Visual Analytics Supporting Knowledge Management:

A Case Study of Germany’s Federal Employment Agency

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ABSTRACT

The Federal Employment Agency developed over seven years (and still develops) a mission-critical software system that is responsible for hundred-thousand transactions each day and ensures the safe processing of more than EUR 25 billion per year. This system comprises more than 718.000 lines of code and the development team consists of approx. 90 developers. The main problem in this project is that isolated and highly specialized knowledge (implementation details of Book II of the Social Code) is being developed and not sufficiently shared. For this reason, a new knowledge management system (KMS) that focuses on visualization of knowledge and that includes early warning components has been piloted. This pilot relies on Big Data visualization and visual analytics, pattern recognition (endangered code in terms of knowledge management (KM), knowledge isolation, threat of knowledge loss, lost/orphaned knowledge). KM requirements of a large authority are exceptionally high: external expertise is volatility involved and thus knowledge flows are not very stable. The pilot is intended to use computational clusters and cloud technology and is capable of analyzing and visualizing the change (volume, flow and usage) of knowledge over large periods. This paper describes the motivation, challenges, specifics, and implementation of this KMS pilot system.

CCS CONCEPTS

• **Computing methodologies → Artificial intelligence**; *Knowledge representation and reasoning*; **Human-centered computing → Visualization;** *Visualization application domains*; Information visualization;

KEYWORDS

Knowledge Management, Public Sector, Mission-critical knowledge, Big Data Visualization, D3.JS, Angular 4, Neo4J

1 INTRODUCTION

Knowledge and information play a pivotal role not only for private companies but also within the public sector. Particularly in the latter case, high volume information transfer as well as knowledge and information allocation among diverse administrative units and external partners, present major knowledge management challenges [1]. Knowledge management can be described as the integration of tools and methods that "harnesses the value of knowledge and engages it in processes with people, processes, and organizational infrastructure" [2],[3]. An appropriate knowledge management framework focuses, inter alia, on several taxonomical aspects: 1) *tacit knowledge* – which is „personal, context specific and very difficult to communicate“ [4] as well as 2) *explicit knowledge* – which can be distributed in a formal and systematic language. 3) *Individual knowledge* "possessed" by a single entity and 4) *collective knowledge* as well their goal-oriented transfer and interplay [5]. Furthermore, 5) *procedural knowledge* which is important in large projects, since it might advise how to handle diverse kinds of challenges, 6) *causal knowledge*, the "knowing-why" and 7) *relational knowledge*, which provides answers about interactions and interdependencies [6]. Thereby, especially the individually distributed and "hidden" tacit knowledge of the people is critical for successful execution of large projects [7], [8], such as in software development for public authorities. Thus, focusing on people and on the culture of public sector employees have been identified as key factors for future research on knowledge management in public sector [9].

Coming from the perspective that knowledge is as an object (e.g. [10], [11], [12]) to be generated, identified, stored, and manipulated, unveiling knowledge drain while identifying and focusing on critical knowledge bearer might support the success of large and long-term projects, in terms of reducing development times and costs. Within this, knowledge must be identified in such a manner as to be effortlessly identifiable, internalizable, and interpretable for relevant stakeholders such as knowledge and project manager as well as software developer. On the contrary, it is not valuable to identify, generate, and store massive amounts of information and knowledge just in case some might be relevant within a project [13]. It is about the identification of the right information and knowledge at the right time, since only the information is useful that will be processed for finding solutions for present or futuristic challenges [6].

McEnvoy et al. [9] conducted a broad review of knowledge management in the public sector and identified some specifics and potential for further applied research. Knowledge management research in the public sector remains limited [14] and should be conducted as a special research subject and not as a part of the private sector management research for a variety of reasons: Although the above described knowledge types are identical in context of both, the private and the public sector, public sector knowledge management cannot just adapt the private sector thinking [15]. On the contrary, the practices of sharing and transferring knowledge should be fitted to the specifics of the public sector [16], [17]. In particular, customized knowledge management systems that suit the unique bureaucratic hierarchies and cultural features should be developed [18]. Compared to the private sector, the pressure of competitiveness and the efforts to diminish costs are less important, and knowledge sharing is less evident [17]. Furthermore, public sector organizations differ from private sector organizations in goals, environment, and in political influences [16].

Especially in public sector projects, many external consultants are involved. Due to ramp-ups, ramp-downs, or the fact that one or the other consultant is leaving an assigned project, project relevant knowledge is fluctuating and drains-off. This results in the need for an early warning system, which is able to identify knowledge monopoles, flows, critical knowledge bearer and which is able to point out options for actions. Therefore, goal of this contribution is to present a knowledge management system (KMS) on behalf of a case study, which helps to understand the public authorities' knowledge position and its critical knowledge resources by visualizing the development, atrophy/degeneration, and endangerment of knowledge in such highly business critical projects.

The remainder reads as follows. Section 2 provides some background information about knowledge management, knowledge management systems and challenges that occur while their implementation. Section 3 describes the initial situation in the use case. Section 4 introduces the methodical approach and section 5 describes the KMS pilot system. Section 6 illustrates its functionalities within diverse application cases. The contribution closes with a discussion and outlook (section 7).

2 Background

Knowledge may be viewed from diverse perspectives: 1) as a state of mind, 2) as an object, 3) as a process, 4) as a condition of possessing access to information, or 5) as a capability [6]. The first view understands knowledge as a state of knowing and focuses on enabling individuals to expand and apply personal knowledge [23]. Considering knowledge as an object grasps knowledge as a thing which can be generated, identified, stored, and manipulated [12]. Here, the role of information technology (IT) involves gathering, storing, and transferring knowledge. Alternately, knowledge can be described as the simultaneous process of knowing and acting [24]. According to this view, knowledge enables acting via applying expertise. The view of knowledge as a condition of access to information focusses on the organization of knowledge and, within this, on the accessibility of knowledge objects [11]. IT needs to provide effective search, visualization, and retrieval mechanisms. Alternatively, knowledge can be seen as a capability with the potential for influencing future actions, emphasizing on the capacity to use information [25].

Inter alia, processing and transfer of *explicit* and *tacit* knowledge requires the development of different methods and approaches in consideration of their specific features. Explicit knowledge (or information) e.g. can be transferred by communication, by numbers, pictures or language. It can be processed, altered and learned together [19], [20]. Tacit knowledge, on the other hand, is seen based on but not equaled with information and is person-bound and very difficult to articulate.

Additionally, the process oriented knowledge management addresses organization specific taxonomical knowledge aspects, as described in the previous section. Regarding the public sector in particular, *procedural* knowledge, *contextual* knowledge (about relevant legal and political aspects and decisions), and *content* knowledge (about facts and rules) have been pointed out as essential [21], [22].

Voigt [21] points out some knowledge management relevant features of the public sector: 1) in contrast of the profit-oriented private sector, the public sector is saving-oriented and under a constant cost-pressure; 2) the public sector is characterized by a high employee turnover; 3) the public sector acts in the role of a service provider for citizens and enterprises, whereby the quality of the services depends on the quality of process relevant data and information.

Ihringer [1] identifies some public sector typical knowledge management instruments: e.g. experts list, web based portals, document management, business-intelligence, decision-support, controlling systems. However, as most important she points out the development of solutions for bringing experts together and supporting collaboration and communication processes. According to Barachini [27] focusing on people is also a key factor and a big challenge for public sector knowledge management future research. One explanation is, that Individuals generally do not offer knowledge freely. Furthermore, there might exist some differences in the employee characteristics of private and public sector organizations [28]. Another important point is the resistance that is encountered in public sector organizations, when attempting to adapt the cultural characteristics of the private sector [29], [9].

Ihringer [1] further more points out the following challenges regarding the development of appropriate knowledge management solutions for public sector organizations: 1) The consideration of all knowledge management core aspects: technology, people and organization. Focusing on solely one aspect is not sufficient for proper knowledge management and to gain or sustain competitive advantages, it is rather the interaction between technology, people, and techniques that enables effective knowledge management [26]. In addition to this, the strategy of the organization as well as the public sector specific goals should be taken into consideration; 2) The establishment and the support of networking and semi-structured knowledge transfer activities; 3) The establishment of learning processes; 4) The development of customized technical solutions.

The last point in particular builds the focus of this contribution by describing the development of a cloud-based knowledge management system for one public sector authority.

KMS, Cloud Computing and Visual Analytics

Given the complexity and variety of knowledge management relevant aspects in organizations on the one hand, as well as the huge amount of data and information on the other hand, information systems are often implemented in order to support the organizational knowledge management by providing platforms for exchange, retrieval, storage, usage, and visualization of knowledge. Generally speaking, to such kinds of platform is usually referred to as knowledge management systems (KMS). A knowledge management system is an information and communication system that combines and integrates functions for the structured and contextualized handling of organizational explicit and tacit knowledge [30]. Thus, they refer to a class of information systems applied to manage organizational knowledge. They are developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application [6]. Their basic functions include content management, information retrieval, visualization and aggregation of knowledge, and collaboration. Since nowadays collaboration is often characterized by distributed work without any timely limits and cloud computing facilitates, inter alia, scalability, cost-efficiency, availability, and location independence, there exist a tendency towards cloud-based KMS.

Cloud-based KMS provide services, such as searching and retrieving necessary information anytime and anywhere or knowledge sharing and reusing in distributed environments that are not feasible in many conventional knowledge management approaches [31]. Additionally, the handling of big data and application of respective analyses is enabled by a cloud-based KMS [32]. Cloud-based knowledge management systems are more effective and user-oriented distributed KMS solutions in organizations that are generally provided to the users as Software as a Service (Saas), whereby the provider uses Infrastructure as a Service (IaaS) for hosting the cloud-based KMS. The third basic principle of cloud computing (Platform as a Service) allows user-individual customization of the KMS. In addition to these conventional layers, Tsui et al. [31] propose a new service layer named Knowledge-as-a-Service (KaaS) which facilitates the management of personal knowledge, i.e. information retrial, evaluation, and organization of knowledge. Cloud computing enables new models of KMS, integrating additional systems, collaborating with other organizations and facilitating knowledge exchange [33]. The cloud offers infrastructure services (e.g. storage and communication), knowledge services (e.g. knowledge creation, sharing, and reuse), and platform services (e.g. databases) [34] and allows knowledge worker to integrate external content via Web 2.0 tools as well as building up their own knowledge facilitating environment. Thereby, they can easily access various Cloud service platforms and resources through the Internet to obtain their KM demand [35]. Resources are accessed via user interfaces and, thereby, intelligent guidance via the knowledge creation process is provided.

Keim, Mansmann, Schneidewind, Thomas, and Ziegler [36] describe Visual Analytics as an "iterative process that involves information gathering, data, preprocessing, knowledge representation, interaction and decision making." In order to solve a given problem, "visual analytics combines the strengths of machines with those of humans". In the presented case the problem is the volatility of external knowledge that is critical to ALLEGRO and the combination of both abilities, of human and machine, is performed by the developed pilot, which will be described later. Data Mining is a key pillar of Visual Analytics – it "automatically extracts valuable information from raw data by means of automatic analysis algorithms" [37, 38]. In the era of Cloud Computing, entirely new possibilities have opened up for extraction and analytical processes of Data Mining. The processing algorithms are computationally very intensive and have high hardware requirements, which easily can be covered by Cloud Computing. It is not without reason that Visual Analytics increasingly become offered as Cloud Service.

The scope of Visual Analytics in this project is illustrated by Figure 1. We develop a pilot that detects need for knowledge management measures and issues early warnings.

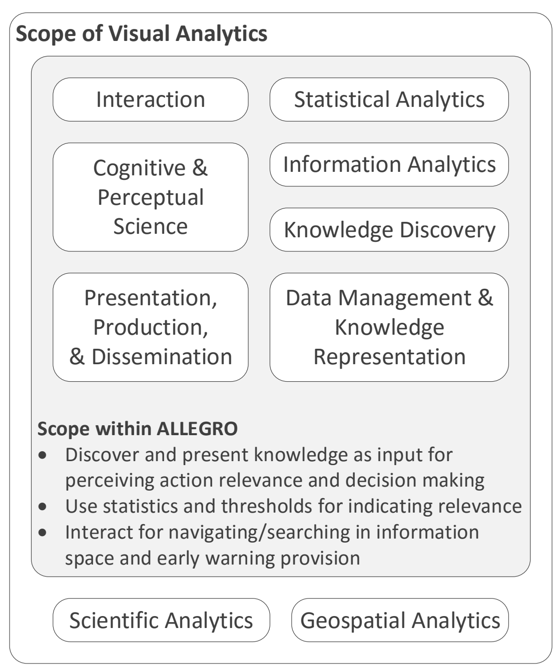

Figure 1: Scope of Visual Analytics [36] applied to ALLEGRO

The topics of this section – knowledge, knowledge management in public sector as well as the role of KMS – provide the necessary framework for the description of the case study and the solution developed within the following sections.

3 INITIAL SITUATION

In the following, the initial situation of the underlying case will be described. Object of investigation is a huge knowledge management project at Germany's Federal Employment Agency (FEA), focusing on the development of an application that aims to improve the identification, visualization, conservation, and sharing of knowledge.

Germany's Federal Employment Agency employs more than 96.000 people and operates one of the biggest IT-infrastructures in Germany, with more than 160.000 networked PC-workplaces, 9.000 servers, two main and several regional data centers. The huge amount of processed data includes email, bank transfers, mails and print products.

Over the last seven years, the FEA has developed (and still develops) the mission-critical software system ALLEGRO. ALLEGRO is an acronym and stands for "Arbeitslosengeld II Leistungsverfahren Grundsicherung Online" (Unemployment Benefits II Performance Benefits Basic Provision Online). The system is responsible for hundred-thousand transactions per diem and ensures the safe processing of more than EUR 25 billion per year. It comprises more than 718.000 lines of code, whereby the development team consists of approx. 90 developer.

ALLEGRO is the core system, with which more than 30,000 power users in Job Centers (nationwide more than 300) work to ensure the monthly basic income in Germany. The software is responsible for retrieving, administrating and processing the data, calculation of unemployment benefits and duration, as well as payment orders for benefits under Second Book of the Social Code (SGB II), reporting and payments to social insurance funds, preparation of decision, including central and decentralized printing. ALLEGRO carries out monthly payments of several billion euros for approx. 3 million benefit communities (approx. 6 million people in benefit communities). ALLEGRO is developed by a 200-strong project team (including requirements engineering, development and test sub teams) with continuous update of development and test environments with over 10,000 updates in a four-month delivery cycle.

It is usual in such huge projects, in private as well as in public sector projects, that external knowledge from external providers including specialized experts / consultants is involved. Due to alternating ramp-up and ramp-down phases and due to the fact that in natural rhythms external personnel is changing projects of their own volition, knowledge bearer are fluctuating and especially knowledge flows are very volatile. Additionally, the situation is characterized by peaks and lows of these knowledge flows and knowledge objects (artifacts, documents, source code, etc.) may be leaved untouched for a while. Thus, the familiarization with these knowledge objects is complicated and time-consuming without the necessary relational and causal knowledge which mainly is or was available as tacit knowledge.

In a large and mission-critical system like ALLEGRO, source code areas arise that are rarely touched but yet of fundamental importance. It is decisive to identify these areas and to be able to (re)act early, for example initiating knowledge transfer at an appropriate early moment or to develop knowledge in such areas, where knowledge needs are high or anticipated to be high.

Functional changes of the system are initiated by specialized departments of the central office in Nuremberg and each Request for Change (RFC) requires specialized skills and a RFC can / should only be authorized when the required knowledge is available.

4 METHODICAL PROCEDURE

As described above, the FEA is responsible for a huge amount of critical data and information, with a high relevance in both contexts - while acting as a 1) employer as well as a 2) service provider. Against this background, an appropriate knowledge management framework has been established and provides a well-structured approach for the identification of knowledge management challenges and the development of best possible strategies and concepts.

The case study presented here represents, inter alia, an interesting knowledge management phenomenon: In order to develop a solution for the challenge of dealing with the huge amount of specific information and data (as one knowledge management topic), the FEA started the development of the core system ALLEGRO. However, given the project specifics described in section 3 (e.g. the importance of tacit knowledge and collaboration, relevance and fluctuation of external experts), a new important knowledge management challenge has been identified – the management of ALLEGRO specific knowledge and information and the success assurance of this very knowledge intensive software development process.

The methodological procedure of the presented project in ALLEGRO consists of the three main steps: (1) interviews and participating observations, (2) identification of critical knowledge and risks, and (3) development of an visualization and early warning system. In order to evaluate the current state of the software development project, interviews have been conducted as well as participating observation have been made. As a next step and as part of the second phase, the importance of external knowledge as well as the risks of knowledge loss have been identified. Within the third phase, the development of an early warning and visualization KMS has been pointed out as a strategical knowledge management goal in the ALLEGRO context.

5 THE PILOT SYSTEM

The pilot system is an internal system which enables the investigation and visualization of several knowledge management issues within the software development process of the ALLEGRO system. This KMS pilot is a web application running on a Jetty server that uses Angular 4 in combination with D3.JS. D3 (Data-

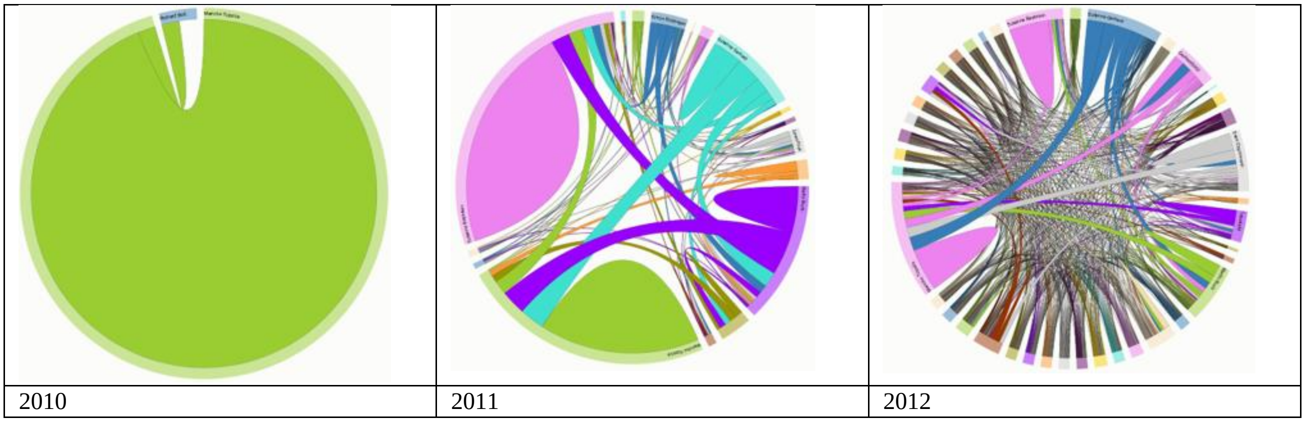

Figure 2: Timeline of commonly developed knowledge

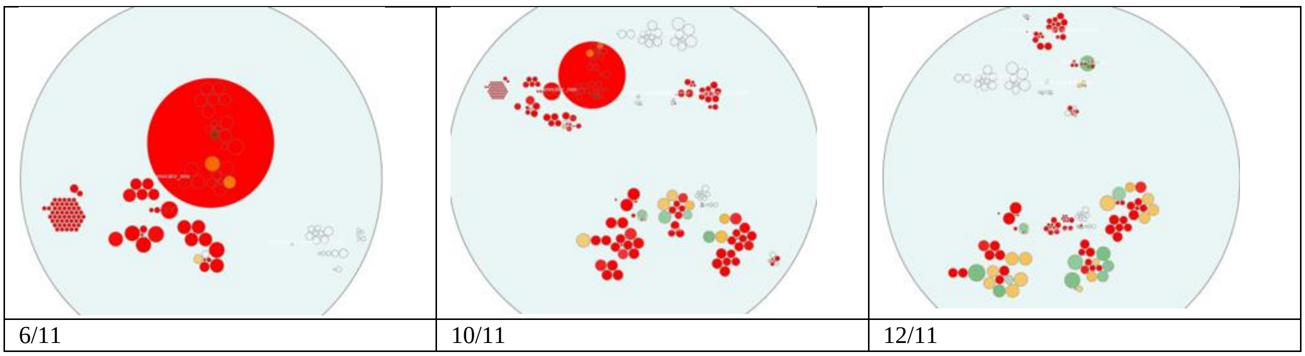

Figure 3: Timeline of individual-centric knowledge development from 06/11 until 12/11

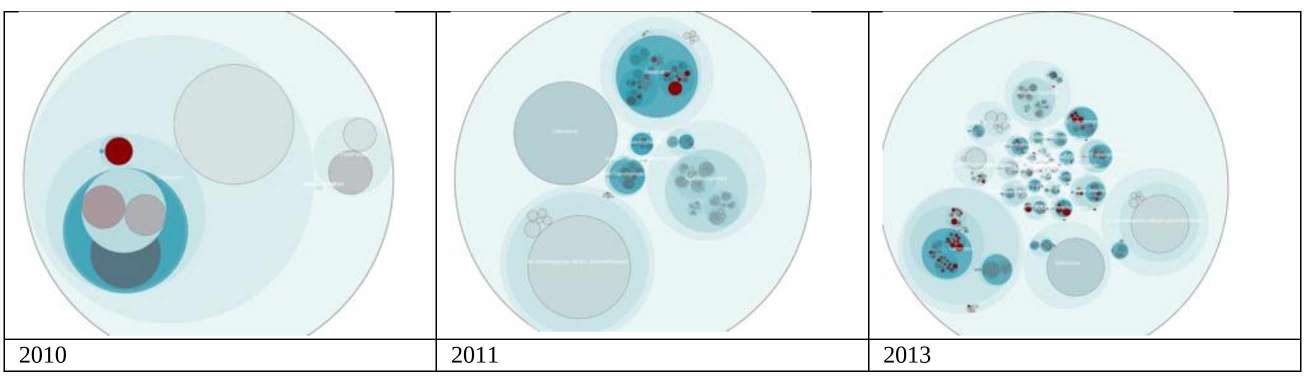

Figure 4: The Pilot's Hot Spot View displays knowledge areas (darker), in which knowledge is heavily developed

Driven Documents) is a JavaScript library for visualizing large data using web standards. It provides graph components that are suitable for visualizing the knowledge objects collected in the KMS pilot. In Figure 2, Figure 3, and Figure 4 screenshots are given, which comprise different D3 views that are provided by the pilot. These views relate to the use cases described later in section 6.

The architecture of this KMS pilot consists of four main layers, a web-based frontend, a service layer containing RESTful Web Services, a data layer that is based on the native graph database Neo4J and a layer comprising backend processes that insert data into the graph database. Figure 5 shows the Architecture of the KMS pilot. The backend processes include connectors, which incrementally import data from the modeling tool *Innovator*, from the *Confluence* server and from the *Gerrit* Server that is connected with a Git Repository. *Gerrit* is a temporary repository, into which developers commit their code for review loops. After the review process is complete, the code will be merged into the central Git repository. *Innovator* is a modeling suite that is widely used at the

FEA. The creation process consisted of two different steps. Firstly, the requirement engineering team has modeled the application, processes and use cases, then, secondly, the development team has transformed the models into code.

The web-based frontend is running on an integrated Jetty server – a Servlet API 3.0 compliant web container. The frontend builds on the Angular 4 Architecture Stack including D3 graph components for Big Data visualization [39]. These graph components used by the frontend fit to the architectural approach of using Neo4J in the backend. Since the knowledge gathered (not only in ALLEGRO) consists of entities such as individuals, key persons, artifacts, knowledge areas and relations between them, a graph database is the best choice for the pilot's data layer.

The service layer includes RESTful Web Services, which provide the knowledge related data that is required for visualization to the frontend. To put the interaction of the components together, the knowledge data collected at the backend is imported into the Neo4J database. Then, the services select this data upon requests which are made at the frontend and provide it to the D3 components located in Angular based frontend.

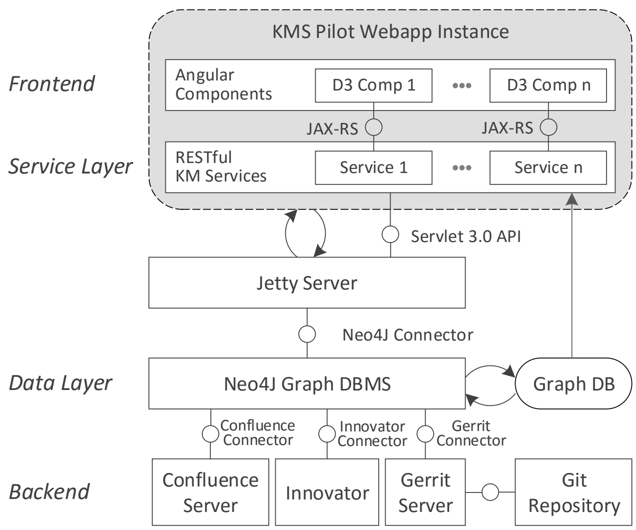

Figure 5: Architecture of the KMS Pilot

6 USE CASES

There exist many use cases for the KMS pilot. Three of them are reflected by Figure 2, Figure 3, and Figure 4. In the following, the most essential cases for ALLEGRO covered by the KMS pilot are described:

Identify and visualize commonly developed knowledge in clustered knowledge areas: This use case relates to Figure 2, which visualizes how *collective* and *relational* knowledge has been commonly developed along three years. The outside edge of the circle represents knowledge holders, in this concrete case committers of ALLEGRO source. A diagonal line between two or more committers means, that these persons have worked (effectively together) at the same area and edited collocated code fragments (classes, methods, etc.).

Identify and visualize knowledge developed by an individual: Figure 3 shows the development of *individual tacit* and *explicit* knowledge of a person. The Diameter represents the modified total lines of code in one code area. Circles that are located in the same encompassing circle are classes within the same package, which is represented by the encompassing circle. The color red means a code ownership belongs to solely one person. The color yellow means that more persons are involved (knowledge is shared) and, thus, visualizes *collective* knowledge. The color green means that many persons are involved (knowledge is sufficiently shared in a collective body).

Identify hot spot areas of knowledge: This case is demonstrated by Figure 4, which displays the pilot system's hot spot view. The diameter represents the volume of lines of code in a knowledge area. The color is darker, the more commits in this area exist. It is possible to show, how the focus on areas is shifting, by visualizing the timeline not additively – each year can be analyzed separately by not including commits from the prior year. Another hot spot metric would be a quotient of total number of commits and the number of commits in an area. This view represents a starting point for the investigation and visualization of *causal* knowledge.

Identify experts and key players / bottlenecks: The analysis of crawled documents, commit history and reviews provides an overviews of key individuals that have specific *tacit* or *explicit* knowledge in distinct areas. Another view of this analysis depicts the degrees on how given knowledge areas are covered.

Identify and visualize the delta between knowledge need and supply automatically: Matching the search queries (sorted by frequency) in the organization-wide Wiki, Confluence and Knowledge Portal with the delivered search results gives a strong indication of a delta between knowledge needs and knowledge supply (between suppliers and demanders of knowledge).

Identify relations between knowledge of a same area that is scattered across disciplines: This is accomplished by crawling document's metadata in the file share that is commonly used by the requirements engineering team, test team and design & implementation team including matching this metadata with those of commits. The result allows us to predict for the next release, if the design and implementation team will run into a bottleneck of required knowledge. The pilot extracts diverse knowledge areas from requirements engineering artifacts and thus several taxonomical aspects of knowledge, focusing on *relational* knowledge. The RE team is currently working on the next release and compares these knowledge areas with the available knowledge in the design and implementation team.

Identify newly created knowledge: By analyzing the content creation and history in the organization-wide Wiki, Confluence, and Knowledge Portal the pilot enables to gain a big picture of the knowledge development in existent areas and emerging new areas of knowledge that becomes relevant for various teams. This identification of new knowledge is not limited to content analysis, but also include the analysis of models, which are created by the requirements engineering team using the *Innovator* modeling tool. Hence, this function addresses the dynamics of the knowledge creation process.

Enable better staffing: Since the pilot is able to visualize and highlight knowledge areas that are insufficiently covered, personnel can be recruited and/or skilled in such areas as well as staffed for specific tasks.

Graph based knowledge queries: As described, the database is a graph database storing the current knowledge available in ALLEGRO. This allows for the formulation of knowledge queries involving specific knowledge objects that are interconnected. For instance, it is possible to query knowledge holders including their connections respectively people, with which they share their knowledge.

7 EVALUATION

For the purposes of validation and continuous improvement, the developed pilot has been shown and exemplarily tested by various members of ALLEGRO including developers, knowledge managers, and project managers during the development and test phase.

The following benefits have been empirically collected by within the validation activities. In the inner core, they can be summarized as follows:

Knowledge Managers get a holistic and atomic overview of the organizational knowledge situation. Thy can trigger, both the project management and the developers to take appropriate action, as for example to share their knowledge or to provide capacity for counter actions against loss of knowledge.

Project Managers gain a basis for deciding on measures such as providing budget for knowledge acquisition and transfer, for investing in externalizing, sharing or renewing knowledge.

Developers are able to see what kind of knowledge will be required from them and they may prepare themselves by participating at training, skill themselves in areas of knowledge that will become relevant for them.

Resilient sources of benefits have been empirically identified. However, more beneficial elements will emerge in daily usage of the pilot system, especially when it becomes more sophisticated and established.

8 DISCUSSION AND OUTLOOK

One of the most influential and charismatic researchers in the field of knowledge management describes the essence of knowledge creation as an "endless innovation" [4]. In organizations, to enable and support the creation of knowledge on individual as well as on organizational level remains to be one of the biggest challenges, however, in congruency with the awareness regarding its hidden innovation potential.

Within this contribution, one positive example of the appropriate balance between organizational knowledge management support and individual creativity and innovation power has been described. The development of an early warning KMS that incorporates Visual Analytics has been initiated bottom-up as an answer towards concrete challenges within the very knowledge intensive project ALLEGRO. However, the well-established and structured knowledge management framework of the FEA builds the basis for immediately support and establishment of appropriate activities in order to meet these challenges.

Given the specifics of *procedural* knowledge as implicitly embodied in individuals, the key source for the identification of critical process success factors have been the internal and external experts involved within the ALLEGRO project. The described use cases of the pilot system address all relevant taxonomical aspects of knowledge in the present context - *tacit*, *explicit*, *individual*, *collective*, *procedural*, *causal* as well as *relational* knowledge, by supporting the handling with both, *knowledge objects (*such as documents and data) as well *knowledge subjects* (collaboration and communication, learning processes and competence development). Furthermore, the pilot project and its results are one appropriate response to the actual knowledge management challenges within the public sector.

Due to the size of ALLEGRO – the software system’s size, the number of team members, and the knowledge involved – this project provides an appropriate volume of data to be processed and visualized by the KMS. The pilot currently provides very useful insights into the FEA’s situation of available, emerging, fluctuating and required knowledge. However it has not already reached its full potential. The system is not yet (but should be) available as a mobile application, in order to be usable on any device. This would fit to the FEA’s “Mobile First” strategy and take advantage of the used technology stack of REST and Angular 4. In its current state the pilot is internally used for investigating knowledge developments within the software development of the ALLEGRO. Within the close future, the pilot should be available and, thus, applicable to all projects in the FEA. In terms of pattern recognition, there are also some development possibilities. In future, the pilot should represent a Knowledge-as-a-Service platform that incorporates machine learning and In-Memory technologies in order to provide stronger insights into the FEA’s knowledge situation.

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