Requirements Engineering for Global Systems: Cultural, Regulatory and Technical Aspects

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Abstract: In this paper we present a formal framework for analysis and optimisation of the requirements specifications of systems developed to apply in several countries. As different countries typically have different regulations/laws as well as different cultural restrictions, the corresponding specific requirements might differ in each particular case. Our framework provides a basis for (1) systematic and formal analysis of the diversity and interdependencies within the sets of the requirements, to avoid non-compliance, contradictions and redundancies; (2) corresponding systematic process for change management in the case of global system development.

1 INTRODUCTION

Software solutions are applied in many areas of our life. In many cases, users of a system have diverse backgrounds, both cultural and technical. The diversity is especially high if the system is developed for application in several organisations or countries. In that case, the overall set of requirements expands by the diverse sets of organisation or country specific requirements, regulations and restrictions. Moreover, cultural diversity might lead to the diversity of culture-related requirements also within a single organisation or country.

Requirements engineering (RE) activities have a critical impact on whether the developed system will satisfy user needs as well as regulations and laws of the countries/organisations, where the system will be applied. RE activities provide a basis for all other activities within the software development life cycle, such as testing, design, architecture, etc., and the errors within them are a major cause of the issues with the delivery of the product on time as well as of the budget overruns, see e.g., (van Lamsweerde, 2008; Pretschner et al., 2007; Rinke and Weyer, 2007). Thus, the task is already complicated even when conducting RE activities for a system that is developed for application within a single country or organisation. When the system should rely on the standards, legal regulations, cultural aspects, etc. that are not uniform, a corresponding solution is required to deal with the related issues in a systematic and scalable way, see e.g., (Prikladnicki et al., 2003).

A number of studies demonstrated that the cultural diversity has to be taken into account to make the system sustainable and applicable in a global context, see (Alsanoosy et al., 2018a; Alsanoosy et al., 2018b; Borchers, 2003; Govender et al., 2016; Shah et al., 2012). In the proposed approach, we investigate how to manage the diversity of cultural and technical aspects (as well as the correlations between them).

The core goals of the proposed framework are (1) to optimise the process of requirements specification and the corresponding change management, as well as (2) to ensure that the system requirements are fulfilled in a global development context, where also diversity in the cultural and regulatory requirements is taken into account. The framework provides methodological structuring of the requirements for the geographically distributed product development and application. The purposed approach will

- help to analyse the relations between requirements formally,

- facilitate the tracing of requirements' changes in a global context, and

- provide an input for the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution, see (Mairiza et al., 2013; Mairiza et al., 2014)), which would allow to identify the most preferable solutions with respect to the conflicting requirements.
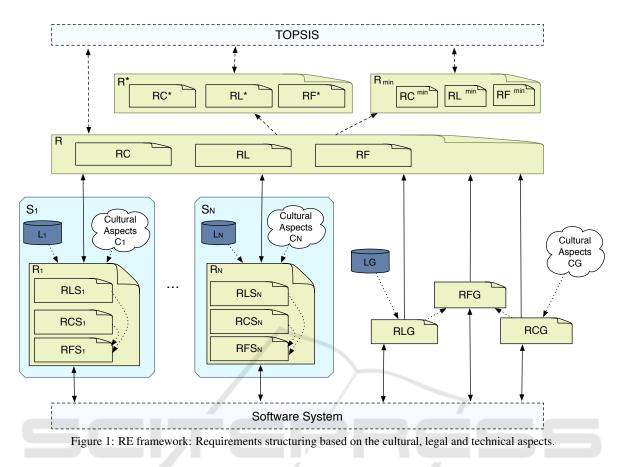
Outline: The rest of the paper is organised as fol-

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Figure 1: RE framework: Requirements structuring based on the cultural, legal and technical aspects.

lows. Sections 2 presents the proposed framework. Related work is introduced in Section 3. Section 4 summarises the paper and the future work directions.

2 COVERING THE DIVERSITY

In the case of global development, the software system requirements have to we have to cover not only the technical aspects, but also aspects related to the diversity in culture and country-specific regulations. Figure 1 presents a logical architecture of the proposed framework for methodological requirements structuring based on the cultural, legal and technical aspects.

Let us assume that we have to develop a software system for application in N countries (or states, organisations, etc.), which we denote $S_1, \ldots, S_N$. With each country/state/organisation S_i, $1 \le i \le N$, we associate

- set L_i of regulations/laws, and
- set C_i of cultural influences.
- set R_i of functional and nonfunctional requirements to be valid for the country S_i, which depends on the sets Reg_i and C_i.

The complete set of requirements is then defined by

$$R = \bigcup_{j=1}^{N} R_j$$

R might contain inconsistencies, i.e. some requirements R might contradict to each other, which should be identified on the early development phases. Thus, in the case $i \ne j$, we might have a situation where

- $L_i \ne L_j$, and/or
- $C_i \ne C_j$

which will also imply $R_i \ne R_j$. This also means that we can divide the sets L_i and C_i into two subsets each to represent

- general components, i.e., regulations/laws and cultural influences common for all countries S_i, $1 \le i \le N$:
  - LG_i, where $LG_i = LG_j$ for any $1 \le i, j \le N$.
  - CG_i, where $CG_i = CG_j$ for any $1 \le i, j \le N$.

  In both cases, we can also omit the bottom index for simplicity and denote the corresponding sets by LG and CG.

- specific components, i.e., regulations/laws and cultural influences that are specific for some of the countries S_i, $1 \le i \le N$:

– LS_i, so that for all sets LS_i, $1 \leq i \leq N$, holds

$$\forall x \in LS_i. \exists 1 \leq i \leq N. \exists y \in LS_j. contr(x,y)$$

– CS_i, so that for all sets CS_i, $1 \leq i \leq N$, holds

$$\forall x \in CS_i. \exists 1 \leq i \leq N. \exists y \in CS_j. contr(x,y)$$

The predicated $contr(x,y)$ denotes the fact that there is a contradiction between x and y, which are in two regulations/laws or cultural influences.

Thus, for all $1 \leq i \leq N$ holds

$$L_i = LG \cup LS_i$$

$$C_i = CG \cup CS_i$$

Respectively, the set of functional and nonfunctional requirements R_i to be valid for the country S_i can be divided in three (disjoint) subsets.

- set RL_i of regulations/laws-based requirements, where some requirements might be country-specific in the case the corresponding regulations/laws are country-specific. Thus, we can specify it by

$$RL_i = RLG \cup RLS_i \qquad (1)$$

where

  – RLG is a subset of regulations/laws-based requirements elaborated on the basis of LG, i.e.,

  $$\forall r \in RLG. elaboratedFrom(r,RLG)$$

  – RLS_i is a subset elaborated on the baseis of LS_i, i.e.,

  $$\forall r \in RLS_i. elaboratedFrom(r,RLS_i)$$

- set RC_i denotes the requirements reflecting on culture and economics related aspects, which could be country-specific:

$$RC_i = RCG \cup RCS_i \qquad (2)$$

where

  – RCG is a subset of culture-based requirements elaborated on the basis of CG, i.e.,

  $$\forall r \in RCG. elaboratedFrom(r,RCG)$$

  – RCS_i is a subset elaborated on the basis of CS_i, i.e.,

  $$\forall r \in RCS_i. elaboratedFrom(r,RCS_i)$$

- RF_i denotes the functional and non-functional requirements on the system. These requirements do not depend on the cultural aspects or the regulations and laws directly, but might depend on them indirectly, via the restrictions from the requirements RL_i and RC_i.

$$RF_i = RFG \cup RFS_i \qquad (3)$$

We have to build the corresponding ontologies and structure the sets of requirements taking into account the country-specific aspects. In the case RC contains a requirement that is a stronger version of another requirement from RC, i.e. is a refinement of it (denoted by $\rightsquigarrow$), the weaker versions should be removed. For example, $r_1, r_2 \in RC_i$, $r_1 \neq r_2$, $r_1 \rightsquigarrow r_2$ implies that r_2 should be removed as redundant.

While analysing the sets of relevant regulations $L_1, \ldots, L_N$, the following options are possible:

1. $LG = \emptyset$. This means $RLG = \emptyset$, i.e.,

$$\forall i. 1 \leq i \leq N. RL_i = RLS_i$$

In this case, we have to analyse all sets RLS_i especially carefully, as it is possible only if the sets of regulations are completely different for all countries $S_1, \ldots, S_N$. This case is very unlikely. Similarly, the case $CG = \emptyset$, where the cultural aspects and restrictions are completely different for $S_1, \ldots, S_N$, is also very unlikely.

2. If the sets of applicable regulations/laws are identical for all countries $S_1, \ldots, S_N$, i.e., $L_1 = \cdots = L_N$, we have the situation when

$$LG = L_1 = \cdots = L_N$$

and

$$\forall i. 1 \leq i \leq N. LS_i = \emptyset$$

which also means

$$\forall i. 1 \leq i \leq N. RL_i = RLG$$

If all requirements in RLG do not change over the time (i.e., are static), the case is the simplest one for the software development: the system can be developed on the basis of RLG to use it within $S_1, \ldots, S_N$. The same holds for the sets of cultural aspects and restrictions: if

$$CG = C_1 = \cdots = C_N$$

we can develop a software system on the basis of RCG to use it within $S_1, \ldots, S_N$, as the sets of corresponding country-specific cultural aspects is empty

$$\forall i. 1 \leq i \leq N. CS_i = \emptyset$$

3. If the sets of regulations/laws are not completely identical for $S_1, \ldots, S_N$, but have some similarities, i.e.,

$$LG \neq \emptyset$$

and

$$\forall i. 1 \leq i \leq N. RC_i = RCS_i \cup RCG_i$$

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where

$$\exists j.\ 1 \le j \le N.\ RCG_j \ne \emptyset$$

This is the most common case for the sets of regulations/laws, as well as for the sets of cultural aspects and restrictions, where $CL \ne \emptyset$ and there are differences in the cultural aspects.

If these requirements are static (which could be the case for culture-influenced requirements, but hardly can be assumed for regulations/laws), a component-based solution would especially efficient: the components implementing the requirements out of the set RCG can be separated from the components implementing $RCS_1, \dots, RCS_N$. As the regulations/laws are typically a subject to change, it is risky to assume that the set RLG will have no changes in the case some RLS_i have changes.

The following optimisation and reduction of the sets RC and RL might increase efficiency of the analysis:

- RC_i^{min} and RL_i^{min} denote the sets of cultural and legal requirements, which should be fulfilled by *any* software system (within the corresponding domain) developed for application in the country S_i.

- RC_i^* and RL_i^* denote the strongest sets of the cultural and legal requirements for the country S_i (within the corresponding domain). We can say that these sets are optimisations of RC_i, and RL_i.

We propose to analyse the sets of requirements based on the optimised views on the sets, i.e., where all redundant (weaker) versions of the requirements are removed, keeping the focus on the cultural and regulatory/legal aspects. As these aspects have different nature, we cannot apply the same strategy to each of them. For example, the sets of cultural aspects are usually static, where the regulation/laws are subject to change over time. While identifying RC^{min}, RL^{min} and RF^{min}, we will analyse which components of the system under development can be reused later. This will allow us to have:

- an efficient process for the development,

- provide a solution for traceability of the requirements changes that were caused by changes in the regulations in $S_1, \dots, S_N$.

Thus, if there are some changes in $r \in R_i$, which becomes r' in the new version, the following options are possible:

1. The changes affect some $r \in RLS_i$, this might lead to the following cases:

  (a) r' is still specific for S_i only, i.e, only the components implementing the country-specific requirements S_i are affected.

  (b) r' is now (semantically) identical to the corresponding requirements for all S_j, $1 \le j \le N$, $j \ne i$, which means that

    - r' should now belong to RLG, and all $RLS_1, \dots, RLS_N$ should be updated respectively;

    - we might reuse here the corresponding components developed earlier for S_j.

2. The changes affect some $r \in RLG$, this might influence the system as whole. The following cases are possible:

  (a) r' is still general for all $S_1, \dots, S_N$, i.e, the corresponding components implementing the general requirements are affected.

  (b) r' becomes specific for some S_i or for all countries, as not all RL_i, $1 \le i \le N$, are affected by these changes. This implies the following

    - we need to revise $RL_1, \dots, RL_N$ to identify for each of the S_j, $1 \le j \le N$, which of the versions – r' or r – should now belong to RLS_j;

    - if RLS_j is now extended by r, no changes are required for the components developed for S_j;

    - if RLS_j is now extended by r', the corresponding changes have to be implemented for the components developed for S_j.

Specification of RC^*, RL^* and RF^*, can provide us a global view on the the system requirements, which is not overloaded with the redundant requirements, as all weaker versions are identified and removed. Respectively, these sets will provide an input for the TOPSIS framework to identify the most preferable solutions with respect to the conflicting requirements. On the TOPSIS level, the focus will be on general conflict decision analysis, assuming that the cultural and regulatory diversity issues are already resolved.

In some cases, we might have even different hierarchy levels to conduct a detailed analysis:

1. *Organisational level*, where the organisational regulations and the corresponding cultural aspects have to be take into account;

2. *State level*, where the state regulations/laws and state-specific cultural aspects have to be taken into account,

3. *National level*, where

  - the national regulations/laws and country-specific cultural aspects, and

  - requirements based on the regulations/laws and cultural aspects of the corresponding states

have to be taken into account.

Thus, in each country S_i, 1 $lei \leq N$, we might have $M(i)$ states $State_1, \ldots, State_{M(i)}$, where M is a mapping from i to the corresponding natural number that specifies the state identifier.

The organisational level might be seen

(1) either as a refinement of a state level, where in each $State_k$, $1 \leq k \leq M(i)$, we deal with $T(i)$ organisations $Org_1, \ldots, Org_{T(i)}$, where $T(i)$ is a mapping from $M(i)$ to the corresponding natural number that specifies the organisation identifier;

(2) or as a level that is orthogonal to the state and national levels, i.e., we assume that all companies that will be using the product are global.

The second option can be used in a very limited number of cases: typically, global companies are presented by their country-based units which might differ from each other in the terms of rules, regulations, etc. This would imply, that each country-based units can be treated as an organisation. Thus, the option (1) is more realistic in general.

3 RELATED WORK

Glinz (Glinz, 2007) presented a survey on the existing definitions of non-functional requirements (NFRs). The survey also includes a comprehensive discussion of the problems with the current definitions as well as of promising solutions to overcome these problems. In our approach, we analyse NFRs from the side of cultural and legal/ regulatory compliance aspects.

Nekvi et al. (Nekvi et al., 2011) introduced a compliance meta-model as well as identified a number of key artefacts and relationships to demonstrate compliance demonstration of the system's requirements against engineering standards and government regulations.

Several other approaches on compliance validation of requirements we introduced by Breaux et al. (Breaux et al., 2008), Maxwell and Anton (Maxwell and Anton, 2009), and Siena et al. (Siena et al., 2009).

Breaux et al. (Breaux et al., 2015) also elaborated techniques for modelling multi-party data flows requirements and verifying the purpose specification as well as limitation principles.

Yin et al. (Yin et al., 2013) proposed an approach for compliance validation of the outcomes of business processes against outcome-focused regulations.

Sleimi et al. (Sleimi et al., 2018) proposed a conceptual model for extraction of semantic metadata using natural language processing, to provide a basis for the analysis of legal requirements. In our future work,

we would like to investigate these approaches more deeply, to identify which of them can be incorporated or reused in the proposed framework within the step of analysis RL_i wrt. L_i, RC_i wrt. C_i, as well as RF_i with respect to RL_i and RC_i.

Levy at al. (Levy et al.,) presented a methodology for knowledge management solutions within RE process, which covers both technical and social aspects. Spichkova and Schmidt (Spichkova and Schmidt, 2015) analysed the RE aspects of a geographically distributed architecture in general. This analysis was then further refined by Spichkova et al. (Spichkova et al., 2015) with the focus on regulatory aspects and variances in compliance. In the presented approach we went further, by taking into account cultural aspects as well as providing a formal basis for change management procedure and analysis of interdependencies among requirements, restrictions/laws and cultural aspects.

Alharthi et al. (Alharthi and Spichkova, 2016; Alharty et al., 2018) analysed individual and social (including cultural) requirement aspects of sustainable systems, focusing on educational domain (so-called eLearning systems).

Mairiza et al. (Mairiza et al., 2013; Mairiza et al., 2014) introduced the TOPSIS framework, which adopts Multi Criteria Decision Analysis approach for NFRs and could assist software developers select the most preferable design solutions with respect to the conflicting NFR. TOPSIS does not take into account possible diversity in cultural and regulatory aspects, focusing on general conflict decision analysis. In our future work we are going to integrate the TOPSIS in the proposed framework.

4 CONCLUSIONS

In the case of global system development, we have to take into account that different countries typically have different regulations/laws as well as different cultural restrictions, which also implies the corresponding specific requirements might differ in each particular case.

In this paper, we present a formal framework that allows

(1) to structure and optimise the sets of requirements, as well as

(2) to have a systematic process for change management in the case of global system development, where the diversity in cultural and legal/ regulatory compliance aspects in taken into account and analysed especially carefully.

We also discussed in this paper our ongoing work on the analysis of interdependencies between the sets of requirements, cultural influences, and regulations/laws.

Future Work: In our future work we are going to analyse, which of the discussed in Section 3 approaches will be the best fit to expand or framework for interdependency and validity analysis of RL_i wrt. L_i, RC_i wrt. C_i, as well as RF_i with respect to RL_i and RC_i.

Another direction of our future work is to integrate the proposed framework with TOPSIS to allow for effective conflict decision analysis.

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