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1a. Project Title: Coordination Process Correctness and Trust Assumptions

1b. Acronym: COOP

1c. Principal Investigator: Dr. J. Gordijn

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2.1 Summary

There is currently a lot of activity to propose standards for cross-organizational application integration, such as standards for web service description, coordination and composition. This will eventually lead to software components that implement these standards. However, very little attention is paid to how to actually use this new technology. To use this technology, business processes must be designed that coordinate applications across organization boundaries. Designing these coordination processes is difficult because they are executed by software owned by different profit centers, that may not all trust each other. Each business partner wants to make a profit by executing its part of the process, and may require safeguards that the other partners perform their part of the process as promised. As a result, a process that makes sense when performed within one organization, may be impossible to perform when attempted cross-organizationally. The research problem to be investigated in COOP is when a coordination process is correct with respect to a networked business model that is profitable to all partners, and that allows for different levels of trust among the partners.

Our solution builds upon our previous research in the design of profitable business networks. In COOP, we will extend this by defining and formalizing a correctness notion of a coordination process with respect to a profitable business network design, and provide tool support for this. Secondly, we will formalize coordination mechanisms that can deal with the lack of trust that partners in a business network may have in each other.

2.2 Abstract for Laymen (in Dutch)

In de afgelopen vijf jaar is een groot aantal standaarden voorgesteld voor integratie van software over bedrijfsgrenzen heen. Die voorstellen zullen uiteindelijk tot een nieuwe generatie software-componenten leiden die in staat zijn software van verschillende bedrijven te integreren. Er is tot nu toe weinig onderzoek gedaan naar de vraag hoe dergelijke samenwerking tussen software van verschillende bedrijven ontworpen moet worden. Voor elk bedrijf in een dergelijke samenwerking moet de samenwerking winstgevend zijn, en verschillende bedrijven zullen niet zonder garanties vertrouwen dat andere bedrijven hun deel van de samenwerking uitvoeren. Een proces dat software binnen één bedrijf coördineert zal in het algemeen dus niet gebruikt kunnen worden om software tussen verschillende bedrijven te coördineren. De onderzoeksvraag van COOP is wanneer een coördinatieproces correct is ten opzichte van een business model dat winstgevend is voor alle samenwerkende partners, en waarin verschillende partners elkaar niet blind hoeven te vertrouwen.

Onze oplossing bouwt voort op onderzoek naar het ontwerp van winstgevende bedrijfsnetwerken dat wij eerder hebben verricht. We breiden dit in COOP uit met een definitie van een formeel correctheidsbegrip van een coördinatieproces ten opzichte van een winstgevend bedrijfsnetwerkmodel, en zullen prototypes van software opleveren waarmee dit formeel geverifieerd kan worden. Ten tweede zullen we coördinatiemechanismes formaliseren waarmee het gebrek aan vertrouwen tussen bedrijfspartners opgevangen kan worden.

3 Classification

- Discipline: Computer Science
- (Sub)disciplines: 1.2 Gedistribueerde systemen (elektronische snelwegen), 2.4 Workflowsystemen (ondersteunen van gestructureerde samenwerking), 3.2 Specificatiemethoden (requirements engineering), 3.4 Testmethoden (formele verificatie)
- NOAG-i theme: Software Engineering (SE), Algorithms and Formal Methods (AFM)

4 Composition of the Research Team

title	name	hours/week
Business Informatics, <i>Vrije Universiteit (VU)</i>		
Prof. Dr.	H. Akkermans (Promotor)	2
Drs./Ir.	Ph.D. student 1	40
Dr.	J. Gordijn	4
Information Systems, Marketing & Logistics, <i>Vrije Universiteit (VU)</i>		
Prof. Dr.	Y.-H. Tan(Co-promotor)	2
Information Systems group, University of Twente (UT)		
Dr.	P.A.T. van Eck	4
Prof. Dr.	Roel Wieringa (Promotor)	2
Drs./Ir.	Ph.D. student 2	40

5 Research Schools

All research members are members of SIKS.

6 Description of Proposed Research

6.1 Research goal

For the past five years, several standardization bodies as well as software vendors have attempted to facilitate e-commerce and value chain automation by proposing standards for cross-organizational application integration, such as standards for web service description, coordination and composition. These activities are still in full swing. Example proposals include BPSS [16], BPEL4WS [7], WSCI [9], and WS-Coordination [13], to name only a few. The aim of these activities is to set a standard for a new generation of software components that are able to deal with the specific problems of cross-organizational application integration [6]. However, little attention is paid to the question how to actually use this new technology. This is the question we want to investigate in the COOP project.

We take a process point of view on application integration, and hence view cross-organizational application integration as a problem of designing business processes that coordinate software applications across organization boundaries, called *coordination processes* for short. Our research question therefore is *how does one design a coordination process to be executed by software components allocated to different organizations?* This design problem is more difficult than designing an intra-organizational business process, because in cross-organizational coordination process design, there is no single decision center. This has two consequences, each of which make the design problem more difficult.

- *Each decision center is a profit center.* Coordination processes are executed in a business network, which exists to produce something of value to its customers [5]. A business will

participate in the network if it can make a profit by that, otherwise it will drop out. The part of the coordination process performed by each business in the network, must therefore be profitable for that business. This requirement is absent from intra-organizational process design. The question, then, is how to determine whether a cross-organizational process is correctly implemented with respect to a networked business model that is profitable for all partners in the network.

- *Each profit center is a trust domain.* During cross-organizational process design, different business partners will not fully trust each other as different actors within one organization trust each other. As a consequence, information about business processes and business rules will be kept secret for other participants in the network, and not all data, functionality or applications owned by one participant will be accessible to software from another participant. A number of these issues will be handled at the application level by existing security mechanisms. However, some of these issues can only be dealt with by the addition of mechanisms to the coordination process. For example, a participant may decide not to pay for a service already delivered, thus committing fraud. To prevent this, we need to add trusted third parties and coordination mechanisms to the network that ensure that less-trusted participants of the network behave reliably.

These problems already exist to some extent when a large business has structured itself into a network of profit-responsible business units, but they appear in their full complexity when independent businesses decide to cooperate by integrating some of their applications. As a consequence, a process that is perfectly sensible when performed inside one business, may not be feasible when performed across businesses.

Solutions to these problems have been studied in branches of management science such as commercial economics, accounting and organizational control theory. However, these solutions assume that coordination processes are performed by people. They are defined too vaguely to be used as software specifications, and do not take the possibilities of automated process execution into account. The coordination processes we are interested in, are performed fully automatically by software distributed over different organizations. This makes designing these processes a software design problem, and consequently we need a much more precise specification of these processes than was previously needed.

6.2 Research approach

Our approach to the problem of designing coordination processes is to separate profitability of the coordination process from the trust assumptions made about the business partners. We will investigate when a coordination process is *correct* with respect to a profitable networked business model, and which mechanisms exist to deal with the *trust assumptions* are made by the coordination process. We explain this in the next two subsections.

Correctness. To ensure profitability of a coordination, we will use the e^3 -value method developed by the principal investigator in earlier research [27] to represent business networks. The e^3 -value method defines the notion of a *value model* of a business network, which is a declarative representation of the value exchanges and value interfaces that ideally take place in the network. A value model represents *value exchanges*, in which objects of economic value, such as goods, services or money, are exchanged between business partners. It also represents *value activities* performed by the business partners. Value models have been studied extensively in the context of e^3 -value and of other business network design methods in the recent past [5, 24, 25, 26, 27, 38, 48] as a technique to design value networks. Figure 1(a) shows the simplest possible value model: A seller exchanges a good for a fee from the buyer. The profitability of this value model depends on the estimated value of the good for the buyer and the seller. The e^3 -value method contains techniques and software tools to verify the estimated profitability of a network represented by a

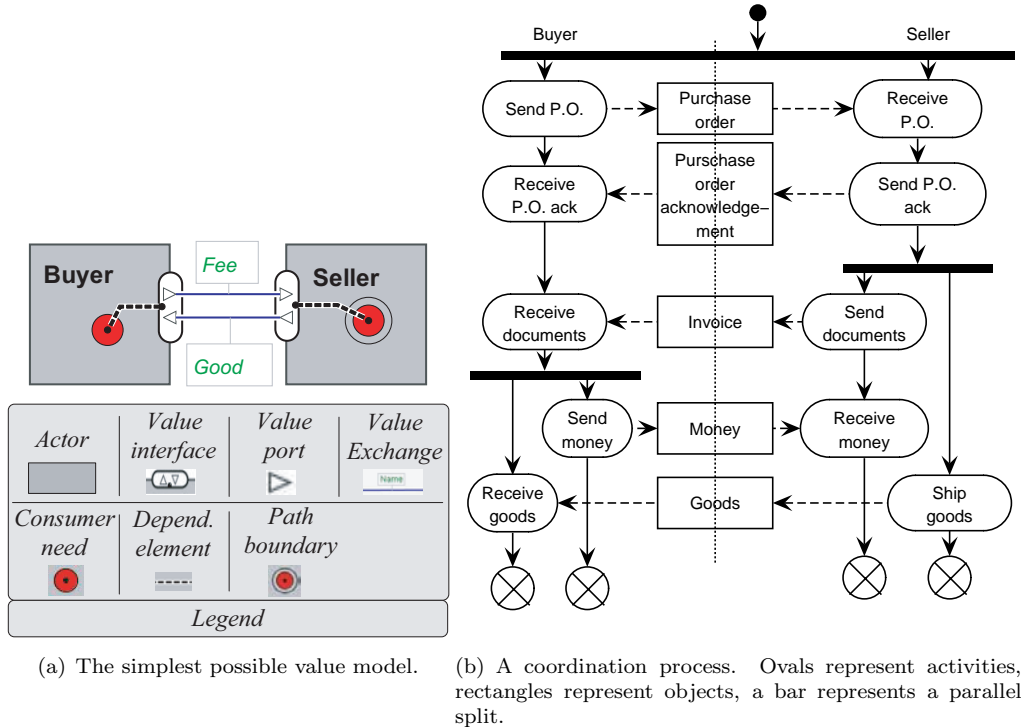


Figure 1: A very simple value model and a coordination process that “correctly” implements it using an intuitive notion of correctness. Based on a more elaborate exploratory study done by us [52].

value model [5]. However, e^3 -value does not contain techniques for coordination process design. A value model is declarative and specifies what profitable activities and exchanges must be achieved, not what must be done to achieve them. In COOP we will therefore study the design of correct coordination processes given a value model of a business network profitable for all participants. Figure 1(b) shows an example coordination process that we think is “correct” with respect to the value model of of figure 1(a). The precise meaning of this correctness notion is the subject of the COOP project. Whatever the eventual formalization of this correctness notion, it should at least entail that if figure 1(a) represents a profitable network, then figure 1(b) represents a profitable coordination process. The first research question we will study is, then,

- *When is a coordination process correct with respect to a profitable value model?*

We will approach this question by means of formal verification techniques. The starting point of our approach is the concept of *dependency path* of value models which, despite its name, is a rooted acyclic subgraph that connects all value exchanges and value interfaces triggered by one consumer need. The business network represented by the value model exists to serve needs of specific actors in the network, called consumers. The root of each dependency path is labeled by the consumer need that triggers this path. A profitability computation actually computes the aggregated profitability of executing the exchanges and activities on the path over a period of time, given the estimated frequency of occurrence of this need during this period.

In an exploratory study of correctness performed by the proposers [52] it turned out that a correctness notion for coordination processes must deal with the phenomenon that a value exchange between actors A and B can be implemented in the coordination process as a communication activity between quite different actors C and D . For example, when a buyer’s representative A receives a letter of credit from the buyer’s bank B —an activity in a coordination process—then

the buyer C and seller D exchange certainty of payment (a value object for the seller) for certainty of delivery (a value object for the buyer)—an exchange in the value model. A possible correctness notion that satisfies this is that the coordination process is correct with respect to a dependency path in a value model if at the end of every possible execution of the coordination process, the value exchanges on the dependency path have taken place. Our initial exploration suggests that we can encode a dependency path in a propositional formula against which we can verify a coordination process. Thus, we need to verify correctness of a coordination process against a correctness formula derived from a profitable value model.

To elaborate on this, we need to formalize the correctness properties that follow from a profitable e^3 -value value model so that they can be used in a formal verification. Secondly, we need to choose a process notation technique to specify coordination processes. We will *not* define a new process notation, as the currently notations suitable for intra-organizational processes are perfectly suited to inter-organizational processes as well [3]. We will work with UML activity diagrams, which have been studied by previous research of one of the proposers. We have defined a formal execution semantics for activity diagrams [21]. We also have developed a graphical front end for the nuSMV model checker,¹ which allows us to edit activity diagrams, enter a correctness property, let nuSMV check this property of the activity diagram and, if the property is false, show a counterexample to it as an execution path through the activity diagram [22, 23].² We will build upon these results to verify properties of a coordination process that is specified as a UML activity diagram, where the properties are derived from a profitable value model.

To work this out, we need to determine exactly which requirements a profitable value model puts on a coordination process, and how to formalize these as formal correctness properties. A second important open question is how to represent value objects in the coordination model. An obvious candidate is to use object flows to represent value objects. However, our current formalization of activity diagrams does not yet contain object flows. Extending our semantics with it, and defining an interface to model checkers that deals with data, is a challenge. Thirdly, it remains to be investigated whether the desired properties that we derive from a value model can be represented in the property language of whatever model checker we use. Although we currently use nuSMV, there is no reason why we could not use other model checkers. Each model checker comes with a property language with its own restrictions, and we need to investigate what the impact of these restrictions is on our ability to verify coordination processes against a value model.

Trust assumptions. Consider now the trustworthiness of the business partners in a network. The model of figure 1(a) specifies, from a trust perspective, an ideal world in which both partners reciprocate the economic value they receive. Likewise, the coordination process in figure 1(b) specifies a process in which both partners trust each other. The process allows the seller to deliver the goods before being paid and it also allows the buyer to pay before being delivered the goods. But if the buyer and seller do not trust each other sufficiently, then they will not want to execute this process in any possible way. The process is then still correct with respect to a profitable business model, but it is unrealistic. The standard solution to this in business practice is to extend the coordination process with a procedure involving a letter of credit and a bill of lading, handled by one or more trusted third parties, namely banks [11, 29, 52]. The procedure is such that if buyer and seller trust that the banks faithfully perform their part of the coordination process, the seller is guaranteed to get his payment and to ship the goods. (To get a guarantee that the buyer actually receives the goods, or a value equivalent to it, additional mechanisms are needed, such as insurance of the goods.)

Generalizing from this example, we conclude that even if a business network used a correctly implemented cross-organizational workflow management system (WFMS) that would coordinate the execution of correctly implemented applications, and we would feed the WFMS a correct coordination process specification, then the participants in the network could still distrust each

¹<http://nusmv.iirst.itc.it/>

²See also www.cs.utwente/~tcm.

other and refuse to perform the process. So each coordination process comes with certain trust assumptions about the business network that may or may not be satisfied by a given network. Our research question concerning trust is now

- *Which coordination mechanisms can be used to deal with a lack of trust among partners in the network?*

There is a wealth of knowledge in accounting and organizational control theory about mechanisms to deal with lower level of trust in some partners in a business network, such as the use of banks, insurance companies and other trusted third parties, the separation of duties, etc. [14, 40, 43, 44, 45, 46]. However, these mechanisms assume manual coordination processes and are specified very informally. We need to formalize and verify these mechanisms for the situation that the coordination process is executed by a network of software applications distributed across a business network. We intend to formalize these mechanisms as coordination patterns consisting of a process model fragment and the value model fragment that it implements.

Issues to be resolved are how to formalize these coordination mechanisms, in which sense a coordination mechanism is correct with respect to a value model fragments, and how different coordination mechanisms interact. A typical coordination process contains many of these mechanisms, and these may interact in such a way that one mechanism may cause another mechanism to become incorrect.

Interaction between correctness and trust assumptions. Before we summarize our research questions, we want to point out that addition of a coordination mechanism to a coordination process may have an impact on the value model. The letter of credit procedure is an example of this. For example, the addition of a bank to a coordination process implies the addition of a bank to the corresponding value model, as well as the addition of value exchanges between the bank and the other business partners, such as the buyer and seller paying for the services provided by their banks. Since all participants in the extended network will want to make sure that their participation is profitable, profitability computations must then be redone. And because the value model and coordination process are both changed, the correctness proof of the coordination process with respect to the value model must be redone too. The development of a profitable and realizable coordination process thus involves an iteration of value model design and coordination design and of the proof that the coordination process is correct. This interaction is essential to the design of trust mechanisms, because many of these mechanisms work by creating conflicts of interest or otherwise exploiting the value models that each of the partners have of their own activities. We will investigate the interaction between trust-enhancing coordination mechanisms and value models in the COOP project.

6.3 Research questions

In summary, we identified the following research questions.

- *When is a coordination process correct with respect to a profitable value model?*
 - Q1 Which formal correctness properties of a process model follow from a value model?
 - Q2 How can we formalize correctness of a coordination process with respect to a value model? Can we use object flows to represent value objects?
 - Q3 Can we provide tool support for checking correctness of a process model? What is the impact of differences in property languages of available tools?
- *Which coordination mechanisms can be used to deal with a lack of trust among partners in the network?*

- Q4 Can we formalize coordination mechanisms that allow us to decrease the level of trust in particular partners in a network? In which sense is such a mechanism correct with respect to a value model fragment?
- Q5 How do coordination mechanisms for dealing with different levels of trust interact?
- Q6 How do coordination mechanisms for enhancing trust impact the value model of a business network?

6.4 Research method

We have considerable experience with doing design research by means of case studies done in a business context, and in COOP this will be our research method too. We will iterate over doing case studies, generating hypotheses, and validating these in additional case studies. More in particular, we will start doing some simple case studies to get a feeling for the models, mechanisms, and correctness notions involved. These cases will come from industrial case studies done by us in the past in the newspaper and electricity industry [28]. The results will be consolidated by formalizing them and validated by doing more case studies. These will come from the intellectual property rights / music sector and the health care sector, using our current contacts [5].

Once the concepts are stable, we will implement tool support, building upon our existing tools, and validate these tools in additional case studies. The result should be a validated and formalized correctness notion for coordination processes, tool support for this, and a library of coordination mechanisms for dealing with lower levels of trust.

6.5 Scientific relevance

The proposed research fills a gap in cross-organizational process design, and our results should be relevant for cross-organizational workflow modeling, service-oriented computing, as well as application integration.

6.6 Related research elsewhere

Distributed computing. Distributed computing has yielded a number of decentralized coordination algorithms for distributed systems that seem to be relevant to cross-organizational application coordination [47]. However, in distributed systems design, there is almost always an assumption that all systems are fully willing to cooperate to pursue a joint goal, even if the activities of an individual system are not profitable for the system itself. This makes these algorithms less applicable in cross-organizational application coordination.

Multi-agent systems. Coordination protocols for multi-agent systems are designed based on insights from cognitive science or game theory. By contrast, we base our protocols on value models that indicate the business viability of a coordination among business actors. Moreover, the goal in multi-agent systems research is often to develop algorithms that enable agents to determine their own coordination protocols. Our approach, by contrast, focuses on correctness and realizability of coordination processes.

Coordination theory. Coordination theory as a multidisciplinary field arose in the 1980s by the work of Malone and others [34]. This has led to a handbook containing useful patterns of business processes [35]. The on-line version (<http://ccs.mit.edu/ph/>) also contains links to other useful reference models, such as the Supply Chain Operations Reference Model. These models will be among the sources of our library of coordination mechanisms. Our patterns differ from these patterns because we add a value model to them.

Service-oriented computing. Much work is currently done on defining languages that can specify services and their quality, service coordination protocols, service compositions, etc. [6, 37]. Networked businesses are created that at the ICT level are viewed as networks of service providers and requesters. The service view of these networks abstracts from the implementation

in information technology, which allows businesses to negotiate about services independently from the implementations running at the various partners [49]. There is as yet little published research about the design and correctness of service coordination protocols. Our research results will be fully applicable in the area of service-oriented computing.

Coordination languages and business process languages. Coordination languages have been proposed as a mechanism to construct software from components in a compositional manner [8]. They can be used to compose coordination processes from web services and are therefore candidate notations to implement coordination processes [15]. Another suitable notation are Petri Nets, which are used for business process specification [1, 2, 11, 33]. In COOP, we are not investigating languages but correctness notions and trust-enhancing mechanisms. We will use UML activity diagrams as notation, but a detailed comparison of UML activity diagrams and Petri Nets performed by us earlier [20] provides a strong indication that our results should be transferable to Petri Nets as well.

Organizational control. Patterns for doing business are known in organizational control theory [42]. They have partly been formalized by Elsas [19], using Petri Nets, and by Schaad and Moffett [41], using Alloy. This research is relevant and we will use these results where possible. The difference with our research is that we start from a value model and will investigate the role of trust in coordination mechanisms.

Business process design. Recent research in business process design has yielded a variety of control patterns in business processes [4, 39]. These are recurring control fragments in business processes, whereas the patterns we are searching have a higher level of aggregation. We expect that our coordination mechanisms will exhibit some of the patterns inventorized in business process research.

6.7 Related research of the research team

The Business Informatics (VUA) group is active in the field of Ontology engineering and the Semantic Web, Intelligent systems and services, and Networked e-business modeling. Specifically relevant to the proposed research is the e^3 -value method developed by Gordijn and Akkermans [27, 29], which allows for representation and analysis of a constellation of enterprises and end-consumers creating, distributing and consuming things of economic value. The e^3 -value approach has been developed and tested in a series of (inter)national projects in various industries, including Internet service provisioning, entertainment, energy, banking and news. In recent research, tool support for e^3 -value has been realized [12, 36]. On trust, there is an ongoing collaboration between the Business Informatics group and the Information Systems, Marketing & Logistics group, both VUA. Preliminary results of this collaboration show that e^3 -value can be extended such that value aspects of trust controls can be represented [44, 32, 31]. We also developed modeling approach [5, 10] for business value networks specifically offering e-services.

The IS (UTwente) group has done extensive research in design methods for reactive systems [50, 51], which we have used to find design guidelines for business processes. We developed the TCM software tool for most current specification diagram techniques³ and will use this when graphical tools are needed in the COOP project. Recent research that we will use in defining correctness notions includes a formalization of UML activity diagrams and a combination of TCM with the nuSMV model checker⁴ to checking properties of business processes [22, 23]. We also compared activity diagram and Petri Net formalizations [20], which is relevant for the transfer of results from one notation to another.

In recent years, the proposers have cooperated on a number of topics in value modeling. We studied organization design from value models [17, 30], patterns in value modeling [28, 53, 54], and value-based ICT outsourcing [18]. We also performed an exploratory study to determine the feasibility of the COOP project [52].

³www.cs.utwente.nl/~tcm

⁴<http://nusmv.irst.itc.it/>

7 Work Program

Phases

The duration of the project is four years. Two Ph.D. students will work on the project, Ph.D. 1 (VU) and Ph.D. 2 (UT).

Year 1 Ph.D. 1 and Ph.D. 2 will start with a study of current literature and two exploratory case studies. The goal of these case studies is to obtain a more thorough understanding of correctness notions between coordination protocols and value models. During these cases studies, value models and supporting coordination processes will be developed, and an initial, informal, list of criteria will be created that describe correctness properties that follow from a value model (Q1). Ph.D. 1 will concentrate on value model construction, Ph.D. 2 will develop the supporting coordination processes and both Ph.D.'s will work on the list of correctness criteria.

Year 2 Ph.D. 2 formalizes the correctness properties and consistency relations between coordination models and value models, using UML activity diagrams as process notation (Q1 and Q2). No tool support will be given yet. At the same time, Ph.D. 1 works on an industrial strength case study on property rights clearance [5] to extend and improve the correctness criteria, validate their formalization (Q1 and Q2). The results of these validations will be coordinated.

Given this formalized correctness notion, Ph.D. 2 will then develop software tool support to prove correctness of a coordination protocol, using, and possibly adapting, existing tools for activity diagrams. The impact of the property language of the tools will be investigated (Q3). At the same time, Ph.D. 1 will start the conceptualization of coordination mechanisms from organizational audit and control theory to deal with different levels of trust in trading partners (Q4). Ph.D. 1 will test the conceptualisation by means of case studies.

Year 3 Ph.D. 1 and 2 will work together to formalize coordination mechanisms (Q4). Ph.D. 2 will investigate tool support for verifying these mechanisms and Ph.D. 1 will investigate the interaction of trust-enhancing coordination mechanisms on the value model by experimenting with a number of the case studies (Q6)

Ph.D. 1 and 2 will work together to investigate the interaction of different coordination patterns in one coordination model, Ph.D. 1 by doing case studies and Ph.D. 2 by formalizing and verifying them (Q5).

Year 4 The PhD students will complete ongoing research, write their thesis and prepare the defense.

Educational aspects

The research groups are member of the SIKS research school. The Ph.D. students will take part in the training program of SIKS. In addition, the Ph.D.'s will follow relevant courses about verification in the research school IPA. Both the VUA and the UT give courses for Ph.D. students on organizing your research, presentation skills, and writing research papers. The PhD students will take part in these courses.

8 Expected Use of Instrumentation

The VU and UT will provide computing equipment and research infrastructure for the project members.

Five Main Publications of the Research Team

- [1] R. Eshuis and R.J. Wieringa. Tool support for verifying UML activity diagrams. *IEEE Transactions on Software Engineering*, 30(7):437–447, July 2004.
- [2] J. Gordijn and H. Akkermans. Designing and evaluating e-business models. *IEEE Intelligent Systems*, 16(4):11–17, 2001.
- [3] J. Gordijn and J.M. Akkermans. Value-based requirements engineering: Exploring innovative e-commerce ideas. *Requirements Engineering Journal*, 8(2):114–134, 2003.
- [4] J. Gordijn and Y.-H. Tan. A design methodology for modeling trustworthy value webs. *International Journal of Electronic Commerce*, to appear. <http://www.cs.vu.nl/~gordijn/IJEC04-Gordijn.pdf>.
- [5] R.J. Wieringa. *Design Methods for Reactive Systems: Yourdon, StateMate and the UML*. Morgan Kaufmann, 2003.

References

- [1] W. van der Aalst and K. van Hee. *Workflow Management: Models, Methods, and Systems*. MIT Press, 2002.
- [2] W.M.P. van der Aalst. Verification of workflow nets. In P. Azéma and G. Balbo, editors, *Application and Theory of Petri Nets 1997*, pages 407–426. Springer, 1997. LNCS 1248.
- [3] W.M.P. van der Aalst. Don't go with the flow: Web services composition standards exposed. *IEEE Intelligent Systems*, 18(1):72–76, 2003.
- [4] W.M.P. van der Aalst, A.H.M. ter Hofstede, B. Kiepuszewski, and A.P. Barros. Workflow patterns. *Distributed and Parallel Databases*, 14(3):5–51, July 2003.
- [5] H. Akkermans, Z. Baida, J. Gordijn, N. Peña, A. Altuna, and I. Laresgoiti. Value webs: Using ontologies to bundle real-world services. *IEEE Intelligent Systems*, 19(4):57–66, 2004.
- [6] G. Alonso, F. Casati, H. Kuno, and V. Machiraju. *Web Services: Concepts, Architectures and Applications*. Springer, 2004.
- [7] T. Andrews, F. Curbera, H. Dholakia, Y. Golland, J. Klein and F. Leymann, K. Liu, D. Roller, D. Smith, S. Thatte, I. Trickovic, and S. Weerawanara. Business Process Execution Language for Web Services Version 1.1. Technical report, BEA Systems, IBM, Microsoft, SAP, Siebel, 5 May 2003. <http://www-106.ibm.com/developerworks/library/ws-bpel/>.
- [8] F. Arbab and F. Mavadatt. Coordination through channel composition. In *Coordination Languages and Models*, pages 21–38. Springer, 2002. LNCS 2315.
- [9] A. Arkin, S. Askary, S. Fordin, W. Jekeli, K. Kawaguchi, D. Orchard, S. Pogliani, K. Riener, S. Struble, P. Takasci-Nagy, I. Trickovic, and S. Zimek. Web Service Choreography Interface (WSCI) 1.0. Technical report, BEA Systems, Intalio, SAP, SUN Microsystems, 8 August 2002. <http://www.w3.org/TR/wsci/>.
- [10] Z. Baida, J. Gordijn, H. Sæle, A. Z. Morch, and J.M. Akkermans. Energy services: A case study in real-world service configuration. In *LNCS 3084, Advanced Information Systems Engineering. Proceedings of the 16th International Conference on Advanced Information Systems Engineering CAiSE 2004, Riga, Latvia*, pages 36–50. Springer Verlag, 2004.

- [11] R.W.H. Bons, R.M. Lee, R.W. Wagenaar, and C.D. Wrigley. Modelling inter-organizational trade procedures using documentary Petri nets. In *Proceedings of the Hawaii International Conference on System Sciences*, 1995.
- [12] Busmod website, August 25 2004. <http://busmod.e3value.com>.
- [13] L.F. Cabrera, G. Copeland, W. Cox, M. Feingold, T. Freund, J. Johnson, C. Kaler, J. Klein, D. Langworthy, A. Nadalin, D. Orchard, I. Robinson, J. Shewchuk, and T. Storey. Web Services Coordination (WS-Coordination). Technical report, BEA Systems, IBM, Microsoft, September 2003. <ftp://www6.software.ibm.com/software/developer/library/ws-coordination.pdf>.
- [14] T.K. Das and B.S. Teng. Between trust and control: developing confidence in partner cooperation in alliances. *Academy of Management Review*, 23(3):491–512, 1998.
- [15] N.K. Diakov and F. Arbab. Compositional construction of web services using REO. In *Proceedings of The second International Workshop on Web Services: Modeling, Architecture and Infrastructure, WSMAI'2004*, pages 49–58. INSTICC Press, April 13-14 2004.
- [16] *ebXML Business Process Specification Schema Version 1.01*, 11 May 2001. <http://www.ebxml.org/specs/ebBPSS.pdf>.
- [17] P. van Eck, J. Gordijn, and R. Wieringa. Value-based design of collaboration processes for e-commerce. In Soe-Tsyng Yuan and Jiming Liu, editors, *Proceedings 2004 IEEE International Conference on e-Technology, e-Commerce and e-Service, EEE'04*, pages 349–358. IEEE Press, 2004. Taipei, Taiwan, March 28-31, 2004.
- [18] P.A.T. van Eck, R.J. Wieringa, and J. Gordijn. Risk-driven conceptual modeling of outsourcing decisions. In *23rd International Conference on Conceptual Modeling (ER2004)*, 2004. Accepted. http://www.cs.vu.nl/~gordijn/vaneck_etal_er2004.pdf.
- [19] P. Elsas. *Computational Auditing*. PhD thesis, *Vrije Universiteit*, Amsterdam, 5 September 1996.
- [20] R. Eshuis and R. Wieringa. Comparing Petri net and activity diagram variants for workflow modelling – a quest for reactive Petri nets. In H. Ehrig, W. Reisig, G. Rozenberg, and H. Weber, editors, *Petri Net Technology for Communication Based Systems*, Lecture Notes in Computer Science, pages 321–350. Springer, 2003. LNCS 2472.
- [21] R. Eshuis and R.J. Wieringa. An execution algorithm for UML activity graphs. In M. Gogolla and C. Kobryn, editors, *Fourth International Conference on the Unified Modeling Language <<UML>>2001*, volume 2185 of *Lecture Notes in Computer Science*, pages 47–61. Springer, 2001.
- [22] R. Eshuis and R.J. Wieringa. Verification support for workflow design with UML activity graphs. In *24th International Conference on Software Engineering (ICSE 2002)*, pages 166–176, 2002.
- [23] R. Eshuis and R.J. Wieringa. Tool support for verifying UML activity diagrams. *IEEE Transactions on Software Engineering*, 30(7):437–447, July 2004.
- [24] M. S. Fox and M. Gruninger. Enterprise modelling. *AI Magazine*, 19(3):109–121, fall 1998.
- [25] G. Geerts and W.E. McCarthy. An accounting object infrastructure for knowledge-based enterprise models. *IEEE Intelligent Systems and Their Applications*, pages 89–94, July–August 1999.

- [26] J. Gordijn and H. Akkermans. Designing and evaluating e-business models. *IEEE Intelligent Systems*, 16(4):11–17, 2001.
- [27] J. Gordijn and J.M. Akkermans. Value-based requirements engineering: Exploring innovative e-commerce ideas. *Requirements Engineering Journal*, 8(2):114–134, 2003.
- [28] J. Gordijn, J. Schildwacht, V. Kartseva, R.J. Wieringa, and H. Akkermans. A domain-specific cross-organizational requirements engineering method. In *12th IEEE International Requirements Engineering Conference*, page Accepted for publication, sept 6–10, Kyoto 2004. <http://www.cs.vu.nl/~gordijn/RE04-Gordijn.pdf>.
- [29] J. Gordijn and Y.-H. Tan. A design methodology for modeling trustworthy value webs. *International Journal of Electronic Commerce*, to appear. <http://www.cs.vu.nl/~gordijn/IJEC04-Gordijn.pdf>.
- [30] J. Gordijn and R. Wieringa. A value-oriented approach to e-business process design. In *LNCS 2681, Advanced Information Systems Engineering. Proceedings of the 15th International Conference, CAiSE 2003, Klagenfurt/Velden, Austria*, pages 390–403. Springer Verlag, 2003.
- [31] V. Kartseva, J. Gordijn, and Y.-H. Tan. Analysing preventative and detective control mechanisms in international trade using value modelling. In *Proceedings of the 6th International Conference on Electronic Commerce*, 2004. Accepted. <http://www.cs.vu.nl/~gordijn/Kartseva-ICEC04.pdf>.
- [32] V. Kartseva, Y.-H. Tan, and J. Gordijn. Developing a modelling tool for designing control mechanisms in network organisations. In *Proceedings of the 17th Bled International e-Commerce Conference*, page cdrom, 2004. <http://www.cs.vu.nl/~gordijn/Kartseva-BLED04.pdf>.
- [33] R.M. Lee. Documentary Petri Nets: A modeling representation for electronic trade procedures. In W. M. P. van der Aalst, J. Desel, and A. Oberweis, editors, *Business Process Management*, volume 1806 of *Lecture Notes in Computer Science*, pages 359–375. Springer, 2000.
- [34] T. W. Malone and K. Crowston. The interdisciplinary study of coordination. *ACM Computing Surveys*, 26(1):87–119, March 1994.
- [35] T.W. Malone, K. Crowston, and G.A. Herman. *Organizing Business Knowledge: The MIT Process Handbook*. MIT Press, 2003. See <http://ccs.mit.edu/ph/> for the on-line version.
- [36] Obelix website, August 25 2004. <http://obelix.e3value.com>.
- [37] M.E. Orłowska, S. Weerawarana, M.P. Papazoglou, and J. Yang, editors. *Service-Oriented Computing – IC3OC 2003*. Springer, 2003. LNCS 2910.
- [38] A. Osterwalder. *The Business Model Ontology: A proposition in a design science approach*. PhD thesis, University of Lausanne - HEC, Lausanne, CH, 2004. <http://www.hec.unil.ch/aosterwa/PhD/>.
- [39] M.A. Ould. *Business Processes: Modelling and Analysis for Re-engineering and Improvement*. Wiley, 1995. ISBN: 0-47-195352-0.
- [40] M.B. Romney and P.J. Steinbart. *Accounting Information Systems*. Prentice Hall, 2003.
- [41] A. Schaad and J. D. Moffett. A framework for organisational control principles. In *18th Annual Computer Security Applications Conf.*, page paper 25, Las Vegas, Nevada, 2002. ACSAC, Columbia.

- [42] R.W. Starreveld, H.B. de Mare, and E.J. Joëls. *Bestuurlijke Informatieverzorging, Deel II: Typologie van de Toepassingen (in Dutch)*. Samsom, 1993.
- [43] R.W. Starreveld, H.B. De Mare, and E.J. Joëls. *Bestuurlijke Informatieverzorging (in Dutch), Part I&II*. Prentice Hall, Alphen aan den Rijn, NL, 1995.
- [44] Y.-H. Tan, W. Thoen, and J. Gordijn. Modeling controls for value exchanges in virtual organizations. In *LNCIS 2995, Arust Management. Proceedings of the 2nd International Conference on Trust Management*, pages 236–250. Springer Verlag, 2004.
- [45] Y.H. Tan and W. Thoen. Toward a generic model of trust for electronic commerce. *International Journal of Electronic Commerce*, 5(2):61–74, 2000.
- [46] Y.H. Tan and W. Thoen. Formal aspects of a generic model of trust for electronic commerce. *Journal of Decision Support Systems*, (33):233–246, 2002.
- [47] A. Tanenbaum and M. van Steen. *Distributed Systems: Principles and Paradigms*. Prentice Hall, 2002.
- [48] M. Uschold, M. King, S. Moralee, and Y. Zorgios. The enterprise ontology. *The Knowledge Engineering Review*, 13(1):31–89, 1998.
- [49] P. Weill and M. Vitale. What IT infrastructure capabilities are needed to implement e-business models? *MIS Quarterly Executive*, 1(1):17–34, March 2002.
- [50] R.J. Wieringa. A survey of structured and object-oriented software specification methods and techniques. *ACM Computing Surveys*, 30(4):459–527, December 1998.
- [51] R.J. Wieringa. *Design Methods for Reactive Systems: Yourdon, Statemate and the UML*. Morgan Kaufmann, 2003.
- [52] R.J. Wieringa and J. Gordijn. Value-oriented design of correct service coordination protocols. Technical report, Centre for Telematics and Information Technology, Univ. of Twente, The Netherlands, 2004. submitted.
- [53] R.J. Wieringa, J. Gordijn, and P.A.T. van Eck. Value framing: A prelude to software problem framing. In *1st International Workshop on Advances and Applications of Problem Frames (IWAAPF)*, pages 75–84. IEE, 2004.
- [54] Z. Zlatev, P. van Eck, R. Wieringa, and J. Gordijn. Goal-oriented RE for e-services. In *International Workshop on Service-Oriented Requirements Engineering –SORE ’04*, 2004. accepted.

10 Requested Budget

We request the standard budget for two PhD students for four years. The amounts below are in Euros.

Cost	
PhD student 1	157.683
PhD student 2	157.683
benchfee 1	4.538
benchfee 2	4.538
TOTAL	<u>324.442</u>