

December 2003

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Ann Hickey

University of Colorado at Colorado Springs

Alan Davis

University of Colorado at Colorado Springs

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Recommended Citation

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A TALE OF TWO ONTOLOGIES: THE BASIS FOR SYSTEMS ANALYSIS TECHNIQUE SELECTION

Ann M. Hickey

The University of Colorado at
Colorado Springs
ahickey@uccs.edu

Alan M. Davis

The University of Colorado at
Colorado Springs
adavis@uccs.edu

Abstract

Experts in requirements elicitation use a wide variety of diverse elicitation techniques to understand users' needs. Less experienced elicitation practitioners frequently use the same technique repeatedly, often because it is the only one they know or they do not know when to use alternative techniques. The authors are constructing a tool that aids less experienced analysts in selecting the most effective techniques for their project situation. Fundamental to the success of this endeavor is the creation of two unique ontologies. The first is an ontology of elicitation techniques such that if two techniques are suitable in similar circumstances, they will be located close to each other within the ontology. The second is an ontology of the situational characteristics that affect the selection of techniques. The proposed ontologies (1) provide a framework for practicing analysts to make more informed choices of elicitation techniques now and (2) are essential to our longer-term goal to assist novice analysts in the selection of the 'right' requirements elicitation techniques for their situation.

Keywords: Requirements elicitation, elicitation technique selection, systems analysis, ontology

Introduction

More than half the systems constructed by the software industry fail to meet users' expectations (Standish 1995). This indicates either of two situations: (a) a mismatch between what the users expect and what we *think* they want, or (b) our inability (or even lack of desire) to learn what the users' expectations are. In either case, the fault lies on the side of the software industry. And we are clearly failing to perform a good enough job at understanding users' needs and expectations (Hofmann and Lehner 2001). Elicitation (aka systems analysis¹) is the set of activities performed with the primary goal of *understanding* users' needs for a system (Thayer and Dorfman 1994). Although most recent requirements books (Gottesdeiner 2002, Leffingwell and Widrig 2000, Macaulay 1996, Wiegers 2003) describe a dozen or so primary approaches, there are actually hundreds, and perhaps thousands, of variations of alternative elicitation techniques. So, the questions arise, how can the analyst understand all these variations and choose which one to use?

The ultimate quality of a product is driven by the appropriateness of the requirements gathered by the analysts during elicitation (Hickey and Davis 2002). Proponents of many elicitation techniques claim that their techniques are universally applicable in all situations. However, most experts today agree that the selection of an appropriate technique must be a function of the situation (Glass 2002, Kotonya 1998, Maiden and Rugg 1996), but an infinite number of situational characteristics exist. So how can the analyst know which of these many situational characteristics should be taken into account when trying to decide which elicitation technique would make the most sense? And, how does the analyst select a technique that makes sense given those situational characteristics as shown in Figure 1? Our claim is that given any one set of situational characteristics, many appropriate elicitation

¹There is much agreement in the industry concerning the need to better understand user needs, but little uniformity concerning what to call the activity. The IS industry calls it *systems analysis*, *problem analysis*, *business analysis*, or just plain *analysis*. The engineering community calls it *requirements analysis*, *elicitation*, *knowledge engineering* (for knowledge intensive applications), or *requirements engineering*. In this paper we have chosen to use the word *elicitation*.

techniques may exist. In particular, every situation demands any elicitation technique that exhibits specific attributes, as shown in Figure 2.

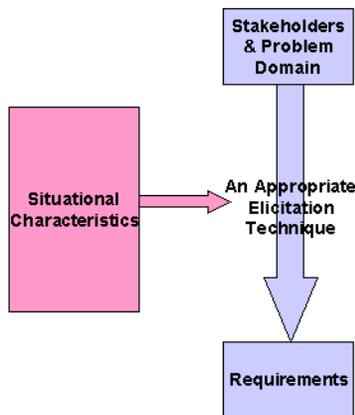


Figure 1. Elicitation Technique Selection

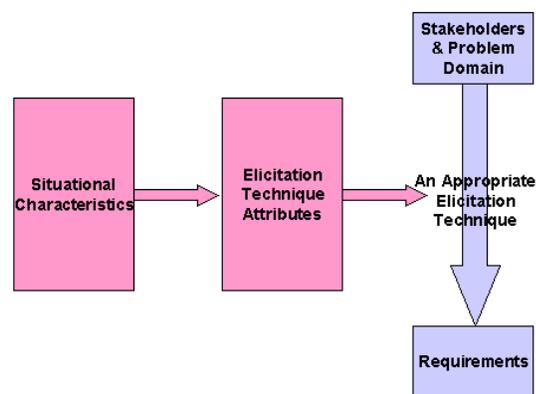


Figure 2. Elicitation Technique Selection Based on Technique Characteristics

Therefore, to select an appropriate elicitation technique, an analyst must first understand what techniques are available, and how they are different/similar. To this end, we have created an ontology that defines key characteristics of elicitation techniques, so they can be understood, compared and contrasted. This ontology can then be used to assign clear semantics to the wide range of current elicitation techniques. If the universe of elicitation techniques is seen as a vector space, then the ontology defines each member of the universe in terms of its characteristic vector. To know which vector to select from the technique ontology's vector space, one needs to understand what characteristics of a situation are important. These situational characteristics are represented in a second ontology, one of characteristics of the domain (Liebowitz 2001). The situational characteristics used in this ontology are those that are relevant to selection of elicitation techniques. This paper will report the usefulness of both of these ontologies for the selection of appropriate elicitation techniques.

Research Approach and Method

The research questions we are addressing are:

- How can we use an ontology to assign clear semantics to currently available elicitation techniques?
- What characteristics of requirements elicitation techniques are important for effective technique selection?
- What characteristics of a situation are important for effective elicitation technique selection?
- How do the characteristics of the situation interact with the characteristics of the elicitation techniques to drive effective technique selection?

Numerous authors broadly characterize elicitation techniques. For example, Lauesen (2002) characterizes elicitation techniques with an ontology based on outputs the techniques produce. Gottesdeiner (2002) organizes elicitation techniques in terms of top-down/bottom-up, and the underlying models produced as a result of applying the technique. Macauley (1996) provides a long list of elicitation techniques and describes each in terms of its characteristics, but falls short of defining an ontological basis. Byrd et al. (1992) characterize elicitation techniques based on communications obstacles, facilities, and the controller of the process.

Similarly, a few authors have studied characteristics of situations that drive elicitation technique selection. For example, Bento (1994) defines a simple three-dimensional ontology consisting of the need to understand the broadness of the problem, wickedness of the problem, and relative task vs. decision emphasis in the problem domain. Maciaszek (2001) presents a model of the influences that affect the success of requirements elicitation. Maiden and Rugg (1996) provide a framework for elicitation technique selection consisting of six facets.

Our research stands on the shoulders of the above research efforts to create more complete ontologies necessary for elicitation technique selection. We are following the research approach shown in Figure 3. The draft ontology of situational characteristics (task 1) was derived from the aforementioned works of Bento (1994), Maciaszek (2001), and Maiden and Rugg (1996) as well as criteria influencing life-cycle model selection from Alexander and Davis (1991), multipliers influencing cost estimation from Boehm et al. (2000), factors influencing requirements approaches from Davis (1993), factors influencing software engineering experimental design from Juristo and Moreno (2001), characteristics influencing the definability of a system from Scharer (1981), problems in deriving needs from Yeh and Ng (1990), as well as our own personal experience.

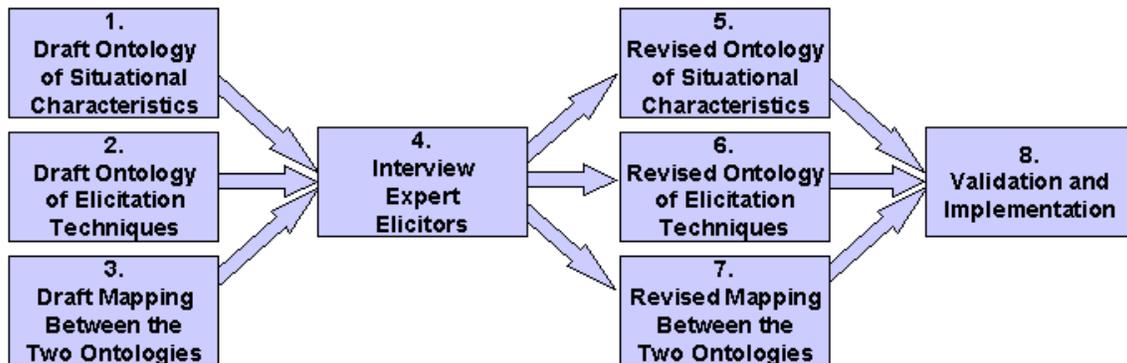


Figure 3. Research Approach

The draft ontology of elicitation techniques (task 2) was derived from the aforementioned works of Lauesen (2002), Gottesdeiner (2002), Macauley (1996), and Byrd et al. (1992), selected textbooks (e.g., Conger 1994, Dennis and Haley Wixom 2000, Hoffer et al. 2002), as well as our own personal experience. We based the mapping from situational characteristics to elicitation techniques (task 3) on our own experience and the limited guidance available from the above references. We are currently in the process of interviewing expert elicitors, and thus far have completed interviews with Grady Booch, Larry Constantine, Tom DeMarco, Donald Gause, Tim Lister, Lucy Lockwood, Don Reifer, Suzanne Robertson, Karl Wieggers, and Edward Yourdon . As we complete interviews with these experts, we are revising the two ontologies for tasks 5 and 6, and the mapping between the two ontologies, task 7. During task 8, we will validate our findings and implement our results in a tool that can be used by less experienced analysts to assist them in selecting the ‘right’ elicitation technique for their situation.

Ontological Analysis of Elicitation Ttechniques

As indicated above, the ontology of elicitation techniques is driven by an attribute vector that locates each technique in a multi-dimensional vector space. The techniques are organized so that any two techniques that are equally applicable in all situations are clustered very closely together in the overall vector space. The vector space currently includes the following ten dimensions:

- *Physical Co-Location.* This attribute has two possible values: “same place” and “different place.” It captures whether or not the technique demands that participating parties be located at the same physical location, e.g., in the same room. We call the value of this attribute PHYS.
- *Temporal Co-Location.* This attribute has two possible values: “same time” and “different time.” It captures whether or not the technique demands that participants collaborate at the same time. We call the value of this attribute TEMP.
- *Record-Keeping.* This attribute has three possible values: “individuals,” “analyst,” and “no record.” It captures whether the results of the elicitation event are recorded for the future by every individual contributor, or by the analyst, or by no one. We call the value of this attribute RECO.
- *Analyst Role.* This attribute has three possible values: “passive,” “facilitate,” and “lead/direct.” Passive indicates that the analyst is observing the elicitation event, but is not participating directly in it. Facilitate indicates that the analyst is aiding

the event, helping to ensure that it has positive results. Lead/direct indicates that the analyst drives the activity. We call the value of this attribute ANAL.

- *Convergence/Divergence.* This attribute has two possible values: “convergent” and “divergent.” Divergent techniques create new ideas; convergent techniques group, filter, or rank ideas. We call the value of this attribute CONV.
- *Anonymity.* This attribute has two possible values: “anonymous” and “public.” Techniques that are anonymous protect each participant from other participants knowing which ideas they generated. Public techniques allow participants to know who generates which ideas. We call the value of this attribute ANON.
- *Stakeholder Count.* This attribute has four possible values: “many,” “few,” “one,” and “none.” It captures the number of stakeholder classes involved. A stakeholder class is one or more stakeholders representing identical opinions. We call the value of this attribute STAK.
- *Tool Based.* This attribute has two possible values: “tool” and “no tool.” It captures whether the technique requires the use of a software tool. We call the value of this attribute TOOL.
- *Product/Human Focus.* This attribute has two possible values: “product” and “human.” It captures the fact that some techniques focus on identifying the requirements for the “product” that solve the users’ problems, while other, socio-technical approaches assume that requirements emerge as a result of the interactions between humans (stakeholders and analysts) in a situational context (Coughlan and Macredie 2002). We call the value of this attribute FOCU.
- *Direct/Indirect.* This attribute has two possible values: “direct” and “indirect.” It captures the fact that some elicitation techniques are performed to directly elicit needs (direct), whereas other techniques (e.g., team-building exercises) are performed to alter the situation to make it more conducive to elicit needs. We call the value of the attribute DIRE.

Any attribute may also have a value of “don’t care,” represented by a “—” in the following examples, indicating that the attribute is not significant or can take on any of the possible attribute values.

We can thus represent any elicitation technique by its attribute vector, (PHYS, TEMP, RECO, ANAL, CONV, ANON, STAK, TOOL, FOCU, DIRE). Let’s look at how these attributes map for some representative techniques.

- *Interview a Single Customer Face-to-Face* (Gause and Weinberg 1989). The values for the attribute vector are (same place, same time, analyst, lead/direct, —, public, one, no tool, —, direct).
- *Conduct a Distributed Brainstorming Session Where Nobody Knows Who Else Is Involved* (Romano et al. 1999). The values are (different place, same time, individuals, facilitate, divergent, anonymous, many, tool, product, direct).
- *Perform a Demographical Market Analysis* (Higgins 2003, Schewe and Hiam 1998). The values are (different place, different time, individuals, passive, divergent, anonymous, many, no tool, product, direct).
- *Observe a Few Stakeholders* (Goguen and Linde 1993). The values are (same place, same time, analyst, passive, divergent, —, few, no tool, human, direct).
- *Do a Group-Voting Session in One Room Where Voting is Anonymous* (Nunamaker et al. 1991). The values are (same place, same time, individuals, facilitate, convergent, anonymous, —, tool, product, direct).
- *Use Soft Systems Methodology* (Checkland and Scholes 1991). The values are (same place, same time, individuals, facilitate, —, public, many, no tool, human, direct).
- *Do a Team-Building Exercise.* The values are (same place, same time, —, —, —, public, —, —, human, indirect).
- *Use a Bulletin Board.* The values are (different place, different time, individuals, —, divergent, —, many, tool, product, direct).

Theoretically, the vector space contains 3,456 discrete vectors, and thus could be used to categorize that many techniques. However, there are two observations that make this incorrect: First, many techniques are incredibly similar, often with just different names being applied to the same approach. In these cases, the techniques coexist in the same vector. Second, we have found some vectors to be meaningless. For example, (same place, different time, —, —, —, —, —, —, —) could represent a message board physically located in one location, but does not correspond to any known elicitation techniques. Similarly, (same place, same time, analyst, —, —, anonymous, many, no tool, —, —) makes no sense because if the stakeholders are all co-located and the analyst is recording everybody's ideas without a tool, then obviously the stakeholders are stating their ideas aloud, and there is no way to preserve anonymity.

Finally, as shown in Figure 3, this taxonomy will be revised and validated after we complete our interviews with experts to ensure that we include all dimensions that differentiate techniques based on their appropriateness in various situations. Therefore, we cannot claim that this taxonomy is complete. However, we can claim that it does identify ten of the key dimensions that differentiate a large variety of the available elicitation techniques and that are critical in selecting techniques for specific situations, as discussed next.

Ontological Analysis of Situational Characteristics

The characteristics of the immediate situation determine which values for which elicitation technique attributes are applicable for that situation. Relevant situational characteristics fall into five broad categories. Techniques should be selected based on:

- *Characteristics of the Problem Domain.* Inherent characteristics of the problem, including the fuzziness of its definition (FUZZ), its complexity (CPLX), the existence of conflicting needs (CNFL), the maturity of the application (MATU), and the importance of non-functional requirements such as security (SECU), response time (RESP), safety (SAFE) and reliability (RELI), have a major impact on the techniques that should be used. Thus, for example, a totally new, unprecedented application may require more extensive use of divergent techniques, but an upgrade of a well-established legacy application would not. A problem for which a fast response time becomes life-critical may necessitate different, possibly more formal, elicitation techniques than one that has no deleterious effect.
- *Characteristics of the Solution Domain.* Similarly, the type of solution anticipated (e.g., application vs. system vs. embedded software (TYPE), custom development vs. customizing vs. commercial-off-the-shelf software (COTS)) may also impact the selection of elicitation techniques. An embedded system may demand different elicitation approaches than a software-only system. Planning to purchase (OUTS) vs. build in-house may also make a difference.
- *Characteristics of the Stakeholders.* Inherent characteristics of all the people involved in a software development project, especially the stakeholders (e.g., customer, users, other sources of needs), are major drivers of the selection of appropriate elicitation techniques. The number of different stakeholders and stakeholder roles (#STK) directly impacts whether individual techniques such as interviews can be used virtually exclusively or various collaborative meeting or mass contact (e.g., questionnaires) should be considered. If the stakeholders are novices (STEX) in the application domain or in the use of similar applications they may have a hard time articulating their requirements, so techniques that facilitate that process such as prototyping may be appropriate. If the situation is such that your customers are major competitors of each other (STCM), then only a technique that enforces anonymity is appropriate. Other key questions that may impact the selection of an elicitation technique include: Do the key stakeholders get along with each other (STCP)? Can the stakeholders travel to a common location (STTV)? Are they accessible (STAC)? Do the stakeholders speak with one voice, or do they represent many different roles with quite different needs (STDV)?
- *Characteristics of the Solution Builders.* The knowledge and expertise of the system builders may also impact the selection of elicitation techniques. For example, if the system builders are experts in the problem and solution domains (SOEX), then elicitation techniques that record requirements using problem domain terminology may be appropriate. Their communication skills (SOCO), software development experience (SOSW) and knowledge of specific tools (SOTO) and techniques may also be factors that should be considered.
- *Characteristics of the Bridge-Builders.* Bridge-builders are the individuals who serve as the communication conduit (or bridge) between stakeholders and solution builders. Bridge-builders may be systems analysts, requirements engineers or any individual from the user or developer side of the project assigned to perform this role. Experience has shown that quality bridge-builders are critical to the success of requirements elicitation. Therefore, the match between the characteristics of the

bridge-builders and the elicitation techniques used is essential. These characteristics include experience in the problem domain and application type (BBEX), knowledge and experience with specific elicitation techniques (BBTE), and communication/facilitation negotiation skills (BBCO). For example, if bridge-builders have limited experience in a domain, they should initially focus on techniques such as interviews with key stakeholders and/or document reviews that enable them to develop their domain knowledge. If they have little or no experience facilitating a group meeting, then a group meeting may not be appropriate. One very interesting observation from the expert interviews we have conducted so far is the importance of the bridge-builders experience with a specific technique. We had assumed that inherent characteristics of the technique were the primary driver in its appropriateness for a specific situation. However, our interviews showed us that a moderately good technique for a specific situation in the hands of an experienced “master” can become an ideal technique for that situation, because of the expert’s ability to mold the technique to the situation. Thus, masters in specific techniques tend to rely on their favorite technique except under special situational circumstances. However, for less experienced analysts, this approach may lead to disaster because they simply do not have the skills required to adapt the technique to those situations for which it is not a “good fit.”

We have isolated over fifty situational characteristics that could influence the decision to select one or more elicitation techniques. As mentioned before, many of these have been adapted from situational characteristics specified for other purposes. We are using our expert interviews (Figure 3, task 4) to identify which of those characteristics are the primary drivers for technique selection. We are midway into the process of interviewing many of the world’s experts in systems analysis to improve our understanding of how situations affect the elicitation techniques they chose to utilize. Without exception to date, we have found that these experts are not *consciously* analyzing situational characteristics to select the technique. However, when we ask questions like “what would you have done if” the situation was slightly different, the experts invariably say they would have selected an alternative approach. Thus, we are receiving consistent evidence that the selection process is in fact situational.

Mapping from Situational Characteristics to Elicitation Techniques

In general, it is the complete set of situational characteristics that imply the suitability of set of elicitation techniques. However, some values for some characteristics may be sufficient by themselves to imply such suitability. We currently capture the mapping in a series of cascading tables. Entries in these tables can be any of the following:

- *NO.* The techniques that possess *these* characteristics are incompatible with situations that possess *those* characteristics.
- *OK.* The techniques that possess *these* characteristics are compatible with situations that possess *those* characteristics.
- *HI.* The techniques that possess *these* characteristics are strongly suggested in cases where *those* situational characteristics exist.

There are so many possible combinations of situational characteristics that it is impossible to describe how they map to specific elicitation techniques. Therefore, this paper will present a few representative examples, some where multiple characteristics are relevant to the decision, and some where just a few of the characteristics are sufficient.

Example I. The stakeholders are many (#STK=many) and diverse (STDV=high), but are easily accessible (STAC=easy) and available for travel (STTV=yes). They have never worked together before, but we have no reason to believe they would be combative (STCP=high). The application is an unprecedented (MATU=low) decision support system (TYPE=dss). In this situation, the analyst should first seek a technique that supports the many stakeholders. Since the stakeholders have not worked together before and are accessible, techniques that support a same time, same place meeting (PHYS=same, TEMP=same) that can be used to build a sense of team would be preferred in the early stages of the project. The diversity of the stakeholders could also indicate a need to start with team-building exercises (FOCU=human, DIRE=indirect). Because of the unprecedented nature of the application, divergent techniques (CONV=divergent) should also be considered early in the process. With either of the latter two types of techniques, the presence of a large group of stakeholders indicates the need for strong facilitation (ANAL= facilitate). With larger groups of stakeholders it may also be more efficient to have the individual stakeholders record their own ideas (RECO=individual). Optionally, efficiency could also be increased through the use of a tool (TOOL=tool) if an appropriate tool was available.

Example II. We are a company with a customizable base product. We sell a highly modified version of the base to each of our customers (COTS=customize, OUTS=in). These customers are strong competitors of each other (STCM=yes). Critical to our business strategy is to never allow our customers to know who our other customers are. In this situation, techniques that preserve stakeholder anonymity (ANON=anonymous) are critical to the company’s business strategy. Therefore, techniques that require

same time, same place interaction (TEMP=same time, PHYS=same place) of *all* stakeholders would not be appropriate (although they could work if applied separately to each company's stakeholders). This need for anonymity and separation, when combined with the existence of the current product, would be a strong indicator for product-focused techniques (FOCU=product).

Example III. We are part of an internal IT organization with a very vocal set of stakeholders within the operating divisions of the company located around the world. These stakeholders have worked together well many times in face-to-face meetings (STCP=high). In this situation, because the stakeholders know each other and have worked together, team-building is not required so they can immediately working on the problem (DIRE=direct, FOCU=product). That prior experience when combined with the geographical dispersion of the stakeholders would be strong indicators for the use of distributed techniques (PHYS=different place), which generally require tool support (TOOL=tool) and would benefit from strong facilitation (ANAL=facilitate) to ensure the team stays on task.

Example IV. We are working as a new analyst (BBEX=low) at a small company developing software (OUTS=in) for a 5-person accounting office. Since the analyst's knowledge of the problem domain is low and the number of stakeholders is few, passive techniques such as observation of a few stakeholders (ANAL=passive, STAK=few) would allow the analyst to gain the required problem domain knowledge rapidly.

The above examples clearly show the relationship between the two ontologies we have created for techniques and situations and the interdependent nature of those ontologies. We feel that these ontologies by themselves represent a significant contribution to the elicitation and ontology literature bases. We plan, however, to perform further research by applying these results to the actual selection of elicitation techniques.

Future Research

The research described in this paper opens avenues for a myriad of follow-on research activities, including:

- *Further Refinement of Elicitation Technique Ontology.* One area we have not yet explored is the inherent richness of communication afforded by various elicitation techniques and the associated communication media they use. For example, same-time/same-place activities enable communication of information to occur as the results of words, intonation, as well as body language. In contrast, email facilitates communication only via words (and emoticons). Media richness theory (Daft and Lengel 1986) indicates that communication media inherently vary in their ability to communicate information. However, many researchers hypothesize that this communication richness is a function of both the media and a variety of situational factors such as the history of the group communication (Burke and Aytes 1998, Dennis and Valacich 1999, Te'eni et al. 2001). This will be explored further as part of task 5 in Figure 3.
- *Further Refinement of Situational Ontology.* The ontology for situational characteristics is being defined from top-down and bottom-up (van der Vet and Mars 1998) simultaneously. From the top, we have defined just one level. From the bottom, we have isolated many specific situational characteristics that affect the decision, as described in the earlier section. More research is necessary before we arrive at a full multi-level taxonomical ontology. This is part of task 6 in Figure 3. In addition, we need to more formally define the values for each characteristic so that practicing analysts have no doubt about what value applies to their situation.
- *Further Refinement of Mapping from Situations to Elicitation Techniques.* For example, are there certain situational characteristics (e.g., a team who knows each other extremely well) that would enable us to use techniques with less richness? This is part of task 7 in Figure 3.
- *Starting Points.* Gause and Weinberg (1989) describe a half-dozen of so distinct starting points for elicitation, e.g., goals, users, problems, scenarios, functions, data, non-functional requirements, and so on. Research is needed to identify if (a) certain situational characteristics should drive the selection of one or more of these starting points, and/or (b) the desire to start at various points is itself a situational characteristic, and/or (c) whether some elicitation techniques are particularly effective at creating specific types of starting points. This may impact tasks 5-7 in Figure 3.
- *Implementation.* We have implemented a prototype tool called CoStar (Colorado Selector of Techniques for Acquiring Requirements). CoStar presents analysts with a list of questions. The responses to these queries identify the characteristics present in the current situation. These characteristics are then mapped to a vector in the elicitation technique attributes vector

space. Finally, the tool presents to the analyst a list of techniques corresponding to that vector. Much more work is necessary before this tool is ready for widespread use. This is part of task 8 in Figure 3.

Contributions

The research presented in this paper directly contributes to both elicitation research and practice. It demonstrates how ontologies can be used to compare the many, often similar, available requirements elicitation techniques and help choose between them for a given situation. The ontologies defined herein are solidly based in the existing literature and on 30+ years of the researchers' experience in elicitation. Even though the proposed ontologies have not yet been validated, initial feedback from our expert interviewees indicates that only minor modifications may be required. As a result, the ontologies and technique selection process presented in this paper can be used now in research and practice as follows:

- Researchers and practitioners can use the elicitation technique ontology to sort through the hundreds of existing and proposed techniques to understand techniques' essential similarities and differences.
- Researchers can use the situational ontology to explicitly describe the situations their new techniques are designed to support, thereby aiding practitioners in identifying the 'right' techniques for their situation.
- Practicing analysts can use the situational ontology to alert them to the factors that may impact the effectiveness of their elicitation process. Analysts with some experience should also be able to use both ontologies and the technique selection examples to improve their current technique selection process, thereby improving the current state of the practice of requirements elicitation.

Summary

This paper has presented two ontologies, created to assist inexperienced analysts in selecting elicitation techniques that are applicable to a situation. The first ontology organizes elicitation techniques and highlights similarity and differences between the seemingly endless variations of elicitation techniques. The second ontology organizes situational characteristics relevant to the selection of elicitation techniques. The technique ontology takes into account this situational ontology so that the closeness of two elicitation techniques is proportional to their relative applicability in similar situations. The proposed mapping between these ontologies was explored for selected examples and provides the basis for the evaluation of the effectiveness of elicitation techniques for specific situations. Finally, the paper explores areas for future research essential for these ontologies to be implemented into an effective tool for the selection of elicitation techniques by inexperienced analysts.

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