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Orchestrating collaboration, Using visual collaboration suggestion for steering of research clusters

André Calero Valdez[a], Denis Özdemir[b], Mohammed Amin Yazdi[c], Anne Kathrin Schaar[a], Martina Ziefle[a,*]

[a]Human-Computer Interaction Center, RWTH Aachen University, Campus Boulevard 57, 52074 Aachen, Germany
[b]WZL - Laboratory for Machine Tools and Production Engineering, RWTH Aachen University, Steinbachstr. 20, 52075 Aachen Germany
[c]RWTH Aachen University, Aachen Germany

Abstract

Interdisciplinary research and large research organizations such as research clusters represent an approach in tackling large complex problems that can not be satisfyingly be answered by individual researchers or disciplines. In order to support the collaboration in these organizations, measures must be taken to foster the flow of information between researchers. As one measure we present a collaboration support tool that helps researchers identify possible collaborators and understand the overall structure of the (often loosely coupled) research organization. Using a participatory design process we first generated requirements for such a solution and integrated them in a design study prototype. This prototype was then tested in a user study with researchers from a research cluster. As key benefits we identified the identification of new knowledge and the confirmation of existing knowledge, along with assistance in problem solving from our visualization. Analysis of results is done qualitatively and quantitatively. We evaluated the tool positively using the system usability scale (84.5) and the net-promoter score (80%) . It was furthermore evaluated by the cluster COO, who frames the use of the tool from a managerial point of view and how it can be used in steering processes to ensure success of the overall venture.

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* Corresponding author.
E-mail address: calero-valdez@comm.rwth-aachen.de

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1. Introduction

Given the complexity of current mega challenges, innovations in technology and products are crucial in dealing with these vital problems. While innovation in former days may have been mainly single efforts of researchers and inventors, today innovation often stems from collaboration of different disciplines, methods and approaches, with both existing and novel partners. Often these new partners can already be part of ones organization but the search, and identification of suitable partners across (internationally acting) organizations can be challenging. Finding suitable collaborators in large organizations is often hindered by organizational structures. Hidden potential can exist, because active management of tacit knowledge of who does what is often not conducted [1].

In the RWTH Aachen University excellence cluster “Integrative Production Technology for High-Wage Countries” [2], researchers from 40 institutes collaborate on extending both practice and theory of production by addressing the polylemma of production.

In order to ensure collaboration in the cluster, so called cross-sectional processes are established. These research groups address sustainability from a theory, human resources and technology transfer point of view. As one measure from the CSPs [3] a social portal is developed to integrate communication in a single source of truth. In this portal a tool for collaboration support is integrated [4]. This tool provides the researcher with an individualized visualization to support finding collaborators that are both relevant and promise fruitful collaboration [5].

2. Related work

The following sections elaborate on related work regarding the intricacies of successful interdisciplinary collaboration, the CoE-Portal, bibliometric visualizations, and general visualization approaches that are relevant to our prototype. Regarding the latter, we limit ourselves to visualizations that are immediately relevant to our approach, as reviews on visualization techniques are abundant.

An increasing amount of research funding goes to interdisciplinary projects [6]. Interdisciplinary solutions may be applicable to problems that singular disciplines or methods are unable to solve [7]. Making interdisciplinary collaboration work though, is challenging. Differences in disciplinary culture, publication behavior, community size, and terminology can cause problems in interdisciplinary teams that are rare in disciplinary settings. Successful interdisciplinary collaboration comes from a high quality in interpersonal relationships [8]. It requires good leadership, trust, receptiveness and a willingness to learn from all partaking researchers.

In a research cluster with over 180 researchers finding collaborators from other disciplines is additionally hard, as opportunities for collaboration are in theory highly available. Yet, individual preferences in how to organize work do influence whether working together can be successful. Suitable collaborators are therefore often found among the previous collaborators of existing collaborators. My colleagues’ appreciated colleagues are also appreciated colleagues of mine. This transitivity of compatibility can be expressed by the saying “birds of a feather flock together”. Research also found that not only similarity but also complementarity is helpful in collaboration [9].

To support collaboration in the cluster of excellence the so-called Scientific Collaboration Portal (SCP) was devised [10]. It is a social networking portal that contains research profiles, publication lists and additional information or tools designed to help researchers in the cluster. It represents a closed community ensuring private sharing of data and maintaining current research efforts, as databases often lack sufficient coverage of publications in the engineering sciences. The portal was designed with using a balanced-score card approach in order to maximize user acceptance. It mostly serves as a centralized source of truth for members of the cluster. Additionally applications are available to directly address complications in interdisciplinary collaboration (e.g. terminology, project planning, etc.). One application addresses finding collaborators within the research cluster. This article investigates the design of this application and its additional features.

2.1. Bibliometric visualizations

In order to understand research efforts bibliometric analyses are often conducted. The objects of these are publications that ideally contain both the originator of an idea and the idea itself. Therefore, bibliometric analysis might seem prefect for analyses to understand collaboration. Often bibliometric analyses investigate how publications are being cited. Citations are considered to be a measure of reputation (albeit a questionable one). In interdisciplinary settings this can lead to several problems. Citation analysis performed with a smattering of knowledge can cause inadequate representations of individual research efforts, as they are influenced by factors not immediately present for the analyst. Factors like community size, average reference count, citation half-life, and so on influence the citation count and can be diverse even within a seemingly related field of research.

For these reasons we approach bibliometric analysis from purely collaboration-centric approach. The aim of our application is to visualize collaboration within the cluster and to identify possible collaborators. Citation analysis is not used in our case. We use graph-based visualizations that show who has worked with whom and allow for social network analysis methods to be applied. A similar approach has been shown to analyze the degree of interdisciplinarity in a research cluster [4].

2.2. Visualization of complex data

In order to find an ideal visualization of collaboration data, we look at visualizations used to analyze large amounts of interconnected data. A plethora of different approaches is available, but only some match the data we want to visualize. Fekete and Plaisant [11] introduced the Million-item visualization. It can handle a large number of data nodes and provides a broad overview of the data. It allows nesting of data and zooming as a drill-down method to get detailed information. Its structure also maps larger data, to larger visual portions directly communicating visual density (see Fig. 1a).

Shneiderman [12] introduced aggregated networks. These can also be used to visualize communality in large amounts of connected data. Community detection algorithms are used to visualize higher-level connections. Also drill-down methods reveal detailed information and allow for further investigation (see Fig. 1b).

Holten [13] uses so-called hierarchical edge bundles to visualize higher order connectedness of data. Adjacency relations are used as a technique for visualization of compound graphs. This reduces visual clutter by bundling edges that run along the same paths. He uses balloon-based layouts so that higher-level connections are presented as bundles between balloons. This communicates both high and low-level connections, without a change in visualization style. Communities also become directly apparent (see Fig. 1c).

Vizster [14] is a visualization of a social community, which provides additional profile information next to the graph-based visualization. Members are shown as their profile picture and relationships are shown as lines connecting them. By switching to X-Ray mode, additional dimensions can be blended in (see Fig. 1d).

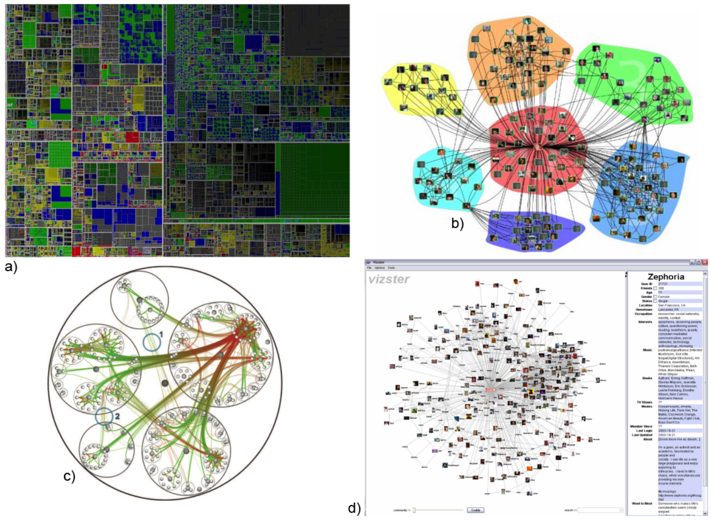

Fig. 1. Example visualizations taken from the respective publications [11-14].

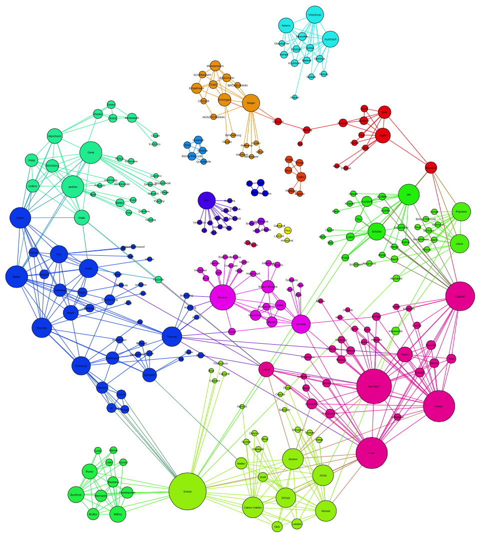

Fig. 2. The layout of authors according to co-authorships and thus collaboration (without PI). A community detection algorithm determines color.

3. Method

In this paper we present qualitative research investigating the collaboration suggestion tool as a means of steering a research cluster. We evaluated the tool using a task-based analysis in regard to suitability for finding possible collaborators from both a researchers point of view and from the perspective of the COO of the research cluster.

In total 20 participants were involved in a participatory design study. Three HCI experts and two members of the steering committee evaluated the final prototype. The COO of our research cluster integrates the findings from a managerial point of view. Furthermore we elaborate on the applicability of the approach in other large-scale research organizations. Changes were added to the prototype according to Slingsby & Dykes [15] to have rapid iterations and improvements during the process to integrate the knowledge of data experts and users lead to an optimal solution.

3.1. Creating the visualization

The purpose of our visualization was to be determined by a qualitative requirements engineering process. For this purpose we interviewed researchers from the cluster, asking them about how they approach forming new collaborations. These requirements (see Section 4) were iteratively included in the visualization that changed over time in a total of ten iterations. Between the iterations we assessed the prototype qualitatively in user tests counting positive and negative remarks on the prototype.

The prototype was based on publication data from the years 2012 to 2014. Authors were suggested as possible co-authors when they shared keywords and common co-authors. For the purpose of this prototype, keywords were extracted from titles (noun-phrase detection) and enriched by profile information from the CoE-Portal (Institute and profile picture, meta-data). Furthermore we removed PIs from the visualization, as this was suggested early during the participatory design process to reduce clutter.

The final view contained three view areas. The cluster view presented an overview of the whole cluster. Authors were represented as bubbles and recommendation was done by highlighting of bubbles, when hovering over individual authors. The orbit view presents a drill-down view, activated after clicking on a single author, presenting only the recommendations for that particular author, including the degree of recommendation. The profile section contains profile information on the selected author (see Figure 3[†]). Authors are grouped according to their institute to facilitate understanding of the organizational structure of the cluster. This contradicts the obvious collaboration-based grouping (see Figure 2), which shows who collaborates with whom, but distorts hierarchical and organizational information, which are both relevant for assessing possible collaboration.

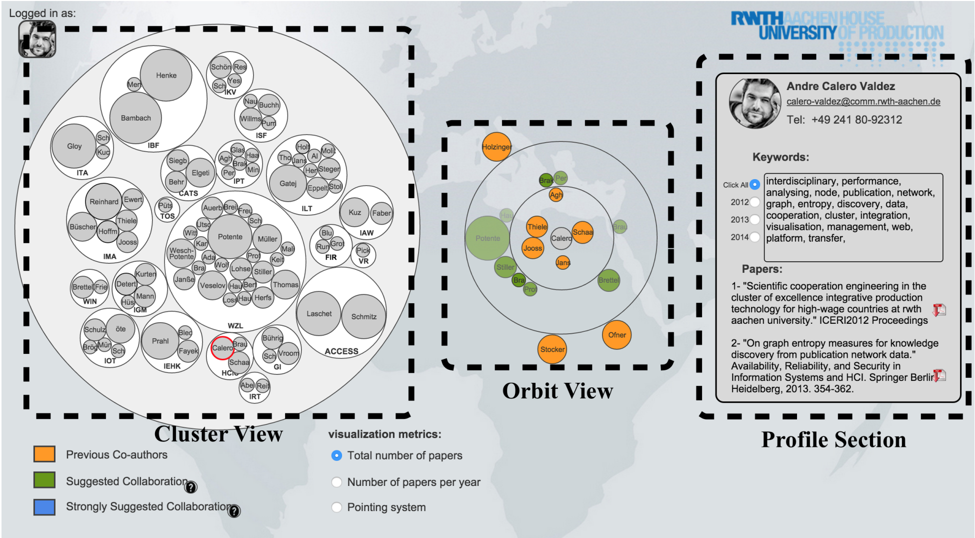

Fig. 3. The final prototype and the three regions of the display.

3.2. Evaluating the visualization

The visualization was evaluated in a participatory design study [16]. We improved the visualization over ten iterations and refined the tool towards the last iteration for final evaluation. The initial prototype was derived from paper-prototyping and selected among a choice of 15 paper prototypes.

During the design phase requirements were collected by interviewing future users about their goals and how a visualization could help them regarding this goal. Furthermore, we wanted to find out what an adequate design for such a tool would look like and whether a tool could assist in further ways than just recommend possible collaborators.

Finally we wanted to know whether such a tool could be used from a steering point of view enabling the COO of the cluster to get better insights into what is happening in the cluster. To ensure reproducibility we videotaped the user studies, performed a transcription of all verbal utterances and analyzed them according to Mayring [17]. Additionally we performed a survey analysis included both System-Usability-Scale (SUS) [18] and Net-Promoter-Score (NPS) [19] to measure usability and possible loyalty to our tool. We controlled for experience by measuring previous publication output.

[†] A short video demonstration of an earlier prototype can be found at: https://vimeo.com/120483587

4. Results

We conducted a qualitative evaluation as a means to establish requirements during the participatory design phase as well as a means to evaluate the final prototype with our users. The quantitative evaluation of the SUS and NPS was performed at the end of the investigation to assess overall usability. The following sections first show the results of the requirements analysis and evaluation of the prototype (see section 4.1). Then the quantitative evaluation is presented (see section 4.2), before concluding remarks on the overall process are given from our cluster COO (see section 5). The latter includes a broader picture of the development from a managerial point of view including improvements caused by the visualization not directly measurable from an inside perspective. The COO has insight into the cluster and its reporting measures and can identify changes, thereby contrasting reporting before and after the introduction of the tool.

4.1. Qualitative evaluation

During the first iterations requirements were continuously assessed in a participatory design procedure. Six categories of goals were identified from the transcriptions and were included in the design. The first category refers to "forming a mental model". Participants wanted to understand how the cluster is structured and organized (e.g. "*There are meetings in this regard but I can only truly imagine my own group of researchers.*"). The overview of the visualization addresses this requirement. Furthermore, researchers wanted to present their own research interests and communicate them to the other researchers (e.g. "*I was talking to some of my friends in cluster and then they came to know my topic.*"), as sometimes awareness of topics was not present. This requirement is address by the profile section of the tool. Researchers also argued that possible collaborators could be identified by common keywords in their publications (e.g. "*I believe other experts in my field also use similar terms and keywords.*"). This hypothesized relationship lead to the development of the recommendation algorithm. A core need communicated by most participants was the need to find collaborators in related research fields, thus confirming the overall aim of the tool (e.g. "*I don't have access to expert or I don't know anybody with experience in my topic*."). This need is moderated by motivation though. Almost equally important is a willingness to collaborate and a high level of motivation of possible collaborators (e.g. "*Everyone wants to do so, but not every one comes to the table*."). To address this requirement publication count was visualized as bubble size in all bubble-based graphs of the visualization. Lastly researchers wanted the visualization to account for changes in research interest (e.g. "*Someone asked me to be his co-author for a topic, but I was working on that topic many years ago*."). For this reason a year-based filtering was added to the visualization tool.

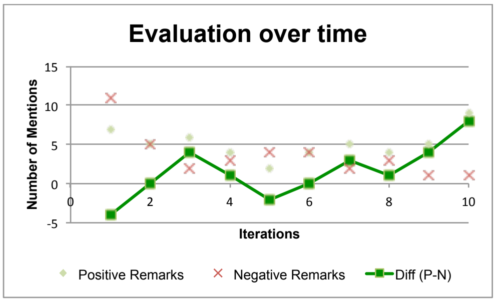

Fig. 4. Evaluation of the remarks on the prototype over time.

The evaluation of the prototype was also done qualitatively. The count of positive and negative remarks regarding single features of the visualization was tracked over time (see Fig. 4). Three categories behind the positive remarks were identified. Negative remarks were mostly suggestions for improvements, which were integrated in the following iteration. The most frequently mentioned positive remarks dealt with the *discovery of new knowledge*. Participants stated that the visualization tool actually gave them new knowledge over either the cluster or even familiar colleagues. The second category of positive remarks contains mentions that deal with *knowledge confirmation*. Researchers found that what they knew about colleagues was adequately represented by the visualization and not being distorted. The last identified benefit of the tool was *problem solving*. Researchers found that the visualization would actually help them in solving current problems by identifying experts in their immediate local network, able to help them on their problems.

Overall the amount of positive mentions fluctuated, as did the negative remarks. In the last iteration the number of positive mentions was ten against only one negative remark (see Fig. 4).

4.2. Quantitative evaluation

The final prototype was evaluated using SUS and NPS. The prototype was evaluated using the System-Usability-Scale with a score of 84.5 indicating good usability. The Net-Promoter-Score was 80% indicating that users would use the system again in the future.

5. Discussion and reflections on the visualization from the cluster COO

Quality and quantity of publications are important Key Performance Indicators for scientific success of research clusters such as within the German Excellence Initiative. However, measuring and controlling publication performance is not a trivial task when around 30 institutions and 100 scientists are involved in a common project. Major problems are that scientists do not report their publications to the management or that the reported data is incomplete or inconsistent. This is not only a problem for the management in terms of controlling, but also for each researcher since his work is not visible to others and thus current and helpful information cannot be found. Since the start of our cluster in 2006 different processes and tools for publication management have been implemented and tested. In the start phase an Excel table was introduced, which was edited by all researchers. This simple solution, however, resulted in massive inconsistencies. Therefore the ownership of the list was given to the cluster management and each researcher was requested to mail his updates to the management.

This approach has lead to better consistency, but still many publications were not recorded. To overcome these problems a new concept has been elaborated in a joint effort of cluster management, scientific cooperation team and university library. The concept is based on three main assumptions:

- Scientists do not want to handle several databases or lists for publication management, e.g. the cluster management list, the university library database and the local list of each institute.
- Measuring publication quantity and impact of each sub-project and making the measuring results accessible to each member of the cluster increases the motivation for reporting publications to the management.
- Visualization tools that bring an added value to reported data further increase the motivation of reporting.

The new publication management system therefore builds on the database of the university library. Each publication that can be contributed to the cluster is labeled correspondingly. The database is subsequently used to measure quantity and impact. The numbers are reported to the steering committee of the cluster on a regular basis. The data is a prerequisite for the visualization. With these visualizations not only the cluster management but each member of the cluster can profit from the good quality of publication metadata. Especially new employees have a kind of “map” of topics, publications, and employees that facilitates getting access to the knowledge of “who does what in the cluster”, leading to more scientific collaboration and cross-disciplinary publications. So far the visualization has only been applied to our own cluster, but further benefits are expected when it is extended to the whole university and to other research clusters. Until now publications that involve researchers from different clusters or institutes that are not incorporated in the same research project are seldom. Even if the people are physically located near to each other. The visualization tool will therefore help to identify new areas of common interest leading to new creative research projects.

5.1. Limitations

Our visualization seems to be effective in generating and visualizing opportunities of collaboration. This approach is uncommon, as it requires dealing openly with success and key performance indicators. Transferring these results may be limited to similarly structured research organizations. Other organizations could potentially be too visually complex to process [20,21]. Allowing individuals to be adequately represented and giving their niches considerable room, requires understanding of bibliometric indicators from a researchers perspective, if these are being visualized. The sample size of the study was relatively small and data was only used from 2012 to 2014. A long-term investigation has not yet been conducted, but is considered crucial when designing of a visualization tool for suggesting collaborators in a research cluster that is not just accepted by researchers, but also considered helpful.

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