Improving Collaborative and Post-WIMP Systems through Requirements Specification

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***Abstract*—A proper requirements specification is paramount for achieving the quality of the developed software products. However, well-known Requirements Engineering (RE) techniques lack of enough expressiveness to model the requirements of CSCW systems (*Computer Supported Collaborative Work*). This is due to the inherent complexity of collaboration among users and their need of awareness. Moreover, the way in which users interact with CSCW systems have evolved greatly to more sophisticated interfaces, beyond the classical desktop computer environments, to those called Post-WIMP (Windows, Icons, Menus, Pointer). Awareness is magnified in such a way that users have to be aware of their context: the artifacts with which to interact, his/her own capabilities as well as those of the others. All this awareness is necessary to allow them to collaborate in virtual and/or augmented environments. This PhD thesis aims at solving this problem by developing a RE framework able to deal with the requirements of CSCW and Post-WIMP systems, making emphasis on the awareness requirements about user's context.**

***Index Terms*—Requirements, quality, CSCW, Post-WIMP, awareness, CSRML.**

I. Motivation

A CSCW system is a kind of software product enabling groups of users to get involved in a common task or goal. Thereby, by means of these CSCW systems, people are able to communicate with each other as well as to work in a collaborative manner. This implies that the group of users can coordinate their activities, solve problems, edit documents and diagrams, or negotiate by using specific technologies. Moreover, the way in which user interacts with computer systems has evolved towards a new paradigm beyond the classical windows, icons, menus and pointing devices (WIMP). This new paradigm, namely Post-WIMP, is based on virtual reality, gesture recognition and wearable computers [30] (among other technologies) that makes the development of these systems significantly different than that based on classical WIMP interaction.

Accordingly, one of the main challenges in the development of avant-garde interactive systems, especially when considering their end-users, is the stage corresponding to the requirements specification. The LoUISE (*Laboratory of User Interfaces & Software Engineering*) Research Group has been carrying out research activities related to the development of both WIMP and Post-WIMP systems for the last 15 years. In this sense, this PhD thesis aims at following the same research line, thus improving the development of collaborative and Post-WIMP systems from a quality perspective, focusing on the specification requirements.

II. Socio-Economical Stakes & Industry Issues

Because of the popularity gained by the Internet in the last years, lots of classical working scenarios have changed to Web-based collaboration systems. Nowadays, millions of users share information and efforts by remotely collaborating on multiple application domains, either in a synchronous or asynchronous way. In this manner, the expected results of this PhD thesis are focused on several application domains: administration, business, education, medicine and so on.

Moreover, the introduction of new social and collaborative features in most of the existing applications makes necessary to develop avant-garde tools, environments and methodologies that facilitate its support. Concretely, collaboration tends to be performed in a more natural way by taking advantage of Post-WIMP interaction. Consequently, the limitations of current interactive systems developments need to be overcome, especially to provide support to the *context awareness*.

III. Research Questions

Taking into account both a literature review and the previous research carried out by the LoUISE group, the following shortcomings and needs for the development of Collaborative & Post-WIMP systems were identified:

1. We have identified different proposals for the development of CSCW systems [10, 28, 35] and Post-WIMP systems [18, 20, 29]. Nevertheless, they only focus on design activities hardly dealing with the first stages of the development process itself.
2. For the development of CSCW systems, a critical issue is the identification of the user's *awareness* [11–13], that is, the identification of artifacts to manipulate, users to interact with, etc. Such awareness concept is mainly associated to characteristics of the software product itself and accordingly, to requirements awareness.
3. Another important issue when developing CSCW & post-WIMP systems is related to *adaptation*, especially when a system has to be used in different contexts as claim international standards, such as ISO/IEC 9126-1:2001 [17] or ISO/IEC 25010:2011 [15].

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Taking into account the previous shortcomings and needs, our research questions (RQ) were established as follows:

- *RQ1*: What, if any, are the shortcomings of current RE techniques for specifying CSCW systems? If so, how can they be improved?
- *RQ2*: What, if any, are the shortcomings of current RE techniques for specifying Post-WIMP systems? If so, how can they be improved?
- *RQ3*: What awareness requirements can improve the user-perceived quality of CSCW & Post-WIMP systems?
- *RQ4*: What adaptation requirements would help to make the CSCW & Post-WIMP systems self-adaptable to their context?

With these RQs, the main technical challenges associated with them are mainly related to the novelty of the studied domain. On the one hand, CSCW systems have been widely dealt from the nineties. However, almost none effort have been put into their RE specification. On the other hand, avant-garde Post-WIMP applications are relatively new-fangled systems. Consequently, we will have to deal with a not-very-mature family of emerging systems for which RE is just starting.

IV. State of the Art

As aforementioned, a CSCW system is a software product where several users work in a collaborative manner, thus performing collaboration, communication and coordination tasks (3C) [5]. In order to perform such tasks, users must be aware of who is able to collaborate, where they are working, what they are doing, when they did certain action and so on. These and several other elements of which the user of a CSCW system must be aware of were identified in the Gutwin's *Workspace Awareness* (WA) [11].

The problem arises when trying to specify the requirements of these CSCW systems by using well-known RE techniques such as Use Cases [19], Viewpoints [8] or Goal-Oriented (GO) [21]. That is because these techniques are not able to properly specify CSCW requirements due to the complexity of the 3C tasks and the user's awareness needs. Because of that, well-known RE techniques should be adapted in order to deal with CSCW requirements properly. Moreover, awareness in Post-WIMP applications goes beyond the collaborators themselves, thus creating the need of being aware of the whole context that surrounds the user [9]. As an example, in classical WIMP application, it could be relatively easy to know where the artifacts we are working with are (e.g. the paragraphs in a document or the items in a 2D classical game). However, when interacting with Post-WIMP systems, users must be aware of the system's artifacts by using several senses. For instance, in a Virtual Reality (VR) environment, a user cannot see something that is behind him/her although it can be perceived by using the rear speakers of a surround sound system, as shown in Fig. 1. Because of this need of context awareness, the set of awareness requirements needs to be enriched to properly specify the requirements of Post-WIMP applications.

Finally, although there are several proposals for the development of Post-WIMP systems, they are mainly focused on the design and implementation of their user-interface, not paying special attention to early stages of such developments, i.e. the requirements specification [10, 28, 35]. Because of this lack of RE techniques for Post-WIMP systems, its requirements are usually specified by using well-known techniques, in a similar way to CSCW systems. The limitation here is that well-known RE techniques focus on WIMP systems, so that the introduction of the context adaptation during the software development is just delayed to the latest stages of the process. This means that, basically, the WIMP systems are able to self-adapt to the device screen and/or communication capabilities [27, 34]. Nevertheless, context adaptation for Post-WIMP applications is far more complex due to the richest real-time hardware-depending adaptation. For instance, in VR games, a user could be aware of receiving damage by means of vibrators [24][26] located on several parts of his/her body. However, if these wearable vibrators were unavailable for any reason, it would be needed an adaptation to provide the user with a visual method such as to show him/her a body representation in a VR display device highlighting the damaged area. Because of these complex adaptation features, it is necessary to deal with them from the very early stage of the development, i.e., since the requirements specification. As far as we know, some works related to adaptation requirements have been carried out [1][2], although none of them focus on Post-WIMP.

Fig. 1. User playing a Post-WIMP First Person Shooter

V. Research Method

In order to perform this PhD thesis, the *design science research* method [14] is being applied. Hence, in order to be compliant to this method, its seven research guidelines will be followed:

1. *Design as an Artifact:* The aim of this research is to produce a series of artifacts: a CSCW & Post-WIMP RE specification language (model), a methodology to apply it (method) and a CASE tool (construct).
2. *Problem Relevance*: The application domain of this PhD thesis is CSCW and Post-WIMP systems. The former is getting more and more popular since the nineties. The later constitutes the foundation of future (and even present) applications. Because of these reasons, the problem relevance is ensured.
3. *Design Evaluation*: Our research will be led by empirical evaluations. In this sense, all the developed models, methods and constructs will be evaluated by means of

controlled experiments and case studies in order to assess and improve them.

4. *Research Contributions*: As anticipated in the first guideline, the clear contribution of this research is a framework for the specification of CSCW and Post-WIMP systems including a modeling language, a supporting tool, a set of methodological guidelines, and a collection of user's awareness requirements.
5. *Research Rigor*: Throughout the research process, several Software Engineering methods [23, 55], statistical techniques [4, 54] and international standards [15–17] will be used in both the construction and evaluation of the artifacts.
6. *Design as a Search*: The research will follow an iterative process whose goal is the quality improvement of CSCW and Post-WIMP systems by providing proper RE techniques. Then, the set of obtained results will be iteratively evaluated and improved until the previous goal is fulfilled.
7. *Communication of Research*: The research result must be presented to a technologically-oriented audience. With this aim, there will be detailed publications related to the research artifacts, focused on RE practitioners, enabling them to use the research artifacts. Moreover, it will also provide researchers with the required documentation for further extension and evaluation of the research artifacts.

Within this PhD thesis, the PhD candidate and the LoUISE group members will participate in the performance of the next activities, whose timing is depicted in Fig. 2:

- *State of the art*: Research issues related to RE, CSCW, Post-WIMP environments, awareness interpretations and adaptation will be identified. This activity will be performed repeatedly throughout the whole PhD thesis.
- *RE for CSCW Systems*: Development of a RE integrated proposal for the specification of CSCW systems, supported by Model-Driven Development (MDD) techniques taking advantage of previous experiences of the LoUISE group [32][33]. Moreover, modifications of processes described by existing CSCW methodologies will be also considered.
- *RE for Post-WIMP Systems*: The suitability of the developed CSCW proposal will be assessed for Post-WIMP systems. Consequently, those modifications required to achieve its suitability will be analyzed.
- *Awareness Requirements*: Identification, development and assessment of an integrated awareness interpretation gathering the most important awareness requirements that a user participating in Post-WIMP environments (whether collaborative or not) can need or expect.
- *Adaptation Features and RE*: Analysis of the RE proposal with regard to the adaptation features necessary for post-WIMP systems. Moreover, the proposal will be integrated into a new version of UsiXML (*USer Interface eXtensible Markup Language*) [7, 22]. This language, in whose definition the LoUISE group has been actively involved, is widely accepted by the community for expressive capabilities for specifying adaptation needs of WIMP systems. Therefore, it will be extended or adapted for dealing with Post-WIMP systems.
- *Support*: Throughout this PhD thesis, several tools will be implemented in order to put into practice the developed proposal.
- *Validation*: In order to validate the developed proposal, several prototypes will be implemented focusing on different application domains such as e-learning or rehabilitation or Post-WIMP CSCW in which the LoUISE group has previous experience [6, 25, 31].
- *Diffusion*: Throughout the whole process of this PhD thesis, different publications will be submitted to both national and international conferences and journals in order to receive feedback. Moreover, as a part of this diffusion process, the dissertation associated to this PhD will be written.

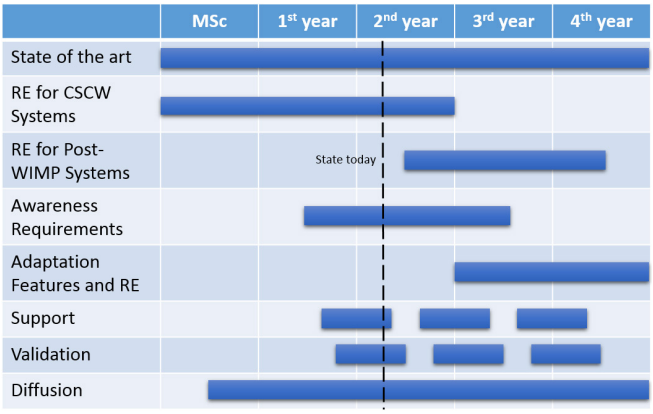

Fig. 2. Schedule of activities

VI. Contributions

In this Section, the contributions of this PhD thesis so far are presented. This will be done by describing the contributions according to the RQ they are related to in different subsections. Finally, the list of the papers published by the candidate will be presented.

A. RQ1: RE for CSCW Systems

The very first task performed when this PhD thesis started was the study and comparison of the existing RE techniques when dealing with CSCW requirements. With this aim, Use Cases [19], Viewpoints [8] and GO [21] were empirically evaluated, concluding that GO approaches were the most adequate to specify CSCW requirements [41]. This results led us to analyze the most widely adopted GO proposals, NFR Framework [3], KAOS [21], *i** [56], in order to identify which one was the most suitable for CSCW systems. After a second empirical evaluation [37, 45], *i** was selected as the best alternative. However, it was also detected that *i** suffers a lack of expressiveness to specify features of CSCW requirements, such as to specify the collaboration among users as well as the need of awareness to perform such collaboration. These shortcomings led us to the development of CSRML (*Collaborative Systems Requirements Modeling Language*), a GO approach based on *i** to properly specify the requirements of complex CSCW system, able to deal with 3C tasks and awareness needs [42, 49]. Moreover, CSRML was empirically validated with regard to *i** by means of a family of experiments

[44, 51], showing that it is more understandable than *i** when CSCW systems have to be specified.

Once CSRML was evaluated, a CASE tool, namely CSRML Tool 2012 (CT'12), was developed in order to help RE practitioners to specify CSCW requirements with CSRML. Hence, CT'12 was created as a Visual Studio extension to model and validate CSRML requirements specifications in a visual and straightforward manner [48]. Moreover, the usability of the tool was empirically evaluated by means of a controlled experiment [38] that provided really positive results. Thanks to this evaluation, several usability flaws were detected and solved in the following release of the tool CT'13.

Furthermore, the aforementioned CSRML language and its supporting tool were combined to define CSRMF (*Collaborative Systems Requirements Modeling Framework*) [46]. This framework also includes a set of guidelines helping analysts to identify and model the whole set of requirements of collaborative systems. Hence, by using the CSRMF guidelines, a CSCW system can be specified starting from the identifications of its (groups of) users and roles, and finishing with the collaboration, awareness and quality factors specification.

Finally, CSRML has proven to be suitable for different application domains, as demonstrated on its brand new extension called CSRML4BI [53]. By means of this extension, CSRML has been used to model collaboration in systems of Business Intelligence (BI) by specifying a clear view of the involved tasks, their participants, and the information to be shared between them.

B. RQ2: RE for Post-WIMP Systems

Regarding the second RQ, its analysis has been started recently so that, there are no significant results yet. Concretely, the first work is being carried out and consisted in specifying the requirements of a complex highly-awareness-demanding and context-depending Post-WIMP system by using the CSRML language. The main goal of this work is to assess whether CSRML provides enough expressive power for specifying post-WIMP systems. It is worth noting that the case study is being defined with the support of several researchers of the LoUISE group who are experts in Virtual Reality (VR).

C. RQ3: Awareness Requirements

As far as this RQ is concerned, the state of the art regarding awareness interpretations has been already carried out. The first conclusion has been that Workspace Awareness (WA), as defined by Gutwin et al. [11], is the most widely and applied interpretation when talking about CSCW. Nevertheless, when it is applied to Post-WIMP applications, such as Augmented Reality (AR) or VR environments, there are some awareness requirements that WA cannot identify. For instance, awareness of future facts or social characteristics cannot be identified by using WA. Because of that, a deeper analysis of the available awareness interpretations has been carried out paying special attention to those concepts shared by more than one interpretation.

The result of this analysis was an awareness requirements catalogue able to represent the most frequent concepts. This catalogue led us to develop a new awareness interpretation for Post-WIMP systems, able to represent the awareness requirements of such systems, that includes present, past, future and social features [36]. Furthermore, the proposed awareness interpretation was empirically evaluated in order to determine whether all the considered awareness elements would improve the user experience of Post-WIMP systems. Concretely, two of the most widely played contemporary 3D games were chosen to perform this evaluation. It was concluded that all the elements of this interpretation improve the user's gaming experience, especially, those which were not already identified in WA.

Finally, based on WA, a design pattern has been defined to provide CSCW designers with the scaffolding for their collaborative applications [40]. This pattern includes elements that feature CSCW systems implementing WA, such as collaborative actions among users, shared artifacts and views, common goals, etc.

D. RQ4: Adaptation Features and RE

The last one of the RQs is in an early stage yet. So far, we are working on the integration of UsiXML and CSRML. UsiXML, the specification language for user interface design, is being adapted or extended to support Post-WIMP applications. Hence, CSRML is intended to be the part of the next UsiXML version by providing proper traceability between requirements and the following stages of the software development process. However, since this integration is being carried out, there are no publications related to this RQ.

E. Publications

The papers published by the candidate up to date related to his PhD Thesis are shown in Table I.

VII. Conclusions and Pending Work

This PhD thesis, which started with the study of the suitability of current RE techniques for CSCW systems, has achieved its greatest accomplishment with CSRML, a Goal-Oriented RE language to model CSCW system requirements. It is worth noting that our research process has been fully led by empirical evaluations, thus assessing every result. Nevertheless, in spite of the suitable acceptation that CSRML has had (as the number of downloads of both the tool and the different papers shows), a considerably amount of work remains to be done.

Regarding RQ1, the CSRMF framework has been defined. However, this framework requires a full methodology in order to help RE practitioners to elicitate, model, analyze, verify and validate CSCW systems. With this aim, the already available methodologies for *i** are being studied for their integration into the CSRMF framework.

The work related to the RQ2 has just started. In this sense, once the case study is specified, the suitability of the current CSRMF framework for Post-WIMP requirements will be assessed. It is very likely that this assessment will lead to an adaptation of CSRMF so that it provides the necessary guidance for specifying the requirements of Post-WIMP systems.

TABLE I. PUBLICATIONS RELATED TO THIS PDH THESIS TO DATE

Publication	RQ
JCR Journals	
Analyzing the Understandability of Requirements Engineering Languages for CSCW Systems: A Family of Experiments [51] (IST, Q1)	1
A CSCW Requirements Engineering CASE Tool: Development and Usability Evaluation [38] (IST, Q1)	1
An Awareness Interpretation for Contemporary Computer Games (submited, HCI, Q2) [36]	3
CSRMF: A Framework for Modeling Requirements of CSCW Systems (submited, RE, Q2) [46]	1
International CORE Conferences	
An Empirical Evaluation of Requirement Engineering Techniques for Collaborative Systems [41] (EASE, CORE A)	1
A Comparative of Goal-Oriented Approaches to Modelling Requirements for Collaborative Systems [37] (ENASE, CORE B)	1
CSRML: A Goal-Oriented Approach to Model Requirements for Collaborative Systems [49] (ER, CORE A)	1
A Design Pattern for Representing Workspace Awareness [40] (CSCWD, CORE B)	3
CSRML4BI: A Goal-Oriented Requirements Approach for Collaborative Business Intelligence [53] (ER, CORE A)	1
International Workshops	
An extension of *i** to Model Requirements for CSCW Systems Applied to Conference Preparation System with Collaborative Reviews [42]	1
Assesing the Understandability of Collaborative Systems Requirements Notations: an Empirical Study [44]	1
CSRML Tool: a Visual Studio Extension for modeling CSCW Requirements [48]	1
Book Chapters	
Comparing Goal-Oriented Approaches to Model Requirements for Collaborative Systems [45] (selected paper from ENASE)	1
National Conferences (*[a] Published in Spanish)*	
Modeling Collaborative Systems Requirements with CSRML[a] [50]	1
CSRML Tool: A Tool for Modeling Collaborative Systems Requirements[a] [47]	1
Analyzing the Understandability of Requirements Engineering Languages for CSCW Systems: A Family of Experiments (disclosure of relevant published papers) [43]	1
A CSCW Requirements Engineering CASE Tool: Development and Usability Evaluation (disclosure of relevant published papers) [39]	1
Multidevice Tool for Collaborative Editing EMF-based Models[a] [52]	2,3

Regarding RQ3, a new awareness interpretation has been defined to gather the awareness requirements of CSCW & Post-WIMP systems. This interpretation has been positively evaluated by means of a survey filled in by users. However, in order to evaluate it more exhaustively, further experiments will be carried out involving in a more active way to the subjects. Moreover, and also related to RQ1, the WA design pattern purposed will be extended to consider this new awareness interpretation. Once the new pattern be developed, and taking advantage of the MDD approach, the necessary transformations will be specified to allow the designers to instantiate this pattern from the requirements, specified by means of CSRML, in an automatic way. This support is considered a must for this proposal to provide the necessary traceability throughout the whole development process.

Finally, since the analysis of the RQ4 has just started, there is a great deal of work to do. The first task is the integration of CSRML in the new version of UsiXML. This integration is being defined to provide CSRML with expressive power for specifying adaptability requirements necessary for Post-WIMP systems. Currently, it has been detected that the expressiveness for tasks, already provided by CSRML, should be extended or adapted to consider the *context* of the system (i.e. available hardware, communication channels, user capabilities and even environmental factors).

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