iRE: A Semantic Network based Interactive Requirements Engineering Framework

Kushal Ahmed*, Lian Wen and Abdul Sattar

Institute for Integrated and Intelligent Systems, Griffith University,

170 Kessels Rd, Nathan, QLD 4111, Australia

Email: kushal.ahmed@griffithuni.edu.au, {l.wen, a.sattar}@griffith.edu.au

Abstract—Requirements engineering (RE) involves processing informal natural language descriptions of system requirements into an integrated and structured formal specification. The traditional RE process is ad-hoc, laborious, time-consuming, and error-prone manual process. For large-scale software intensive systems, the RE process becomes very difficult to manage. It is further complicated by ill-defined, incomplete, and redundantly specified requirements. To streamline the process, an end-to-end seamless RE framework is therefore needed. In this paper, we present an overview of an end-to-end semi-automated change-tolerant interactive requirements engineering (iRE) framework. It keeps and maintains the meta-level information of the interrelated requirements models into a *semantic network model* (SNM), and provides a method and processing system to derive an integrated and structured model. The iRE involves the requirements analysts in an interactive fashion during the modeling process.

Index Terms—Requirements Engineering, Behavior Engineering, Behavior Trees, Semantic Network Model, Defects Detection, Change Management, Model Integration.

I. INTRODUCTION

Requirements Engineering (RE) often deals with a set of scattered and unstructured system requirements with a view to derive an integrated and structured system model that would serve as a formal specification. The requirements are usually represented by graphical models. The requirements analyst (RA) manually visits every model along with its interrelated models, and perform sanity and integrity checking. In this process, the RA, temporarily or finally, makes decisions on which requirement models are at that moment ready to be part of the formal specification. This decision may affect decisions made for other interrelated models in a cascading fashion.

Nevertheless, the traditional RE process is ad-hoc, laborious, time-consuming, and error-prone manual process. It is further complicated by ill-defined, incomplete, and redundantly specified requirements. Sometimes new requirements may be introduced, while existing requirements may be modified or deleted. Since the requirements are interrelated, a change in a requirement affects the *acceptability* of its related requirements for inclusion in the specification; which may again have ripple or cascading effects on other requirements further. Putting all these together, the whole process becomes very difficult to manage for a large-scale software intensive system, even if it is somewhat manageable for a small-scale one. To streamline the process, an end-to-end RE framework is therefore needed.

In this paper, we present an overview of a new end-to-end semi-automated change-tolerant interactive requirements

engineering (iRE) framework. It keeps and maintains the meta-level information of the given requirements models and their interrelations into a *semantic network model* (SNM), and provides a method and processing system to derive an integrated and structured model. The iRE involves the RA in an interactive fashion in the whole modeling process. We also have developed a prototype GUI toolkit [1] for the behavior trees (BTs), a modeling language used in Behavior Engineering ([2]–[4]). BT notation can be used in the entire RE process. We have not chosen other modeling languages such as the Unified Modeling Language (UML) because they pose additional significant challenges due to their use of a number of different models (e.g. use cases, sequence diagrams, state charts, etc.) in the process, and thus making the formalisation of an end-to-end seamless RE framework difficult.

Paper organisation: Section II describes the background about RE process using BTs; Section III briefly describes our interactive RE framework; Section IV illustrates the iRE; Section V describes our GUI toolkit; Section VI explores related literature; and finally Section VII presents our conclusion.

II. BACKGROUND

Consider the requirements of the Security Alarm System (SAS) ([5]) shown in Table I. The SAS will be used as a running example in this paper.

1) *SAS*: The SAS when activated by pressing a set button displays its active status. While active, the SAS can detect motion and can then make alarm sound. The alarm sound can be deactivated by entering a 3-digit code, which can be cleared and re-entered, if a mistake is made. From these requirements, an integrated and structured model would be developed.

TABLE I
REQUIREMENTS OF THE SECURITY ALARM SYSTEM

R1	The detector of SAS sends a trip signal when motion is detected.
R2	The SAS is activated by pressing the Set button.
R3	The set button is illuminated when the SAS is set.
R4	If a trip signal occurs while the SAS is set, a high-pitched tone (alarm) is emitted.
R5	A three-digit code must be entered to turn off the alarm tone.
R6	Correct entry of the code deactivates the SAS.
R7	If a mistake is made when entering the code, the user must press the Clear button before the code can be re-entered.

Note that the SAS is not a representative of the scale of problems that we intend to deal with. The SAS is rather a carefully selected small problem that is interesting enough to elucidate our model and mechanisms.

In this paper, we represent the SAS using BTs i.e. behavior trees. BTs come very close to natural language specification in terms of what they can express [6]. They capture dynamic behaviors of a system in an arguably easy-to-understand graphical format in a manner which stays close to the structure and terminology of the original requirements, but possess a formal semantics [4]. We argue BTs can be used seamlessly throughout the modeling process since it combines use cases, scenarios and state-based behaviors into a single model. Moreover, state machines can be derived from a behavior tree [7].

2) *SAS and BTs*: Requirement R2 in Table I mentions the initialisation scenarios for activating the SAS. R2 is represented by a BT in Fig. 1(a) as BT2. Fig. 1(b) displays the full contents of a BT node. Each node is associated with (a) a component, which has a behavior described by (b) a behavior name and (c) a behavior type. The node has a tag consisting of (d) a status (e.g. original, implied (+), and missing (-)) indicating the level of modifications made apart from the original requirements, and (e) a traceability link to trace the node back to the original requirements. It can also have (f) an operator and/or (g) label which describe the flow of control. The node further may have (h) related nodes to describe relational behavior with other components. A relational behavior may be described by the related component name, the type of relation (what, how, where etc) and its qualifier (on, at, in etc). Note the brackets show the syntaxes.

Fig. 1. Behavior Tree and Attributes of a node

Fig. 2. Behavior Trees (dots: nodes were skipped)

Behavior types are internal ($\langle \dots \rangle$) and external ($\gg \dots \ll$) inputs, internal ($\langle \dots \rangle$) and external ($\ll \dots \gg$) outputs, event ($?? \dots ??$), selection, ($? \dots ?$), state realisation ($[\dots]$) etc (Fig. 3).

Fig. 3. Behavior Types of a node.

The node operators are used to indicate control flow beyond simple sequential execution and branching. An operator (at

source node) refers to another equivalent node (at target node) elsewhere in the behavior tree. The nodes of a behavior tree can be connected in different ways such as sequential, parallel, atomic and alternative ([3], [8]). Formal semantics have been provided to behavior trees using an extension of CSP which can capture state based information [4].

Notice BTs for Requirements R2 and R3 in Fig. 1(a) and 2(a). BT2's ending scenario activating the SAS is the starting scenario of BT3. This means, BT2 and BT3 are interrelated, and so the root of BT3 can be merged with the leaf of BT2 to obtain an integrated model. The integrated BT for BT2 and BT3 has been shown in Fig. 4(b). Informally, integration is performed by merging the associated nodes. Similarly, performing node merging between all BTs (the rest are in Fig. 4(c-g)), we can obtain an integrated holistic model that represents the whole SAS ([3], [8]). This process reveals inconsistencies, incompleteness, ambiguities and redundancies in the requirements ([3], [9]).

Fig. 4. Mathematical Representation and Behavior Trees

3) *Mathematical Representation of BTs*: We use a very generic representation of *Behavioral Model* (BM), denoted by m , to refer to the mathematical representation of a BT [9]. As such, a BT node is referred to as *Behavioral Unit* (BU), denoted by u . A BU consists of a set of *attributes* $\{a_k\}$ and so does an edge between two BUs. Each attribute a_k has a *name*, denoted by $name(a_k)$, and a *value*, denoted by $value(a_k)$. Fig. 4(a) shows a BM for BT3 having two BUs u_0 and u_1 connected by an edge $e_{0,1}$.

4) *Equivalence Relation between BUs*: We defined a *similarity* measure between two BUs u and u' at [9]. The candidate BUs may not have the same set of attributes. Again, the values of the attributes may have compatibility issues. For example, *state realisation* and *external/internal input/output*

are incompatible. We extend the definition to make the concept more generic. Let A denotes the universal set of attributes; $A_u \subset A$ and $A_{u'} \subset A$ denote the set of attributes of the BUs u and u' respectively. Given that there exists no incompatible attribute pair in A_u and $A_{u'}$, the *similarity* measure $u \odot u' = (\sum_{i,j,k} (a_i \odot a_j) * w_k) / \sum_k w_k$ for all $a_i \in A_u, a_j \in A_{u'}$ and $a_k \in A$ such that $name(a_i) = name(a_k) = name(a_j)$. Here, $a_i \odot a_j$ is the *similarity* of the attributes, and w_k is the *weight* of a_k . For a given threshold α , if $u \odot u' \geq \alpha$, then u and u' are *equivalent*. The weights and the threshold values may need to be configured locally for candidate BUs. For simplicity, let's assume a global configuration is used. Suppose the weights of *component-name*, *behavior-name* and *behavior-type* are 50%, 25% and 25% respectively; all the rest are 0%. Then the *similarity* between a BU u_2 of BT5 and the root BU u_0 of BT6 (Fig. 4(c, d)) becomes 0.75. If $\alpha = 0.75$ then the two BUs are equivalent. Note that the weights and the threshold values may be estimated by AI techniques using the data from different case studies (future work). However, the RA may choose these values according to their experience. From our experience, the weight of the *component-name* should be higher than any other attributes for finding equivalence relations in BTs.

5) *Integration Relation between BMs*: A parent BM m_p forms an *integration relation* with a child BM m_c , denoted by $R(m_p, m_c)$, if a BU u_p in m_p is *equivalent* to the root BU u_c of m_c . Notice BT5 and BT6 in Fig. 4(c, d). They form an integration relation because u_2 of BT5 and u_0 of BT6 are equivalent as shown above. The root BU of a child BM may be *equivalent* to multiple BUs of its parent BM. Thus, they may form multiple relations. We use $R^k(m_p, m_c)$ to denote k -th relation between m_p and m_c . Depending on whether u_p is the root, a branch or a leaf in the parent BM, we consider three types: *root-root*, *branch-root* and *leaf-root* relations [9]. Integration relations indicate a candidate merger of equivalent BUs and so a potential integration of two BMs into one.

III. INTERACTIVE REQUIREMENTS ENGINEERING

In a traditional RE process, natural language descriptions of a system's requirements are first translated by the RA into a given model, in our case behavioral models (i.e. BMs). The RA then manually visits every model along with its interrelated models, and perform sanity and integrity checking. The RA might temporarily or finally make decisions about whether a particular BM can be included in the specification or not. Once a decision has been made for a BM, normally the RA then finds another BM, interrelated to the former, to repeat similar kinds of checking and decision making.

In this process mentioned above, the RA might face a number of difficulties. For example, depending on the scale of the system, the RA might not have an overall knowledge on the requirements. So s/he might go through all the BMs and relations each time to find a suitable BM for his next consideration. Moreover, the RA has to remember previous decisions made for other BMs. Sometimes, the process could go back and forth, affecting previous decisions in a cascading fashion. With the absence of a clearly defined mechanism

and any aid from an automated system, these issues must be addressed by the RA through laborious, time consuming and error-prone manual process. The whole process becomes even more complex for large-scale software intensive systems.

In this section, we provide an overview of a new framework of RE, referred to as *Interactive Requirements Engineering* (iRE). In iRE, the target integrated BM would be derived semi-automatically where the RA would get involved with the process in an interactive fashion. We do not opt for a fully automated system because explicit domain knowledge is required in various scenarios during the RE process.

The main concept of the iRE is to capture the meta-knowledge about the BMs and their integration relations into a *semantic network model* (SNM). The iRE system (Fig. 5) would provide an interactive interface to the RA who could utilise the SNM to make domain decisions. A *defects detection and resolution framework* (DDRDF) would detect potential defects [9] using the SNM and the interrelated BMs, and would suggest the RA a set of potential resolutions. The DDRDF could prioritise the defects, and advise what's next to consider for making domain decisions. In the whole process, the RA may make changes in the BMs and/or their relations in the SNM. A *change management framework* (CMF) would synchronise the BMs and the SNM. The *models integration framework* (MIF) would automatically produce the integrated BM based on different configuration settings set by the RA.

Fig. 5. Conceptual Model of iRE

Fig. 6 shows the process flow and Fig. 7 shows the elaborated view of the iRE.

When the RA translates the informal requirements into a set of BMs, the iRE process would determine the integration relations between the BMs (previous work [9]). The iRE then would build the SNM which is a graph with the BMs as its vertices and the integration relations between BMs as its edges. In the SNM, the RA may want to choose the initialisation BM(s). Note an initialisation BM consists of behavioral scenarios to initialise a system. The SNM then would undergo a sanity

Fig. 6. Process flow of iRE

checking, and decisions would be temporarily or finally made by the RA for its individual vertices i.e. the BMs to be ready for integration. Because of various types of relation in BMs, the temporary decisions could be revised back and forth, and

thus could affect similar other decisions in a cascading fashion. In order to keep the cascading operation manageable, the SNM imposes a number of inference rules. Putting these altogether an SNM is called a *normalised SNM* when it passes the sanity checking and conforms to the inference rules. Expert opinion would be taken where necessary.

Fig. 7. Elaborated view of iRE

A *normalised SNM* is called a *well-formed SNM* when it is connected and it has one Init model. If the *normalised SNM* is not well-formed, the DDRF would detect potential defects; and would present the RA potential resolutions. The RA would make changes to the BMs and/or their interrelations in the SNM. The CMF would then reflect the changes and synchronise the BMs and the SNM with a view to get another *normalised SNM* from the previous *normalised SNM*. Once the SNM becomes well-formed and is verified by the RA, an integrated BM may be derived by the MIF (formalised in [10]). This integrated BM would be utilised to derive an executable specification, that is used for model-checking (e.g. [11]), simulation (e.g [12]) and further development works.

IV. ILLUSTRATION OF THE IRE FRAMEWORK

In this section, we illustrate the functionalities of the components of the iRE framework using the BMs of the SAS.

A. Determine Relations in the BMs.

Let, m_1 to m_7 denote the BMs for R1 to R7 respectively. Using the same *similarity* measuring formula and parameters as in Section II, Table II shows the relations in them. Column *BMs* shows parent and BMs (parent and child) having an integration relation, column *Relations* indicates the relation type, column u_p shows the parent integration BU (note that the child integration BU u_c is omitted since it is always the root BU of the child BM), and column $u_p \odot u_c$ shows the *similarity* measure between u_p and u_c .

TABLE II
RELATIONS OF THE BMs OF THE REQUIREMENTS OF SAS.

BMs	Relations	u_p	$\odot$	BMs	Relations	u_p	$\odot$
m_2, m_3	leaf-root	u_3	1	m_2, m_4	leaf-root	u_3	1
m_3, m_4	root-root	u_0	1	m_4, m_3	root-root	u_0	1
m_4, m_5	leaf-root	u_2	1	m_6, m_2	leaf-root	u_2	1
m_5, m_6	branch-root	u_2	.75	m_5, m_7	branch-root	u_2	.75
m_6, m_7	root-root	u_0	1	m_7, m_6	root-root	u_0	1

B. Develop SNM from the interrelated BMs.

The SNM consists of vertices that represent the BMs and the edges that represent the integration relations between BMs. Fig. 8(a) shows a graph where the vertices refer to the BMs, and the edges refer to their relations annotated with *similarity*. We gradually develop the SNM as shown in Fig. 8(b).

Fig. 8. Interrelated BMs and SNM

Firstly, we annotate each vertex by assigning an *acceptability* state. We consider three states: Included (IN), Excluded (EX) and Undecided (UN). A BM is IN if the RA accepts it as valid, and thus the BM is included in the specification. A BM is EX if the RA does not accept it as valid and so is excluded from the specification, and it is UN if no decision has been made. Initially, all BMs are EX. To start, s/he selects a BM as an Init (initialisation) BM by discretion. Suppose s/he selects m_2 as the Init BM. We say it is Included in the specification and the CMF updates the SNM by assigning IN state to m_2 (Fig. 8(b), double border: Init).

We also annotate each vertex by assigning the *confidence* of each BM to quantify the credence for inclusion in the specification. We assign *confidence* 1 if a BM is IN and 0 if EX. Otherwise, *confidence* of a BM is the *confidence* of its parent multiplied by the *similarity* measure of its corresponding integration relation. For simplicity, we consider the maximum value when multiple parents exist.

In addition to the *similarity* measure, an integration relation is annotated by its state. We consider two layers of thresholds: (1) IN threshold α_{IN} and (2) UN threshold α_{UN} where $\alpha_{UN} < \alpha_{IN}$. We assume a relation is IN if *similarity* $\geq \alpha_{IN}$, and EX if *similarity* $< \alpha_{UN}$, and UN otherwise. For domain dependency, the decision is committed on RA's consent.

C. Develop Normalised SNM.

After developing the SNM as shown in Fig. 8(b), the CMF derives a simplified version of the SNM where the relations are evaluated, minimised and organised, and the *acceptability* states and the *confidences* of the BMs are updated.

Fig. 9(a) shows the *root-root* relations between m_3 & m_4 . In this case, the integrated BM would be the same irrespective of which relation we consider. So, a *root-root* relation can safely be eliminated. From the candidate BMs, we choose a BM, referred to as the *leader* model, that is either an Init model or the closest model among others from an Init model. We then eliminate the relation incoming to that *leader* model. However, the elimination is committed upon the RA's consent. If there is a tie, the model having more (or equal) children is chosen as the *leader* model. In Fig. 8(b), m_4 is the *leader* among $\{m_3, m_4\}$. Even if their distance from the Init model (m_2) is 1, m_4 has more children (2) than m_3 (1). Similarly, m_6 is the *leader* among $\{m_6, m_7\}$. Therefore, the relations between m_3 & m_4 , and m_7 & m_6 are eliminated as shown in Fig. 9(b).

Fig. 9. root-root relations

Again, Fig. 10(a) shows that m_2 & m_3 , and m_2 & m_4 form *leaf-root* relations, and m_4 & m_3 form *root-root* relation. These three models will eventually be integrated into one model. Therefore, the root-root relation can safely be eliminated. The relation between m_6 & m_7 can also be eliminated. Fig. 10(b) shows the updated SNM.

Fig. 10. Transitive root-root relations

A set of BMs may have root-root relations in a cyclic order, which can be simplified by choosing a *leader* model from them and create root-root relations from the *leader* model to all other models. It eliminates a relation as well. Again, the number of parent and child relations may change for a BM. So the *leader* model for a root-root relation may also change. In that case, the direction of the root-root relation can be reversed. Further, if a set of BMs is connected by root-root relations, they can be transformed into a *tree-structure* by selecting the *leader* and creating root-root relations from the Init model to all other BMs. It is similar to breaking cyclic *root-root* relations except it does not reduce the number of relations.

A BM can be validated before assigning an *acceptability* state. For example, the scenarios for the Init model m_2 can be examined to extract a set of rules:

- 1) (L1) if {}, then $\neg SAS-Activated$. That is, by default SAS is not Activated.
- 2) (L2) if SET-BUTTON-Pressed, then SAS-Activated. This rule overrides rule L1.

The above rules have been expressed in Clausal Defeasible Logic (CDL) [13], which is implementable [14]. We can form a *rule-set*, from the above L1 and L2 rules i.e. *rule-set* = $\{L1, L2\}$. Since incremental refinement of a (conflicting) rule set can be performed in non-monotonic logic ([15], [16]), the *rule-set* can be gradually developed from the BMs. In this paper, we assume that the BMs are valid against the *rule-set*.

Suppose the relation between m_5 & m_6 is accepted by the RA. As shown in Fig. 11(b), we can then infer IN states for m_3 , m_4 , m_5 and m_6 . We further infer UN state for m_7 since neither its parent nor the relation is EX. Lastly, we infer EX for m_1 since it is no way connected with the Init model.

Fig. 11. Circular Relation in BMs and SNM

- 1) **Inferring IN State:** We set $IN(m)$ if m is an Init BM that the RA has chosen with discretion. We infer $IN(m)$ if it is valid against the *rule-set* and there exists at least one pair of IN state parent and relation.
- 2) **Inferring UN State:** We infer $UN(m)$ if it is not IN, it is valid against the *rule-set* and there exists at least one pair of parent and relation such that both are not EX.
- 3) **Inferring EX State:** We infer $EX(m)$ if it is neither IN nor UN.

Further, Fig. 11(a) shows a circular relation consisting of m_2 , m_4 , m_5 and m_6 . Now, if these BMs are integrated, it over-specifies the scenarios of the behaviors. Fig. 12 (a) shows the integrated model where the border lines show the same sequence of behaviors $\langle u_0, u_1, u_2, u_3 \rangle$ and $\langle u_{10}, u_{11}, u_{12}, u_{13} \rangle$. To avoid this over-specification, a relation must be eliminated. We again select m_2 as the *leader* model. Fig. 12(b) shows the updated SNM, which we refer to as *normalised* SNM.

D. Defects Detection and Resolution

The SNM aids finding out defects in the requirements earlier. The BM m_1 gets EX state and it does not have any relation, so requirement R1 is incomplete. Please refer to our

Fig. 12. Over-specification (long arrows at (b) indicate branching)

previous paper [9] for techniques of potential defects detection. Defects may be resolved based on a set of resolution heuristics and suggestions could be presented to RA for making domain decisions, which are kept as future work.

E. Develop Well-formed SNM

This property determines whether the system requirements can be integrated into one formal specification or not. A *normalised* SNM is *well-formed* if (1) the number of Init models in the SNM is 1, (2) all models have IN states, and (3) all existing relations have IN states.

The RA may want to analyse why m_1 could not form a relation. The BM m_1 is about sending the trip signal when a motion is detected. It is easily understood that a precondition is missing. Suppose RA thinks that m_1 should happen when the SAS is activated (Fig. 13). Now, it forms root-root relations (*similarity* 1) with m_3 and m_4 , and leaf-root relation with m_2 (Fig. 14(a)). Fig. 14(b) shows the *normalised* SNM.

Fig. 13. Modified m_1

Fig. 14. Modification of the BM m_1

If the RA accepts the relation between m_5 and m_7 , the BM m_7 becomes IN. Fig. 15 shows the updated SNM, which is *well-formed* as well.

Fig. 15. *well-formed* SNM

F. Derive Integrated Model

The *well-formed* SNM can be traversed from the Init model utilising *breadth-first-search*, so an integrated BM can be derived as well. Fig. 16 shows the integrated BM of the SAS. The integration of BMs has been formalised at [10].

Fig. 16. Integrated BM for the SAS

V. INTERACTIVE RE TOOL

A GUI toolkit [1] has been developed using Eclipse Modeling Framework (EMF) and Graphical Modeling Framework (GMF). This tool demonstrates creating SNM from models and their relations. The link provided in [1] instructs how to install the tool. Many textual and graphical editors are available for behavior trees (e.g. [17], [18]). Among those, Oskar et al. [17] used the same underlying framework (EMF and GMF). Therefore, we plan to integrate the iRE with their editor.

VI. RELATED WORK

Traditional Behavior Engineering [3] provides an end-to-end process to derive a formal specification from a set of system requirements. It builds up a holistic view of the system by gluing the requirements together as if the RA is solving a jigsaw-puzzle. As a result, the process is ad-hoc and deriving a formal specification for a large-scale system becomes a laborious, time consuming and error-prone manual process. In this paper, we proposed a new end-to-end semi-automated change-tolerant interactive mechanism for requirements engineering.

Kung et al. [19] performed impact analysis on class diagrams for a change in inheritance, encapsulation, polymorphism etc. Briand et al. ([20], [21]) derived an automated approach to analyse the change impact on different types of

UML diagram such as Class Diagram, Sequence Diagram and State-chart Diagram. However, UML diagrams [22] represent variety of aspects of the system across several diagrams. Further, some UML diagrams do not have formal semantics. As these diagrams have different syntax and semantics, it often becomes difficult to define relationships between the diagrams. In UML, a number of overlapping partial views of the system along with the contextual switch when moving between diagrams makes it hard to formalise the impact of a change in the requirements in the modeling stage [23].

Göknil et al. [24] formally defined different types of relation in the requirements using first-order logic and developed change impact rules based on a requirement metamodel. However, they did not show how the requirement metamodel can be utilised for the management of the requirements models at earlier stage of system modeling. Wen and Dromey ([25]) proposed a traceability model to determine the impact of a change on the architecture and design of the system by embedding the changes in the specification behavior tree. To the best of our knowledge, there exists no framework that utilises a semantic network of behavioral models as *knowledge-base* in the earlier stage of requirements modeling.

Our proposed mechanism is highly inspired by the techniques applied to an epistemology-based system such as Ellis's belief system [26] from the Philosophy field and Doyle's Truth Maintenance System (TMS) [27] from the AI field. Ellis ascribes a sentence A of a language L as true T , false F or an absence of firm belief X and uses a number of *acceptability criteria* to determine the equilibrium (e.g. *consistency*, *normalisation*) condition. Doyle used a semantic network model as the epistemic state of belief, where the *nodes* refer to a set of objects of beliefs and *links* refer to the relations of the beliefs. Doyle also developed *truth maintenance mechanisms* to maintain the beliefs and the reasons of beliefs. In our model, justification of the *acceptability* of a BM depends on the validity against the *rule-set* and the related BMs. Our developed SNM also captures the *confidence level* of each of the BMs. Three types of states, along with the *confidence level*, explicitly portray a mental judgement on a BM.

VII. CONCLUSIONS AND FUTURE WORK

In this paper, we presented an overview of a new approach of requirements engineering. We used a *semantic network model* as a *knowledge-base* to capture the meta-level information of the system requirements and their relationships. We then illustrated how the SNM can support the requirements engineering in a seamless fashion. In near future, we would like to formalise each of the components (SNM, CMF, MIF and DDRF) of the iRE framework along with their implementation. We also plan to perform experimental evaluation of the iRE framework by emulating large-scale software intensive systems. Our plan also includes evaluating the approach using large-scale real case studies collaborating with industries.

REFERENCES

- [1] "Interactive RE Demonstration Tool." [Online]. Available: <http://www.beworld.org/BE/iRE/>
- [2] R. G. Dromey, "Architecture As An Emergent Property of Requirements Integration," in *ICSE*, 2003, pp. 77–84.
- [3] —, "Formalizing the Transition from Requirements to Design," *Mathematical Frameworks for Component Software-Models for Analysis and Synthesis*, pp. 156–187, 2006.
- [4] R. J. Colvin and I. J. Hayes, "A Semantics for Behavior Trees Using CSP with Specification Commands," *Science of Computer Programming*, vol. 76, no. 10, pp. 891 – 914, 2011.
- [5] S. J. Prowell, C. J. Trammell, R. C. Linger, and J. H. Poore, *Cleanroom Software Engineering: Technology and Process*. Boston, MA, USA: Addison-Wesley, 1999.
- [6] P. Lindsay, "Behavior Trees: From Systems Engineering to Software Engineering," in *8th IEEE International Conference on SEFM*. IEEE, 2010, pp. 21–30.
- [7] S.-K. Kim, T. Myers, M.-F. Wendland, and P. A. Lindsay, "Execution of Natural Language Requirements using State Machines Synthesised from Behavior Trees," *JSS*, vol. 85, no. 11, pp. 2652 – 2664, 2012.
- [8] T. Myers, "The Foundations for a Scaleable Methodology for Systems Design," PhD Thesis, School of ICT, Griffith University, Australia, 2011.
- [9] K. Ahmed, T. Myers, L. Wen, and A. Sattar, "Detecting Requirements Defects Utilizing A Mathematical Framework for Behavior Engineering," *JSCSE, Advanced Academic Publisher*, vol. 3, no. 3, pp. 187–198, 2013.
- [10] K. Ahmed, M. A. H. Newton, L. Wen, and A. Sattar, "Formalisation of the Integration of Behavior Trees," in *29th International Conference on Automated Software Engineering (ASE)*, Sep. 2014.
- [11] P. Lindsay, N. Yatapanage, and K. Winter, "Cut Set Analysis Using Behavior Trees and Model Checking," *Formal Aspects of Computing*, vol. 24, pp. 249–266.
- [12] T. Myers, R. G. Dromey, and P. Fritzson, "Comodeling: From Requirements to An Integrated Software/Hardware Model," *IEEE Computer*, vol. 44, no. 4, pp. 62 –70, April 2011.
- [13] D. Billington, "Propositional Clausal Defeasible Logic," *Logics in Artificial Intelligence, Lecture Notes in Computer Science*, vol. 5293, pp. 34–47, 2008.
- [14] D. Billington and A. Rock, "Propositional Plausible Logic: Introduction and Implementation," *Studia Logica*, vol. 67, no. 2, pp. 243–269, 2001.
- [15] D. Billington, V. Estivill-Castro, R. Hexel, and A. Rock, "Non-Monotonic Reasoning for RE: State Diagrams driven by Plausible Logic," *5th ENASE*, pp. 68–77, 2010.
- [16] L. W. Chan, R. Hexel, and L. Wen, "Rule-based behaviour engineering: Integrated, intuitive formal rule modelling," in *22nd ASWEC*, June 2013, pp. 20–29.
- [17] O. Rest, G. Wachsmuth, J. Steel, J. S., and E. Visser, in *Theory and Practice of Model Transformations*, ser. LNCS, K. Duddy and G. Kappel, Eds., 2013, vol. 7909.
- [18] T. Myers, "TextBE: A Textual Editor for Behavior Engineering," *3rd Improving Systems and Software Engineering Conference (ISSEC)*, 2–5 August 2011.
- [19] D. Kung, J. Gao, P. Hsia, F. Wen, Y. Toyoshima, and C. Chen, "Change Impact Identification in OO Software Maintenance," in *ICSM*, 1994, pp. 202–211.
- [20] L. Briand, Y. Labiche, and L. O'Sullivan, "Impact Analysis and Change Management of UML Models," in *ICSM*, sept. 2003, pp. 256 – 265.
- [21] L. Briand, Y. Labiche, L. OSullivan, and M. Swka, "Automated Impact Analysis of UML Models," *Journal of Systems and Software*, vol. 79, no. 3, pp. 339 – 352, 2006.
- [22] M. Chaudron, W. Heijstek, and A. Nugroho, "How Effective is UML Modeling?" *SoSyM*, vol. 11, pp. 571–580, 2012. [Online]. Available: <http://dx.doi.org/10.1007/s10270-012-0278-4>
- [23] R. G. Dromey and D. Powell, "Early Requirement Defect Detection," *TickIT Journal*, pp. 3–13, 2005.
- [24] A. Göknil, I. Kurtev, K. van den Berg, and J.-W. Veldhuis, "Semantics of Trace Relations in Requirements Models for Consistency Checking and Inference," *SoSyM*, vol. 10, pp. 31–54, 2011, 10.1007/s10270-009-0142-3.
- [25] L. Wen and R. G. Dromey, "From Requirements Change to Design Change: A Formal Path," in *IEEE International Conference on SEFM, Beijing*, 2004.
- [26] B. Ellis, "Rational Belief Systems," *Rowman and Littlefield*, vol. 23, no. 1, pp. 109–114, 1979.
- [27] J. Doyle, "A Truth Maintenance System," *AI*, vol. 12, no. 3, pp. 231–272, 1979.