A Model for Requirements Validation through Viewpoint Control

Mohammed Messaoudi
IMSIU, College of Sciences, Riyadh, Saudi Arabia

ABSTRACT
While requirements analysis is the process of building a conceptual model of part of reality, requirements validation involves maximizing one's confidence that the resulting conceptual model 'mirrors' the stake holders' original intent. In particular, validation involves assessing the model for correctness, completeness, and internal consistency. This paper describes an approach to the very early validation of requirements based on learning about the viewpoints and building models of their behavior. The paper is part of the work reported by the author in [1].

General Terms
Software Engineering, Requirements Engineering, Viewpoints, Validation

Keywords
Requirements Engineering, Viewpoint-based Requirements Engineering, Early Validation, Viewpoint Analysis, Viewpoint Resolution. Natural Language Processing, Truth Maintenance

1. INTRODUCTION
Viewpoint resolution is part of requirement elicitation process for identifying viewpoints, reasoning within a viewpoint, reasoning between different viewpoints, and revising a viewpoint [2]. The basic principles of the approach stem from combining ideas from the fields of uncertainty management and requirements engineering.

The Viewpoint Resolution Method, proposed here, is a collection of domain-independent heuristics to build internal models of the viewpoints that record their performance in providing information, to assess information, and to resolve conflicts between viewpoints. The starting point in devising such model is to regard requirements elicitation as a belief formation process in the context of a truth maintenance system. The model is designed to operate within an environment that supports relevant aspects of natural.

2. DEFINITIONS
A *belief* represents the degree of language engineering support assigned to a statement. Its meaning is defined by a set of endorsements qualifying it [17].

An event is the basic unit for validation that is to which a belief is assigned. The natural language engineering environment processes a piece of information and translates it into a series of connected events. For example, the statement: 'the system notifies the staff' is represented as follows (a number attached to a node is the internal representation of that node):

* event: 29071 *

universal.:
event - 7688 - rank: universal - definition,

subject.:
system - 29069 - rank: individual - suspended.

action.:
notify - 4639 –

object.:
staff - 29070 - rank: individual - suspended.

time.:
present. - 20989 –

date:
26 September 2021

viewpoint.:
Mike - 19845 - rank: named individual

status.:
suspended. - 29025 –

The set of events with attached beliefs is called the belief base. The belief base, also called the world model, represents the world in view of the belief formation process, as shown in Figure 6.1.

A *viewpoint* is the source of information about the system

A *Viewpoint Model* is a structure that captures a record of a viewpoint. The record includes the ability, goals, trustworthiness and helpfulness of the viewpoint. A viewpoint model for a company's secretary may look like:

secretary:
Ability:
      expertise: secretarial_work
      experience: high(default)
      reasoning: high(d)
Beliefs: none(d)
Goals: time-saving

secretary ⟶ manager?
      Helpfulness: high(d) (helpfulness of the secretary
      Trustworthiness: high(d) towards the manager)

manager ⟶ secretary?
      Helpfulness: high(d)
      Trustworthiness: high(d) (trustworthiness of the
      manager towards the secretary)

A *universe of discourse* is the set of the existing viewpoints together with the current viewpoint models. The universe of

discourse sets the context in which the information is validated (see Figure 1).

The results of the analyses carried out by an activity is passed on to other activities through cases. A case records the 'verdict' accumulated from the different analyses of a particular event. It takes a form like:

Casel:

      Event: event 1
      Viewpoint: viewpointA
      Importance Analysis
      Viewpoint: yes
      Information: may be
Information Evaluation
      Determination: ok
      Problem of Responsibility: no
      Problem of Advantage: no
      Problem of Ability: no
      Problem of Trust: no
      Result: believe as given
Conflict Analysis:
      Event: event3
      Viewpoint: viewpointB
      Same Context: no
      Type: reinforcement
      Problems of Trust: none
      Problems of Ability: none
      Result: reinforce belief and add viewpoint
Viewpoint Re-evaluation
      Classification: clerical? (The viewpoint is probably of class clerical)
      Expertise: none
      Reasoning: average (default)
      Judging information: average (d)
      Experience: high (d)
      Beliefs: none (d)
      Trustworthiness: average (d)
      Helpfulness: average (d)
      Result: may be clerical classification

Cases act as links between the universe of discourse and the information base. Thus they allow tracing information back to their viewpoints. They also make it easier to look up the general results and problems of a previous stage of analysis to use them as a guide for further analysis and as a means to take an immediate decision if necessary. Entries may also be modified in the light of results from further analyses and enquiries.
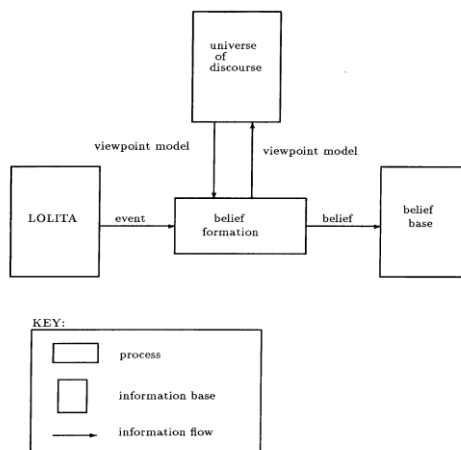

Figure 1: Validation as Belief Formation

3. OVERVIEW OF THE VIEWPOINT CONTROL MODEL

Figure 2 depicts the architecture of the operational model underlying the Viewpoint Control Method. The guide coordinates the different activities of the method; it operates on a 'start-do-stop' basis. The guide is represented by a set of heuristics to assist an analyst in deciding what to do next, that is, deciding what type of analysis heuristics need to be activated at any point of the investigation. The guide needs to pass on cases, *events* and *viewpoint models* from one process to the next so each process has the necessary data to work on and can use the results of previous evaluations in its analysis. The control heuristics look like:

If there is a new case, then request an initial importance analysis

If the importance analysis shows that the information or viewpoint is interesting, then request information evaluation else store information and evaluate when required.

If the information evaluation shows that the interest in the information is greater than the problems with it, then request conflict analysis

If there are problems and the case is important then try to do an enquiry by communicating with viewpoints, else try to find an explanation by introspection

I f there are problems and the case is not important, then return result so far and store information

If after the conflict analysis there are problems involved then try to find out more else return the result. If the case has been completely analyzed, then request a viewpoint re-evaluation. If the viewpoint re-evaluation is having problems and the viewpoint is of above average importance, then try to enquire to find an explanation
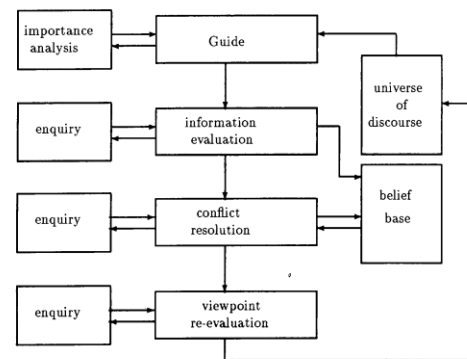

Figure 2: The Viewpoint Control Model

Importance analysis assess the importance of the case for the investigation. The information will either proceed to the next stage or be expelled immediately. The importance will come from the analyst's motivation towards the viewpoint or because there is an interest in the information.

The information evaluation checks if there is a problem with the information, and if so considers whether the case is worth pursuing further. If the problem is serious, in the sense that it needs investing serious efforts to solve, then the case needs to be sufficiently important so the problem can be investigated.

Conflict analysis evaluates the information in relation to the existing information, either from the same viewpoint or from a different one. Again, importance analysis must establish whether it is worth going into conflict analysis and the subsequent resolution of conflicts and enquiries.

The enquiry can occur at any stage of the investigation where more insight, about the information under analysis or about the viewpoint, is needed. The enquiry can either exploit the existing information or ask the viewpoints for more information.

Once the analysis has finished the results are passed to the viewpoint re-evaluation process, which has to consider the viewpoint models in the light of new information and to decide whether it is necessary to adjust them.

4. THE VIEWPOINT CONTROL ACTIVITIES

The Viewpoint Control Method comprises the following activities; Figure 3 shows a SADT model of the method (the figure shows the life histories of an event and a viewpoint model):

- Universe of Discourse Initialization
- Information Validation
  - Importance Analysis
  - Information Evaluation
- Communication
  - Conflict analysis
  - Enquiry
  - Universe of Discourse Update

Figure 3 is further decomposed in Figure 4 and Figure 5. The Viewpoint Control activities are driven by a collection of domain-independent heuristics to decide whether or not to take interest in a particular piece of information, in assessing information, in resolving conflicts between pieces of information, in enquiring to produce further information and also in reevaluating the corresponding viewpoint models.
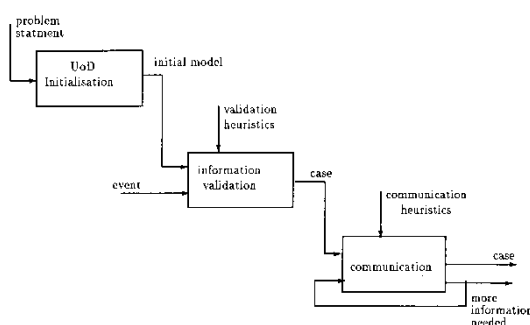

Figure 3: The life histories of an event

These heuristics operate on a number of parameters (the entries in a case) some of which are immediately available from the events under analysis and others are implicit and need to be extracted using the available information. For example, to identify the degree of commitment one may use the following heuristic:

If Commitment not indicated and trustworthiness is average, then

if helpfulness is low and information volunteered then Commitment suspect
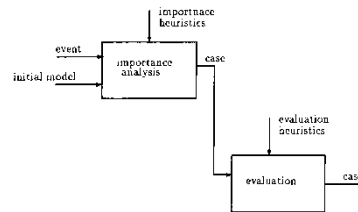*elseif information asked for then Commitment expected*
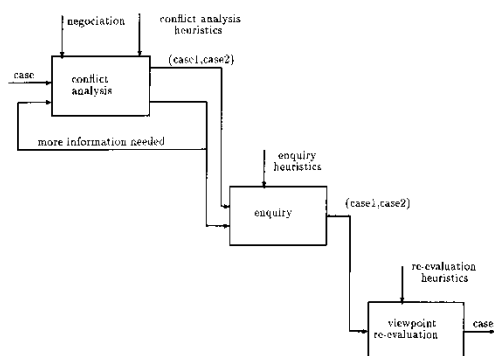

Figure 4: Importance Analysis Activities

Figure 5: Conflicts Resolution Activities

4.1 Universe of Discourse Initialization

Establishing the universe of discourse requires selecting the relevant viewpoints that will take part in viewpoint resolution and establishing the relationships between them. The relationships are represented in a viewpoint hierarchy. A viewpoint hierarchy may represent membership relationships, e.g. a person belongs to a department, reporting relationships, e.g. who reports to whom? Where do they get information from? etc., and ownership relationships, e.g. a person supervises another person or a team. Due to the explorative nature of requirements elicitation, it is difficult to establish what the relevant viewpoints and their properties are, before the acquisition process begins. As a starting point, an initial set of viewpoints is defined. Initial viewpoint models are then constructed using a default and a classification mechanism by which default values of viewpoint models can be produced and used in the absence of concrete evidence. Viewpoints which can be associated with a particular class are assumed to have the typical properties of that class. These class defaults are then used until further evidence either confirms or rejects them. For example, a doctor and a nurse may be selected as initial viewpoints of a patient monitoring system that is responsible for notifying the staff of an abnormality in the conditions of an intensive care patient. Later, another member of staff is added if necessary.

Doctor D:
Ability:
expertise: General_Medicine(d)
experience: 3_year.practice
reasoning: high(d)

Beliefs : none(d)
Goals: ?
doctor > nurse?
Helpfulness: high(d)
Trustworthiness: high(d)
nurse > doctor?
Helpfulness: high(d)
Trustworthiness: high(d)

It must be noted that the viewpoint model contains only information which is relevant for the purpose of assessing information. Thus, if a viewpoint has a strong belief which does not impair its subjectivity, then that will not be represented in the viewpoint model.

4.2 Importance Analysis

The role of importance analysis is to decide how far the analyses should go. There are three types of importance analysis: pre-processing importance analysis, pre-conflict importance analysis, and pre-enquiry importance analysis. Given an event and the corresponding viewpoint model the pre-processing importance analysis recommends:

1. proceed to information evaluation
2. accept the information as given, or
3. reject the information as irrelevant.

Pre-conflict importance analysis recommends one of the following:

1. proceed to conflicts analysis, that is to analyze the event in the context of the existing information.
2. launch an enquiry to further analyze the current event in isolation
3. stop analyzing the event any further.

Pre-enquiry (post-conflict) importance analysis recommends one of the following:

1. enquire not
2. enquire about the viewpoint
3. enquire about the information
4. re-evaluate the viewpoint and investigate

4.3 Information Evaluation

Information evaluation assesses a piece of information both in isolation and against the universe of discourse. The ultimate objective of the information evaluation process is to reach a decision on how much credibility can be attributed to a piece of information by considering its external features and the features of its source (viewpoint).

The information is analyzed for consistency, correctness, and incompleteness. A piece of information is:

• incorrect if it is attributed a very low or a nil belief.
• inconsistent if it does not live up to the expectations of the viewpoint model or if it causes conflicts with related information
• incomplete if there is evidence of the need for more information that requires an enquiry to reach a decision about it.

The distinctive feature of this approach to validation is its exploitation of the correlation between the problems of inconsistency, incompleteness, and incorrectness to form an opinion about a piece of information, thus making the maximum use of the information available. For example, an inconsistency may provoke an enquiry to find an explanation, and the enquiry may reveal evidence that may lead to the modification of the viewpoint model which in turn affects the decision on the degree of the information reliability.

Information evaluation considers the following attributes: the relative strength of the argument
• the degree of the viewpoint's commitment
• the degree of the viewpoint's advantage
• the viewpoint's trustworthiness
• the viewpoint's ability - expertise, experience, etc.

The final outcome of information evaluation is one of the following recommendations:

1. accept the event as given,
2. modify belief as a function of the viewpoint's ability,
3. reject the event.

For example, given the ability and the trustworthiness of a viewpoint the information evaluation may use the following heuristics:

if the helpfulness expected from the viewpoint model is low, the trustworthiness of the viewpoint is low, and the actual helpfulness of the viewpoint is high (i.e. the information was not solicited, but volunteered), then the viewpoint's advantage can be expected to be high (i.e. one can suspect a hidden advantage or vested interest) and one can conclude that the certainty of the information is low.

4.4 Enquiry

An enquiry is required if more information is needed. Information may be required to find out more about a particular viewpoint or about the information under analysis. There are two types of enquiry. The post-information evaluation enquiry which is prompted by problems with the current event when analyzed in isolation. The Post-Conflict Resolution enquiry prompted by the results of analyzing the current event in relation to the existing information, either from the same viewpoint or from a different viewpoint. The objective of an enquiry is to re-evaluate information via different venues. An enquiry can recommends the following:

1. accept the event as given,
2. modify belief as a function of the viewpoint's ability,
3. reduce belief to below the action point, or
4. reject the event.

4.5 Universe of Discourse Update

Once a case has been completely analyzed the viewpoint re-evaluation process takes over to revise the corresponding viewpoint model i n the light of any new evidence about the viewpoint characteristics.

Figure 7 shows that requirements validation is the composition of two processes: information evaluation and information viewpoint evaluation. The information evaluation process feeds details about the information to the viewpoint

model. In return, the viewpoint re-evaluation process provides its evaluation about the viewpoints by returning revised viewpoint models. Revising a viewpoint model is to modify the information it records, namely:

1. Ability related indices:
   a. the viewpoint's expertise in different areas
   b. the viewpoint's reasoning capabilities
   c. the viewpoint's competence in judging information
   d. the viewpoint's capabilities in handling its own experience

2. Trust related indices:

   a. The viewpoint's fundamental beliefs
   b. The viewpoint's goals
   c. The viewpoint's special relationships

The re-evaluation process produces one of the following recommendations:

> 1. adjust index
> 2. split index
> 3. replace default index with index based on evidence
> 4. record evidence and stop
> 5. introduce a new index for the class
> 6. investigate

4.6 Conflict Resolution

If one add a new event p to the existing belief base, then a problem has arisen because of some kind of conflict between p and some other event q. If p contradicts q then there is no non-arbitrary way of choosing between them unless the 'supports' of p and q are known. The support of an event is estimated from the values of the its external attributes and from the record of the corresponding viewpoint, using some kind of attributes utility analysis. There are two cases to be considered:

> • The conflicting events originate from the same viewpoint (single-viewpoint conflicts).
> • The conflicting events come from different viewpoints (multiple-viewpoint conflicts)

There are four types of conflict considered here:

> • Contradiction - two events at odd with each other.
> • Reiteration - the two events are roughly identical (redundancy).
> • Reinforcement - the new event strengthens the old.
> • Weakening - the new event weakens the old.

Contradictions are considered to be the most relevant type of conflict. Viewpoints are not judged just on the occurrence of contradictions. Contradictions are used as a signal to trigger a more complex evaluation. The outcome of the conflict analysis process is one of the following:

> • Accept information as given
> • Modify belief as a function of the viewpoint's ability
> • Reject information
> • Expel both pieces of information

• adjust belief according to the relative strength of the viewpoints
• merge both pieces of information
• set belief at even level, i.e. low/low or medium/medium
• suspend and investigate.

For example, in the case of a single-viewpoint contradiction one may have the following:

If there is a contradiction and both pieces of information are of high claimed certainty and there is a problem of trust and there is no problem of ability then reject both pieces of information.

In case of a multi-viewpoint contradiction one may have the following case: if there is a case of contradiction and the old information is less solid than the new and there is no problem of trust then suspend and investigate.

This resolution method can be seen as a combination of judicial and extra-judicial resolution methods [12]. A judicial resolution method covers situations where a third party is called upon to take a decision, taking in to account the cases presented by each viewpoint. An extra-judicial resolution method covers situations where a decision is determined by factors other than the cases presented (e.g. by the relative status of the conflicting viewpoints). However, if a deadlock is reached, there is the need to start a negotiation process in order to reach a new solution. Negotiation is a complex, iterative process of generation followed by evaluation [19]. The techniques of importance analysis, information evaluation, enquiry, and viewpoint re-evaluation can be part of such an iterative process.

Also, the information recorded in the viewpoint models and cases can be part of an 'agenda' for the negotiation. Using the fuzzy-logic based formalism [18] implemented to support interactively the parties in achieving a common solution, we can illustrate how the Viewpoint Control techniques can play a significant part in a negotiation process, especially in an uncertain environment. The conflict resolution approach can be outlined in the following steps:

1. On the basis of ability and trustworthiness of the viewpoints assign a weight to each viewpoint. These weights can be changed following re-evaluation of the viewpoints.

3. Evaluate the advantages and disadvantages of each option on the basis of the beliefs assigned to them by the information evaluation process and some domain-dependent knowledge.
4. Evaluate the consensus degree and shifting of positions:

(a) build a matrix representing the judgment of each group on each option, expressed in fuzzy linguistic terms, i.e. each element of the matrix is the value of a linguistic variable the range of which is pre-defined. For example: V = (very low, low, medium, high, very high). The viewpoints are made aware of the weights assigned to the options (stage 2).
(b) Measure the distance of each viewpoint from the general agreement on the value of each option, taking in to account the weights placed on the viewpoints. The options may then be chosen for

further discussion, and viewpoints may be asked to shift their positions.

(c) Rank the options, and repeat the process until an acceptable solution is found or a deadlock is reached.

5. Start a negotiation process if a deadlock is reached.

Note that the importance analysis and enquiry processes can be called at any stage if needed.

5. SUMMARY

A method for the very early validation of requirements has been developed. The method provides techniques to decide the relevance/importance of a piece of information, to assess it for correctness, to detect inconsistencies, to resolve conflicts between different viewpoints, to enquire for producing further information, and to re-evaluate viewpoints in the light of the accumulated evidence with regard to the performance of the viewpoints in providing information. These processes are coordinated by a guide operating on a 'start-do-stop' basis. The Viewpoint Control has the main ingredients of a validation method. These ingredients have been described earlier as the ability to:

• detect wrong information, inconsistencies, and missing information with respect to the universe of discourse as early as possible,

• allow for traceability between the information and the universe of discourse,
• encourage the users' involvement i n the process, and to
• support the negotiation process for resolving the problems with the requirements.

Although the Viewpoint Control concentrates on the fact-validation part of the requirements elicitation process it supports the fact-finding sub process through its importance and enquiry techniques and supports the communication sub process through its support for the negotiation process (see Figure 1).

The Leite method lacks many of the above ingredients. Firstly, the method supports neither fact finding nor communication. The elicitation subprocesses (fact-finding, fact-validation, communication) are naturally tied with each other that it becomes difficult to separate them. The Leite method is inadequate to cope profitably with the iterative and feedback nature of these processes.

Secondly, within fact-validation itself the Leite method does not deal with the correctness problem, e.g. two statements may be consistent but wrong with respect to the universe of discourse.

The development of the Viewpoint Control Method has concentrated on the causes of the inadequacies in Leite's method in order to improve on it.

These causes can be summarize as follows:

• The method depends on the quality of the viewpoints selected to take part in viewpoint resolution. Viewpoints in the Viewpoint Control Method are themselves evaluated and reevaluated as the investigation progresses.

• The method is restricted to two viewpoints. This is not an issue for Viewpoint Control since statements from different viewpoints are integrated as the requirements evolve.

• The context (i.e. universe of discourse) in which facts are validated is not defined. As a result there are no links between universe of discourse and information. The Viewpoint Control Method uses a domain-independent universe of discourse defined by the relevant viewpoints and by the viewpoint models. Furthermore, the use of cases relates the viewpoints to the information they contributed.

• The method is unable to supply the negotiation and conflict resolution process with the 'roots' of conflicts. For the Viewpoint Control Method each statement is associated with a case and a viewpoint model; the case records the results of the 'verdict' as to its quality and the viewpoint model captures the record of its source.

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