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A TRIAD-BASED CONTEXTUALISATION APPROACH FOR BETTER CRITICAL ISSUES' DECISION MAKING SUPPORT

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ABSTRACT

In many research and development fields, the stakeholders faced dilemma to acquire the accurate multi-criterion decision making (MCDM) outcomes. Observations showed that the inaccuracy of MCDM outcomes might be due to the missing of the right context for decision making process. This research is motivated to propose a contextualization approach for better critical issues' decision making support. The proposed triad-based contextualisation approach comprises three (3) processes namely the context characterisation, context representation, and context interpretation. At the end of a contextualisation process cycle, a set of consistent triad relationships would be derived to represent the current context of a critical issue. The context could be served as the right objective for guiding any critical issue's MCDM process. Experiment showed that the consistency of the Analytic Hierarchy Process (AHP) outcome has been improved when the stakeholder used the proposed contextualization approach to depict the right context as the objective for decision making deliberations. It is believed that once the proposed approach is conducted in many contextualisation process cycles with the help of machine learning systems and advance analytics tools in the future, it could produce a useful set of contexts or objectives for better critical issues' decision making insights.

Keywords: context, critical issue, decision making support, inconsistency detection, triad relationships.

INTRODUCTION

In many research and development (R&D) based enterprises, the experts often needed to resolve critical issues which have been identified as the opportunities or problems that could seriously affect the overall success of an organisation (Evans, 2013). Generally, critical issues could be found in almost every field such as requirements and software engineering development (Zakaria *et al*., 2011), business strategic planning ((Evans, 2013), (Falque, 2012)), education development ((Pathways, 2014), (DeWitt, 2014)), transportation development (TRB, 2013), health care development (Sharfstein *et al.,* 2013), community neighbourhood's environmental support (I'DGO, 2008), and many other fields.

In the process of resolving critical issues, multi-criterion decision making (MCDM) tools were often adopted by the experts in the R&D enterprises (Toloie-Eshlaghy and Homayonfar, 2011). However, the adoption of MCDM tools often yielded inaccurate outcomes due to inconsistent responses answering (Ishizaka and Labib, 2011). It was observed that the root cause of the inaccurate MCDM outcomes was due to the contexts of the critical issues were always assumed to be not important for the MCDM process. The critcal issues were also often expressed without any context. In addition, the experts often expressed or defined the requirements in their own terms with no regard for the background, thinking and experience of the other stakeholders during the MCDM process. Hence, it was hard to imagine the eventualities of a critical issue which was completely devoid of a context (O'Callaghan, 2011).

In this regard, it is felt that an approach for contextualisation support is important and should be exploited for assisting the relevant experts to better understand a critical issue with a right context prior to any decision making process. The research problem can now be phrased as: 'How can the contexts be identified and segregated in a contextualisation process cycle to better support decision making process? This is in fact the subtle but crucial problem of which this research is trying to resolve. The following section focuses on the review of current contextualisation approaches to identify the need for a new contextualisation approach. In section 3, a new triad-based contextualisation approach is proposed to support better MCDM process. Subsequently, section 4 focuses on the evaluation aspect. This paper is wrapped up with the discussion of future work and conclusion in section 5.

LITERATURE REVIEW

Context

According to Dey (2001), a context can be defined as "any information that can be used to characterise the situation of an entity" whereby an entity can be referred to an object, a place, or a person that is considered relevant to an interaction between a user and an application, which includes the users and the applications themselves. A broader definition of a context as given in (O'Callaghan, 2011) covered all aspects, regardless of it being observable, non-observable, conscious, subconscious, central, or even ancillary.

The importance of context was recognized in (Rudy, 2009) whereby context played a special role in recalling of episodes. On the other hand, context also provided the drivers for flexibility in a business process (Rosemann *et al*., 2008). Context is also important because without a proper context, we may get different responses or answers to a same question if the respondents defined the terms differently under different contexts (Eckerson, 2007).

The contextualisation aspect could be divided into three processes. They are context characterisation, context representation and context interpretation.

Context characterisation

There are many attributes that could be used to characterise a context such as people, place, time, requirements, criteria, factors, and others. The different types of contextual attributes used in various previous contextualisation research are such as design factors (Zisko, 2008), software requirements ((Onabajo, 2009), (Lapouchnian, 2011), (Gross, 2011), (Winbladh, 2010)), and safety requirements (Wang, 2010).

It is observed that all the proposed characterisation methods (expect (Winbladh, 2010)) as mentioned above were not personalisable. The characterised attributes were mostly derived by the relevant experts only. In addition, the attributes were not adjustable in the contextualisation approaches. Therefore, more flexible context characterisation methods should be researched into.

Context representation

Context representation refers to the method that is used to qualify or quantify requirements, attributes or metrics in different decision units for describing a context. The existing context representation methods included ontology-based (Gómez-Romero *et al*., 2011), topology based (O'Callaghan, 2011), semantic web based ((Wang, 2010), (Serafini and Homola, 2011)), fuzzy logic (Padovitz *et al*., 2008), and query language modelling (Riva, 2006).

The researchers Perttunen *et al.* (2009) had claimed that the contextual requirements representation was essential in software system developments with the emerging of computing paradigms such as ambient, pervasive, and as well as ubiquitous computing. However, there were only limited requirements engineering frameworks that could explicitly capture and analyse the requirements-context relationship as of year 2015.

On the other hand, the researchers Serafini and Homola (2011) and Perttunen *et al*. (2009) had proposed a list of requirements for context representation modelling. However, the current established context representation methods which were proposed by O'Callaghan (2011), Serafini and Homola (2011) and Gómez-Romero *et al*. (2011) rarely fulfilled the proposed requirements in providing flexibility and validation support to make the context representation outcomes more accurate and consistent.

Hence, there is room for improvement for the existing context representation methods. In this regard, more possible validation method for detecting the inconsistency of contextual relationships could be explored.

Context interpretation

As mentioned in the Introduction Section, the MCDM contextualisation support were either not existed or the context was directly defined by the experts who based on their personal knowledge only. Hence, a more formalised way of context derivation and interpretation should be proposed to better understand any critical issue and derive the right objective for decision making support. It is argued that the relevant contexts for decision making deliberations could be elicited by interpreting the relationships of decision making's attributes from the attributes comparison process. Whenever inconsistencies are detected from the attributes comparison outcomes, it is also argued that more human mental models or contexts could be elicited to represent the critical issue for different agendas. The argument is valid from various perspectives including rationalism, psychology, and human behaviours. A psychology professor in Princeton University - Philip N. Johnson-Laird had been quoted saying that "human reason by imaging a situation in which the premises are true – that is, we construct a mental model of them" (Ahmed, 2011). In this regard, it is argued that the process of interpreting and reasoning the inconsistent responses in triads would allow the experts to better understand the critical issue under reviewed and elicit more relevant contexts to represent the critical issue at different period of times. The attributes comparison question-answering and inconsistent detection process could serve as a good platform for depicting one to many possible contexts which could be used as the objective for a MCDM process.

THE TRIAD-BASED CONTEXTUALISATION APPROACH

In this research, a new context representation method has been proposed whereby each context is represented by a set of triads. A triad T is a set of three (3) relationships (R), where $T = \{R1, R2, R3\}$. Each triad consists of three (3) criteria/attributes. Each criterion set C, refers to the criticism that is used to judge the current issue in a context, such as $C = \{C1, C2, C3, C4, ...C_n\}$ where n is the total number of criteria in the chosen set of criteria. The three processes in a contextualisation process cycle are illustrated in Figure-1.

Process 1 context characterisation

In this process, the criteria (hereby could also be in the form of attributes, metrics or requirements) from a particular critical issue's field are selected as the elements to characterise a context. The criteria used for context characterisation are those that have been derived and recognised by the experts of the relevant research field. In this research, the number of criteria that is selected for undergoing the context characterisation process is ranged from three (3) to eight (8) criteria. The stakeholder could further select one (1) out of four (4) criterion set with different number of criteria to be used in the current contextualisation process cycle such as:

Set 1: Contains only three (3) criteria
Set 2: Contains only four (4) criteria
Set 3: Contains only six (6) criteria
Set 4: Contains only eight (8) criteria

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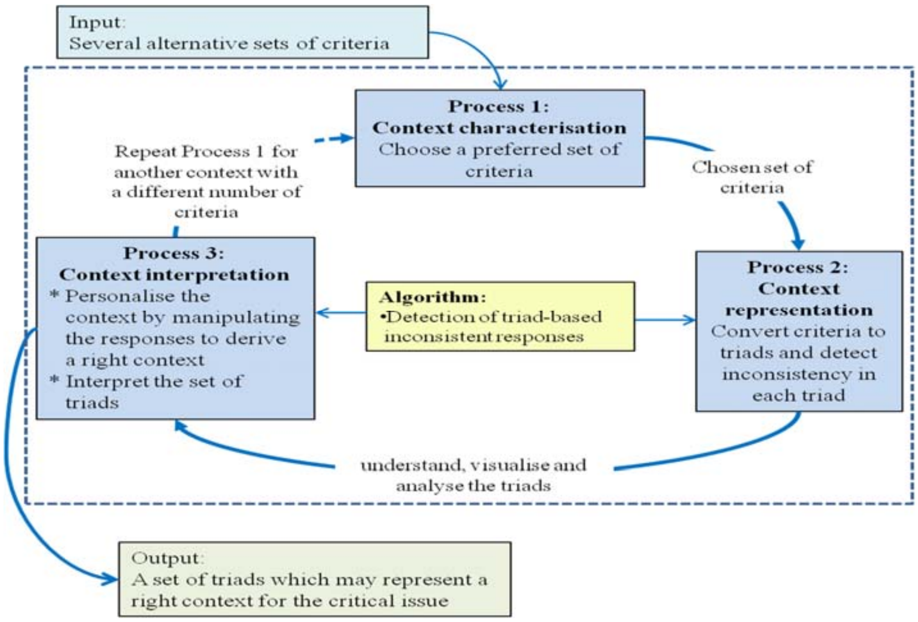

Figure-1. Processes in the proposed contextualisation approach.

Process 2 context representation

In this stage, the chosen set of criteria from the Process 1 is converted to a set of triads. The stakeholder would answer a set of questions in the form of "Is C_j more important than C_k, ($C_j > C_k$)?", where criteria C_j, $C_k \subseteq \{C_1, C_2, C_3, \ldots, C_n\}$ and n is the total number of criteria in the chosen criterion set from Process 1 to form triads.

Basically, a triad contains three relationships which involve only three (3) criteria. For example, with reference to Figure-2, when the question Q3 has been responded by the stakeholder, a triad could be formed together with two previously answered responses in Q1 and Q2, which compare (*C1, C2*) and (*C1, C3*). The consistency of the triad would then be detected with a logical inconsistency detection method.

In the triad formation process, inconsistency detection is conducted in the form whereby logical rules are used to validate the consistency of triads. Two (2) sets of logical rules have been derived to validate the triads. Table-1 shows the four (4) logical rules that are used to identify consistent triads while Table-2 shows the two (2) logical rules that are used to identify inconsistent triads.

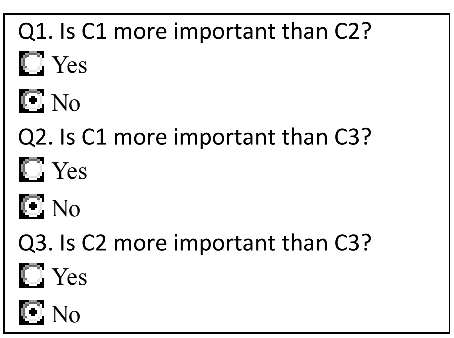

Figure-2. A set of three questions to form a triad.

Table-1. Logical rules for identifying consistent triads.

Rule No.	Rule components
1	**IF $C_i > C_j$ AND $C_i > C_k$ THEN $C_j > C_k$ OR $C_k > C_j$**
2	IF $C_i > C_j$ AND $C_k > C_i$ THEN $C_k > C_j$
3	IF $C_j > C_i$ AND $C_i > C_k$ THEN $C_j > C_k$
4	IF $C_j > C_i$ AND $C_k > C_i$ THEN $C_j > C_k$ OR $C_k > C_j$

Table-2. Logical rules for identifying inconsistent triads.

Rule No.	Rule components
5	IF $C_i > C_j$ AND $C_k > C_i$ THEN $C_j > C_k$
6	IF $C_j > C_i$ AND $C_i > C_k$ THEN $C_k > C_j$

The triads are validated as inconsistent if they violated either one of the logical rules as shown in Table-2. Whenever a triad is found to be inconsistent, it would not be used to represent the current context. Process 2 is considered complete when all possible triads have been formed and validated with the logical rules for context representation.

Process 3 context interpretation

Once the Process 2 is completed, a stakeholder may choose to accept or reject the triads validation outcomes based on his/her personal interpretation on the triad relationships. If the existing triad relationship is inconsistent, the stakeholder could reverse his/her previous question-answering response to make the triad consistent, so long as the conflicting relationships do not exist in other represented triads, for the same context. Similarly,

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the stakeholder could revert a consistent response to drop a triad from representing the current context.

Eventually, the outcomes of a contextualisation process cycle are a set of consistent triad relationships and a set of inconsistent triad relationships. The consistent triad relationships could be used to represent a current context for identifying the right objective for a MCDM process. Meanwhile, the inconsistent triad relationships could be stored in a repository for future processing in different contextualisation cycles to derive other context for the same critical issue.

EVALUATION

This evaluation section demonstrated how the proposed triad-based contextualisation approach could be used in the pre-processing stage of multi-criterion decision making (MCDM) process to assist a test department manager in a R&D enterprise to determine the right objective for test optimization's critical decision making support.

In the first experiment, the manager answered the pair-wise criteria comparison questions in the MCDM system directly without using the proposed approach to determine the right objective for the decision making process. The outcome of the answering process is shown in Table 3. Analytic hierarchy process (AHP) method and consistency ratio (*CR*) were used to evaluate the consistency of the question answering process. It was found that the manager did not answer the questions consistently (*CR* = 0.386, whereby a consistent set of responses should have *CR* < 0.1).

Table-3. The MCDM process result for experiment 1.

Criterion	Weight	Ranking
Voltage accuracy	**0.21**	**3**
Current accuracy	0.24	2
Bandwidth	0.31	1
Temperature compensation	0.13	4
Screen frequency accuracy	0.02	7
Analogue signal	0.03	6
Digital signal	0.06	5
Consistency Ratio (CR)	0.386	

In the second experiment, the manager used the proposed triad-based contextualisation approach to identify the right context as the MCDM objective prior to answering the questions. With reference to Table-4, when the manager answered the questions of set 1 in the contextualization process, he could be thinking of a context "time and speed optimization" to enhance the test process. However, when the manager answered set 2, 3 and 4, he happened to change his thinking of another context such as "quality performance" in enhancing the test process. In this case, two contexts have been elicited from the manager's point of view.

Table-4. The triad comparison outcomes from the proposed triad contextualisation approach.

Set	Question 1			Question 2			Question 3			Triad consistency (yes/ no)
	Criterion 1 (C1)	Criterion 2 (C2)	C1>C2 (Yes/ No)	Criterion 1 (C1)	Criterion 2 (C2)	C1>C2 (Yes/ No)	Criterion 1 (C1)	Criterion 2 (C2)	C1>C2 (Yes/ No)	
1	Bandwidth	T.C.	Yes	Bandwidth	Voltage accuracy	Yes	T.C.	Voltage accuracy	Yes	Yes
2	Bandwidth	T.C.	Yes	Bandwidth	Current accuracy	No	T.C.	Current accuracy	Yes	No
3	Bandwidth	Voltage accuracy	Yes	Bandwidth	Current accuracy	No	Voltage accuracy	Current accuracy	No	Yes
4	T.C.	Voltage accuracy	Yes	T.C.	Current accuracy	Yes	Voltage accuracy	Current accuracy	No	Yes

Note: T.C. = Temperature Compensation

Through undergoing the necessary context representation, interpretation, and personalisation processes, the manager has managed to ascertain his mental model that he should consider quality performance factor as the main objective for conducting the test optimization MCDM process. The manager proceeded to answer the pair-wise criteria comparison questions in the MCDM system. The result of the MCDM process outcomes is shown in Table-5. The MCDM process with contextualisation support showed significant improvement in consistency outcomes from *CR* 0.386 to 0.061. In addition, the ranking of test optimization criteria have been able to portrait the objective of considering quality performance for test optimization decision support by giving highest priority to "current accuracy" with high weight value of 0.47 in comparison to other criteria.

The experiments showed that the proposed contextualisation approach could help the stakeholders who wish to use MCDM system or questionnaire by providing them a right context as the objective to better understand the critical issue in view prior to decision making deliberation.

Table-5. The MCDM process result for Experiment 2.

Criterion	Weight	Ranking
Voltage accuracy	**0.19**	**2**
Current accuracy	0.47	1
Bandwidth	0.15	3
Temperature compensation	0.10	4
Screen frequency accuracy	0.02	7
Analogue signal	0.03	6
Digital signal	0.04	5
Consistency Ratio (CR)	0.061	

CONCLUSION AND FUTURE WORK

This research explored an approach to better understand a critical issue for decision making support through three contextualisation processes which included context characterisation, representation, and interpretation. In this research, the inconsistency detection process would inspire the stakeholders to self-evaluate their understanding of the vision, missions, and objectives of a critical issue. Unlike other contextualisation approaches which focused on only what the stakeholder wanted, the proposed approach also covered what the stakeholder does not quite want and what he or she has not previously thought of – as described in knowledge progress stage 4 "*I don't know what I know*" (Kleinwaechter, 2012). In addition, it has been unexpectedly found that the pair-wise criteria relationships among all the relationships in a set of triads could provide much better insights for the understanding of a critical issue, subject to the consideration and execution of contextualisation.

In short, this research aimed at providing a meaningful qualifier for the stakeholders to acquire impactful insights for critical issues' decision support. It also paves a way for the interested researchers to fill many outstanding research gaps created in the course of this research. If the criterion set for context characterisation and representation is large, some machine learning systems must be trained to automate the processing of many different sets of criteria and triads. Similarly, some advanced analytical tools are required to analyse the large number of relationships resulting from the automated triad formation process.

Eventually, the proposed triad-based contextualization approach could be used as a pre-processing tool to identify the right objective for conducting any MCDM process. It could ensure better accuracy of decision making outcomes whereby all the stakeholders would be following the right direction, objective, and agenda to make their decisions. It is expected that the proposed approach would be used across various fields that require contextualization support for better critical issues' decision making.

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