THE DIFFICULTIES REPORTED BY ENGINEERS IN SEARCHING INFORMATION

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Abstract

Efforts have been made by researchers in the area of knowledge management to understand engineers' information searching behaviors, such as the types of information searched by engineers, and the sources and tools they use to address their information needs. However, few studies pay attention to the difficulties that engineers are experiencing in fulfilling their information needs. This paper presents an exploratory study that investigates the problems of information searching in engineering design development. In this research, eight engineers with different level of experience were interviewed to identify the difficulties they deal with in searching required information. The reported problems that participants are experiencing include: 1) formulating information queries; 2) hesitation in consulting others; 3) the limitations of existing retrieval tools.

Keywords: Human behaviour in design, Information management, Design practice, Knowledge management

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1 INTRODUCTION

The rapid IT evolvement has lead to many computer-aided tools for information management in industry. As a consequence, engineers now have more options in various forms of information sources and retrieval tools to fulfil their information needs. Investigations have been made to understand what new information sources and tools have been introduced and how engineers prefer the new ones. Efforts made the researchers in this area mainly focus on what information systems were developed and how good these systems assist design process. However, it is not very clear how good information sources and tools fulfill engineers' information needs and what dissatisfactions that need to be pay attention to for improvement.

This paper reports a study in investigating what difficulties engineers are experiencing in searching required information for design tasks and what their dissatisfactions are in available information sources and retrieval tools. Eight engineers with different level of experience were recruited for interview study. Interviews are analyzed following a general inductive approach. The participants reported three main types of difficulties, namely 1) formulating information queries; 2) consulting others; 3) limitations of existing retrieval tools. The limitations of retrieval tools could be subdivide into: a) finding required information; b) interaction with information tools; c) the characteristics of retrieval tools. The findings of this report indicates future research directions for those who intend to improve the performance of information retrieval tools or any other forms of information tools for engineers in design tasks.

2 LITERATURE REVIEW

Many models have been proposed to understand the design process. The most widely accepted one is developed by Pahl & Beitz (2013) who believed that the engineering design process is generally divided into three phases, i.e. the conceptual phase, the embodiment phase and the detailed phase. In the conceptual phase, technical requirements given to designers are defined as design tasks and associated with design concepts and ideas. It is usually the case that there are several feasible design solutions for a given design problem. During the embodiment phase, the designers explore and develop the selected design solution. Design details are developed in the detailed phase. The activity of design involves information processing to identify the sub-problems and to provide possible sub-solutions using tools that assist them in drawing on existing knowledge. The final product definition is the combination of sub-solutions considering all potential issues and trade-offs (Bracewell et al. 2009).

Whether experts or novices, it is a great challenge for engineering designers to gather and retain all the information they need to solve complex design problems. There is a constant need for them to retrieve information through conversation with colleagues, studying technical reports and drawings, and possibly looking into a database if there is one available. The efficiency of retrieving and using external knowledge resources is pivotal, as it determines not only the design outcome but also the time and cost spent on the product development.

Empirical studies of information in engineering design began in the 1990s. One key study (Marsh 1997) focused on the method of knowledge acquisition in designers' daily work in an aerospace company in 1993, which was before technology was able to efficiently support electronic communication media such as emails and intranet, and before documented extracted information had been introduced. This research aimed to verify the assumption that designers extracted their information through documents. The observational study revealed that half the series of documents were not referred to effectively. The author identified poor document indexing systems and the lack of useful information (Marsh 1997) as the main reasons why designers prefer to obtain information through consulting with their trusted expert colleagues rather than through documents.

Studies done by other researchers in the last 25 years focus on the information needs, the approaches to search for required information and the sources used to fulfil information needs. Kuffner (1991), Baya (1996), and Eris (2002), Jagtap (2008) and Heisig (2010) focus on the requests of information; while Gruber and Russell (1992), Court (1995), Marsh (1997), Rodgers and Clarkson (1998), and Aurisicchio (2005) study the requests for information and engineers' search approaches or the sources used to address these requests.

Existing studies in this area mainly focus on the nature of the information requests that engineers make. Attention has been paid to the search methods and the knowledge sources, but there is still a lack of a

more comprehensive understanding of the difficulties that engineers are experiencing in searching information.

3 METHOD

The hypothesis this research will be exploring is that 'we don't know what issues designers currently experience in fulfilling their information requirements.' To address these gaps in knowledge, the proposed study focuses on how designers handle their information needs during design development. More specifically, this can be further divided into the following research questions: 1) How do designers search for required information? 2) What are difficulties they find in acquiring information?

An interview method is adopted for this exploratory study, because it is the perspectives of designers that we are initially interested in exploring. Applying an interview method assumes the following: 1) interview participants are able to describe their own design practice and 2) the questions asked in interviews can express the intentions of the researcher (Brewer 2001). For this study, we adopt the general inductive approach developed by Thomas (2006), which, although "not as strong as some other analytic strategies for theory or model development" (Thomas 2006), is more suited to the exploratory stage than more constraining processes for coding data (such as grounded theory).

A general inductive approach was adopted with findings generated from raw data (Thomas 2006). Themes identified in raw data were recorded if they were deemed to be relevant and important. The main steps of analysis, taken from the general inductive approach (Thomas 2006), were:

1) Transcribing and organizing the data by removing noisy parts literally and standardizing the format.
2) Getting familiar with the content of the data by reading through it.
3) Coding by labelling parts of the text and naming themes.
4) Creating code families by grouping the labelled segments and defining the sample code which represents the meaning of the corresponding category.
5) Refining codes by cutting overlap in categories, identifying sub topics and negative samples, and explaining inconsistencies (Brewer 2001).
6) Developing the model by selecting the most important categories and exploring their relationships and dependencies.

For this exploratory research, both convenience sampling and chain sampling were applied, sampling from various vehicle companies in China, using personal contacts and asking interviewees to name other likely participants. The sample includes designers or engineers with various levels of experience in similar roles in different companies. The sample is dependent on the scope of research – recruited participants are expected to come from different companies working on different work to generate a general understanding of designers' information needs, their search methods and the knowledge sources used to aggress their needs. A brief summary of participants' information is presented in Table 1 below.

Table 1 Participant Information

Participant No.	Job title	Work	Level of degree	Experience
1	Senior Product Engineer	Automotive Electronics	Bachelors	7 Years
2	Product Engineer	Power System	Masters	3 Years
3	Product Engineer	Braking system	Bachelors	3 Years
4	Senior Product Engineer	Power System	Bachelors	6 Years
5	Product Engineer	Automotive Electronics	Masters	4 Years
6	Product Engineer	Overall Assembly	Masters	3 Years
7	Senior Product Engineer	Automobile	Bachelors	5 Years
8	Senior Product Engineer	Automotive Electronics	Bachelors	5 Years

With the participation of eight engineers from industry, an interview study was performed to understand the difficulties that engineers are experiencing in fulfilling their information needs. The participants have different levels of experience and are all involved in the development of an engineering product. Semi structured interviews were used in the research. Because of the various geographical locations of

participants, the interview was conduct by phone. The length of interviews ranged from 33 to 48 minutes. A list of prompt questions leads the loose structure of interviews. The content of interviews changed when new themes were identified. The interview structure included three sections:

a) Participants were asked to introduce their background/experience and job role in the company.

b) Participants were asked to describe what difficulties they experience in search for required information.

c) Participants were asked to explain their dissatisfactions in the approaches of information retrieval.

The content of interviews was recorded by taping. The records were transcribed immediately after the interview. Notes were also taken during interviews for extra information such as valuable thoughts or points generated in interviews. The researcher followed a general inductive approach to analyse the interview transcripts.

4 INTERVIEW STUDY

According to thematic analysis, Participants' responses revealed three main areas of difficulty when searching for information: 1) formulating the information queries; 2) hesitation in consulting others; 3) the limitations of existing retrieval tools.

4.1 Formulating information queries

Designers realized that "asking the right question" in information retrieval would lead them to required information.

'*If I can find out the essence of the problem, then it would be easy to solve it. In most cases, asking the right question means solving design tasks.*' – Interview 02

On the other hand, failing to correctly formulate the appropriate query would lead to unsuccessful searches which were costly in terms of time.

'*It happens sometimes. A wrong question would lead to working on a wrong direction. You will realize that it is not right at a certain point later, which wastes time.*' – Interview 05

'*When I was just given the task, without enough background knowledge, I would be easily led by the superficial problem and explore something that seems to be relevant and helpful for understanding the problem, but not to solve the problem directly, which may waste time.*' – Interview 02

4.2 Consulting others

Participants' responses revealed that the frequency with which different individuals were consulted was in large part determined by power relationships. For example, designers would consult suppliers more frequently than they would supervisors, most likely because they would feel no embarrassment at having to ask simple or naive questions, while still being able to have confidence in the responses.

'*I also ask our cooperative suppliers for information... If I find any problems, I usually talk to them directly. If the suppliers are also not sure about the answers of problems, or if it is not easy to explain clearly orally, they will send me their documents or ask for more detailed information from their suppliers or look into their own database.*' – Interview 02

One participant reported that he would spend a significant amount of time trying to find the information by himself before asking other designers close to him. As already mentioned in the last section, designers tend to build a preliminary understanding of the problem before consulting others. When they start to consult, they choose those designers who they feel are most approachable. We conjecture that is largely due to social pressures. The one participant who reported asking colleagues first was the one with the least experience, working on new business for which there was no relevant database in the company. Apart from this relatively less experienced designer, all other participants do not start searching information by consulting others.

When participants did consult colleagues for information, these were always designers in the same group or department (except for discussing test reports or assessing products).

'*If I couldn't find my way to solve a problem and have no idea what to do with it for hours, I would start to ask and consult other people. Sometimes, it depends on how close you are with the person you consult. You may ask a person at the very beginning if you know they have the experience and you are very close to him/her. But I cannot describe a 'one-for-all' situation... Firstly, you need to build your own understanding of the issue. Then you will form a question that expresses what you want. You can't*

ask other people before you get a basic idea of it. People would be annoyed. Besides, it is not efficient.' – Interview 04

'*When you are given a design project, almost everything about the project is unknown for you. I usually start with asking the colleagues who worked on this project before and ask for required documents if they have any.*' – Interview 02

One interviewee reported that he felt that his work was disturbed when consulted by novice designers to explain how to solve design problems. This may be one of the reasons why designers are reluctant to consult others and spend significant time on independent retrieval.

'*If it happens when I am busy, it (being consulted by others) affects the progress of my work at hand. Well it also depends on the information they need. If it is a short question that I can answer by one or two sentence, it is fine. But if it requires me to explain for an hour or something, then it affects my work efficiency.*' – Interview 08

All participants only used their supervisors as the last resort when searching for information, even though 1) designers are aware that they need the help from supervisors when dealing with an innovation task; and 2) usually supervisors may help them find required information in a faster way (compared with the many hours designers may have spent on independent search and asking around).

'*I only consult them when it is a serious issue. I search information by myself most of the time...*' – Interview 01

'*... Consulting an expert may be necessary when solving a creative design task.*'– Interview 03

'*I usually start with asking the colleagues who worked on this project before and ask for required documents if they have. If these colleagues leave the company, I have to talk to the suppliers when I need relevant information. If I couldn't find the required information at the suppliers' end, the last thing I can do is to ask my supervisor/boss who may help to search for the information.*' – Interview 02

Despite the fact that supervisors might be excellent sources of information, none of the participants fully exploited this. Supervisors' roles were largely confined to reviewing and assessing the design solutions proposed by designers. We conjecture that supervisors, who may decide whether designers can get promoted, are regarded as 'examiners' rather than experienced colleagues who are there to help.

'*For example, if I have a preliminary idea of design solution, I need to test and verify it by modelling or simulation. Then I will show the solution to an expert or a director for approval. Usually, supervisors in higher position have more experience and are able to give us some advice in how to improve it. We can then work out the details based on their feedback.*' – Interview 07

'*Designers should report to their directors or supervisors in higher position. We need to modify our design based their feedback sometimes.*' – Interview 05

'*I may also want to discuss my idea with suppliers, colleagues or supervisors to assess the feasibility of the design.*' – Interview 08

4.3 Limitations of existing retrieval tools

The retrieval tools used by designers are all based on keyword search. Many of the interviewees pointed to the limitations of this search method, stemming from the fact that, in some cases, the system cannot fully understand designers' information needs.

'*For example, there is different information for one concept or one concept referring to different information. I wish the system can better distinguish and categorize the information when the query is not explicit.*' – Interview 05

However, it is worth noting that although designers realize the limitations of keyword retrieval, they still see it as the most natural form of search.

'*I hope it would be fast, convenient to use and efficient. I hope I can just type the keywords and the system would know what I want.*' – Interview 07

'*The simpler, the better. I wish it could provide links leading us to find the required information. I just need to submit keywords and get returned results in categories. I hope the user interface is simple to find what I need. Simple and fast.*' – Interview 08

We conjecture that 1) designers experience difficulties in expressing their information queries, or 2) they are reluctant to learn how to use a complex retrieval system.

4.3.1 Difficulties in finding required information

One interviewee reported feeling lost when searching for relevant information when he didn't have sufficient background knowledge.

'*When I was just given the task, without enough background knowledge, I would be easily led by the superficial problem and explore something that seems to be relevant and helpful for understanding the problem, but not to solve the problem directly, which may waste time.*' – Interview 02

The same interviewee wished to be reminded of design issues he failed to consider when retrieving information.

'*Sometimes the problem is not very difficult but I just couldn't figure it out for the moment. I need something to remind me.*' – Interview 02

4.3.2 Interactions with information tools

From the interviews, designers acknowledge that they need assistance in expressing their information needs, i.e. asking the right question.

'*Well, it depends on the problem to solve. If it is a normal design task, I usually work out the questions one by one and find out the essence by analysis.*' – Interview 02

'*It is quite normal to ask wrong questions when I search information in database. You have to rely on your own knowledge and the experience in picking up the keywords to form your query... I wish I did not need to form queries and submit my queries in computers. I mean, there are always limitations in words and languages. I don't want to translate my queries into words. I wish someone or a computer can understand what I need.*' – Interview 04

In terms of interaction with information tools, designers desire simplicity. Two interviewees expressed the wish to have a simple user interface and a search engine which doesn't require complex information queries.

'*The simpler, the better. I wish it could provide links leading us to find the required information. I just need to submit keywords and get returned results in categories. I hope the user interface is simple to find what I need. Simple and fast. That's what I want.*' – Interview 08

'*I hope it would be fast, convenient to use and efficient. I hope I can just type the keywords and the system would know what I want.*' – Interview 07

By contrast, one interviewee felt that existing retrieval methods did not allow sufficient control over parameters to specify the required information. This might require something more complex than simple keyword retrieval.

'*The retrieval system is for the theoretical knowledge and information in text such as reports and papers. For example, it can retrieve all the stands. But it is not capable of finding out the required stand with specific characteristics like the size and assembly requirements. I guess the index only classifies components without involving detailed information. You can only search by groups and sub-groups.*' – Interview 03

The observations above reflect: 1) designers often have difficulties in expressing queries when they lack background knowledge, i.e. they need more assistance in exploratory searches; and 2) they wish to have a 'keyword plus' method which could express more specific and detailed requirements in queries.

4.3.3 The characteristics of retrieval tools

When designers generate a non-explicit query, they wish to have a retrieval system that can better distinguish or understand what they really want.

'*For example, there is different information for one concept or one concept referring to different information. I wish the system can better distinguish and categorize the information when the query is not explicit.*' – Interview 05

One interviewee reported wanting to get a brief idea of retrieved results before reading through them individually. It seems that he still needs to look into the retrieved result to find out whether it is what he required.

'*As I can image, I hope the system could categories the information of components in details. Like, there is a brief description of each component. I wish it could search the component by submitting the parameters of the required component. At present, we have to open each document of the component to see the detailed information.*' – Interview 03

One interviewee expressed his desire to have a communication platform where designers can share experience.

'*A platform sharing experience can be helpful. The lesson learned in previous cases can help novice engineers understand the design problem.*' – Interview 02

His desire might suggest that 1) this participant has difficulties in searching for required information independently because of i) the lack of efficient information in the database or ii) the lack of efficient retrieval tools; 2) it is not easy for him to consult other designers, because i) colleagues are not available; ii) he has no idea who is the right person to ask; or iii) he hesitates to ask for help from others face-to-face.

5 DISCUSSION

Interview participants explicitly express their dissatisfaction with existing retrieval methods and tools, and suggest improvements or types of assistance that might be helpful: 1) participants need assistance in exploring knowledge; 2) participants need to be reminded of issues not considered; 3) participants need to find out all relevant information of the design problem they are working on; 4) participants have difficulties in expressing information needs; 5) participants wish search engines to be simple and easy to use; 6) participants prefer not to submit complex information queries in retrieval; 7) participants hope to set specific values of the characteristics as constraints in retrieval, i.e. advanced retrieval; 8) participants wish search engines to be able to understand implicit queries; 9) participants hope to get brief synopses of retrieved results before reading through them individually; 10) participants would like to have a communication platform for sharing experience.

By cross-comparing the statements in Section 3, statements 1), 2), 4) and 8) fall into formulating the right question (aspect a); statements 1), 2), 3), 8) and 10) are in line with the difficulties in consulting others (aspect b); and all the statements excluding 5) and 6) highlight the limitations of existing retrieval tools (aspect c).

By comparing the issues identified in interview analysis and those reported by designers, those that consistently surface are likely to indicate problem areas that most directly and saliently affect designers. However, issues that are not consistently mentioned are not necessarily unimportant. Although statements 5) and 6) do not relate straightforwardly to any of the three areas, the two statements still reveal that designers are ambivalent about their expectations in retrieval systems. They desire to use advanced retrieval methods that go beyond keywords but are still reluctant to formulate complex queries, most likely due to the more subtle difficulties in formulating the right question.

The existing keyword retrieval and hierarchy indexing schemes have poor recall, although they are quite precise. Issues identified from the recent interviews reveal designers' wishes to improve the situation, supporting the findings of previous studies (Blessing 1994; Marsh 1997; Charlton 1999). For example, Charlton's (1999) statement says 'the natural tendency of classifications is to separate information, eliminating any similarity between different elements.' The information retrieval experience of designers supports this finding: a knowledge base, which uses a single index or hierarchy, is not able to provide the full range of suggestions that are related to designers' inquires. When comparing a query against an index, the piece of information is only matched in one classification, based on some of its attributes (for instance, a component is grouped in a classification that consists of all the components that belong to a part/unit). As such, the other attributes of the piece of query will neither be detected in that classification and will nor be compared with in other classifications (for instance, the component grouped in the classification of components for a specific part/unit may not be grouped in the classification of the components from different part/units that can perform a certain function). As a result, designers cannot explore knowledge or get reminded of the issues which are not considered or related.

6 CONCLUSION

This research project fills a gap in the literature between the previous understanding of designers' information handling behaviours and current design practice. The exploratory research identified that designers' dissatisfactions with the performance of keyword-based retrieval methods in dealing with complex information queries. The finding of this research indicates potential directions for further research: building a more detailed understanding of designers' current practice, specifically designers' queries, methods of searches, information sources and the interaction between designers and information sources. The outcomes of the research would have an impact on the relevant research area: re-shaping the direction of the future studies by providing researchers with an up-to-date understanding of designers' information handling behaviours.

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