An Evaluation of Requirements Management and Traceability Tools

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Abstract—Requirements management is critical to software delivery success and project lifecycle. Requirements management and their traceability provide assistance for many software engineering activities like impact analysis, coverage analysis, requirements validation and regression testing. In addition requirements traceability is the recognized component of many software process improvement initiatives. Requirements traceability also helps to control and manage evolution of a software system. This paper aims to provide an evaluation of current requirements management and traceability tools. Management and test managers require an appropriate tool for the software under test. We hope, evaluation identified here will help to select the efficient and effective tool.

Keywords—Requirements Traceability, Requirements Traceability Tools; Requirements Management, Requirement Engineering

I. INTRODUCTION

REQUIREMENT engineering involves the activities for discovering, documenting and maintaining a set of requirements for a computer-based system [1]. "Requirements engineering is the branch of software engineering concerned with the real-world goals for, functions of, and constraints on software systems. It is also concerned with the relationship of these factors to precise specifications of software behavior, and to their evolution over time and across software families. [18] Requirement engineering activities are often divided into five categories. These categories include requirement elicitation, requirement analysis, requirement specification, requirement validation and requirement management [1,2]. According to Gorschek [3] documentation, change management and traceability are the key activities of requirement management. One of the main tasks of requirement management is to assure requirements traceability from start through the system evolution and maintenance. In addition to this traceability is desired in a system where changes occur so frequently. Requirements management and traceability tools can be helpful in an environment with constantly changing requirements, where the effects of these CHANGES must propagate to all other artifacts in the system, without breaking it. Traceability is also recommended as a

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necessary activity by various standards such as IEEE Std. 830-1998 and CMMI. According to Easterbrook & Nuseibeh [14], requirements traceability lies at the heart of requirements management. In recent years, computer industry has grown beyond the expectations of everyone with very technical and diversified software. Vendors and operators have to work hard with the highest efficiency and effectiveness in this age of competition. Requirements management and traceability tools helps to achieve this goal. As there are different tools suitable for different systems and industry, we are focusing on tools that support requirements management and trace requirements links between different artifacts.

The rest of this paper is organized as follows. Section II describes the overview of requirements management and traceability. Section III reports the tools for requirements management and traceability. Section IV provides evaluation of the tools based on a set of criteria. Threats to validity are discussed in section V. Finally section VI presents an analysis table and concludes this paper.

II. REQUIREMENTS MANAGEMENT AND TRACEABILITY

Managing the different levels, types and attributes of requirements throughout the software life cycle is called requirements management. Hoffmann et al. [19] define requirements management as the structuring and administration of information from elicitation, derivation, analysis, coordination, versioning and tracking of requirements during the complete product lifecycle. Requirements management tools are developed to create, retrieve, update and remove requirements and everything related like relations, reference documents, etc with these.

Requirements traceability is concerned with documenting the life of a requirement and to provide bi-directional traceability between various associated requirements. It enables users to find the origin of each requirement and track every change which was made to this requirement.[15]. According to Gotel & Finkelstein [16] requirements traceability is —the ability to describe and follow the life of a requirement in both forwards and backwards direction (i.e., from its origins, through its development and specification to its, subsequent deployment and use, and through periods of on-going refinement and iteration in any of these phases)". Another researcher [17] defines requirements tracing as, "Requirements tracing is concerned with recovering the source of requirements and predicting the effects of requirements". Requirement Traceability tools enable the engineer to link requirements to their source, to changes in requirements, and to modeling elements that satisfy the requirements. They provide traceability among the successive documents that are used to review the system development.

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:5, No:6, 2011

III. REQUIREMENTS TOOLS

This section presents state-of-art requirements management and traceability tools that create, retrieve, update and remove requirements and link requirements to their source. There are many requirements management and traceability tools that are available in literature and on the internet, commercially or lab version. Following are some of these tools.

A. Doors

DOORS is a requirements management tool developed initially by Telelogic. It has been acquired by IBM Rational in 2008. IBM® Rational® DOORS® help to reduce costs, increase efficiency and improve quality by enabling you to optimize requirements communication, collaboration and verification [4]. It provides easy ways to create and traverse the links between different requirements. DOORS supports change management and manage changes to requirements with either a simple pre-defined change proposal system or a more thorough, customizable change control workflow through integration to Rational's change management solutions. It supports Unix Solaris and Windows operating systems.

B. Rational RequisitePro

Rational RequisitePro is also a requirements management tool developed by IBM. It helps project teams to manage their requirements, to write good use cases, to improve traceability, to strengthen collaboration, to reduce project rework, and to increase quality [5]. It supports Microsoft Word for requirement authoring and communication; complements document-based entry with a commercial database to add organization, tracking and management capabilities. It also supports requirements traceability and impact analysis and currently in use in industry.

C. Retro

REquirements TRacing On-target (RETRO) [6] is a requirements traceability tool. It uses information retrieval (IR) methods for requirements tracing. It has ability to assess an existing Requirements Traceability Matrix (RTM) and also an enhanced functionality for filtering the display of candidate links. The case study results revealed that RETRO produced more accurate results than tracing requirements manually.

D. Tram

TRAM [7] is a tool for managing system requirements, system architectures and the traceability between them. This tool is equipped with a set of document templates, to provide practical guidance to the user. The document templates are based on an information model for capturing system requirements, system architectures and their traceability. All together, the information model, the document templates and the tool itself provide a practical project start-up kit for requirements and architecture management.

E. DesignTrack

DesignTrack [8] is a requirements traceability tool. It is a prototype tool providing an integrated design environment for requirement specification and form exploration in the same design session. DesignTrack provides a navigation environment for complex design information spaces via enabling requirement traceability. It evaluates the applicability, power, and drawbacks of requirement traceability enabled computer-aided design. This tool can also be used to to manage issues of design requirements.

F. Cradle

Cradle is an acclaimed Requirements Capture, Requirements Management and Systems Engineering tool that delivers stable Requirements Management [9]. It delivers outstanding improvements in interoperability, management and cost savings. Cradle assist in maximizing control, efficiency, traceability, security, usability and durability of projects.

G. XTie-RT

XTie-RT [10] is a powerful requirements management and analysis tool used to manage critical programs. It is particularly applicable in all aspects of systems engineering and project management. XTie-RT ensures product quality and integrity by managing the requirements and enforcing the traceability of requirements throughout a systems development life-cycle. It can manage the programs in the areas such as Proposal Management, Requirements Capture, Requirements Organization, Requirements Traceability, Quality Assurance, Risk Analysis and Requirements.

H. DevCpmplete

DevComplete [11] is developed by SmartBear software. It provides full traceability among requirements tracking, project tasks, and defects to improve team agility. With a clear and understandable map showing project tasks, defects, and requirements, it can implement workflow to lock requirements from change once approved and base-lined. DevComplete allow freedom to make requirement changes based on the demands of the moment. This tool can also find the impact of adding software requirements.

I. SLATE

SLATE (System Level Automation Tool for Engineers) is computer-aided engineering tool for system designers. SLATE [12] accelerates the design process by managing the entire design life cycle, from pre-proposal and proposal through implementation. Its life cycle management functions include facilitating the major design tasks such as design capture, decomposition, partitioning, performance allocation and analysis, verification and simulation, requirement capture and tracking, document generation as well as supporting multiple design objectives required for a successful product. It uses MATLAB to evaluate all aspects of each design.

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:5, No:6, 2011

J. *SAT*

Scenario Advisor Tool (SAT) is built to help requirements engineers to generate sufficient sets of scenarios in the domain of socio-technical systems [13]. Scenarios act as mediators between requirements engineers and software artifacts like software requirement specification, design document. This tool provides traceability between scenario models and requirements and helps to generate new scenarios and scenario variations.

K. *CaliberRM*

CaliberRM is the requirements management tool by Borland. It is designed to capture and manage business, technical, functional, and operational requirements. CaliberRM enables stakeholders across the organization to collaborate effectively so that projects are delivered on time, within budget, and to specification [20]. The tool maintains traceability information between various requirements and also between artifacts in other tools. It also offers a number of ways to keep an overview of all requirements and it combines these features to analyze the impact of change proposals. CaliberRM keeps a record of all changes to both artifacts and the links between them, so it is possible to go back in time to see what changes have been made previously to the requirements.

L. *TopTeam Analyst*

TopTeam is a complete solution for Requirements gathering and management [21]. It also supports use cases and test cases to support the requirements specification process. It has a powerful repository for all requirements artifacts such as Screen Prototypes, Documents, etc. it creates and visualize traces to system elements using four different interfaces. TopTeam supports different ways to import requirements into the tool.

M. *ReMa*

Requirements Manager (ReMa) [22] is a systematic and powerful tool, which helps the project managers to track requirements and manage them through the entire software life cycle. It stores the requirements in separate documents termed as modules, and can also present the same module in different visuals. It keeps track of all the changes made on a requirement. ReMa import requirements from MS Word, RTF, Text and DOORS.

IV. EVALUATION OF THE TOOLS

This section describes a comparative evaluation of various requirements management and traceability tools. We have excluded some tools because they look like dead and there is no activity in these for many years. The evaluation criteria consist of tools category, functionality and empirical evidence.

A. *Tools Category*

Requirements tools can be classified into three categories; requirements management tools with traceability support (RMT), requirements traceability tools (RTT) and others.

RMT are tools that support requirements management but also facilitate traceability. RTT are meant purely for requirements traceability. Table I shows a list of the tools with their category.

TABLE I
. TOOLS WITH CATEGORIES

Tools	Categories		
	RMT	RTT	Others
DOORS	✓		
Rational RequisitePro	✓		
RETRO		✓	
TRAM		✓	
Cradle			✓
XTie-RT	✓		
DevComplete		✓	
SLATE			✓
CaliberRM	✓		
TopTeam Analyst	✓		
ReMa	✓		

B. *Functionalities*

Different tools have different features and functions. We are using two tables to describe their functionalities like automatic link detection, automatic link creation and change, coverage analysis support, documentation support, graphical representation and tools integration. All the functionalities are described briefly in following.

Automatic link detection: This functionality describes that the tool should be able to automatically detect relations between artifacts through for example information retrieval techniques, monitoring of change history, naming schemas or model transformations.

Automatic link creation and change: It means that the tool must be able to enforce the creation and change of certain traceability links. If a requirement is altered, traceability information may remain consistent.

Coverage analysis support: This property explains that the tool must be able to produce an overview of the artifacts that have no traces to previous or subsequent artifacts.

Documentation support: The tool needs to be able to read and import requirements from requirement specification documents created outside the tool. At the same time, it needs to support the creation of documents describing the requirements in the tool.

Graphical representation: It is user-friendly representation of traces in graphical form. The traces can be shown using matrices, trees or graphs, so the information can always be shown in an appropriate form which is more understandable.

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
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Tools integration: It is the property that every tool needs to be able to interface with other tools in the product life cycle to make information stored in them visible and linkable.

C. Empirical Evidence

All the tools except DesignTrack have been evaluated empirically. Some tools are being used in industry for a long time such as DOORS and Rational RequisitePro. Cradle, XTie-RT and DevComplete are also available commercially. RETRO and TRAM used case studies in articles. Scenario advisor tool conducted an experiment in the lab to prove its results. Graphical User Interface (GUI) and reporting is also an important feature for comparing the tools. Some tools have both GUI and batch mode version to fulfill the needs of different users. Most of the tools especially commercially developed, produce automatic summary reports. Table II and Table III describes each tool's functionality.

Tools			
XTie-RT	✓		
DevComplete	✓		
SLATE	✓		
CaliberRM	✓	✓	✓
TopTeam Analyst	✓	✓	
ReMa	✓	✓	✓

TABLE II
TOOLS FUNCTIONALITIES (A)

Tools	Automatic Link Detection	Automatic Link creation/change	Coverage Analysis Support
DOORS	✓	✓	✓
Rational RequisitePro			✓
RETRO		✓	
TRAM		✓	
Cradle		✓	✓
XTie-RT		✓	
DevComplete		✓	
SLATE		✓	
CaliberRM			✓
TopTeamAnalyst		✓	✓
ReMa		✓	

TABLE III
TOOLS FUNCTIONALITIES (B)

Tools	Documentation Support	Graphical Representation	Tools Integration
DOORS	✓	✓	✓
Rational RequisitePro	✓	✓	✓
RETRO	✓		
TRAM	✓		
Cradle	✓		✓

V. THREATS TO VALIDITY

We have collected all the information about requirements management and traceability tools from websites and literature. We have focused on the tools that are most commonly used. There is a possibility that some papers and websites may be missed causing exclusion of some tools or properties of included tools.

VI. CONCLUSION

This paper evaluated eleven requirements management and traceability tools. We have compared some of their features including tools category, different functionalities of tools and their empirical evidence. We believe, these are the best criteria to test the requirements management and traceability tools.

Table IV summarizes our analysis. It looks that requirements management tools are more popular and used instead of purely traceability tools. Each tool has some strong and weak points. But none of them supports automated link detection clearly. Some have limited semi-automated support or good for manual creation. No tool fully supports automated link detection of requirements and still needs a lot of manual work. There is a need to do more research in this direction. However, DOORS supports most criteria and has the best basis for a requirement management tool. Users and developers can select the tool according to their need. We hope our work will help in more usage and selection of the tools.

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:5, No:6, 2011

TABLE IV
ANALYSIS

TOOL	CATEGORY			FUNCTIONALITIES						EMPIRICAL EVIDENCE
	RMT	RTT	OTHER	AUTOMATIC LINK DETECTION	AUTOMATIC LINK CREATION / CHANGE	COVERAGE ANALYSIS SUPPORT	DOCUMENTATION SUPPORT	GRAPHICAL REPRESENTATION	TOOLS INTEGRATION	
DOORS	✓			✓	✓	✓	✓	✓	✓	In industry
Rational Requisite Pro	✓					✓	✓	✓	✓	In industry
RETRO		✓			✓		✓			Case study
TRAM		✓			✓		✓			Case study
Cradle			✓		✓	✓	✓		✓	Commercial
XTie-RT	✓				✓		✓			Commercial
DevComplete		✓			✓		✓			Commercial
SLATE			✓		✓		✓			Commercial
CaliberRM	✓					✓	✓	✓	✓	Commercial
TopTeam Analyst	✓				✓	✓	✓	✓		Commercial
ReMa	✓				✓		✓	✓	✓	Commercial

World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:5, No:6, 2011

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