Task-oriented requirements management by application of information agents

Müller, D.

Die Behandlung von Anforderungsspezifikationen von komplexen Produkten stellt sich durch die verbundene große Menge an Anzahl und Verknüpfungen als schwierig dar. Sie repräsentieren aber die rechtliche Grundlage für die Produktentwicklung. Ein Konzept für eine aufgabenorientierte Filterung und Bereitstellung von Anforderungsspezifikationen zur Unterstützung des Ingenieurs in seinem Informationsmanagement wird in diesem Artikel vorgestellt. Der Ansatz setzt auf einer semantisch erweiterten Anforderungskategorisierung auf. Anforderungsauswahl und Überwachung werden mithilfe von Informationsagenten ausgeführt.

Requirement specifications for complex products are hard to handle due to their high amount of number and interrelations. Thereby, requirements represent the legally binding basis for the product development. In this paper, a concept for a task-oriented filtering and provision of requirement specifications is presented to support the engineer in his information management. The approach is based on a semantically enhanced requirements categorization. The requirements selection and change monitoring will be implemented by means of information agents. The approach enables an optimized personal requirements processing which backs an efficient product development.

1 Introduction

It is essential for the manufacturing industry to bring new products in short time at low costs and of high quality onto the market. Innovations represent the unique selling point in competition [1]. Innovative solutions are primarily realized by extended application of electronics and software in automotive or aerospace industry. This is associated with an increased product complexity, which is characterized by the type, diversity and number of elements and relations, as well as the dynamics of the system [2]. The development of innovative products is linked with the integration of processes and domains. The control, management and implementation of such an integrated product development is one of the challenges that have to be tackled nowadays.

It is commonly known, that the product development is primarily responsible for the determination of a product's total costs. Thereby, requirements represent the legally binding basis. A requirement is an expression of a perceived need that something be accomplished or realized [3]. This definition by Gabb et al. includes the demands and wishes a desired product has to fulfill, as well as the constraints regarding e.g. system environment, services or personnel entities.

Three abstract user profiles can be identified that are concerned with requirements. The developer is the recipient of a requirement. He is directly responsible for the problem solving and component design with reference to the stated requirements. The system analyst is responsible for the general requirements engineering and system design in the early development phases up to the start of production. He is engaged in the extensive elicitation, analysis, negotiation and documentation of qualitative requirements, as well as the fundamental system conception. The stakeholder characterizes a person with a not explicitly defined involvement along the development. This can be a supplier participating in the requirements elicitation and negotiation process, or a person in charge with access to the requirements specification to support his tasks (e.g. marketing).

The design process can be characterized as follows. It is definitely personal, based on creativity, and dynamic. The agreement on requirements and problem-solving solutions is marked by negotiations and compromises. The engineers' tasks are based on their individual knowledge by interpretation of available and acquired information. Several systematic approaches to engineering design have been proposed (among others [4], [5], [6], [7]). Despite the variances, general tasks are common to all these approaches:

- Requirement specification and planning
- Search and development of solutions
- Selection and optimization of variants

Requirements have a relevance in all these tasks. After determination, its fulfillment and adaptation have to be considered continuously [8]. The procurement of information changes its focus during the course of the development cycle [9]. It is problem-oriented in the beginning (What has to be created?), and alters to solution-oriented to the end (Does my solution fulfill all demands?). The aforementioned user profiles are also characterized by different informational needs. Additionally, the view on information is influenced by the respective task, e.g. regarding the level of detail.

The statement of requirements represents a problem regarding their qualitative documentation, especially in matters of clearness and analysis. Nowadays, the specification of requirements results still predominantly in a natural language based format. Model-based or graphic approaches are not widely distributed yet in the manufacturing domain. The application of text is linked with problems of e.g. incompleteness, inconsistency or ambiguity [10]. This restricts a computer-based processing. Additionally, the increasing product complexity affects the number of requirements and the level of interrelations. This has an aggravating influence on their processability.

The identification of relevant requirements has a positive influence on the quality of the generated results [11]. Nevertheless, the complexity of the requirements document raises the need for a specific support, as a manual analysis and processing is extremely time-consuming respectively hard to realize. This is supported by the psychological point of view. The human ability to handle a great amount of information is limited, which leads to an incomplete or reduced consideration [12]. Requirements of high quality and the opportunity of their goal-oriented processing will meet the problem of information overload and support the necessary systematic proceedings [13].

The approach to enable a supported provision of only those requirements that are relevant for a specific task leads to the objective of a flexible, task-oriented requirements filtering. The user should be able to extract requirements from a database-driven requirements document by specification of a task-specific retrieval request. Additionally, the user should be notified on relevant changes in requirement specifications to always act on the latest status of requirements. This problem entails:

- Intelligent analysis/ selection of requirements,
- Task-oriented requirements editing and processing,
- Continuous, flexible requirements management,
- Change monitoring.

The remainder of this paper will describe the conceptual approach for the task-oriented requirements management by intelligent assistance regarding requirements filtering in detail, followed by the specification of the associated agent system, and conclude with the synopsis and evaluation of the proposed concept.

2 Concept Development

The functions that will be fostered by the introduced approach focus on the coverage and control of the complexity in requirements specifications, enable an efficient search and selection of requirements, and can be flexibly and continuously adopted by users during their variable tasks. Fundamentals to this method are the semantically enhanced categorization of requirements, information model integration, and the adoption of information agents for the task-oriented analysis, filtering, and monitoring of requirements.

With reference to Belkin and Croft, the problem of information filtering can be identified as the selection of information relevant for an individual user [14]. The qualification of information agents can be gathered from the definition. Klusch characterizes an information agent as an autonomous, computational software entity that has access to one or multiple, heterogeneous and geographically distributed information sources, and which pro-actively acquires, mediates, and maintains relevant information on behalf of users or other agents preferably just-in-time [15].

The basic skills of an information agent are divided in communication, collaboration, knowledge, and low-level tasks [16]. Communication can be accomplished with information systems including databases, agents or users. The interaction respectively collaboration with users or agents can be established on higher-level. Data, information or knowledge of different formats can be processed by the information agent, including ontological knowledge, metadata, profiles and natural language. Main tasks regarding the handling of information involve its retrieval, filtering, integration and visualization. The basic skills are interrelated and form the specific capability of an information agent.

The general applicability of information agents still asks for a task-specific configuration and determination regarding agent, environment, and information basis. As mentioned before, the processing of natural language by IT-systems is limited. This includes especially the identification of relevant information. It is necessary to cope with the vagueness and complexity of semantic relations of requirements. Therefore, an enhanced organization of requirements is necessary based on a formal specification mechanism, which can be achieved by a categorization of requirements, in accordance with Gabb [3].

It is mandatory that the semantic relationships will be covered by a defined schema. By mapping of requirement contexts, the efficiency regarding their IT-supported analysis will be improved significantly. The semantic allocation of data is of high complexity and within the focus of several actual research initiatives, e.g. the developments of the Semantic Web[1] are of high importance in this area. Thereby, the integration of ontologies has been considered as formal specification mechanism. Gruber specified a commonly agreed definition, whereas an ontology is an explicit specification of a conceptualization [17]. An ontology extends the linguistic means of expression of a corresponding representation [18]. A basic product ontology refers mainly to classification systems [19]. Methods that are used by ontology integration approaches are e.g. text similarity, keyword extraction, structural analysis, and data interpretation and analysis [19].

The generation of a classification system for requirements solely realized per ontology requires immense efforts due to the existing complexity and diversity. A reduced system would limit the functionality and flexibility. Due to this fact, the integration to the standardized systems engineering reference model ISO 10303 STEP AP233 has been taken into account, pre-published as publicly available specification ISO/ DRAFT-PAS 20542:2004(E) [20].

[1]see http://www.w3.org/2001/sw/

The following is within the scope of AP233:

- Products with system concept conformity,
- System definition and configuration control data pertaining to the design and the validation phases of a system's development,
- Requirements,
- Functional analysis data including functional behavior specifications,
- Physical architecture and synthesis data providing a high level view on the system under specification,
- Elements that are used to represent and trace requirements and functional allocation.

Fig. 1 shows a conceptual view of the AP233 system model in UML syntax, whereas every box represents a group of related entities. The central unit of functionality for requirements allows the integration of a classification system, besides the general representation of requirements, their interrelations and assignment to system specifications. The standard does not specify a fixed structure for requirement classification. A dynamical structure is provided instead by requirement classes and relationships. The semantics of requirement relationships will be covered by determination of explicit characteristics.

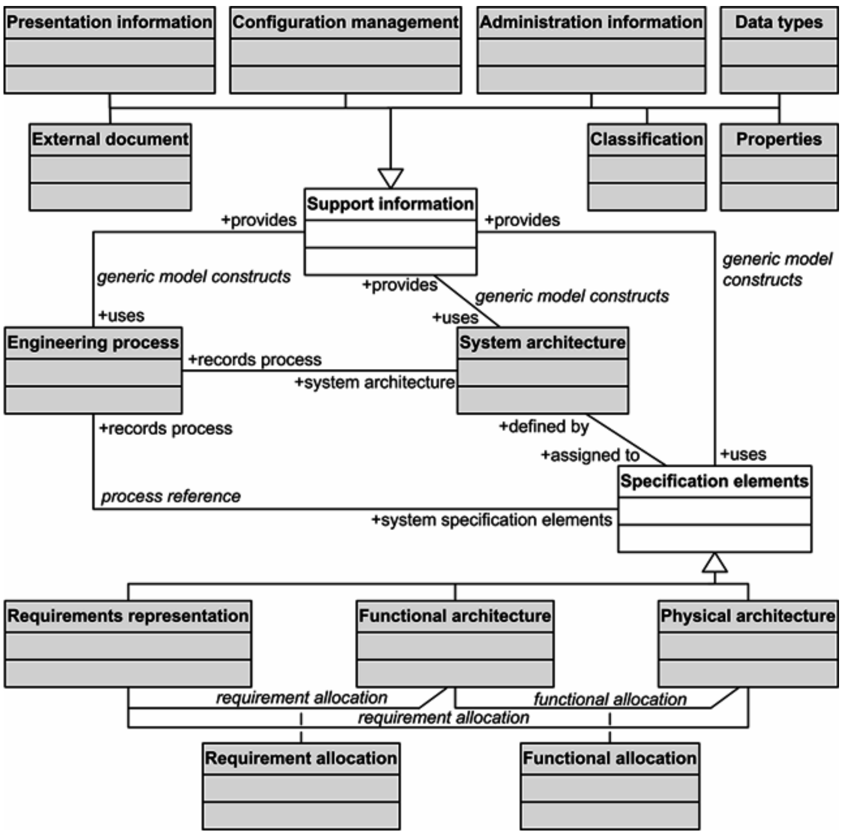

Fig. 1. Conceptual view of AP233 as described in [21]

The proposed extension of the AP233 reference model offers a great potential, which has not been exploited before. The mature, comprehensive requirement categorization adds a fundamental, semantic component to the information model. Additionally, the direct link of classification schema, requirements specification, and furthermore other system components enables an extended, flexible, complementary arrangement including an improved processability by IT systems.

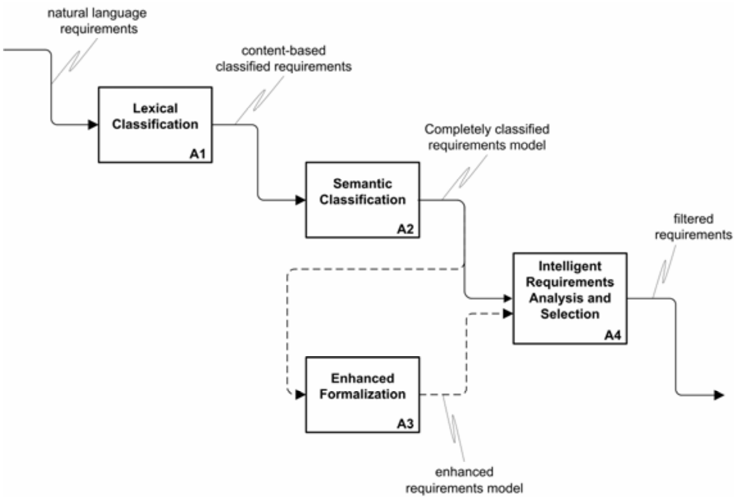

Fig. 2. Requirements formalization and analysis process

The enhanced, categorized requirements respectively the modeled system specification represents the operative basis for a task-oriented requirements management. Nevertheless, it is necessary to prepare present requirements accordingly. The defined process of a classifying formalization is responsible for the transformation and categorized organization of natural language based requirements. Fig. 2 displays the relevant steps.

Set up on a structured, interpretable information basis, intelligent algorithms can be applied to deliver better and more reliable results regarding their advanced, selective tasks. The representation of categorized requirements promotes the mapping of existing relations, derivations or subdivisions. This fulfills the premises for an assisted detailing of requirements. The user will be able to make an goal-oriented inquiry about requirements.

The lexical classification (node A1) includes the content related analysis of the natural language requirements regarding explicit characteristics. The resulting requirements model, initially extended by content-based classifications, will be completed within the following semantic classification (node A2). This step is responsible for the identification of implicit requirements characteristics and interrelations. The accordingly produced requirements model fulfills every qualification for a user initiated, intelligent assisted requirements analysis and selection (node A4). The entire process delivers filtered requirements as result, subject to a specified inquiry. The output will be presented to the user in the form of partial requirements lists.

The process of the classifying formalization can be optionally extended by application of an enhanced requirements formalization (node A3) according to Heimannsfeld [10]. This formalization is responsible for the transformation of natural language based requirements to a model based representation by systematic identification of linguistic and grammatical elements. The extensive generation of a formally enhanced requirements model promises improvements regarding the outcome of analyses and more precise information on details. Such specific type of information is not primarily in the focus of the aforementioned user profiles. Thus, it has to be balanced if the extra effort is reasonable.

Nevertheless, the standardized, model-based approach of the concept allows a variable, scalable implementation depending on respective needs. It should be noted, that the tasks of nodes A1 to A3 are carried out by human interaction, usually by the system analyst. These tasks require in-depth knowledge that is so far not reproducible or deducible by current IT systems. The system of information agents is responsible for the filtering of accordingly organized requirements. The design of an exemplary agent system for the realization of the proposed approach will be described in detail in the following section.

3 Agent System

The accomplishment of complex tasks regarding filtering, monitoring, and management of complex, numerous requirement specifications comprises the core functionality that has to be covered by the agent system. The systematic methodology according to [22] was chosen for the applied system development. This approach aims for the use of the JADE (Java Agent DEvelopment framework) platform in particular, including their inherent agent management concepts. JADE is a software framework by TILAB[2] (Telecom Italia Lab) incorporating Java technologies. The enclosed middle-ware complies with the FIPA[3] (Foundation for Intelligent Physical Agents) guidelines and supports the implementation and control of the agent system by provision of a basic agent architecture.

The modeling of the use case for the task-oriented requirements management and the systematic analysis of necessary agent tasks, interaction, and behavior based thereon resulted in the determination of four agent types. Thereby, security issues have not been considered, as well as agents for the general agent management non-specific to the problem. The overall concept of the system is displayed in Fig. 3.

Besides the agent types indicated by the circle, the aforementioned user profiles indicated by the actor symbol and three external resources indicated by the rectangle belong to the system. Acquaintances of components that require an interaction during execution are represented by the double-headed arrow.

The users of the system initiate the task-specific requirements retrieval by specification of search attributes and consideration of user related preferences. The agent system autonomously works off the request. The database of the requirement model constitutes the central information basis. Additionally, information on the user profiles will be managed and maintained in a database. The change management component is responsible for the system monitoring.

The Filter Agent takes on the interface function among user and system components. It represents the central point of organization and coordination of the task-oriented requirements filtering. Based on the conveyed search criteria specified by a request and extended by general user preferences, relevant categories, attributes or model elements have to be identified and analyzed for the requirements selection. The determination results in the transfer of partial, goal-oriented search requests to a Provider Agent. The returned values of the multiple queries have to be correlated regarding e.g. relevance, redundancy or consistency. The disclosure of ambiguous or incomplete results will cause renewed queries. The filtered requirements will be presented to the user with finalization of the query. A user related rating of filtered requirements regarding relevance optimizes further filtering processes. Query and result will be stored in the user profile index-based to enable traceability regarding updating.

The Provider Agent establishes the connection to the classified requirements model. The main task is to answer the queries. The Provider Agent directs the query to the database. Furthermore, it is able to perform task-oriented analyses of query and selected requirement attributes on his own and to activate specific sub-retrievals. This enables among others an additional tracing of structural requirements regarding insufficient classification, an extended examination of interface specifications, or an identification of relevant relations.

The Profile Agent represents the interface to the master data of the user profiles. This agent type coordinates the user related information management. This includes the allocation of the user profile at login, maintenance of user preferences and properties, and securing of indexed queries. In addition, requests from Filter Agent or Control Agent have to be served.

The Control Agent is responsible for the change monitoring of requirements. The completion of requirement adjustments will be registered based on a change management. Possible approaches are the setting of a change flag or the continuous surveillance. The notification process will be initiated autonomously. This incorporates the investigation of persons that have to be notified on a modification on the basis of stored query indexes or assigned person attributes. An identification causes a notifi-

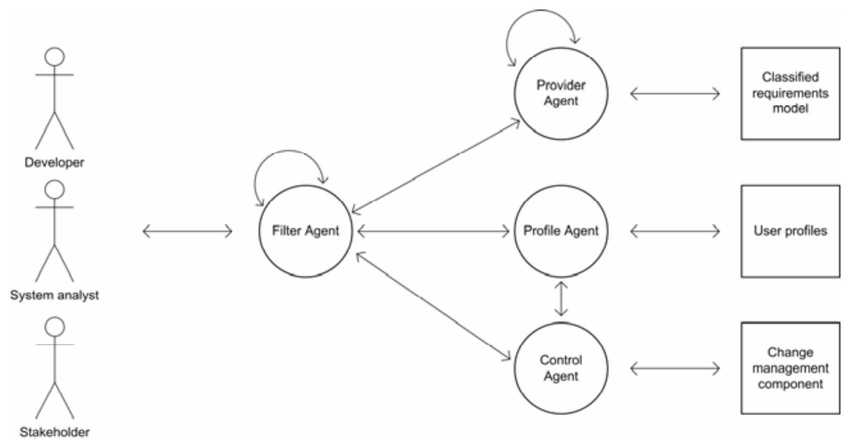

Fig. 3. Schema of the agent system

2 http://jade.tilab.com/

3 http://www.fipa.org/

cation (e.g. news service, email) of the respective person, inclusive the transmission of the updated requirement. It will be possible to transfer directly the requirement to the task-oriented portfolio including an update of the linked query index, or to start another query.

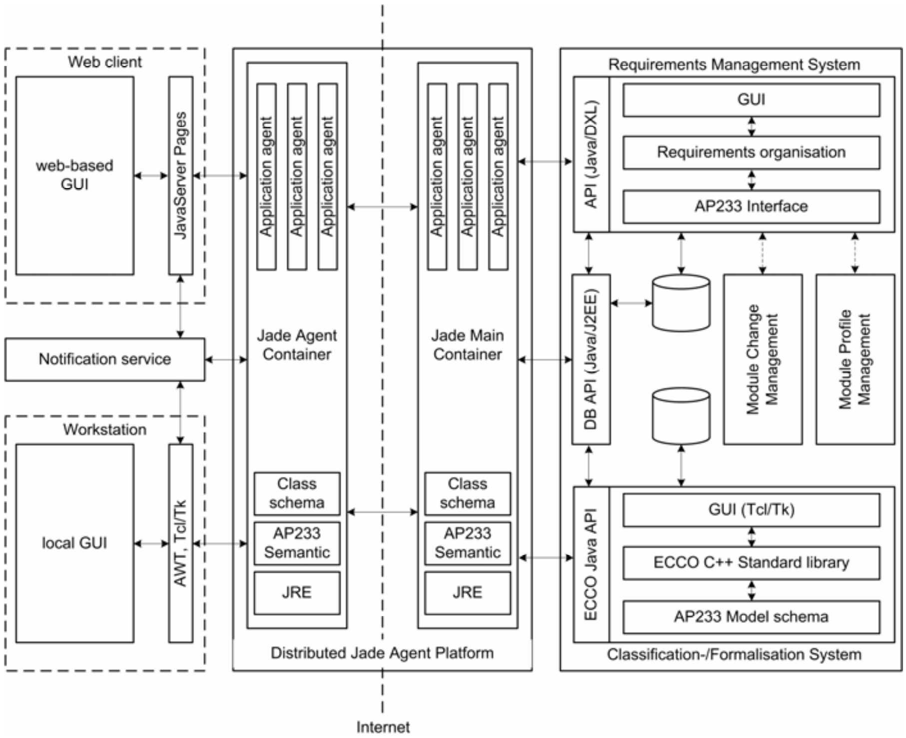

Fig. 4. Conceptual architecture

The filtering of requirements is a complex, iterative process. Due to the variety of attributes that have to be investigated, it is not possible to realize it by only one, combined query, even by categorized requirements. This is another argument for the application of information agents. Filter Agent and Provider Agent are mainly responsible for the proactive generation of partial queries by their agent types, which can be identified by the self-referencing arrows in Fig. 3. The system conception needs some more detailing, e.g. regarding definition of explicit behaviors or interaction patterns, but this should be out of the scope of this paper.

An exemplary architecture for the agent system will be presented below. The main components can be divided in the system for an IT-based requirements engineering and management, the agent platform and the user interface, as displayed in Fig. 4. The proposed architecture still features degrees of freedom regarding the implementation.

The requirements management system (e.g. Doors XT[4]) is the central application for the documentation and organization of requirements. The specified information model has to be supported, e.g. per configured interface for the data exchange. The model-based classification and transformation of natural language based requirements can be realized by functional integration or by linking to an external system, which is the preferred solution. Such a system has been developed within the European research project KARE[5] and can be integrated by simple extension regarding the categorization. The tool *demanda II* is based on an ECCO C++ standard library as application instance, generated by the ECCO Toolkit[6] of PDTec GmbH. Additionally, the modules of change and user profile management have to be integrated. The provided APIs can be used for the access by the information agents.

The agent system performs the analysis and filtering of requirements as well as their monitoring. The decision for the Jade platform has been justified before. The initialization of the platform incorporates the immediate generation and establishment of the default administrative components. The Jade platform is not restricted to only one host, as can be gathered from Fig. 4. The distributed execution is based on an application instance in form of the Java Virtual Machine (JVM). Each JVM corresponds to one agent container per host with a functional run-time environment for a parallel implementation. The task-specific customization of the agent environment is only necessary for the communication and behavioral patterns of the application agents, as well as the interface functionality. Every container based on a Java run-time environment

4 http://www.telelogic.com/index.cfm?

5 KARE - Knowledge Acquisition and sharing for Requirement Engineering, EU ESPRIT No. 28916, 1998 - 2001, http://www2.imw.tu-clausthal.de/kare

6 http://www.pdtec.de

(JRE) features the defined application agents with underlying class schema and AP233 semantics.

The general utilization of the system in terms of selected requirements retrieval and change information service will be handled by the user component of the system. This constitutes the main interface visible for the common user, which is responsible for the behavior controlling interaction of agent system and user. Thereby, it is possible to implement the graphical user interface (GUI) as local application on a workstation or web-based via a web client using a standard internet browser. The realization is supported by appropriate programming languages, such as Tcl/Tk or Java. It is not necessary to force an integration to the requirements management system, as the overlap within the user groups has to be assumed small. This should be considered only with respect to further developments of distributed requirements management solutions. The main focus of the development for this component is on the interface specification. The exemplary implementation uses JavaServer Pages technologies for the web-based solution respectively Tcl/Tk or the Abstract Window Toolkit[7] (AWT) for the machine-based approach. Nevertheless, the web-based approach will be favored with respect to best possible extensibility and connectivity to further agent systems. Additionally, possible mobile solutions will be supported. The notification service is a relevant feature of the user component. Possible solutions are email or news service, as mentioned before.

4 Conclusion

The conception of a system for a task-oriented filtering and provision of complex requirement specifications has been introduced in this paper. The realization of the approach will be achieved by comprehensive categorization of requirements, incorporating important semantic aspects, to provide a computer-interpretable information basis. On this groundwork, an agent-based filtering and monitoring of requirements is applicable to assist the user in his tasks by an easier, advanced and timesaving information management. The optimized, flexible and individually oriented processability of complex requirement structures improves their integration and consideration during the system respectively product development. The system concept supports also the general accessibility of requirement specifications by all persons involved in modern, distributed development environments. The application of the approach will lead to a mature, efficient and less defective product development.

The detailed investigation of the task-oriented requirements management is presented in [23]. The relevance of the concept has been verified with the help of three case studies from different industrial areas. The characteristic activities of a task-oriented requirement categorization, their intelligent filtering, as well as the value-added, practical integration in the development process have been demonstrated. It is possible to master the complexity of requirements by semantically enhanced, categorized structures and hence intelligent interpretation. The integration of the approach can be achieved without major efforts, as just the requirements engineering process has to be adapted regarding the categorization. A domain-specific customization is recommended as well as the statement of guidelines, e.g. regarding scope and preciseness. The extent of the implemented categorization and the quality of the enquiry affect fundamentally the relevance of the results.

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