UNDERSTANDING THE ROLE OF INFERENTIAL REASONING IN THE REQUIREMENTS ELICITATION PROCESS

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Research-in-Progress

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Abstract

A critical aspect of information system development (ISD) projects is identifying, interpreting and specifying the requirements for a proposed information system. In this article we focus on the reasoning process employed by the stakeholders of the RE process. We argue that new insights in RE may be gained by trying to explore the reasoning process that underlines RE. Specifically we argue that a deeper understanding of this process can be developed by exploring it through the Naiyayika system of inference. During the course of this paper we explain the special nature of this school of inference; which relies on empirical observation to create a rule based mechanism for assisting one’s understanding of the context. Initial insight is developed from applying the lens of Naiyayika school of inference to the qualitative data collected from Indian IT services organizations is discussed from a perspective of seeking new insights about the RE process.

Keywords: Requirements Elicitation, Inferential reasoning, Naiyayika School
Introduction

A fundamental and critical aspect of information system development (ISD) projects is identifying, interpreting and specifying the requirements for a proposed information system. These activities are traditionally considered to be the part of the requirements engineering (RE) process and have a significant impact on the success of the overall ISD project. While the criticality of RE process has been widely accepted, its failures have been well documented leading to downstream project phases, in terms of quality, productivity and budget (Curtis et al. 1988). The criticality of this activity makes this an important area of focus for both academia and practice. There is a long tradition of research in this area that has attempted to understand this activity more deeply, focusing on its many challenges. These challenges have been investigated and documented by the extensive research carried out in this area.

A substantial extent of the research on RE has roots in software engineering, systems modeling literature and aims to provide a normative and prescriptive view of the process (Hickey and Davis 2002; Sommerville, 2007). The research adopting a more behavioral lens draws mostly from theoretical work in sociology, psychology, organization behavior and management literature. An important section of such literature looks at the collaborative process. This literature takes a contextually situated, non-deterministic view of the process and understands it in terms of a collaborative activity involving stakeholders with diverse worldviews, who understand and co-construct the requirements through the process of knowledge transfer and sense-making (e.g., Davidson 2002; Gasson 2006; Urquhart 1997). There has also been prominent research that has used an individual level of analysis. The focus of this research has been the stakeholders of the RE activity. Examinations have been carried out in the areas of skills, analysis processes, impediments, enablers etc. (Browne and Ramesh 2002; Deifel 2009; Hickey and Davis 2002; Sommerville 2007) and socio-collaborative activities of the stakeholders (e.g., Chakraborty et al. 2010; Urquhart 1997).

Our focus in this research is on the process used by individual stakeholders to understand requirements and the manner in which they process inputs from the environment. In other words, how the experiences from the immediate surrounding is used to create an objective representation of the world (a subsequent input to the collaborative interaction of co-constructing the requirements with other stakeholders). Existing research has previously examined a similar problem using perspectives from cognitive psychology (Browne and Rogich 2001; Orlikowski and Gash 1994; Pitts and Browne 2004). Such research has provided evidence that cognitive strategies can improve the outcome of the RE activity (e.g., Davis, 1982; Walz, Elam and Curtis, 1993). Specifi cally research has examined influences of cognitive differences leading to analyst performance (e.g., Schenk, Vitalari and Davis 1998; Vitalari and Dickson 1983), and also the cognitive appropriateness of different tools and techniques (e.g., Browne et al. 1997; Browne and Ramesh, 2002; Browne and Rogich, 2001; Lohse, Daiwan and Olson 1995) in eliciting requirements (Pitts and Browne, 2004). Research has also examined the RE activity in terms of technology frames, representing schemas and mental models that individuals develop and evolve in an attempt to better understand the requirements (e.g., Orlikowski and Gash 1994; Davidson 2002). Browne and Ramesh (2002) suggest that a particular issue in RE stems from the problems with the nature of reasoning employed by individuals to infer beyond and to extend their own mental models. Such erroneous and often illogical inferences can result from incomplete knowledge, inadequate mental models and inadequate arguments used to support claims about the system and can lead to inaccurate requirements specifications (Browne and Ramesh 2002). Therefore it is perhaps important that RE research investigates the nature of the reasoning process, paying attention to possible fallacies and how such a process may be facilitated. In this research we specifically examine the reasoning process wherein the individuals apply existing and new information inputs to obtain an understanding of the information system requirements. In this endeavor we depart from existing tradition of drawing from cognitive psychology and apply insights from the philosophical traditions involved with the rational or logical mechanisms. We have chosen to be informed in this enquiry by the approach to inferential reasoning evident in the thoughts of the Naiyayika school of reasoning and philosophy. Our research endeavor tries to answer the following main research questions.
What new insights can be gained about the reasoning process underlying the RE activity by examining it through the lens of the Naiyayika traditions of inferential reasoning?

How can such insight be applied to both research and practice?

Our central motivation in attempting to consider inference as a possible approach to understanding reasoning as a process as well as a behavioral thematic. We attempt to elucidate this assumption and articulate our stance in subsequent sections. Second we assume that inference has the potential to shed light on the RE reasoning process. Third we want to borrow the essence of inferential reasoning from Indian Logic to instantiate and possibly elucidate the reasoning process of RE. Our endeavor is to move beyond the general frame of linking it to either a process or a behavioral thematic and concentrate on the nature of how an participant of the RE process converts his experience of the world into a rule based representation of that world using the nature of inference from the Naiyayika school of thought. The context for representation may be embedded in a process or derived from converting an observed pattern of behavior into a mechanism that is objective and generalizing for representing that specific context.

The rest of the manuscript has been structured in the following manner. In the next section we discuss in length the notion of “reasoning “within the RE context. We then clarify what informed our choice of reasoning mechanism/tradition, and describe its fundamental tenets. Next, we provide details about our methodology and discuss our initial findings. We conclude with a discussion of potential contributions to research and practice.

Understanding “reasoning” within the RE context

The RE process has been characterized as a complex and interaction intensive activity which requires the stakeholders (particularly the systems analyst) to “structure an abstract problem, acquire and organize necessary and diverse information, and transform that information into a complete and accurate set of requirements” (Pitts and Browne 2004, pg 205). Research (Pitts and Browne 2004; Vitalari and Dickson 1983) suggests that the capability to do so requires critical problem solving abilities. Within the context of RE, problem solving refers to the reasoning process the stakeholders use to analyze the specific information system requirements determination (Vitalari and Dickson 1983). This reasoning process is vital to the process of RE. Browne and Ramesh (2002) suggests that a faulty process to be one of the challenges that inhibits accurate and comprehensive RE. Given such a background, understanding the nuances of such reasoning process, offer the potential for better understanding how the RE activity may be improved. However in order to do so, it may be useful to understand what such reasoning entails given the environmental conditions underlying the typical RE activity.

RE has been acknowledged to be a socio-collaborative process where system requirements are understood through intense interactions between the participating stakeholders (business users and systems analysts) (e.g., Chakraborty et al 2010; Urquhart 1997). An important characteristic of this process is that the participants bring into the forum diverse world views and perspectives about the proposed information system. Such world views or perspectives are essentially frames of reference that encapsulate their individual interpretations of their world. Gioia (1986) suggests that such frames define an individual’s understanding of the organizational reality and includes “assumptions, knowledge and expectations, expressed symbolically through language, visual images, metaphors and stories” (Orlikowski and Gash 1994, pg 176). In the context of RE, the two main actors, the business users and the systems analysts have frames of reference that are quite distinct. The business user’s subjective reality of the organization is couched in terms of business processes, their dependencies and related information elements. On the other hand the system analyst’s organizational frame of reference is far more technology centric, and bounded by a systems view of the organization. However research (e.g. Jarke and Pohl 1993; Orlikowski and Gash 1994; Urquhart1997) indicates that while there exists substantial differences in the frames of references of participants, a necessary condition for the success of RE is the development of shared frame of reference. Orlikowski and Gash (1994) terms such potential frames as technology frames. These frames represent the organizational actor’s assumptions, expectations and knowledge to understand the nature and role of technology as well as its application and consequence within the context of an organization. It is important to note at this juncture, a very important aspect. The technology frame that is developed needs not only to be shared but also congruent (Orlikowski and Gash 1994). The implication of this is that the technology frame that is developed is distinct from the original frame of reference in that for both the actors, the frame of reference needs to incorporate elements of frames of reference of the other (i.e. organizational context for the systems analyst and the systems context for the business user). Therefore both the actors participating in RE are forced to develop an interpretation of the organizational reality with unfamiliar elements that are not easily
The shared and congruent technology frame is developed by the stakeholders through a socio-collaborative process of mutual knowledge transfer (Chakraborty, Sarker and Sarker 2010). This socio-collaborative process is iterative in nature and results in gradual evolution of the subjective understanding of the individual stakeholders of system requirements to a mutually shared and congruent understanding. It can be logically construed that underlying this iterative socio-collaborative process and facilitating the development of the shared and congruent frame is the process of reasoning employed by the individual stakeholder. In other words, the stakeholders apply the process of reasoning to the sensory input received through the knowledge transfer and social interaction and develop the mutually shared understanding of the system requirements. It should be noted that as this shared understanding (the technology frame) contains elements that are initially unknown or not understood by the stakeholders, it is evolved through a process of making initial interpretive assumptions about the requirements that are modified and reformulated as further sensory input are received and processed (Pitts and Browne 2004). Therefore in summary the nature of reasoning that underlie the RE process can be characterized as a process where

1) Subjective individual understanding of the stakeholders about the requirements are evolved into a more objective shared understanding.
2) The evolution of shared understanding is further enabled through
   a. A process of initial interpretive assumptions beyond what is individually known
   b. Verification of such assumptions through empirical observation and sensory inputs
   c. Rejection of assumptions that are invalidated by the empirical observations and sensory inputs

The reasoning underlying the RE process, as described above, has certain similarities with the traditions of inferential reasoning, particularly to that belonging to the Naiyayika school of logic. In the next section we elaborate on inference in general and the Naiyayika school in particular, and justify its appropriateness as a lens to better understand the reasoning process within RE.

The Nature of Inference in the Naiyayika Traditions

Our aim for the context of this paper is to identify a mechanism of reasoning that allows objective representation of the subjective in a scientific manner (De Morgan 1860). In order to elaborate on our choice of the Naiyayika tradition of inferential reasoning, we will focus first on establishing the similarity between science in the Indian tradition and science in the western fold. We then discuss the Indian inferential schema and draw some distinctions. Finally we provide justifications about the appropriateness.

It is perhaps taken for granted that modern science is a byproduct of ancient Greek thinking on truth, matter and the role of logic. If one considers the relationship between Greek thought and science, the key lies in the attempt to search for universal rules and provide conceptual relations between objects whose relationships are universal and eternal, meaning always true and demonstrable. Consequently science in the Greek scheme was preoccupied with objectivity where syllogisms were one of the tools to facilitate objectivity. However a fact that needs to be acknowledged, is that there existed a rich scientific tradition in India, in its theories about positive and negative debate, inferential techniques, mathematics which needs to be considered,(Sarukkai 2005). For instance De Morgan (1860) “noted that, the two races which have founded the mathematics, those of the Sanskrit and Greek languages, have been the two which have independently formed systems of logic, Further Colebrook’s (1824) inquiry into Indian scientific thought suggests that the ancient Indians were as aware of the syllogism as the ancient Greeks. Several common features of the methodological and conceptual motivations are embedded in the two rational traditions and the practice of science. First both the Greek and the Indian traditions look at philosophy as the deployment of ideas and recognizing of patterns, developing the argumentation and the meaning of the subject from outside its sphere of influence and understand its implications. Science in both the traditions is thus preoccupied with understanding the foundational structures of knowledge and attempting to objectify it, (Sarukkai 2005). Further Indian science was preoccupied with the development of epistemology, language and logic, which was similar to the preoccupations of Greek thinkers. “For the Indian logicians, exemplified by the Nyayika school, doubt is the
beginning of inquiry. The purpose of inquiry is to resolve a doubt and reach a state of certainty” (Bochenski 1956 ).

The Naiyayika inferential scheme relies on the linkage between the empirical world and the conceptual world (Bhattacharyya 1987; Ganeri 2001) and can be described as the systematic study of informal inference-patterns, the rules of debate, the identification of sound inference vis-à-vis sophistical argument (Ganeri 2001). Naiyayika is the examination of things with the help of methods of knowing (pramana). It is an inference supported by observation and authority. This is called a “critical proof”’ (anviksa). A 'critical proof' is the proof of things desired, supported by observation and authority.

Inference, in general, can be understood as the capacity to say something more than what is known initially. This capacity is already one that is central to the definition of reason. Reason allows us to know more than is available to us through the senses and inference is one important way by which we transcend the limitation of sensory experience, (Bochenski 1956 ). But these sensory experiences are then converted into observable rules with the observation of an empirical instance being predicated on that instance and the observed relation as universal (Bochenski 1956 ). In effect the Naiyayika reasoning scheme is a rule based system of inference driven by constancy in an observed phenomena. This perhaps can be better explained by contrasting the Naiyayika logic with a generic logical system (Bochenski 1956 ). For instance a familiar logical schema can be represented by the three lined illustration as:

(i) All men are mortal.
(ii) Socrates is a man.
(iii) Socrates is mortal, (Bhattacharyya 1987)

The traditional syllogistic system has three features, first, the syllogism consists of three sentences and three different terms, second, they are presented in sequence which is causal and logical or having a logical form, meaning there must be a subject, a predicate and a copular that is not either part of the subject nor the predicate. (Bhattacharyya 1987). The key feature of the western syllogism indicates a drive towards objectivity. This encapsulated by a pursuit towards knowing if something is an object, consequently, to know that something is an object is to access it in some manner. According to Gadamer (2002) it is the objectification that is the key to the western syllogistic traditions.

While objectivity remains the goal of the Naiyayika tradition, there are subtle differences. Naiyayika suggests that the person making the inquiry must be able to precisely set out for the audience a piece of knowledge that is the consequence of a precisely formulated demonstration (avayava). The structure of the Naiyayika schema as described by (Colebrooke 1824) is as follows; A regular argument or syllogism (nyaya) consists of five members (avayava) or component parts. 1st, the proposition (pratijna); Second, , the reason (hetu or apadela); third, the instance (uclaharana or nidariana); fourth, the application (upanaya); fifth, the conclusion (nigamana).

1. This hill is fiery:
2. For it smokes.
3. What smokes is fiery: as a culinary hearth.
4. Accordingly, the hill is smoking:
5. Therefore it is fiery. (Kennedy 1839)

There are several ways through which the Naiyayika can be distinguished from its western logical counterpart (Ganeri 2001 ). First, because the Naiyayika is predicated on an empirical observation in the singular and is not predicated on a particular relationship but establishes a general rule that is pervasive. For example, where ever one observes smoke there will be fire, like in the kitchen is an example of an inference based on transient empirical relationships between fire and smoke which is considered to be universal, (Sarukkai 2005). The Second difference between the Aristotelian and the Indian syllogisms is reflected by the nature of the terms. “Unlike the Aristotelian syllogism, whose major, middle and minor are classes, the Indian schema has as its 'field' (paksa) a single individual, in which there occur two properties, the property that serves as a “reason” (hetu) and the property that is 'to-be-inferred' (sadhya) (Sarukkai 2005). The third, difference is the insistence that while the Aristotelian syllogism is a thesis, the Indian syllogism is a combination of inferential rules (Bochenski 1956 ). The fourth, difference between these two systems of logic relates to how they treat subject, predicate and the copula. In the Naiyayika scheme of inference, each of the sentences expressed must be articulated in terms of subject, predicate and copular where as in the traditional western syllogism, the copular will not be part of the subject nor the predicate but will be a separate
part of the sentence. A fifth difference between the two arises from their understanding of how knowledge is created. In the Naiyayika schema of inference where knowledge is considered as a process of knowing and talks about rules that establish the validity of knowledge and not its semantic construction, knowledge is such, only when it is expressed, (Bhattacharyya 1987) and finally for Indian logic, (Inference) need to respond to empirical concerns, it is precisely this demand on logic that makes Indian logic essentially correlated to scientific methodology.

Our focus on the Naiyayika school is influenced by two reasons within the context of RE. First, the inferential technique relies on an observation that then is converted into a rule based system based on universally valid relationships. Second, it lends itself to application in non Philosophical contexts. In other words it represents a reasoning schematic which allows for the conversion of the subjective to objective understanding, but through a process of empirical validation. The key conjecture to note is that the Naiyayika system of inference is primarily engaged in developing a set of rules that than assist in forming the inferential basis for socially co-constructing knowledge. This focus on empiricism, we feel makes it an appropriate lens with which to better understand the mechanism of reasoning within RE process

**Methodology**

**Data Collection**

The data collection was done in two organizations -EduTech and CompuTech (both pseudonyms). These companies are based in two different regions of India, and have a fairly large software production base. Both have a similar management structure: software projects are handled by managers, with analysts and developers assisting the process. Both companies employ advanced methodologies for the software development process and employ fairly large developer community, approximately 100 in each firm. Both companies have a relatively limited number of analysts in relation to the developers, approximately 10 each. The main source of income in both companies comes from sales of software in the domestic market and the main activities of both the companies are client specific software development.

The primary strategy data collection based on semi-structured interviews. All interviews were conducted by one of the authors of this article. The interviews were conducted on site, during the project with analysts, developers and managers, lasting for approximately 90 minutes. These interviews were initiated with the following three questions:

a) What does requirement analysis mean to you?

b) How do you share the contents of requirement analysis within your team members?

c) How do you share your requirement analysis experience with other teams?

We would like to note at this juncture, that the above questions were kept intentionally neutral to our research focus, in order to avoid responses biases such as Hawthorne effect, often evident in qualitative research employing interview techniques (Myers and Newman 2007). Over the course of the interview the responders were subsequently prompted to reflect and provide insights into how they understood the requirements for specific projects

**Analytic Strategy**

The analytic strategy adopted for this study comprises of two phases. The phased approach is predicated by the focus of our inquiry - the reasoning process behind RE. In Phase 1 we adopted a protocol analysis approach (Newell and Simon 1972; Bettman and Park 1980). The interviews were all transcribed, subsequently the text was searched for instances where the respondents had verbalized about particular instances of reasoning processes used by them to understand the requirements. These text excerpts represented the verbal protocols of the respondents and consisted of single instances of how the respondent understood requirements (Bettman and Park, 1980). The protocols were then coded using the five step framework of the Naiyayika school of inferential reasoning. Phase 1 was planned to consist of multiple iterations. In the first iteration the first author (who conducted the actual interviews and was therefore more familiar with the text) , identified the protocols and conducted the first level coding of these protocol excerpts. The second author then validated the coded protocols to ensure that the steps of the Naiyayika School were correctly and appropriately represented in the coding. In the second iteration the roles are planned to be reversed, where the second author would trawl the text for the protocols and code it, while the second author would verify the coding. It is hoped that the two iterations would enable us to reach saturation in terms of identifying all relevant
protocols from the transcribed interviews. At the time of reporting this research the first iteration of phase 1 has been completed.

In table 1 we below we provide an illustrative example of a coded protocol representing a single instance of the reasoning process employed by one of the respondents. The context of the conversation was the preliminary scoping process for a teaching tool. EduTech (the organization that employed this analyst) was trying to formulate a strategy for a teaching tool that they were planning to develop and market. The primary objective of the analyst was to understand the nature and objectives of such a teaching tool. As table 1 indicates, the systems analyst intrinsically felt that the important factor in teaching was not the tool but the quality of teaching; hence the proposition about seemingly archaic chalk and talk method. For the analyst the proposition was self evident because his experiences with good teachers (as demonstrated in the second row and the premise for the inference for the self). However this was not sufficient for him to convince the others. This brought forth the example of Encyclopedia Britannica and an illustration of tools only being of value if they are used appropriately. This creates a generalized premise for the application and use of tools. The analyst further reinforces his argument by contextualizing to the present case and providing alternative example of when a tool may replace an individual and when it may not. He also uses the contextual application to define the objective of the teaching tool of enhancing the quality of teaching, through its role as a teaching aid. Finally all this is brought together by a conclusion that the aim of the tool should not be to replace a teacher at the secondary level. The above discussion indicates the reasoning process is inherently empirical and consists of the individuals making assumptions of what is not known to them and then verifying them using empirical or experiential evidence.

<table>
<thead>
<tr>
<th>Table 1 – Exemplar coded protocol</th>
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<td>Instance of an inference</td>
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<td>Proposition</td>
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<td>Reason</td>
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<td>Example</td>
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<td>Application</td>
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<td>Conclusion</td>
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During Phase 2 of our analysis strategy we would be using the source texts of the coded protocols to gain deeper insight about the reasoning process employed by the respondents. We propose to use the tenets of Grounded Theory Method (GTM) (Glaser and Strauss 1967) to perform this second level of analysis

We would like note at this juncture that the empirical component of our research is at a very initial stage, and this is just a beginning of what we hope is a long and fruitful journey. However we feel encouraged that while the empirical investigation is indeed preliminary in nature, we have found initial evidence of mechanisms of inference in the reasoning process underlying RE.
Contribution and Future Research

While this research is at a very preliminary stage, we feel that our primary contribution lies in proposing an innovative perspective with which to re-examine the RE process. Existing research (e.g., Urquhart 2001) has acknowledged that RE success is contingent on the stakeholders achieving a shared understanding about the proposed information system. We feel that our proposed approach may be instrumental in opening the “black box” of how exactly such shared understanding is achieved by explicitly examining the intellectual reasoning process of the participants.

We also feel that there are certain practical implications in using this system of inference as a lens toward understanding the RE process. First, since the Naiyayika system of inference needs to be based on empirical observation, it provides a formal mechanism on how empirical observation can be used during the process of RE. In the context of RE it could mean that the business analysts are able to rely more explicitly on the empirics for co-constructing meaning of the observed world. Second, given that the Naiyayika system of inference is a rule based system where the preoccupation is to link the experience of what is observed by developing rules about how these observations can be communicated or shared it could be used during RE to capture and convert empirical experiences into rules about such experiences, which would be easier to store for later use and re-use. Third, because the Naiyayika system of inference requires the inferring context to carry the empirical observation embedded in the formal argument, it has the potential to remove ambiguity during the RE process and fourth because the Naiyayika system of inference considers knowledge not as objective fact but a subjective observation supported by a universal rule, it can lend itself to cross cultural work where culture of the parties is less important than their empirical rule based observation.

References


