *sociomatrix* represents the interconnections between actors in matrix format.

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

When modelling a dataset representing a phenomena under investigation 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 [7] (cf. [13]).

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 social network visualisation is the 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 [14] 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 visual social network analysis as an act of data-driven information visualisation and aim to close the gap between a) the systems where the visualisation 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. 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 [22]. Historian Alfred Crosby [5] 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. [6]). 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" [17].

3 Analysis Process

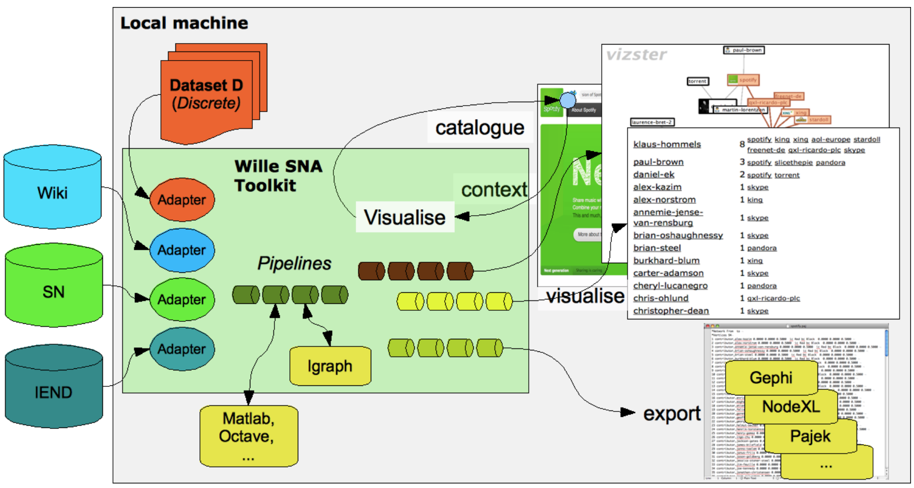

Fig. 1. Data-driven visual SNA with Ville

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 for building visualisation applications developed in the Hypermedia Laboratory at Tampere University of Technology. The objective of the latest generation of the system, Wille2, is to function as a component-based data preprocessing 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 a given analysis process. The toolkit comes with a set of reusable, extendable and tailorable components for SNA data processing, visualisation, and export.

The basic principles of Wille SNA Toolkit are presented in Figure 1: Adapters feeding the data into the pipelines can be created for different data sources. The pipeline components may be created from scratch or they may act as wrappers for existing software. In particular, Wille SNA Toolkit can be extended either by integrating existing SNA software to be used as Wille components. The data can be fed to existing SNA tools for analysis and, importantly, Web-based visualisation widgets can be served to the user in a context-sensitive manner as will be described in Chapter 3.2

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 is in use to access the data. Quite often, the data-crawling process is very slow as are some of the SN analysis processes, too. 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 visualisation data processing, Wille SNA Toolkit introduces means to deliver visualisation tools to different contexts in Web from where the data is originated or the actors within the data are appearing. A Wille application "Visualise" collects context information from the pages that the user, an analyst, for example, is browsing on the Web and notifies, in the spirit of *augmented browsing*, when either visualisations of possible interest or usable visualisation data are 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 [20] for a detailed description of the means to automatically collect context data when launching visualisations and to inject the visualisation tools to source applications.

3.3 Visual

The main social network visualisation tool included in Wille SNA Toolkit enabling context-sensitive launch is Vizster [11], 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 visualisation data in a dialect of GraphML, capability of 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, social network data can be exported in different formats to support the usage of different state-of-the-art 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 may 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 regural office graphics. Recent development on geospatial visualisation, i.e. visualising SNA data on a geographical map with tools including Google Maps, Google Earth, Tulip, and R adds to the potential means to visualise SNA data.

3.4 Representing SNA Data

A lot of ground can be covered with 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 within data representing actions. When geospatial views are created, location data is required. 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. GEXF (Graph Exchange XML Format) is a format more easily extendable than non-structured Pajek NET format, a simple plain text legacy format still often supported by SNA tools. We are looking forward to putting the open source graph database Neo4j into use in Wille SNA Toolkit. We see the graph database approach as a major step towards more expressive means in managing SNA data.

4 Case knowledgefederation.org

To make the discussion of visual social networks analysis more concrete during the Knowledge Federation 2010: "Self-Organizing Collective Mind" workshop at Dubrovnik in October 2010, the authors of the paper developed a prototype for collecting and visualising data on the contributions made to knowledgefederation.org wiki. The leading idea in visualising the social structures between the wiki co-creators is to help in seeing how the people are interconnected through their actions.

During the workshop, however, it became clear that the wiki is not going to be the primary tool to be used for federating the workshop content or for collaboration after the conference. Thus, we chose not to concentrate on the results of the analysis of the co-creation within the wiki but rather describe the approach to take in order to follow the process of context-driven social network visualisation in a wiki context.

4.1 Design and implementation

In Figure 2, we list the core components needed to collect contribution data from the Knowledge Federation wiki. 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. The Knowledge Federation wiki is an instance of MediaWiki with the Semantic MediaWiki

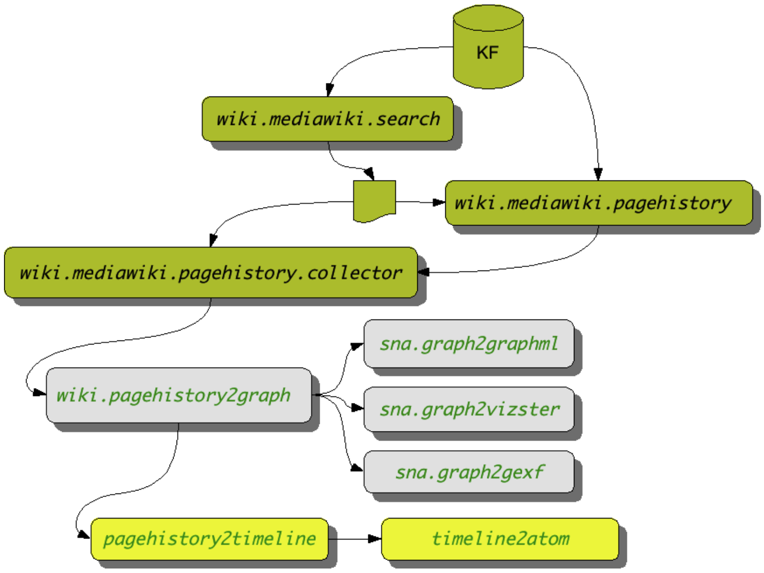

Fig. 2. Core components for collecting and processing wiki contributor data

(SMW) extension enabling the use of added semantics (metadata) in wiki content. 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.

Once an aggregate of all the contributions is ready, a logical sociogram may be 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 chose 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 he or 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.

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, Geph, 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 knowledgefededation.org, however, this is not yet possible because there is no means to explicitly define user profiles.

The main benefit of the component-based approach is the potential reuse of the components. The `wiki.mediawiki.pagehistory.collector` component and the two components it uses are specific to MediaWiki but `wiki.pagehistory2graph` is, in principle, general to any platform enabling collaboration. Similarly, additional timeline-related components could be implemented for use in various contexts.

For the prototype implementation, a Wille application `sna-mediawiki` was implemented to tie together the different components described above. For now, the location of the wiki system has to be configured manually to the application but a more general approach could also be taken. To enable context-specific analysis of knowledgefededation.org, Wille Visualise application is used in the prototype for sensing the location of the user in the wiki and to enable the launch of different visualisations and export utilities related to the context. For example, the user can be provided with a view showing the contributors of a given wikipage and the other pages that they have contributed to.

4.2 Discussion

In the context of wiki systems, selecting the dataset to be used in an investigation can be done in various ways. In a wiki system targeted to a specific use such as the Knowledge Federation wiki, the whole wiki can be crawled in a timely manner whereas Wikipedia, for example, would require a completely different crawling approach. (In fact, Wikipedia does not allow the use of crawlers at all. Instead, analysts may use the public dumps of Wikipedia content.)

In a smaller wiki, starting from recent changes is a viable approach when analysing wiki development in a real-time manner. Wiki categories may as well be used to specify a dataset for analysis. The context-sensitive approach can be developed even 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 provided to the user to enable a "sneak peek" to the (social) whereabout 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 or MongoDB provide a more efficient alternative for managing the data and for graph-like data, Neo4j and other graph databases are a viable option.

The absence of semantic HTML markup makes the 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 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, eventually a matter of interpretation.

5 Conclusions

While Wille SNA Toolkit implements the core components of the social network visualisation and visual analysis toolchain, it is not meant to replace the existing social network analysis and visualisation 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, the 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 a local machine. This gives the investigator the possibility to use also sensitive data as a source of analysis data. The investigator can, for example, manually log in to a system to collect the source data to be processed with Wille or, when technically possible, use Wille to log into the source system to crawl the data automatically.

Many of the social network data processing steps can be generalised in a way that reusable components may be developed. The best possible modelling and interpretation solutions are, however, often context-specific and thus have to be implemented or at least tailored 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 software 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 social network data for further analysis. This all promotes the incremental development of new social network data processing toolchains for streamlining social network visualisation.

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. Finally, we plan to validate our approach through different case studies where visual, data-driven, context-sensitive social network analysis is applied and refined.

Acknowledgments. Our work is partly funded by OPAALS (IST-034824), a European Network of Excellent project coordinated by London School of Economics (LSE). Martha G. Russell, Neil Rubens, and Kaisa Still of Innovation Ecosystems Network have played a significant role in providing requirements for our work. Finally, we express our deep appreciation to the members of the Knowledge Federation community for their enthusiasm, feedback and support.

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