ICON-BASED LANGUAGE: AUXILIARY COMMUNICATION FOR REQUIREMENTS ENGINEERING

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Abstract:
In requirements engineering, numerous modelling approaches have been addressed to support communication and shared understanding, for instance, UML (use case diagram) and GORE (goal graph). Most of them use abstract geometrical shapes as fundamental elements. The RE stakeholders, therefore, need to master the prerequisite skill to understand this complex set of abstraction. Recently, there has been an increasing need for a simple and an easy-to-learn modelling technique. We propose an icon-based language as an alternative to RE modelling. Unlike other RE notations, icon-based language is devised principally from a set of icons. Our approach can be derived by identifying RE world, defining icon world and combining these two worlds. This development yields the demand to have a modelling language that unifies requirements activities. The result can be used to overcome the communication barriers between technical and non-technical stakeholders, and to have icon attributes that can be attached to individual requirement.

Keywords: Icon-based language; Visual construction; Requirements engineering; Stakeholder.

1. Introduction
Requirements engineering (RE) is one of the most vital factors for project success in software-intensive systems [Pohl (2010)]. The empirical evidences [Emam and Koru (2008); Cerpa and Verner (2009)] reveal that inappropriate and inadequate RE leads to scope and requirement changes in a project which finally influences the project failure syndrome. Many RE visual modelling languages have been developed to communicate, elicit, analyze, and deliberate the stakeholders’ needs [Agarwal et al. (2010)]. For example, UML and goal-oriented models are two outstanding visual techniques. The UML has been widely accepted as the industry standard language for modelling and analyzing the requirements [Morris and Spanoudakis (2001)]. The recent emergence of a goal-oriented model has been employed for formulating different levels of abstraction from high-level goals to the lower level of operational requirements [Moody et al. (2010); Lamsweerde (2000)]. Their distinctive function of using graphical elements is claimed as a major advantage. However, both methods use abstract graphical notations and syntax, whose meaning is difficult for novices to understand. Consequently, notational characteristics in existing visual languages have led to misinterpretation and confusion [Morris and Spanoudakis (2001)]. The challenges with existing visual modelling language have motivated the current research, which aims to conduct uncomplicated visual constructions based primarily on iconic representations. Icons have been recognized as the vehicle to transfer information and easy recognition for any context by any person. Presently, icons exist in almost every computer graphic user interface. Their information encryption helps the reviewers to perceive the intended meaning of particular situation in a user friendly manner. The difference between icons and other visual modalities such as graph and diagram lies on intuitive and recognition-based information. Typical examples are icons used in many public information spaces, in trains, traffic signs, aircrafts, and cars [Khanom et al. (2012); Heimbürger et al. (2011a); Heimbürger et al. (2011b)]. Several benefits of icons have been asserted, but surprisingly, there has been little discussion about applicable icons in RE research.

We propose an icon-based language as an alternative communication avenue for multifaceted RE stakeholders. With designing an icon-based language, the focus of the study is dedicated to the construction of feasible visual notations to represent RE context. The visual notation is modelled from the basic elements of visual vocabularies, their syntactic rules, and a set of semantics [Harel and Rumpe (2004)]. The visual vocabulary is the construction of the group of icons. Visual semantics defines the meanings of each icon by mapping it to the construct it represents. Visual syntax generates the relationship between visual vocabulary and visual semantic of the notation. Each construction is originated to represent a concept, an object, an action, or a relation. The apparent potential of the icon-based language would make it an attracting option to bridge the communication gaps among multi-stakeholder. The contributions of this development are expected to allow both experts and non-experts in different nationalities to deliver requirements and attributes that can be ascribe an individual requirement such as status, priority and number of change.

The paper is organized as follows. In the following section, we first give a brief overview of icon communication in relevant fields and visual languages in RE. We then describe our methodology and our
approach to icon-based language. In Section 4, we developed two artifacts that demonstrate the approach. Final section concludes the paper and presents future work.

2. State-of-the-Art

Recent studies by [Moody (2009); Moody et al. (2010)] indicate that icons and visuals represent important benefits for communication research. Research efforts have been done in developing computer-intensive iconic communication systems, which primarily aimed at fostering people to communicate with each other. For instance, Choo et al. (2005); Basu et al. (2002) have dedicated the icon-based systems as a communication tool for the impaired people. Most of these proposals are complex to comprehend and rudimentary on linguistic theories that the units of meaning correspond to the grammatical rules of clause and words (e.g. [Fitrianie et al. (2007); Leemans (2001)]). A detailed research has been emphasized on designing the system that facilitates the reviewers to mutually communicate without sharing common language [Leemans (2001)]. In the crisis environment, Fitrianie et al. (2007) has announced a comprehensive icon-based interface containing graphic symbols to represent concepts or ideas.

In the area of RE, A wide range of researches has highlighted on the use of diagrams for improving requirements engineering activities. Extended features of use case diagram have been devised by Yang-Turner and Lau (2011) to support the tasks of stakeholders in elicitation activity. In similar manner, Helming et al. approached an incremental UML as a communication means for delivering collaborative environment. The contemporary approach of goal-oriented model [Moody et al. (2010)] has enormously driven the importance of the visual notation in the RE field. Other visualization techniques adapted and researched in identifying and modularizing requirements are, for instance, the Aspect-Oriented Requirements Engineering (AORE) [Oliverira et al. (2010)] and physicalization material such as stickers, markers and sketchpads [Callele (2010)]. Scenario-based approach has also been accepted successfully as a prominent tailor to bridge the communication impediments among multifaceted stakeholders [Sutcliffe et al. (2011)].

3. Research Approach

The current research is carried out using a design science research approach. Havner et al. (2004) designates design science research as a building and evaluating process with the purpose to conduct a set of artifacts. Our main goal is to design and develop icon artifacts that support RE context. Since icon-based language is a novel approach, its design can involve an iterative evaluation and refinement of artifacts. The research approach we employ follows Peffers et al. (2007) (see Figure 1).

![Fig. 1. Design science research methodology.](image)

We first identified the problems of RE according to literature review, e.g. [Hansen and Lyttinen (2010); Mathiassen et al. (2007); Kaiya et al. (2005)]. We arrived at three difficulties stakeholders encountered in performing RE. Firstly, there is the ability challenge of system stakeholders to express their needs concisely and concretely. In broad spectrum, requirements are heavily hard to discover in situations where there is a communication gap between technical and non-technical users that appear to speak different languages and apply different approaches for desired outcomes. Secondly, requirements complexity happens when stakeholders experience the difficulty to understand, specify and communicate requirements. Finally, requirements volatility signifies to the stability of requirements that easily change as a result of environmental dynamic or individual learning.

We then defined concrete objectives to inform the requisites of a possible solution to the abovementioned problems. Our first objective is to find a solution that enables RE stakeholders to deal with quality requirements. The large variety of stakeholders’ backgrounds makes it necessary to find ways for an easy adaptation of a supportive method. A second objective is to reduce the requirements analysis effort. Icon-based language that allows flexible composition of various attributes and relationships increases the number of model elements to
support stakeholders to analyze and prioritize requirements, as well as resolve conflict and make negotiation. In addition to that, icon-based language could provide RE stakeholders to investigate requirements change and keep tracking requirement life cycle and traceability.

At the design stage (see also Figure 1), the key insights of our approach in the design solution can be obtained by defining RE world, defining icon world and integrating those two worlds together. We infer the necessities for our artifacts by drawing on theoretical foundations in the interdisciplinary fields of RE, human-computer interaction, and cognitive phycology. We further combine knowledge and techniques from the research fields of modelling languages and iconic communication in order to make design decisions that principally effect the direction of our approach.

In the evaluation phase, we conduct two iterative evaluations: one with inexperienced users and another one with expert users. The first iteration will be tested by multicultural students in the RE course of the Department of Mathematical Information Technology at the University of Jyväskylä. For the latter iteration, intercultural software companies both in Thailand and Finland are the key players. The primary goal is to evaluate whether icon-based language is applicable in practice and whether it can be used in real software project. We take advantage of usability testing to evaluate if the utility of a defined icon-based language model supports the tasks of RE stakeholders. The results of these two iterations are used to inform improvement possibilities.

4. Proposed Solution

In this section, we will describe how our objectives for supporting RE stakeholders inform the development of various artifacts that provide consensus requirements types, attributes and relationships. These artifacts include a RE world definition, icon world definition and integration of those two worlds.

4.1. Artifact 1: The definition of RE world

Cooperating with this question what are the tasks of RE that can be supported by icons?, we have established a list of boundaries that stimulated by RE exercise in multicultural backgrounds. We focus on extracting those potential activities that impact entire RE process by conducting a thorough literature review on related work. As a given example shown in Figure 2, the central concept of requirement artifact begins with patterning the scope, associated actors, attributes and scenarios.

![Fig. 2. The use case scenario of requirement characteristic.](image)

Firstly, to discover the purpose of the system under development in elicitation phase, different catalogs of requirements are distinguished on the basis of quality characteristics in [ISO/IEC 9216]. Secondly, to monitor the lifespan of requirement, status and priority attributes granted to every requirement are significantly helpful. It embraces the identification of actor who is authorized to change a status, and update status only when the conditions are satisfied. Furthermore, to accelerate the requirements management, the number of requirements changes is systematically retained in the project. Finally, to support requirements traceability, the association among requirements facilitates the ability to describe and follow the life of requirements [Gotel and Finkelstein (1994)].

In the next step, we model the sets of concepts of RE that are able to be expressed by icon-based language in structure of meta-modelling. The meta-model given in Figure 3 is the example of requirements artifact in Deliverable type. In order to systematize the requirements granularity, we identify generic attribute and activities of requirements [Pohl (2010), Wiegers(2003)]. Two types of model can be defined accordingly to the
purpose of icon-based language that will be using icons to represent either what are already existed in the RE research and what are newly proposed in this research work. We name those two types as Deliverable and Classification. However, any other exclusive types can be extended in the customization. In the one hand, Deliverable typifies the scenario of scope, actor and goal that needs interrelation between each activity. Typically, this dynamically describes the requirements' behavior under various conditions. In the other hand, Classification is a kind of RE activities such as requirements taxonomy, elicitation tasks, or analysis tasks that we categorize to be individually and statistically exemplified by icon(s). Requirements captured in DeliverableModel contain a set of relevant attributes, actors and relationships.

Fig. 3. The meta-model representing concept of requirement artifact, its attributes, relevant actors and relationships.

A Requirement is characteristics of requirements artifacts that have a unique identifier (ID property), a name, a description, a highLevelGoal (BusinessReq), a priority (taking values from PriorityType), a status (determining the requirements life cycle values from StatusType), and a number of changes (NoOfChange). The model may contain three different kinds of requirements: business, functional and non-functional requirements. Business requirements are high-level requirements that reflect a goal or vision of the organization that the system must accomplish. Under business requirements, it may contain functional requirements that present a behavior of a system under specific condition. Otherwise, it enables to contain non-functional requirements that represent a quality attribute in which the system must have. A requirement may be attached with business rules, law, policy, or procedure which constrains the certain degree of freedom in delivering a solution. BusinessReq contained by a Requirement class relies on a unique identifier (ID), a description, type (selecting one or more of the values in a series of RequirementType), and constraint (grasping the value from BusinessRule). Number of change is the level of the requirements that is happened to change over the software life cycle. It is important to keep information about individual actor (actorID, name, and description) for further inquiry. The requirement can be associated to each other through link types: Dependency and Parent-Child. Three relationships of Dependency, require, refine and conflict, have been delineated to qualify the association between two or more different requirements. Moreover, one requirement can be divided into sub-requirements and those sub-requirements are connected to their parent with Parent-Child link. The requirements engineer can use two types of decomposition corresponding to logical combination – one is AND-Parent-Child and the other is OR-Parent-Child. In AND relationship, unless all of sub-requirements are satisfied, their parent requirement cannot be satisfied. On the contrary, with OR relationship, a parent requirement could be satisfied when at least one sub-requirement is satisfied.

4.2. Artifact 2: The definition of icon world

In Figure 4, the entire stages in icon-based language design are iterative [Costagliola et al. (2004)] which means that if tests expose usage drawbacks, we might decide to review the Icon Library, Grammatical Rule and Semantics Library, as well as, to replicate the usability testing in the next version. Our limitation is the fact that all visual vocabularies in this paper are only used to represent the concepts and ideas. They are not fitness design for what they are representing. The design perspective must be done by the designers who are expert in the area and it relies enormously on cultural experience and cognitive effectiveness.
In the context of icon world, first of all we need to derive the icon library of a visual notation being designed. After analyzing and defining the RE context, icons are necessarily produced to simplify that context. For each icon notation that has to be conducted, we must generate a final Icon Library. The Icon Library contains the series of iconic symbols and visual sentences symbolizing the icon notation. When designing iconic symbols, guidelines and standards such as [ETSI EG: 202-048, ISO/IEC 11581] can guide us to gain applicable design for particular purpose. Since the interpretation of icons is a vulnerably subjective matter, the icons should be properly selected, developed and evaluated. Therefore, we will apply ETSI EG 201-379 framework that its direction would ultimately relief such challenge. To solve the problems of misinterpretation and cultural prejudice, the test participants will be chosen to include different nationalities. An example of icon representations depicted in Figure 5 describes requirements attributes in which priority types utilize different vehicles with different speed characteristics to express how urgent of the requirements is, whereas the action icons are representative of status states. Additionally, logical signs, “AND” and “OR” gates represent the Parent-Child relationship.

During the Iconic Syntax Modelling, we refine the specification of the iconic symbols according to the attribute-based representation approach that must be conformed to the criteria for proper visual syntax. Grounded on the attribute-based tactic, the grammar of icon-based language can be qualified depending on the structure of its iconic objects on the way they can be composed in order to form visual sentence. The criteria of good visual syntax are based on cognitive effective phycology [Moody (2009)]. He provides nine principles of a perspective theory that can be employed throughout the development of notation. The principle of Semiotic Clarity states that there should be one-to-one correspondence between syntactic and semantic constructs. The principle of Perceptual Discriminability affirms that different graphical symbols should be noticeably discriminate from each other. The principle of Visual Expressiveness asserts that the utilization of full range of variables such as color should be accommodating to represent the notation elements. The principle of Dual
Coping presumes that the employment of textual coding have a duty to augment graphic forms. The principle of Semantic Transparency supposes that the exploitation of visual representations whose appearance advocates their meaning reduces the memory load. The principle of Cognitive Integration is taken into consideration when multiple diagrams are used to represent the complete system. The principle of Graphical Economy declares that a limit number of different graphical symbols should be cognitively manageable. The principle of Complexity Management insinuates to the competence of a visual notation that can represent information without over memory load. The principle of Cognitive fit, finally, is mentioned that different visual dialects suitably support different tasks and users.

Accordingly, a language comprises of syntactic notations so called syntax and the meaning (semantics) of those elements. Thus, in Semantics Generator stage, the meaningful language elements (semantics) are mapped from the syntax constructs to the semantic domain [Harel and Rumpe (2004)]. For instance, reverted to Figure 5, we take for granted that different people might be able to view semantics of icon representations for priority types form their velocity as baby carriage for “very low”, bicycle for “low”, car for “fair”, train for “high” and aircraft for “very high”. The semantics of the iconic sentence can be translated that a function requirement (REQ01) can be decomposed into three children, REQ01_1, REQ01_2 and REQ01_3 respectively which means that a parent requirement can be accomplished only when REQ01_1 and REQ01_2 are both accomplished. Plus, stakeholder (BusTeam) assigns “very high” priority to a parent requirement. We must analyze the semantics aspects of the icon-based language model notation and designate extra semantics attributes on the whole visual symbols.

5. Conclusion

This paper has given an account of the importance and problems of RE in software development, and the gaps of the available modelling techniques. The purpose of the study was to initial the icon notations used to communicate requirements activities among multifaceted stakeholders in RE. The icon-based language model relies on visual symbols, syntax properties, and semantics. The model provides a competent way to specify, trace and verify requirements life cycle which requires a small amount of prior knowledge. The model can be used for demonstrating the visual notations of requirements activities along the software development life cycle. It would give ways to arrive at the definition of requirements with unambiguity, completeness and consistency. Besides, we aim that icon-based language could elevate stakeholders to deal with essential requirements attributes such as status, priority and number of change. Under this scenario, the expectation of the research is pointed to low technology-oriented audiences. Nevertheless, development teams who are experts and have some methodological experience can also use the model.

In the near future, we need to establish first iterative empirical evaluation for testing the proposed concept of icon-based language by students. It will continue together with the formulation of questionnaire and test scenarios. Different kinds of scenarios will be asked when testing icons (e.g. icon meaning and icon category). Data is collected using a combination of methods: the user test and the user satisfaction questionnaire. The appropriated way to reach the heterogeneous participants is web-based icon test. By having the electronic survey dispatched on the Internet, it can possibly grasp information from any person in any location that has access to the Internet. Currently, the web-based survey is developing to be ready for the first participant group.

References