Process Mining for Electronic Data Interchange*

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Abstract. Choreography modeling and service integration received a lot of attention in the last decade. However, most real-world implementations of inter-organizational systems are still realized by traditional *Electronic Data Interchange* (EDI) standards. In traditional EDI standards, the notion of process or choreography is not explicitly specified. Rather, every business document exchange stands for its own. This lack of process awareness in traditional EDI systems hinders organizations from applying Business Process Management (BPM) methods in such settings. To address this shortcoming, we seek to derive choreographies from EDI message exchanges. Thereby, we employ and extend *process mining* techniques, which have so far concentrated on business processes within single organizations. We discover the interaction sequences between the partners as well as the business information conveyed in the exchanged documents, which goes beyond the state-of-the-art in process mining. As a result, we lift the information gained on the IT level to the business level. This enables us to derive new insights that help organizations to improve their performance, e.g., an organization may get insights into the *value* of its business partnerships to support an efficient decision making process. This way we hope to bring the merits of BPM to inter-organizational systems realized by traditional EDI standards.

Keywords: process mining, EDI, EDIFACT, inter-organizational business processes.

1 Introduction

Electronic Data Interchange (EDI) is the exchange of business data between applications based on a format that is understood by all participating parties [9].

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While recent academic research for Web services and business process modeling places lots of emphasis on modeling choreographies of business processes [2], many inter-organizational business processes are still realized by means of traditional EDI systems. However, traditional EDI systems usually lack the explicit notion of a business process. They are solely responsible for sending and receiving messages. Hence, every exchanged document stands for its own and the process context is lost. This results in a number of shortcomings.

Shortcoming #1. An inter-organizational business process comprises one or more message exchanges between companies for conducting an electronic business transaction. When companies intend to analyze their inter-organizational processes they generally have to rely on a-priori models, if models documenting the business processes exist at all. In case there are models, those may describe the business processes as they were planned, which is not necessarily in sync with the real-world business processes.

Shortcoming #2. EDI documents convey a lot of redundant information, while only a minimal subset of the conveyed information is actually sufficient for a certain step of a transaction. In other words, an inter-organizational business process does not require the exchange of complete business documents as in a paper-based world, but only the appropriate delta of information required to handle the next step in the process. As information is electronic, redundant information does not need to increase the transfer costs. However, it may cause semantic heterogeneity and additional checks.

Shortcoming #3. The specifics of inter-organizational business processes require not only focusing on the executed activities, but also on the actual exchanged business information. However, combined information from process data and business performance data of the exchanged EDI messages, such as EDIFACT messages, is currently not being exploited in a systematic manner. Despite the attainable insights for decision-making there are – to the best of our knowledge – no such approaches for EDI systems.

In this paper we present an approach, though at an early stage, that addresses the three shortcomings presented above. We build upon state-of-the-art process mining techniques [1,16], which we extend for inter-organizational systems realized by means of EDI. Thereby, we focus on EDIFACT [3] since traditional EDI standards like EDIFACT and ANSI X12 still play a dominant role in Business-to-Business (B2B) e-commerce and will presumably continue to be the primary data formats for automated data exchange between companies for years [19]. However, our approach is generic in terms that it is independent of the underlying transfer syntax. Hence, it can also be used for more recent EDI formats such as XML-based business documents.

The remainder of this paper is structured as follows. First, Section 2 introduces process mining as enabling technology. However, thus far process mining is mostly applied within one organization and existing techniques do not exploit the specifics of EDI. Section 3 elaborates on the principal research questions and discusses the resulting challenges. In Section 4, the technical architecture of our approach is described. Section 5 discusses related work. Finally, in Section 6 a summary and conclusion is given.

2 Process Mining

Process mining serves a bridge between data mining and business process modeling [1]. The goal is to extract process-related knowledge from event data stored in information systems. Process mining is an emerging discipline providing comprehensive sets of tools to provide fact-based insights and to support process improvements. This new discipline builds on process model-driven approaches and data mining.

Figure 1 shows that process mining establishes links between the actual processes and their data on the one hand and process models on the other hand. Today's information systems log enormous amounts of events. Classical WFM systems, BPM systems, ERP systems, PDM systems, CRM systems, middleware, and hospital information systems provide detailed information about the activities that have been executed. Figure 1 refers to such data as *event logs*. Information systems that are process-aware provide event logs that can be analyzed directly using existing process mining tools. However, most information systems store such information in unstructured form, e.g., event data is scattered over many tables or needs to be tapped off from subsystems exchanging messages. In such cases, event data exist but some efforts are needed to extract them. Data extraction is an integral part of any process mining effort.

Event logs can be used to conduct three types of process mining: (a) discovery, (b) conformance, and (c) enhancement [1]. The goal of *discovery* is to extract

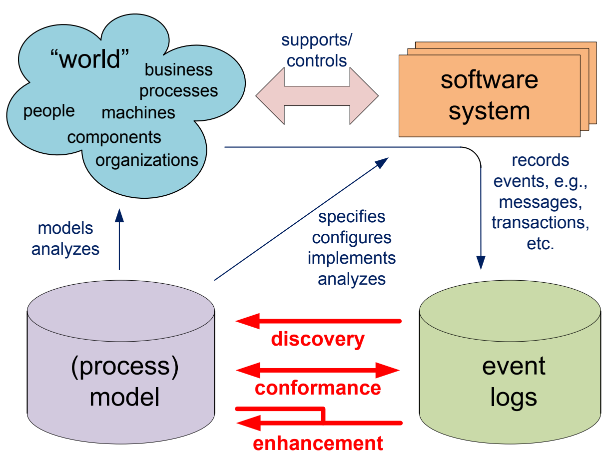

Fig. 1. Three main types of process mining (discovery, conformance, and enhancement) positioned in the classical setting where event logs are collected within a single organization

models from raw event data in information systems (transaction logs, data bases, audit trails, etc.). A discovery technique takes an event log and produces a model without using any a-priori information. An example is the α-algorithm [17] that takes an event log and produces a Petri net explaining the behavior recorded in the log. The second type of process mining is *conformance*. Here, an existing process model is compared with an event log of the same process. Conformance checking can be used to check if reality, as recorded in the log, conforms to the model and vice versa. Techniques as presented in [14] may be used to detect, locate and explain deviations, and to measure the severity of these deviations. The third type of process mining is *enhancement*. Here, the idea is to extend or improve an existing process model using information about the actual process recorded in some event log. Whereas conformance checking measures the alignment between model and reality, this third type of process mining aims at changing or extending the a-priori model, e.g., adding a new perspective to the process model by cross-correlating it with the log. An example is the extension of a process model with performance data. For instance, by combining the timestamps in the event log with the discovered process model it is possible to show bottlenecks, service levels, throughput times, and frequencies.

To illustrate the basic idea of process discovery consider an event log containing information about 50 cases. Each event is characterized by an activity name. (Note that logs also contain timestamps and case data, but we abstract from these in this simple example.) Therefore, we can describe log L as a multiset of traces containing activity names: $L = \{ \langle a,b,d,c,e,g\rangle^{18}, \langle a,b,c,d,e,g\rangle^{12}, \langle a,b,c,d,e,f,b,d,c,e,g\rangle^{7}, \langle a,b,d,c,e,f,b,d,c,e,g\rangle^{5}, \langle a,b,c,d,e,f,b,c,d,e,g\rangle^{3}, \langle a,b,c,d,e,f,b,c,d,e,f,b,d,c,e,g\rangle^{3}, \langle a,b,d,c,e,f,b,c,d,e,f,b,c,d,e,g\rangle^{2}\}$. There are 18 cases that have a trace $\langle a,b,d,c,e,g\rangle$ in the event log, 12 cases followed the path $\langle a,b,c,d,e,g\rangle$, etc. Process discovery algorithms such as the α-algorithm [17] can extract a process model from such a log. Figure 2 shows the resulting process model. All trace in L can be "replayed" by this model. The α-algorithm discovered that all cases start with a and end with g, that c and d are in parallel, that f initiates another iteration, etc. Note that here the process model is represented as a Petri net. However, the notation used is not important. Process mining tools such a ProM can convert the result to the desirable notation. The real challenge is to find the underlying process, not the notation to depict it.

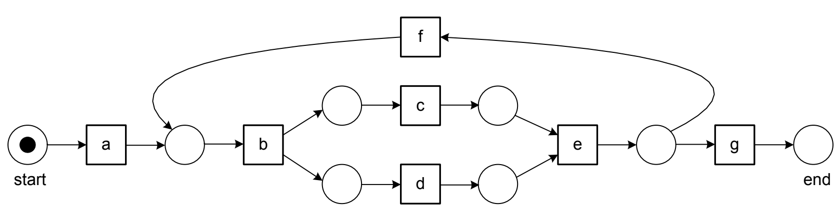

Fig. 2. Process model discovered based on an event log L containing 50 cases characterized by sequences of activity names

Now let us suppose that Figure 2 shows the desired process and log L contains a trace $\sigma = \langle a, b, c, e, g \rangle$. Conformance checking techniques such as the one described in [14] are able to detect that σ deviates. These technique can diagnose an event log, highlight, and quantify deviations.

Figure 2 is a bit misleading given its simplicity and focus on control-flow. Process mining is *not* restricted to the control-flow perspective and may include *other perspectives* such as the resource/organizational dimension, the time/performance dimension, and the object/data dimension. Moreover, process mining techniques can be applied to processes with hundreds of different activities, thousands of cases, etc.

Using ProM, we have applied process mining in over 100 organizations. Most of these applications focus on processes inside one organization. Moreover, despite the omnipresence of EDI, we are not aware of any process mining applications systematically analyzing inter-organizational EDI data. In Figure 2 we assumed the transitions to be activities. *However, in an EDI context these may also correspond to (the sending and/or receiving of) messages.*

3 Challenges and Research Questions

To address the shortcomings presented in Section 1, we identified the following set of research questions.

3.1 Deriving Process Choreographies

A choreography describes the public message exchange between multiple parties [11], with the purpose of supporting interoperability. However, traditional EDI systems lack the explicit notion of a business process, since they are solely responsible for sending and receiving messages. This leads to the first research question, which is to derive choreographies of inter-organizational business processes based on EDI messages that are interchanged between companies.

The hypothesis is that in traditional EDI systems choreographies have been implicitly implemented in the document exchanges, although they have not been explicitly agreed upon beforehand. We intend to develop means for discovering these implicit processes by extending current process mining techniques. However, process mining presupposes the explicit notion of a process (or case) in order to log activities and to correlate them to instances of a process. Hence, we need to group EDI messages to process instances before choreographies can be derived. Thereby, we examine meta-data as well as the actual business data conveyed in the EDI messages, since they carry implicit references to previously sent messages of the same business case. In other words, we use redundantly transferred information in the EDI messages to correlate them to business cases. At the same time, these redundancies are subject to further analyses in EDImine as described in the following section.

3.2 Identifying Redundancies in Business Documents

Redundant information in EDI-based business documents is not problematic for the cost of its transfer, but it may cause undesired semantic heterogeneity. The reason for redundancy is twofold:

First, the strategy for standardizing EDI documents follows a top-down approach [10]. This means, that for designing an EDI business document type the various requirements from different industry domains have been collected and incorporated into the standardization work. The resulting business document type corresponds to a super-set of all the requirements containing a high degree of optional information as well as having the same type of business information positioned in different places.

Second, the absence of an explicit process notion in traditional EDI approaches every business document is rather considered *standalone* and not in the context of a set of document exchanges. This has led to the fact that EDI documents convey a lot of redundant information, while only a minimal subset of the conveyed information is actually sufficient for a certain step of a transaction. In other words, an inter-organizational business process does not require the exchange of complete business documents as in a paper-based world, but only the appropriate *delta* of information required to handle the next step in the process.

This leads us to the second research question which is to develop methods for identifying the minimum as well as the redundant part of information exchanged in the course of a discovered EDI process. Based on this question, the hypothesis is that inter-organizational process mining allows identifying redundantly transferred information and, consequently, allows pointing out the minimal subset of information that is really needed. Our objective is to extend existing mining techniques for identifying redundancies. While such methods for identifying redundancies will be of less utility for already implemented systems, they can highlight current problems in message and process design. The insights gained through process mining will be of value for EDI-related standardization committees. For enabling an appropriate comparison of the similarities as well as the differences between distinct EDI messages it is required to investigate the semantics of the conveyed information. We aim at applying ontological approaches to assign semantically unambiguous meaning to the exchanged information.

3.3 Analyzing Business Performance

Current process mining techniques concentrate on the life cycle of executed activities (e.g., started, finished, canceled, suspended, etc.) and their ordering, to discover the flow of cases in a business process. This is supported by the information contained in log files of a process-aware information system. However, inter-organizational processes need to be monitored in a different manner. The log files of EDI systems are clearly scoped (or limited) to the boundaries of the system – i.e., sending and receiving messages. At the same time, we are able to work with richer information by examining the actual content of the messages that are sent and received by EDI systems. In other words, we do not treat transferred business documents as opaque objects, but combine them with log data.

The resulting research question is whether we can lift the information gained on the IT level (from the log files as well as from the messages) to the business level in order to support companies in decision-making. In addressing this question, semantics is one of the key ingredients. We intend to provide a semantic framework for conceptualizing the process data and business data gained on the IT level. The concepts can then be used to build queries on the business level.

Our goal is to provide a business cockpit comparable to navigation systems supporting car drivers [1]. Such a system will be able to visualize the networks of companies, show the flow of business documents and warn about bottlenecks in document processing. The system may be able to suggest deviations from the regular process flow in case something goes wrong (i.e., detours) – an example may be to order from a different partner, if an order has been sent, but no confirmation was received for a certain time. Consequently, our objective is to answer business-related questions on two levels: (i) business process performance and (ii) general business performance.

Questions on the first level focus on the process performance of an enterprise with the outside world. They cover the discovery, the monitoring/measuring (identification of bottlenecks, average durations, etc.), and the improvement of processes.

Questions on the second level focus on business performance with regard to a company's economic relationships with partners (e.g., number of orders or order volume as indicators of the economic importance of the partnership, etc.). Having information of their value chain at hand, enterprises are able to identify value drivers, cost drivers as well as dependencies on external relationships. By combining process performance and business performance they also gain new insights on the *value* of business partnerships (e.g., does the order volume of a certain partner justify exceptions to the desired workflow leading to higher process costs).

4 Architecture

Our approach conducted in EDImine will be supported and validated by a corresponding tool implementation. Thereby, we do not develop a tool from scratch, but build on an existing open-source solution - the ProM tool[1] [18]. ProM is developed at the Eindhoven University of Technology and is the most prevalent tool in the area of process mining. The architecture of ProM has been designed with extensibility in mind by means of plug-ins. We leverage the extensibility mechanisms of ProM by providing the appropriate plug-ins for the aforementioned research goals.

Figure 3 illustrates the basic architecture of our approach. The starting point for performing the mining tasks is given by two types of data from the EDI systems of an organization: event logs and the contents of EDI messages. In order to allow for further processing in the ProM tool they have to be combined and transformed to a data structure that conforms to the *eXtensible Event Stream*

[1] `http://www.processmining.org` (visited Feb 8, 2011).

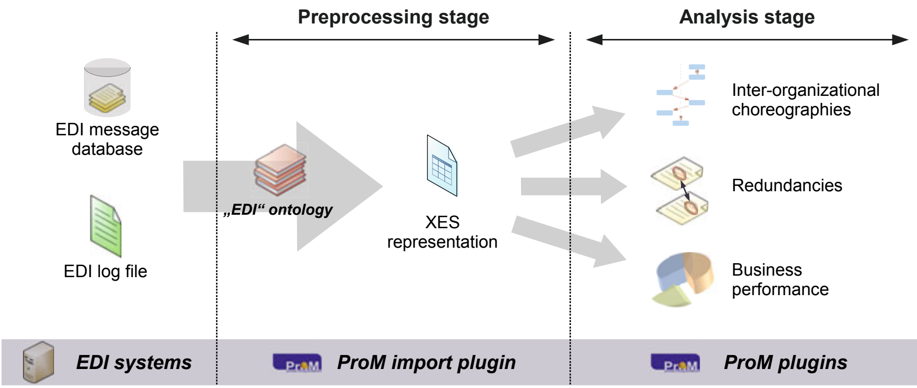

Fig. 3. Preprocessing and analysis stages

(XES) format [18]. XES is an XML-based format for storing event logs and the standard input format for ProM (as of Version 6). The conversion is performed in the preprocessing stage and implemented in a ProM import plug-in. In the subsequent analysis stage, further analyses with regard to the aforementioned research questions can be performed. The tasks of the analysis stage are also implemented by means of corresponding ProM plug-ins. In the following sections, the preprocessing and analysis stages are described in detail.

4.1 Preprocessing Stage

Figure 4 illustrates the architecture of the preprocessing stage in more detail. Business partners participating in an inter-organizational EDI setting record the contents of the exchanged business documents and keep a log of the transactions. Such a log is expected to contain information about sender and receiver of the messages, a timestamp and a reference to the actual message contents. The provided log data and message contents form the primary input for the EDImine preprocessing plug-in which combines them to an XES-conforming representation.

As described in Section 3.1 the log entries have to be grouped according to process instances. However, since EDI systems usually lack awareness of the underlying business processes in whose context they exchange messages, this is not a trivial task. To tackle this challenge, we aim at comparing and matching information of the EDI message exchanges contained in the logs as well as pieces of business information which are repeatedly transferred in the individual messages. This recognition of redundantly transferred information is fostered by a conceptual representation of the transferred business information. The concepts describing business data elements in EDI message types are defined in an external ontology.

Table 1 lists the structural elements of XES documents and their meanings. These elements have to be enriched with attributes in the form of key-value

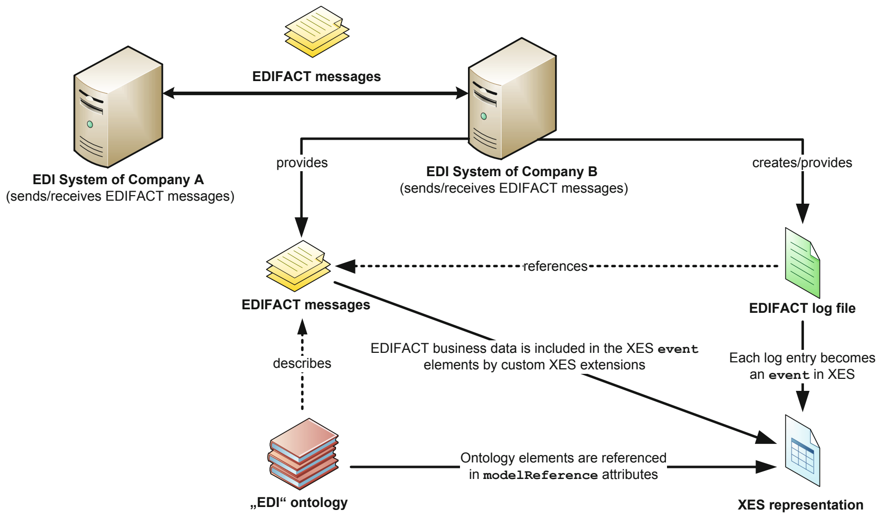

Fig. 4. Preprocessing log data and message contents for mining

Table 1. Structural elements of an XES document

Element	Usage/Meaning
log	Root element of an XES document containing a number of *traces*.
trace	Represents a group of *events* which belong to the same process instance.
event	Contains a single event. In process mining applications this usually corresponds with the execution of a single activity in a process instance.

pairs in order to include actual information about recorded events. The XES standard provides a mechanism through which attributes can be declared in well-defined extensions to the meta-model of XES. In addition, there are a number of predefined *standard extensions* in the XES standard which are generally useful in process mining contexts.

The EDImine preprocessing plug-in converts each log entry from the EDI message exchange log to an *event* element in an XES representation. Furthermore, the business data payload contained in the conveyed EDI messages is included in attributes which we define through extending the XES meta-model. Moreover, the concepts used for conceptualizing the business data are referenced through *modelReference* attributes using XES' standard extension *Semantic*. The *event* elements are grouped to process instances in corresponding *trace* elements.

4.2 Analysis Stage

In the analysis stage the prepared XES data serves as a database for mining the inter-organizational choreographies, for identifying redundancies and for business performance analyses. The conceptualization of the EDI data by means of an ontology as described in Section 4.1 plays a key role for performing the tasks of this stage. First of all, it allows for mapping EDI message types to concrete and human-understandable activity labels in the mined inter-organizational choreographies. Secondly, it permits the identification of redundancies by matching the business data contained in the individual EDI messages with regard to their conceptual belonging. Thirdly, the knowledge in the ontology is used for business performance analyses allowing the user to build sophisticated queries using the concepts from the ontology. These tasks will be realized in ProM plugins; however, the algorithms for these tasks have yet to be developed and are subject to further research.

5 Related Work

Process mining techniques [1,16] extract knowledge about business processes by analyzing event logs. It is seen as part of Business Intelligence (i.e., BP Intelligence [8]) and process mining techniques are also being embedded in commercial BPM suites. So far, the focus has been on the analysis of processes inside a single organization. There exist a few papers on process mining in cross-organizational settings such as [15], which focuses on choreography conformance checking between the mined workflows from event logs of SOAP message exchanges and abstract BPEL models. Similarly, [13] also emphasizes on verifying behavioral properties in Web service choreographies. This reveals that process mining in an inter-organizational context tends to focus on the area of Web services. In practice, however, neither explicit choreography modeling nor Web services are widely employed in electronic business transactions. Rather, *traditional approaches to Electronic Data Interchange (EDI) such as EDIFACT still play an overwhelmingly dominant role* [3,19]. In an unpublished work [12], the topic of mining EDI messages has been approached, but best to our knowledge no further research has been conducted.

In order to achieve the goals of EDImine we intend to conceptualize the data from EDI business documents by means of ontologies. Previous attempts to ontologize various EDI standards include works performed in the course of the Tripcom project[2] [6,7], which aims at creating an ontological infrastructure for business processes and business data. Tripcom defines ontologies for EDI in terms of both syntax and semantics. However, regarding semantics Tripcom focuses on the structure of message types. In contrary, EDImine focuses on building EDI ontologies for business domain specifics (e.g., bank transactions, invoice transactions, etc.) in order to provide a higher conceptual level.

So far, in existing process mining techniques there is little consideration for the semantics of events. For example, activity names are just considered as labels without much consideration for the meaning and their relations to other entities. In the SUPER project[3] [5], a semantic approach has been developed that aims at the deployment of semantic BPM techniques. For instance, the SA-MXML

[2] `http://tripcom.org/ontologies` (visited March 14, 2011).
[3] `http://www.ip-super.org` (visited March 14, 2011).

(Semantically Annotated Mining XML) format, an annotated version of the MXML format, was developed to collect and store event logs such that events are linked to ontologies. The use of ontologies and reasoners causes an immediate benefit to process mining techniques by raising the level of abstraction from the syntactic level to the semantic level [4]. However, the MXML format has shown several limitations which is the reason for choosing the XES format [18].

6 Conclusion

In this paper we introduced our approach for mining inter-organizational business processes. We discussed the lack of process awareness in common Electronic Data Interchange (EDI) systems and three shortcomings resulting thereof: (i) the unavailability of information about real-world business process execution, (ii) redundancies in the transferred business documents and (iii) the lack of support for systematic analyses of business performance and decision-making. We further described how we intend to address these shortcomings by extending existing process mining techniques and applying them on inter-organizational systems. Lastly, we proposed a two-staged technical architecture for our approach that integrates with the existing process mining tool ProM by means of plug-ins.

We expect that the unveiling of the inter-organizational choreographies will help companies to rediscover and document the relationships in their business network. Furthermore, we believe that insights gained from the combination of process and business performance data will aid companies in decision-making with regard to their interactions with business partners. Finally, methods to identify redundancies in message exchanges will be less relevant for already implemented EDI solutions, but can help standardization bodies to streamline future business document standards. The overall goal is to bring the merits of Business Process Management (BPM) to inter-organizational systems realized by means of EDI.

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