Applying Concepts of Process Mining in Healthcare (Case study, Treatment of Sepsis Patient in Omdurman Military Hospital)

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Abstract **- Healthcare processes are a series of activities aimed to diagnose, treat and prevent any diseases in order to improve a patient's health. The provision of high-quality services depends to a very great extent on the appropriate and efficient execution of such processes and could have a great impact on the quality of life of the patient. In this paper, we demonstrate the applicability of process mining to the healthcare domain by examining how such an approach can be used to obtain insights related to care flow. This research case study was conducted in Omdurman Military Hospital, with the aim of improving the healthcare process through applying process mining principles and techniques. Healthcare processes were analyzed from different perspectives. By using the ProM6.9 framework, relevant event logs were extracted from the hospital's information system and analyzed to find out the degree of compliance with the medical guidelines of a group of patients affected by sepsis. This study has used three algorithms - heuristic, inductive visual miner and multi-perspective process explorer (MPE) - for the process analysis. The results show that process mining can be used to provide new insights that facilitate the improvement of existing care flows in the health sector.**

keywords **- Data Science, Healthcare, Healthcare processes, Process Mining, ProM6.9.**

1. Introduction

Healthcare is an important service that has a direct impact on human life. However, healthcare is characterized by a high degree of complexity in that hospitals have to focus on the best ways to deliver high quality care while offering the best possible service at a competitive price to ensure patient satisfaction. Hospitals try to streamline their processes and, in order to do so, it is essential that they have an accurate view of the "care flows" for which they are responsible [1]In this paper, we have applied process mining techniques aimed at obtaining meaningful knowledge about these flows, e.g., to discover the typical paths followed by a particular groups of patients .

A case study of Omdurman Military Hospital, the largest military hospital in Sudan, was used to inductively investigate raw data that was extracted from the hospital information system for a group of sepsis patients treated in the hospital, and for whom all diagnostic and treatment activities were registered.

Sepsis is diagnosed as a dangerous condition that threatens the life of people. A fast response in terms of diagnosis and treatment can save the patient's life. Many cases reported complications in achieving better treatment, while some patient's deaths were reported.

1.1. The Problem Statement.

In this case study we intended to discover and validate the processes associated with the treatment of sepsis patients, and their compliance with medical guidelines using process mining concepts and techniques to identify deviations and bottlenecks if these existed in the process model.

1.2. Objective of the Study.

The primary objective of this study is to contribute to the establishment of bases and standards for the development of medical care processes at the Omdurman Military Hospital through improving the treatment process by implementing data mining processes. The secondary objective of this study is to improve and provide high quality healthcare processes and to encourage Sudanese hospitals to adopt process mining techniques to improve the quality of care.

1.3. Structure of the Paper.

In this paper the abstract summarises the study, followed by an introduction to the research and a consideration of its context. This is done by clarifying the importance of healthcare and the implementation of process mining within the scope of the study that is related to sepsis patients in Omdurman Military Hospital. The study problem statement regarding the implementation of process mining principles in healthcare, specifically in the case of sepsis patient treatment, was then specified. The study objectives were then highlighted. The healthcare and process mining definitions and implementation were presented in Section 2 to include the healthcare process characteristics, process mining and the implementation of process mining in healthcare. In Section 3, the methodology used to fulfil the study objectives was declared, followed by the study results and discussion as revealed in Section 4. Then the contribution of the study was declared in Section 5. Finally, the conclusions were presented in Section 6.

2. Healthcare and Process Mining:

In this section we present the characteristics of healthcare, the types of process mining, and the implementation of process mining in healthcare from different perspectives:

2.1. Healthcare Processes' Characteristics.

A dynamic nature characterizes healthcare processes and portrays their complexity. Changes occur for various reasons such as the introduction of new administrative procedures or the discovery of new drugs. Meanwhile, challenges arise from the unpredictability of patient treatment, and the influences of the complex medical decision process. Moreover, the healthcare process needs multi-disciplinary contributions from different levels in terms of healthcare decisions, an aspect that depends on distributed human collaboration and skills [2].

2.2. Process Mining:

A process is an aggregation of activities and behaviors performed by human beings or machines to achieve one or more results, or a set of one or more linked procedures or activities that collectively achieve a desired goal, usually within the context of an organizational structure which operates in terms of functional roles and relationships [3].

Process mining has been applied successfully in a variety of domains such as hospitals, banks, e-government, customer relationship management, remote monitoring, and smart diagnostics. The abundance of data collected in today's hospitals can be used to improve care processes [4][7]. Its main use is to discover, monitor and improve real processes (i.e. not assumed processes) by extracting knowledge from event logs that are readily available in today's systems. In this way it provides detailed information about the activities that have been executed [5][15]. Scholars have defined three types of process mining techniques that can be used to enhance systems:

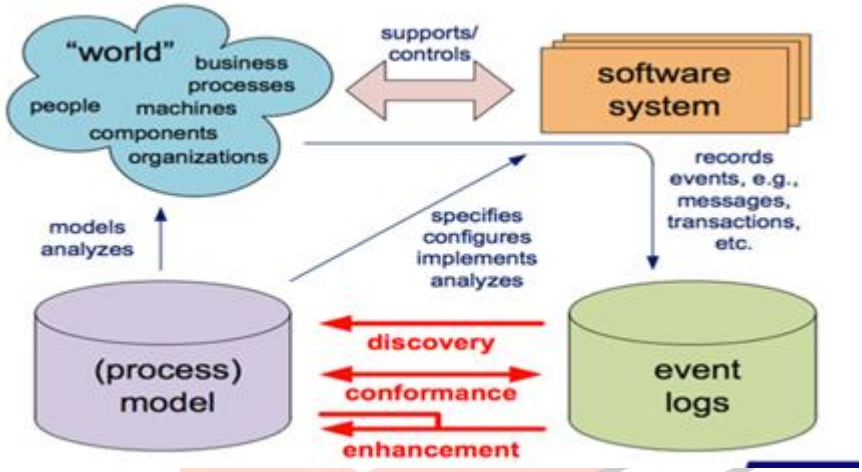

Figure.2.1: Relationship between the three type of process mining: discovery, conformance, enhancement [2, p.32]

Discovery: Inferring process models are ones that are able to reproduce observed behavior. The inferred model may be a Petri net, a Business Process Model Notation (BPMN) model, and the chosen model may describe the steps typically taken before action.

Conformance: This involves checking if behavior observed in the event log conforms to a given model. For example, it may involve checking whether or not a medical guideline which states that a lab test or an X-ray always needs to be done, is conformed with.

Extension/ Enhancement: This involves the projection of the information extracted from the log onto the model. For example, performance information may be projected with regard to a discovered healthcare process in order to see for which examinations a long waiting time exists [6] [15].

Process mining has emerged as a new way to analyze specific processes based on event logs. There are a series of software programs that enable process mining techniques and algorithms to be applied to an event log in order to generate models, tables and data for analysis. In healthcare, the most commonly-used tool is ProM, 6.9 which consists of an extensible plug-in open source tool for process mining.

2.3. Implementation of Process Mining in Healthcare.

Process mining is applicable to a wide range of systems. These systems may be pure Process Aware Information Systems (e.g., ERP systems) or systems where the hardware plays a more prominent role (e.g., embedded systems). The only requirement is that the system produces event logs, thus recording (parts of) actual behavior in healthcare through the hospital's information systems which can them be implemented through the use of process mining [1]. However, understanding the nature of the processes in healthcare is not an easy task due to their complexity and diversity which in turn are due to the involvement of many disciplines, working sometimes in isolation. Another factor is that different results may emerge when implementing the same process in a group of patients having the same diseases [2]. Therefore, a knowledge of process mining activities in terms of data extraction, data filtering, loading and reconstruction and data analysis, are necessary. The availability of such knowledge has to be considered before a hospital is able to apply any process mining techniques [8].

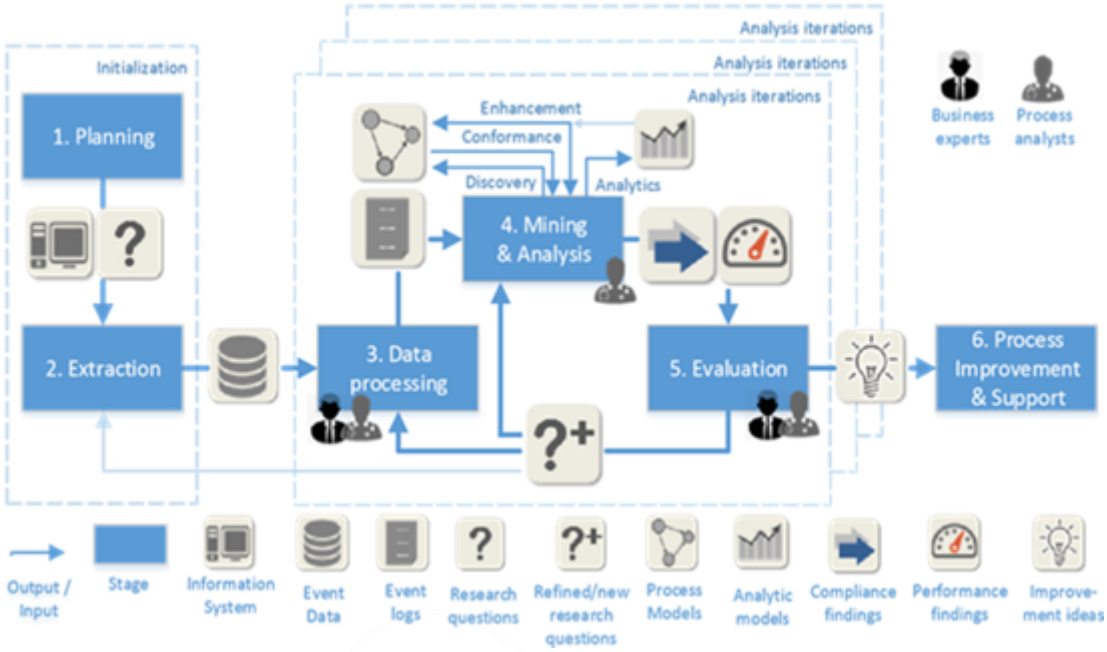

Figure.2.2: An overview of the PMPM methodology [9, p.3].

Figure 2.2 highlights the stages for applying process mining in healthcare systems. It is initiated by a planning process, followed by data extraction from the information system where the event data is located. The data which is collected with regard to the event under consideration is then utilized by healthcare experts and process analysts in the data processing stage. The outcome of this stage is the creation of an event log which is analyzed iteratively by process analysis in the mining and analysis stage. The aim is to discover the degree of conformance and to enhance the processes using process and analytical models to generate compliance and performance findings. The findings are then re-evaluated in the evaluation stage by healthcare experts and process analysts and, if the outcomes suggest ideas for improvement, they will be transferred to the process improvement and support stage. Otherwise, it will be sent back to the previous stages for more analysis or data input.

3. Methodology.

This case study intends to determine the concerns and complications that impact the quality of healthcare services and cause the lack of achievement when it comes to sepsis treatment. By making use of process mining techniques we intend to determine the pathway followed by particular groups of sepsis patient in Omdurman Military Hospital in order to find the degree of compliance between the medical guideline and process models, and to determine the existence of any bottlenecks in the sepsis process model which has been extracted from the event log. The aim will be to find any deviations or bottlenecks between activities and, in addition, to highlight the strengths of the system and to offer recommendations with regard to applying process mining in a healthcare situation.

In this inductive case study, the methods associated with ProM6.9 software has been implemented due to the large number of techniques and algorithms that it offers, and which have been used in a range of different case studies. Consequently, its applicability, richness, flexibility, sustainability and efficiency are capable of addressing the study problem and of achieving its objectives. The methodology implemented through the involvement of the three types of process mining techniques in the form of Discovery, Conformance and Extension, follow IEEE task force team recommendations [6] [10][13][14] in order to apply the process mining in the following stages:

Planning - The questions were identified, and a healthcare process was selected to help us to extract the data which was used to answer the study question. The Petri net model was selected in accordance with the event log data.

Extraction - The empirical data set of the case study was extracted from the Hospital Information System. There were about 1,050 cases from a total of 15,214 events that were recorded for 16 different activities. Moreover, 39 data attributes were recorded such as the group responsible for the activity, and the result of tests and information from checklists. Events and attribute values were anonymized. The time stamps of the events were randomized, but the time between events within a trace were not altered. We used the open source tools provided by ProM6.9 [11][12] and the event logs extracted from the Hospital Information System.

Data processing - In this stage, data filtering was applied. Incomplete data or events in process were isolated so that we focused only on completed events. By using a simple heuristic algorithm, logs were filtered.

Mining and analysis - In these stages, process mining techniques were applied on filtered event logs to solve the case study problem. The input at this stage were the event log, a mining heuristic, an inductive visual miner algorithm to (re)discover the process model in order to define the trajectory of the flow of a group of patients to obtain information about any deviation in the process model. In addition, the multi-perspective explorer process was used to check conformance and to identify any bottlenecks.

Evaluation - The objective of the evaluation stage is to relate the analysis findings to improvement ideas that could be used to achieve the project's goals. The inputs are the process models, performance and compliance findings from the analysis stage.

The outputs are improvement ideas or new research questions. The activities for this stage are: Diagnose, Verify and Validate (V&V).

Processing improvement and support - The objective of this stage is to gain insights in order to modify the actual execution of the process. The inputs of this stage are the improvement ideas that emerge from the evaluation stage. The outputs of this stage take the form of process modifications. The activities involve implementing improvements and supporting operations.

4. Results and Discussion.

To solve the problem explored in this case study, we first filtered the sepsis event log using ProM6.9 and an event log extracted from HIS. The output was in the form of the sepsis event log which had been filtered as a simple heuristic. Figure 4.1 shows the information associated with the event log.

Figure. 4.1: Sepsis case – event log filtered using simple heuristic information

To discover the sepsis process model and to determine the trajectory of the group of patients under consideration, a filtered sepsis event log was used with a heuristic miner algorithm. Figure 4.2 and Figure 4.4 show the sepsis process model so generated, and to obtain the trajectory of patients and iteration in terms of CRP and leucocytes.

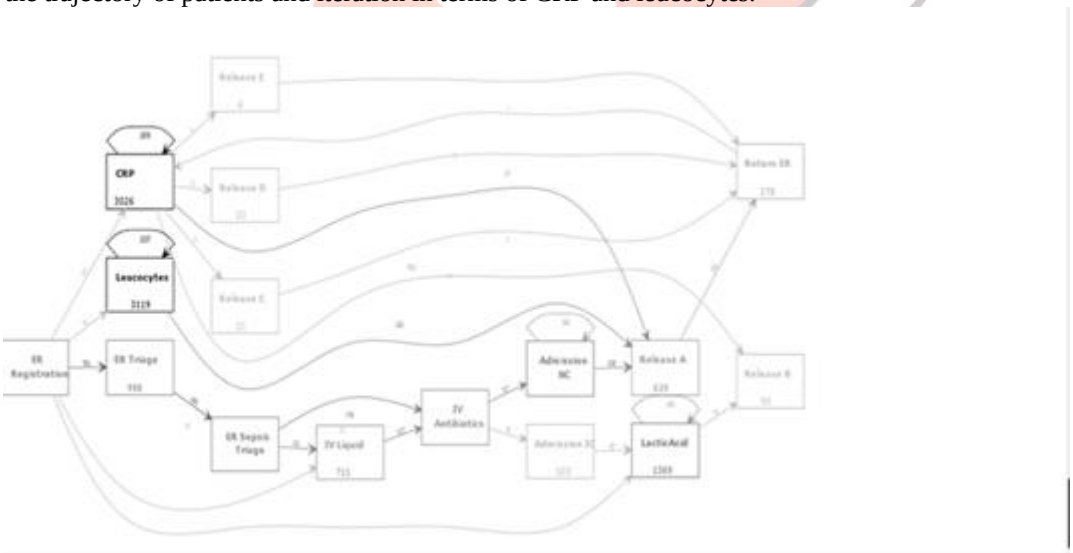

Figure. 4.2: Sepsis process model, using a heuristic miner algorithm

To determine the deviation, the inductive visual miner algorithm was used with the filtered sepsis event log to generate a sepsis process model incorporating deviation and patient flow. This is shown in Figure 4.3.

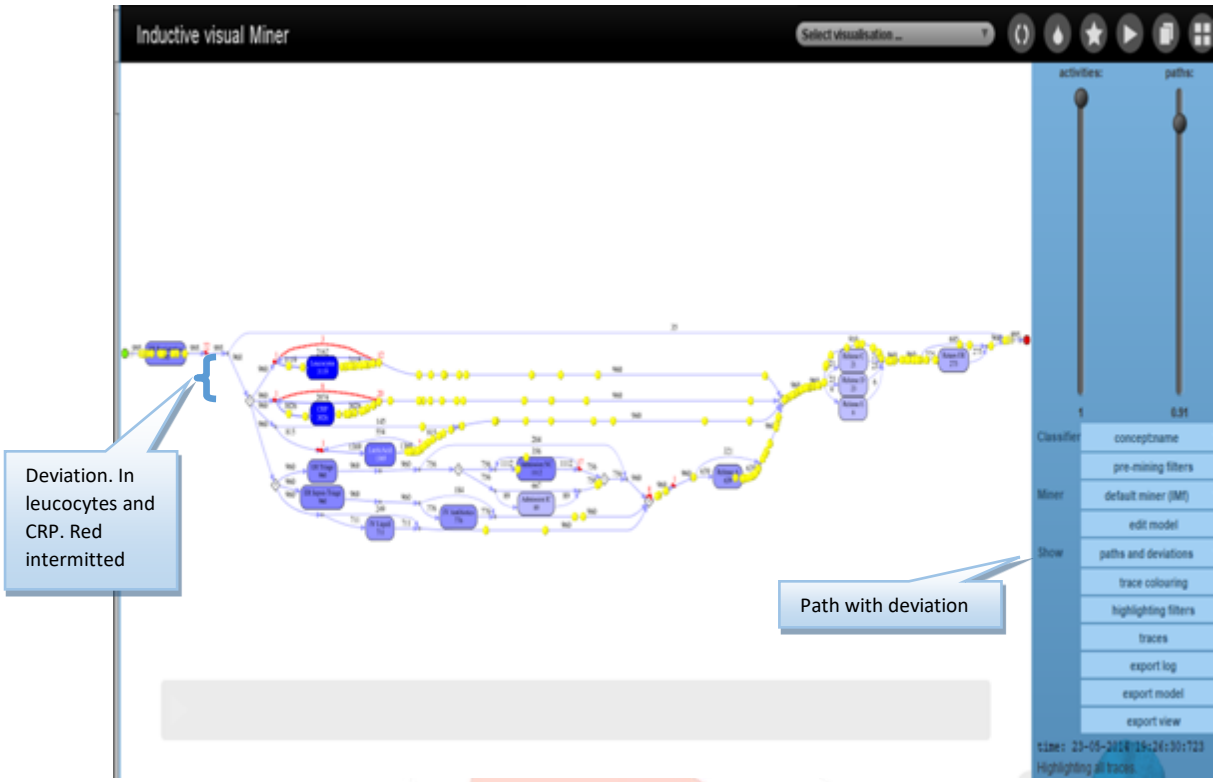

Figure. 4.3: Sepsis process model with deviation and patient flow using the inductive visual miner

To apply a conformance check to determine the compliance between medical guidelines and the process model, and to determine any bottlenecks in the sepsis process model, the filtered sepsis event log and the Multi-Perspective Explorer (MPE) process was used. Using the sepsis process model which the MPE generated, we used the fitness mode to determine the fitness of the model. The result was 91% which indicates how good the process model was. The remaining percentage determines the deviation percentage. Figure 4.4 illustrates the sepsis process model incorporating the fitness mode.

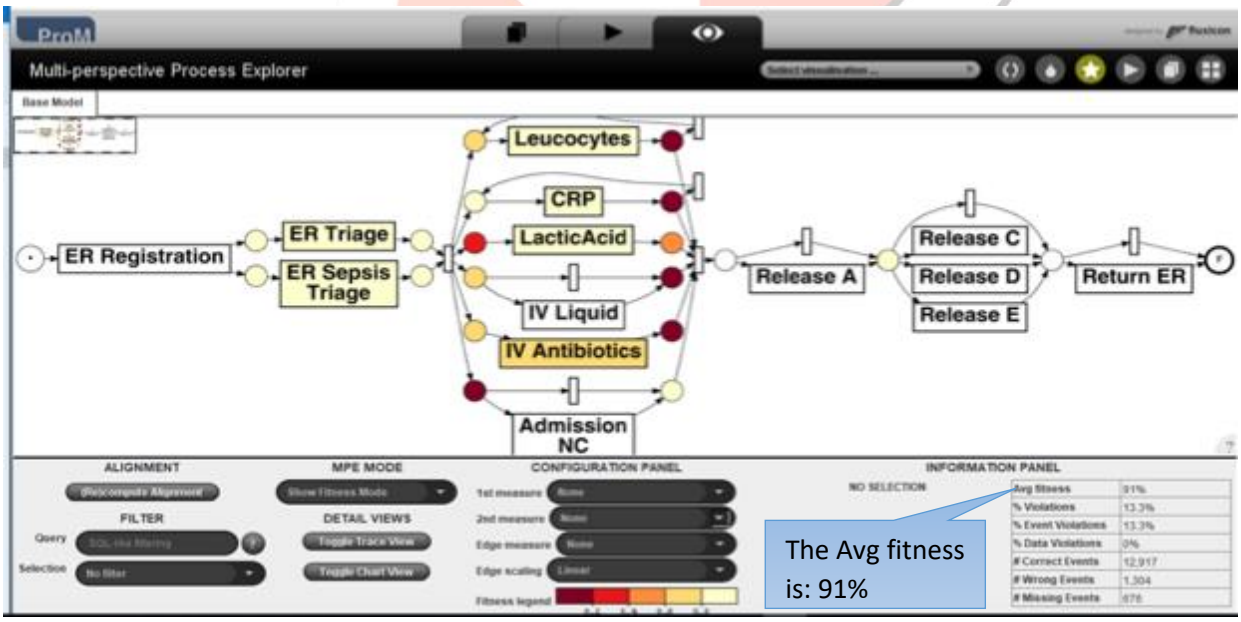

Figure. 4.4: Sepsis process model with MPE defined fitness

When we used the performance mode to determine the degree of compliance between the medical guidelines and the sepsis process model, we found that the time between ER Triage and IV Antibiotic was 2 hours, but the time between ER Sepsis Triage and Lactic Acid was 14.8 hours. This indicates a bottleneck between the two activities, and we want to reduce the time given that, according to the medical guidelines, it should be less than 4 hours. Figure 4.5 illustrates the situation.

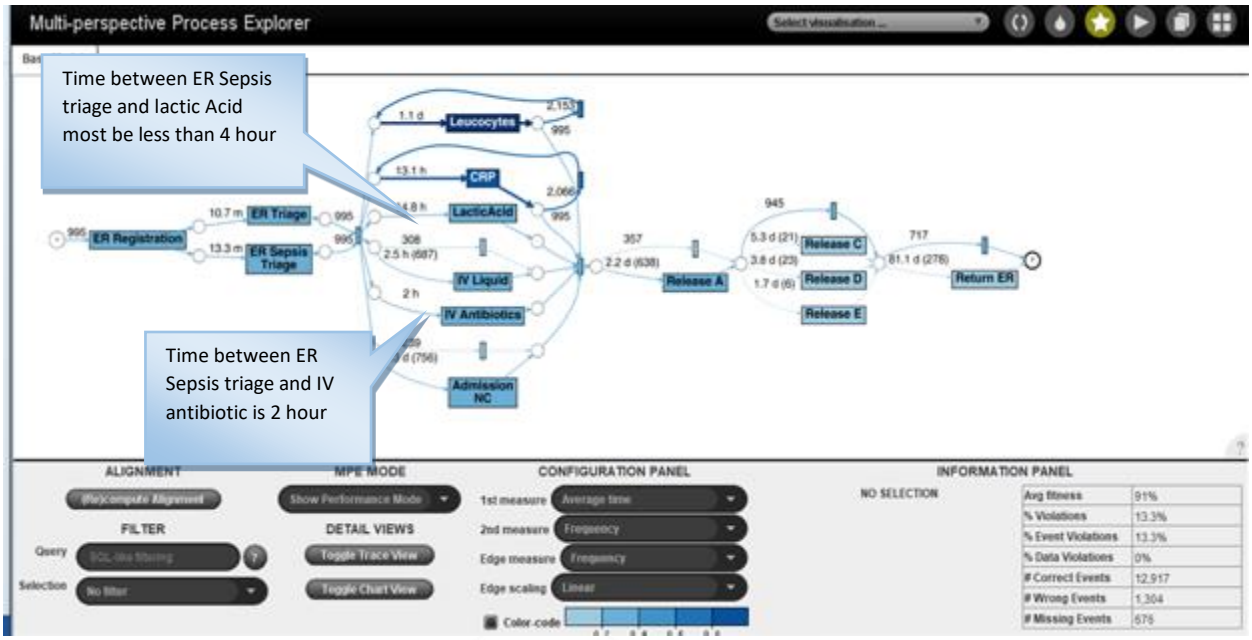

Figure. 4.5: Sepsis process model with MPE conformance check to determine the degree of compliance and the extent of bottlenecks

We can conclude that the heuristics miner is able to highlight all low frequency behavior. This makes it easy to use in support of extension/improvement research in the medical domain. The inductive visual miner shows the deviation in terms of process and frequent procedures loops. The multi-perspective process explorer (MPE) is able to show the behavior of Conformance Checker to make sure that all discrepancies between the original process and the acquired event log are identified.

5. The Contribution of the Study

The benefits that can obtained from applying process mining to improve healthcare processes in Omdurman Military Hospital are as follows:

Enhancing and clarifying the visualization of the patient flow in the hospital.

Helping the hospital to monitor their processes by focusing only on the quality indicators.

Checking the conformance to the medical guidelines of the hospital in the context of treatment and patient logistics processes.

Simplifying the understanding of the nature of the processes by using the data recorded in event logs.

Helping the hospital to improve their processes to make them more competitive.

By obtaining the behavior of process, identifying bottlenecks, and finding solutions.

6. Conclusion

The existence of bottlenecks and the lack of compliance in the treatment process in hospitals is one of the most common problems in the health sector. The literature review contained in this paper revealed that it is possible to use process mining techniques in healthcare processes. Furthermore, no study has investigated this issue in any Sudanese hospital. The case study using sepsis patient data in Omdurman Military Hospital had been tested by using multi mining process techniques In order to fulfill the study objectives and to solve the study problem, data was collected from the hospital information system for 1,050 cases within a total of 15,214 events that were recorded for 16 different activities and 39 data attributes. By using the ProM6.9 tools and algorithms, the study concluded that a medical process can be analyzed and improved by using a combination of data analysis and process mining. Moreover, by applying the concept of process mining with regard to a medical treatment process, the results can be used to optimize and improve the medical process in order to achieve a high quality in terms of processes.

This study introduces the opportunity for new studies to be conducted by applying process mining techniques to improve organizational processes in different sectors in Sudan.

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