Modeling and Application of Requirements Engineering Process Metamodel

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***Abstract*—With deeper researches on requirements engineering (RE), the researchers gradually realize that the requirements engineering processes are very complex and the related technologies are in a great variety. Thus, in order to analyze and compare different types of requirements engineering processes more deeply, a simple, clear, unified description method of requirements engineering process is needed. In this paper, the requirements engineering process itself is taken as the research object and a formal description method of requirements engineering process, Requirements Engineering Process Metamodel (REPM), is proposed. The REPM is a simple and unified method for describing different types of processes, in which different RE tools are applied. In this paper, the formal definition of REPM is given, and three typical requirements engineering processes are also described and analyzed using REPM. Furthermore, a new integrated RE process is defined using REPM as well.**

Keywords-requirements engineering; metamodel; modeling

I. INTRODUCTION

From 1990's, Requirements Engineering (RE) [1-4] has been one of hot topics of researches. With deeper researches on requirements engineering, the researchers gradually realize that the requirements engineering processes are very complex and the related technologies are in a great variety. Thus, a simple, clear and unified method which can describe all kinds of RE processes is needed, so as to analyze and compare the advantages and disadvantages of different types of RE processes more deeply.

RE is a process that has continuously repeated requirement definition, record and development, and get to the confirmed requirements in the end [4]. From the angle of its process, RE mainly has three types [5]:

(1) Top Down: start from the target and task of destination system, collect related information and materials abundantly, classify and decompose them gradually, until form an destination system specification which can be accepted by users and can support development of the system;

(2) Middle Out: start from the specific domain knowledge[6] of destination system, base features of the destination system, on one hand clarify the user' requirements, on the other hand make out functional and unfunctional requirements of the destination system;

(3) Bottom Up: that is using the methodology of reverse engineering [7] in RE processes, comprehensively analyze whether the existed systems can satisfy the users' requirement, and whether the specification of the existed systems can be used for the development of destination system?

Additionally, in RE processes, usually the technologies, methods and tools proved to be effective are applied to do activates of the requirement elicitation, analysis, description, validation and management, etc., and finally form requirement documents. As shown in Fig. 1, there are plenty of technologies, methods and tools which are related to RE. At the same time, where and how are these RE methods applied, as well as how to match them each other, make the modes of RE more complicated.

This paper takes the RE process itself as the research object and proposes a formal description method of RE process, Requirements Engineering Process Metamodel (REPM). The REPM is a simple and unified method for describing different types of processes, in which different RE tools are applied. In section 2, the formal definition of REPM is defined; in section 3, REPM is used for describing and comparing three typical RE processes, and a new integrated RE process is defined using REPM as well. Section 4 is the conclusion and research work which is needed go further.

II. DEFINITION

Definition 1: the set of RE activity types is STYPE = {*ELICITATION*, *ANALYSIS*, *DESCRIPTION*, *EVALUATION*, *VALIDATION*, *MANAGEMENT*, …}. The STYPE includes all the types of engineering activities used in RE processes. For example, *ELICITATION* stands for requirement elicitation; *ANALYSIS* stands for requirement analysis; *DESCRIPTION* stands for requirement description; *EVALUATION* stands for requirement evaluation; *VALIDATION* stands for requirement validation; *MANAGEMENT* stands for requirement management. With the development of requirements engineering, numbers of the engineering activity types used in RE process may increase.

Definition 2: the set of RE tool types is *TTYPE* = {*ttype*| *ttype* is a technology or method or tool applied in a specific RE

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activity which is proved to be effective}. With the development of RE, the proved to be effective RE technologies, methods and tools will increase continuously. Fig. 1 shows partly the RE technologies and tools.

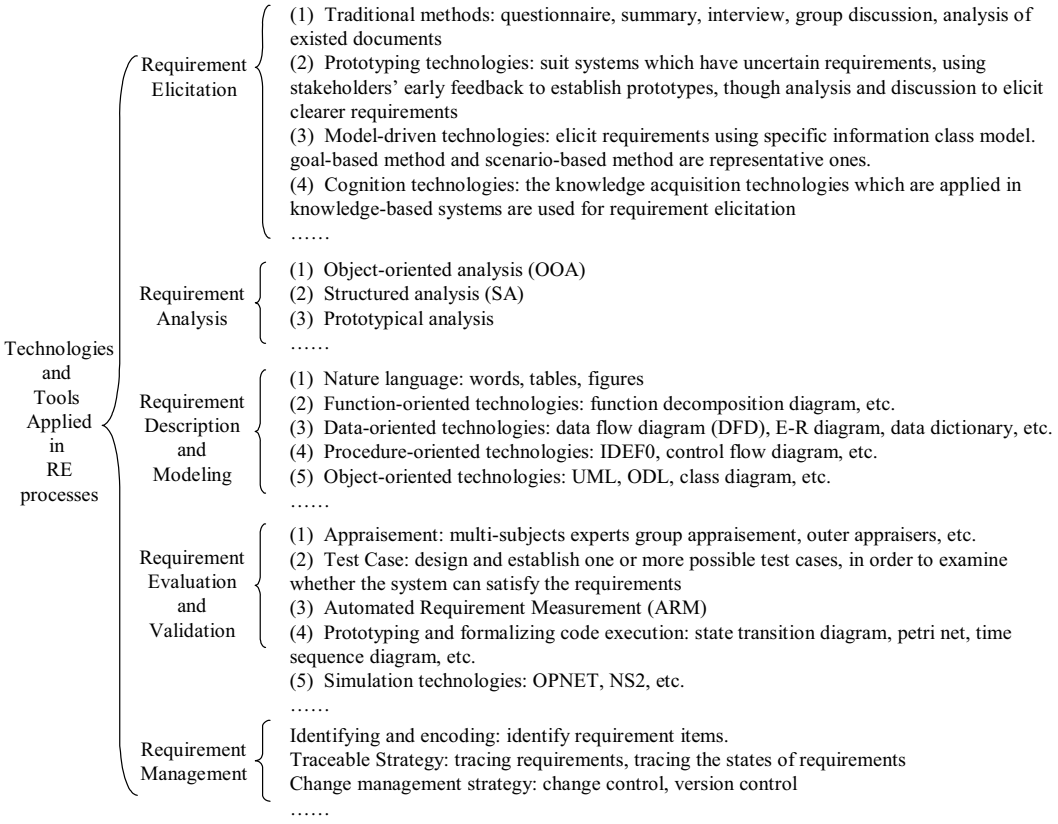

Figure 1. Technologies and tools applied in RE processes

Definition 3: the set of RE information types is $ITYPE$ = {*itype*| *itype* is an information or data pattern used in a specific RE activity}. The typical RE information patterns include: system target and task, domain knowledge and model, stakeholders' viewpoint, operation environment, organization environment, requirement draft, system definition, system functional requirement, system unfunctional requirement, system model, system architecture, system specification, system requirement document, and so on. The RE information patterns can be also added with adjuncts such as "informal", "semiformal" or "formal".

Definition 4: a RE process can be formally defined as a vector $REP = <S, E, T, I, TR, IR>$. Node set $S \subset STYPE$, is the set of the stages in the RE process; Direct edge set $E \subset S \times S$, is the set of stage-connecting relationships in the RE process; direct edge$<s_1, s_2> \in E$, stands for pointing from $s_1 \in S$ to $s_2 \in S$, representing the output of stage s_1 is the input of stage s_2; $T \subset TTYPE$ stands for the set of the proved to be effective technologies, methods and tools used in the RE process. $I \subset ITYPE$ stands for the set of information or data patterns used in the RE process. TR is a tool-applying relationship function, noted as TR: $T \to 2^S$, $TR(t)=\{s|\ s \in S \wedge t$ is applied in stage $s\}$, 2^S is the power set [8] of S (the set of all sunsets of S); IR is an information-using relationship function, noted as IR: $I \to 2^{S \cup E}$, $IR(i)=\{se|\ (se \in S \wedge i$ is an input/output information or data pattern corresponding to $se)\} \vee (se \in E \wedge i$ is an input/output information or data pattern corresponding to $se)\}$, $2^{S \cup E}$ is the power set of $S \cup E$ (the set of all sunsets of $S \cup E$).

Definition 5: a RE process model $REP = <S, E, T, I, TR, IR>$ can be is illustrated as a direct graph; $s \in S$ is represented with a rectangle (with caption inside); $e \in E$ is represented with a solid-dash arrow; $t \in T$ is represented with a triangle (with caption inside); $i \in I$ is represented with a ellipse (with caption inside); TR is represented with a dots-and-dashes arrow; IR is represented with a dotted-dash arrow.

Definition 6: given a RE process $REP = <S, E, T, I, TR, IR>$, $s \subset S$, s is called as the starting point of the RE process, if and only if: $\{<s', s>|<s', s> \in E \wedge s' \in S\}$ is empty. The starting point of RE process is represented with a big solid dot in the RE process model graph.

Definition 7: given a RE process $REP = <S, E, T, I, TR, IR>$, $S'' \subset S$, $REP' = <S', E', T', I', TR', IR'>$ is called as the subprocess of REP about S'', if and only if: $S' = S''$, $E' = \{<s_1,s_2>|<s_1,s_2> \in E \wedge (s_1 \in S'' \vee s_2 \in S'')\}$, $T' = \{t|\ TR(t) \in S''\}$, $I' = \{i|\ IR(i) \in S'' \cup E'\}$, $TR' : T' \to 2^{S'}$, $TR'(t') = TR(t')$, $IR' : I' \to 2^{S' \cup E'}$, $IR'(i') = IR(i')$.

Definition 8: given a RE process *REP* = <*S*, *E*, *T*, *I*, *TR*, *IR*>, $s \subset S$, *REPSDG* is the subprocess of REP about {*s*}, *REPSDG* is called as the stage description graph of *s*.

III. DESCRIPTION AND ANALYSIS OF RE PROCESSES

A. Formal Description using REPM

Fig. 2 is the Top-Down RE process description graph using REPM.

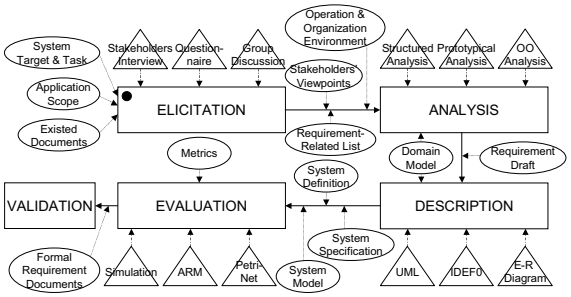

Figure 2. Top-Down RE process model

Fig. 3 is the Middle-Out RE process description graph using REPM.

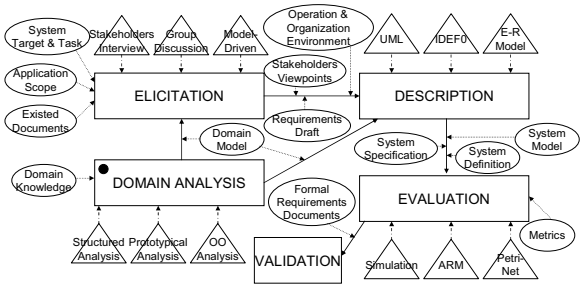

Figure 3. Middle-Out RE process model

Fig. 4 is the Bottom-Up RE process description graph using REPM.

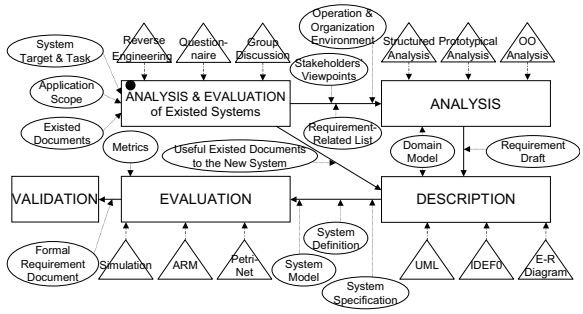

Figure 4. Bottom-Up RE process model

B. Analysis and Comparison

Based on formal modeling of the above three typical RE processes using REPM, though analysis and comparison, the points can be summed up as the following:

(1) The starting points of the three processes show respectively that: (a) Top-Down: its starting point is "*ELICITATION*", from the stakeholders' viewpoints, through gradual decomposition, modeling and evaluation, finally form system requirement documents; (b) Middle-Out: its starting point is "*DOMAIN ANALYSIS*", establish domain knowledge and model of the destination system, use model-driven method to elicit and describe requirements, finally evaluate and form system requirement documents; (c) Bottom-Up: the starting points is "*ANALYSIS & EVALUATION of Existed Systems*", through the analysis and comparison, fully inherit the existed achievements, furthermore, through analyzing, describing and evaluating requirements of the destination system, form system requirement documents in the end.

(2) The above three typical RE processes have their own advantages respectively: (a) the Top-Down process is most straightforward and has wide suitability; (b) the Middle-Out process suits for the systems with abundant domain research achievements very much, such as C4ISR system, financial system and so on; (c) the Bottom-Up process suits for transplanting, extending, improving and upgrading existed systems.

(3) If there are same stage description graphs existed in different RE processes, even the stage captions may be different, the same engineering activities can be illustrated to be existed in different RE processes. The stage description graphs of "*EVALUATION*" and "*VLIDATION*" are the same in the above three RE process description graphs. The stage description graphs of "*ANALYSIS*" are the same in the Top-Down RE process description graph and the Bottom-Up RE process description graph

(4) Even the stage captions are the same, but the stage description graphs are different in their own RE process, which means they are different engineering activities. In the above Top-Down and Middle-Out RE processes, the two "*ELICITATION*" stage description graphs are different. They use different requirement elicitation methods.

C. A New Integrated RE Process

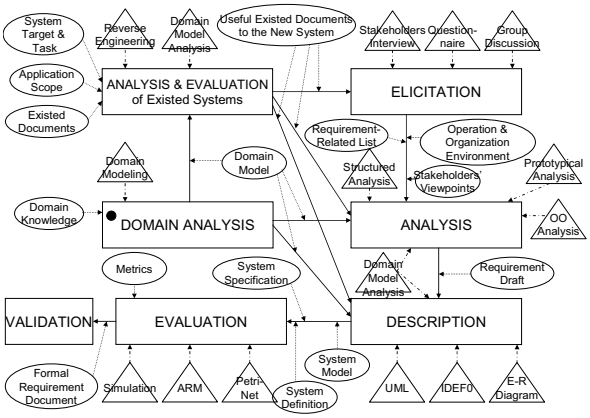

Figure 5. A new integrated RE process model

Through analysis and comparison, we can further realize that: the three typical RE processes can be used as an integration in practically. A new integrated RE process is defined using REPM in the Fig. 5.

IV. CONCLUSIONS AND FUTURE WORK

This paper takes the requirements engineering process itself as the research object and proposes a formal description method of requirements engineering process, Requirements Engineering Process Metamodel (REPM). The formal definition of REPM is given, and three typical requirements engineering processes (Top-Down, Middle-Out and Bottom-up) are also described and analyzed using REPM in the paper. Furthermore, a new integrated RE process is defined using REPM as well. The REPM is a simple and unified method for describing different types of processes, in which different RE tools are applied. Based on REPM, the advantages and disadvantages of different types of RE processes can be analyzed and compared more deeply.

Our future work includes: design of ASN.1-based [9] or XML-based REPM description syntax, research on RE process maturity model [2,10] based on REPM. The REPM description syntax is used for recording and storing RE process models as text files in a formal language. The REPM-based RE process maturity model is an evaluation method of RE process. REPM should make the evaluation easier and more precise.

REFERENCES

[1] I. Sommerville and P. Sawyer (writer), W. Y. Zhao Wenyun and E.Ye (translator), Requirements Engineering: A Good Practice Guide, Beijing: China Machine Press, 2003.

[2] A. Abran, J. W. Moore, P. Bourque, R. Dupuis, and L. L. Tripp, Guide to the Software Engineering Body of Knowledge, SWEBOK project of the IEEE Computer Society Professional Practices Committee, 2004.

[3] D. G. Firesmith, (2006). "Requirements Engineering Tasks," Journal of Object Technology, vol.5, no.8, pp.21-29, November-December 2006.

[4] M. S. Li and Q. Wang, "Status Guo of Researches on Requirements Engineering," http://www.boxuege.com/a001/015/0000007339.html, 2006.

[5] S. H. Dam, Generating C4ISR Architecture Products Using Systems Engineering Processes, Systems and Proposal Engineering Company, 2002.

[6] Z. K. Lin and D. L. Yang, "Overview of domain analysis methods," Journal of Computer Engineering and Design, vol.27, no.4, pp.593-596, 2006.

[7] L. P. Zhou and P. Chen, "Research on development of reverse engineering," Journal of Computer Engineering and Design, vol.25, no.10, pp.1658-1660, 2004.

[8] Y. Y. Wang and S. F. Li, Discrete Mathematics, Beijing: Science Press, 1994.

[9] X. R. Xie, Computer Network, Dalian: Dalian University of Technology Press, 1996.

[10] J. Raynus (writer), Z. P. Qiu (translator), Software Process Improvement with CMM, Beijing: Publishing House of Electronic Industry, 2002.