HOSPITAL MANAGEMENT BASED ON SEMANTIC PROCESS MINING: A SYSTEMATIC REVIEW

Majid Jangi1, Fateme Moghbeli*2, Mahya Gaffari3, Alireza Vahedinemani3

1 PhD Candidate in Medical Informatics, Department of Health Information Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran.
2 PhD Candidate in Medical Informatics, Department of Health Information Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran.
3 PhD Candidate, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, Canada.

INTRODUCTION

The quality of hospitals depends on the true and well-organized processes. Hospital processes are a good work that is expected to analyze any maladies for improving a patient's wellbeing [1, 2]. It is clear that hospital processes are really complex multidisciplinary and many researchers are interested in analyzing and improving these processes. Enhanced hospital processes might have a high influence in the quality of patients’ lives. However, improving these processes is a big trouble task and many challenges -usually present. There are dependably the needs to decrease the expenses of hospital processes, increase the abilities to take care of the demands, omitting patient's waiting times, and increment forms straightforwardness [3, 4].

Before, various procedures have been used to analyze the different processes in hospitals, like Business Process Redesign [5], Evidence Based Medicine [6], and Lean [7]. This review concentrates on using semantic web like ontologies that extracts false processes and tries enhance them, known as Semantic Process Mining [8].

How to cite this paper
Jangi M, Moghbeli F, Gaffari M, Vahedinemani A. Hospital Management Based on Semantic Process Mining: A Systematic Review. Front Health Inform. 2019; 8(1): e4. DOI: 10.30699/fhi.v8i1.171
relationships between different activities and resources in complex processes. On the other hand, the ontology used in semantic process mining has two useful goals: first, modeling the entities and relationships in hospital network, and second, making the controlled vocabulary for merging different data in heterogeneous sources [10, 12-14].

Semantic process mining wants to bring the usual process mining methods from the level of label-based to the conceptual-based analysis. As we know, log is the starting part of mining algorithms and some methods can use a model as an input. Actually, the key idea in semantic process mining is to annotate different elements explicitly in a log with the concepts that are shown. It can be reached by connecting the elements to concepts in ontologies [3, 15].

Fig 1 shows a summary of the usage of semantic process mining. It also shows the information sources for semantic process mining [16].

![Fig 1: Semantic process mining in healthcare](Image)

In other words, semantic process mining can empower process mining methods. Finally, using semantic information in event logs shows the process mining methods from the label-based to the concept-based. This feature allows to work with different levels of abstractions while getting feedback about processes and their properties in a special log [17-19]. Besides, it supports less demanding reuse of asking description over logs [17].

This study tries to identify and characterize the articles that semantic process mining has been used in the healthcare domain specially in hospitals, it also help researchers to follow the best path when they are using semantic process mining methods; and highlight some of the positive points of using this technique.

**MATERIAL AND METHOD**

**Background and objectives**

Regarding semantic process mining in healthcare, there is only a literature review and systematized literature review devoted to process mining [3]. However, there is no comprehensive study that gather, shows articles that semantic process mining has been used in the healthcare domain and hospitals.

This review has two main objectives:

First, identifying and describing existing articles that semantic process mining has been used to hospitals. Second, making a characterization of existing articles, like the description of the most applicable aspects, such as methods.

None of these objectives has been investigated in the previous papers, making this review an important goal to understanding the context of this domain and improving the future application of semantic process mining methods in hospitals.

**Search process**

The method used for this search was conducted in one stage. Fig 2 shows the ways implemented for the search in PRISMA. This stage covered the search for papers in PubMed, dblp and Google Scholar, using a combination of the keywords “process mining” or “semantic process mining”, “hospital” and “healthcare” and “ontology”. These keywords were used to make the highest amount of studies where semantic process mining has been used in hospitals.

The search was done by the two authors, independently.

The inclusion characteristics are: all identified articles that include semantic process mining methods have been used in the hospital domain, all articles published until January 1, 2017 and publications in English were used [10, 20-25].

The exclusion characteristics are: articles that do not include a semantic process mining in healthcare were excluded and articles with only process mining were excluded. Finally, to support the quality of the search process a series of activities were done. The first extraction, analysis and evaluation of the articles from the web searches were done by the two authors. Any disagreements with the inclusion and exclusion of a study and data analysis were resolved through discussion.
RESULTS
By analyzing the literatures showing the using of semantic process mining in hospitals, a content study was done. This study characterized and classified the relevant aspects found on the articles. Table 1 shows a general view and a summary of only the most crucial characteristics of these aspects. The titles are shown as below.
The classifications according to the tools and methods are shown in following sections.

Semantic process mining and ontology tools

There are groups of software that can use process mining methods to be used to an event log to make different models for analysis.

In healthcare, ProM (Process Mining tool) is the most common tool, which is an open source tool for process mining. ProM is a framework that supports a variety of process mining techniques in the form of plug-ins. It is implemented in Java, and can be downloaded freely [27, 28].

Additional tools can use in these studies like, Disco with a friendly interface for process mining. The improvement in process mining technology in Disco helps to make fantastic visual maps from process data in a short time [29].

Semantic process mining methods

Semantic technologies has gained an important interest with process mining [30, 31]. The advance is Semantic Process Mining which is being adopted and used as a tool for enhancement of processes, derived from logs created through old process mining.

Several mining algorithms has also been developed which practically have been shown to be practical in process analysis [17, 32]. To this effect, useful information about the connections of activities in a process environment has been made possible, and necessary for extracting models capable of making new knowledge. Process mining method can apply for mining of processes in events log sequences [17]. Existing Process mining methods depend on tags in event logs information, and therefore, to a certain extent are limited. It means that these methods do not gain from the real knowledge (semantics) that describe these tags. The challenge will pave way for Semantic Process Mining which takes the benefits of the semantics explained in event data of a process, and links them to concepts in ontology to extract applicable models by means of Semantic Reasoning. Semantic reasoning is supported due to the formal meaning of ontological idea and expression of relationships that is between event logs of a process. The technique uses the semantics of the sets of activities within a learning process to make rules and events relating to task, to discover automatically and improve the process model ontology in the information knowledge base through semantic annotation of the elements. One of the key usage provided by semantic process mining is the ability of explaining the semantics behind the tags in event logs for discovery of new knowledge. Semantic process mining is a new area in the field of process mining and there are few existing applications that shows the capabilities of this method [33].

**DISCUSSION**

According to this review, discussion has two different approaches: first, characterizing the aspect most useful in the studies like tools, medical field and results; and second, identifying the most important method for mining processes in hospitals.

More than 70% of the related articles for using semantic process mining in hospital management are after 2015. So it shows the effectiveness of semantic process mining method and its importance in these days.

ProM is the most common tool that is used in the semantic process mining and the most useful results are the positive point of ontology in process mining. In most of articles, ProM is called the best one for process mining [3, 24].

The process mining method is one of the important and useful among other methods that enable the processes analysis behavior for discovering, conformance checking and enhancing [35, 36]. However, the process mining approaches try to analyze the process based on the event log label strings, without considering the semantics behind the label. A semantic approach on the event logs could overcome this main problem and could enable the reuse and sharing of the knowledge [26, 30, 35, 36].

The key concept of semantic process mining is to annotate the log with the concept in ontology; this action will let the inference engine derive the new knowledge [10].
The use of the semantics and the processes together can help to exchange process knowledge between the applications in the best and true way. Ontologies are used to capture, show, use and exchange knowledge. The best definition for ontology was that it is an explicit characterization of a conceptualization, and is a description of the different ideas and connections in this domain [10, 11, 17].

The ontology is built, to share usual understanding of the information structure among software agents or people. The ontology can use to separate domain knowledge from the operational, to reuse and analyze domain knowledge to make assumptions about a domain explicit.

The future challenges in terms of semantic process mining in hospitals show its importance. One of the negative aspects of current process mining is the absence of the semantic part in process models and the results obtained, especially in complex and less-structured processes, such as those found in the hospitals.

CONCLUSIONS

The application of semantic process mining in hospitals with the goal of healthcare allows health providers to get the real execution of processes: discovering, checking conformance with guidelines or experts, and improvement. This article provides a review about the main approaches used to apply semantic process mining in hospitals. It includes the summary of related articles. Future challenges and trends have also been explained. The goal of this review is to serve as a reference for using semantic process mining for improving process in hospitals.

AUTHOR’S CONTRIBUTION

All the authors approved the final version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this study.

FINANCIAL DISCLOSURE

No financial interests related to the material of this manuscript have been declared.

REFERENCES

1. Aldin L, de Cesare S. A literature review on business process modelling: New frontiers of reusability. Enterprise Information Systems. 2011; 5(3): 359-83.

2. Rebuge A, Ferreira DR. Business process analysis in healthcare environments: A methodology based on process mining. Information systems. 2012; 37(2): 99-116.

3. Rojas E, Munoz-Gama J, Sepúlveda M, Capurro D. Process mining in healthcare: A literature review. J Biomed Inform. 2016; 61: 224-36. PMID: 27109932 DOI: 10.1016/j.jbi.2016.04.007 [PubMed]

4. Mans R, Schonenberg H, Leonardi G, Panzarasa S, Cavallini A, Quaglini S, et al. Process mining techniques: An application to stroke care. Stud Health Technol Inform. 2008; 136: 573-8. PMID: 18487792 [PubMed]

5. Jansen-Vullers MH, Reijers HA. Business process redesign in healthcare: Towards a structured approach. Information Systems and Operational Research. 2005; 43(4): 321-39.

6. Grol R, Grimshaw J. Evidence-based implementation of evidence-based medicine. Jt Comm J Qual Improv. 1999; 25(10): 503-13. PMID: 10522231 [PubMed]

7. Radnor ZJ, Holweg M, Waring J. Lean in healthcare: The unfilled promise? Soc Sci Med. 2012; 74(3): 364-71. PMID: 21414703 DOI: 10.1016/j.socscimed.2011.02.011 [PubMed]

8. van der Aalst W. Process mining: Discovery, conformance and enhancement of business processes. 2011; Springer-Verlag: Berlin.

9. El Kharbili M, Stein S, Markovic I, Pulvermuller E. Towards a framework for semantic business process compliance management. Proceedings of GRCIS. 2008.

10. Grando MA, Schonenberg M, van der Aalst W. Semantic process mining for the verification of medical recommendations. Proceeding of International Conference on Health Informatics 2011; 1: 5-16.

11. Kim G, Suh Y. Ontology-based semantic matching for process business process management. Advances in Information Systems. 2010; 41(4): 98-118.

12. de Medeiros AKA, Van der Aalst W, Pedrinaci C. Semantic process mining tools: Core building blocks. Proceedings of European Conference on Information Systems (ECIS). 2008; 1: 1-13.

13. Mans RS, van der Aalst W, Vanwersch RJF, Moleman AJ. Process mining in healthcare: Data challenges when answering frequently posed questions. Process Support and Knowledge Representation in Health Care: Springer; 2013; 1: 140-53.

14. Jangi M, Ferandez-de-las-Penas C, Tara M, Moghbeli F, Ghaderi F, Javanshir K. A systematic review on reminder systems in physical therapy. Caspian J Intern Med. 2018; 9(1): 7-15. PMID: 29387313 DOI: 10.22088/cjim.9.1.7 [PubMed]

15. Pedrinaci C, Domingue J. Ontology-based metrics computation for business process analysis. The 4th International Workshop on Semantic Business Process Management; 2009: Greece.

16. Mans RS, Schonenberg M, Song M, van der Aalst W, Bakker PJ. Application of process mining in healthcare—a case study in a dutch hospital. Biomedical Engineering Systems and Technologies. 2009; 1: 425-38.
17. Mans RS, van der Aalst W, Vanwersch RJ. Process Mining. Process Mining in Healthcare; Springer: 2015.

18. Gupta S. Workflow and process mining in healthcare. MSc Thesis, Technische Universiteit Eindhoven. 2007.

19. Moghbeli F, Langarizadeh M, Younesi A, Radmard AR, Rahmanian MS, Orooji A. A method for body fat composition analysis in abdominal magnetic resonance images via self-organizing map neural network. Iranian Journal of Medical Physics. 2018; 15(2): 108-16.

20. Langarizadeh M, Moghbeli F. Applying naive bayesian networks to disease prediction: A systematic review. Acta Inform Med. 2016; 24(5): 364-69. PMID: 28077895 DOI: 10.5455/aim.2016.24.364-369 [PubMed]

21. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. BMJ. 2009; 6(7): e1000100.

22. Antonelli D, Bruno G. Application of process mining and semantic structuring towards a lean healthcare network. In: Camarinha-Matos L, Bénaben F, Picard W. (eds) Risks and resilience of collaborative networks. In: Ciardo G., van Dongen BF, de Medeiros AKA, Verbeek H, Weijters A, van der Aalst W. The ProM framework: A new era in process mining tool support. In: Gardo G., Darondeau P. (eds) Applications and Theory of Petri Nets. Lecture Notes in Computer Science, vol 3536. 2005; Springer, Berlin, Heidelberg.

23. Yang W, Su Q. Process mining for clinical pathway: Literature review and future directions. 11th International Conference on Service Systems and Service Management (ICSSSM), 2014; IEEE.

24. Alvarez C, Rojas E, Arias M, Munoz-Gama J, Sepúlveda M, Herskovic V, et al. Discovering role interaction models in the emergency room using process mining. Journal of Biomedical Informatics. 2018; 78: 60-77.

25. Fauzan R, Sarno R, Sidiq M. Ontology and process mining for diabetic medical treatment sequencing. Proceedings of The 7th International Conference on Information & Communication Technology and Systems (ICTS); 2013.

26. Baker K, Dunwoodie E, Jones RG, Newsham A, Johnson O, Price CP, et al. Process mining routinely collected electronic health records to define real-life clinical pathways during chemotherapy. Int J Med Inform. 2017; 103: 32-41. PMID: 28550999 DOI: 10.1016/j.ijmedinf.2017.03.011 [PubMed]

27. Rubin V, Günther CW, van der Aalst W, Kindler E, van Dongen BF, Schäfer W. Process mining framework for software processes. In: Wang Q, Pfahl D, Raffo DM. (eds) Software Process Dynamics and Agility. Lecture Notes in Computer Science, vol 4470. 2007; Springer, Berlin, Heidelberg.