Towards Automated Logistics Service Comparison
Decision Support for Logistics Network Management

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Abstract: A recurring task when managing logistics networks in which logistics companies jointly offer services is the comparison of logistics services based on their underlying processes. The comparison is necessary for the integration of processes, the selection of logistics providers and the evaluation of a company's performance. Due to a high diversity of logistics services and their properties as well as due to the high amount of services automated logistics service comparison is needed to support this task. This paper presents basic requirements and evaluates the state of the art with regard to these requirements. In addition, an initial solution approach providing a solid base for future work is outlined.

1 INTRODUCTION

Logistics management plays a central role for most companies in manufacturing industries. It organises flows of goods and information across corporate value chains. Increased value orientation, progressive globalisation, ongoing concentration on core competencies, higher requirements towards the quality of service, and innovation in information and communication technology led to a high diversity logistics management has to deal with (Pfohl, 2004).

As a consequence, logistics companies such as warehouses or carriers start to arrange themselves in logistics networks in order to jointly offer a logistics service bundle that is able to meet customers' expectations. These logistics networks are usually managed by *Logistics Network Service Providers* (LSP) like third and fourth party logistics providers (Gudehus and Kotzab, 2009). LSPs do not necessarily have to provide own physical logistics assets such as trucks for the service delivery. Instead they need to have a wide knowledge of logistics processes and of information technology enabling them to act as the central point of contact to the customer and to coordinate logistics companies in order to flexibly configure services within the network with regard to the customers' requirements.

The main task for LSPs is therefore the network management which was introduced by (Sydow and Duschek, 2011) and which comprises four tasks: the selection of logistics companies which should be part of the network; the regulation of tasks necessary to implement the demanded logistics services; the allocation of these tasks to the companies within the network; and the evaluation of the network.

A recurring problem within those tasks is the comparison of logistics services. When selecting logistics services the LSP needs to check whether the services offered by companies fit to those required by the network. Within the allocation it needs to be examined whether those services are suitable to implement services needed by customers. Furthermore, LSPs have to find similar logistics services which indicate options to obtain economies of scale during the regulation. Finally, a central task when evaluating services is to verify that they still correspond to their initial design. As a manual comparison of logistics services can be quite cumbersome due to the high amount and diversity of logistics services and their properties the objective of this paper is to briefly outline an automated approach to the comparison of logistics services to support decision making within the management of logistics networks. In particular, the contribution of this paper is the evaluation of state of the art based on basic requirements as well as the introduction of an initial approach satisfying these requirements.

The paper is structured as follows. In section 2 the requirements towards the comparison of logistics services are outlined. Afterwards, section 3 evaluates related work with regard to these requirements. The approach is introduced in section

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4. Finally, section 5 concludes the paper and gives an outlook on next steps.

2 REQUIREMENTS

This section introduces the basic requirements towards the automated service comparison within logistics network management. These requirements were determined by conducting expert interviews and case studies in the context of two research projects and in collaboration with a logistics network emphasizing the practical need for an appropriate approach. The requirements are outlined in the following and examples that are partly based on the ARIS SmartPath reference processes are used to illustrate the purpose of the requirements.

Requirement 1 (Flow semantics): The most important requirement is that the comparison of logistics services has to be based on the examination of the behaviour of the business processes which implement the services independently of which business process notation is used. Processes as sets of activities performed in coordination by a single company (Weske, 2007) and collaborations of them allow to capture the flows of goods and information which are implemented by a logistics network in order to perform the main task of logistics, namely transferring goods in space and time (Gudehus and Kotzab, 2009). The reason for explicitly looking at the behaviour of processes is that logistics processes are usually characterized by a high degree of variability. A typical example is to compare consignment processes to identify consolidation options. In order to deal with different types of goods there might be some activities whose execution depends on the type. In such a case two processes might be quite different from a structural perspective as the number of types that can potentially be handled by a company might differ from those of another company. Comparing the behaviour instead helps to determine cases which both processes can handle. The behavioural view also allows to compare the actual process execution with process templates in case of unexpected runtime variations. This would probably not be possible from a structural perspective as the variations are commonly not captured in a model. The actual behaviour instead can be reconstructed from data within information systems. Additionally, notation-independence is needed because the companies within the network usually employ different notations, e.g. BPMN, EPC etc, affecting the identification of appropriate services.

Requirement 2 (Context semantics): While the flow semantics consider how a service is delivered, it is also essential to take account of what is done. Common process notations allow to label activities using phrases like "transport goods" and "pick order". This is not sufficient in logistics where it is necessary to consider the context in which a process is executed, e.g. during regulation two transport processes can only be consolidated if their routes are close to each other or during selection it is necessary to determine if a company is able to process individual orders in a special format. Hence, the second requirement is that activities are compared under consideration of a detailed functionality description rather than simply relying on their labels.

Requirement 3 (Level of abstraction): The third requirement refers to the first two requirements. It demands that the approach must take the different levels of abstraction that services can be viewed from into consideration. For example, there might be the option to consolidate a simple transport service with a composed service which consists of a couple of services, but which depicts a similar transport. Considering the flow semantics in such a case, a simple process must be compared to a process collaboration. Furthermore, companies may provide more process details than necessary to the LSPs that are mainly interested in a coarse-grain view onto the activities and the points of interaction. In this case a few activities from an LSP's view could correspond to a complex flow of activities offered by the companies. At the context level there is also a difference between the representation of services offered by companies and of those requested by customers. While services of companies usually illustrate companies' capabilities, services demanded

Table 1: Summary of the requirements.

	Key phrase	Description
Req. 1	Flow semantics	The comparison must be based on a notation-independent analysis of the behaviour of the business processes implementing the logistics services.
Req. 2	Context semantics	Process activities have to be compared on the base of a detailed functionality description rather than relying on labels.
Req. 3	Levels of abstraction	The different levels of abstraction services can be described on need to be regarded.
Req. 4	Presentation of results	The results must enable analysts to investigate reasons for the similarity of two processes.

by LSPs are specified with regard to a certain contract. A simple example to illustrate this is a transport service. A carrier would usually name the region in which it is able to conduct transports, e.g. Central Europe etc., while in a contract there is usually a demand for a specific tour, e.g. from Hamburg to Prague. This requirement is most important when tasks are allocated to companies.

Requirement 4 (Representation of results): In order to support an LSP in decision making it is not sufficient to present the result of a comparison of two services as a single number indicating the degree of overlap or difference between the services. Such a number might indeed be useful to preselect suitable services. Unfortunately, in this case the reasons for the classification are hidden behind a single number, which makes it hard for analysts to further investigate on the most suitable solution. Thus, the fourth requirement is that an analyst must be able to examine reasons for commonalities and differences for decision making using the results.

To summarize this section Table 1 provides an overview of all four requirements.

3 RELATED WORK

After having outlined the requirements in the last section existing work is presented and assessed on the base of these requirements here. Because of the flow semantics being the central requirement and all other requirements being based on it the focus is on approaches that compare processes.

In literature a couple of equivalence notions for comparing processes can be found, e.g. bisimulation (Hidders, Dumas, van der Aalst, ter Hofstede and Verelst, 2005). Following (van Dongen, et al., 2008) those notions can be excluded from the explanations in this section for various reasons. The most important one is that they compute the equivalence of two processes, i.e. they answer the binary question if two processes are equivalent or not. As the fourth requirement states, it is important to make a statement about the degree of equivalence and to give hints for further investigation. This is clearly not satisfied by those notions. Thus, this section deals with approaches in the field of process similarity that measure the degree of equivalence.

The first approach outlined here is presented in (van der Aalst, et al., 2006). Here processes are compared on the base of finite sets of traces. These sets usually comprise a certain number of actual process executions, but can also be derived from simulations or user defined scenarios. To compare two processes using sets of traces two metrics are defined. Both are asymmetric and measure the similarity based on one of the processes. Besides counting the number of transition connections that appear in traces of the original as well as in the compared model the metrics also account for the transitions that are enabled within the traces.

In (Dijkman, et al., 2009) the Graph Edit Distance which indicates how many operations are needed to transform one process graph into another one is used to calculate the similarity. To calculate this metric, the mapping of nodes of two graphs is determined in four different ways each of them relying on activity labels.

In (van Dongen, et al., 2008) an approach is presented that relies on so called causal footprints. These footprints consist of all nodes of a process graph and two sets for each node. The first set comprises all nodes which can be executed before and the second set comprises those which can be executed

Table 2: Assessment of existing approaches.

Approach	Flow semantics	Context semantics	Levels of abstraction	Presentation of results
(Dijkman, Dumas and García-Bañuelos, 2009)	- Structure - Business process graphs	- Labels	- Not considered	- A symmetric metric
(Ehrig, Koschmider and Oberweis, 2007)	- Structure - Petri nets	- Labels	- Not considered	- A symmetric metric
(Kim and Suh, 2010)	- Structure - Special ontologies	- Context information	- Not considered	- A symmetric metric
(Lu, Sadiq and Governatori, 2009)	- Structure & behaviour - Process variant scheme	- Labels - Context information	- Not considered	- A symmetric metric
(van der Aalst, de Medeiros and Weijters, 2006)	- Behaviour - Petri nets	- Not considered	- Not considered	-Two asymmetric metrics
(van Dongen, Dijkman and Mendling, 2008)	- Behaviour - Causal footprint	- Labels	- Not considered	- A symmetric metric
(Zha, Wang, Wen, Wang and Sun, 2010)	- Behaviour - Transition adjacency relations	- Not considered	- Not considered	- A symmetric metric

after the current node. Transforming the footprints into vectors makes it possible to calculate the similarity as the cosine of the angle between these vectors. During the transformation matching activities that are based on labels and in case of EPCs also on information derived from events surrounding a function are employed. A similar approach is introduced in (Zha, et al., 2010). There a process is represented as a transition adjacency relation comprising pairs of activities of a process that can be executed directly one after the other. The similarity is defined as the ratio between the cardinality of the intersection of two transition adjacency relation sets and the cardinality of their union.

In the field of process variants an approach to determine whether a certain process variant meets a query which is a collection of features is introduced in (Lu, et al., 2009). These features can be classified as behavioural, structural or contextual features. For all classes algorithms to measure the similarity are proposed and the general similarity is then defined as the ratio of the similar features and the number of features in the query.

Some approaches rely on ontologies used to describe processes. In (Ehrig, et al., 2007) Petri net models are represented using an ontology. The similarity of two concepts from different models is the weighted sum of the syntactic, the linguistic (synonym and homonym relations) and the structural (taking related process concepts into account) similarity. The similarity of two processes is the sum of the similarities of concept pairs determined beforehand by mapping concepts from one model to those from the other one. In (Kim and Suh, 2010) five ontologies are defined to describe different views onto a process including organizational, domain, structural, resource and service aspects. Based thereon matchmaking is employed to classify the match between properties of two processes and to sum the corresponding similarity degrees.

The assessment of these approaches with regard to the requirements outlined beforehand is summarized in Table 2. As can be seen in this table, approaches exist which examine the behaviour of processes independently from a certain business process notation by relying on a representation that can be derived from such notations. While most of the approaches use labels to match activities or assume the match to be done beforehand, two approaches consider context information. However, none of the approaches fulfils both requirements. Regarding the demand for supporting different levels of abstraction it can be seen that none of the approaches addresses this requirement. Lastly, all approaches calculate a single degree of similarity but do not provide further information. The approach presented in (van der Aalst, et al., 2006) is slightly more advanced as it calculates the similarity for each of the processes being compared.

It is subject to future work and a relevant open issue to develop an approach which is designed with regard to all requirements. A first blueprint for such an approach is introduced in the next section.

4 PROPOSED APPROACH

The basic approach to the automated comparison of logistics services and the reference of each step within the approach to the requirements are presented in Figure 1.

The first step is the *transformation* of the process models into notation-independent models with activity annotations. Candidates for a meta-model are Petri nets, transition systems etc. On the base of such a meta-model different transformations have to be written in order to ensure that process models of various notations can be compared as demanded by the first requirement. Existing approaches, like (Raedts, Petkovic, Usenko, van der Werf, Groote and Somers, 2007) where BPMN models are transformed into Petri net models, can be reused.

A further important part of the first step is to annotate the models during the transformation in order to add information about the logistics functionality as necessary due to the second requirement. The annotation is based on the IOPE-model which is used within several service specification approaches like the Unified Service Description Language (Cardoso, Barros, May and Kylau, 2010). This model allows for describing activities with regard to their inputs and outputs as well as the preconditions and effects as representations of the state of the world that need to remain valid before and after activity execution. Furthermore the IOPE-model allows for applying the scheme introduced by (Hömberg, Hustadt, Jodin, Kochsiek, Nagelö and Riha, 2007). This scheme can be used to describe logistics functionality in terms of the information and goods that flow through an activity (input and output) as well as in terms of the changes made to the time and the space as well as the states of the information and goods (precondition and effect). To make these annotations interpretable for machines, different ontologies as explicit specifications of a conceptualization (Gruber, 1993) need to be employed. Regarding the third requirement the concepts of these ontologies must reflect different levels of abstraction and must be related to each other, e.g. an ontology to describe states regarding space must enable a modeller to define regions and routes for transports. While the region is necessary to describe a company's abilities the route is needed to specify contract related requirements. This ontology should also connect the concepts route and region so that a machine is able to determine whether a company can handle routes in a certain region. The actual annotation can then be done in different ways. If the source model is already annotated in some way, these annotations also need to be transformed, e.g. if different ontologies are used, ontology matching algorithms (Euzenat and Shvaiko, 2007) will need to be integrated. In case of missing annotations they can be added manually while annotations on the base of the proposed ontologies can simply be copied.

Afterwards the second step is to *normalize* the models. This is done because of the third requirement. The goal of this step is to transform fine-grain process models into more coarse-grain ones in order to bring both models to the same level of abstraction. A simple rule could be to summarize activities that are arranged in sequence without any points of decision or interaction in between. One of the approaches supporting this step is presented in (Koliadis and Ghose, 2007) where effects of activity executions within processes are summarized supporting the summary of the overall preconditions and effects.

The third step prepares the process models for the actual comparison by *matching activities* of one process to the ones of the other process. The rationale here is to calculate the similarity of all activity pairs on the base of their annotations. Afterwards the optimal mapping is determined by an appropriate heuristic whereby optimal means that the sum of the similarity of all mapped pairs is as high as possible. This step is oriented towards the approach outlined in (Dijkman, et al., 2009) where the optimal mapping of activities is computed on the base of the syntactic and linguistic similarity of their labels. By relying on the annotations this step also accounts for the second requirement.

The fourth step is the *comparison of the models* on the base of their behaviour. As presented in the previous section there already exist approaches to compare processes from a behavioural perspective, like the one presented in (van der Aalst, et al., 2006). Nevertheless, extension is necessary to consider the fourth requirement, i.e. besides the computation of a degree of similarity the main reasons for the result must also be collected.

The last step is then to present the results to the customer using an appropriate *visualisation* that not only presents the degree of similarity but also the indicators that were collected in the previous step. As the services might rely on different notations it is important to present the results in a way that allows an analyst to investigate them although he or she is not familiar with the used process notations.
As the comparison of the original service to a set of other services is done in pairs and as there might be a lot of services that need to be compared the computation time can be high. In order to reduce it different strategies are possible. The first one is to estimate the similarity beforehand and only take those services into consideration which are believed to be similar to a certain degree, like it is done in (Yan, Dijkman and Grefen, 2010). A further option is to preselect services based on the purpose of the comparison, e.g. in the allocation and in the selection only services representing a company's capabilities are regarded. The last option mentioned here is to configure the features taken into account within the approach like it is proposed in (Lu, et al., 2009). Of course all these strategies can be commonly employed. It is also possible to proceed iteratively and refine the result set step by step.

5 CONCLUSION & NEXT STEPS

This paper motivated why it is necessary to support

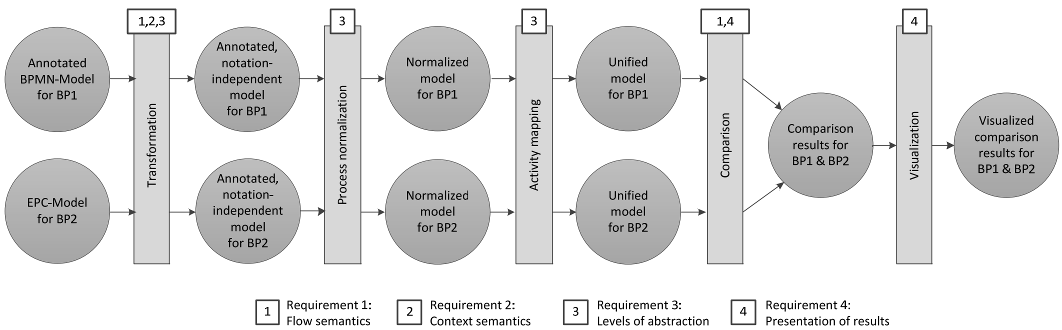

Figure 1: Basic approach for the service comparison.

the management of logistics networks with an automated approach for logistics service comparison. The central requirements determined in cooperation with a logistics network were introduced. Subsequently, the state of the art was evaluated with regard to these requirements. As a first step towards the automated comparison an approach which consists of five steps was proposed. These steps include some pre-processing in form of the transformation into a notation-independent representation as well as the normalization of the representation and the activity mapping to equalize the different levels of abstraction. Afterwards the comparison is done using the notation-independent, normalized and mapped process models. The final step is the visualization making the results interpretable for experts.

The first step to implement the basic approach is the selection of a notation-independent representation and of a basic comparison algorithm. On the one hand this represents the main functionality of the approach and on the other hand it constitutes a solid base for adding the other requirements. It is planned to evaluate the approach in each development step in order to ensure the benefit for logistics management. Hence, experts opinions and the results of the automated approach will be compared on the base of scenarios derived from logistics reference processes and from case studies conducted within the logistics network.

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REFERENCES

Cardoso, J., Barros, A., May, N. and Kylau, U. (2010). Towards a Unified Service Description Language for the Internet of Services: Requirements and First Developments. *Proceedings of the 2010 IEEE International Conference on Services Computing*, 602-609.

Dijkman, R., Dumas, M. and García-Bañuelos, L. (2009). Graph Matching Algorithms for Business Process Model Similarity Search. *Proceedings of the 7th International Conference on Business Process Management*, 48-63.

Ehrig, M., Koschmider, A. and Oberweis, A. (2007). Measuring similarity between semantic business process models. *Proceedings of the fourth Asia-Pacific conference on Comceptual modelling - Volume 67*, 71-80.

Euzenat, J. and Shvaiko, P. (2007). *Ontology matching*. Heidelberg, Germany: Springer.

Gruber, T. R.(1993). A translation approach to portable ontology specifications. *Knowledge Acquisition*, 5,199-220.

Gudehus, T. and Kotzab, H. (2009). *Comprehensive Logistics*. Springer: Dordrecht.

Hidders, J., Dumas, M., van der Aalst, W.M.P., ter Hofstede, A.H.M. and Verelst, J. (2005). When are two workflows the same? *Proceedings of the 2005 Australasian symposium on Theory of computing - Volume 41*, 3-11.

Hömberg, K., Hustadt, J., Jodin, D., Kochsiek, J., Nagelö, L. and Riha, I. (2007). *Basisprozesse für die Modellierung in großen Netzen der Logistik*. Technical University Dortmund: Technical Report.

Kim, G. and Suh, Y. (2010). Ontology-based semantic matching for business process management. *ACM SIGMIS Database*, 41, 98 - 118.

Koliadis, G. and Ghose, A. (2007). Verifying Semantic Business Process Models in Inter-operation. *Proceedings of the IEEE International Conference on Services Computing SCC 2007*, 731-738.

Lu, R., Sadiq, S. and Governatori, G. (2009). On Managing Business Processes Variants. *Data & Knowledge Engineering*, 68, 642-664.

Pfohl, H.-C. (2004). *Logistikmanagement - Konzeption und Funktion*. Berlin: Springer.

Raedts, I., Petkovic, M., Usenko, Y.S., van der Werf, J.M.E.M., Groote, J.F. and Somers, L.J. (2007). Transformation of BPMN Models for Behaviour Analysis. *Proceedings of the 5th International Workshop on Modelling, Simulation, Verification and Validation of Enterprise Information Systems*, 126-137.

Sydow, J. and Duschek, S. (2011). *Management interorganisationaler Beziehungen : Netzwerke - Cluster - Allianzen*. Stuttgart: Kohlhammer.

van der Aalst, W.M.P., de Medeiros, A.K.A. and Weijters, A. J. M. M. (2006). Process Equivalence: Comparing Two Process Models Based on Observed Behavior. *Proceedings of the 4th International Conference on Business Process Management*, 129-144.

van Dongen, B., Dijkman, R. and Mendling, J. (2008). Measuring Similarity between Business Process Models. *Proceedings of the 20th international conference on Advanced Information Systems Engineering*, 450-464.

Weske, M. (2007). *Business Process Management*. Berlin, Germany: Springer.

Yan, Z., Dijkman, R. and Grefen, P. (2010). Fast business process similarity search with feature-based similarity estimation. *Proceedings of the 2010 international conference on On the move to meaningful internet systems - Volume Part I*, 60-77.

Zha, H., Wang, J., Wen, L., Wang, C. and Sun, J. (2010). A workflow net similarity measure based on transition adjacency relations. *Computers in Industry*,61, 463-471.