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Basic Principles of Financial Process Mining A Journey through Financial Data in Accounting Information Systems

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ABSTRACT
Auditors and process managers often face a huge amount of financial entries in accounting information systems. For many reasons like auditing the internal control system a process-oriented view would be more helpful to understand how a set of transactions produced financial entries. For this reason we present an algorithm capable to mine financial entries and open items to reconstruct the process instances which produced the financial entries. In this way, auditors can trace how balance sheet items have been produced in the system. Traditional process mining techniques only reconstruct processes but pay no regard to the financial dimension. The paper wants to close this gap and integrate the process view with the accounting view.

Keywords
Financial Process Mining, Business Processes, Enterprise Resource Planning Systems, Financial Data, IT Audit, System Audit, Process Audit, Process Performance Improvement

INTRODUCTION
The modeling of Business Processes is a broad and well-known area of research in the field of information systems. Several business process modeling languages like Event Driven Process Chains (EPC) (Scheer and Nüttgens, 1995; Scheer and Nüttgens, 2000) or the Business Process Modeling Language (BPMN; (BPMN, 2004)) have evolved in recent years inspired by researchers and practitioners. With the aid of business process modeling languages, business processes are visualized for better understanding processes or for analysis and improvement purposes. Usually, business process modeling languages provide a set of elements as abstractions of real-world objects and allow users modeling processes which were evaluated manually before. In this paper, we want to propose an approach how financial business processes can be evaluated based on entries in the accounting module of an enterprise resource planning (ERP) system. We use open item accounting in the ERP system to link documents and items and to reconstruct the financial business processes. Processes are automatically "mined" based on existing financial data in the database of an ERP system. As a result, the manual modeling of these processes becomes obsolete to save time and improve accuracy of the visualization and the evaluation of properties of existing financial business processes. With our approach, we address two main groups of users: auditors who analyze processes for compliance reasons (internal as well as external auditors) and process managers who are interested in performance aspects of business processes.

The paper on hand has one aim: it can be understood as a feasibility study to show that our approach to automatically mining financial business process instances works in a real-world ERP system environment. We have chosen SAP as a well known and widely used ERP system and have implement a basic mining algorithm in the Java programming language to mine and visualize individual process instances. As a proof of concept, we provide some exemplary processes which have been mined with our algorithm.

The paper is organized as follows: we first explain the stakeholders being potentially interested in financial process mining. After that related work is discussed and the research gap is revealed. The basic principle and our prototypical implementation are shown in the next section.

STAKEHOLDERS OF FINANCIAL PROCESS MINING
The main stakeholders include business process managers / process owners, external and internal auditors and risk managers but are not limited to those. Several of these stakeholders and their interest are outlined below.

In some cases there is no clear differentiation between the tasks of the different stakeholders, the boundaries are rather fluid. For that reason the most obvious beneficiary will be presented first, followed by the less obvious.

(External) Auditors: Public accountants are required to follow the International Standards on Auditing (ISA) or at least the local Generally Accepted Accounting Principles (GAAP). ISA 315 states that "The auditor should obtain an understanding of the information system, including the related business processes, relevant to financial reporting (…)" ISA 315.81 (IFAC, 2008-I). Equally important in this context is the so-called materiality (for a definition see ISA 320.3 (IFAC, 2008-I)). Since only processes could be of interest having processed an amount above a predefined materiality limit it is essential to link the process dimension with the financial dimension e.g. the amount that has been posted to financial accounts by the process. In addition "when the auditor intends to use information about the entity and its environment obtained in prior periods, the auditor should determine whether changes have occurred that may affect the relevance of such information in the current audit" ISA 315.12 (IFAC, 2008-I). For the audit of the Internal Control System this means that processes need to be checked each year. For that reason time-consuming and error-prone face-to-face interviews are carried out. These interviews could be avoided or reduced to a certain extent if automated approaches like financial process mining are used. For the highly recognized Sarbanes-Oxley Act of 2002 Section 404 reflects the requirements of ISA 315.12 (Public Law 107-204-JULY 30, 2002). Furthermore according to ISA 240 the auditor has extensive responsibilities regarding risks of material misstatement due to fraud (IFAC, 2008-II). So-called fraud scans could be simplified by using financial process mining.

Internal Auditors: Together with the external auditors, internal auditors have their local legislation as well as international standards. These international standards are set by the Institute of Internal Auditors (IIA) (Richards, Oliphant and Le Grand, 2005; Coderre, 2005; Juergens, 2006; Rehage, Hunt and Nikitin, 2008; Wegrzynowicz and Stein, 2009; Askelson, Lanza, Millar, Prosch and Sparks, 2009). Generally speaking, the IIA requirements result in the same challenges as those described for the external auditors. As an example for local GAAP again the Oxley Act of 2002 Section 404 can be quoted. Beyond the requirements already mentioned the internal auditor is interested in some more possible applications of financial process mining e.g. Critical Paths Analyses or performance issues.

Business Process Managers / Process Owners: It is essential for this group of stakeholders to create and define processes on a high level but also to verify, predict and optimize the actual implementation. For a lot of processes this can be done by the mining techniques already implemented (described in the section "related work"). For all three aspects – verification, prediction and optimization - a fast and easy way of analysis as well as graphical presentation is necessary. The prediction of processing times of financial process is of great interest for discounts as well as for fines. Besides, processing times are applicable to the optimization of financial processes. In the case of an optimization an iterative approach could be of great interest. This approach requires several cycles of process mapping and graphical presentation. For financial processes the existing tools are not adequate since they ignore the financial dimension. Only with the financial dimension can the process owner be sure about the values which pass through certain processes and therefore about the importance of these processes.

Risk Managers: Beside some legal requirements and de facto standards like the COSO Framework (COSO, 2004), which are fundamentally analogous with those of (internal) Auditors, a risk manager could use financial process mining for Bottleneck analyses, critical path analyses and single point of failure analyses.

RELATED WORK AND MOTIVATION

By now, process mining as a whole is a fairly well researched field of science. First research was done in 1995 by Cook and Wolf for the software engineering process (Cook and Wolf, 1995). In 1998 process mining was first adapted to Workflow Systems by Agrawal and Gunopulos (Agrawal, Gunopulos and Leymann, 1998). A full overview until 2002 is given in (Van der Aalst, van Dongen, Herbst, Maruster, Schimm and Weijters, 2002) by W.M.P. van der Aalst et al.. Till now most of the process mining techniques are developed for workflow systems.

For financial process mining all the workflow management based process mining techniques are of minor interest. Our main focus is on Enterprise Resource Planning Systems (ERP) or Accounting information systems (AIS) managing the accounting, such as Oracle E-Business Suite and SAP ERP. Some research related to process mining and ERP Systems was accomplished in the past (Ramesh, 2006; Van Giessel, 2004). But none of them uses open items to mine the financial business processes.

We would like to emphasize that traditional work in the field of process mining completely omits issues related to materiality and financial entries. From an auditor's perspective regarding process flows only does not take into consideration the rear side of the medal: materiality and risk assessment of processes. Materiality and risk assessment can only be done by considering the amounts and accounts used by transactions. Otherwise auditors are deaf in one ear. With our work we want to

close this important gap and develop automated approaches and methods for auditors and other stakeholders to improve quality and reduce hours of work.

BASIC PRINCIPLES OF FINANCIAL PROCESS MINING

Structure of Accounting Data in IT Systems

Basically, entries in the accounting of an IT-system are structured in a simple way (Romney and Steinbart, 2008). Each entry consists of an accounting document and at least two items posted as credits and debits. If open item accounting is in use for a particular account, each item contains a flag whether indicating the item has already been cleared or not. If an item has been cleared, it also contains a reference to the entry / document which cleared the item.

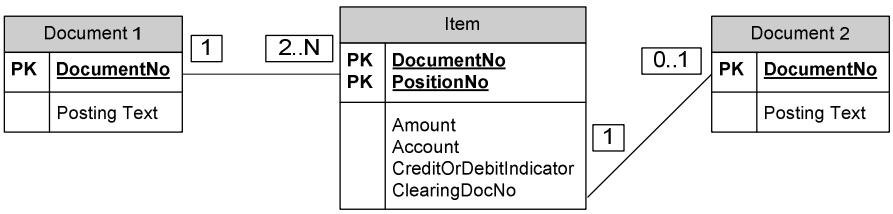


Figure 1: Generalized and simplified data structure of a financial entry using open item accounting

Figure 1 depicts the general data structure of an entry in a database. One document consists of two or more items posted on different accounts. Each item can be linked to one (other) document (=item cleared) or does not refer to (another) document (=item still open). As an example, an outgoing payment might clear an open invoice of a vendor. According to this generalized data structure entries are linked by clearing document references and can result in comprehensive "networks" consisting of documents and items.

Concept of the Basic Mining Algorithm

Accounting Documents as a Graph

Based on the generalized structure of financial entries one can define a financial business process as a directed graph with two kinds of nodes: documents and items. We define such a financial business process graph as a graph having the following properties:

According to the nodes in the graph:

1 Two types of nodes exist: Documents and Items
2 Nodes of the type "Document" have at least the following properties but are not limited to them: DocumentNo (=unique identifier of the document)
3 Nodes of the type "Item" have at least but are not limited to the following properties: DocumentNo and PositionNo (=combined unique identifier of the item), Amount (=Amount of the Item), Account (=Account number where the item has been posted to), CreditOrDebitIndicator (=Indicates if the item has been credited or debited on the account)

According to the edges in the graph:

4 Directed edges from a node of type "Document" to a node of type "Item" means that the document consists of the item. In general, a document must have edges to at least two item nodes (at least one credit and one debit item).
5 Directed edges from a node of type "Item" to a node of type "Document" means that the item has been cleared by the document node. An item can have only one edge to a document. If an item has no edge to a document this means that it has not been cleared so far or the account where the item has been posted to is not using open item accounting.

The Algorithm

As already explained, we implemented a prototypical algorithm to reveal a "network" of interrelated documents and items which are considered to be an individual financial business process instance. Since the algorithm has been developed in an object-oriented style we at first explain the most important classes needed to mine through financial entries.

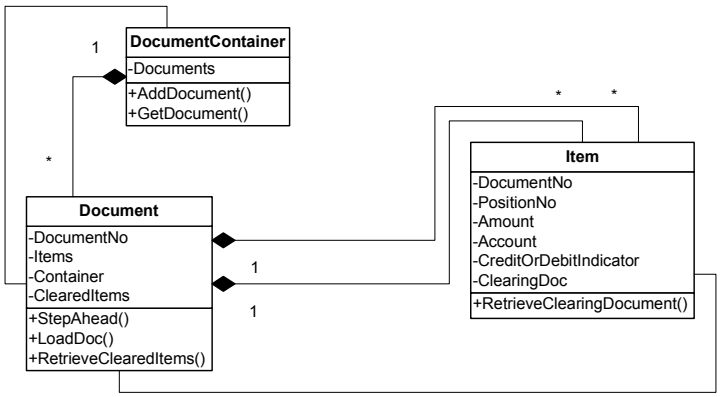


Figure 2: Classes used to mine financial business processes

Figure 2 depicts the classes needed for the mining process. The class *Document* encapsulates a document in the database as shown in figure 1. The class *Item* encapsulates an item in the database. The class *DocumentContainer* is a collection of documents. Whenever a document is found by the mining algorithm within a graph of documents and items, it is put in the *DocumentContainer*. When the mining algorithm has finished and found all documents in a graph, the *DocumentContainer* contains a complete graph of documents and items. The methods indicated in figure 2 can be explained as follows:
Item.RetrieveClearingDocuments(): Retrieves the clearing document of the item from the database.
Document.LoadDoc(DocNo): Retrieves the data of a document with document number *DocNo* from the database. Also retrieves all the items of the document and stores these items in the collection *Items*.
Document.RetrieveClearedItems(): Retrieves the items which have been cleared by the document.
DocumentContainer.AddDocument(): Adds a *Document* to the *DocumentContainer*.
Document.StepAhead(): This method is the algorithm doing the mining of the graph. It starts with the document calling the method *StepAhead()* and then jumps to interrelated documents and items. It implements the "tree-traversal" needed to mine the complete graph.
Since the method *Document.StepAhead()* contains the core algorithm for the financial business process mining we want to explain it using pseudo source code in Java style.
The method *StepAhead()* is called by an arbitrary document which is an arbitrary node in a graph of documents and items. The method starts traversing the documents and associated items in the graph. For this reason, the algorithm first "steps forward" by calling the method *StepAhead()* again for all clearing documents which cleared the items belonging to the starting document. In a second step the algorithm "steps back" and retrieves the items which have been cleared by the document. For the cleared items found, the associated documents are retrieved and for these associated documents *StepAhead()* is called again. The algorithms stops if no new documents are found in the graph. All the documents found in this process are stored in a *DocumentContainer* which contains the set of documents being the result of the traversal process. By stepping forwards and backwards in the graph all the documents and items belonging to these documents are finally found and put in the DocumentContainer object. It is possible that documents are evaluated more than once when applying the algorithm on a graph. In order to avoid infinite cycles leading to non-termination of the algorithm, all documents evaluated once are put on a watch list. If the algorithm starts to evaluate a document a second time, this will be noticed by the watch list and the evaluation of this document terminates while the algorithm starts evaluating the next document (leaping of already evaluated documents).

Implementation of the Algorithm

As already mentioned, we implemented the described algorithm in the Java programming language. We use the SAP ERP system to apply our algorithm to real-world accounting data. The accounting data used origins from a SAP IDES installation which is featured with training data from SAP. In order to access SAP, the SAP proprietary Remote Function Call (RFC) (Deimel, 1998) mechanism is used. Remote Function Calls allow to call programs within an SAP system by a remote client program. To get accounting data the Function RFC_READ_TABLE is called by our algorithm. In order to use the Remote Function Call mechanism the SAP JCo Application Programming Interface (API) (Yang, Su, Wu and Liu, 2008) for Java is used in our implementation. Our Java algorithm produces a file containing the graph structure of the process instance. We apply the Graph Modelling Language (GML) (Himsolt, 1997) for this purpose which is a hierarchical ASCII-based file format. For the visualization of the process graph an arbitrary program capable of reading GML files can be used. For our prototypical implementation the free program yEd (yWorks, 2010) has been chosen. yEd is capable to visualizing the GML process graph in a simple and quick manner. Furthermore, yEd has a feature to apply automatic layouts to a range of different diagrams and networks. As a result, our algorithm does not need to calculate coordinates and alignments for objects to be visualized. Figure 3 shows the relevant components of our prototypical implementation of the mining algorithm.

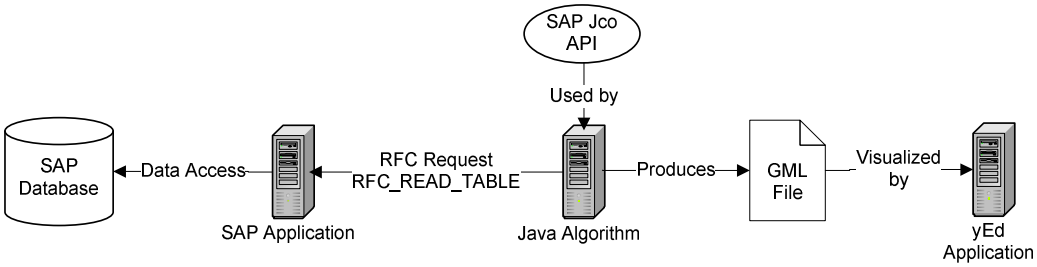


Figure 3: Relevant components for the implementation of the algorithm

Information Visualization and Examples

In order to mine the structure of a process graph the algorithm needs the unique identifier of only one document. Starting with this document, the algorithm starts crawling through documents and items and finally reveals the complete process instance. It was one of our goals to visualize the financial process as best as possible. We also wanted to integrate two dimensions in the visualization: activities and accounts. Activities are normally addressed by business process modeling languages, but the financial accounts are often not addressed. Table 1 shows the legend we used to visualize financial process instances related to both the flow of activities *and* accounts.

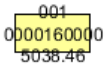
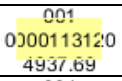
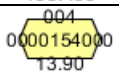
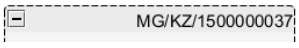
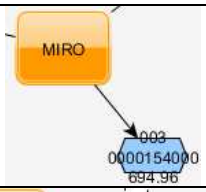
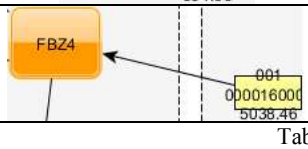
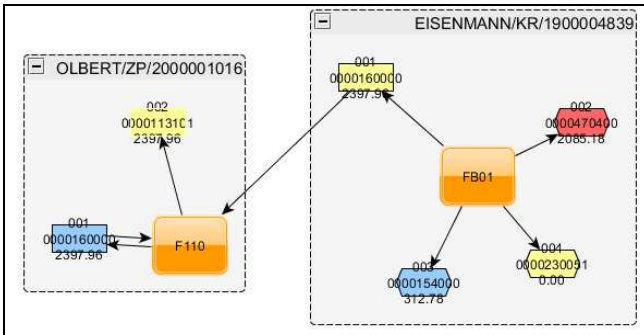
	Represents a **business activity**. The label of the activity is the transaction or sub-program used in the ERP System to post an entry to the ledger.
	**Box with border:** Represents a **cleared item** of a financial entry. The three labels mean: "001": Number of the item in the accounting document "160000": Account number the item has been posted to "5038.46": Amount of the item
	**Box without border:** Represents an **open item** of a financial entry that has **not been cleared** so far. At this stage, this business process is not finished since a clearing is still needed.
	**Hexagon**: Represents an item of a financial entry that is **neither cleared nor uncleared** because the financial account used is not involved in open item accounting.
	Represents a **head of an accounting document**. An accounting document groups the business activity and the items posted by the business activity. The three labels mean: "MG": Person or user which conducted the business activity and thus did the ledger entry. "KZ": Document type (KZ here means "Payment of a Vendor") "Number": Document number
Color of the Items	**Blue**: The item has been posted to a balance sheet account on the asset side. This means an additional asset has been posted or a liability has been compensated. **Yellow**: The item has been posted to a balance sheet account on the liability side. This means an additional liability has been posted or an asset has been compensated. **Green**: The item is an income posting (Profit & Loss is affected). **Red**: The item is an expense entry (Profit & Loss is affected).
	An **edge from a business activity to an item** means that the business activity has produced the item as a part of the complete entry.
	An **edge from an item to a business activity** means that the item has been cleared by the accounting document produced by the business activity.

Table 1: Symbols used to visualize financial processes mined with the algorithm

In order to demonstrate that our algorithm works we show some exemplary mined financial processes and explain what these processes have processed and how they can be interpreted from an auditor's perspective. We start with some simple examples but also show more complex processes. The graphs showing the processes only contain a baseline of information (like title of business activity, account number, amounts etc.). It would be easy to include more information like date and time of entries in order to analyze performance aspects. Figure 4 depicts a simple purchasing process.



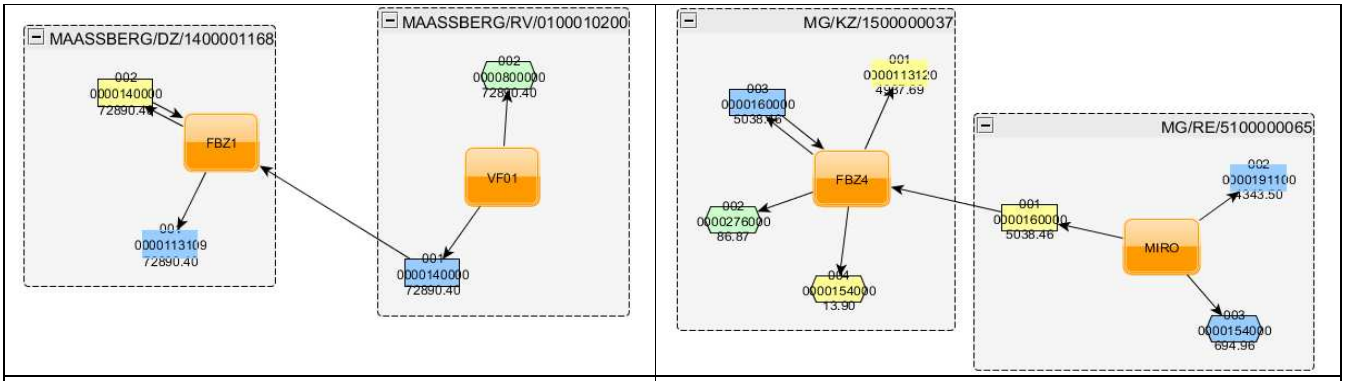
Business Activities:
F110: Parameters for Automatic Payment (Payment run)
FB01: Post Document

Accounts:
160000 Trade Payables - domestic
154000 Input tax
113101 Deutsche Bank - checks payable
230051 Gain/loss Euro conversion / document difference
470400 IS-RE Apportionable operating costs

Document Types:
KR: Vendor Invoice, ZP: Payment

Figure 4: A simple purchasing process instance

The process instances above can be interpreted as follows: user "Eisenmann" posted a document (FB01) (here: invoice) to the accounts payables and after that user "Olbert" did the payment run (F110) and cleared the accounts payable item. Since there is a red item, the costs have been directly posted to the P&L and not to the inventory. The process is not complete. An open item on account 113101 still exists since the item has no borders indicating an uncleared item. From an auditor's perspective this process might be a little unusual since the business activity "Post Document" is very generic and allows the posting of almost arbitrary documents to arbitrary accounts. The process would be more integrated if a more specific business activity would be used allowing the posting of invoices only and thus restricting possible postings due to a specific purpose.



Business Activities:
FBZ1: Post Incoming Payments
VF01: Create Billing Document

Accounts:
800000 Sales revenues - domestic - finished goods
140000 Trade Receivables - domestic
113109 Deutsche Bank - customer payments

Document Types:
DZ: Payment of a customer, RV: Billing Document Transfer

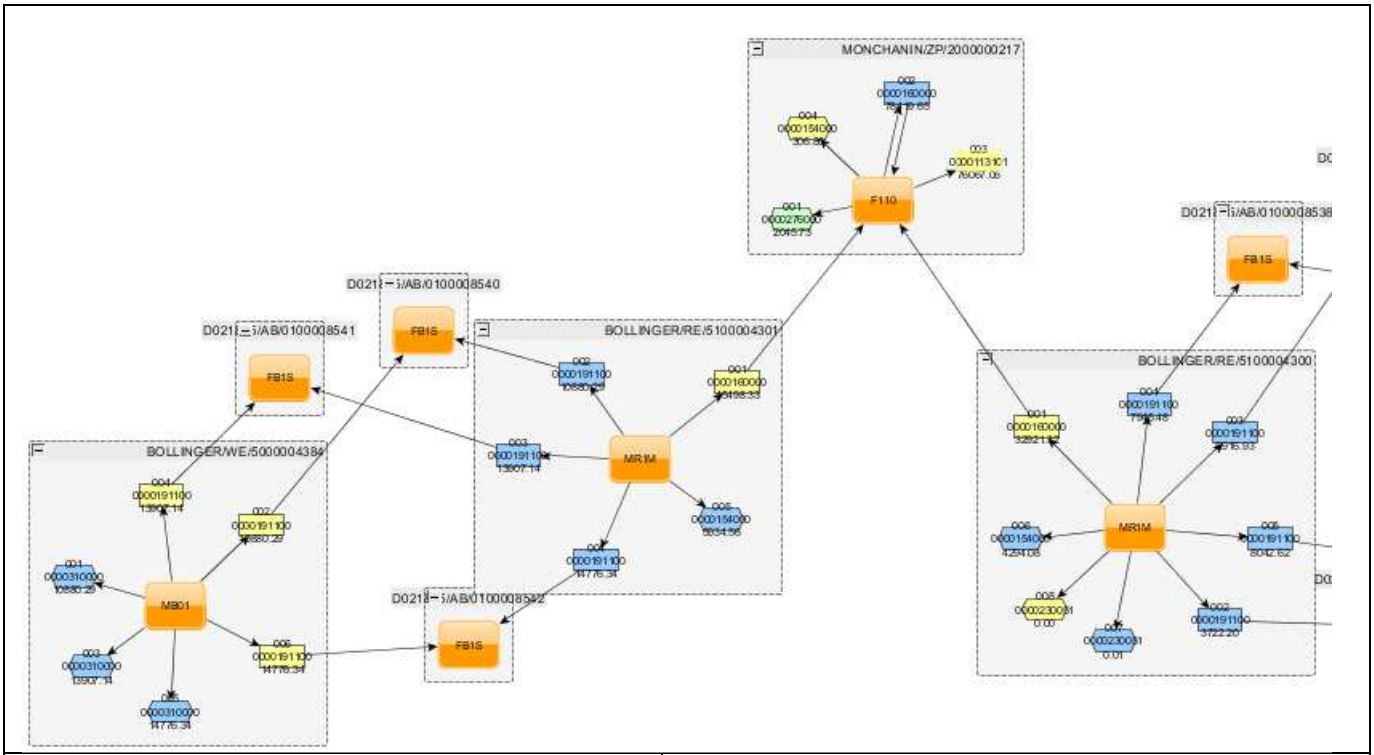
Business Activities:
MIRO Enter Incoming Invoice
FBZ4 Payment with Printout

Accounts:
160000 Trade Payables - domestic
154000 Input tax
113120 Deutsche Bank - checks payable with checkmanagemt
276000 Discount received
191100 Goods Rcvd/Invoice Rcvd (third party)

Document Types:
KZ: Vendor Payment, RE: Invoice Receipt

Figure 5: A sales process instance (left) and a purchasing process instance (right)

The process instances in Figures 5 show a simple sales process instance (left) and a purchasing process instance. In the process instance on the left user "Maassberg" first posts a billing document (VF01) and then clears it with an incoming payment (FBZ1). From an auditors' perspective, two issues might arise: firstly, both activities are carried out by the same person. The process instance should be checked for segregation of duties violations. Secondly, the complete amount has been posted as revenues without any taxes. It should be checked if the sales transaction exempt from VAT taxes (Input Tax). In the process instance on the right the user "MG" enters an incoming invoice (MIRO) and then conducts a payment (FBZ4). As a result, it seems to be certain that a segregation of duties conflict occurred.



Business Activities:		**Accounts:**	
F110	Parameters for Automatic Payment (Payment run)	191100	Goods Rcvd/Invoice Rcvd (third party)
MR1M	Enter Incoming Invoice (Old Version)	154000	Input tax
FB1S	Clear G/L Account	160000	Trade Payables - domestic
MB01	Post Goods Receipt for PO	230051	Gain/loss Euro conversion / document difference
		310000	Trading Goods
Document Types:		113101	Deutsche Bank - checks payable
ZP: Payment, RE: Invoice Receipt, WE: Goods Receipt, AB: Accounting Document		276000	Discount received

Figure 6: A more complex purchasing process instance (displayed only partly)

Figure 6 depicts are more complex purchasing process instance. At first, goods are received (MB01) and posted to a "goods received / invoice received" account. Then, the incoming invoice is posted (MR1M) without clearing the "goods received / invoice received" items. An additional business activity is used to link and clear the open invoice with the open goods received items (FB1S). This is indicated by a document without any items (this violates property 4 of the graph properties as defined above and must be regarded to be SAP specific). The complete process instance reveals two independent "Goods Received – Enter Invoice" sub process instances which are finally paid and cleared by one payment (F110). Again, the same user "Bollinger" received the goods and posted the appropriate invoice without applying a system-based 4-eyes principle.

Validation of the Algorithm

To validate the algorithm, we applied it to several documents on open item oriented accounts. Our findings can be summarized as follows:

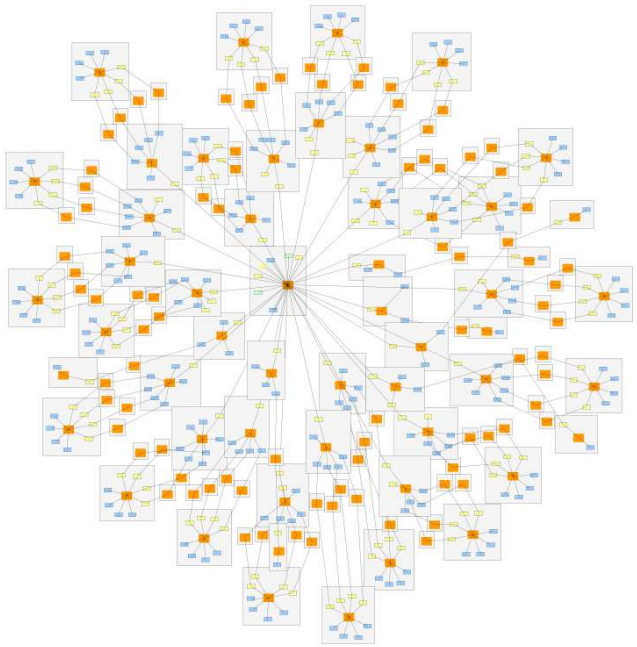


Figure 7: Schema of a complex process graph of a purchasing process instance

(1) The algorithm works and always revealed the complete process instance.

(2) The complexity and size of process instances vary very widely. Complex graphs seem to evolve if different individual process instances "run" in a "central" business activity affecting these all together. A prominent example is an outgoing payment to a vendor which clears e.g. all invoices of a particular time interval. In this case, all purchasing process instances of that time interval regarding this vendor are linked by one big payment. Several (often similarly structured) purchasing process instances "run" to a central payment entry. Figure 7 shows the scheme of such a complex process.

(3) So far, mining processes show a relatively bad performance. Normal process instances need a couple of minutes to be analyzed.

Figure 7 shows a very complex process instance. Each box is one accounting document. The box in the center is a "big" payment clearing several invoices ("inner circle"). The "outer circle" is the goods receipt document of each sub process instance. All process instances "run" to the payment in the center. This complex process instance took about 40 minutes to be mined using the prototypical implementation of our algorithm.

According to the findings due to the validation of the mining algorithm, we will derive the following issues to be improved in the next research steps:

According to finding (3) the performance of the algorithm needs to be improved. The algorithm works serially and mines all documents step by step. We are quite confident that performance improvements will be possible if the algorithm works in a parallel manner using threads and connection pooling. This will be one of the next tasks to be implemented.

SUMMARY

In this paper we have provided and validated a basic algorithm for mining financial business process instances in ERP or accounting information systems. The validation took place using SAP as a well known and widely-used ERP system. With regard to this mining algorithm two aims have been achieved. Firstly, the algorithm revealed relevant documents and items belonging to a process instance and was able to evaluate the relationships between documents and items. Secondly, process instances have been visualized by using different symbols and colors depending on the properties of documents and items. The visualization of financial processes shall help auditors and process managers to shift the view they have on financial processes: from regarding a set of entries on T-accounts to a process-oriented perspective that is interwoven with a value flow on financial accounts. Using appropriate symbols and colors of symbols this process view aims at a better and faster understanding of the relationships within the accounting by allowing an easier cognitive processing. Future work will be founded on the provided algorithm to aggregate accounting information as explained in the research agenda and to provide approaches even easier to understand with respect to compliance and performance issues in accounting departments.

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