Context Factors: What they are and why they matter for Requirements Problems

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***Abstract*—When eliciting requirements, it is important to understand why some information may remain implicit, while other are shared by stakeholders. This requires knowing which variables influence if an individual shares implicit information during requirements elicitation. Based on our past experimental work on decision-making, we identify variables – *Context Factors* (CFs) – which influence whether implicit information is shared, and we define a procedure to validate CFs. Our contribution is that we present and define a set of CFs, we define an experimental procedure to validate CFs, and we discuss how the understanding of CFs helps identify information that can remain implicit during elicitation, and can thereby help to increase the completeness of requirements. We relate CFs to the common Requirements Problem concept, and we highlight the main limitation of our results.**

***Keywords*—Requirements Problem, Elicitation, Context Factors, Implicit Information**

I. Introduction

Although Requirements Engineering (RE) is a complex activity, the basic problem that it aims to solve within a systems engineering project – called the *Requirements Problem* (RP) – can be stated in simple terms: *Given assumptions about the domain in which the system-to-be should run, and the requirements of the system's stakeholders, find and describe a design of that system which is consistent with the domain assumptions, and together with domain assumptions, satisfies the requirements.* If we denote domain assumptions with K, requirements with R, and the description – specification – of the system-to-be with S, the idea above amounts to the RP statement from Zave & Jackson [1]: given K and R, find S such that $K,S \vdash R$, where $\vdash$ is some consequence relation.

An RP instance is the result of elicitation and design activities a requirements engineer does. If we denote with I all information that she can potentially elicit from stakeholders and discover or design on her own, we can split I into I_X, the information that the engineer manages to document, and other information I_M that remains **implicit**. Since we assume that K, R, and S are documented, they are parts of **explicit** information I_X.

The obvious **risk** that this **explicit/implicit distinction** highlights, is that *the implicit K_M, S_M, and R_M may include key information on stakeholders' expectations and assumptions, so that if they remain implicit, the requirements engineer may end up solving a wrong RP instance.* The goal of this paper is to advance our understanding of this risk and contribute to research on how to mitigate it. To do so, we view the relation between I_M and I_X as a function:

$$I_X = f(CF, I), \tag{1}$$

where I_X depends on the available information and other variables, which we call *Context Factors* (CFs). The objective of the paper is then to *identify, justify and suggest a way to validate the content of CFs*. Our contribution is that we identify variables that go into CF, and that we define an experimental procedure for validating CFs, *based on our past experimental work* on the role of implicit information in decision-making [2], [3].

The rest of this paper is organized as follows. We first discuss the relation between RP and CFs, and introduce the notion of a filtered RP (§II). We define CFs, and provide their taxonomy (§III). We define our experimental procedure (§IV). We discuss related work (§V), and summarize conclusions and directions for future research (§VI).

II. Filter in Requirements Elicitation

A. Introductory Example

Consider the chief financial officer of a firm. She wishes her company's accounting software to be connected with the ecommerce software, so that ecommerce sales can be automatically recorded. Denote this proposition with p. Once p is communicated to the engineer, it is part of explicit information I_X. Also, since p seems to be a requirement, it would likely be part of R_X in the RP, provided p remains relevant during RE.

How p fits an RP instance, depends on other information in both I_X and I_M. In I_X, because it may already be part of I_X that accounting software is not to be changed through work on the new system-to-be, so that p as a requirement falls outside the scope of the systems engineering project. In I_M, because the requirements engineer may assume that, the stakeholder was not informed about the scope of the systems engineering project, and so gave p on the basis of wrong assumptions.

Suppose now that the stakeholder makes assumptions when giving p, that the requirements engineer does not know so that they are in I_M. For instance, that the accounting department needs to be motivated to use the system-to-be, that this motivation can arise if they see the system-to-be will simplify their work and that the connection with the ecommerce software is a simplification of that work. Those assumptions directly relate to the context of the business.

The way we see the situation in the example, is that the explicit information which will be shared by a stakeholder i depends on information accessible to her, and on other variables, the CFs: $I_{Xi} = f(CF(i), I_i)$. By $CF(i)$, we mean that the importance of specific CFs will vary across stakeholders. We do not write CF_i, because we are interested in CFs that apply across different stakeholders. That is, we assume that CFs will influence information sharing for all stakeholders, but we cannot assume that every CF has exactly the same effect on every stakeholder.

Equation $I_{Xi} = f(CF(i), I_i)$ is not good enough, as it does not account for the role of elicitation strategies that the engineer applies. If we denote E elicitation strategies, such as interviews, observation, study of documentation, etc., and we denote g the engineer who applies these strategies, we have the following:

$$I_{Xi} = f(CF(i), E_g, I_i). \tag{2}$$

We can then relate CFs to the RP, as follows: The *explicit* Requirements, Domain assumptions, and Specifications, are based on information which is *filtered*. We consider this observation important, because it leads us to consider what the filters may be, and how they work. This suggests there are three types of filters:

- *Expertise*, in the sense that individual stakeholders, based on their interests, responsibilities, and so on, have access to part of all information that may be relevant. Hence the subscript on I: I_i need not be equivalent to I_j of a stakeholder j;
- *Context Factors* (*CF*) influence which information will be shared, and depend on the environment other than the elicitation strategies;
- *Elicitation strategies* (E) that the engineer applies.

For instance, as financial officer of the company, the stakeholder may have limited knowledge about the system's design and the kind of information that it requires to be correctly performed. Because of her *expertise* in a domain, she may not be conscious that some information she has is relevant to RE. She will therefore filter it involuntarily. The situation in which the elicitation happens also acts as a filter. For instance, considering that the company has financial troubles would probably influence the communication of the officer, because in such context an error would be even more damageable. Hence, the stakeholder can be influenced by some specific *context factors*. Finally, a stakeholder will filter information depending on what is being asked to her and how it has been asked, regardless of her expertise or the context. In other words, the stakeholder is influenced by *elicitation strategy* adopted by the engineer.

B. Requirements Problem Filters

As an answer to the previous observations, we suggest the **filtered requirements problem**. Considering the previous example, we claim it is more relevant to write the RP as $K_X, S_X \vdash R_X$, instead of $K, S \vdash R$: the former reminds us that domain assumptions, requirements, and the specification are the result of filtering. In $K_X, S_X \vdash R_X$, we read K_X, S_X, R_X as follows:

- R_X is the result of the engineer's analysis of individual stakeholders' requirements, where for each stakeholder i, we have $R_{Xi} = f(CF(i), E_g, R_i)$;
- K_X is the result of analysis of individual stakeholders' domain assumptions, where for each stakeholder i, we have $K_{Xi} = f(CF(i), E_g, K_i)$;
- S_X is the result of the engineer's decisions on the design of the system-to-be.

The main problem of RE is then to make sure having the largest K_X, R_X and S_X and hence minimize the implicit/filtered information. We are aware that there can be interaction between CFs and Elicitation strategies, and that it may be more appropriate to put them together, as one combination of variables. Yet, we keep the distinction, because we believe that we should first attempt to understand CFs separately from E_g, in part because research on the design of Elicitation strategies can be informed by a better understanding of CFs.

C. Internal and External Factors

Before we proceed further on CFs, we explain the reasoning that led us to the filtered RP, and the three types of filters. Our basic assumption is that a stakeholder's reasoning, when deciding to share information, is non-monotonic: the stakeholder checks the information to share against her assumptions, chooses to share, does share, and can retract the information (change her mind) if she finds out new information, which invalidates her prior assumptions. Research on non-monotonic reasoning distinguishes two types of variables that influence reasoning, namely internal and external variables.

Internal variables concern the way an individual uses knowledge and heuristics in reasoning [4], [5], [6], [7]. Factors are internal when they are not specific to the environment in which the reasoning takes place. We leave all internal variables as being related to I_i in $I_{Xi} = f(CF(i), E_g, I_i)$, that is, as influencing the information from which the stakeholder picks that, which she will share. We are not interested in internal variables in this paper, mainly because our aim is to work on factors that can be influenced in a more straightforward manner, being related to the environment of the stakeholder. This restriction in the scope of our research also means that we cannot recognize if/when there are interactions between internal and external variables. We consider, however, that this limitation should not hold us back from drawing relevant conclusions about external variables.

External variables concern the environment of stakeholders and are not related to reasoners [8], [9], [10]. We divide these variables into CFs and E_g, as we want to emphasize that, while elicitation is an external influence on stakeholders, it is not the only one which influences how stakeholder shares.

The rest of the paper focuses on a taxonomy for CFs and ways to validate it.

III. Context Factors

CFs are variables characterizing the context of the stakeholder during elicitation. The purpose of identifying and analyzing CFs is to adjust elicitation strategies to the specifics of the context. In this paper, we consider operational definitions of context [11], [12], as their are composed of a finite set of well defined dimensions.

Operational definitions are useful when deciding about elicitation strategies, since there exists a finite number of context dimensions – or CFs – to investigate. To make sure the engineer does not miss key implicit information, questions should be asked about each CF. This brings us to the related question of *which CFs there are*. We explore this question below: we give an operational definition of context, that we argue accounts for the dimensions of context that are relevant in the scope of a requirements elicitation.

A. Taxonomy of Context Factors

Strictly speaking, CFs are not a set of concepts defining a particular context. By defining CFs, we are not defining an entity-relationship-like model of a particular context. If we model objects in a given context as instances of concepts, then CFs are meta-concepts, the instances of which are concepts that we would expect to recur over different specific contexts. We see the set of these meta-concepts as a non-exhaustive checklist to use in improving the elicitation of information about a specific context. CFs are issued from an extended review of the literature on context and ubiquitous computing [3], and is composed of six categories that have been proved to be relevant for RE.

Some CFs are dimensions dealing with the range of a context, i.e. the *scope of context*. The engineer must be careful to identify and investigate these factors, in order to adapt the elicitation strategy, determine the scope of context and hence increase completeness of I_X.

Items deal with *salient entities existing inside the context*. They can be instantiated across two groups, human and artificial: human items are real and living entities that likely interact with the system (e.g. stakeholders), while artificial items are typically objects that have been created by human items (e.g. softwares, devices, furniture, etc.). Such distinction matters, since human and artificial instances likely have different impact on filtering process, and therefore on the filtered RP instance.

Rules deal with *constraints existing in the context, which hold true regardless of Items' states*. They refer to notions such as laws, cultures, habits, etc. Rules deal with any constraint that applies to elements of the context and which survives after their death. Rules deal with the nature and the content of the constraints, but also with their justification and status inside the context.

Localization deal with *the position of the context*. Localization divides into two subcategories: one relating to the time, the other dealing with place. Defining the scope of a context requires the review of Items and Rules combined with Localization Factors to support engineer in determining at what time and what place formerly identified instances are to be considered.

Some other CFs must be studied to make sure scoped elements of the context have been sufficiently detailed, i.e. the *depth of context*. Depth CFs do not make sense if considered without regards to scope. It is not relevant – or at least not efficient – to ask detailed questions to stakeholders if the scope is not correctly defined.

Connections deal with *the relationships/links between Items and/or Rules*. They focus on the way entities of the scoped context relate to each other.

Activities deal with *objectives of those Items instances, which are intentional*. They refer to set of goals and intentions of such Items existing in the scope of context.

Granularity deal with *the nature, the quantity and the level of information that is provided about Items*. They must be considered at two different levels. A first level called "Micro" handles factors related to instances. A second level called "Macro" deals with information that only makes sense a the level of the entire context.

The six previous categories together form what we consider to be the set of CFs. A major drawback of our approach is the impossibility to demonstrate these categories are the only to be part of CFs. If the set of factors we identify as being part of CFs is referred to $B = \{I, R, L, C, A, G\}$, then we have that $CF \supseteq B$. We claim this set of factors is necessary but not sufficient for eliciting information about context. By necessary, we mean that omitting any of these categories would lead to misunderstanding about how CFs filter, and hence to gaps in the identification of I_{Xi}.

B. Elicitation Strategy

Beside the filter they represents in the RP, CFs can be used to adjust the Elicitation strategies E_g to the specifics of the context, and hence improve completeness of the elicitation. By asking the right questions in the right way, we claim it is possible to enforce the stakeholder's filter and get more information than what would be shared spontaneously. This section illustrates what CFs are, and how they suggest questions to be asked to stakeholders in order to increase completeness of I_{Xi}. This discussion in not exhaustive and suggests no methodology. It simply shows how CFs can identify types of information to elicit. Questions are to be considered in the context of our introductory example.

Items factors lead to questions such as:

- Who are the members of the accounting team? Who else need access to the system?
- From which system(s) do e-commerce data come? What hardware is used to exchange data?
- What are the expected output of the system? What is meant by sales results? What are the reports? Who are the requesters of these outputs?

Rules factors may lead to questions such as:

- What are the regulations for the treatment of e-commerce data? Who/What is the source of these norms, guidelines, etc.? What if the rule is violated?
- What are the internal rules from the management? What conditions make these rules applicable?
- What are the best practice, the norms and the guideline in e-commerce?

Location factors may lead to questions such as:

- When and where the reports will be accessed, be published, be communicated?
- What is the frequency of sales results updates? When do transactions happen? Where are they recorder? How much time do they occur in time?
- How and how often do Items change over time?

Connection factors may lead to questions such as:

- What are the relations between the departments of the company? Do they work in collaboration or in conflict? How much are part of the relation?
- How strong is a connection between departments? What are the consequences if it disappears? What is the purpose of the relation? Which department is active in this connection?

Activity factors may lead to questions such as:

- Why are the reports important to the financial officer? What does she expect from it?
- What is the core business of the company? What is the vision and strategy for business?
- Who sets the targets of the company? What are the mechanisms to ensure the compliance?

Granularity factors lead to questions such as:

- Do we have a clear understanding of the metrics expected by the business? Do we need to refine?
- Do we have enough details about the kind of data that are required to compute sales results?
- Is there some imprecision in the available data? How detailed and precise is the information?

IV. Prototype Experiment

We claimed in this paper that stakeholders retain information according to three filters: expertise in a domain, CFs and Elicitation strategy. Moreover, we discussed the significant relations between CFs and Elicitation strategies. Although CFs presented in this paper are issued from a literature review on context, our ongoing work is the empirical validation of CFs we presented, as actual and valid members of the filter function $I_{Xi} = f(CF(i), E_g, I_i)$. This section presents a prototype experiment to be used for such validation, and is based on our past experiments on context and non-monotonic reasoning [3], [2].

A. Questionnaire

It consists of six distinct groups of "assertions" that are to be read as pieces of context. Those assertions are potential instances of the CFs meta-concepts. Two tasks are required for each assertion. Subjects are first asked whether they judge the assertion relevant in the scope of an IT project, i.e. if it would be more difficult to perform RE without that assertion being clarified. In a second time, subjects are asked about the likelihood that a customer discuss the assertion spontaneously. Based on this double evaluation, it is possible to determine whether CFs are relevant to RE, but also to analyze whether practitioners consider CFs as being filters in the communication of stakeholders.

The list of assertions used in our experiment is presented in Table 1 (one line per CF). The table is the result of authors experience, and aims to stay relevant with the sample of questions suggested in section III-B. Evaluation of the assertions is done on a 5-level scale. Subjects have the possibility to suggest other relevant assertions, for each CF.

A pilot study has been conducted with a dozen subjects, to ensure the questionnaire is easily understandable, the instructions are clear, and the Internet based collection method is appropriate. Feedback of subjects were positive, and preliminary results suggest interesting results for a larger scale experiment. The pilot study also contributed to the definition of the final assertion list.

Situation described to subjects: Your colleague asks you some advice for next mission. She has to design a system, and plans a first conference call with the customer to collect as much relevant information as possible. She is not sure about how to proceed during the interview, and asks you some advice.

Instruction described to subjects: Knowing about your experience, she asks you to evaluate some assertions that she thinks will enable her to have a good idea of the business. Her concern is to cover as much content as possible. You are asked to judge the relevance of her assertions, and the likelihood that a customer discuss it spontaneously. Use a value between 1 and 5 to express the relevance/confidence toward statements, 5 being the largest grade.

B. Target Population and Procedure

We will mainly submit the questionnaire to professionals in computer sciences, software and requirements engineers. We also target participants with experience in project management, ICT or other relevant management skills. Information about participant's professional status will be collected and treated to ensure the validity of the experiment.

To collect feedback on the questionnaire, and repeat the experiment, the questionnaire will be published on the Internet, under the form of a regular questionnaire. Participants will be asked to carefully read the assignment before answering. The assignment will clearly ask to read the problem statement and the different choices that are offered before starting the grading activity.

The approach of the experiment is top-down. We start from some broad meta-concept – CFs – and try to validate instances of these CFs that are relevant in RE. This implies the list of assertions suggested in this experiment is not complete. This also implies the work should be extended through additional studies.

TABLE I. SUMMARY OF ASSERTIONS SUBMITTED TO SUBJECTS' EVALUATION

	Q1	Q2	Q3	Q4	Q5
I	Units and Structure of the business (department, team, ...)	People interacting with the system	Objects related to the system	Other IT systems of the company	Input and Output of the system
R	Applicable laws and regulations	Best practices in business	Recommendations and Constraints from management	Norms, guidelines or culture	Habits, traditions of the business
L	Place/time where or when the system is used	Frequency of use of the system	Aspects of the business changing over time	Phenomena occurring at regular interval	Synergies inside the business
C	Types of relations between items (friends, enemies, etc.)	Respective power of agents inside a relation	Nature of important relations in the business	Importance of these relations to the company	Strength of the relation
A	Core business of the company	Vision and Strategy for the business	Purpose of the system	Intention behind the IT solution	Goal and Targets assigned to employees
G	Metrics relevant to the business	Legal or Financial status	Atmosphere in offices, on market	History, Evolution in the past of the business	Particularities of the company

V. RELATED WORK

The empirical validation of factors that influence decision-making – and among other the decision to share information – has been a center of attention in many fields of research. Yet, considering origins of our contribution, we specifically focus this section on context studies in non-monotonic reasoning literature (NMR) and context in RE.

As already explained, we see two different categories of CFs. A first one is related to human cognition and influences what information I_i is accessible to stakeholder. Ford and Billington [4], [5] propose an experiment to validate the impact of such subjects-related factors. They present factors such as *the reluctance to draw conclusion based on conflicting rules* or *the number of positive and negative sentences*, which they argue influence the consistence of subjects when reasoning. Hewson and Vogel [6] present an experiment which suggests human reasoning is consistent with some basic assumptions of NMR literature, but found that people do not always satisfy literature's predictions when reasoning about a chain of negative sentences. Vogel [7] proposes an extension of previous study, designing an experiment to test other forms of negative reasoning.

A second category includes factors which are not, strictly speaking, specific to the person and influence the content of I_{Xi}. Wason and Shapiro [10] propose experiments that emphasize the difference in performance between subjects, depending on the way problems are introduced to them. They suggest these differences are due *to the concreteness of terms that are used* – some are concrete while others are abstract terms– , thereby emphasizing the intrinsic influence of information. Elio and Pelletier [8], [9] propose that reasoning is likely to be influenced by several external factors. They highlight that whether an objects is *naturally-occurring* or *artificial* influences the way people think about this object. They also discuss the influence of other factors like the *quantity of information* that is provided or the information about the *relative size* of the objects.

In addition to previous NMR studies, we performed several experiments to get better insight into the influence of external factors on RE and elicitation. For instance, we showed that some external factors proposed by Elio and Pelletier do not have the same influence in the context of RE [2]. We also have some other ongoing experiments on context [3]. We propose a Context Framework – issued from a literature review on context-aware and ubiquitous computing – to account for several dimensions of context and their influence on reasoning in RE.

There has been limited attention regarding the question of accurate context's definition in RE. Yet, context as a source of information is not new. Many papers propose high level discussions about context in RE: Potts and Hsi [13], [14] emphasize the existence of *Contextualism* – opposed to abstractionism – as a possible alternative design philosophy for information systems. Sommerville et al. [15] propose discussions about how *ethnographic analysis* is value-added to RE, thereby broadening the scope of RE context to culture questions. Beyer and Holtzblatt propose the Contextual Design model [16], which increases the scope of relevant information to any data about *the field where people are living*. Previous works illustrate the trend to include even more data in the scope of RE relevant information.

Cohene and Easterbrook [17] discuss a topic closer to what we address in this paper. They suggest elicitation techniques that are used in a interview should be adapted to fit the kind of information engineers are trying to find, i.e., adapt the elicitation technique to the situation – or context.

Previous related works highlight how valuable information about context is to RE. But few papers propose a structured definition of context. Sutcliffe et al. [18] go on a method for requirements analysis which aims to accounts for individual, personal goals and the effect of time and context on requirements. They suggest a list of aspects to deal with, but do – to the best of our kowledge – no empirical validation. RE community seems to agree on the importance of further research on the link between context and RE. Cheng and Atlee [19] stress the importance of context and empirical validation of RE models as a direction for future research to accelerate the transfer of research results into RE practice.

VI. Conclusions

In this paper, we tried to contribute to the clarification of how stakeholders may keep some relevant information implicit during the elicitation of requirements. We argued that instances of the classical RP are obtained through a filtering process, we suggested a conceptualization of variables that influence the filters, and called them CFs. We discussed how CFs relate to requirements problem, suggested a list of CFs, and proposed an experimental procedure for validating the relevance of some individual CFs.

Our ongoing work consists of applying the experimental procedure, the resulting refinement of CFs, and the study of how CFs relate to requirements elicitation strategies. We believe that this work is relevant with regards to increasing the rigor in requirements elicitation, and for enabling future design of systematic elicitation strategies. We also see this research as part of ongoing RE research on defining and using the notion of context in requirements.

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