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Multi-Site Software Development and Its Challenges in Requirements Engineering Using Goal Based Approach

FATIMA ZOHRA, MISBAH IQBAL & NADEEM MAJEED
University of Engineering and Technology, Taxila Pakistan
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ABSTRACT Global Software Development has gained significant acceptance in recent times. Commercial and technologies reasons have both triggered a global offshore software development. Offshore software development has become a development model of choice for many organizations due to cost and other advantages such as time efficiency, etc. Studies have revealed that cross-site or multi-site work takes longer than the single-site work and that software teams working in offshore and diversified environment face problems such as development delays, requirements understanding *(*RU), issues of collaboration, among others. The aim of this paper, therefore, is to identify the challenges of Global Software Engineering in multi-site software development and its influence on factors of development. The paper also examines ways of supervising and managing these challenges in order to perform the multi-site offshore development effectively and efficiently.

Keywords: Requirements Understanding (RU), Requirements Engineering (RE), Global Software Engineering (GSE), Goal based Approach (GBA), Global Software Development (GSD)

Introduction

Since the beginning of the 21st century the term 'globalization' is commonly used in and has also crept into the field of software development. Globalization of any organization, particularly software organization, account for a significant factor in business expansion and profitability (Yucel and Dagdelen, 2010). Communications between different stakeholders of [mostly] large organisations take place in globally dispersed geographical regions. These regions have different cultures, languages, environment and approach towards different areas. The phases of software development lifecycle (SDLC) contain mainly requirement analysis, design, implementation, testing and evolution. In any first phase of requirement analysis, the requirement engineer or analyst has to determine whether this requirement is valid or not as well as how it can be further designed. For this, the analyst has to be well informed and knowledgeable about the contextual information needed for analyzing requirements of stakeholders that belong to different global positions.

The increasing demand of software market globally has invariably focused attention on the engineering process required in different multi-site software firms and organizations. During the requirements elicitation or gathering phase, for example, it is might be difficult to negotiate and collect all necessary functional, non-functional requirements and constraints. This negotiation issues become more intense and severe when the environment in which the organization operates is not amenable to prevailing culture in the community. A multi-site organization with virtual offices at different sites all over the world will have to ponder about the communication and synchronization across them. It is therefore important to analyze and study the consequences of these problems in the process of software requirements engineering.

Software engineering is continuously transforming; its methodologies continue to develop from hitherto traditionally centralized development to a more portable distributed development operating, some cases, beyond geographical borders. Studies suggest that software projects have been developed in collaboration between USA and India (Herbsleb, 2001) and Asia and Europe (Carrmel, 1999). Most common problems that occur during this type of development systems relate to communication and collaboration both of which involve [mostly] in early activities of requirements gathering, planning, analysis and negotiation.

When the concept of globalization first crept into the software industry, it was not unusual to meet customer requirements via arranging face-to-face meetings or even visiting the user operational base. Various techniques were used in this respect like prototyping the requirements and then doing alpha or beta testing before deciding whether the requirements are correct or not. But

when the organizations continue to expand its services all around the globe through internet technologies and virtual offices, it became increasingly difficult to interact with customers across the globe (Matthews and Thakkar, 2012). Remote development sites also face enormous problems in conducting the requirements engineering activities like requirements elicitation, requirements analysis and negotiation, requirements specification and requirements validation – because of only the validated requirements could be agreed upon and further processed.

The world has become a global village where technologies are lifeblood and where software organizations are moving from location-dependent development methods to offshore development methods. Global Software Engineering (GSE) has gained significant acceptance in recent times. In GSE, different [geographically dispersed] development teams work together to continuingly refining relationship with customers—something that is generally accepted as the main strength of GSE. Other strengths of GSE are: less usage of development time and resources and shorter turnaround time for development. In spite of these strengths, however, GSE also its weaknesses—such as dealing with the challenges of co-ordination, cultural diversity, communication, trust, and knowledge management (Herbsleb, 2001).

In the process of GSE, requirement gathering is considered to be the most critical phase (*D. E. Damian, 2003*). Requirement engineering is a complex and mass concentrated action but GSE – or offshore software development – had made it further complicated. In requirement engineering (RE), requirement gathering is being affected by the problem of coordination and communication among organizations. Another problem relates to requirement understanding. Problem of requirement understanding (RU) might occur at any stage of requirement engineering like requirement specification, requirement prioritization and requirement negotiation. Requirements are often misunderstood by challenging factors in GSE such as cultural and time zone issues, deficiency of coordination among different teams and lack of communication.

Since the beginning of the century, software development, management and its maintenance have developed and evolved from a single-site concentration to a multi-site, global and distributed software development. This trend is due to a number of reasons—a significant global growth in demand for software services and software products to which many IT firms often struggled to meet. Nonetheless, multi-site organizations face problems in communicating between cross-functional stakeholders comprising individuals based at the headquarters and off-site [often distance] developments workplaces. Studies have been carried out examining aspects of negotiating requirements with off-site stakeholders (*Damian, 2000*) none have yet address the requirement understanding in global software development or GSE. This paper aims to fill this gap. The paper will

seek to identify main challenges facing software organizations that are multi-site and have cross-functional stakeholders. The paper will address the challenges using Goal Based Approach.

Brief Literature Review

Since 1960s, software development has become challenging due to issues of customer satisfaction, low quality, scheduling and cost effectiveness concerning products and services delivery. Kotonya (1998) describes one of the key issues as requirements misunderstanding and complications regarding requirements. Requirement engineering is the first phase of software development lifecycle (SDLC). Requirements must be cleared in all phases of Requirements Engineering (RE) – i.e. requirement gathering, design, development, testing and maintenance all requisite in getting good quality products. At the end of the RE phase, its output is considered as the input to the next phase of software development i.e. the design phase. Similarly, the output of the design phase is considered as the input to the development (coding) phase and so on until a final product is released. So, if at the start of a software development lifecycle, the requirements at the initial phase are understandable, clear, precise and accurate, the outcome will be high quality product, but if requirements are ambiguous and are not well understood in the starting phases then the quality of resulting product will be of low resulting in unfulfilled customer needs and cost and schedule overrun over run.

GSE Challenges on Requirement Engineering

Requirement Engineering serves as the most challenging and critical phase of SDLC in GSE as discussed in the previous paragraphs. Global software engineering addresses challenges presented by time zone differences, cultural diversity, geographically-dispersed environment, communication gap, communication/ coordination breakdown, etc in Requirements Engineering (RE). The following paragraphs will highlight some of the challenges of GSE challenges in RE.

Cultural differences may lead the requirements to misunderstanding and miscommunication among software teams as people from *different cultures* have different beliefs, views and values. For example, multi-site [and often multicultural] development teams that are located in diverse corners of the globe will almost certainly interpret requirements differently according to their cultural values and beliefs. These differences in views are very hard to interpret and generate problems like conflicts, misinterpretation and ambiguities in requirement understanding.

Similarly**,** *time zone* can also have an impact on requirements as the time required for synchronized communication among teams might be short. However,

in multi-site development area where communication is not synchronized might cause a delay and misunderstanding of requirements.

Another challenging factor on multi-site software development is Knowledge Management. The 'absolute' requirements might not be shared with the customers present in the multiple remote sites, with the developers. In order to reinforce the power of various positions in companies, business requirements are further directed towards the developers through the direct stakeholders and development team manager.

Furthermore, while doing offshore development, inadequate communication/coordination can also pose additional challenge. Remoteness may cause hindrance for the comfortable and interactive (face to face) communication as the stakeholder's interaction with the team depends upon the communication medium which can be synchronized or asynchronous. In GSE, different stakeholders like customers, developers and

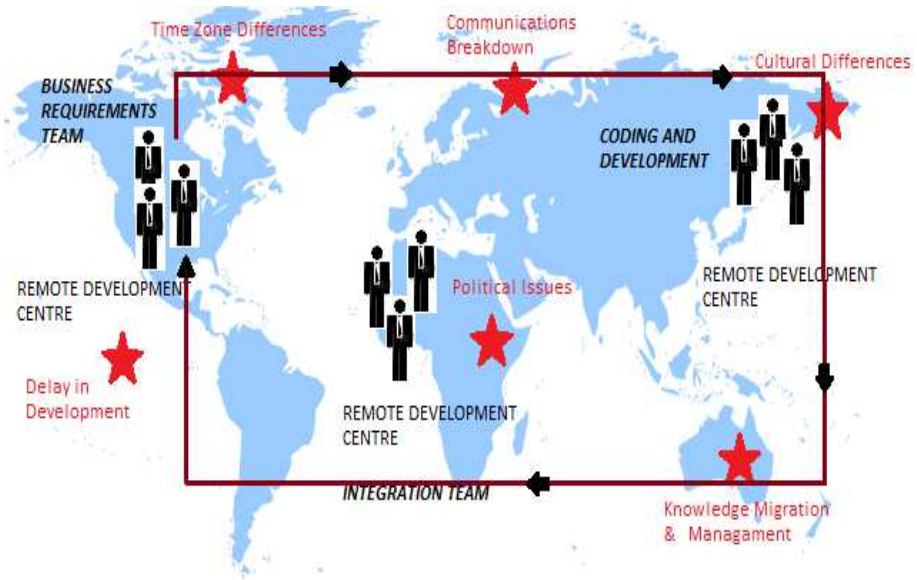

Fig 1: Problems in Multi-site Organization

Other management people from the software team just wanted to exert their control and authority over other offshore team members which may lead to an ineffective communication.

For achieving an effective association among the geographically distributed stakeholders and remote teams for negotiating the requirements that satisfies the offshore customer market. For this purpose, various techniques and technologies are used. Some of them are defined below:

Collaborative Development Tools

A review of the various methodologies used in such circumstances shows that globally distributed team can share their information or communicate with each other by using various media. It can be basic cellular phone, video conferencing, emailing etc. depending upon the conditions and needs. The most important among all of them is Emailing beyond formal meeting sessions among the key stakeholders of any software product. Since the stakeholders involved in any software product are mostly technology related so Emailing is not an issue for them. Hence phone and email is the major collaborating sources for them. Internet technologies have also reduced the tensions of communication. The main usage of Email is discussed below briefly:

Simple Email

Email is considered to be a leading asynchronous tool due to the factors of time difference. It serves astonishing in sending and receiving documents or files. Different versions of Software Requirements Specifications (SRS) can be easily transmitted between stakeholders through email. It has many advantages but it does contain some shortcomings as well when it comes to requirements management. It can provide the requirements containing each and every detail and these are automatically saved in written form. These requirements in black and white can give useful history of requirements that can be viewed any time with the availability of internet. The data is saved on the cloud and individuals are not obliged to keep a copy. They can access it whenever they need it through their emails. Customers who generally cannot specify their requirements in spoken and are not fluent in English can communicate effectively using email. It also does not take into account the differences in location and geographical regions and take feedback from different stakeholders.

Furthermore, it cannot handle ambiguous and vague requirements and data related to it. It is not that much interactive as it is required in requirements management so it results in difficulty to handle ambiguous requirements. For example you can invest your time and resources to answer an email and in the end you get to know that you misunderstood the question. Some Emails are not delivered due to some internet problems and some are forgotten because of large no of emails. Consequently the collaboration issues are not handled properly. These unhandled requirements may produce devastating results in the end. There is no surety of when the other person will see mail and reply back or even will reply back or not. This can induce substantial interruptions in managing requirements.

Rich multimedia for collaborative requirements analysis

It is formulated for the same purpose of collaboration and communication during the process of requirements gathering and analyzing among the distant stakeholders of the software project. National and international requirements engineers use this integrated computer technologies for meetings. In this method the tools or applications used are namely Microsoft PowerPoint, Microsoft Excel and NetMeeting. Microsoft PowerPoint is used to create diagrams or graphics that give an abstract level of system and the interconnection between its components when they are realized. Microsoft Excel is used to identify and capture the software practical requirements. To interact with other stakeholders residing on their own computers we can use NetMeeting that will help to work with the former applications interactively. Any of the stakeholders can create its document by accessing the documents residing on others computers. Now a day's videoconferencing and teleconferencing are also very popular mean of communicating and discussing software requirements in multi-site organizations. These tools help a lot in collaborating activities which might not be possible without them.

Another very effective tool used for collaboration activities among stakeholder is known as *Rational's Requisite Pro*, it is with all above common techniques. Its works on the principle that the requirements are imported into it, through which it generate an effective software requirements specification document. Further by using configuration/change management tool all the project members can access the latest copy of the requirement document.

Proposed Methodology

Managing the requirements from a wide range of customers and users serves as the basic and an essential problem in RE, as the geographical dispersion in GSE creates a lot of problems regarding requirements gathered for the development of the system.

In order to solve the problems and issues related to software requirements engineering in multi-site organizations, they must be first identified and measured. Some of the major issues and challenges identified by researchers but after a complete and detailed analysis in this domain, this paper describes some additional factors that have a great influence on development process. All such challenges after detailed observation are listed in this work. Through thorough consideration the major issues are mainly listed and challenges faced in this respect are:

Political

Political differences prevail in every organization and they are obviously different in two organizations acting in two diverse locations or country. Different workplace politics leads to different hierarchical structures and layers of the organization. These structural differences lead to communication and collaboration problems for the involved workforce.

Linguistic

Different geographical locations have their own language and accent. Though English is a universal language and most widely used for educational purposes but still people from different regions have their own accent and pronunciation. This fact might also hinder the process of requirements gathering and communicating with the stakeholders located at far off locations. Without understanding the language of the customer or peer worker software cannot be properly developed because language is the key to interact and communicate with each other.

Cultural Difference

Different organizations have different cultures even if they are located in the same country or city. The working environment of the employees working in an organization constitutes a culture. It also hinders the effective communication between different organizations particularly software organizations or even in same organization sited at different geographical locations. The behavior of human is so unpredictable in different scenarios and circumstances. So all this also affect the process of software requirements gathering and validation.

Geographical Dispersion

It is the root cause of all other issues regarding software requirements engineering in multi-site organizations. The geographical dispersion of the workplaces lead to the creation of almost all other challenges. This is the major realm that must be considered seriously. Due to disperse location they will have disperse time scales, working methodologies, cultures, languages and technological aspects.

Time Zone Difference

Different stakeholders that are dispersed in different places on the planet earth are also facing the problem of time zone differences. They cannot respond to the

email at that time and may take too much time to send a reply. This can be frustrating for the person waiting for an answer. This forbids the possibility of synchronous communication. For conducting an online meeting or something between stakeholders residing at different locations many compromises should be made with work routines. Mostly they are conducted very early in the morning or too late in the evening. Hence mostly the communications take place asynchronously through teleconferencing.

Knowledge Migration &Management

Knowledge management is the creation, transfer and application of knowledge among the people for competitive advantage of organization. In our case it is the creation, transfer and application of software requirements. In multi-site software organizations these requirements data is not properly managed and shared with the intended personnel. This can lower the strength of the organization.

Budget Management

Budgetary issues also come when you have to invest a lot in every group meetings and interviews. Whether they are formal or informal it will consume a lot of cost, time and resources. So budget management issues are also a major problem in the process of requirements gathering in multi-site organizations.

Change Management

Software requirements keep on changing with the passage of time and they are never determined as final. With the increased demand of innovations and creativity in the software application it seems impossible to get satisfy with the software system that is built with initially defined requirements. The process of requirements change is continued throughout the software development life cycle. Sometimes it becomes difficult to manage change and keep the inventory up-to-date in all of the multi-site organizations. It demands updated distributed repository mechanism.

Increased Competition

With the increased globalization in the software industry the organizations are experiencing tremendous increase in the competition and requirements of customers. Organizations now strive for excellence in order to meet the non-ending requirements of the customers and users. The requirements are like the

death race they will never come to an end. All this has made the requirements gathering and negotiation difficult to conduct.

Technology Management

It is the dilemma of software industry that its technology and development platforms keep on updating and changing after very short period of time. It becomes difficult for all of the organizations to cope with it and update their work environment. This hinders the collaboration process.

Communication/Coordination Breakdown

Distances have created hindrance in conducting face-to-face communications and daily formal meetings like standup meetings and retrospective meetings. Due to this alternative communication techniques as described in previous section are followed. In these collaboration processes there remain many chances of communication breakdown where data received on the other end is not exactly same as it was sent and in most cases it was not received. The information is distorted during the transmission.

Loss of Team-ness

When all the team members are not present in real and they interact virtually with each other than the sense of team work may get lost. He team will not be as much enthusiastic as needed. And they might feel less determined and assertive.

Delay in development speed

Delay in communication and collaboration results in delayed software product. The overall speed of development depends upon the delay in the communication between effective stakeholders of the project. This can frustrate the customer and eventually results in loss for the organization. This loss can be in the form of resource, time or cost or a combination of them.

Proposed Methodology (Goal Based Approach)

All such challenges had created complications while conducting RE activities in remote/offshore or multi-site software development. In order to overcome such issues to the maximum possible way, a model is proposed which is based on a goal based approach. After identifying challenges, we can use this model to

describe these challenges in further detail. Further explorations have shown that while resolving such challenges we have to face some more problems specified with each challenge. After that, the impacts of all these problems on various stages of requirement engineering process are described.

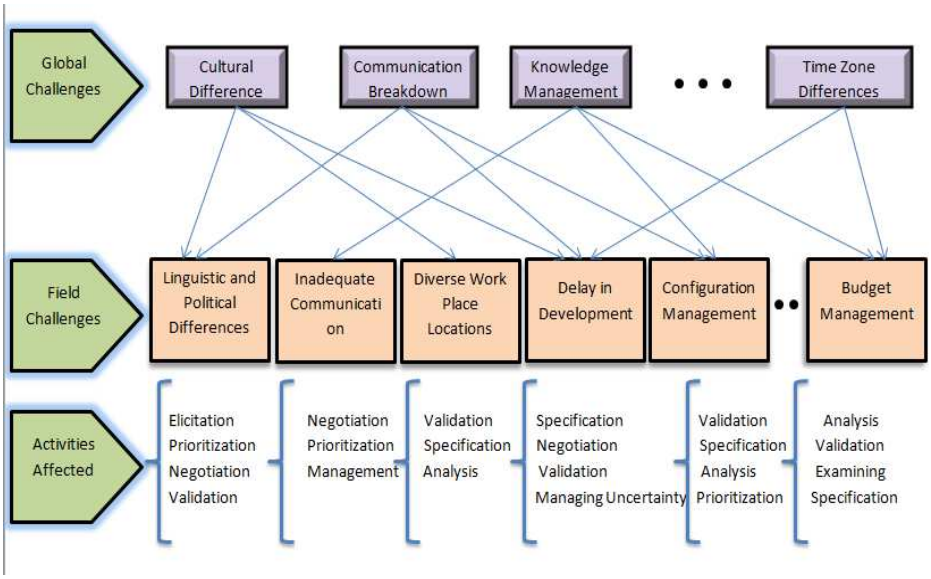

Figure 2: Proposed Approach that describes the relationship and impact of challenges over RE activities

The model defines a complex phenomenon that demonstrates the relationship between the identified challenges and problems present in the first two layers of the model with the help of arrows. These challenges are defined in the first layer of the models as goals that we need to overcome. They are further described in the later stages of the model and their impacts on RE activities.

Challenges like cultural diversity, linguistic differences, time zone differences, knowledge management etc. are set as goals which we have to face during multi-site development. These goals are set at the first layer of the model. Then in the second layer of the model, problems regarding overcoming these challenges are described. In the third layer, the impact of these challenges on different activities of requirement engineering. For instance, market trends and business needs may differ according to the values and demands of various cultures. Distances grows the probability of diversity in time, culture, values, knowledge criteria and some other problems of communication, lack of data confidentiality, delays and so on in present methodology.

The Figure 2 describes the relationship between the major challenges and its impacts on different requirement engineering activities like requirement nego-

tiation, specification, validation, and various others. It defines that which challenge will be caused by which factors and which RE phases are highly influenced by which challenge. In this way we can identify the nature of different challenges and their impacts throughout the whole development process in multi-site context.

Potential limitations of the proposed methodology

Although all the steps are there and proposed beforehand but still there are certain ambiguities that are unable to solve e.g. all the steps of RE could not yield 100% result or certainty. It may also be possible that the software requirements engineer or personnel disqualify some issues as goals and corresponding challenges or vice versa. Also it is possible that some leading goals are being missed by the respective authority to identify or analyze. So chances of human error is always there and it cannot be assured that it is an error free methodology. What it tries is to come to an optimal criteria or performance in SRE.

Conclusion

Research on the multi-site software development in a global context has an increasing popularity and has significance in multiple sectors due to which number of solutions to these identified challenges are reported by many practitioners. But most of the solutions have not been thoroughly evaluated. In this paper, the authors define almost all the identified challenging factors and problems like lack of discussions, limited knowledge sharing, cultural differences, loss of team -ness, lack of interactive meetings etc. that come in the way of doing effective offshore software developments. Software teams in multi-site development face all such challenges and need to overcome these issues in the best possible way in order to generate an effective output as a result of GSE. To overcome all these problems this paper proposed a model based on goal approach in which challenges are considered as goals which software firms need to resolve by achieving them. This approach defines these challenges in detail and cover different reasons that directly influence the development procedure. It also elaborates the impacts of these problems over different phases/activities of RE and their relationship.

Correspondence

Fatima Zohra, Software Engr
Software Department
University of Engineering and Technology, Taxila
Pakistan
Email: chunkbar@yahoo.co
Tel: +923455065079

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