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ERP objects become “social”: a process model for the identification of social business objects for an enterprise knowledge graph

Completed Research Paper

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Abstract

ERP systems contain the business-critical information of companies and public agencies. In practice, organisational data is distributed across multiple information systems, making it difficult to gain a comprehensive and consistent view of the available information. *Enterprise Knowledge Graph (EKG)* and *Social Network of Business Objects (SoNBO)* are new integration approaches in the field of computer science that are aiming to connect distributed ERP objects by means of a graph structure with the help of an ontology. The successful implementation of an EKG or a SoNBO requires a suitable method for the identification of business objects in the distributed Enterprise Systems. This paper describes and illustrates the necessary process steps to design a Social Network of Business Objects for a heterogeneous business software environment. The method was developed in a Design Science Research project in which a prototype of a SoNBO application was developed, configured and evaluated.

Keywords

EKG, SoNBO, Social Network of Business Objects, Integration, ERP system.

Introduction and Motivation

Business application systems are used by organisations to acquire, process, transmit and store information and thus provide the backbone of electronic information processing (Schwarze 2000). They can be subdivided into the following four types of software: (Type 1) *Process-oriented business systems* (often in the form of enterprise resource planning systems such as SAP ERP or customer relationship management systems such as Salesforce) (Davenport 1998), (Type 2) *enterprise collaboration systems* (such as HCL Connections) (Schubert and Glitsch 2015; Schwade and Schubert 2017; Williams 2011), (Type 3) *enterprise content management systems* (such as Alfresco) and (Type 4) *business process management systems* (such as Camunda) (Weske 2012). Historically, business-related information is distributed across different systems, making it difficult to establish an overview of the entirety of available information (Schmidt et al. 2010). Therefore, it has become necessary to develop integration concepts and applications in order to allow the employee to gain the necessary comprehensive and consistent view of the information. The aim is a flexible and effective data integration in today's dynamic corporate world (Auer et al. 2014).

An innovative and modern integration concept from computer science (or more specifically the area of Semantic Web) is the so-called Enterprise Knowledge Graph (EKG) (Galkin, Auer, and Scerri 2016; Galkin, Auer, Kim, et al. 2016; Gomez-Perez et al. 2017), which uses an ontology to describe the information in the business software and to make it available to the user in one uniform interface. The ontology (Guarino et al. 2009) describes the structure of the information by means of *concepts* or classes, e.g. *employee* or *invoice* (and not instances of classes such as "Müller" or "1725"). The Knowledge Graph is the combination of the ontology with the data in the databases (fact base): The KG uses the ontology as a schema for the representation of the data. Technically, Enterprise Knowledge Graphs are often implemented in companies using graph databases (Stuber 2012) and RDF (= Resource Description Framework) (Song et al. 2017) as the language to describe the ontology.

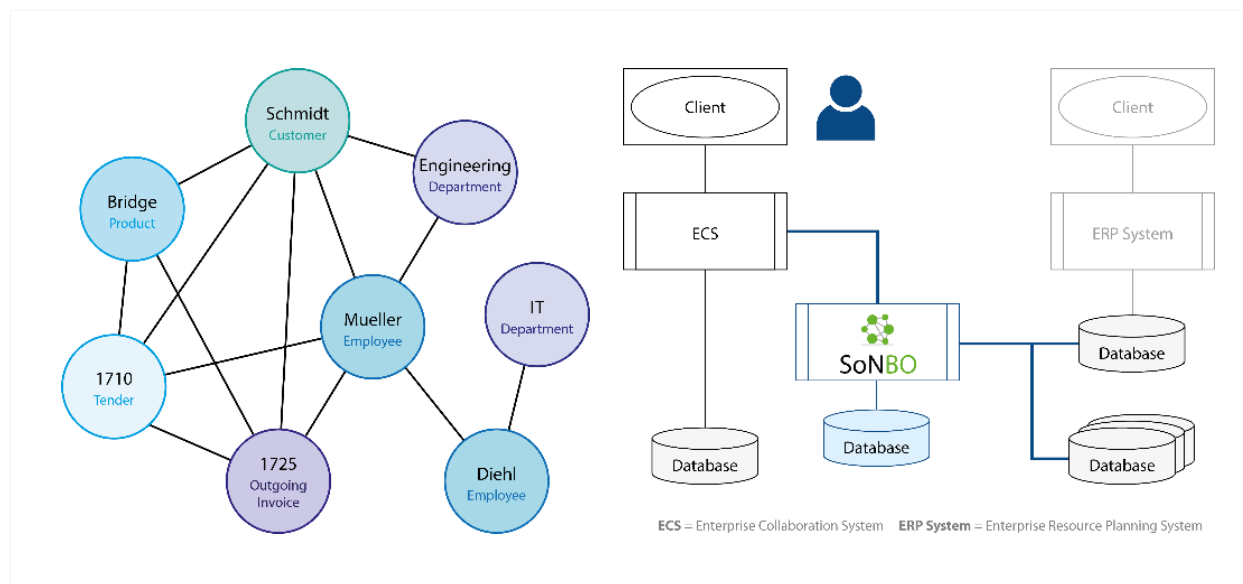


Figure 1. SoNBO concept (Gebel-Sauer and Schubert 2019)

The Social Network of Business Objects (SoNBO) (Gebel-Sauer and Schubert 2019; Gewehr et al. 2017; Götz and Gebel-Sauer 2018) is an information integration concept that was identified in practice in the company Vössing Ingenieurgesellschaft mbH where it had been developed and used (Gewehr et al. 2017). It was further developed using theories from computer science, most specifically the concept of the *Enterprise Knowledge Graph* (EKG). The EKG is a special form of a Knowledge Graph in which a corporate ontology is used to describe the information in the distributed databases. At runtime, a Web application called "SoNBO Explorer" collects the information from the databases and presents it to the user. In our prototype the SoNBO Explorer is embedded into the client of the ECS (see Figure 1, right side). In this application, the EKG is called Social Network of Business Objects and is exemplified in Figure 1 (left side). The term "social" indicates that the graph makes use of concepts from social networks (such as Facebook or

LinkedIn). In the graph, the nodes are not just people, but potentially all relevant concepts such as invoices, tenders, orders or projects. The common feature is that the user can navigate through the Social Network (of Business Objects) and can see the information from the point of view of the respective node (e.g. an invoice). In the SoNBO concept, the nodes in the graph that are based on the ontology are called social concepts or social subconcepts and the graph is called Social Network of Concepts. The nodes in the graph that result from the ontology and the data from the databases are called social business objects and this combination of ontology and data is called Social Network of Business Objects. Example: social concept = person; social subconcept = employee; social business object = Peter Müller. The SoNBO Explorer can be used in the enterprise by various groups of people (e.g. clerk, project manager or managing director) for information access. SoNBO is a concept mainly for *information retrieval*. The input of data (such as an invoice) is still done directly in the source system(s).

The above-mentioned approaches to integration originate in the discipline of computer science and there are no established methods available to date that support the actual implementation of these concepts in an organisation (Galkin, Auer, and Scerri 2016). The biggest challenge is the modelling of the Social Network of Concepts as an ontology, which is then subsequently configured in the SoNBO Explorer (an activity comparable to the customizing of an ERP System). In this paper, we describe an example of the necessary (structured) process which was carried out for an ERP system. The insights gained from the prototypical implementation were used to propose a process model. It is important to mention that the SoNBO is a concept for the integration of *multiple distributed* information systems. In this paper, however, the focus is on the integration of *one* ERP system to demonstrate the feasibility and to show its applicability to other systems with the help of a process model. We address the following research questions:

- (1) What are the necessary steps for the identification of ERP objects as social concepts for use in a SoNBO? (development goal: *process model*)
- (2) What does a suitable enterprise ontology for a common ERP system look like? (development goal: *Social Network of Concepts*)

Research Design

Guided by the principles of Design Science Research (DSR), we followed the research steps shown in Figure 2 to address our research questions. The goal of DSR is to learn through the act of “building” (development) (Kuechler and Vaishnavi 2008; Peffers et al. 2006). The development creates an artefact that can take on different forms. For example, an artefact can be a prototype, a model or a method (Gericke and Winter 2009). The steps in a Design Science Research cycle are usually characterized by four phases: problem awareness, first solution, development and evaluation. These four phases are not strictly sequential and loops between the phases may (and should) occur (Kuechler and Vaishnavi 2008).

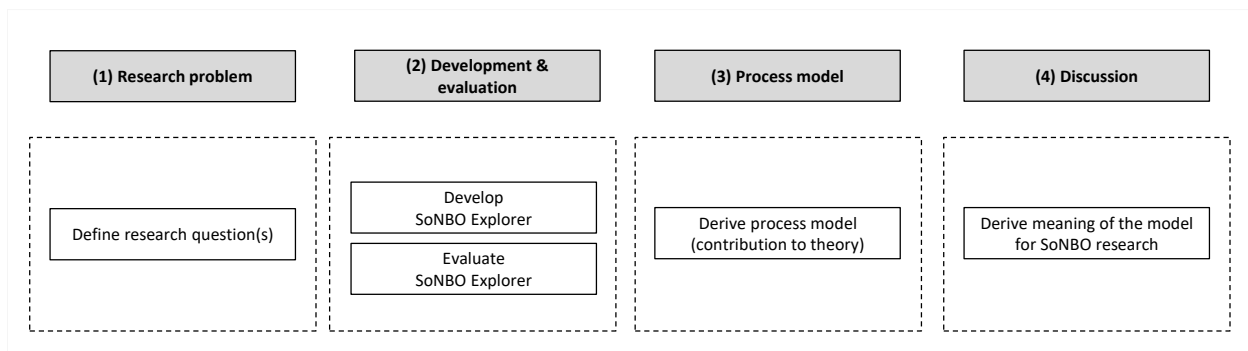


Figure 2. Research steps

After (1) defining our research questions, a (2) SoNBO Explorer was developed as a prototype (artefact) that integrates information from the Microsoft Dynamics NAV ERP system. The application was then evaluated to demonstrate conformance with the requirements. A first version of a process model was designed, tested and refined during the development of the ontology for MS NAV. The resulting (3) process model addresses our first research question and represents the contribution to theory. The resulting ontology (i.e. the Social

Network of Concepts for MS NAV) addresses the second research question. In the last step, the results were critically reflected in the context of the umbrella research programme on SoNBO.

The Process Model

Figure 3 describes the process model for the development and implementation of a SoNBO Explorer in an organisation. The process model was inspired by the steps of the CRISP-DM (= CROss-Industry Standard Process for Data Mining) model.

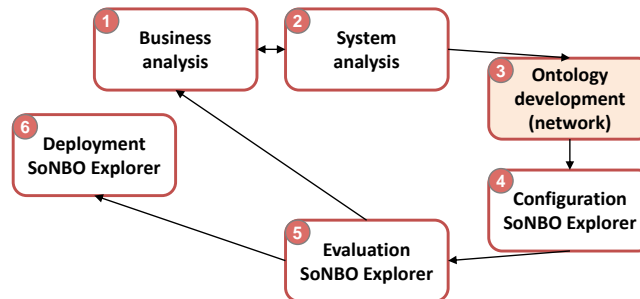


Figure 3. The process model (inspired by CRISP-DM)

In the first step, a business analysis is performed, which is then supplemented with a system analysis. This links the requirements of the business with the requirements of what is technically possible. On this basis, the social concepts are identified, which are then assembled as an ontology into a Social Network of Concepts. This is followed by the configuration of the Social Network of Concepts by mapping the elements of the ontology to the dimensions of the database tables. At runtime, the Social Network of Business Objects provides the basis for navigation for the user and allows to retrieve the node-related information from the enterprise systems. In a subsequent evaluation, the implementation team decides whether a modification of the graph is necessary or whether the SoNBO Explorer is ready to be deployed and used in the company. The development of the process model showed that the greatest amount of time is needed for the design of the Social Network of Concepts and the development of the ontology which makes the third (highlighted) step the most important one. The six process steps will be further described in the next sections.

Business analysis: Case Study Müllerland

In the first phase of the process model, the company is analysed to determine the requirements of the network. For this, the organisational structure (e.g. departments, locations) and the business-relevant processes are identified and described.

The prototypical development of the SoNBO Explorer in this paper was done using the data of the ERP system MS NAV that is also used for teaching. In a simulation game, students are placed in a fictitious company setting which requires them to use functionalities of an ERP system in order to fulfil predefined tasks (Schwade and Schubert 2016). The student activity generated the master and transactional data that was used to develop and test the SoNBO Explorer. The business game is based on a real furniture retail company (Müllerland). Each student is put in the role of an intern who goes through various departments of the company. At the start, product master data is created. In the sales department, customer master data and quotations are created. The components of the kitchen are ordered (purchasing department) and the corresponding orders and purchase invoices are created. The warehouse processes are carried out by the students and the sales invoice is prepared to match the delivery of the kitchen. The data is generated by about 120 students per semester, so that the data basis for the development of the prototype was sufficient for the purpose.

System analysis: Microsoft Dynamics NAV (ERP system)

The second phase of the process model contains the analysis of the information system landscape and the identification of the systems that need to be integrated. The information in the databases was analysed and the possibilities for technical integration with a focus on existing interfaces (APIs = application

programming interface) were identified. An important aspect was the finding of a solution for the adequate authentication (user access rights), which is ideally implemented as an SSO (single sign on) solution.

The NAV ERP system was originally developed in Denmark, later purchased by Microsoft and is now offered as a product for medium-sized companies under the name MS Dynamics NAV. The system is used in Germany by 20,000 and worldwide by over 300,000 customers. Microsoft offers a range of interfaces for access to NAV. Our team used the Open Data Protocol (OData), which is suitable for building and consuming RESTful APIs for CRUD operations (= create, read, update, delete). Access is implemented via web services. Access to the data requires both, authentication and authorization that reflects the permissions of the current user. An ideal solution would be OAuth 2.0 (Open Authorization), which enables a standardized and secure authorization process without user credentials. However, this only works in a Microsoft Azure environment. For on-premise customers (in our case), there are two alternative options: using a keystore or Basic Auth. The keystore contains passwords and thus implies a security risk. The other option is Basic Auth, which means that the user must log on to the subsystem (here: NAV) repetitively for every new session. For the prototype, this solution was chosen because our goal was not to provide a convenient solution for a company setting but to demonstrate the feasibility of the concept (i.e. a prototype). For use in a commercial enterprise, the Azure solution would probably be the more favourable.

Ontology development: Identification of the Social Network of Concepts

The third phase of the process model contains the development of the ontology (= Social Network of Concepts). An ontology is a formal conceptualization of a domain of knowledge (Weller 2014). The term emerged in the field of knowledge management and was taken up for the Semantic Web for the development of knowledge graphs. Its purpose is to facilitate communication between human-human, human-machine and machine-machine. Guarino et al. (2009) propose the following definition of an ontology, which we use in this paper: "An ontology is a formal, explicit specification of a shared conceptualization." One component is a (1) conceptualization, which is an abstract, simplified view of the world represented for a purpose (Gruber 1995). The (2) specification is constructed using rules consisting of a language (e.g. RDF) with a vocabulary (Guarino et al. 2009).

For the *conceptualization* (first part of the definition), a first, informal visualization was created (c.f. Figure 4). In this visualisation, the concepts of the ERP system are depicted. We kept the image as generic as possible so that the representation in Figure 4 can serve as a reference model for basic ERP objects in a future project which can be adapted according to the needs of an organisation. The SoNBO Explorer described in this paper was developed for the simulation game described above (cf. *Business analysis: Case Study Müllerland*). Only the grey concepts in Figure 4 were used for this case.

This form of presentation was chosen for two reasons: First, it is a rough orientation for the meaningful structuring of social concepts. There can be many forms of a correct visualisation but the selected structure and representation should match the character of the system represented. Furthermore, through the simple visualisation the figure is understandable for every stakeholder.

The second reason is that through this kind of visualisation, neutral terms can be used. Objects such as "invoice" (in NAV "sales invoice" and "purchase invoice") were standardised into an unambiguous taxonomy. The image shows the two types of invoices (incoming/outgoing) according to their location. To ensure reusability of the taxonomy, the neutral naming of social concepts is of great importance because the language in organisations usually follows the terms dictated by the ERP system. For example, an outgoing invoice may be called "outgoing invoice", "sales invoice" or "customer invoice" in three different divisions of the same company. A consistent naming of these social concepts in the SoNBO Explorer is of paramount importance.

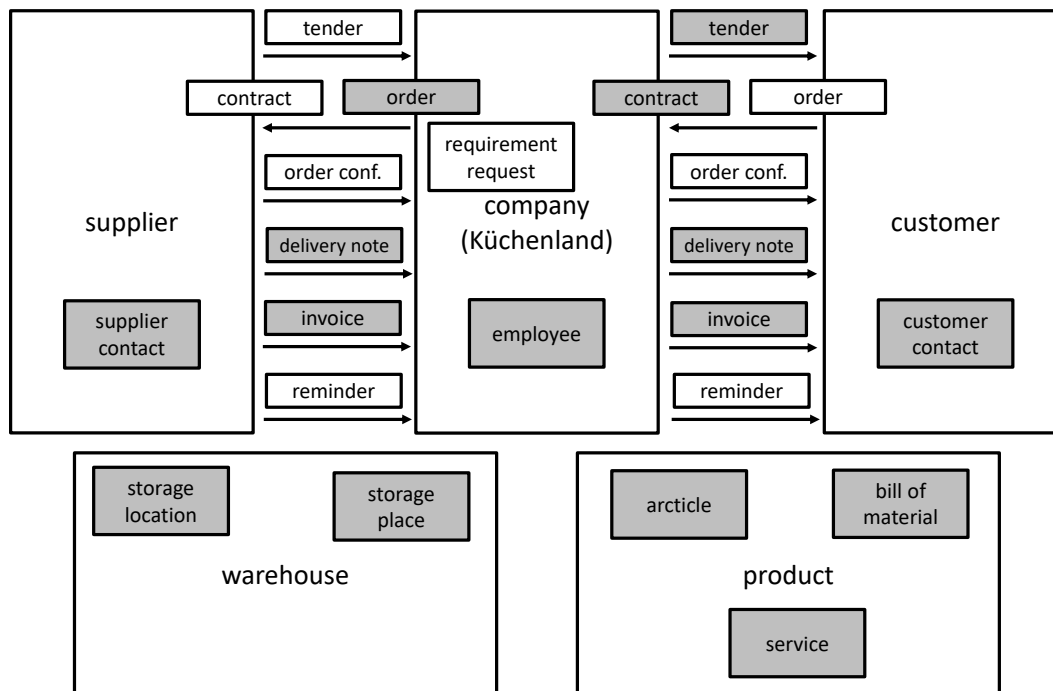


Figure 4. Social (sub)concepts (grey: data records generated in the simulation game)

This first visualisation also serves as the basis for creating the *specification*, which is the second part of the definition of an ontology. For that, a taxonomy (Table 1) is derived from the first visualisation. A taxonomy contains a controlled vocabulary that describes relations between concepts. These can be hierarchical, with a source node (e.g. Apollo program), multiple sub nodes (e.g. Apollo mission, astronauts, ...) and further sub nodes which belong to the higher-level nodes (Blumauer 2014).

The purpose of the taxonomy is to provide a uniform linguistic basis for e.g. an ontology. For the configuration of the SoNBO Explorer in our project we limited the taxonomy to the grey boxes (Figure 4). From these boxes, we derived the social subconcepts that were then categorized into social concepts (c.f. Table 1). For example, the documents „order, delivery note und invoice“ (Figure 4), that are exchanged between the supplier und the case company, are derived as social concepts (taxonomy) and are classified into the social concept „supplier-related document“. On the basis of the taxonomy, the ontology is created by identifying and modelling the relations between the social (sub)concepts. The ontology is then visualised as a network (Figure 5 and Figure 6).

The creation of the ontology for a company can be started by first looking at a limited area (e.g. one department or division) of a company and then (successively and iteratively) adding further social concepts. This is also suggested by Sequeda and Miranker (2017), who developed a similar approach in a related ontology-based integration concept called OBDA (= Ontology-Based Data Access). The concept SoNBO and the SoNBO Explorer are flexible with regard to the extension of the network.

It is important to limit the social concepts to a manageable number (here: five), so that the visualisation is still readable for humans. The visualization was created with a special tool (the SoNBO Visualizer) and the result is shown in Figure 5 and Figure 6. The tool had to be specifically developed because there was none available that could model the information in the transactional systems as a network in this way, and in which the user can switch between the two levels (social concepts and social subconcepts). The Social Network of Concepts (Figure 5) consists of Social Concepts (nodes) listed in Table 1 and their relationships (edges). There is, for example, a relationship between a supplier-related document and a product because an order contains products.

Social Concept	Social Subconcept	Example for a Social Business Object
Supplier-related document	Order (supplier)	Order 000876 to Fa. Kleinert
	Delivery note (supplier)	<i>Delivery note 000896 from Fa. Kleinert</i>
	Invoice (supplier)	Invoice 000867 from Fa. Kleinert
Customer-related document	Tender (customer)	Tender 000856 to Paul Hermann
	Contract (customer)	<i>Contract 000225 from Paul Hermann</i>
	Delivery note (customer)	Delivery note 000843 to Paul Hermann
	Invoice (customer)	Invoice 000868 to Paul Hermann
Person	Employee	<i>Employee MRIEDLE</i>
	Customer contact	<i>Customer Paul Hermann</i>
	Supplier contact	Supplier Kleinert
Warehouse	Storage location	Hall 2
	Storage place	Shelf 285
Product	Article	<i>Cooking spoon</i>
	Bill of material	Kitchen set
	Service	Building kitchen

Italic: See screenshot in Figure 7

Table 1. Taxonomy: social concepts, social subconcepts and social business objects

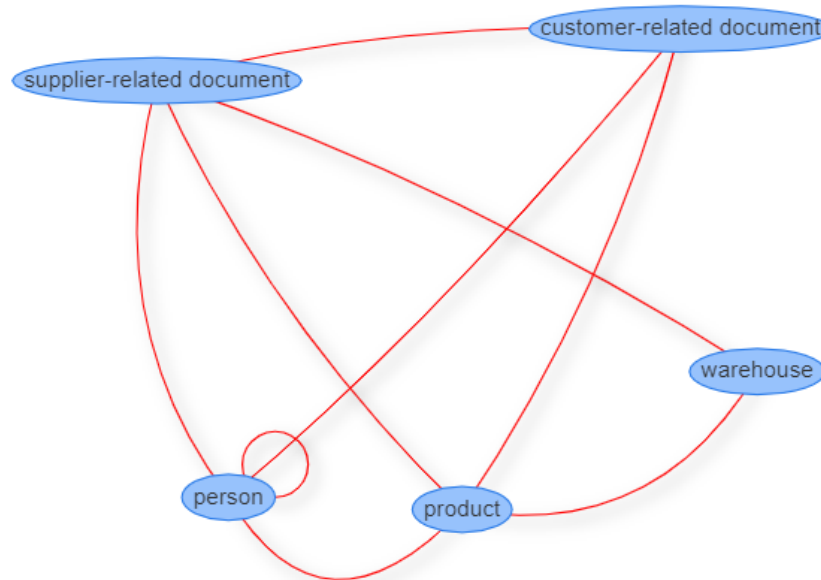


Figure 5: Social Network of Concepts

Figure 6 shows the Social Network of Subconcepts. It was drawn by creating the subconcepts (for example, *tender* and *supplier*) in the tool and then assigning them to their parent concept (for example, *supplier-related document*). The relationship between the subconcepts is then automatically generated based on the relationships of their parent concepts. If one of the resulting relationships between subconcepts does not exist in reality, it can be removed manually. In the above mentioned example, there is a relationship between an order and an article (a cooking spoon). However, there is no relationship between order and service because the company does not purchase service and employs its own staff to assemble the kitchen.

In Figure 6, the resulting Social Network of Subconcepts is visualized with the SoNBO Visualizer. As can be seen, a network is created that is no longer adequately readable for humans. It demonstrates how complex such a network can become. In the next step, the database links are configured and the tool can then access the ERP data to visualize the Social Network of Business Objects (which is not shown here due to space limitations). Due to the large amount of actual data records, this is even more complex. A future version of the tool should support the automatic transfer of the resulting Social Network of Subconcepts into the configuration of the SoNBO Explorer.

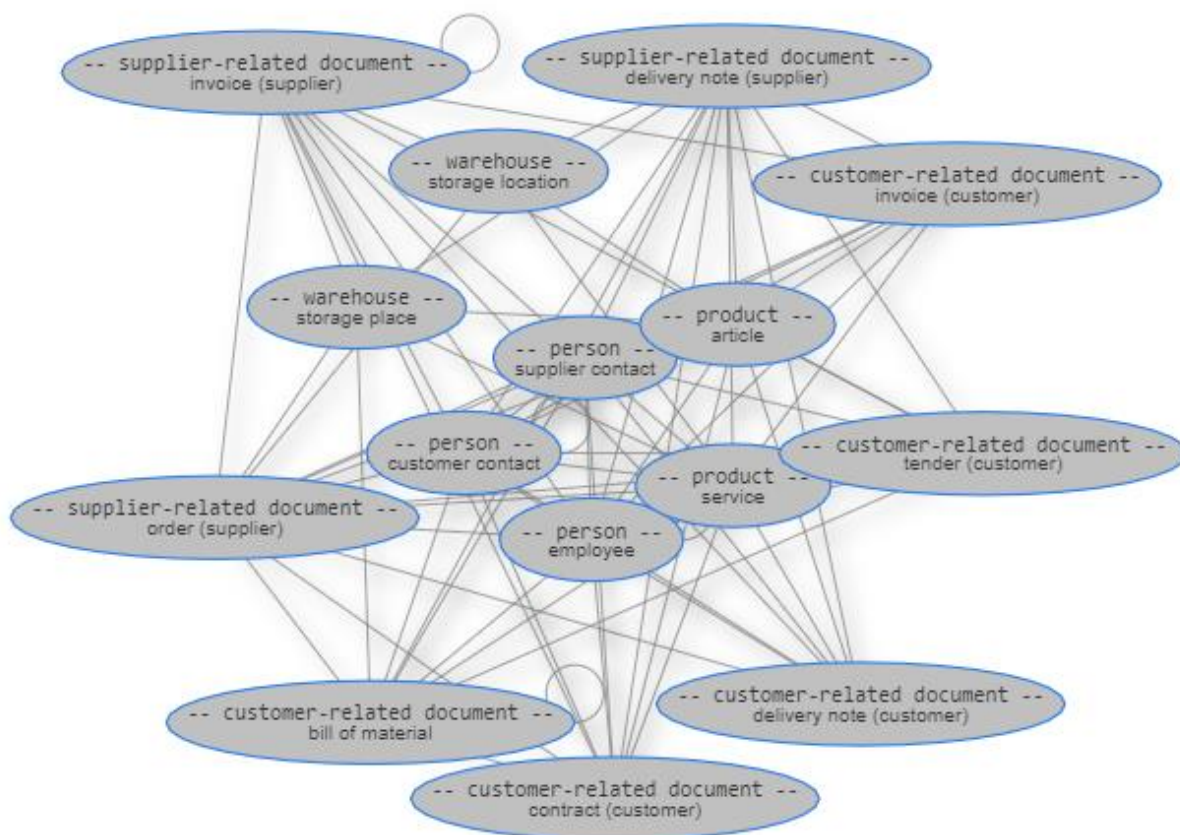


Figure 6. Social Network of Subconcepts

As described above, the idea of SoNBO is that the user can navigate through a network similar to the Social Networks known from public Social Media. This idea was taken up in the design of the frontend and the information is visualized as a profile. Each social business object (SBO) has a profile as shown in Figure 7. The (1) upper area shows the name of the SBO (here: order 000225) and the associated social concept (here: order - customer). In addition, there is some information about the SBO in this area (here: customer: Paul Hermann, status: released, ...). In (2) below the bar are the social concepts and social subconcepts related to the social business object. If the user selects a social concept (e.g. "customer-related documents") and an associated social subconcept (e.g. delivery note - customer), the related SBOs are displayed in the (3) result

area (here: delivery note 000896 Fa. Kleinert). In the screenshot, all SBOs that are related to the order 00225 are in the result area. On the (5) left-hand side, this result area can be further filtered by attributes. The (6) right-hand area displays the most recent events concerning the SBO. This way, the user can see the information from the point of view of the respective SBO depending on his/her authorization. The (4) area at the top left contains the path through which the user navigated. In this example, the first SBO was the employee himself (MRIEDLE), who then navigated to the SBO order 000225. In principle, the starting node is always the user himself (here: MRIEDLE), since the idea of SoNBO is that the network is explored starting from one's own node (as is also the case in public social networks).

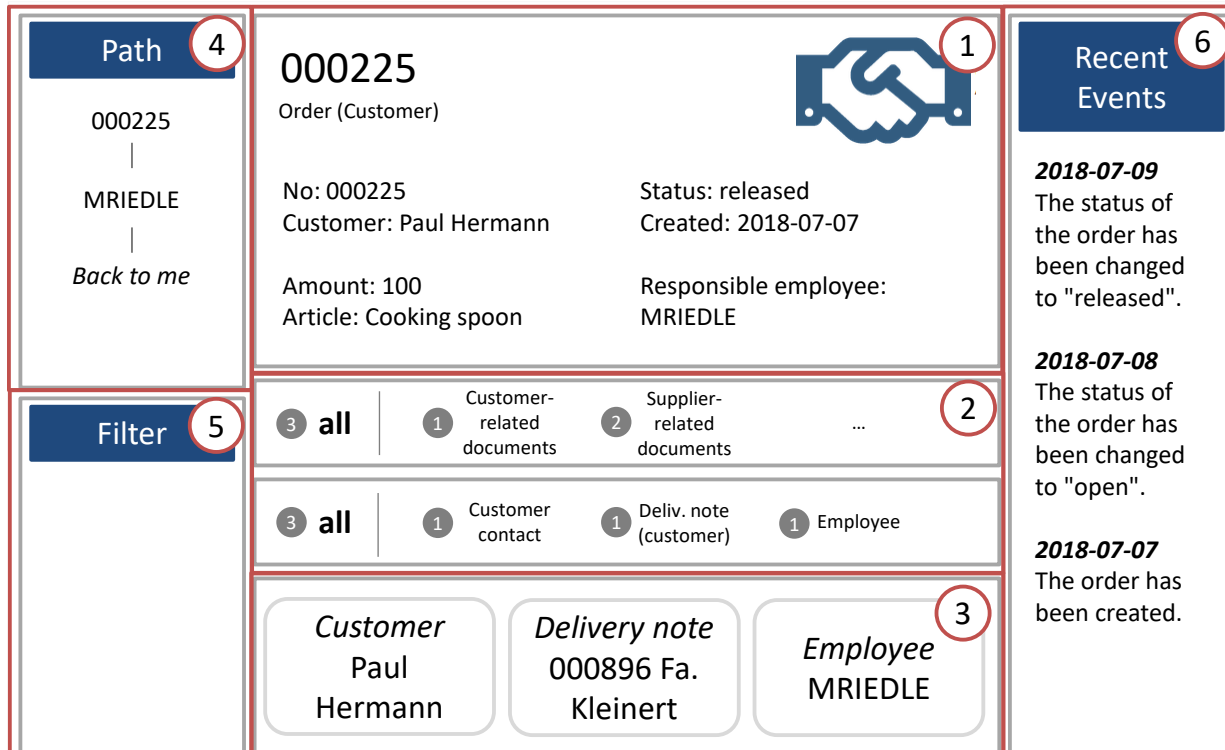


Figure 7. Frontend SoNBO Explorer for ERP data

The frontend is integrated in the Enterprise Collaboration System HCL Connections, which also includes an activity stream. The SBOs also post updates to the activity stream, which is explained in the next section.

In its current form, the user is only able to "read" information (only the "r" from CRUD). However, the interface can also support further operations (create, update, delete). These actions will be added to the SoNBO Explorer in a future version.

In summary, modelling the Social Network of Subconcepts requires a thorough understanding of both, the SoNBO and the target domain (business and system view). The structure of the database tables guides the modelling process but there is still a lot of flexibility left for the SoNBO expert. It is a great advantage of the SoNBO approach that the network can be tailored to the exact needs of the employees. However, the network cannot be automatically derived from the information systems, which is why it can be challenging to model an appropriate network.

Configuration of the SoNBO Explorer: customizing the SoNBO application

The fourth step is to configure the previously modelled network in the SoNBO Explorer. This is comparable to the customizing process of a standard software. During configuration, the attributes for each social subconcept are determined. It is important to choose unambiguous names. In the case of the social subconcept "employee", for example, it makes sense to choose the e-mail address since it is a unique identifier. The necessary attributes are defined during the configuration of the SoNBO Explorer. First, the attributes that are visualized in the frontend in area (1) (e.g. order number) are defined (c.f. Figure 7). Next,

the attributes for the tiles in area (3) are selected. In addition, the SoNBO expert needs to specify the attributes that can be used for the filter in area (4). Also, the latest events (6) and the posts in the activity stream of the collaboration system HCL Connections need to be defined. The latest events are shown as posts in the frontend of the SoNBO Explorer and are visible to anyone who navigates to this particular SBO. For example, when creating the order 000876 to Fa. Kleinert, MRIEDLE generates a post in the profiles of the associated SBOs (here: order 000876, company Kleinert, MRIEDLE).

The text for the post in the profile of the *order* is composed as follows (in passive voice): "07.08.2019: *Vendor order 000876 was created* by employee MRIEDLE." The post in the profile of the *employee* is similar but here the wording is in an active voice because it describes the action of a person: "07.08.2019: *Employee MRIEDLE created* the order 000876." In addition, the creation of the order triggers a post, which is sent to the activity stream of the collaboration system. This is only visible to the user. In the event that the order was created, the following post is created: "07.08.2019: Vendor order 000876 was created by you." The structure of these posts is configured for each respective social subconcept.

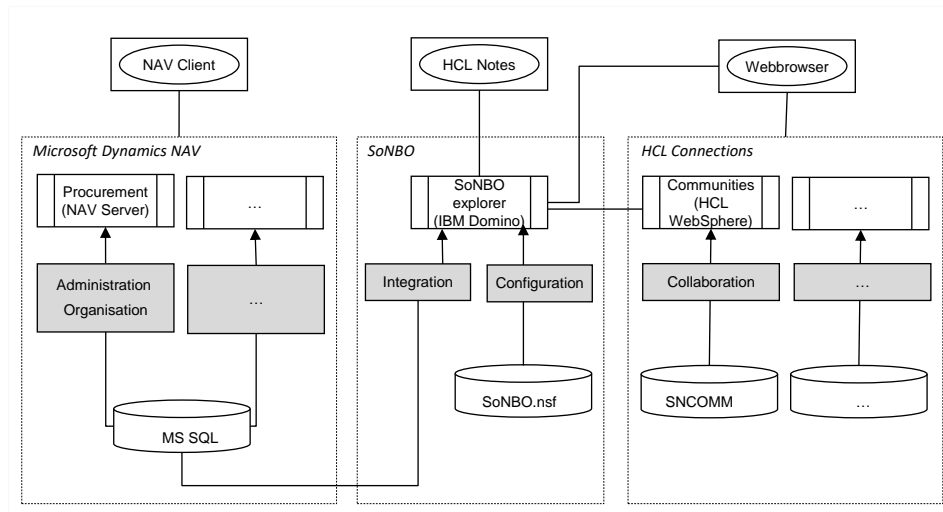


Figure 8. Application view: SoNBO Explorer and its source systems

Figure 8 shows the application view and the embedding of the SoNBO Explorer in the surrounding IT landscape. The figure uses the standard three layer architecture (client, application, database). On the left side is the ERP system, whose information is integrated with the SoNBO Explorer. The SoNBO Explorer has access to the data in the SQL database via an interface. It should be mentioned again that the SoNBO Explorer makes use of an ontology (Social Network of Concepts) to access the data and generates the Social Network of Business Object at runtime. This prevents the redundant storing of the ERP data. However, the SoNBO Explorer has a database in which the configuration (i.e. the Social Network of Concepts) is stored. On the right side is the Enterprise Collaboration System HCL Connections, in which the SoNBO Explorer is integrated. The user gains access to the information from the ERP system through the Enterprise Collaboration System.

Evaluation of the SoNBO Explorer: functionality check

In the last phase, the SoNBO Explorer was evaluated in the test environment. The evaluation was conducted with a group of eight users: three students, four research assistants and one professor. All users were familiar with the ERP system NAV. The key question for the evaluation was: Will users be able to retrieve the required information faster and easier with the help of the SoNBO Explorer compared to using the source system? To answer this question, user tests were conducted using the Think Aloud Method (Jaspers et al. 2004). For this purpose, the participants were given a set of questions relating to information in the ERP system and asked to find the answers using the SoNBO Explorer. The question "When was the last time that a customer ordered something from you?", for example, targets the use of the activity stream. When asked "When did the customer pay for an order consisting of cooking spoons?", the test candidates were meant to find the answer using the recent events component. The outcome of the evaluation was

positive and the feedbacks indicated that the SoNBO Explorer provided the required information in a fast and efficient way.

Deployment of the SoNBO Explorer

The SoNBO Explorer was subsequently deployed and is now available as a demo application in the research group. It is not used for every-day operations because the ERP system MS NAV is only used for teaching.

Conclusion and Outlook

In this paper, we discuss how concepts from computer science (especially the Enterprise Knowledge Graph) can be applied to the domain of ERP systems as a means of information integration. We demonstrate how an EKG (we call it Social Network of Business Objects) for a concrete ERP system can be identified, modelled and finally configured in the SoNBO Explorer. With the help of the concept of "social profiles" the business objects stored in the relational databases of an ERP system "become social".

The main contribution of this paper is a process model that contains six generic steps which are necessary to develop and apply a Social Network of Business Objects for an organisation. The steps comprise a business and system analysis, the identification of social concepts in the existing information systems (which are then described in an ontology), the configuration and evaluation of the SoNBO Explorer and the final deployment in the organisation.

The process model is generic and we believe that it can be used for other ERP systems as well as other types of business software (e.g. CRM systems). It is technology-agnostic (independent of a specific technology or commercial software product). In this paper, we limited our description to a single ERP system but it is the principle idea of SoNBO that it can integrate information objects from a variety of different (heterogeneous) enterprise systems making them available in a single uniform frontend (the SoNBO Explorer).

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