Comprehensive Demonstration on Heart Failure Treatment

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1 Demonstration on Heart Failure Treatment

In the following, we demonstrate the event log extraction method for MIMIC-IV and present the different levels of the event hierarchy for the heart failure treatment case[3].

Goal The goal of this project is to discover the hospital treatment process of patients having heart failure and to identify, if common treatment practices are applied.

Cohort The cohort consists of heart failure patients. Heart failure is the leading cause of hospitalizations in the U.S. and represents one of the biggest cohorts in MIMIC-IV besides newborns, with 7,232 admissions [2]. It was chosen based on ICD codes and DRG codes[4] related to heart failure.

Case Notion We have selected the hospital admission as the case notion, because we want to focus on the steps taken specifically for patients with heart failure instead of analyzing the complete patient history.

Case Attributes We have chosen case attributes that are related to the hospital admission, such as *admittime*, *admission_location* and the list of diagnosis (from the `diagnosis_icd` table).

Event Types and Attributes

[3] The detailed event log descriptions with their configuration files can be found in a GitHub repository: https://github.com/bptlab/mimic-log-extraction/tree/main/sample$_c onfig_f iles$.
[4] The selected ICD and DRG codes can be found in the configuration files.

Event Type – Admission The first level of the event hierarchy are the admission events. The discovered process model is illustrated in Fig. 1. It provides a high level view on the hospital process of heart failure patients. One can identify, how many patients entered the hospital via the emergency department (*edreg*) or were referred to a ward immediately (*admit*), how long their hospital stay was, and how many of them were successfully discharged (*disch*) or died (*death*). Even though the dates in MIMIC-IV were shifted for means of anonymization, it is possible to analyse the treatment duration.
On this level of abstraction, the hospital process is still quite structured with defined event types. Thus, existing techniques, such as different discovery algorithms, can be applied on this level without any challenges.

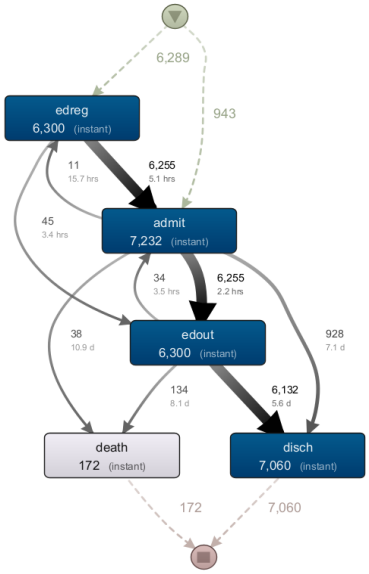

Fig. 1: Admission Events illustrating high level events during the hospital process. All activities and paths are displayed.

Event Type: Transfer The second level of the hierarchy gives a more detailed representation of the hospital treatment process by showing the hospital wards patients were visiting. Dependent on the disease under investigation, the hospital wards visited can differ significantly. For example, cardiovascular diseases are expected to be treated in cardiovascular related departments, such as Cardiology. The hospital ward transfers are displayed in Fig. 2.

To retain a comprehensive view, only 20% of the transfer events and 30% of the paths are shown. As heart failure is a cardiovascular disease, the most com-

mon departments visited are inner medicine (medicine), cardiology, and coronary care unit. The events in this perspective contain information about the start and end of the department visit, which allows applying methods of performance analysis. Additionally, the frequency and average duration (in brackets) gives an indication for the workload of hospital wards for specific patient cohorts. With the tool, it is possible to enhance the events with additional event attributes by adding aggregations from other tables, such as laboratory values or medications given. For example, one could add the mean value of a certain laboratory value to see, how it evolves throughout the process for the cohort, as shown in [1].

This view comes with some challenges. The high amount of hospital wards and the high variability of visits results in complex and spaghetti-like process models. One could make use of trace clustering to distinct different types of heart failure patients or of event abstraction, such as abstracting ICU visits, to have a more structured process model. Additionally, one could compare treatment activities conducted in different hospital wards.

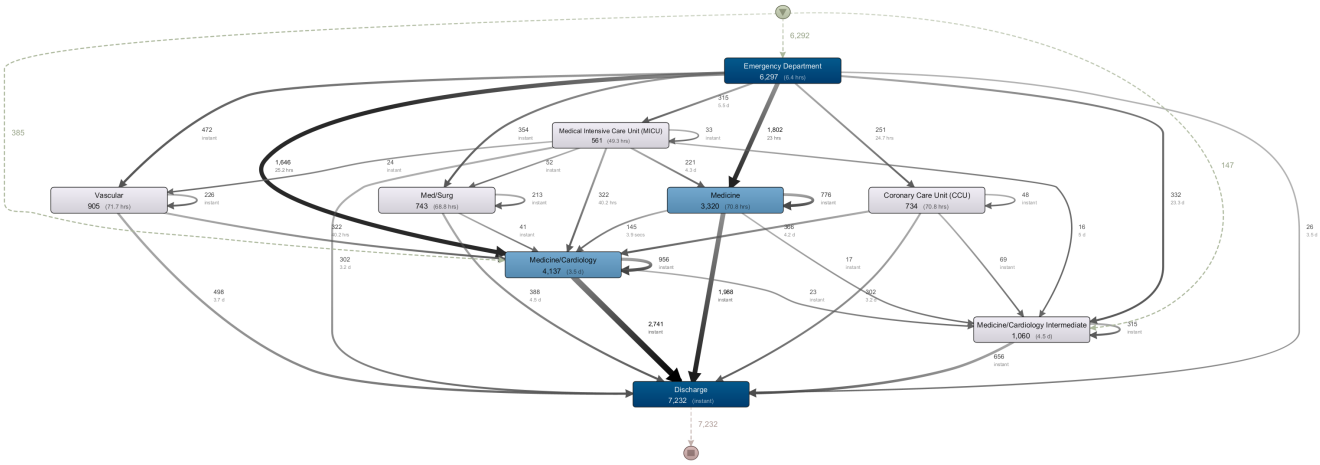

Fig. 2: Transfer events, showing the hospital wards visited by patients. Activity filter: 20%, Paths filter: 30%

Event Type: POE A more detailed view about the activities conducted for patients with heart failure is shown in Fig. 3. The process model illustrated in Fig. 3 shows the sequence and frequency of heart failure related treatments and procedures ordered for the patients. We filtered manually for events that are typical activities performed for patients with heart failure [3].

We displayed frequency and case coverage in brackets for each activity. This process represents typical characteristics of healthcare processes, including highly

repetitive tasks and missing order of activities. It can be observed that monitoring is very important for heart failure patients, especially telemetry is common for patients suffering from cardiac conditions as well as X-rays or CT scans for the diagnosis. Additionally, activities for managing heart failure can be observed, such as oxygen therapy, renal replacement therapy in the form of hemodialysis, or palliative care [3].

Repetitive events, such as Vitals/Monitoring make it almost impossible to derive a process order, especially in directly follows graphs, as these events have a high amount of ingoing and outgoing arcs. Identifying these automatically and dealing with them can be an interesting way of making process models more readable. Additionally, one could think about methods and visualizations to analyse discontinued orders (*discontinue_of_poe_id* and *discontinued_by_poe*). As the POE level contains a high amount of different events, one could also think about methods supporting process analysts and domain experts to find events of interest.

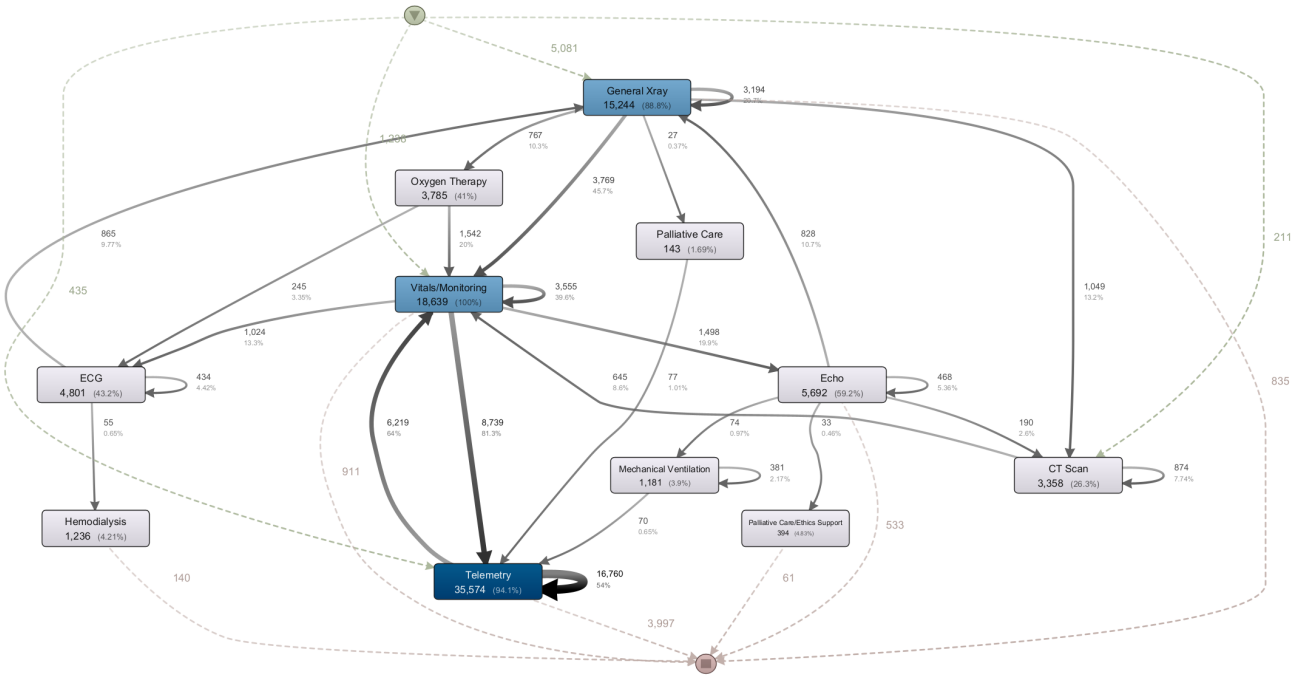

Fig. 3: POE events, showing treatments and procedures ordered at the hospital. Activity filter: Manually selected events given in a guideline [3] (10% of all with 100% case coverage), Paths filter: 45%

Event Type: Labevents and Pharmacy As the POE events gives an overview about treatments and procedures ordered, the other tables provide information about the exact execution of those. For example, the `pharmacy` and `labevent` table provide information about which medications were given and which laboratory values were measured at which time of the treatment process. Fig. 4 illustrates the interplay of a heart failure related laboratory value (Bicarbonate) and a heart failure medication (Furosemide) enhanced with the dosage.

Similar to POE, a highly repetitive process is presented, as the laboratory value measurement Bicarbonate occurs 65,401 times for 7232 cases. The interplay of the measurement and medications given is interesting, as it is recommended by clinical guidelines to check laboratory values before increasing the dosage of medications and at least every 24 hours [3]. This check routine results in a "flower" for the Bicarbonate check, which has a high amount of ingoing and outgoing arcs. It allows analysing the average duration until the laboratory was measured after giving the medication, which is between 14 and 27 hours, depending on the dosage given. It does not allow seeing, if dosage was increased/decreased after a laboratory measurement was conducted. How to achieve this, could be an interesting challenge.

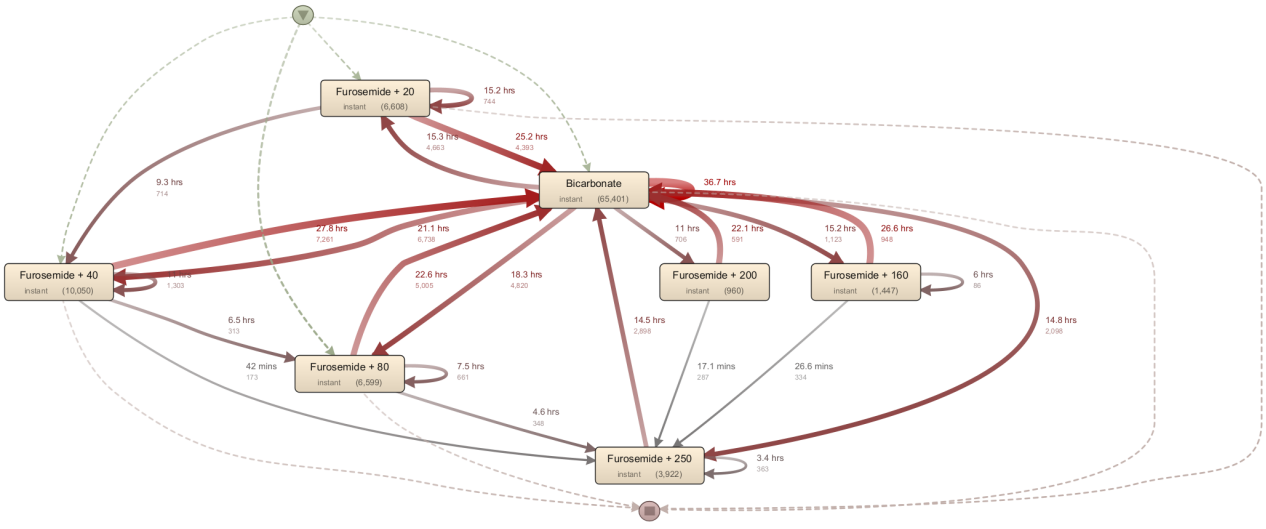

Fig. 4: Pharmacy and laboratory events, illustrating the interplay of heart failure laboratory values and medications given: Activity filter: Manually picked Bicarbonate and Furosemide (4% of all with 99% case coverage), Paths filter: 60%

Add additional event attributes As the transfer events include two timestamps indicating the beginning and end of treatment in the department, it is possible to add additional event attributes from any other table in MIMIC-IV. For demonstration, we added the average number of Furosemide, a heart failure medication, given to a patient. With that, it is possible to analyse the amount of medications given in different hospital depart

Table 1: Characteristics and Challenges

Level	Characteristics	Challenges
Admission	clear process, organizational view	-
Transfer	clear start and end, organizational view, activity duration available	understanding effect of deprtment visits on patient's development and treatment activities, event abstraction, performance analysis
POE	detailed treatment orders, lifecycle information available, repetitive events	identifying events of interest, visualizing and analyzing lifecycle behaviour, analyzing ordered and executed treatment activities
Low	high variety of events detailed events with many event attributes	finding the right events for the analysis goal, event post-processing to derive meaningful events, event attribute analysis

Table 1 provides a summary over the identified characteristics and challenges of each level. We see, that each level is different and presents different research challenges, which can be tackled in the future.

References

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3. McDonagh, T.A., et al.: 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. European Heart Journal **42**(36), 3599–3726 (08 2021)