Early requirements engineering for public private partnerships: Aligning agents' mental models

Brigitte Burgemeestre

Faculty of Economics and Business Administration,
Vrije Universiteit Amsterdam, The Netherlands
cburgemeestre@feweb.vu.nl

Abstract. Developing decision support systems is a complex process. It involves stakeholders with diverging interpretations of the task and domain. In this paper, we propose to use ontology mapping to make a detailed analysis of the overlaps and differences between mental models of stakeholders. The technique is applied to an extensive case study about EU customs regulations. Companies which can demonstrate to be in 'control' of the safety and security in the supply chain, may become 'Authorized Economic Operator' (AEO), and avoid inspections by customs. We focus on a decision support tool, AEO Digiscan, developed to assist companies with an AEO self-assessment. We compared the mental models of customs officials, with mental models of the developers of the tool. The results highlight important differences in the interpretation of the new regulations, which will lead to adaptations of the tool.

Keywords: e-government, shared mental models, decision support systems

1 Introduction

The Dutch Tax and Customs Administration (Dutch TCA) aims to modernize and reorganize its processes through the introduction of a new form of governance, called "horizontal supervision", which is based on mutual cooperation and trust. Dutch TCA engages in horizontal supervision with companies that are trustworthy and in control of their business processes. The companies receive more responsibilities: they have to exercise a form of self control supported by their (IT) infrastructure and openly report the results to Dutch TCA. If companies are able to exercise self control in a responsible way, Dutch TCA can assign fewer resources to these companies and exercise strict control on unreliable companies.

To build software that supports the processes of horizontal supervision, one has to take the new roles of the participants and their changed tasks into account. Norm enforcement has changed into a more collaborative activity. Dutch TCA can therefore be seen as one of the actors within the system, instead of an external entity that imposes norms upon the system [1] [2]. Requirements engineering methodologies such as [19] [4] are intended for modeling processes which involve multiple (autonomous) actors. A contribution of these methodologies is that they include an

analysis of the actors' goals and dependencies before addressing detailed system requirements. This gives developers a deeper understanding of the environment in which the software must operate, and of the kind of interactions that should occur between the actors [4].What is often implicitly assumed in methodologies, like [19] [4], is that mental models of the task and domain are shared among actors. In practice however, this assumption is not always met. Especially in public-private partnerships like horizontal supervision, where the parties involved have different interests and backgrounds, differences in the interpretation among various actors can exist. Overlap in task-specific knowledge structures or having a „shared mental model is argued to have a positive influence on performance and effectiveness in collaborative situations [5]. We suggest that for successful collaboration actors must have either a similar interpretation of the task, or have accessible mental models, so that other actors can adapt their models. We argue therefore that early requirements engineering should involve the identification of the differences and similarities that exists among the mental models of the stakeholders. With the differences clarified, the stakeholders become aware about each other's mental model constructs, which they in turn can use to align their approaches already in an early stage in IT development. Unlike some of the empirical work on shared mental models, however, we are not satisfied with mere lists of differences. Instead we propose to build conceptual models, to detect divergent or synonymous mental model constructs in a systematic and precise way.

2 Related work

Semantic heterogeneity is a phenomenon that emerges in distributed heterogeneous environments as separate systems are often engineered based on different and sometimes even incompatible conceptualizations [14]. General domain ontologies were seen as a solution to overcome the problem: separate systems would need to match their own conceptualizations against a common ontology of the application domain, such that all systems would be semantically interoperable. Nowadays the increasing number of distributed domain ontologies itself is a source for semantic interoperability problems [11]. Ontology matching [17] is seen as a promising solution to overcome the semantic heterogeneity problem [11]. It aims at finding correspondences between semantically related entities of different ontologies There are different matching techniques available [11] [13]. Most techniques require the existence of some commonly shared body of knowledge, structure or syntax. However in an innovative public private partnership such as horizontal supervision where both the businesses and government have to adapt to their new roles, responsibilities and ways of interaction such a thing does not exist. The shared body of knowledge is evolving as best practices are developed, procedures are maturing and lessons are learned based on experiences in the field.

Multi agent systems research addresses this issue through meaning negotiation or semantic negotiation [14] [3]. They try to offer a dynamic and flexible form of semantic coordination for situations in which no priory coordination exists. Bouquet et al. introduce in [3] a method that makes the meaning of nodes in structured semantic models explicit by combining three types of knowledge: lexical, domain and

structural knowledge. They combine the knowledge sources to build a new representation of the problem, where the meaning is encoded as a set of logical formulae. The problem of semantic coordination is no longer tackled as a problem of computing structural similarities but as a problem of deducing relations between the formulae that represent the meaning of each concept in a given semantic structure. Van Diggelen et al focus in [6] on the use of ontology negotiation protocols to overcome communication problems between agents with heterogeneous ontologies. The idea is that a negotiation protocol enables agents to gradually build towards a semantically integrated system by sharing parts of their ontologies. In their solution they combine a normal agent communication protocol with an ontology alignment protocol. In [6] they propose that an ontology negotiation protocol should enable sound and lossless communication between the agents. The agents should furthermore deal with communication problems at the moment they arise and should built up a relatively small communication vocabulary such that it remains easy to learn and to process.

Another approach to match ontologies are the instance based methods [7] [16]. These methods determine the similarity between concepts of different ontologies by examining the extensional information of concepts [7]. Various approaches to instances based methods exist: in [7] machine learning techniques are used to identify mappings and in [16] a lexical search engine is used to map instances from different ontologies. Concept classification information is exchanged between these mapped instances, to generate an artificial set of common instances shared by concepts from two ontologies, so that simple similarity measures can be applied. The advantages of this method are that it does not depend on the availability of concept labels or a rich ontology structure.

3 Research approach

To identify the differences and similarities that exist between the mental models of actors, we propose a combination of ontology matching and semantic negotiation techniques. A combined approach is needed to compensate for the absence of shared domain ontologies and the likelihood of different conceptualizations by the actors. As a starting point we propose the use of generic knowledge model templates, from knowledge engineering methods such as CommonKADS[15]. These generic templates can function as a basis for the actor specific mental model constructs. In line with the CommonKADS method, the mental model of the actors we construct will therefore consist of three knowledge categories: domain knowledge, task knowledge and inference knowledge [15]. After we have constructed the actors' mental models we like to compare them. Since the actors in a public private partnership have a different background it is important to thoroughly assess the meaning of the concepts implemented in the mental models before comparing them. Therefore we will use an approach similar to [3] which makes use of distinct sources of semantic knowledge to focus on the meaning of the concepts used by the actors when matching their ontologies. Furthermore we will explore matching techniques based on instance-matching to derive general concepts based on instances observed in

the field. To conclude our research we will compare the actors mental model constructs with each other to construct a model that presents the encountered differences and similarities and provides means for the agent models to converge.

4 Case study: AEO self assessment support

We conducted a case study on AEO self assessment, which is part of the application procedure for companies to qualify for Authorized Economic Operator (AEO). AEO's benefit from reduced customs inspections while for non-certified enterprises customs will continue the traditional supervision.
To qualify for the AEO status a company must assess itself on a number of criteria, which are described in the community customs code and [9] [10]. The company reports its findings to customs. Customs then visits the company to check if the self assessment is performed correctly and to gather additional information. The customs then determine whether the AEO certificate is granted or not. The self assessment is a nice example of public-private collaboration, because a traditionally public task (compliance assessment) is partly delegated to a private party (a company). The private party therefore needs insight in the mental model of the public party (customs authority) to perform the task according to their standards. The customs, on the other hand, are interested in the mental model of the company, because the legislation is new and customs need to learn from best practices of early AEO applicants. Consultancy firms offer services and tools to assist companies in performing the self assessment. The AEO Digiscan developed by Deloitte's Tax Advise unit, is an online tool that works as a classic expert system and is based on the AEO guidelines. Experts of Deloitte contributed to the development of the AEO Digiscan, by specifying the guidelines, and turning them into clear questions. The questions that a company has to answer depend on the company's role in the supply chain and on answers to earlier questions. Scores are expressed on a 5 point scale ranging from "Potential risk can be considered high" till "Potential risk could be considered low and acceptable".

4.1 Case analysis

This section presents the initial results of the research towards the mental models of AEO self assessment. We compared a mental model embedded in a decision support system with the mental models of customs experts. For the data collection we used the following methods: document analysis and semi-structured interviews [8] [20]. We studied internal and public documents from both Dutch TCA and Deloitte on AEO certification and self assessment. To elicit detailed expert knowledge in the interviews, we showed the experts the AEO application of a petrochemical company, which had used the Deloitte AEO Digiscan, and asked them how they would have assessed this company (if there would have been no AEO self assessment) and if they could point out points of interest.

Domain, task and inference model. To analyze the interview results, we use an adapted version of the knowledge model templates for the assessment task of the

CommonKADS methodology [15]. As the self assessment task is concerned with identifying risks, implementing and evaluating control measures to mitigate risks we consider the IT risk management model of NIST [18] an appropriate starting point for a domain model. Risk management is the activity of continuously assessing risks, defining and implementing control measures to mitigate risks and evaluating and improving the results. A risk assessment identifies the threats facing a company given its line of business and its environment. The vulnerability of a company to threats depends on its current control measures. A risk assessment therefore contains an estimation of the likelihood of threats having an impact, and the expected size of the impact. Control measures either reduce the likelihood, by dealing with vulnerabilities (preventative controls), or reduce the impact (detective and corrective controls). Consider for example the risk of smuggling: someone places an additional item in a container, along with the rest of the cargo, without the trader, the shipping company or customs knowing about it. The vulnerability can be reduced by limiting physical access to all premises where containers are loaded and unloaded, on the basis of the principle of 'least privilege'. Only those employees are allowed to have access to the containers, who need it because of their job.

We also include the AEO criteria and the AEO guidelines in our domain model. They are merely attention points, which – given a business environment – indicate the main risks for the company. It is however the responsibility of the company to set their own internal norms, depending on the actual risks encountered.

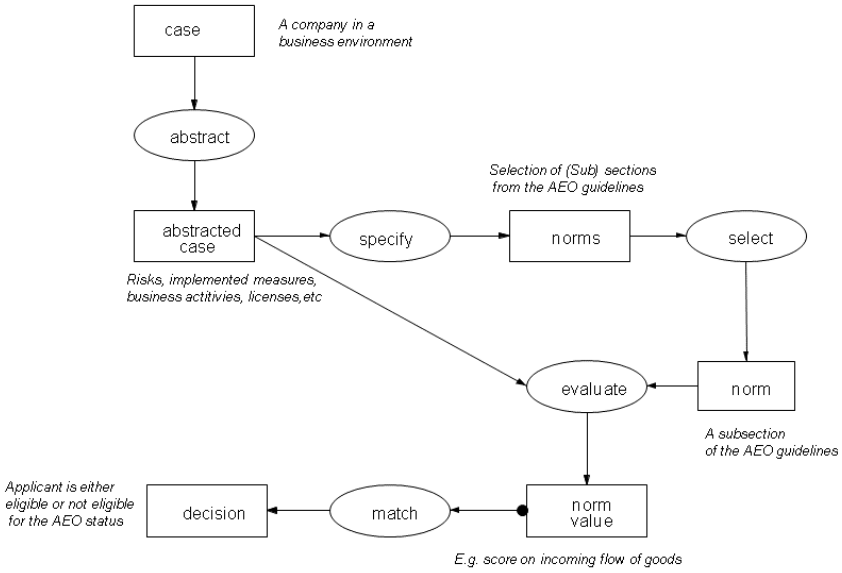

Fig. 1. Inference structure of the assessment task [15]

The purpose of a domain model is to specify key concepts and indicate how they are related. The implementation of these relationships is then further worked out in the inference structure, which we show in figure 1. Figure 1 depicts the inference structure adapted for AEO self assessment. Basis is the generic assessment model,

taken from [15]. The input is a company that applies for the AEO status, the "Case". The "Abstracted Case" is the data relevant for the self assessment: the potential risks, the measures that mitigate these risks, and the quality level of the measures, related to the company's business activities and its role in the supply chain. The AEO guidelines provide an overview of risk indicators that companies can use in the identification of potential risks. After the abstraction the company must specify which (sub) sections addressed in the AEO guidelines are applicable to the company's specific situation and need to be evaluated and reported in the AEO summary to the customs. From this set of (sub) sections a company selects a single subsection that needs to be evaluated.
For each subsection a company determines if the risk mitigation is sufficient and evaluates the implementation of the measures. The output value is an integer (0-5) indicating the implementation level of the measure according to the COSO definition of levels of internal control. A company has to report the values in the AEO summary. The "Match" function checks whether the scores on the self assessment summary lead to a decision if a company is AEO compliant or not. The "Match" function only stops prematurely in case of (clear) incompliance. A company is only AEO compliant if it scores well on all the (sub) sections that are applicable. We will not present a CommonKADS task model as the domain and inference diagram contain all the necessary information.

Constructing and comparing mental models. We found that the interpretations of Deloitte and Dutch TCA of the task and domain model for AEO self assessment overlap. Both are based on the AEO guidelines, and therefore use similar attention points. Both make use of risk analysis methods. However, important aspects of the self assessment are interpreted differently. In general we found that the approach offered by the AEO Digiscan is more structured and requires less expertise on AEO legislation, than the Dutch TCA approach posted on their website. However the scope of the AEO Digiscan is limited; it focuses on risk assessment (identifying risks and measures) while Dutch TCA's approach focuses on all parts of risk management, including implementation of measures. We also observe a difference in scoring: a measure of the implementation of control measures by Dutch TCA and a risk-based scoring by Deloitte. The risk management versus risk assessment view also is in line with the views that Dutch TCA and Deloitte have on the AEO certification. Dutch TCA sees the AEO self assessment as a means to judge the quality of companies' internal control system, and to create awareness of potential risks. In contrast, Deloitte efficiently provides companies with an indication of their position with respect to achieving the AEO status. The Deloitte approach is therefore more aimed at compliance with AEO legislation, whereas the Dutch TCA approach aims at companies being 'in control' of their internal procedures regarding safety and security.
These are all important aspects should have been addressed during the early requirements phase of the development of the Digiscan tool. These aspects greatly influence the kind of tool that is developed and the role the tool will fulfill within the task of "self assessment". They lead to different system requirements. Figure 2 summarizes our findings. The grey concepts are only covered by the Dutch TCA

approach; the concepts depicted in white are part of both the Deloitte AEO Digiscan and the Dutch TCA approach.

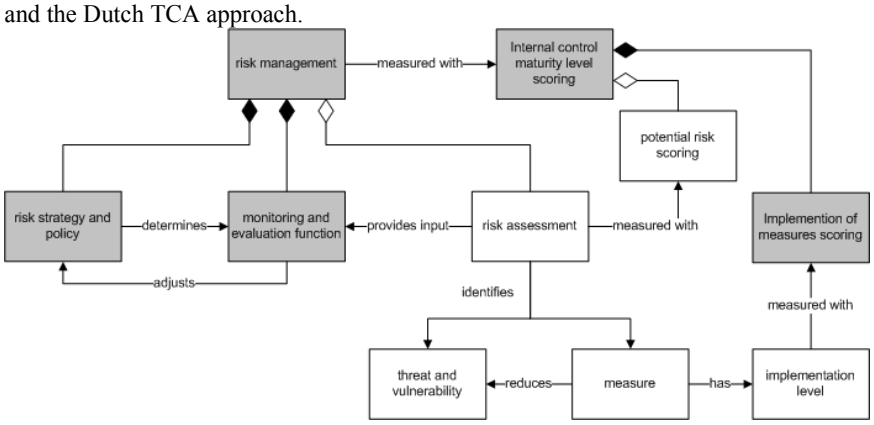

Fig. 2. Model of differences (dark) and overlap between DTCA and Deloitte

5 Discussion and conclusion

Charting the differences between mental models of stakeholders is an important element of developing a complex decision support system, because it helps to identify differences in expected functionality, and in the way the system is expected to be used. Differences in task and domain models will lead to different system requirements, consider for example the difference in scoring. Where most approaches only identify the difference in scoring, mental models help to unravel the underlying issues that contributed to these differences, such as the differences in scope and the perception of the task. Therefore mental model mapping should be part of the early requirements engineering phase [19] [4]. Note that expectations may be too complex to implement. It is easier to design and implement an expert system about compliance (rule-based), than about risk assessment in context (principle-based). Once such expectation gaps have been identified, it is important that the stakeholder, who is having the system developed, makes clear choices about the intended functionality of the system, and communicates these to the other stakeholders. A less ambitious system, with a task that naturally aligns with one or more sub-tasks of the task model, may be easier to get accepted, than an overly ambitious system which will disappoint some stakeholders. An interesting side-effect of our research is that the stakeholders themselves have now realized what their respective positions are. The differences are not insurmountable. In fact, some Deloitte experts have expressed a willingness to adapt their tool, and especially the risk-based scoring model, to address concerns of Dutch TCA about the implementation of control measures.

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