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New approach for resource allocation indigital healthcare 4.0

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Abstract

Abstract: The examination and automation opportunities in healthcare processes, which aims at reducing patient journey and their waiting time, while increasing the utilization of medical equipment as well as monitoring patients.

Waiting times are playing a significant role in the total process time of patient care. One of the main reasons is the insufficient resource allocation. This research presents a methodological improvement which supports decision making in digital health processes. The current research provides a methodology that makes weekly human resource scheduling more efficient than before.

With the combination of process mining and operations research, we developed a weighted forecast for the probable number of patients. During the research we processed historical data as well as we identified the bottlenecks in the examined health process. Furthermore, we took the causality into account.

In today's fast-paced societies, IT-based solutions are more and more frequently used in healthcare, with the aim of reducing risks and increase patient satisfaction. The method created by us offers a fast, precise and efficient solution to decision making in digital health processes.

Keywords: *Process Minning, Risk analysis, scheduling.*

1. Introduction

Hospitals have to focus on high quality care and cost reduction at the same time. Hospitals face many challenges nowadays such as increasing costs, strict standards, lack of human resources. Hospitals are forced to improve the quality of care their services under financial presussres by governments. Can business process improvement and process mining be the solution to the previously mentioned problems? Business process improvement is the field of increasing efficiency of organizations and decrease operation costs Anyanwu et al. (2003). The goal of process mining is to extract process knowledge based on "event-logs" from different information systems. Event logs consist of information about the start/end dates of a particular activity, required resources and actors Anyanwu et al. (2003).

The aim of this paper is to present a case study in the field of healthcare. In this case study process mining was applied within business process improvement frameworks. The examined case is a sample identification process in the Department of Medical Microbiology from the receiving sample to the point of cosnsulting with the doctor about the result. Process mining was used to reveal bootlenecks in the sample indentification process, after that resource allocation was carried out to balance out the workload of human resources. The amount of the incoming samples was predicted, and the scheduling of workers was calculated with the new balanced workflow.

2. Literature review

2.1. Business Process improvement and Process Mining

Business Process Improvement is a part of the Business Process Management System. Business Process Management focuses on solving current business problems by improving the related processes Malinova, M., & Mendling, J. (2018). Many companies follow the Business Process Management (BPM) cycle to manage business processes. This cycle consists of 6 different steps. These are the following:

1. process identification
2. process discovery
3. process analysis
4. process redesign
5. process implementation
6. process monitoring

The BPM life-cycle provides a logical way to improve business processes. One of the most important parts of BPM is process modelling Malinova, M., & Mendling, J. (2018). Sometimes the models are not structured and at a wrong abstraction level. Another barrier of good modelling is that it requires skilled process analyists. Without a good process model it

is not possible to execute an improvement well. At this point, process mining can help us. In the service sector, such as health care it, is not easy to modell processes because they are known to be commonly chaotic and unidentified.

Process mining attempts to eliminate the previously mentioned limitation of process modelling. With the use of process mining the reality can be presented as a petri net, wich is a good starting point of modelling. The following data are required for process mining: Case ID, timestamp, name of activity, resources. Figure 1 shows an example.

Case id	Event id	Properties				
		Timestamp	Activity	Resource	Cost	...
1	35654423	30-12-2010:11.02	register request	Pete	50	...
	35654424	31-12-2010:10.06	examine thoroughly	Sue	400	...
	35654425	05-01-2011:15.12	check ticket	Mike	100	...
	35654426	06-01-2011:11.18	decide	Sara	200	...
	35654427	07-01-2011:14.24	reject request	Pete	200	...

Figure 1: Example Event Log. Source: Van der Aalst (2016)

The case is identified by Case ID e.g. a sample is recieved. Then, the sample preparation, and several activites that are executed by the workers.The next two columns demonstrated the information about the time and activity duration is important to generate the right sequence.

The process discovery technique automatiacally generates and learns a process model from an event log database. Figure 2 shows the generalized model of discovery technique.

Figure 2: Process discovery. Source: Van der Aalst, et al. (2011)

The result of the discovery is a fact-based ‘as-is” process model that present how the process works in reality. It is based on historical data Burattin, A. (2015).. Compared to the traditional process model technique, process minig discovery makes it possible to model unstructured processes Pourmasoumi, A., & Bagheri, E. (2017).

2.2. Generalized Network Models

Generalized network models are applicable in several fields of use, such as manufacturing or healthcare, where parallel or sequential activities can be carried out Chachra (1979), Murty

(1992). The purpose of these kind of models is to either ascertain a material flow, or determine a probable total process time (TPT) or total process cost (TPC) based on Pusztai et al (2018). These models usually determine the direction of the objective, which are usually related to cost. In this kind of model nodes are for machines or events, while arrows display material flow or activities.

The generalized **objective** of the model can be seen in the equation below:

$$\min z = \sum x_{i,j}$$

where $x_{i,j}$ is the representation of the unit cost/unit processing time of a given activity.

To the subjects of:

$$\sum_{j=1}^{n} x_{i,j}\lambda_{i,j} - \sum_{i=1}^{n} x_{i,j} - I_i \geq 0$$

where:

- $x_{i,j}$ illustrates the gross material flow,
- $\lambda_{i,j}$ demonstrates the possible performance (within the range of 0-1),
- I_i displays the Inventory in the node i.

3. Problem statement and aim of the research

Two analysts deal with the blood and urin samples identification at the department of Microbiology. Unfortunately, the workflow is unbalanced and the analysts are overloaded. That is why some mistakes can occure during the procedure such as: wrong identification, machines breaking down, sample sorting problems. The goal of the project is to try out a new approach with the use of wich bottlenecks can be determined and additional workforce can be assigned for problematic stations to equalize the unbalanced work and eliminate the problems.

4. Material and methods

The scope of the research is the bacteria identification procedure based on 2 different types of samples, blood and urine. In the first step the process was modelled and analysed by process mining discovery methods based on event-logs. The software provided information about the bottlenecks and the workflow. In the next step the resource allocation was improved by Generalized Network Problem (GNP) method. The amount of the incoming samples was predicted for the next period, and the workload was calculated with the new scheduled workflow.

In this research process mining and Generalized Network Problem method were combined to extract information from the process and find solution to optimal scheduling for decrease overloaded human resources.

A random choosen daily event-logs were collected for process discovery.

5. Result

The process model was generated by process discovery. Based on the process model 3 paths can be seen. The first is when the blood sample result is negative, in this case 3 activites were executed from "incoming sample" to "Communication" the negative result. If the blood sample result is positive the previous process is extended with the following main activites:

- MALDI TOF identification,
- antibioticum resistans examination.

The second and the third paths are about the urin sample identification. There are two type of urin sample identification procedures. The first is the urin native sample when inoculate the agar plates with urin is necessary. The middle path demonstrate this process. The second type of urin sample arrived in uricult. The path on the left hand side demonstrates this process.

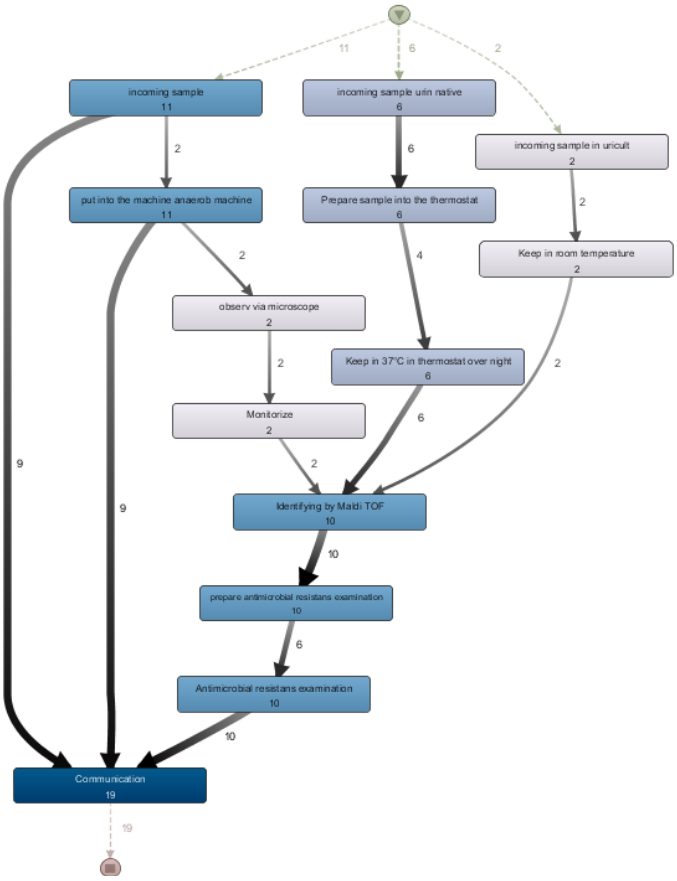

Figure 3: Process model: discovered paths

The numbers beside the arrows present the output of cases' frequencies. The numbers in the middle of the rectangle display the occurrence of a certain activity. The figure 3. present the discovered paths.

The figure 3 presents that there are 11 blood and 8 urin samples out of 19. Two positive blood sample results were communicated and there were 9 negative blood sample results. 6 urine native samples arrive and 2 urine uricult samples arrive. The performance of human resources are appeared from the analysis of the process model. The "prepare antimicrobial resistans

examination" activity is the most frequently and it takes the longest time. So this is the bottleneck. This activity occurs on every path when the sample is positive. The table 1. presents the data of the bootleneck activity.

Table 1: prepare antimicrobial resistans examination activity data

Frequency	**Performance**
Absolute frequency: 10	Total duration: 107 mins
Case frequency: 10	Median duration: 7 mins
Max repetitions: 1	Mean duration: 10.7 mins
Wrokers: 1	Max duration: 44 mins
	Min duration: 4 mins

Source: based on the authors' result (2019)

The process model and the result of process analysis are the input of the GNP model. The GNP model provide the sample flow. The result of network provides that if additional worker is implemented to the bottleneck the total duration of the activity can be descended by 50%/worker. The figure 4. presents the network modell of the process.

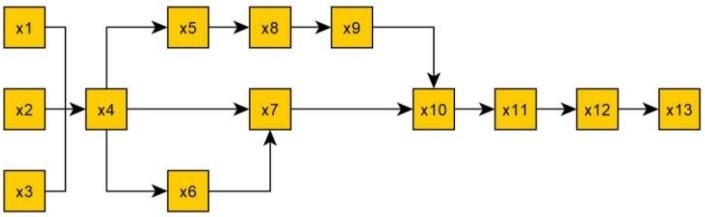

Figure 4: Generalised Network Model of the process

If we add an extra human resource to this activity, total activity time of sample identification can be reduced, because there is no any resource which means bottleneck in this process step.

The bootleneck activity data will change in the improved state. The table 2 present the improved activity data.

***Table 2:* prepare antimicrobial resistans examination improved activity data**

Frequency	**Performance**
Absolute frequency: 10	Total duration: 54 mins
Case frequency: 10	Median duration: 7 mins
Max repetitions: 1	Mean duration: 10.7 mins
Workers: 2	Max duration: 42 mins
	Min duration: 4 mins

Source: based on the authors' result (2019)

6. Concept for the new approach

The following data are necessary to the GNP model to determine the lowest TPT: cost/cycle times of activity, structure of process. The research reveal the fact that process discovery technique can provide the input data for the GNP model. GNP provide the best material flow where TPT is minimum. Based on the optimum material flow, the daily tasks for the microbiologists, analysts and assistants can be determined by the start of the shift. If a cloud is implemented the information flow is easy between the participant. Futhermore, the combination of process mining and calculated of operations research model can be automated by Robotic Process Automation (RPA). Figure 5 presents the new concept with the use of it Business Processes can be optimized and the results can be communicated with the stakeholders automatically. The new concept is called as Framework for Optimized Process with Integrated Algorithms (FOPIA).

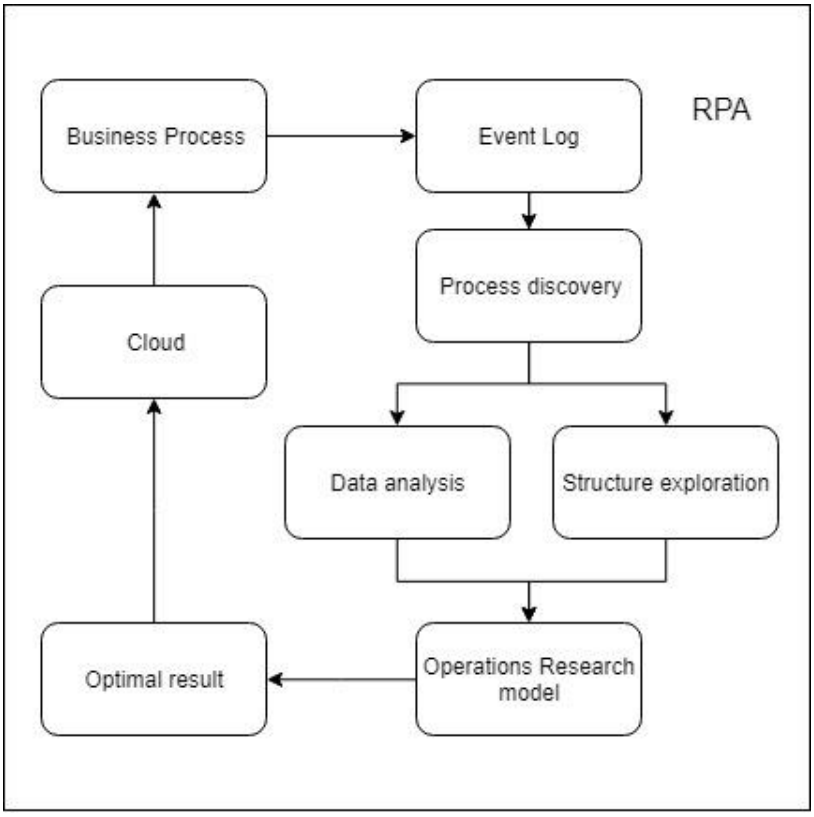

Figure 5: Concepts of Framework for Optimized Process with Integrated Algorithms (FOPIA).

7. Conclusion

Hospitals face with many challenges nowadays. The good scheduling is a fundamental part of the daily operation. A new concepts were applied to schedule a health care process as a business process. The research pointed out that the result of process discovery can be the input of GNP operations research model. So the process mining and the operation research a good conbination for optimizing of BP. FOPIA concept provides an automated, integrated system with the use of which the scheduling and the optimal resource allocation is performed and communicated via cloud system.

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