Analysing Requirements Negotiation in Software Ecosystems with Multi-Agent Systems Techniques

George Valença[1], Carina Alves[2], Patrícia Tedesco[2], Lucas Moreno[2]

[1]Departamento de Informática – Universidade Federal Rural de Pernambuco (UFRPE)
Recife, Pernambuco – Brazil

[2]Centro de Informática – Universidade Federal de Pernambuco (UFPE)
Recife, Pernambuco – Brazil

georgevalenca@deinfo.ufrpe.br, {cfa,pcart,lma5}@cin.ufpe.br

Abstract. *A Software Ecosystem (SECO) can be seen as a distributed network of software companies interacting either in a cooperative or competitive manner, being connected by a shared platform. They participate in complex interrelations and play different roles. This perspective brings several social, managerial and technical challenges. The goal of this paper is to investigate the challenges involved in requirements negotiation within a SECO. In particular, requirements must be negotiated by multiple and distributed actors, who have different and sometimes conflicting expectations. This paper starts a discussion on requirements negotiation strategies for a SECO by drawing concepts from Multi-Agent Systems field.*

1. Introduction

Software Ecosystem (SECO) sheds light on the co-evolutionary relationships of organisations in the software industry. Software companies become connected to a wider business strategy and share a technological platform. According to Jarke and Lyytinen (2010), this perspective shifts from projects where systems are developed from scratch to a broader landscape of integration of existing applications and interdependent networks of developers and users.

Santos et al. (2012), and Campbell and Ahmed (2010) stress that SECO approach impacts on the traditional Software Engineering (SE) models and requires novel processes.Accordingly, it brings new challenges to Requirements Engineering (RE). By putting together multiple and dispersed actors, SECO approach hampers requirements elicitation, communication and negotiation, state Manikas and Hansen (2013). In particular, Bosch and Sijtsema (2010), Fricker (2009), Kazman and Chen (2010) highlight that negotiation activities face constraints such as:

- Actors in an ecosystem are diverse and globally distributed, which causes the inefficiency of negotiation activities that rely on face-to-face communication or that assume interaction between teams;

- The majority of requirements are defined by participants of the ecosystem, rather than elicited from users. Requirements emerge through communications amongst the actors of the ecosystem, whose expectations and goals must be understood to align needs with solutions;

- Since players must create value while providing innovation within the ecosystem, requirements definition cannot be disconnected from business processes governing the ecosystem (e.g. product management). Hence, business strategy of SECOs must guide the negotiation and prioritisation of requirements that will turn into product functionalities.

Recent research in SECO has examined the relationships among stakeholders and communication aspects during RE (Fricker (2009, 2010), Knauss et al. (2012)). However, there is no proper guidance on how organisations should conduct RE activities in a SECO, states Huang et al. (2013). This paper explores this issue by focusing on requirements negotiation along ecosystem's evolution from a social dimension. We start a discussion on how to conceive requirements negotiation strategies for SECO inspired by Multi-Agent Systems (MAS) field. Briscoe (2010) claims that any ecosystem can be analysed making use of MAS concepts. These establish a basis to define the key properties of an ecosystem and allow one to reason about its functioning.

The outline of this paper is as follows. Section 2 provides an overview of SECO field and reports on related work. Section 3 outlines our proposal for requirements negotiation within SECO. Section 4 discusses the use of concepts from MAS to develop requirements negotiation strategies for SECO. Finally, Section 5 concludes the paper and presents future research.

2. Background and Related Work

The emergent notion of SECO is described by Bosch (2009) as *"a set of software solutions that enable, support and automate the activities and transactions by the actors in the associated social or business ecosystem and the organizations that provide these solutions"*. This concept is gaining popularity amongst large organisations and relies on the adoption of a common technological architecture for multiple product development; state Campbell and Ahmed (2010). Examples of SECOs are the closed commercial oriented Apple and Microsoft, and the open social oriented Eclipse and Drupal.

In a SECO, organisations participate in complex interrelations and play different roles. Hanssen (2012) describes three fundamental role types in a SECO. The keystone is one organisation or a small group that leads the development of the central software technology. Niche players are third party organisations that use the central technology as a platform to develop related solutions or services. Finally, end-users of the central technology need it to carry out their business.

According to Campbell and Ahmed (2010), a SECO can be examined from three perspectives. In its business dimension, we can analyse factors such as vision, innovation and strategic planning. It also encompasses profit and financial revenues of the companies. Its architectural dimension is concerned with Domain Engineering, Product Line Architecture, and Commonality & Variability Management. Finally, SECO social dimension is related to the actors in the cooperative development environment. It addresses the relationships among companies in the ecosystem.

The decentralised and collaborative nature of SECOs has its roots in Distributed Software Development. In this field, Daniela Damian's evolved the understanding of distributed negotiations by exploring the use of mixed media for requirements selection.

Damian et al. (2008) discusses the combination of synchronous and asynchronous media during negotiations. It evidences that negotiations are more effective when asynchronous discussions of requirement issues are undertaken prior to synchronous negotiation meetings. In its turn, Seyff et al. (2005) proposes an approach based on the EasyWinWin technique for distributed contexts. It promotes active negotiation among success-critical actors to improve cooperation in decision-making, with the support of the ARENA (Anytime, Anyplace REquirements Negotiation Aids) application.

Kukreja (2012) considers the increasing popularity of Facebook to conceive an innovative way for collaborative requirements elicitation and management. The tool is named Winbook and was essentially designed to follow the WinWin negotiation process. It is based on the social networking paradigm and email organization using labels. Alimazighi and Boumahdi (2011) investigates the complexity of RE in a scenario of networked organisations. The study adopts MAP process models to comprehend the multiple goals that arise from interconnected companies. A collaboration model between common and shared goals is established, supporting requirements analysis.

In SECO field, Samuel Fricker contributed to the analysis of RE practices. Fricker (2009) proposes a modelling notation based on negotiation and network theory to describe a requirements communication network in a SECO. The approach focuses on the relationships among interdependent players that need to collaborate and agree with each other to bring new products and systems to success. Fricker (2010) introduces the notion of "requirement value chain". It describes connections among several actors and requirements information diffusion from end-users or customers to the ecosystem.

The former proposals seek to define mechanisms that foster interaction of stakeholders to align goals and priorities. However, there is a need to examine actors and relationships properties in a SECO to evaluate their influence on a shared decision-making. We believe that exploring this gap we may pave the way for SECO success.

3. Towards a Requirements Negotiation Model for SECO

Requirements negotiation involves a decision-making process conducted by several different actors along SECO lifecycle. Based on Moore (1993), such evolution is composed by four stages. At birth, the ecosystem focuses on defining customer requirements. Players join the SECO to participate in the conception of products and services that meet market needs. During expansion, the SECO experiences the growing of the software platform and customer base, with disputes among rival ecosystems. At leadership, the SECO proves to be profitable and internal disputes emerge among participants to get more power. Lastly, the self-renewal stage aims to keep the ecosystem strong by increasing its capacity to innovate and adapt to changes.

In this networked scenario organisations become part of a value chain and the decisions taken should be aligned with the Software Platform Management, states Peeters (2012). This framework consists of four macro processes: Portfolio Management, Roadmap Definition, Release Planning, and Requirements Management. The later includes requirements gathering and prioritisation by relevant stakeholders.

Given this context, our premise is that an appropriate requirements selection directly contributes to ecosystem success. Our intention is to deeply understand the

particularities of RE in SECO to develop a Requirements Negotiation Model (Figure 1). This model aims to provide a group of strategies that support the decision-making involved in negotiation activities. Its initial structure is established over three dimensions, which are following presented:
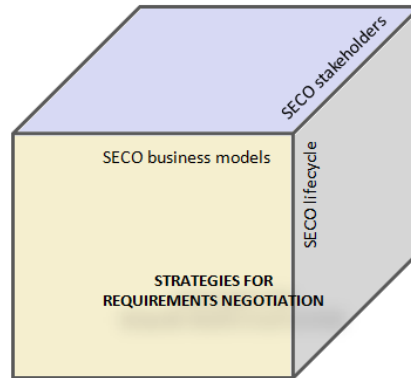

Figure 1. High-level representation of the model initial structure

- **SECO stakeholders**: it explores the relations among organisations and their influence on requirements definition in a SECO. This dimension shall describe the origins and flows of influence in requirements negotiation, as well as the steps taken by stakeholders during this activity. It must also detail the factors that should be considered during decision-making, having stakeholders' goals and constraints as parameters.

- **SECO lifecycle**: it analyses requirements negotiation along lifecycle phases. This dimension will depict how negotiation strategies assist the ecosystem to thrive by considering the health elements productivity, robustness and niche creation, as defined by Iansiti and Levien (2004). It shall explore how strategies collaborate to enhance products performance and shape SECO evolution.

- **SECO business models**: this dimension must consider the varied dynamics of cooperation and competition among organisations to propose negotiation strategies. Valença and Alves (2013) present one possible classification for SECO as commercial or social environments. The iPhone ecosystem illustrates the first type, where suppliers, external integrators and customers are related via financial transactions. The later type concerns communities such as Eclipse, where a consortium represents the wishes and commands of the members.

The requirements negotiation model shall be integrated in the Software Platform Management. Peeters (2012) presented this framework as an evolution of Software Product Management, for organisations with a directed SECO approach. However, it does not provide these companies with mechanisms for requirements negotiation. Hence, we aim to enrich its Requirements Management process by proposing negotiation strategies for SECOs. In the following section we discuss how Multi-Agent Negotiation Techniques can inspire the definition of these strategies. We outline the adaptation of these concepts to RE in SECO.

4. Applying Multi-Agent Techniques in Requirements Negotiation

SECOs are inherently distributed systems, with self-interested components that often need to reach agreements. We can thereby draw concepts from Artificial Intelligence when proposing strategies for requirements negotiation. In particular, Multi-Agent Systems (MAS) area focuses on the relations among several autonomous agents. They interact with each other to either further their own interests or in pursuit of a joint goal, states Woolridge and Wooldridge (2001). Hence, MAS provides a useful background considering its long research on models and techniques for automated negotiation.

In MAS, it is essential to establish means of coordinating efforts. This allows agents to pool their knowledge, goals and skills to solve complex problems, claim Bond and Gasser (1988). When acting in an environment, agents may act either cooperatively or competitively, states Demazeau and Muller (1990). In both situations, it is often the case that agents need to reach a consensus due to a shortage of resources, for instance. They thereby engage in the process of negotiation.

According to Raiffa (1982), negotiation can be seen as the process of making joint decisions. It involves either direct of implicit communication among individuals trying to reach an agreement for mutual benefits. To allow for negotiations in MAS or any social system, three issues should be tackled: (i) all involved parties should be aware of the object under negotiation as well as of its market value; (ii) a common language should be shared by all parties; (iii) a negotiation protocol must be established. Thus, we believe that it is possible to define a parallel between MAS and SECOs.

Depending on the attitudes displayed by components of MAS, different types of negotiation can be employed. We analyse how two of these may support requirements negotiation in a SECO. Bilateral Negotiation and Voting techniques are described in the following sections, which discuss their adoption to define negotiation strategies.

4.1. Bilateral Negotiation

According to Rosenschein and Zlotkin (1994), when only service values are being bargained and the negotiation is on a one-to-one fashion, a Bilateral Negotiation can be used. This type of negotiation involves a negotiation space (the set of possible agreements), a protocol (the rules of encounter) and a strategy (private to each agent).

This approach could be used to define a negotiation strategy for closed commercial SECOs such as the AUTOSAR Tool Platform (Artop). This ecosystem belongs to automotive tool development area and its members have to agree to a license before using the platform, details Weiss (2011). In a bilateral negotiation, the direction of the project and each developer willing to contribute to the platform could be seen as agents. The Artop Software License would act as a protocol, where the proposal of requirements would determine legal moves in the negotiation history. The application of bilateral negotiation steps would lead to an agreement or a conflict.

Strategies using bilateral negotiation shall specify how an agent uses the protocol to get the best possible payoff for themselves. A Monotonic Concession Protocol (MCP) is a form of negotiation where both agents make simultaneous proposals in several rounds, according to Rosenschein and Zlotkin (1994). Agreement is reached if one agent proposes an agreement that is at least as good for the other agent as their own proposal.

As contributors to the ecosystem, here niche players would allow end-user to include functionality in the platform after negotiating versions of the specific application. The keystone would then make a concession considering degree to which the proposal is a differentiating feature for the SECO, for instance.

4.2. Voting

When the system is pressed for time and the attitude prevailing is that of cooperation, a voting scheme can be employed. In this situation, a collective decision is taken, considering an objective holding a central position for the community. Agents are seen as voters, where candidates are decisions that lead to states of the world with well-defined utilities for them. In this scheme, each agent has an order of preference for the candidates. To choose one specific order, it is possible to adopt either (1) a social welfare function, where candidates are ranked considering a degree of preference by agents, or (2) a social function, whose result is a single candidate.

This approach can be appropriate for open social SECOs, given their community oriented development. According to Weiss (2011), products are constructed by using and creating plug-ins in the Eclipse ecosystem. The Eclipse Foundation acts as a keystone. It is responsible for technical infrastructure and coordination of SECO development processes. The direction of development efforts is set by three councils, which are responsible for requirements, planning and architecture. The requirements council collects, reviews and prioritises incoming requirements.

A voting scheme for requirements negotiation in this scenario would consider requirements as candidates, and developers and the councils as voters. Since the requirements council is comprised of strategic members and representatives of project management committee, parameters such as weights, priorities or contexts would be needed. Therefore, a voting could adopt a weighted logic and a combinatorial approach to analyse proposed requirements. These would be democratically selected, although votes would be evaluated considering actors position in the network (power, influence).

5. Conclusion and Future Work

This paper presented a preliminary model for requirements negotiation in SECOs, which is established over three dimensions: SECO stakeholders, SECO lifecycle and SECO business models. The model aims to provide strategies to support the decision-making during requirements negotiation. In this sense, we discussed how Bilateral Negotiation and Voting could be employed to support negotiation activities. We believe that the steps underlying these techniques can provide insights on how to develop such negotiation strategies. This solution can be foundational for better guidance on Requirements Engineering regarding the Software Platform Management.

Possible further research directions include a deeper analysis of how MAS negotiation techniques can be adapted to define strategies for requirements negotiation and decision-making among SECO actors. In addition we shall analyse primary studies from the systematic review in Manikas and Hansen (2013) to gather descriptions of SECOs and understand how negotiation takes place during RE. This will enable us to develop the negotiation model, which should be evaluated through case studies carried out in organisations responsible for open and closed ecosystems.

7. Acknowledgements

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