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BPI LAB
Business Process Intelligence

Seoul National University Bundang Hospital

Introduction

Seoul National University Bundang Hospital (SNUBH) is one of the major hospitals in Korea with a professional medical staff, state-of-the-art facilities, and an advanced medical environment. It is well known for its advanced health information systems. SNUBH has reached Stage 7 on the HIMSS Analytics Electronic Medical Record Adoption Model (EMRAM) scale. It is the first hospital outside the United States to achieve Stage 7 at which only 1 percent of U.S. hospitals rank. The hospital is involved in several ICT (Internet and Communication Technology) research projects, such as U-Healthcare project, Smart Hospital project, etc. In this research funded by the Korean government, we applied process mining techniques to analyze the outpatient care processes in SNUBH.

Fig. 1 The panorama of SNUBH

Goal of the Analysis

Recently, SNUBH has extended its care facility; the number of beds is now 1,356 and more than 4,500 patients visit the hospital every day. The increase of patients made healthcare processes more complicated. To provide a high-quality service for patients, improvement of the processes was required. As a starting point, the hospital would like to understand their processes. i.e. whether patients follow their standard processes. After the analysis, the hospital would like to build a smart guidance system for patients considering the patient types. Furthermore, the hospital tried to simulate the care processes to control the patients' waiting time for consultation. Thus the goal of the research is to help the hospital to understand the care processes by analyzing the event log. We analyzed the log with several process mining techniques, such as process discovery, performance analysis, and pattern analysis techniques.

Event Log

For the analysis, an event log for outpatients was extracted from the hospital information system at SNUBH. The event log contained 15 tasks: consultation, test, payment, etc. It included information about resources, departments, patient types, etc. The log contained the patients visiting times in May of 2012. The summary information is as follows:

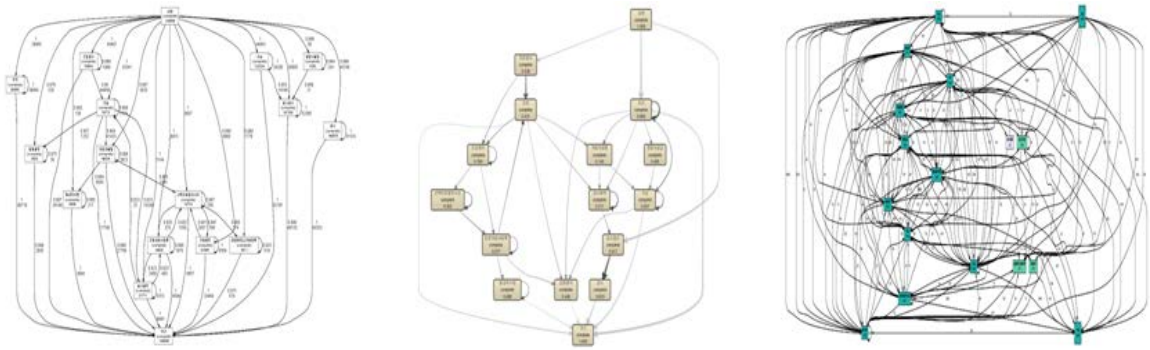
- About 120,000 cases (patients that were treated)
- About 700,000 events (activities performed for these patients)
- 15 different tasks (e.g. consultation, test, payment, etc.)

Process Mining Results

To analyze the processes, we had in-depth discussions with the medical professionals and set the direction for the analyses. The following questions were posed:

- Does standard model in the hospital explain actual patients' movements in the hospital?
- How much of increase in patients is allowed?
- Are the process patterns different depending on the patient types?

For these questions the following results were obtained:



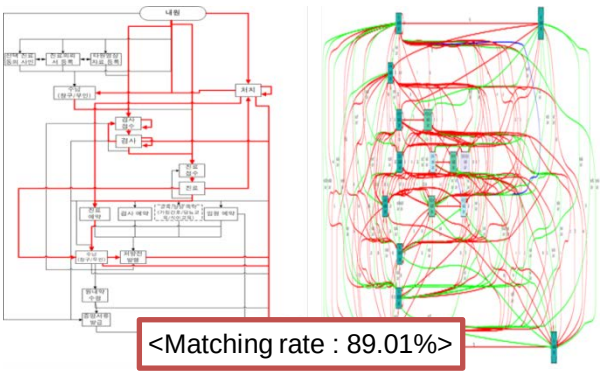
(a) (b) (c)

Fig. 2 The models using (a) Heuristic Mining, (b) Fuzzy Mining and (c) Comp Mining

Evaluation of the Standard Model

To evaluate the standard process model in the hospital, we derived process models from the log using several control-flow discovery techniques and compared them with the standard one. We applied the heuristic mining, the fuzzy mining, and the comp mining which we developed in the project. Figure 2 shows the derived models that show actual process flow in the hospital. The heuristic mining result and the fuzzy mining result showed major flows in the outpatient process, while the comp mining result showed all possible paths among the activities including less-frequent flows. The most frequent flow is from *reception of consultation room* and *consultation, which* occurred 63,392 times. The flows happened more than 10,000 times are as follows.

- *Reception of consultation room → Consultation*
- *Test → Reception of consultation room*
- *Consultation → Payment*
- *Reservation for consultation → Payment*
- *Payment → Payment*
- *Test → Preparation for test*
- *Payment → Preparation for test*
- *Preparation for test → Test*
- *Payment → Issuance of a prescription*
- *Payment → Treatment*



(a) (b)

Fig. 3 Comparison with the Standard Model

Figure 3 (a) is the standard model in the hospital and Figure 3 (b) shows the differences between the standard model and the comp mining result. In the figure, the red lines and the green ones represent non-matching and matching flows respectively. We calculated the matching rate between two models which is 89.01%. The comp mining result shows that the actual outpatient care processes were very complex compared to the standard model, since the standard one contains only the important flows among all possible movements. However, during the discussion with medical professionals we were not able to find any undesired patterns in the derived model, i.e. the process is well-managed by the hospital.

Performance Analysis and Simulation

We have performed basic performance analysis from the log and used the result for a business process simulation. To make a business process simulation model, several parameters are needed such as a process model, a arrival rate of a case, and time information of activities, etc. For the simulation, we calculated the execution time for the activities by applying the performance analysis, which is one of process mining techniques. Based on the performance analysis result, we made a simulation model for a doctor. Using the simulation model, we analyzed the change of consultation waiting time according to the increase of patients. Figure 4 shows how the waiting time became longer according to the increase. In the figure, the 10% increase of patients makes the biggest increase in waiting time which is about 25%. Thus, we suggested less than 10% of increase if they need the change of the number of patients.

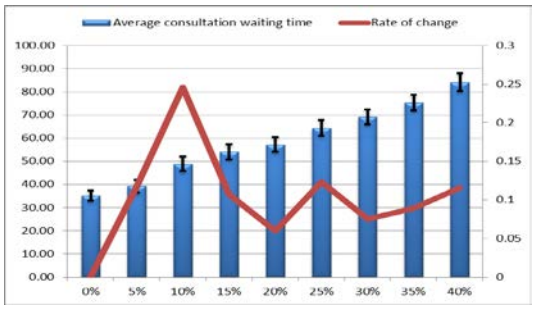
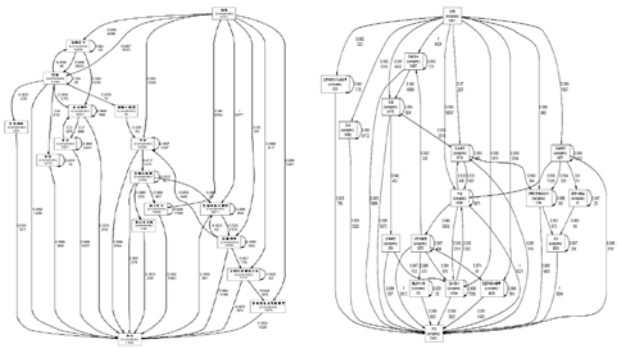


Fig. 4 The result for consultation waiting time

Process Pattern Analysis

In the hospital, there are several types of patients. Among them, there are patients who visit the hospital for the first time ('new patients') and patients who already have medical records ('returning patients'). To analyze the differences between the types of patients, we derived process models and performed the process pattern analysis considering patient types.



(a) (b)

Fig. 5 The models of (a) 'New Patients' and (b) 'Returning Patients'

Figure 5 shows the derived process models. The 'returning patients' enrolled a consultation room and got a consultation as soon as they visited the hospital, while the 'new patients' were registered an outside referral document for the first task. The pattern analysis shows that 'new patients' stayed longer than 'returning patients' in the hospital. The most frequent patterns for each patient type is as follows.

- 'New patients': RORD→RCR→C→P
- 'Returning patients': RCR→C→RC→P→IP

(RCR: Registration of consultation room, C: Consultation,
P: Payment, RC: Registration for consultation,
IP: Issuance of a prescription,
RORD: Registration of an outside referral document)

The pattern analysis result was used to build the smart healthcare system in the hospital. Patients can use a smartphone to find their route that is recommended based on the pattern analysis result.

Conclusion

In this project, based on the outpatients' event log in SNUBH, we derived the process model and compared it with the standard model in the hospital. In addition, we conducted performance analysis to make a simulation model and analyzed the process patterns according to patient types. The results and applications are following:

- According to the result of comparing the event log and their standard process model, the matching rate was as 89.01%. That is, they relatively well understood workflows of outpatients and the process was well-managed by the hospital.
- Using the performance analysis result, we generated the simulation model. The simulation shows that the 10% increase of patients makes the largest change in consultation waiting time. Thus, we recommended less than 10% of increase.
- We extracted the process models and analyzed the process patterns according to patient types. The most frequent pattern of each patient type was discovered. (e. g. 'Returning patients': RCR→C→RC→P→IP) The patterns are used to build a smart guidance app in the ubiquitous healthcare system in the hospital.

After seeing the results, the medical professionals were impressed and showed a deep interest. They requested the further analyses such as the call center process analysis and the payment process analysis, etc. These works will be conducted in the near future.