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Process Mining in Healthcare Systems: A Critical Review and its Future

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ABSTRACT

Nowadays, process mining is the emerging technique and is widely used across industry domains. Process mining is evolving important role for patients as well as hospital management. In this paper, we applied process mining techniques in health care industry. We used the process mining techniques to find the flow of process in different categories of users involving in processes. This process mining is used to provide an accurate solution of the care flows under each consideration. Our study explores various journals and conferences about the usage of process mining in dynamic health care systems using different algorithms and finds the patient's process flows and effectiveness of employees in hospital. The process flow extracts the information from the event log and visualizes the care flow with respect to different attributes and improves the work flow of process. This survey aims to study the various research papers about process mining using different techniques in health care and analyses gathering the findings.

Key words: Event log, Health care, Process mining, Process mining algorithms.

1. INTRODUCTION

Process mining[1] is the mining process to combine process models and event log data in different techniques. By this process mining models, the management of the organization can find out what people and the organizations really do. For example, process models create models from the event data automatically. In process mining, specialized mining algorithms are applied to event log data to identify various patterns, graphs and Petrinet diagrams from the event data which are records in the information management system. Compliance[2] can be accounted by evidence models with event data. The time frame can be used to find bottlenecks of the events and can be solved by the corrective actions later. So, process mining is used to find the deficiency, indirection, bottleneck and event risks.Process mining is a most important technique used in organization management that supports the improvement and quality analysis of the processes based on the information event log data. Process mining software can help organizations easily capture information from enterprise transaction systems and provides detailed and data-driven information about how key processes are performing.

Process mining techniques and algorithms provide specialists in medical processes the ability to respond to frequently posed questions about these processes, thereby generating improvement opportunities.In process mining, we are using the different data mining algorithms to find the patterns and predict the anomaly activities in process using the details in the information event log. Process mining technique is used to improve process efficiency[3] and the models explain Business Process Discovery(BPD)[4].

2. LITERATURE SURVEY

The Contribution of Process Mining in Different Industry:
Below in the figure1, it shows the importance of process mining in various industries, which shows that process mining is used widely in service [5] industry (49%) and followed by healthcare [6] industry (35%). This research work is done in healthcare domain because process mining efficiency gives better result for patient[7] life threatens issues including time and cost constraints. So the process mining is non-trivial activity in healthcare systems.
There are many various algorithms for process mining. The internal local relations between the activities data is modelled by heuristics miner algorithm. The global or external relations between the activities are modelled by genetic mining[8] and fuzzy miner[9].

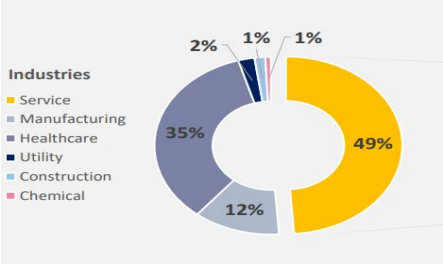

Figure 1: Process mining in various industries [10]

There are algorithms list are shown is Figure 2, which can be used for a specific purpose. Heuristics miner [11] uses frequencies and parameterization to handle noise; while genetic process mining [12] can mine complex and noisy logs, but is resource intensive. More recent approaches focus on managing complex real world models or noisy logs using clustering and abstraction, for example at the trace or activity level[13].The algorithms are applied on an artificial clinical data and the results are used for further process analysis.

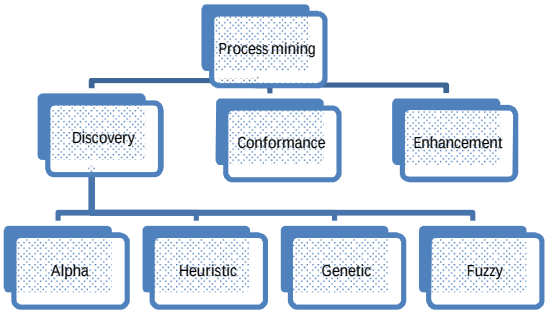

Figure 2: Stages of Process mining Architecture

In this paper, we are exploring the various process mining journals in order to find the usage and methods of algorithms in discovery.

A. Alpha algorithm
B. Heuristic miner
C. Genetic miner
D. Fuzzy miner

A. Alpha Algorithm

The α-algorithm scans the event log for particular patterns. This algorithm works a set of sequence of events with concurrency. This follows the ordering relation of the activity in the event log. It shows the result in Petri net design diagram [14]. For example, if activity X is followed by Y but Y is never followed by X, then it is assumed that there is a causal dependency between X and Y. To reflect this dependency, the corresponding Petri net using ProM tool [15] should have a place connecting X to Y.

We distinguish four log-based ordering relations [16] that aim to capture relevant patterns in the log. This can generate the clinical work flow and display the process in the form of Petri net diagram. But the alpha miner cannot highlight the bottlenecks of the process.

B. Heuristic Miner Algorithm

Heuristic algorithms contribute the order or sequence of the activities and the occurrence or frequencies of events. This algorithm finds the frequent and infrequent paths in the process. This algorithm builds the causal nets design diagrams. This is the robust model because of frequencies of process.

Heuristic miner is closely following the alpha algorithm. This algorithm addresses many problems addressed by alpha algorithm and new issues in real world also. The heuristic miner uses XOR and AND logical connectors [17] from dependency relations [17]. This can draw the complicated problems in the real world using these connectors.

The output of this miner is heuristic net which is next level of Petrinet [18] what is used in ProM tool which helps to visualize[19] the process and predict[20] the flow. This flow diagram can be converted to other types of process models.

C. Genetic Miner Algorithm

Genetic algorithm [21] is additionally called as evolutionary approach which uses an iterative procedure to interpret the process of natural evolution. These approaches don't seem to be deterministic and enthusiastic about randomization to search out new alternatives. This produces process model built on casual matrices [22]. It handles all kinds of data like noisy, duplicate, incomplete and hidden activities also. The genetic algorithms havefour main steps: (a) initialization, (b) selection, (c) reproduction, and (d) termination.

D. Fuzzy Miner Algorithm

Fuzzy miner is a new process discovery algorithm[23]. This is used to build design[24] unstructured process and non-behavioral conflict events too. This method gives the probable maximum precision in performance[25] measures. It is the non-trivial algorithm for large number of activities.

This is the complicated, dynamic and complex algorithm to solve the unusual activities in the event log. The fuzzy algorithm[26] used to develop the fuzzy models that determine the event log metrics and aggregate the entire process. So this can produce the specific visualization of the process and we can predict the risk[27] in process. The confusion matrix [28] is used to find the prediction [29] in the process.

3. KEYWORD AND WAY OF SEARCH PROCESS

Search is based on the topic and related questions; a search word was framed according to the search topics and find the results from the multiple databases available in the search engine to find the literature survey. The search is mainly using "process mining" and "health care systems". Further, the topic was split into “process mining” and “workflow mining”. Then, we downloaded the early birds in the field and did the research on those papers. The few words helped us to derive the conditional words are: “event log” or “log file. By these concepts, the search phrase is derived as follows:

1. Health care AND Process mining
2. Process mining AND Workflow in health care
3. Event log data OR log file OR process flow
4. Process mining AND Algorithms

The search phrase was used to retrieve many papers, relevant to the search topics from thedatabase. Multiple articles are retrieved from the standard set of databases to survey the process mining.

The table mentioned below gives the surveyof various research papers [1-36] in year wise from different journals. The core content of the research paper and future findings are displayed in table 1.

Table 1: The Findings of the Process mining in health care domain from journals

Year of Publication	Title of paper	Author name	Journal	Proposed system	Drawbacks	Findings
2020	Activity Pattern Mining for Healthcare [13]	JIAXIN JIN, WANRONG SUN, FADI AL-TURJMAN, MUHAMMAD BILAL KHAN, AND XIAODONG YANG	IEEE Access	1. Activity pattern mining and classification algorithms were used. 2. This System was feasible to help doctors detect Cerebellar Ataxia.	Research was done with one department and not suitable for multiple departments.	1. Improve the accuracy of the performance in different subjects. 2. Applied in different fields in subjects.
2019	Efficient Deviation Detection Between a Process Model and Event Logs [9]	Lu Wang, Yuyue Du, and Liang Qi	IEEE/CAA JOURNAL OF AUTOMATICA SINICA	1. Detection of Deviations on Causal Nets was found using alpha algorithm. 2. Found all the abnormal activities, namely missing, additional and dislocated activities, in traces.	Dislocated activities for noisy data and the quality analysis are the drawbacks of this research.	1.Repair the process model 2. Quality dimensions of the model.
2019	A Survey on Multimodal Data-Driven Smart Healthcare Systems: Approaches and Applications [6]	QIONG CAI, HAO WANG, ZHENMIN LI, AND XIAO LIU	IEEE Access	1. Multimodal data fusion and cross-border association technique was used. 2. Decision making was found by using the fusion technique.	Continuous performance analysis and security issues of the system are the drawbacks.	1. Performance has to be enhanced by using various algorithms. 2. Protectionissues (in terms of security and privacy) has to be recovered in data utilization.
2018	Process Mining Algorithms for Clinical Workflow Analysis [11]	BernisTibeme, HossainShahriar and Chi Zhang	IEEE Access	1. Mine complex hospital processes, especially when treatment of patients, organization's workflow. 2. Process mining techniques work well with structured processes despite its complexity.	Unstructured process is the drawback of this research.	1.Focus on how the technique and application can be applied to unstructured processes 2. Re-engineer certain workflows for better outcomes.
2018	Machine Intelligence in Healthcare and Medical	OMID RAJABI SHISHVAN, DAPHNEY-	IEEE Access	1. Classification, feature extraction methods were used.	Data challenge and algorithm challenge are the drawbacks.	1. Improve the database standards in order to remove misinterpretation.

	Cyber Physical Systems: A Survey[20]	STAVROULA ZOIS , AND TOLGA SOYATA		2. Healthcare application was explained with conceptual diagram. 3. Developed multiple department activities.		
2018	Optimal Process Mining for Large and Complex Event Logs [14]	Martin Prodel , Vincent Augusto, Baptiste Jouaneton, LudovicLamarsalle , and XiaolanXie	IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING	1. Tabu Search Algorithm using DISCO tool. 2. Explained the advantages of combing techniques in process mining.	Research cannot produce the Petrinet diagrams automatically.	1. Develop the computation technique to improve the efficiency of the process. 2. Develop the new model with realistic process model.
2018	Systematic Mapping of Process Mining Studies in Healthcare [25]	TUGBA GURGEN ERDOGAN AND AYCA TARHAN	IEEE Access	1. Classification method is used to make the survey. 2. Developed the process model with different parameters and various categories of application in healthcare systems.	Database and performance analysis are the issues	1. Design the descriptive analysis in order to find the mapping with systematic literature reviews. 2. Develop the application dashboards containing with performance and efficiency indicators.
2018	GME: A Contemporary Approach workflow Process Improvement of Software by Uncovering hidden Transactions of a healthcare legacy application [3]	Shashank Sharma and Dr. SumitSrivastava	IEEE	1. Petrinet flow design was used. 2. Displaysa philosophyhowprogramming occasion log information. 3. Analyzed to grasp and advance the product work process byutilizing arrangement andstreamlining for thehuman services area application.	This research was done only using petrinet.	1. Conductingadditional experiments using different variety of event logdatasets. 2. A reasonable succeeding phase is to progress withtool support for domain-based information managementsystems.
2017	Guest Editorial: Special Section on Biological Data Mining and Its Applications in Healthcare [35]	Fei Wang, Xiao-Li Li, Jason T. L. Wang, and See-Kiong Ng	IEEE/ACM TRANSACTIONS ON COMPUTATIONAL BIOLOGY AND BIOINFORMATICS	1. Contains seven high quality papers,which cover different aspects on biological data mining in health care domain.	As this is the guest editorial, this gives the suggestions about process mining.	1. Integration of biological and clinical data. 2.Privacy preservation Knowledge integration.

2016	A Hybrid Feature Selection With Ensemble Classification forImbalanced Healthcare Data: A Case Study for Brain TumorDiagnosis [18]	SHAMSUL HUDA, JOHN YEARWOOD1, HERBERT F. JELINEK, MOHAMMAD MEHEDI HASSAN, GIANCARLO FORTINO, AND MICHAEL BUCKLAND	IEEE Access	1. Feature selectionand ensemble classification with bagging were used. 2. Developed the diagnostic rule set in pathology department and find the process model in brain tumor patients.	Restricted with pathology department only.	1. Using the feature selection in search process in healthcare industry. 2. Ensemble techniques with the additional morphological features.
2015	Automatic classifier based on heart rate variability to identify fallers among hypertensive subjects [31]	Paolo Melillo Alan Jovic, Nicola De Luca, Leandro Pecchia	The Institution of Engineering and Technology	1. Found the accuracy and performance in diagnostic process with diagram explanation.	Performance analysis was done with only cardio patients.	1. Need to develop in classification approach for sensitivity accuracy. 2. Multi departmental approach has to develop to prevent and predict falls in accuracy.
2015	Efficient Motif Discovery for Large-Scale Time Series in Healthcare [16]	Bo Liu, Jianqiang Li, Cheng Chen, Wei Tan, Qiang Chen, and MengChu Zhou,	IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS	1. Classification and discovery algorithm used. 2. Experimental results andreal-world healthcare application on ECG classification validatethe effectiveness ofMDLats.	It was done with small scale data.	1.Validate MDLats on more benchmark studies, and apply it to other application Domains.
2013	Event Sequences and Its Applications in Healthcare Data [7]	Fei Wang, Noah Lee, Jianying Hu, Jimeng Sun, ShahramEbadollahi, and Andrew F. Laine,	IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE	1. Temporal eventmatrix representation and learning on both synthetic and real world datasets.	Smaller database visualization	1. Clinical assessment for visual interactive knowledge discovery in large database.

The table mentioned below gives the survey of various research papers [1-36] in year wise from different journals. The core content of the research paper and future findings are displayed in table 2.

Table 2: The Findings of the Process mining in health care domain from Conferences

Year of Publication	Title of paper	Author name	Journal	Proposed system	Drawbacks	Findings
2019	Bridging the Gap between Process Mining and DES Modeling in the Healthcare Domain [15]	Oscar Tamburis	The 7th IEEE IC EHB 2019	1. Alpha algorithm using ProM tool. 2. A new approach was described to figure out a DES model using Process Mining techniques.	This research was using ProM and DES model only.	1.Find more solid Evidence as to the usefulness of PM techniques for determiningthe DES models construction.
2019	An overview of Process Mining and its applicability to complex, real-life scenarios [26]	Roberto Gatta , Mauro Vallati , Jacopo Lenkowicz , Jacopo Lenkowicz , Francesco Cellini , Andrea Damiani , Vincenzo Valentini	IEEE	1. ProM tool used. 2. Reviewed the efficiency of process mining depends highly on the clarity of the problem formulation and obviously on the adopted approach and algorithms.	Structured and simple process was only analyzed.	1.Focus on those manipulations of the event logs and how they might improve upon the accuracy 2. Extraction fromheterogeneous and complex event logs related to real-lifeprocesses.
2018	A Framework for Event Log Generation and Knowledge Representation for Process Mining in Healthcare [2]	Roberto Gatta , Mauro Vallati , Jacopo Lenkowicz , Jacopo Lenkowicz , Francesco Cellini , Andrea Damiani , Vincenzo Valentini	30th ICTAI	1. R package had developed to integrate in the PM pipeline of pMineR. 2. Automation of generating event logs was produced to interact with other structure.	Simple process flow was derived from this model.	1. Plan to extendthe pMineR and Ste architecture withdifferent data sets. 2. Investigate how the approachcangeneralize on different sets of guidelines and events.
2017	Process-oriented Iterative Multiple Alignment for Medical Process Mining [1]	Shuhong Chen, Sen Yang, Moliang Zhou, Randall S. Burd, Ivan Marsic	2017 IEEE ICDMW	1. Process-oriented iterative multiplealignment (PIMA) framework was used for iterative and alignment algorithm also used in this process.	This research was not able to find the global minimum.	1. Analyze of PIMA with better database to show the improved process. 2. Improve theextraction of process in better way. 3.Exhibit the benefits of iterative alignment.
2017	An Approach to Fuzzy Process Mining to Reduce Patient Waiting Time in a Hospital [36]	Ganesha K , Dhanush S , Swapnil Raj S M	2017 ICIIECS	1. Fuzzy miner was used. 2. Showed the soundness was able to read the end state without bugs. 3. Maximizing the throughput and optimal	The time and maximizes the obtainability of resources was high.	1. Uses huge event log for the CT scan test. 2. Reduces time frame

				resource utilization.		
2017	Analogize process mining techniques in health care: Sepsis case study [21]	G. Kukreja and S. Batra	4th IEEE ICSPCC	1. Comparison of various process mining algorithms was used. 2.The data visualization using process mining was done in one hospital	This is the case study with various algorithm.	1.Include more data from different hospitals 2. Provide cross organizational mining.
2017	PROCESS MINING APPROACH FOR EFFICIENT UTILIZATION OF RESOURCES IN A HOSPITAL [30]	K. Ganesha, S. M. Swapnil Raj, and S. Dhanush	2017 ICIIECS	1. Alpha algorithm was used to draw Petrinet. 2. Deviations were detected with the use of ProM tool. 3. Corrected the inefficiency of deviations and improvements were determined in the hospital management.	Process only concentrated with patients.	1. Improve the patient process flow and satisfaction rate. 2. Resource utilization improvement has to be maintained and improvement should be shown in process flow.
2017	Applicability of Process Mining in the Exploration of Healthcare Sequences [19]	KrisztinaTóth, KárolyMachalik, GyörgyFogarassy, ÁgnesVathy-Fogarassy	2017 IEEE 30th Jubilee Neumann Colloquium	1. Fuzzy and heuristic miner were used. 2. Include the managing of data integration, heterogeneity treatments, and time-related problems.	Problem was solved with cancer department only not multiple department.	1. Define a workflow, which proposes a solution for theseproblems and organizes the tasks in one unit.
2016	Enhancing medical evidence discovery through Interactive Pattern Recognition and Process Mining [4]	V. Traver, A. Martinez-Romero1, J.L. Bayo1, P. Sala1, P. Carvalho, J. Henriques, M. G. Ruano, A. Bianchi, C. Fernández- Llatas1	2016 GMEPE / PAHCE	1. Used pragmatic way, to visualize the resource details in the hospital system.	Dynamic process was the drawback.	1. Improve the scalability and pattern recognition in process mining technique. 2. Make the application with easy use and easy practice in different possibilities in process mining.
2016	Process Mining for Healthcare Process Analytics [22]	T. Erdogan and A. Tarhan	2016 JCIWSM and ICSPPM	1. Plan to complete thedevelopment of the process analytics tool and conduct a case-study in an intensive care in hospital.	Cross departmental process and analysis were the drawbacks.	1. Future directions of process mininganalytics research in healthcare with different departments.
2016	Temporal Data Mining on the Stay Time of Outpatients and Treatment Processes	S. Hirano	2016 IEEE 16th ICDMW	1. Method for miningrules that predict the stay time of outpatients from treatment. 2. Processes based on the temporal mining method.	Processed only patient details.	1. Consider the use of other event sources such as the time whenthe next patient called into the consultation room.

	[5]					
2015	RTLS-based Process Mining: Towards an Automatic Process Diagnosis in Healthcare [34]	R. Miclo, F. Fontanili, G. Marquès, P. Bornert, M. Lauras	2015 IEEE ICASE	1. Disco tool used. 2. Make a diagnosis and propose improvements. 3. Visualize the data.	Complex file was not able to use.	1. Work deal with employees in health care. 2. Complex database usage.
2011	Abnormal Process Instances Identification Method in Healthcare Environment [12]	Bingning Han, Lihong Jiang, HongmingCai	2011 International Joint Conference of IEEE TrustCom-11/IEEE ICESS-11/FCST-11	1. Classification algorithm used. 2. Abnormal activities were detected.	Automatic and optimal solution did not find.	1. Automating solution discovery algorithm

4. CONCLUSION AND FUTURE SCOPE

In this paper, we have analyzedvarious research papers on process mining in the healthcare systems. The significance of process mining is used to improve the various aspects of health care systems. Process mining explains the key performance indicators in terms of patients, employees and management. Though process mining is an emerging technique, it can be implemented with process mining algorithms. So this survey explains these different algorithms and provides comparison under different categories.

We have done the survey on different papers to derive the implication and future findings. The challenges that our literature table explains are clearly based on the future research works. The future scope is to find the appropriate and efficient algorithm for unstructured events in healthcare systems using noise and incomplete data. This survey gives the idea about the future works focusing on latest technical knowledge, by finding the research gaps those are explored in our survey which are elaborated above.

In future, we canplan to collect the clinical data from the real time data sources, hospital warehouses and hospital information systems and find the maximum and minimum level of granularity from the dataset. Based on the collected data we could analyze the unstructured process in the health care system with heuristic and fuzzy process miner for higher accuracy. Finally, we could plan to develop the dashboard to define the performance indicators for features with interactive manner.

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