

# Understanding User Requirements in Context: A Case Study of Developing a Visualisation Tool to Map Skills in an Engineering Organisation

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**Abstract**—We provide a case study of understanding the environment and work context of a visualisation tool used in a collaborative engineering organisation, in order to inform the design, development and evaluation of a software network tool that uses a novel algorithm to search knowledge topics in a document corpus. We utilise focus group and qualitative interview data to understand the dynamics of existing knowledge searches and the visual analytics process of collaborative working environments in an engineering domain. We discuss the enablers and functionality needed in the network tool, and the envisaged challenges in its implementation. These challenges and enablers of a knowledge management visualisation software are then discussed in relation to evaluating the tool in a way that is grounded in the contextual working environment in which it will be used.

**Keywords**—network visualisation; knowledge management; social collaborative systems

## I. INTRODUCTION

It is widely recommended that requirements be derived from understanding the people and practices in which a software tool is being designed for [1]. For information and knowledge visualisation designers there is a need to understand the context in which the visualization tool will be used [2]. However in terms of understanding the development of information visualisation in a workplace [3, p7] it has been noted “hardly any papers devoted solely to analysis at this level [problem characterization] have been published”. It has been maintained [4] that studying people and their task processes is still rarely carried out and there are only a few exceptions of academically published research. A first notable example was research [5] that sought to design information visualization tools for collaborative use and derived a framework that captured the analysis activities of co-located teams and individuals. Another example [6] conducted an ethnographic field study examining the ways in which building design teams used visual representations of data to coordinate their work. Furthermore there have been other contextual understanding of information visualisation in work practices but this has sought to evaluate software rather than to design software. For instance field observations [7], in which eight experts were observed in their workplace. Interviews [8], in which geo-visualisation experts were interviewed to learn about multi-disciplinary collaboration. As well as laboratory observations [9], whereby the ways in which people interacted with

visualisations were studied. Additionally there have been others who have evaluated visualisations in context using quantitative methods (e. g. [10] and [11] etc.).

The aim of this paper is to work towards a contextual understanding of the challenges and enablers of knowledge visualisation design in practice. Knowledge visualisations, in distinction to information visualisation, are the examination and use of visual representations to improve the transfer and creation of knowledge between at least two persons [12, 13 and 14]. We seek to understand the business context, social dynamics and work environments in which knowledge searching occurs and how a knowledge visualisation tool can exist within current organisational practices.

## II. KNOWLEDGE MANAGEMENT VISUALISATIONS IN ORGANISATIONS

Knowledge Management has been defined as a “management perspective that offers theories strategies and methods to manage, i.e., to identify, access, share and create knowledge in organizations, with the aim to help an organization to compete by being more innovative, effective and thus more profitable.”[15 p239]. It is a concept that stems from organisational learning [16, 17 and 18], and sees knowledge as a key productive and strategic resource in an organisation [19, 20, 21, 22]. Although there are many diverging perspectives of knowledge, knowledge management can be seen as having three main objectives: 1) optimizing processes 2) introduction of systems for storing, identifying, retrieving, and gaining access to information 3) development of a corporate knowledge culture. It can also be categorised as containing four main processes [23]: 1) creation 2) the storage and retrieval 3) transfer and 4) the application of knowledge. In this paper we consider knowledge management visualisations within an engineering organisation. The visualisation tool we discuss aims to address the intentions of knowledge management, and specifically at the retrieval of information (the second knowledge management process – [23]).

In most knowledge related activities, the knowing of what others know is a necessary component for coordinated action to take place (e.g., [24]). As Busby stated, “learning from experience, and attending to the consequences of one’s work, are strong norms in design organisations” [25, p103]. This means that effective knowledge creation and sharing require that the points of view of others be realistically

imagined [26]. Therefore individuals working for an organisation need to communicate with each other by a number of different means, such as face-to-face conversations, telephone, electronic mail, ordinary mail, etc.

The performance of an organisation can be improved by helping workers learn more about one another so that they can make better use of the company's human resources [27 and 28]. Among these resources, the work related knowledge of team members, often referred to as the team's intellectual capital or knowledge assets, is important.

A typical situation has been that the stored knowledge is retrievable only when an individual knows what it is and where it is. In the search for a solution to a problem, for example, an individual team member may know what the problem is but not know the possible solution. The successful retrieval of the solution thus requires the prior knowledge of what might be the solution and where the solution might be. This means that knowing where a possible solution is to be found can be more important than merely knowing the solution [29].

However, the amount of data organisations has been exploding, beyond the capability of human cognitive processes. Analyzing large data sets—so-called big data—has become a key basis of competition, underpinning new waves of productivity growth, innovation, and consumer surplus [30]. Analysis results of big data give meaningful quantitative base for further qualitative understanding for transferable meaningful knowledge.

According to boyd and Crawford [31] big data is, in many ways, a poor term. Manovich [32] observes, it has been used in the sciences to refer to data sets large enough to require supercomputers, although now vast sets of data can be analyzed on desktop computers with standard software. Big data is notable not because of its size, but because of its relationality to other data. Due to efforts to mine and aggregate data, big data is fundamentally networked. Its value comes from the patterns that can be derived by making connections between pieces of data, about an individual, about individuals in relation to others, about groups of people, or simply about the structure of information itself [31]. Therefore, we see that this would be an important new area to explore in connection to network relation and knowledge management in organisations.

### III. THE CASE STUDY

In this paper we introduce a case of an engineering Catapult organisation within the U.K. The Catapult in question is a collaborative engineering workplace that contains several technology companies, research and development laboratories, design and engineering departments, and joint research facilities with universities. The Catapult provided us as researchers a textbook example of a collaborative engineering workplace with its advantages and with its challenges in co-creation and collaborative engineering work.

In order to understand the contextual requirements of the network knowledge tool, seven formal documented interviews were carried out, recorded and transcribed. The formal interviews, in general, lasted approximately an hour

in length, and provided an understanding of how knowledge is gathered currently within the Catapult, the social dynamics of searching for knowledge in a large organisation and the overall requirements for the tool. A framework for the interview questions was based on questions for understanding environments and work practices [4]. The interviews were then coded in Nvivo using a grounded theory [33] approach to elicit themes and generate hypothesis.

The interviewees described how and why individuals sought knowledge and people with skills. Scenarios that were envisaged in the interviews included: firstly a new staff member wanting to know about an area they have been tasked with, a staff member who has been with the organisation for some time, but wishes to know about a new subject area. The executive team who wish to understand the landscape of the organisation and where skills are lacking or abundant, or how the skill set of the organisation is changing over time (what are the new skills emerging or what the organisations core skills are). Finally the allocation of people to projects based on their knowledge of certain skills. This scenario is described in more detail in Table I.

Additionally a focus group was conducted to test the prototype. This consisted of 5 people, over an hour-long session, who were asked to pretend to act out the four scenarios outlined from the interviews. The focus group aimed to discover if the participants would gain insights from the visualization tool. The questioning framework [34] sought to ask the participants to formulate questions about the data that they expected the visualization tool to answer.

TABLE I. EXAMPLE USE SCENARIO

Goal	To identify the internal capabilities within the Catapult.
Sub-goals	<ul style="list-style-type: none"> <li>● To show clusters of capabilities.</li> <li>● To search for potential capabilities within the Catapult.</li> <li>● To show dominant capabilities.</li> <li>● To show where capabilities are lacking in the organisation.</li> </ul>
Main actors	Engineering Capability Managers (ECMs).
Pre-conditions	<p>A new project or idea has been put forward.</p> <p>Resources need to be allocated, particularly for Category 3 and 4 projects where risks are higher (greater costs/resources and less precedence than Category 1 or 2 projects).</p>

#### A. Description of the Software

Prototype network visualization was developed to address the use-case scenarios outlined in the interviews. Data was taken from the organisations' document corpus of completed project reports (that do not contain sensitive information which cannot be shared). Using this data, a

novel algorithm was created which pulls topic themes, the reports they appear in and individuals associated with the reports. This involved the creation of a bi-grams/tri-grams of words that had formed from a rule base strategy:

- could not have any stop words
- alphanumeric
- appeared between a set number of the document corpus (as we were looking for words that could be used to group the documents)
- appeared a minimum number of times

The resulting data was then filtered to remove those bi-grams/ tri-grams skills that had a low edge weighting (skills that weren't linked to many other). This allowed isolated skills to be removed. Hierarchical clustering analysis was carried out to identify groups of skills and to further allow the topics to be grouped and for themes to emerge. This data was converted into a graphical file for conversion into a web based (NetworkX) tool. The network visualisation showed the clustered terms, which reports the terms featured in and who were the authors of the reports (fig 1). This allowed the user to ascertain who has a skill within the organisation because of their contribution to a report that includes reference to that skill. The centrality and density of each cluster was calculated to enable the identification of innovative new skill areas, and established core skills areas.

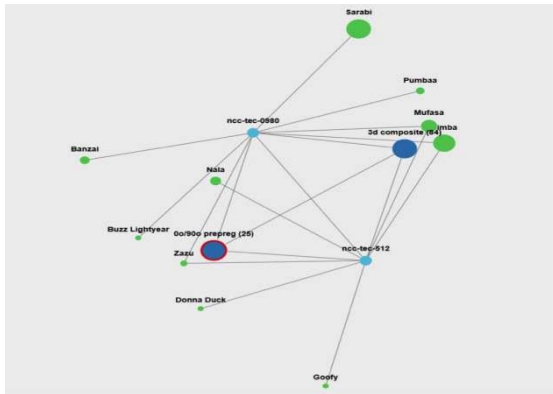


Figure 1. Screen shot of network visualisation (dark blue node=topics, light blue node=report. and green node= anonymised person)

### B. Dynamics of Accessing Knowledge Digitally

In this paper we focus on the qualitative requirements of the data, which would be needed. In order to be able to collect a large amount of data (often called big data) from different organizations, the data would need to have certain features. Secondly in order to share this data there are challenges exhibited from the different values and cultures of collaborating companies.

The Catapult centres provide businesses access to manufacturing talent and facilities, with its aim being to rapidly allow prototypes to be tested and brought into the commercial domain whilst also allowing for scientific expertise to be accessed. However as the Catapult has grown it has become difficult to know the capabilities of the whole organisation and its staff. This has resulted in a knowledge-sharing problem.

Currently data, in which knowledge resides, can be found in various forms in the Catapult but is perceived to be found on their intranet. However strategies to access data usually involved web searches, extractions of academic papers and then accessing people via email prior to accessing internal knowledge sources. The interview data suggests people tend to carry out wide knowledge searches (utilising google etc.), then people with specific knowledge before turning to internal documentation. However to comprehend the internal documentation also requires ‘pointers’ by key individuals that are known to them. It was generally felt that the internal documentation system was not good enough to search for skills and topics within the organization and supporting knowledge in the Catapult through the use of technology was not straightforward. A summary of the emerging themes found from the interview data were:

- Searching for knowledge through internal technical means is a low priority choice. People preferred to talk to knowledgeable people face-to-face.
- Persons are sought for ‘lessons learnt’ type knowledge.
- New starters may traverse the network differently unless guided (e.g. by knowledgeable people who sit near them, or fortuitous contacts).
- The importance of access to knowing who to contact (what they look like, who they work with, where they sit).
- High level (skimming) processes are carried out to scan documents (save time).
- There are bureaucratic hold ups to implementing knowledge management in socially complex environments.
- Confidentiality a major hurdle for accessing knowledge.

The inter-relationship between companies at the Catapult are complex, with influence, interpretations, and the needs of individuals often competing or generating conflicting accounts. This makes the task of understanding a network of knowledge within the Catapult all the more difficult. It also makes the development of software for that task equally as problematic. This is compounded if the engineering activity does not occur through a technological medium and knowledge is gained tacitly. Searl [35, p4] noted, “complex social structure of reality is, so to speak, weightless and invisible”. This requires a software solution that maps people and associated knowledge that may be compartmentalised into knowledge areas that may shift over time and whose capabilities may not be formally documented. The attribution of people to capability may also not be formatted in a meaningful way to access implicit knowledge. The prototype software is based upon individuals and their associated knowledge explicitly referenced in project report documentation. Tacit knowledge would need to be elicited by liaising with staffing (based initially on their explicit knowledge as documented in project reports). However there are particular issues for new starters and how they approach searching for knowledge and where to start the search. Even persons who have been in the organisation

for a while struggles to know the best avenue to take, especially if (key) people leave, there is a significant change in a person's skill set and if people move from where they usually sit.

### C. Knowledge Sharing

In the Catapult there are many challenges to sharing knowledge and learning. Firstly, issues relating to information sharing and the Catapult's growth in size. In large communities no-one can know the whole organisation. Large collaborations require some kind of division of labour, and that people perform their role at a specific time. In contrast an individual could not achieve large undertakings alone, group creativity enables a project to be divided and allocated to individuals with specific skills to meet the task at hand. To a certain extent this kind of set-up can be achieved in formal collaborative teams, with people working for the same company. However with organisations like the Catapult, "fields" of engineering expertise exist within a complex network of collaborating companies that are working within the umbrella organisation of the Catapult.

Furthermore as the Catapult has grown it has become increasingly more difficult to access knowledge. In particular, who has the knowledge in the organisation, and who is aware of that knowledge. Managers and engineers are unaware of what other engineers are doing. Managers in Catapults may not be aware of where skills lie in the wider organisation, where capabilities are missing or interrelate to each other. This requires the automatic extraction of data from sources that gives an indication of where knowledge lies, without a human gatekeeper knowing where capabilities lie and acting upon that knowledge to fulfil project demands.

Consequently people tend to work in silos, working in day-to-day teams of a size that are manageable to their knowledge base. The challenge in the Catapult is how to break boundaries between these silos. In the Catapult, these silos can form around distinct companies that are part of its organisation. However lessons can be learnt from knowledge in each distinct company, even if that knowledge may be company or product specific (assuming there are no security issues in sharing certain company specific knowledge).

## IV. CONCLUSION

Collaborative engineering environment such as the Catapult aim to gather, leverage and analyse their internal data to enable insights that will help their business practice [36]. Business intelligence and analytics, such as the internal reporting strategy and its associated knowledge at the Catapult, allows for the transformation of data into a visualisation and to draw data-driven insights [37]. However, many business intelligence and visualisation tools do not focus on the context in which they being used. It has already been maintained [4] in information visualization research studying people and their task processes are rarely carried out, except for a few exceptions [e. g., 5 and 6]. Consequently, this paper aims to outline the context of a novel knowledge extraction method and associated management visualisation tool used in a Catapult. The needs, requirements and functionality of the knowledge network

tool are provided in this paper, as are the perceived challenges to its implementation. This understanding is grounded within the business environment in which the software is to be used, and this organisational context is often not reported in academic literature but is vitally important to user acceptance of software tools.

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