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A Study of Architectural Information Foraging in Software Architecture Documents

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Abstract—**When using Software Architecture documents (ADs), users typically "forage" for information. However, it is little understood how they do this foraging or how to structure architecture documentation to assist them. We conducted a survey of two different groups of foragers, industry practitioner and academic AD users, to investigate issues – types of forages, foraging sequences and styles - related to task-based architectural information foraging in software architecture documents. Our results show that there were different pre-conceived ideas of what to forage for prior to the search, but during foraging there was commonly foraged information. The different groups of foragers place different emphasis on information related to quality requirements, purpose of the system, use cases, physical view and process view. Foraging sequences starting with certain information were suggested to better support understanding of the described SA. These sequences typically followed the written order of the information as dictated by the AD producers. This reinforces the critical responsibility of AD producers to structure the architectural information for understanding. Diagrams, views and design decisions were most frequently cited as supporting understanding of the SA. The main hindrance was too much text and a lack of diagrams.**

Keywords – foraging; exploration; understanding; software architecture document;

I. INTRODUCTION

Creating useful software documentation is difficult, but if it is not useful, the effort required is wasted. As Lethbridge et al. comment "Finding useful content in documentation can be so challenging that people might not try to do so" [1]. This difficulty of finding needed information also applies to software architecture documents (ADs) [2], the main purpose of which, after all, is to clearly inform.

ADs may have inherent limitations for finding information in them, for example depending on the search capabilities available. However, the behaviour of those seeking information can also impact their usefulness.

Our default assumption is that AD users forage, which our study seeks to confirm. This is consistent with Information Foraging theory [3] which assumes that humans are *informavores* [4], and so try to maximize the value of knowledge gained per unit cost of interaction [3]. This is similar to the way animals forage in a patchy environment for food maximizing the rate of energy gained per effort expended [5]. This maximization tendency for architectural information could be due to limited resources (time or budget) that the forager has to spend on finding information. To better structure and utilise ADs, we need to better understand the foraging behaviour of their users.

This paper presents the findings of a study investigating issues - forages, foraging sequence and styles - related to architectural information foraging in ADs when trying to discover the software architecture (SA) of described systems. We studied two different groups of foragers, industry and academic professionals. Studies show considerable differences between academics and industry in their perception of SA and reusable assets [6]. Our focus is SA documents and our interest is whether there is any different emphasis on architectural information in ADs between the SA academics and practitioners. By looking at architectural information in ADs commonly foraged by the two groups, we can gain some insight on this. Any differences between the two groups can serve as motivation for further study to reduce the gaps between academic research and industrial practice in terms of software architecture documentation. We also investigated the features of ADs that supported or hindered understanding.

II. RELATED WORK

Information foraging relates to "activities involved with assessing, seeking, and handling information sources" [7]. Related studies mainly focus on understanding the navigation behaviour of the foragers to improve navigation tools. Some studies had been conducted on the navigation of program code during software maintenance [8] [9] and debugging [10]. These studies build upon the underlying concepts of information foraging theory [3] to explain code navigation behaviour. The theory suggests that people will adapt themselves to their information environments or modify the latter, to maximize their rate of gaining valuable information. Central concepts include patchy structure of the task environment (*information patch*), selective consumption of the forage (inf*ormation diet*) and the use of information cues (*information scent*) to decide paths to take. For example, the concept of information patch could be used to explain developers' tendency to visit files in clusters [9]. The information scent concept supports developer's use of cues in their tools to support the code foraging process [8].

As far as we know no previous study has investigated the foraging of architectural information in ADs and how that supports understanding of the described SA. Our focus is on (AD) document navigation specifically the i*nformation diet* [3] resulting from the tendency to maximize benefit per cost. In particular is there any 'commonly foraged information' in the information diets across different foragers and if so what this is. We are also interested if there are 'common sequences' of foraging supporting better understanding. These can give insight to support AD usage.

Other studies have investigated ways to produce understandable ADs and to support finding relevant architectural knowledge (AK) in them. One proposal was to enrich ADs by annotating them with formal AK [11]. To improve the retrieval of the needed information, another suggestion was to index ADs with an ontology [12]. The foci of these studies were on the production of ADs or AK to support SA understanding and retrieval of information.

Relevant to AD usage, a survey of how software engineers perceive the usage of software documentation in general [1] found software engineers often do not maintain documentation. Despite that, out-of-date documentation remains useful. Another study investigated the perceptions of AD producers on the relevance of the different parts of an AD to its perceived stakeholders and their concerns [2]. This showed a scattered pattern of stakeholders' interests in an AD's content. The insights gained from perceived usage of ADs are useful but need to be verified by actual AD usage.

Most existing related work focuses on how ADs can be *produced* to make them better and *perceived* usage. Our study focuses on *actual usage* of ADs and the behaviour of their users. The closest study to our work is a study of AD consumers' usage of the two types of media (text and diagrams) used in ADs [13]. One main finding was that those who predominantly use text show better understanding. Our study differs in that we investigate the understanding issue from a wider perceptive and by investigating foraging.

III. STUDY DESIGN

We have conducted a study of industry and academic professionals with an SA background exploring ADs to solve information-seeking tasks. Two ADs were used. There were three tasks for each AD, which were similar for the two ADs.

The first task was to discover the SA of the system described by the given AD, by assuming the role of a software architect new to a software project. The rationale of this task was to investigate the foraging of architectural information in ADs when trying to obtain an overview of the SA of a system. We wanted to know, given an AD, what a software architect would look for when attempting to elicit the software architecture of the described system. We think that for a software architect, it is important for them to obtain an overall picture of the described SA, in addition to more specific architectural issues. Despite the subtle issue of what constitutes SA, we wanted to see what the most commonly-sought information in ADs is.

The second task was to elicit how to change a certain part of the system and, in doing so, which parts of the system are affected. The role assumed is a developer. The rationale was to investigate the foraging of architectural information in ADs when trying to find information to make a change to the software system. We wanted to see in general what AD users look for to perform this type of task and to assess the impact of the change. As such we did not state specifically what 'parts' and 'affected' mean. 'Parts' can refer to anything of the system that might be affected: system; subsystems; configuration; no change, etc. "Affected" could mean code changes, quality or other things. The third task was to find out how the system was designed at an architectural level to achieve a certain quality attribute, assuming a system maintainer role. The purpose was to investigate foraging of architectural information in ADs while trying to find information related to a quality attribute of a system.

The tasks for the study participants were phrased in terms of a scenario together with the role to be assumed. For example for the first task: "You are a software architect new to the X project. You would like to know what the software architecture of X is". Adopting the same role helps participants view a task with a similar mindset. Tasks were designed to suit the corresponding roles. Roles were chosen to relate to the main stakeholders of ADs or AK [14].

The first (24-page) AD we used defines the architecture of a real industrial system managing digital web content (DWC) for future preservation. The second (16-page) AD describes the SA of a storage management platform. Their length, complexity and quality of content suited the exploratory information seeking tasks in this study. We chose these ADs due to their availability, technical detail, target system characteristics, and mix of usage of textual and visual representations. We wanted to gather users' perceptions of the content of the AD. For this, we inserted annotation widgets to capture tags, comments, ratings and reading sequence, to the beginning of the sections of the ADs following their original organization. Each section that could be annotated was also enclosed by a border to visually distinguish them. The annotation widgets and border were inserted automatically using a script. Sub-sections that contained a substantial amount of information or contained distinct information by themselves were also instrumented with the annotation widgets and the border (but with no change to order or organization). To gather perceptions of different types of representation of architectural information, diagrams were instrumented with the annotation widgets separately from surrounding text as well. The DWC AD contained 47 annotatable sections, with 6 containing diagrams (one containing two closely-related diagrams). The second AD had 62 such sections, 7 containing diagrams.

The expected time of participation for each participant was 1 hour 15 minutes. Each participant was given one of the ADs and two of the three tasks for the given AD. The two tasks were given in a different sequence for each alternate participant. For each task, the participant explored the AD to find their answer. The participant was asked to state the time the task was started (start time) and the keywords or terms searched for in relation to the task, at the beginning of the task. As the participant looked for the answer, he or she was asked to highlight information in the AD relevant to the task. For each section visited, the participant was asked to provide two ratings (of importance to the task and of importance to overall understandability of the described SA). In the case of Task 1, though on the surface both ratings relate to the "software architecture of the system", there could be other things or information that contribute to the "overall understandability of the software architecture" as compared to "what is the software architecture of DWC". For example does the information on the organization of the AD content (such as "Table of Contents") contribute to the understanding, apart from the technical content? Participants also tagged and commented visited sections but this was not mandatory. A tag is keyword reflecting a section's content. A comment is a more elaborated opinion of the section.

Participants provided answers to tasks in bullet-point form. They also stated in which AD section each answer point was found, and whether it was found by looking at the section's title, reading the section or it was not obvious from the AD but came from his or her past experience and knowledge. After completing the answer, participants recorded their finishing time. Then they suggested their view of the "best" sequence of reading for those sections relevant to the task. This sequence, in their opinion would support a better understanding of the described SA.

After completing all tasks, participants completed a questionnaire on occupational background and SA-related experience, experience with ADs and the described system, perception of the AD's content, exploration characteristic, perception of the usage and the usefulness of textual descriptions and diagrams in supporting understanding.

The data collection instruments thus comprised:

- The instruction and guidelines on the information seeking tasks to be completed.
- A form for each task for participants to provide the start time, stop time, keywords, answer in bullet-point form, where and how each of the answer point was found.
- One of the ADs for the participants to explore and provide tags, comments, reading sequences and highlight relevant information.
- The questionnaire which contained structured Likert-scale questions and un-structured free-text questions.

The data collection instruments were adapted from our earlier work [15], where participants captured their own exploration paths during information seeking by using a prototype tool we developed [16]. Relevant feedback from 20 participants from that work are also included in this study.

A. Participant Recruitment and Data Collection

This study sought participants with an SA background. Due to the exploratory nature of the information seeking tasks, a considerable amount of time and effort were required to complete the tasks. Hence, to be realistic in the recruitment of participants, the following selection criteria were used: at least 2 years of industry experience related to SA (for industry participants), those who have taught a SA course or provided training on SA (for academic participants), and a willingness to commit the required time and effort. We believe that these criteria are reasonable for this study, since seeking information by reading specialized documents is a common task that can be performed well with the right background and the availability of time.

The selection criteria discouraged the use of random sampling as the targeted groups often do not respond to invitations from unfamiliar sources. Therefore non-probabilistic sampling techniques, convenience and snowball sampling, were used to invite potential participants. The former involves recruiting participants who meet the selection criteria and are available and willing to participate in the study [17]. The latter refers to asking participants of the study to recommend other potential respondents [17].

Recruitment of participants was undertaken by sending email invitations to potential participants using the researchers' personal and professional contacts, and their referrals. 32 industry participants were contacted with 27 responding, 11 were excluded as not meeting selection criteria, 16 took part, 4 dropped out half-way through with 12 completing the study. 28 academics were contacted. Of the 17 responding, 3 were excluded as not meeting selection criteria, 14 took part, 1 dropped out half-way through and 13 completed the study. Altogether 25 participants completed the study, 12 industry and 13 academics. At this point, one academic respondent was excluded as the responses given were too vague to make any interpretation.

A set of the data collection instruments was given to those who consented to take part in the study. For physically accessible participants, a face-to-face meeting was conducted with them to explain the tasks to be completed and to clarify any question. For more distant participants, clarification was either done through email or online chat discussion. Participants returned their responses by uploading to a dropbox or sending them to the researcher's mailbox.

IV. Results

We employed descriptive statistics and qualitative analysis on the data collected. For qualitative analysis the data was coded and their number of occurrences counted to find the main theme(s) or concept(s). The codes were words extracted from the participants' responses or representative words derived by the researchers based on the responses.

It is important to note that the findings reported in this paper were based on the responses of 8 participants who were involved with the information seeking task of finding out what is the SA of the system described by the DWC AD (first task).

We do not verify the "success" of participants in carrying out the tasks. This is because our assumption is that informavores try to maximize the rate of valuable information gained per unit cost and this comes at the expenses of the quality (in terms of completeness) of the information gained. The data on tags and comments were excluded from this paper due to the small number of responses. The ratings were also excluded.

A. Software Architecture-Related Experience

The industry participants' had on average 10.75 (minimum 3 and maximum 24, Table I) years of SA-related industry experience. The averages for more specific SA experience were 11.25 (SA design), 6.7 (referring to SA of software systems to perform tasks), 8.5 (changing SA), 5.88 (reviewing SA) and 4.25 (other SA experience) years respectively. ‘Other’ experiences specified by the participants involved architecting specialized systems. The domains of systems designed were different between the 3 industry participants who responded on this. These were embedded, smart devices, autonomous, transactional (finance and banking), and engineering systems. Systems referred were real-time measurement and control, resource constraints and embedded systems.

TABLE I. PARTICIPANTS’ SA EXPERIENCE

	SA Teaching experience	SA Industry experience	Designing	Referring	Changing	Reviewing	Other
	2	3	4a	4b	4c	4d	4e
Industry Practitioner							
Mean		10.75	11.25	6.75	8.5	5.875	4.25
Min		3	2	4	0	0.5	5
Max		24	24	15	24	12	12
Academician							
Mean	9.25		6.25	9	5.75	8.25	6.5
Min	3		2	3	8	8	3
Max	16		15	15	15	15	15

On average, the academic participants had 9.25 years (minimum 3 and maximum 16) of experience in teaching or providing training on SA. Their average years of more specific SA experience are 6.25 (SA design), 9 (referring to SA), 5.75 (changing SA), 8.25 (reviewing SA) and 6.5 (other SA experience) respectively. The domains of the systems designed were different between the 2 academic respondents and included web-based or fat-client, point-of-sale, telecommunication, automotive, data processing and software tools. Systems referred are similar to those designed plus case studies in books and architecture of web browsers. ‘Other’ SA experiences include undertaking SA research.

All participants had prior exposure to ADs in general. In terms of how often they read AD, on a 5-point Likert scale (where 1 is never, 5 is always and the in-between were not specified), 2 out of 4 of the participants from both categories chose 5 indicating that they always read ADs (Fig. 1). One of the industry participants chose 4 and the other chose 3. The remaining 2 academic participants chose 4. For reading and making use of ADs in their tasks, 1 of the industry participants chose 5 and 2 of them indicated that they did that on a less frequent basis by choosing 4. Most of the academic participants did that less frequently with 3 out of 4 of them choosing 4. The remaining 1 from each group chose 2.

In terms of writing ADs, 2 out 4 of the participants from each group chose 4 and 1 from each group chose 2. The difference was that the remaining industry participant chose 5 (wrote ADs always) whereas the remaining academic participants chose 3. With regards to updating ADs, 1 industry participant chose 5 and 4 respectively and 2 of them chose 3. No academic participants chose 5 for this aspect. Two of them chose 4 and the other 2 chose 1 showing that they have never updated an AD.

For the industry participants, the distribution of responses for the aspect of ADs writing was the same as for reading and making use of ADs. When no differentiation is made between the industry and academic participants, 7(87.5%), 6(75%), 5(62.5%) and 4 (50%) out of 8 participants were quite often (chose 4 and above) engaged in reading AD, reading and making use of ADs in their tasks, writing ADs and updating ADs, respectively.

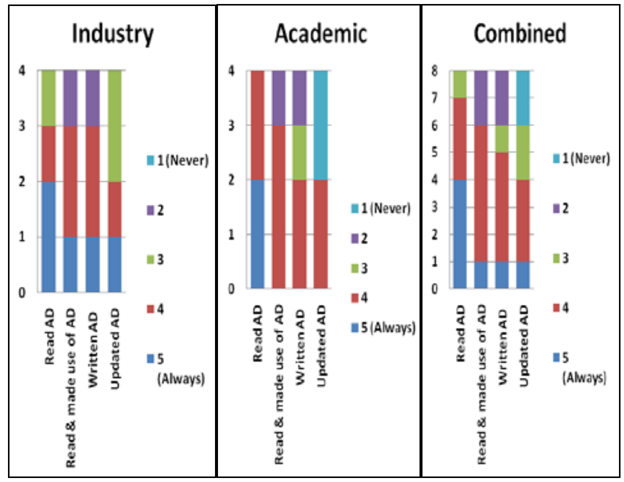

Figure 1. Exposure to ADs

All participants had some prior background with DWC style systems. Half of the industry participants had read ADs related to these. The rest either had architected or documented a similar type of system. All academic participants had read about similar types of system.

The average time spent by the industry participants on the task was 46.3 minutes (minimum 23 and maximum 85) whereas the academic participants spent on average 40 minutes (minimum 12 and maximum 80). It is worth mentioning that half of the academic participants attempted this task as the second task on their list. Therefore these participants could have spent less time for this task due to the familiarity with the AD they acquired during their earlier round of exploration of the AD for the first task. It was also intended for half of the industry participants to attempt the task as the second task. However not all participants followed the sequence of the tasks as instructed. In addition, after analyzing the experiences of some participants, they were put into a different group from initially anticipated. For those who had both industry and teaching experience in SA, the length of experience decided their group.

B. *Perceptions of the Given AD*

On a 5-point Likert scale (1 - strongly disagree, 2 - disagree, 3 - undecided, 4 - agree and 5 - strongly agree), all the academic participants agreed (4) that the language the given AD was written was easy to understand and they had no problem in understanding the domain concepts in the AD. Two out of 4 of the industry participants strongly agreed and 1 of them agreed on the ease of understanding the language. The remaining 1 strongly disagreed on this. However none of the industry participants strongly disagreed that they had no problem in understanding the domain concepts, their responses were evenly spread across the remaining choices (with 1 participant each choosing 2, 3, 4 and 5).

When both groups are combined, 7 out of 8 of the total participants were in agreement (chose 4 and above) with the ease of understanding the language the AD was written and 6 out of 8 agreed or strongly agreed that they had no problem in understanding the domain concepts in the AD.

We did not further validate the participants' responses on these aspects. Our participants were professionals and the ADs that we chose describe the software architecture of systems of reasonable complexity. These questions were asked as an added check on the suitability of the participants and the ADs for the study.

C. Architectural Information Forages

To understand what industry and academic professionals with SA background forage for when trying to find out about the SA of a system by exploring an AD, the keywords, answers and highlighted information were analyzed. Answers and the highlighted information contained cues about what information was searched for.

Three out of four industry participants provided keywords: architecture goal, constraint, design decisions, framework, interface, overview, pattern, purpose, quality, software architecture and views. Only one academic participant provided keywords. These were modules, processes and system architecture.

The answers given by the participants were either generic or specific. Generic answers contained general terms that reflected the content of the sections (for example 'use cases') whereas specific answers pertained specifically to the described system (for example 'use case UC1'). Table II shows the main themes discovered in the participants' answers, together with the percentages of the total number of participants in whose answers the themes were discovered. The table also contains the same information discovered in the highlighted content provided by the participants.

Analysis based on the participant answers shows that 3 out of 4 (75%) industry participants looked for main logical components, quality requirements or the purpose of the system. One looked for the actors or use cases. Three out of four (75%) academic participants looked for main logical components, process view or components deployment. Two (50%) looked for use cases, external dependencies, underlying platform or data persistency. Only one looked for other things such as quality requirements, actors, purpose of the system, communication protocol, rationale of decision, design pattern and so on.

When the answers from both groups were combined and analyzed, the top three things searched for were main logical components (6 out of 8 participants i.e. 75%), purpose of system (50%) and quality requirements (50%). Among other things searched for were: use cases, process view, deployment of components (37.5%); external dependencies, actors, underlying platform and data persistency (25%).

The participants' highlighted information in the AD was also either generic or specific. 75% of the industry participants highlighted information that was related to main logical components or quality requirements (Table II). Half of them highlighted information related to use cases, process view, purpose of the system or user interface view of the system. The most highlighted information by the academic participants was related to use cases (100%). This is followed by information related to main logical components (75%), quality requirements, process view, components deployment and distributed nature (50%).

TABLE II. MAIN CONCEPTS IN ANSWERS & HIGHLIGHTED INFORMATION

	Answer			Highlighted Information		
%	**Industry**	**Academic**	**Combined**	**Industry**	**Academic**	**Combined**
100					use cases	
75	main logical components	main logical components	main logical components	main logical components	main logical components	main logical components
	quality requirements	process view		quality requirements		use cases
	purpose of system	components deployment				
62.5						quality requirements
50		use cases	quality requirements	use cases	quality requirements	
				process view	process view	process view
		external dependencies	purpose of system	purpose of system	components deployment	
		underlying platform		user interface view	distributed nature	
		data persistency				
37.5			use cases			
			process view			
			components deployment			
25	use cases	quality requirements	external dependencies			components deployment
	actors	actors	actors			actors
		purpose of system	underlying platform			distributed nature
		communication protocol	data persistency			user interface view
		rationale of decision				arch.goals & constraints
		design pattern				packages of java code

For the combined group, the following concepts (based on the highlighted information) emerged at the top of the list: main logical components and use cases (75%); quality requirements (62.5%); process view (50%); components deployment, actors, distributed nature, user interface view of the system, architectural goals and constraints, and packages of java code (25%).

D. Foraging Sequences to Support Better Understanding of SA

Apart from the information foraged for, the foraging sequence is also of interest, specifically in terms of the order of reading the information to support better understanding of the described SA. The participants were asked to suggest the sequences of reading the sections (relevant to the task) which would help to better understand the SA of DWC.

Table III shows the participants' suggestions on the first five types of information or sections to be read to support better understanding of the SA of DWC. The numbers in the bracket represent the actual order they were written in the AD. For example. participant E3 suggested to start by reading Table of Contents (TOC), followed by sections related to Introduction, main logical components, use-case view and logical deployment, where the actual order of these sections in the AD are 1st, 2nd, 6th, 5th and 13th respectively.

TABLE III. FIRST FIVE SECTIONS IN SUGGESTED READING SEQUENCES

Order in the sequence	Suggested Reading Sequence: Industry Participants – E2	Industry Participants – E3	Academic Participants – E4	Academic Participants – E8	Academic Participants – E9
1	TOC (1)	TOC (1)	TOC (1) Quality Req. (3)	TOC (1)	TOC (1)
2	Quality Req. (3) * External Dependency (4) *	Introduction (2)	Main logical components (6)	Use-case view (5)	Introduction (2)
3	Main logical components (6)	Main logical components (6)	Arch design package - signi. use cases (9)	Main logical components (6)	Quality Req. (3) * External Dependency (4) *
4	Size & performance (15)	Use-case view (5)	Distributed Nature (10)	Deployment view (12)	Size & performance (15)
5	Resiliency & testing (16)	Logical depoyment (13)	Process view (11) * Alternative deployment diagram (13) *	Introduction (2)	Resiliency & testing (16)

* Those in the same cell have the same order

Two industry and three academic participants suggested reading sequences. Those suggested by the industry participants have Table of Contents (TOC) and main logical components as the first and third section to be read. The rest of the first-five sections differed between the two sequences. Reading sequences suggested by the three academic participants also have 'Table of Contents' as the first-to-read section. The sections related to main logical components and Introduction had two academic participants suggesting them in the first-five sections to read but at a different order in the respective sequence. The rest of the first-five sections varied between the academic participants.

Due to the highly-variable reading sequences suggested in each group, we focused on the suggested sequences from both groups as a whole. Of all the five participants who suggested reading sequences, Table of Contents was proposed as the first to be read. Three suggested the section on main logical component as the third section in the reading sequences after reading either Introduction, architectural goals and constraints (which include quality requirements and external dependencies), or use case view. The introduction section was suggested as the second-to-read section by two of the participants. Sections on 'size & performance' and 'resiliency & testing' were suggested as the fourth and the fifth section to be read by two of the participants. Other sections (such as use-case view and quality requirements), which has two or more participants suggesting them as the first-five sections to be read, are in different order in the suggested sequences.

The first 3 sections in the reading sequences suggested by the different participants revolve around sections related to Table of Contents, quality requirements, external dependencies, Introduction, main logical components and use cases. Subsequent sections (4th and 5th) in the reading sequences tend to be more variable across the participants.

In comparison with the actual order of the sections as written in the AD, some of the participants suggested reading sequences that followed the written order of these sections, with different participants recommending different sections to be read while skipping some sections. Some participants (E2 and E8) suggested reading sequences which were slightly different from the stipulated order of sections in the AD. For example, participant E8 suggested to read Introduction section after reading sections related to use-case view, main logical components and deployment view, but the Introduction section came first in the AD before these sections. When asked about whether they backtracked to previous sections most of the time during the exploration of the AD, one disagreed and the other was undecided. This shows that their suggestions of out-of-order reading sequences were more inclined to their perceived usefulness of these sequences in supporting understanding, rather than due to their individual exploration styles.

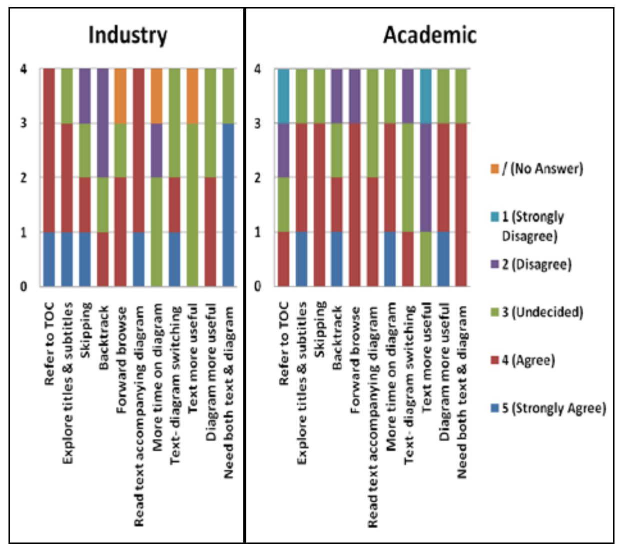

Figure 2. Foraging Styles and Perception on Text and Diagram in Supporting Understanding (Industry and Academic Participants)

E. *Foraging Styles*

Do the foragers explore based on table of contents, titles and subtitles? What about sections skipping, backtracking and forward-browsing? These foraging styles were also investigated.

On a 5-point Likert scale (where 1 is strongly disagree, 2 disagree, 3 is undecided, 4 is agree and 5 is strongly agree), all the industry participants agreed or strongly agreed that they frequently referred to the Table of Contents (Fig. 2). Three out of four of them also explored by looking at the titles and subtitles on a page most of the time. Half of them tended to skip some sections whereas the remaining was either undecided or disagreed on this. Frequent backtracking to previous section is not popular among them (1 out of 4). Half of them tended to forward-browse long sections (i.e. look ahead of the section to see where it ended before focusing on its content) most of the time.

Only one academic participant referred to the Table of Contents most of the time. Three out of four frequently explored based on the titles and subtitles on a page, often skipped sections and engaged in forward-browsing. Half of them backtracked to previous section most of the time.

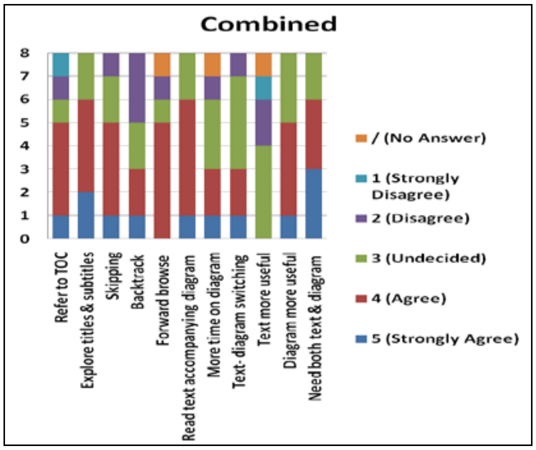

Figure 3. Foraging Styles and Perception on Text and Diagram in Supporting Understanding (All Participants)

When the participants from both groups are combined, their collective responses show that some foraging styles are quite popular among them (5 or more participants) i.e. referencing of Table of Contents, exploration based on titles and subtitles on pages, skipping sections and forward-browsing long section (Fig. 3). Of less popularity is backtracking to previous section (3 out of 8).

F. Understanding Support and Hindrance

When asked about the ways this AD supported their understanding of the SA of DWC, industry participants stated the following: use of terminologies, styles, patterns, standard protocols, notation, the structure of the document, charts and diagrams, and the presence of information that is generally included in ADs such as views (mentioned twice by different participant) and design decisions. For the academic participants, the following supported their understanding: diagrams (mentioned twice) and the related explanation, use case description, design considerations and decisions to achieve functional and non-functional requirements and having the expected information which was generally easy to find.

On what hindered their understanding of the DWC SA, the responses from the industry participants were descriptions without diagrams or examples, separation of design and execution time quality constraints, and the AD not being very precise or concise. The academic participants viewed too much textual description (mentioned twice), no mapping of modules to components, some out-of-order sections, inconsistency in naming sections and grouping contents, as factors that hindered their understanding.

V. DISCUSSION

Our interpretation of the data is presented here following the same organization as in the previous section.

A. Software Architecture-Related Experience

The two groups have comparable average years of SA experience in their occupations, making them suitable for the purpose of this study. The industry participants have longer experience in designing and changing SA of software systems whereas the academic participants' have longer experience in referring to and reviewing the SA of software systems. The 'other' SA experiences for both groups were different and therefore not compared.

All of the participants had prior exposure to software AD in general. Collectively there is little difference between the two groups in reading ADs, reading and making use of ADs in their tasks and writing ADs. An obvious difference is seen in terms of AD updating. All the industry participants had experience in that while half of the academic participants did not.

Collectively the industry participants were quite equally engaged in consuming (reading and making use of ADs in their tasks) and producing ADs (in terms of writing ADs) though half of them did not update ADs that often. The academic participants, collectively, were more consumers than producers of ADs, especially having lesser involvement in updating of ADs. This is in line with the job nature of the two groups.

The combined group shows a diminishing trend in terms of reading AD (7 out of 8 or 87.5%), reading and making use of ADs in their tasks (75%), writing ADs (62.5%) and updating ADs (50%). This shows that generally there was more engagement in AD production than in consumption among the participants. This is not a concern for this study as its main focus is on the usage of ADs.

Some industry participants had experience in architecting or documenting systems similar to the DWC system, while the rest (especially all the academic participants) had only read about similar types of system. The participants were also asked how each of their answer points was found (i.e. either by looking at the section title, reading the section or came from his or her past experience and knowledge). Only one participant from each group indicated that one of his or her answer point was not obvious from the AD but derived from past experience and knowledge. As such, the lack of experience in architecting or documenting systems similar to DWC among the participants is not a concern for this study.

B. Perceptions on the Given AD

The industry participants are slightly less in agreement on the ease of understanding the language the AD was written and the domain concepts, when compared to the academic participants where all agreed on these aspects. Nevertheless, generally the participants found the language the AD was written was not a barrier to understanding its content and the domain concepts were comprehensible. This again reinforced the suitability of the participants and the AD for this study.

C. Architectural Information Forages

To discover what information was foraged, the keywords, answers and highlighted information provided by the participants were analyzed.

The two groups of participants were not compared based on the keywords because of the imbalance in the number of participants from the two groups who provided them. Nevertheless one observation is that there is no repetition of keywords across different participants. One possible explanation is these participants have different pre-conceived ideas on what to look for with regards to the SA of a system prior to the exploration task.

However analysis on the participants' answers shows there are some similarities among the participants in each group in terms of what they were looking for when trying to find out about the SA of DWC. Comparing the two groups, it is interesting to note that one of the most common thing industry participants specified in their answers i.e. quality requirements of the system, was not common in the answers given by the academic participants. Nevertheless they seemed to place equal emphasis on main logical components with a majority of the participants (3 out of 4) from the two groups having it in their answers. Other than that, the majority of the industry participants also focused on the purpose of the system, whereas the majority of the academic participants focused on components deployment and process view. When the groups are combined, the information most searched for relates to main logical components.

The observation made from the analysis of the answers is also evident in the analysis of the highlighted information, i.e. though the majority (3 out of 4) of the two groups emphasized the main logical components of the system, they were also after other types of information. The highlighted content showed that information related to use cases was most sought after among the academic participants whereas the industry participants were more after quality requirements.

Similarly to what was found from the analysis of the answers of the combined group, the most sought after information was related to main logical components. In addition, analysis on the highlighted information uncovered another main information searched for i.e. use cases.

All in all, the variation of keywords searched for during the information foraging suggest that individual participants had different pre-conceived ideas on what to look for with regards to the SA of a system prior to the exploration task. However, the analysis on the participants' answers and the highlighted information shed some insights on the commonly foraged information with regards to the SA of a system. Combining the findings from both the analysis on the answer and the highlighted information, it seems that the majority of the industry participants (75% or more) were foraging for information related to main logical components, quality requirements and purpose of the system. The majority of the academic participants were seeking after information related to main logical components, components deployment, process view and use cases. This shows that apart from the information related to the main logical components, both groups have different emphasis on information related to quality requirements, purpose of the system, component deployment, process views and use cases, when looking for the SA of the system.

This perhaps points to a bias for academics to be more concerned with logical structure and function with industry participants being also concerned about structure but more concerned about quality attributes impacting on that structure.

D. *Foraging Sequences to Support Better Understanding of SA*

An analysis of suggested foraging sequences reveals that at the outset certain information is essential to be read first ('Table of Contents', quality requirements, external dependencies, 'Introduction', main logical components and use cases) to gain understanding of the SA of DWC. Following that, subsequent sections tend to vary among the participants indicating their requirements of different types of other information and of different sequences in reading them, to better support their understanding of the SA.

Comparison with the actual order of the sections in the AD shows that to support better understanding of the SA of DWC, the participants suggest foraging sequences that follow the sequencing of information as dictated by the AD producers, but skipping some of the sections and deviating intermittently from the flow. This could possibly mean that the sections in this AD have been ordered in a way that supports the understanding of the SA of DWC or the written order of the sections has some influences on the participants' perceptions on the reading sequence that would best support the understanding of the described SA, or both. In either of case, it reinforces the critical responsibility of ADs producers to structure the architectural information conducively in ADs for understanding purposes.

E. *Foraging Styles*

In terms of foraging styles, the most apparent difference between the two groups is that the industry participants frequently referred to 'Table of Contents' whereas only a minority of academic participants did that. This could be due to our coincidental recruitment of participants with the aforementioned-foraging styles for both groups.

Some foraging styles are quite popular among the combined participants i.e. referencing of table of contents, exploration based on titles and subtitles on pages, skipping sections and forward-browsing long section, with the exception of backtracking to previous sections. This phenomenon could be because most of the participants are sequential readers or the information in the AD is well-sequenced with each section sufficiently self-contained.

F. *Understanding Support and Hindrance*

The industry participants emphasized 'views' as the way the AD supported their understanding of the DWC SA. The academic participants emphasized the diagrams. A diagram can be part of a view but not vice versa. For example a deployment view may consist of a deployment diagram as well as textual explanation related to deployment. All in all, diagrams, views and design decisions were most frequently cited by the combined group of the participants as supporting their understanding of the SA of DWC.

The main problem stated as hindering understanding was too much text with lack of diagrams. But the availability of diagrams topped the list when asked about the ways the AD supported the understanding. Further inspection uncovered that those who stated that the availability of diagrams in the AD supported their understanding were also the ones who said that too much text with lack of diagrams hindered their understanding. It seems that diagrams played a vital role in assisting these participants to understand the SA of DWC and though were present in its AD there were still not enough for them. There are 7 diagrams in the 24-page AD namely: use-case diagram, high level logical components diagram, high level diagram on distributed nature, process diagram and 3 diagrams related to deployment. Nevertheless for graphical-oriented foragers these are still inadequate.

We posit the existence of graphical-oriented foragers, whose inherent cognitive styles [18] were more inclined towards imagery as opposed to verbal. This is in tandem with the discovery of a developer group who predominantly made use of diagrams in ADs [13]. AD producers should take into consideration the existence of graphical-oriented foragers so as to produce ADs that support their needs as well as the needs of more textual-oriented foragers.

G. Threats to Validity

The use of non-probabilistic sampling techniques in recruiting the participants rendered the results not generalisable to the target population [17]. Also contributing to that was the small number of participants who took part in foraging architectural information in search of the SA of the described system, in our study. However, these participants had strong experience in SA with 5.75 to 11.25 average years of experience in designing, referring, changing and reviewing SAs of systems. The domains of the systems designed were different between all the five participants who provided information on this. Collectively they also had good experiences in the production, and especially in the consumption of ADs, which is the focus of this exploratory study. This leads us to believe that the findings are useful for providing early insights into architectural information foraging. In addition, as in any qualitative analysis, our study is subject to the bias of the researcher when coding the data. This is mitigated by undertaking two meticulous rounds of coding. The choice of the DWC AD could have some influence on participant foraging activities and therefore findings. This will be addressed using a second AD in future.

We instrumented the ADs with the annotation widgets and borders, and separated the diagrams from the texts for annotation purposes. This may have affected the behavior of the foragers. However, all the participants involved were given the same instrumented AD and since we are looking for 'commonly' foraged information and foraging sequence amongst the participants, this does not affect our results.

VI. Conclusion

In this study we discovered a number of interesting insights with regards to architectural information foraging in AD. These include issues related to the forages, foraging sequence and styles, features of AD that supported or hindered understanding. There seems to be different pre-conceived ideas on what to look for with regards to the SA of a system prior to the exploration task. However, it turns out that during the foraging process there was some commonly foraged information. The most popular among the industry participants was information related to main logical components, quality requirements and purpose of the system. The majority of the academic participants were also after information related to main logical components but not the other two. Instead they foraged for information related to components deployment, process view and use cases.

Interestingly, apart from the information related to the main logical components, both groups have different emphasis on information related to quality requirements, purpose of the system, components deployment, process view and use cases, when looking for the SA of the system. The focus on the main logical components shows that the most important view for the industry participants was the logical view. The academic participants seemed to prefer a more diversified views of the SA by looking at logical view (main logical components), process view and physical view (component deployment). The focus of industry participants on the quality requirements could be due to their experience with the impact of this type of requirement on the sustainability of the systems they developed. The academic participants most likely had less experience here as the impact of quality requirements might not be fully manifested in the one-off prototype systems they usually built.

It seems that the industry participants were comfortable with knowing the purpose of the system without the use cases to get an overview of the SA of a system. However the academic participants required detailed use cases description to understand the functionalities of the system. It was cited as one of the ways the AD supported their understanding of the SA. This shows the two groups required different levels of information in this aspect to understand the described SA.

In terms of foraging sequences, those that started with certain information such as the overview of AD (‘Table of Contents’ and Introduction), logical view (main logical components), quality requirements, use cases and external dependencies (which may affect other design decisions) were suggested to better support understanding of the described SA. Subsequent sections to be read and their ordering varied based on the requirements of the individuals. Suggested foraging sequences typically followed the written order of the information as dictated by the AD producers, albeit skipping some of the sections and deviating intermittently from the flow. This shows that it is of vital importance for the ADs producer to structure the architectural information in the ADs in ways that support understanding.

In general some foraging styles were quite popular i.e. referencing of table of contents, exploration based on titles and subtitles on pages, skipping sections and forward-browsing long section, with the exception of backtracking to previous section. One possibility of not much backtracking could be the foragers are predominantly sequential readers and therefore sections of ADs should be sufficiently self-contained. The industry participants reported a more balanced experience in terms of consuming and producing ADs whereas the academics were more of consumers. We need more data to see if this could have influenced their foraging of architectural information in ADs.

While foraging of architectural information in ADs is quite dependent on individuals, there exists commonly foraged information and general foraging styles. These insights serve as useful considerations for AD producers when writing ADs. The suggested foraging sequences which typically followed the written order of the information in the ADs, further reinforces the critical responsibility of AD producers to structure the architectural information conducively for understanding purposes. We are working on reconciling these findings with the second AD to provide better insights on architectural information foraging in ADs.

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