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A STUDY OF INFORMATION RETRIEVAL IN THE AEROSPACE DOMAIN

Francisco del-Rey-Chamorro, and Ken Wallace

Abstract

The role of documentation in design is becoming more important due to the increasing mobility of employees. Higher mobility of experienced staff, and the fact that aerospace products are often in service for many decades, means that designers are obliged to retrieve more information from records. Documentation is also undergoing major changes. Relevant information, traditionally captured in folders and books such as technical standards and manuals, is becoming online. An exploratory case study identified that some designers still prefer to access information from paper-format instead of electronic format, when both were available. This paper presents an ongoing empirical research on the access of documentation by designers. Five designers were asked to work on a design case for three hours using the think-aloud protocol. The aim is to provide an understanding on the paper-format retrieval mechanisms adopted by designers and its lessons for electronic-format retrieval of technical information.

Keywords: Information management

1 Introduction

The way in which engineering designers in the aerospace industry obtain their information is changing [1]. Traditionally, young designers would join a company as apprentices and leave at the retiring age. During their careers, these designer would become extremely knowledgeable and a valuable source of information for the next generation of designers. Thus, a master-apprentice relationship was established and knowledge stayed in the company. However, career development and job opportunities encourage many to transfer out of the design process. This represents not only an invaluable loss of experience and knowledge in itself, but also interrupts the knowledge transfer to the next generation. If experienced designers will not be available in the future, designers will have to retrieve that information from what remains in the company. At the moment this is essentially documentation. Documentation systems are also undergoing major changes. New technologies are providing the platform to move from paper to electronic format. Electronic documentation is easier to update and maintain. Designers are being obliged to move to this new information system whether they like it or not.

Some designers feel they are not benefiting from these new technologies. These designers are still using old manual folders and handbooks when they are still available. This study aimed to provide an understanding how designers access paper-format documentation, and identify the key issues that should be mapped into software tools.

2 Characteristics of the access of documentation

Documentation gathers together a specific type of information in the engineering domain. Its content relates mainly to engineering standards and procedures. However, engineering documentation includes not only background details of the technology and concepts used, but also project-specific information such as requirements specifications, memos, guidelines and codes of practice [2]. An analysis of blade cooling documentation [3] shows that documents are composed of text (63%), graphic information (34%), tables (2%), and numeric data, such as equations (1%). Ullman et al [4] argue that documentation plays a significant role in engineering design. Five mechanical engineers were observed undertaking two engineering problems using the think-aloud approach. It was observed that catalogues presented new design possibilities to designers, as well as the information designers were seeking. Furthermore, design decisions were justified by reference to information stored in documentation [5].

Researchers in the Information Retrieval (IR) domain study documentation in order to make it more readily accessible electronically. IR targets issues such as the lack of a common structure of documentation, increasingly large number of documents, lack of a precise semantics, and lexicographical issues. IR proposes how to structure documentation better in order to improve the recall of information. Solutions are based on concept mapping of domains, and new structures of documents leaving aside users and its interaction with the documentation. One example of this type of solution in the engineering domain is proposed by Charlton [6].

The emergence of the Information Technology (IT) has also increased the number of studies on the access and use of documentation. The interaction of users with documentation is classified into groups: information-seeking behaviours and information-searching behaviours [7]. The former focus on the conditions and situations that trigger information-seeking. The latter pays attention to the behaviour and activities dealing with the search of computerised information. Beaulieu [8] presents a review of both information-seeking and information-searching models. In the engineering domain, Ellis [9] addresses the information-seeking patterns of engineers and research scientists. His work includes other types of information sources such as personal contacts, and concludes that engineers still consider personal contacts to be far more effective to other sources of information.

3 Research methodology

An empirical research in the aerospace industry was carried out in order to understand the access and use of documentation. The research methodology was based on an experiment using a realistic design case study. Such experiments have been successfully used in the past to study information management in engineering design [5][10]. They allow the control some of the factors influencing the process [11], and help to focus on the main issues of interest to the research.

3.1 Set-up

The experiment case study was based on a military aircraft flight control surface (FCS). This case study was prepared by an experienced designer within the company. During its development, it was observed that designers do not access much recorded information during the conceptual stages of the design. Most of the information was extracted from their long-term memory by referring to past projects. Thus, the design case was based on the detail stage

where designers have to access documentation in order to meet the specific design requirements.

Designers were given a scheme of the FCS (Figure 1) and the set of issues to be resolved by the end of this design stage. These issues included structural sizing, required standard parts, and aerodynamic tolerances. The duration of the whole task was estimated to be about three months. Five designers were asked to undertake part of this task for a maximum of three hours. The only information available was paper-based documentation. The designers were provided with the company's technical standards and procedures manuals related to the issues to be addressed. The participants were also allowed to bring their own handbooks along with related past project documentation and drawings.

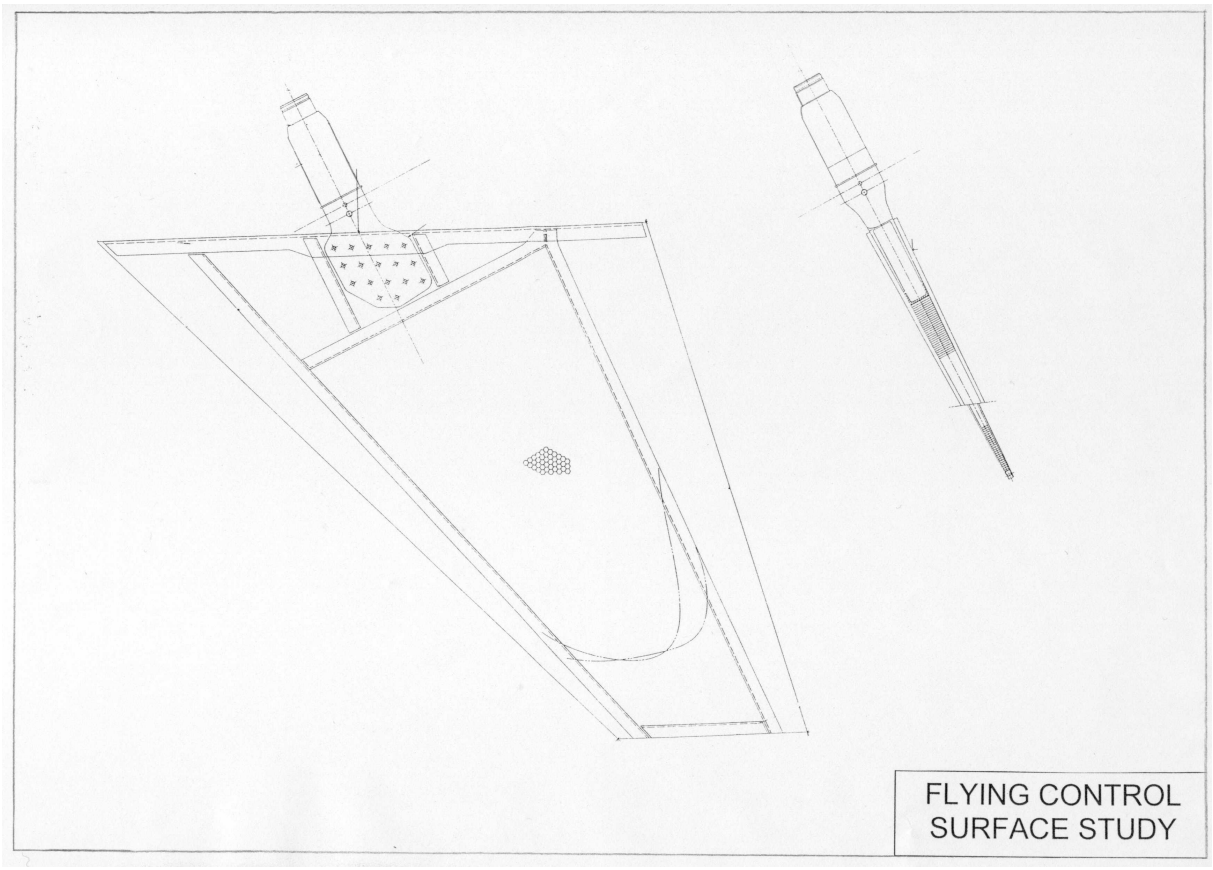

Figure 1. Scheme of the FCS

The experiments were run in a controlled environment. They were undertaken in a separate room at the company's premises. During the experiments, the participants were asked to think aloud whilst addressing the design issues. Due to security issues, two of the experiments were transcribed manually by two researchers, whereas the other three were audio-recorded and transcribed later. Field notes and 10 to 15-minute post-experiment feedback sessions completed the data collected.

3.2 Participants

In total, five experienced designers from the company completed the experiment. They have been in the company from 15 to 36 years. The participants had different design background: three of the participants were involved in projects on supersonic fighters whereas the other two were working on a training fighter. However, all claimed to be familiar with the task in

the post-experiment feedbacks. The participants had considerable experience of detail design, but three of them were currently involved in different activities in the company. All of them classified the design case as “easy”. None of them were familiar with the provided documentation and its structure. The participants were expected to access documentation according to their engineering understanding. Familiarity would have altered the experiments and the results would have not been so interesting. Think-aloud protocol is essential to establish the rationales behind the searches [5]. As a result, all designers highlighted the difficulty of dealing with the folders. They thought that the given task would have been easier if they have been familiar with the structure of documentation.

3.3 Experiments

For the sake of the quality of the results, the participants were told to finish the design case whenever they felt tired. During the experiments, the participants were reminded to verbalise their thoughts. Some designers decided to bring some extra information with them. This information dealt with materials, manufacturing codes, and drawings of past projects. It was noticed that designers who were still working in detail design brought documents and drawing referring to past projects, whereas the others brought old materials and design textbooks. The participants were free to undertake any of the issues included in the given set. As a result, not all the participants covered the same issues or in the same order.

4 Findings

This paper only presents the preliminary results of the study. The analysis of the transcripts identified 62 episodes [12] on the accesses and use of information contained in paper-format documentation. The number of episodes, quality and length varies across transcripts. These results focus on what functionality paper-based information provides designers, and how designers undertake the retrieval of this information.

4.1 Characteristics of paper-format documentation

The Human-Interaction (HI) domain has found that users often reject automation in favour of pre-existing paper-based processes. Users claim paper provides a stronger and more accessible platform and allows easier face to face communication [13][14]. The analysis of these experiments has identified additional characteristics of paper documentation that may influence the access of information:

- *Folders are rigid systems of documentation.* The structure of the documentation is fixed by the producer. Designers are not allowed to customise the structure according to their needs or preferences. Thus, designers have to learn how documents were structured in the first place in order to be able to locate pieces of information. The participants found this pre-determined structure very time-consuming, and very frustrating, particularly when the structure was not consistent.
- *Folders help to create a mental picture of how the information is structured*. During the experiments, some of the participants expressed their unfamiliarity with the structure of the folders as the biggest difficulty. The participants found that paper-format documentation helps to provide a mental picture of the structure of the documentation. For example, one participant said that understanding the logic of how the manual was structured in the first place would help him find information easier and quicker. During

the experiments, it was observed that designers became more familiar with the rationale behind the structure of folders, which increased the speed of the retrieval process. In addition, the participants also pointed out that the folder system provided them with a means to memorise where the information was, saving time accessing the same piece of information repeatedly.

- Browsing through folders helps designers to identify other issues related to the design. One of the main characteristics of folder systems is that designers have to access the required documents manually. Designers have to flick through other related documents in order to find what they need. This is particularly useful when designers are not very familiar with the sort of task they are undertaking. For example, one of the designers commented that when browsing through the manuals one can come across information that may be relevant later on in the design. He considered this especially useful when you are dealing with a task or type of component that one has not worked on before.

These characteristics of paper documentation influence the way designers access information. Documents are grouped according to the main characteristics that define each set of documents, indexed, and then presented to designers. Designers can only access those documents through the indexes, and in the some cases, also through cross-reference from other documents. However this study suggests that managing folder systems also requires an understanding on how manuals are structured in the first place. It has been observed that the participants were very fast in accessing information once they were familiar with the documentation structure.

4.2 Information-searching in paper-format documentation

Accessing of documentation has to be considered as whole, as it is embedded in the context in which it takes place. Designers not only access standards and manuals, but also interact with other information sources such as past projects. In this study, the participants were observed accessing standards and manuals and when undertaking the design activities. Analysis of the experiment suggests designers follow a general pattern of information access (Figure 2). The information access starts when designers identify an information need that may be contained in documentation. Information cannot be queried due to the rigid structure of documentation. Designers analyse the information they need and select in what folder or folders the information might be located. Once a folder has been selected, designers apply one of the following information-searching strategies.

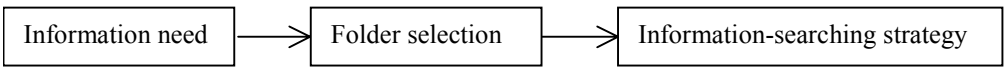

Figure 2. Information access pattern in paper-format documentation

- When designers access unfamiliar documentation, the most common and successful information-searching strategy is *navigation through the documentation* and *cross-referencing*. Indexes provide an insight into the content of manuals and standards. Designers narrow down their searches by selecting the title of the chapters that contain keywords related to the search. Once in the selected chapter, they browse the content for the keywords that represent their design context. For example, one designer used the navigation strategy to identify the distance between hole positions in order to attach the leading edge to the core structure of the FCS. The designer selected the folder in which he believed the information was contained, *codes of practice*, then read through the table of contents and went to chapter 2.04, *Fasteners*. Reading through this chapter, he identified a

cross-reference to information related to *spacing* in the appendix. Finally, he accessed a table in this appendix and applied the data of this particular FCS.

- Towards the end of the experiments, the participants were more familiar with the documentation and how it was structured. This allowed participants to use *browsing* as information-searching strategy. They took the folder which they thought may contain the information needed, open the folder by where they expect to find this sort of information, and browse around till the find it. The participants thought it was faster and easier, but they were not always successful using this strategy. They believed it was due to either a lack of understanding of structure of the folder documentation or lack of consistency in the documentation structure.
- Some of the participants also used another information-searching strategy based on accessing *past projects*. These designers retrieved schemes containing related features of the FCS. The main purpose was to get a guideline of the sort of information they needed to access in the documentation. This strategy was favoured by more senior designers, as it provided examples of the application of their information needs. For example, one designer consulted a previous related project on the use of honeycomb construction in order to identify the sort of issues he had to access in the standards manual. He believed that this strategy provided him with a more detailed description of the required documentation such as the specific standards numbers. This saved time when looking up information.

The participants were not familiar with the folder system, so number of instances for each strategy is not representative. The analysis of the experiments suggests that designers were learning how the folder system was structured at the same time as they were designing. Designers were constructing their own mental picture of the structure of the documentation.

5 Conclusions

These experiments showed that the characteristics of paper-format information helped designers to search and retrieve information. It was observed that paper-format information helped designers learn how the information was structured, i.e., the meta-information. This speeded up the information retrieval, as the designers were able to use browsing as an information-searching strategy instead of navigation. Accessing paper-format information also allowed the designers to discover *new* pieces of information. The fact that designers need to browse through pages and read the contents to locate exact pieces of information provided the designers with additional useful information on a topic. This newly discovered information was not necessarily related to that stage of the design, but the designers considered it might be useful in the future. Finally, it was observed that in detail design some designers use past projects to identify what information needed to be retrieved rather than retrieving past rationale. This information consisted of specific standard numbers and notes added to drawing. This approach helped them to narrow down the search and speed up the information retrieval.

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Corresponding author:
Francisco del-Rey-Chamorro
Engineering Design Centre, Department of Engineering, University of Cambridge
Trumpington Street, Cambridge, CB2 1PZ, United Kingdom
Tel: Int +44 1223 330271, Fax: Int +44 1223 332662, E-mail: fmd21@eng.cam.ac.uk