ONTOLOGY-DRIVEN FMEA METHOD

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ABSTRACT:
This article aims to put a basis for improvement of FMEA (Failure Mode and Effects Analysis) method using an Ontology-Driven approach. The main ideas of such improvement are introduced and described. Next, particular phases of ontology employment for development of more exact approach to FMEA method are determined. Farther, selected ontology editor tools, suitable for our objective, are introduced. Furthermore, hereinafter described approach is exploited in research projects applying an Ontology-Driven FMEA method in the area of software project management. Finally, the outputs of this research are also included in the university courses of Software Project Management and Architecture of Software Systems provided by the Faculty of Electronic Engineering.

KEYWORDS:
FMEA, quality management, model based, ontology-driven, domain ontology, applied ontology, process modelling

INTRODUCTION

A Failure Mode And Effect Analysis (FMEA, [1]) is an engineering method used to define, identify and eliminate known/or potential defects, failures, problems, errors, etc., incurred in the system, design, process or service before they reach a customer or an user. It is the method to maximize the satisfaction of the customer or the user by eliminating and/or reducing known or potential problems. To do this, the FMEA method must begin as early as possible

The FMEA is the most widely performed technique in an initial phase of system development especially during a conceptual design stage of that in order to assure that all possible failure modes have been considered and that proper provision has been made to eliminate all the potential failures.

This article focuses on one special problem of the FMEA method, namely, the problem how to recognize preferably all potential defects, failures or errors of the system, design, product or service. A convention FMEA method guidelines or instruction manuals usually deal above all with the method how to accurately calculate values of RPN (Risk Priority Number, explanation see below in the next section) but unfortunately say very little of the method how all potential defects can be discovered at all. The Author claims that the most important part of the FMEA method is that that is concerned exactly with the way of identification of all potential defects before they can ever come into being, especially in the case of complete new product that was not made never before. Such method of identification must be based only on the logical model of the system comprehensive of reason-effect knowledge base of the target domain. The work of the Author, herein presented, makes effort to build such method on the basis of an ontology-driven modelling approach.

The rest of this paper is organized as follows. Next, in Section 2, we start off by description of traditional FMEA method performance. Section 3 introduces the studied problem statement we make effort to resolve. After that, Section 4 gives the account of our approach and results

we have attained, and finally, Section 5 summarizes the paper, points out the up-to-date status of the work, and eventually, suggests and discusses future directions for research.

TRADITIONAL FMEA METHOD

The FMEA method can be used in many areas or phases of product or service development and operation as well. Traditionally are defined four basic FMEA application areas, namely System, Design, Process, and Service, as described in the following. Nevertheless must be note that FMEA method can be used in other application areas as well and present-day trend lies in a dissemination of the method to all kinds of application areas as possible.

- System FMEA – (called also a concept FMEA) is used to analyse a system or subsystem in an early phase of conceptual design of the system. It focuses on failure modes caused by functional (i.e., function requirements) deficiencies.
- Design FMEA – (called also a product FMEA) is used to analyse products before they are released to manufacturing. It focuses on failure modes caused by design deficiency.
- Process FMEA – is used to analyse manufacturing and assembly processes. It focuses on failure modes caused by process or assembly deficiencies.
- Service FMEA – is used to analyse services before they reach the customer. It focuses on failure modes caused by service deficiencies.

But FMEA method can be targeted or customized do many other areas of enterprise [2] as follows:

- Software FMEA – is used to analyse a software system or subsystem in an early phase of design of the system. It focuses on failure modes caused by functional (i.e., function requirements) deficiencies.
- Hardware FMEA – is a specialisation of Design / Product FMEA used to analyse hardware products before they are released to manufacturing. It focuses on failure modes caused by design deficiency.
- Acquisition FMEA – is a specialisation of Service FMEA used to analyse acquisition services before they reach the customer. It focuses on failure modes caused by service deficiencies.

As [2] states, the software FMEA is a special type of product FMEA. The most important phase of analysis process is partitioning of the whole product to small independent components or modules. In contrast with hardware products the partitioning process depends mostly on software developer intention and not on a nature of given physical components.

As a tool, for an architectural description of software systems, is possible to use many different diagrammatical tools. The usage of well-know UML is not favourable, because an employment of UML for architectural description is criticised by many authors, see [3]. There are software tools more suitable to this goal, namely ArchiMate [4] and ARIS [5].

The FMEA method is initiated when a new system, design, product, process or service is arisen or is going through the process of innovation or improvement. The classical process steps of the FMEA method execution are as follows.

1. Initiation of FMEA process.
   1.1. Process review and constitution of the FMEA team.
2. Brainstorming and potential failure modes discovering.
   2.1. List potential effects of each failure mode.

3. Calculate the risk priority and criticality number for each failure mode.
   3.1. Assigning severity, occurrence and detection ratings.
   3.2. Assign a severity rating for each effect.
   3.3. Assign an occurrence rating for each failure mode.
   3.4. Assign a detection rating for each failure mode and/or effect.
   3.5. Prioritize the failure modes for action
4. Take actions to eliminate or reduce the high-risk failure modes
   4.1. Assign the responsible persons for each action in order to eliminate or reduce the high-risk failure modes
   4.2. Recalculate the risk priority and criticality numbers after execution of these actions
5. Asses changes of risk priority and criticality numbers after execution of the actions

The whole process of execution of the tradition FMEA method is briefly depicted in Fig. 1.

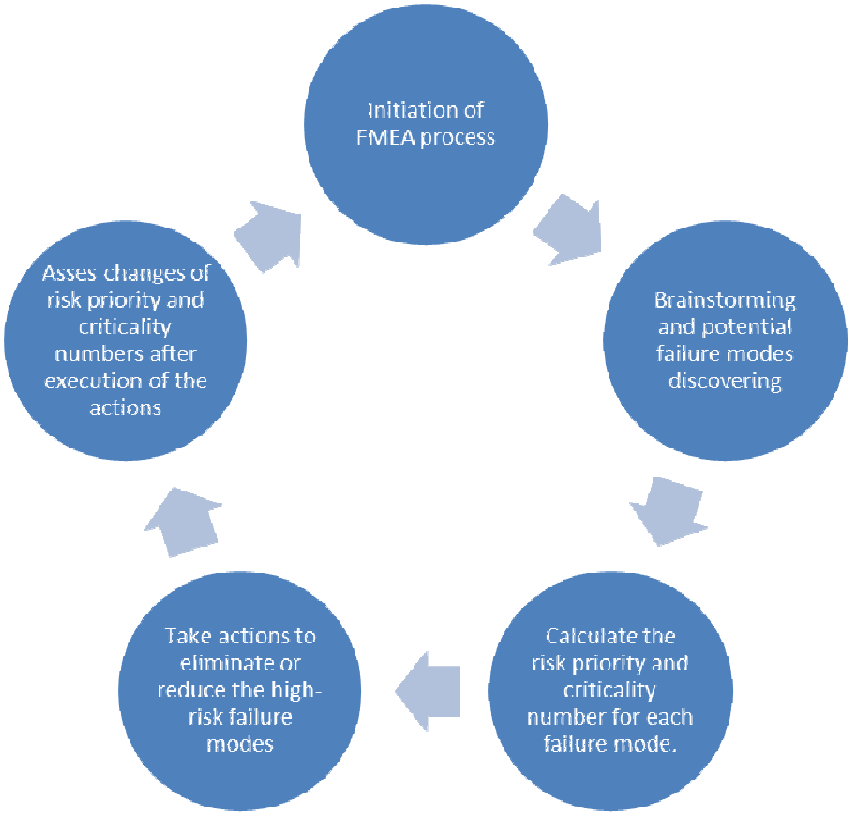

Fig. 1. FMEA Life Cycle

PROBLEM STATEMENT

This article focuses in step number two of above described FMEA life cycle process. There are some very crucial problems we need to resolve.

Firstly, the most important question is how we can discover really all potential failures? By traditional FMEA process this step very depends on an experience of experts participating in brainstorming sessions. Secondly, is it possible to eliminate a strong dependency of results of brainstorming sessions on level of knowledge of the experts? And finally, are there some tools or methods that increase our efficiency of the process and put more precisely our outputs? These are the most important question we must resolve. According to the Author, the

possibility to find out all potential failures is more important than capability to more precisely calculate the RPN and CN numbers. Alternatively say, the non-discovered failures are more hazardous than risk priority number inaccuracy of those that are discovered.

Nowadays, there is one modern approach that is very discussing now and many experts, including the Author, believe in it. It is so-called Model Based FMEA approach [6]. The traditional FMEA approach recommends usage of so-called Block or System Model as a proper tool for increasing an efficiency of the brainstorming process inside the frame (the step two in our description before) of FMEA method. But traditional FMEA approach says regrettably nothing about the model in itself, about the type of that model; moreover, it says nothing about the proper method how to use such model at all. On the contrary, the Model Based FMEA approach specifies more precisely not only this very same model, but also proposes a method how to use just the same model for increasing an efficiency of the process, of potential failures discovery, itself.

OUR APPROACH AND RESULTS

In the frame of model based FMEA approach, it can be used any different types of models. Our approach is based on advanced modelling technique lies in an exploitation of ontological paradigm. Ontology in philosophy is a study of the nature of being, existence or quality in general, as well as, of the basic categories of being and their relationships [7]. In our work we deal with the more specialised kind of ontology, i.e., the informatics ontology (see [8] and [9]). Especially, we are engaged in a creation of so-called domain ontology, concretely, the domain ontology of the FMEA method itself and our approach will be referenced as an Ontology-Driven FMEA method in the following text. Finally, notwithstanding that ontology is a part of philosophy science, for the case of our aim, we are using this more simple definition of it.

> As defined by Wikipedia: "*Ontology is a formal representation of a set of concepts within a domain and the relationships between those concepts. It is used to reason about the properties of that domain, and may be used to define the domain*". [8]

An execution of the FMEA method is very complicated task and therefore it seems to be effective to find some domain ontology, which will formalise it. The goal of this work is a verification of presumption that employment of an ontological approach will help to solve problems mentioned in the previous section. Our advancement will be composed from the following steps.

1. Selection of some PC-based FMEA SW tool, open and free preferably.
2. The FMEA analysis of selected exemplar issue without the use of Ontology-Driven approach.
3. Selection of a PC-based ontology editor suitable for our approach, open and free preferably.
4. A literature study of process, product and defect ontologies.
5. Design of an ontology scheme of selected exemplar issue under inspection.
6. Design of the method to accomplish a suggested Ontology-Driven FMEA method.
7. The employment of just mentioned method on the selected exemplar issue.
8. The comparison and evaluation of results found in steps 2 and 7.
9. The embodiment of this newly developed approach into the courses oriented on quality education at our university, as well as, other dissemination of the results.

As noted in [10] and [11], the ontological approach supports a processing of the FMEA method by two important modes.

- First, it offers a common understanding of the concepts of the domain under our focus and the FMEA procedure ourselves as well.
- Second, the knowledge held in an ontology based model can be effectively computationally processed.

Both these issues support the idea of using an ontological approach for improvement of the FMEA execution. Inspired by [11] we propose the own method performing the ontological driven process FMEA. The right design of the method (the step 6 in previous text) is a key factor of our success. Hence, our proposal, in the case of software process FMEA, is as follows

1. Software product requirement analysis.
2. Functional analysis.
3. Searching for failures.
4. Propagation of discovered failures.
5. Selection and application of failures.

It is clear that conceptual framework of application method is same both for system and for process FMEA. Also, we can note that framework for product FMEA is same as for system FMEA and framework for service FMEA is same as for process FMEA.

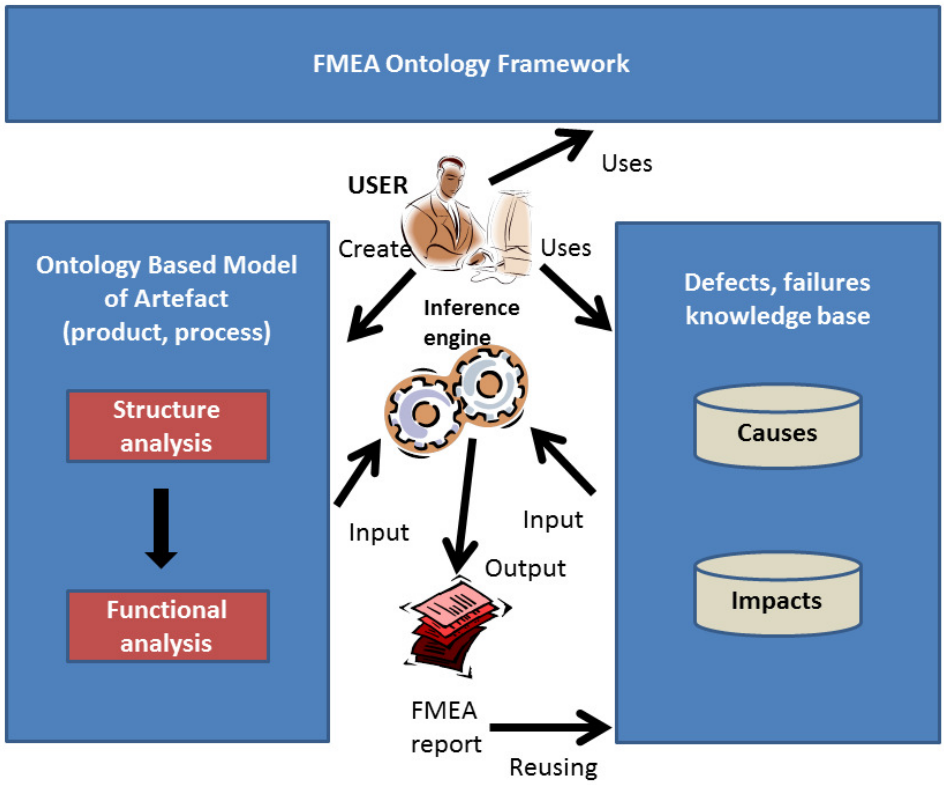

Fig. 2. Ontology-Driven FMEA approach

To summarise this section, the main contribution of ontology driven approach is a clear and consistent graphical description and visual presentation of all FMEA concepts and dependencies. An informal scheme of this approach is intelligible depicted in Fig. 2. In addition, the Ontology-Driven FMEA method performs a synergy effect for analysts and other FMEA stockholders.

Finally, the storage of all FMEA model concepts and dependencies in the form of an ontological model in computerised form allows us to perform a computerized processing, searching and reporting of all facts contained inside a particular FMEA model under processing.

CONCLUSION AND FUTURE WORK

As a practical exemplar issue in order to verify our approach has been chosen the case of complex software development process based on Ambler approach, i.e., Object Oriented Software Process (OOSP). This issue has been chosen on account of already on-going research in this area of the Author.

An ontology editor suitable for our needs has been put under the selection. Three ontology editors have been examined, namely, Protégé [12]. SWOOP [13] and JOE [13]. Despite the fact that Protégé has many useful features and is regard as the most widespread of them, it has been decided that we need continued our searching for more better one or undertake an effort to construct one's own fully satisfying all special demands.

The present state of our work is in the phase of performing steps 1 to 6. A primary ontology scheme of the knowledge of the software development process is under constructing and assessing. As a preliminary proposal of the software ontology, at present, we used EvoOnt (A Software Evolution Ontology) [15] . A fragment from EvoOnt is shown in Fig. 3. Though, it is necessary to note that our work is still at the beginning phase of the whole research project.

In conclusion, according to our opinion mainstreaming of ontology approach in the FMEA procedure is a valuable contribution to the field of quality management in general.

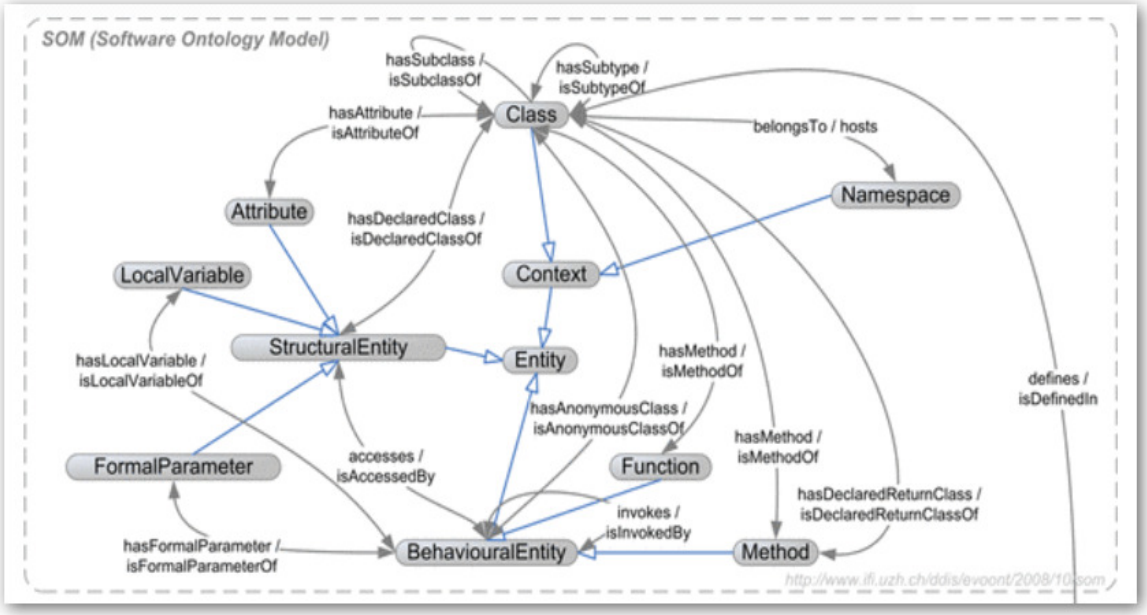

Fig. 3. A proposed SOM (Software Ontology Model)

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