Smart collaboration networks – a toolkit and a vision for creating and predicting trusted partnership

Gregor HEINRICH[1], Tobias KEIM[2], Christoph JUNG[1], Urs KRAFZIG[1], Stefan NOLL[1]
[1]*Fraunhofer Institut f. Graphische Datenverarbeitung,*
Fraunhoferstr. 5, 64283 Darmstadt, Germany
Tel: +49 6151 155 209, Fax: +49 6151 155 559,
Email: {heinrich,krafzig,cjung,noll}@igd.fhg.de
[2]*Univentures GmbH, Taunusanlage 21, 60325 Frankfurt/M., Germany*
Tel: +49 69 25626867, Fax: +49 69 25626880,
Email: keim@univentures.de

Abstract: In recent years, modern forms of collaboration such as virtual project teams gain importance. But how do individuals identify and select their collaboration partners possessing the required sets of hard and soft skills? - While internet-based applications model individuals' resumes or contact networks, to date no application exist that merge both worlds: human and social capital. Therefore, in this paper we present a software toolkit complementing expertise attributes by a set of historic and swift trust attributes. We then argue that merging these attribute sets will only be an intermediary step towards IS supported smart collaboration networks. We outline a decentralized architecture in which relational recommender systems allow for the prediction of trusted collaboration partnership thus assisting individuals in identifying the most suited collaboration partners from within or outside their personal contact network.

1. Introduction

The Internet has transformed both, the ways people find work as well as the ways they effectively collaborate. The processes of searching for and applying for jobs are increasingly digitalized [12] [13] and the same is true once the partnership is established. As IS supported collaboration across space, time and organizational boundaries gains importance the number of people engaged in temporary virtual project teams augments [24] [15]. Thus, individuals are more often brought together with new projects, individuals and tasks within their work history than in times of lifetime employment. But what can information systems contribute beyond the partner identification phase to the partner selection stage? How can we build decision support for team design? How can we model and represent personal and interpersonal attributes in order to enhance team configuration?

2. The Toolkit: The Online Partnership Lens

Finding answers to the above questions is a challenging task as various research strands such as work psychology, sociology and others have been dealing with how to design teams for work contexts. In the following, we briefly summarize some considerations on team configuration. We then present a concrete implementation to support such scenarios: the Online Partnership Lens (Opal).

2.1 Social Aspects in Partner Identification and Team Collaboration

Team building has been considered by a variety of disciplines. Sociology driven approaches showed that successful team configuration needs to consider task-related as well as social aspects or attributes [8]. Work psychology regarded the same problem under the terms of person-job fit, person-vocation fit and person-organization fit [22]. It has been pointed out that when working together in teams the interdependencies between subtasks do necessitate high levels of interaction between team members. Thus, team work requires high levels of trust between the collaboration partners [10]. Misztal therefore characterized trust as "sustaining a smooth-running of co-operative relations" [17].

While current applications on the Internet focus on the representation of task-related attributes such as peoples' competencies and certificates, social factors or interpersonal attributes are often neglected. This is astonishing as researchers pointed out that with the ruptures of time, space, location, organizational and cultural membership emerging in modern forms of collaboration such as virtual teams [24] social aspects such as trust are of even higher importance. Also, interpersonal relations not only complement formal or organizational relationships within the collaboration phase as described in [7]. They also help already in the partner identification stages. For example, Granovetter showed that labour market processes like recruitment and selection are deeply rooted in social relations [5]. Also, informal relations have been identified as reducing attraction costs [21] and screening costs when seeking for candidates [14]. Even more importantly, information gained through informal networks has been characterized as highly reliable, thus leading to fewer frictions once the candidate is hired [23] [18]. However, while the advantage of informal relations is that they transmit "thick information" [3], it is obvious that they are limited to a small number of trusted contacts [2]. Therefore, additional trust models are needed that are not only based on historic shared experience, but for example are based on swift or situational trust cues. We conclude that in order to successfully model team configuration processes, we need to consider two dimensions. Individuals need to be brought together (1) with tasks for which they posses the competencies to carry them out and (2) with other individuals with whom they are able to collaborate successfully. Within the latter dimension, different trust constructs play a major role.

2.2 The Online Partnership Lens

With the objective of enhancing the configuration phase of virtual teams, we designed a framework for partnership building. The system, the Online Partnership Lens (Opal), is based on the assumption that it *is* possible to measure, represent and thus establish trust online. Thus, the system is grounded in research such as undertaken by [1] and [20]. As trust is an important element of any social relation and in consequence also of (virtual) working relationships, the implementation aims to enhance virtual collaboration by establishing trust online. The Opal architecture is conceptualised around three concepts:

- *Layers* cover the main dimensions of partnership building.
- *Profiles* form the integral component of personal and interpersonal attributes that belong to one individual.
- *Filters* are modules that implement the evaluation of candidates according to a specific trust criterion.

The layer structure is directed towards extending current competency-focused systems by relational attributes that can be identified between actors. While human capital attributes contained in many state-of-the-art systems and CV-databases are modelled in the Competency layer, we provide additional Confidence and Compatibility layers for this relational knowledge (see also Figure 1):

- The Competence layer represents the structural side of partner matching. It describes *trust into the explicit skills* of an actor such as "*A* is an expert in topic *T*.", which can be modelled either as a "unary" statement within the profile, e.g., "*A* is expert in topic *T*", or through referral, e.g. "*C* rates *A* an expert in topic *T*.".
- The Confidence layer considers the relational side of partner matching from a situation-independent perspective, modelling *trust into a* person *as a context-independent variable*, e.g. "*A* trusts *B*.".
- The Compatibility layer extends the previous layers by integrating the cognitive side of partner matching. It describes *trust into the actual* instance *of a collaboration partnership* such as "*A* can work well with *B* in topic *T*.".

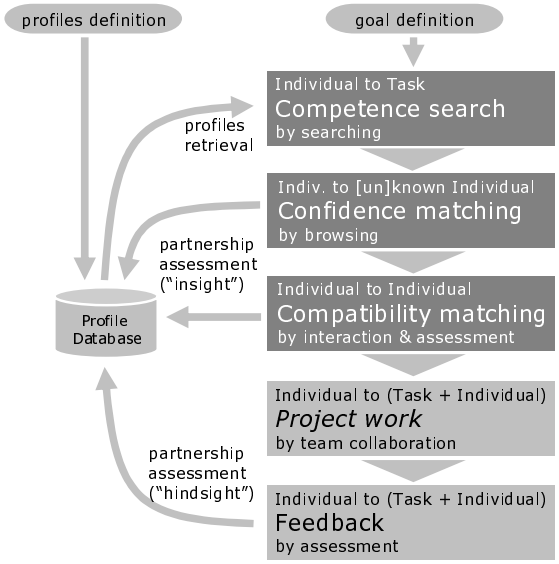

Figure 1: The Opal layers (inverted boxes), their relation to profiles and the example partnering process.

For each of these layers, we implemented a number of filters that can be connected to different stages of the partnership creation process. These filters serve to refine the list of candidates by reducing its size and in parallel increasing the trust into the remaining candidates. The partnering process starts with the definition of profiles pre-requisite for system usage. These profiles contain the expertise information about a specific person and serve as a basis for refinement during later usage. For the later steps, it is necessary to distinguish expertise searchers and providers. The searchers will start a search process actively by defining their goals. Given these goals, the process enters the Competence layer where a search for candidates according to primarily competence-based criteria is possible. The obtained list of competent candidates can be filtered through Confidence and Compatibility criteria. For competence filtering, generally two different approaches to trust elicitation and modelling are used: historic and swift trust. Figure 2 shows examples of both trust filters.

The main component to analyse historic or hindsight trust is by way of a network browsing and search interface. Figure 2 (left) shows the search for trusted candidates in a specific query about project management that are close to the searcher according to their social distance or radius within the social network.

To extend the limitedness of historic trust relations as mentioned above or to verify their quality for a specific context or project in consideration, we implemented a second trust mechanism: the swift or insight trust module. This module provides an online interaction

mechanism in order to support the pre-structured assessment of candidates who are not yet members of a user's direct or indirect personal network or who are known to him but not within the right context.

After finishing the Confidence layer, the Compatibility layer is entered, that structurally resembles the Confidence layer because the compatibility criteria can be filtered again via the graphical browsing tool and the structured interview video tool. However, whereas the Confidence layer measures and establishes interpersonal trust trying to generalise on the situation, the Compatibility layer focuses on the mutual understanding of the particular task at hand. The finalisation of the Compatibility layer results in a list of candidates that actual collaboration can be started with. Here, predictions need to prove their correctness, which is assessed in the last step. Like the other assessment filters, the result of the evaluations can be uploaded to the system and serve as an additional criterion during search. Thus, we obtain a structure of dynamic, composite expertise and trust profiles within our database.

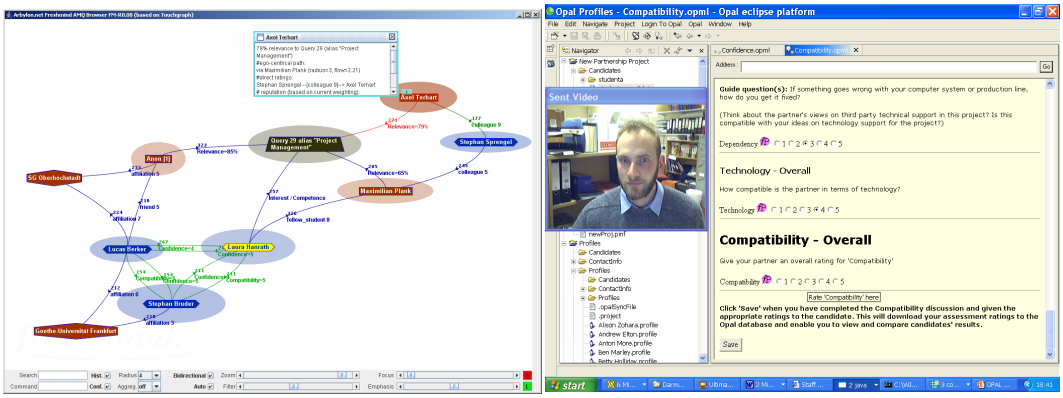

Figure 2: User interface of two example filters. Left: Social network browser / search interface. Right: Video conferencing and questionnaire for structured interviews.

Based on the above considerations, we integrated historic and swift trust relations into a single multidimensional network of weighted relations. The network serves as the basis for accessing the trust structure of the community in consideration thus resulting in an "ontology of trust". Besides the trust attributes in our ontology, the main class types are the individuals between whom trust is to be represented, which are generalized in a class Actor. Also, a number of "auxiliary" classes are required, e.g., to model contextual information necessary to describe side-conditions under which trust was established (e.g., the role, the quantity, the location, measurable entities, like time or assessment values). We chose the means of information visualization as our approach of accessing the information in the trust ontology, resulting in the trust browsing functionality as seen above in Figure 2 (left).

In order to validate the approach chosen, a two-day validation workshop was carried out with a group of twenty students. The workshop showed that the swift and the historic trust modules were perceived as highly complementary. Respondents appreciated to be provided with a support for online interactions by means of the structured questions forms. They considered the questions suggested as relevant for partnering and teaming scenarios. The tool was perceived as useful in situations where partnering time was short. Also, it was stated that the approach added new information to the partnership configuration process through the online interactions. "Seeing and interacting" was perceived as a clear benefit in trust production in online team building. The browser visualization was rated as highly intuitive. One participant said he "did not know in advance he had so many friends he trusted". Thus, the Opal concept clearly possesses a value in virtual partnership building and therefore it is worth to further pursue and build on this experience.

3. The Vision: The Predictive Peer Partnership Lens

Building on the Opal system prototype and the research on trust ontologies, our network browsing approach and interactive assessments, this section investigates how social network analysis, computer graphics and machine learning techniques can extend the current results to provide more automatic recommendations. Further, we develop the idea of a peer-to-peer infrastructure for partnership recommendation to leverage a number of advantages of such an architecture, ranging from scalability over privacy to regionalisation issues. We dubbed this approach the Predictive Peer Partnership Lens (P3Lens).

3.1 Predictive partnership matching

In our above consideration on the Online Partnership Lens, we presented a system that can be understood as a *descriptive* approach to partnership matching. The system describes what is in the database and provides filtering and comparison methods but otherwise maintains a low degree of automation. Predictions are made solely by the user, based on his intuitive judgement on a specific setting of interpersonal and personal attributes, which itself is based on an appropriate presentation by the system. Although the idea behind this way of human-computer interaction is compelling – leaving the decision task to human intuitive capabilities but providing all necessary prerequisites – in many usage scenarios it is desirable to stronger support the user in his decision, in the best case by a prediction on how he would judge a situation or candidate as well as by a transparent representation of that estimated judgement. We call this more autonomous modus operandi the *predictive* approach to partnership matching, noting that the two mentioned approaches are points on a continuum of automation degree. An overview of the difference between descriptive and predictive matching is illustrated in Figure 3. Matching itself is performed on the basis of the predicted relations, i.e., given known successful situations (and their expression in terms of a relational structure between individuals), new situations with predicted relations can be predicted in terms of success.

As a basis for the predictive approach, we postulate two work hypotheses: The first hypothesis is that the unary (i.e., propositional) and relational attribute structure latently captures personal qualities that generate degrees of trust, possibly conditioned on specific situations and roles. For instance, looking at a known relational confidence attribute with a source *A* and a target *B* (e.g., *A* assesses *B*), it is predicted that similar relations (with respect to type and weight) can be measured for sources similar to *A* and targets similar to *B*. E.g., if *A* assesses *B* positively, *C* similar to *A* is predicted to assess *C* similar to *B* positively, as well.

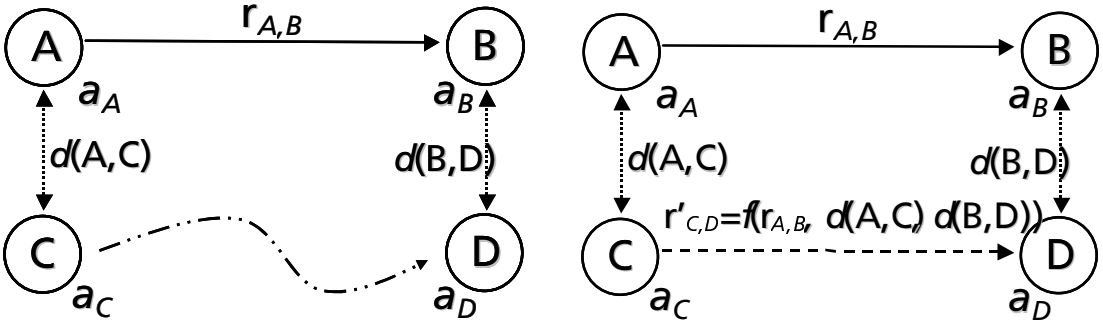

Figure 3: Example for descriptive approach and predictive approach. A has a hierarchy of relations r_{A,B} to B and A is similar to C, B to D with respect to their attributes a, including relations other than r_{A,B}. (d() is a distance measure). In the left picture, the relation between C and D is inferred by the user. In the right one, the relation is predicted by the system based on trained correlation between personal and interpersonal attributes and relations.

The second hypothesis of the approach is that some dimensions of trust are transmissible through a referral network. This means, for example, that looking at such a higher-order trust relation, *A* trusts *B* and *B* trusts *C*, again possibly conditioned on a situation or role, trust from *A* to *C* can be predicted. This is the conceptual basis of referral systems, such as ReferralWeb [11] [26]. The question is what trust dimensions do exhibit this transitive behaviour to which degree.

In particular, the first hypothesis can be mapped to the emergent scientific area of statistical relational learning (SRL), in which solutions are sought where graph properties are learned from data, and the local graph topology surrounding newly observed nodes are predicted. The second hypothesis is related to the Friend-of-a-Friend principle, which is the basis for transitive trust relations and is, in fact, used in the existing Opal system already. This latter hypothesis has a strong influence on the kind of relational learning algorithms employed in the system. In principle, the more influence comes from a more remote graph environment, the more complex the statistical models become.

Several relational learning approaches to solve the search problem can be considered, and we note the work of Jensen, Neville and Wolfe [19] [25] [9] and of Heckerman, Meek and Koller [6], as a basis for a generic social network prediction algorithm.

Further, within the framework of latent concepts, we plan to connect actors with documents and extract concepts of actors also from the content assigned to them or authored by them. This extends the idea of explicit profile creation to implicit methods of profile creation thus allowing for bootstrapping a real system by connecting it to existing document bases. A scientific basis for work into this direction can be found in [16]. Merging both the content and the social network into a 'smart' collaboration network to us seems a promising idea when considering the many real-world knowledge management problems and applications. However, several challenges appear when modelling profiles for the predictive approach to partner matching. These are:

- the modelling of complementarity and compatibility for team building scenarios. This includes incorporation of research on matching different personal traits with express expertise measures to optimise team staffing.
- the capturing of "inter-rater trust". Within this functionality, the bias of a rater will be used to remove bias from ratings and will also be incorporated as a specific rater characteristic. This has been partly solved in our existing Opal system via a matrix-based assessment browser as presented in [4].
- the resolution of disreputative scenarios. The case where candidates are assessed badly must be resolved in a way that conserves overall integrity and privacy in the community but still allows marking negative experiences. This is an often-encountered scenario where most rating-based systems capitulate.

3.2 Peer-to-peer approach

Besides the predictive approach to partnership formation, we further aim to create an extended infrastructure. While the current Opal system is based on a server-centric approach with the communication subsystem in a point-to-point topology, we envisage constructing a completely decentralised peer-to-peer infrastructure, which in principle could be extended to a grid approach. This architecture provides the following advantages:

- local storage: secure data handling by physical separation. Scalable privacy features: localised vs. global storage.
- scalability: algorithms become viable that per se scale worse than inverted indexes (semantic annotation, machine learning approaches). Also, context-sensitive load balancing is allowed by this means.

- regional search: peering different latent indexes (“peered latent spaces”) with focus on thematic or regional domains for indexing and query dispatch should be enabled. This implies a peer-structure of localised concept-based methods like latent semantic analysis.

By means of this architecture, the envisaged system is – to our knowledge – the first one to use such a localised structure in order to meet privacy requirements present in most scenarios. As part of our research, the questions of disclosure policies and processes as well as of query mapping to localised concept-based indexes will be explored as scientific contributions. Building on this architecture, the system provides context awareness along a couple of dimensions, which serve as dimensions to scale down search spaces on the Competence layer:

- geographic context ("*regionalisation*"),
- thematic context ("*topicalisation*") and
- role context of the active user ("*roleisation*").

3.3 A bird’s eye view

A particular challenge of a system like the one envisioned in this section is to prepare the results in a visually simple interface that transports the wealth of information inherent in the data considered to the user. We imagine that an approach similar to the one taken in our realised system can be a very fruitful one.

The network visualisation could, in fact, be extended to a full-fledged graph-based search interface, where queries are constructed either in natural language and then interpreted and visualised as a graph, or graphs are used directly as a search interface, similar to a mind map where all aspects of a target profile are stated.

Especially we plan to include a “meta-query” mechanism, which can be imagined as a tool that recommends queries for a number of common situations a user might himself find in, by identifying important queries to ask for a given common task, which is especially useful for inexperienced users to optimally use the search features.

4. Conclusions

In this article, we showed how trust-aware collaboration construction is possible with a methodology that combines “hard” with “soft” features or expertise-oriented attributes with a trust ontology. Our research evaluation showed that this tool goes in the right direction. Based on this experience, we aim to extend our research from the current “descriptive” approach that entirely leaves interpretations to the user to a “predictive” approach that will provide recommendations to the user about new social relations possessing a high likelihood of success. Thus, we aim to build a relational recommender that based on the nodes’ characteristics, e.g. the individual attributes, in the network as well as on the characteristics of the edges, e.g. the interpersonal, relational attributes, will predict new social relations that individuals should or could engage in. By this means, we hope to enhance partnership building for collaboration scenarios. The "bird's eye" view on the community of experts or network of companies represents another important pillar of this approach as it allows the identification of experts or knowledge hubs for a specific domain within these social or relational structures. This combination of human and social capital as well as of content and social networks to us is a challenging, but necessary step towards the knowledge economy.

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