



Methodological Review

Process mining in healthcare: A literature review

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ABSTRACT

Process Mining focuses on extracting knowledge from data generated and stored in corporate information systems in order to analyze executed processes. In the healthcare domain, process mining has been used in different case studies, with promising results. Accordingly, we have conducted a literature review of the usage of process mining in healthcare. The scope of this review covers 74 papers with associated case studies, all of which were analyzed according to eleven main aspects, including: process and data types; frequently posed questions; process mining techniques, perspectives and tools; methodologies; implementation and analysis strategies; geographical analysis; and medical fields. The most commonly used categories and emerging topics have been identified, as well as future trends, such as enhancing Hospital Information Systems to become process-aware. This review can: (i) provide a useful overview of the current work being undertaken in this field; (ii) help researchers to choose process mining algorithms, techniques, tools, methodologies and approaches for their own applications; and (iii) highlight the use of process mining to improve healthcare processes.

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1. Introduction

The provision of quality hospital services depends on the suitable and efficient execution of processes. Healthcare processes are a series of activities aimed to diagnose, treat and prevent any diseases in order to improve a patient's health. These processes are supported by clinical and non-clinical activities, executed by different types of resources (physicians, nurses, technical specialists, dentists, clerks) and can vary from one organization to another [1]. It is known that healthcare processes are highly dynamic, complex, ad-hoc, and are increasingly multidisciplinary [2], making them interesting to analyze and improve. Healthcare processes improvement might have a high impact on the quality of life of patients. However, improving them is not an easy task and several challenges are always present. There is always the need to reduce the cost of services and improve capabilities to meet the demand, reduce patient's waiting times, improve resources productivity, and increase processes transparency.

The analysis of both clinical and administrative processes can be useful in meeting these objectives, as well as helping to respond any related questions posed by experts. In the past, different strategies have been used to analyze hospital processes, including Business Process Redesign [3], Evidence Based Medicine [4], and Lean [5], among others. This research paper concentrates on the progress made using an emerging discipline, known as Process Mining [6].

Process mining is a relatively young research discipline; [7,8] can be highlighted among the seminal articles. It focuses on extracting knowledge from data generated and stored in the databases of (corporate) information systems in order to build event logs [6]. An event log can be viewed as a set of traces, each containing all the activities executed for a particular process instance. Process-Aware Information Systems (PAIS) [9] are systems that are readily able to produce event logs. Specific examples of such applications include Enterprise Resource Planning systems (e.g., SAP¹), Customer Relationship Management Systems (e.g., Salesforce²), and Hospital Information Systems (e.g., HIS [10]). Event log data are not limited simply to the data from these applications, as many other systems can also provide useful data about process execution. Moreover, data relating to a complex process may come from more than one single source of information.

Fig. 1 shows a general outline of the application of process mining in healthcare. Normally, any activity executed in a hospital by a physician, nurse, technician or any other hospital resource to give care to a patient is stored in a HIS (compound of databases, systems, protocols, events, etc.). Activities are recorded in event logs for support, control and further analysis. Process models are created to specify the order in which different health workers are supposed to perform their activities within a given process, or to analyze critically the process design. Moreover, process models are also used to support the development of HIS, for example, to understand how the information system is expected to support the process execution.

There are three main types of process mining: process discovery, conformance checking, and enhancement. In [6], it is explained how automatic process discovery allows process models to be extracted from an event log; how conformance checking allows monitoring deviations by comparing a given model with the event log; and how enhancement allows extending or improving an existing process model using information about the actual process recorded in the event log.

Having an accurate model of the real behavior of a process improves the capacity of specifying and implementing the process requirements in the HIS that support the process, configuring any additional requirements not included in the system, and supporting the process analysis. In addition, the author in [6] notes the possibility of extending the analysis through other approaches, such as organizational mining, automatic construction of simulation models, model extensions, model repair, predicting process behavior, and recommendations based on history.

Healthcare processes are seen as an area with complex models and which are subject to significant variation over time [2]. These variations are caused by multiple factors, including the different conditions of patients and the multiple ways and sequences in which activities can be performed by the resources (physician, nurse, and other healthcare professionals).

The ability to use techniques for discovering process models and analyzing their performance provides valuable opportunities for taking advantage of information stored in HIS event logs. Using process mining techniques in healthcare processes not only ensures such procedures can be firmly understood, but can also generate benefits associated with process efficiency. For example, they can improve the quality of provided services as well as having a positive impact on the management of medical centers.

Besides improving the management of medical centers, additional benefits can be obtained through the application of process mining in healthcare. It can help to identify and understand the real behavior of resources and the patients; to come up with suggestions for redesigning the process; to analyze the performance and to reduce waiting and service times; to obtain insight and improve the collaboration between peers; to predict the behavior of patients according to previous cases; to add additional information to activities such as patient data; to identify which are the activities causing bottlenecks in the process; and can help to identify decision rules applied in different cases.

In order to identify opportunities for applying process mining, it is crucial to be able to understand frequently asked questions posed by healthcare experts regarding such processes. In this study several frequently posed questions were identified in Section 3.3.

The process mining research area has been used in the field of healthcare processes for discovering process models from event logs [11–13], for conformance checking [14,15], and analyzing social networks [12,13,16], among others.

This study aims at identifying and characterizing the case studies where process mining has been applied in the healthcare domain, providing an overview of the state of the art of this field, helping and guiding researchers on what path to follow when applying process mining techniques, methodologies, algorithms and tools; and highlighting some of the advantages of using this discipline.

¹ <http://go.sap.com>.

² <http://www.salesforce.com>.

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