

# Master Thesis: Discovering Clinical Pathways of an Adaptive Integrated Care Environment

Simon Bönisch, 18.01.2019, Kick-off Presentation

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## **Problem Statement**

- Connecare – Adaptive Integrated Care Environment
- Process Discovery Motivation
- Research Questions

## **Research Approach**

- Process Mining Challenges in Healthcare
- Process Mining Methodology for Healthcare
- Methodology Adaptions for Context of Connecare

## **Implementation**

- ELK Stack
- Deployment
- Process Mining Analysis

## **Timeline**

# Connecare – Adaptive Integrated Care Environment

- EU-Project: In **productive use in four hospitals** across the continent
- Management of chronic clinical cases
- Integrates with medical devices for home use
- **Monitoring** of patients' activities and status
- Patient aids and recommendations to **self-manage** their condition
- **Alerting** for patients and professionals (e.g. “Remember taking your prescribed medicine” or “Patient measurement exceeds threshold”)
- **Messaging** functionality for patient-professional and professional-professional communication
- **User roles** for access control enable interdisciplinary collaboration
- Enables chronic patients to reduce number of hospital visits by e.g. supporting measurement devices for home use and enabling remote monitoring and communication



CONNECARE





English

Welcome: Simon

**My  
Cases**

**New  
Case**

**Manage  
Users**

🔍

**Notifications**
Actions

- Monitoring Prescription (Blood Pressure)**

Groningen CS2 | Eloisa Hopkins (38)

The measured values are out of range. Please check th...

✕

13:24
- Patient Questionnaire (SF12)**

Groningen CS1 | Christine Hopkins (32)

The patient did not complete the questionnaire as sch...

✕

Su 24.04
- Patient Questionnaire (EQ5D)**

Groningen CS2 | Eloisa Hopkins (38)

The patient did not complete the questionnaire as sch...

✕

Sa 23.04
- Monitoring Prescription (Temperature)**

Groningen CS2 | Thomas Williams (84)

The measurement taken is out of range. The measure...

✕

Fr 22.04

**Messages**
Actions

- Jak Smith | Team**

Groningen CS2 | Eloisa Hopkins (38)

Could you please elaborate on the final ...

13:24
- Felix Hansen | Team**

Groningen CS1 | Christine Hopkins (32)

We found that this patient does not behave as ...

Su 24.04
- Eloisa Hopkins | Patient**

Groningen CS2 | Eloisa Hopkins (38)

Can you please explain me how to accomplish ...

✓

Sa 23.04
- Felix Michel | Team**

Groningen CS2 | Thomas Williams (84)

It seems to be that this patient has issues with ...

✓

Fr 22.04

**Tasks**
Actions

- Monitoring Prescription (Blood Pressure)**

Groningen CS2 | Eloisa Hopkins (38)

Due 2 days ago

👁
- Patient Questionnaire (SF12)**

Groningen CS1 | Christine Hopkins (32)

Due in 3 days

👁
- Patient Questionnaire (EQ5D)**

Groningen CS2 | Eloisa Hopkins (38)

Due in 15 days

👁
- Monitoring Prescription (Blood Pressure)**

Groningen CS2 | Thomas Williams (84)

Due in 3 weeks

👁
- Carlson**

Groningen CS2 | Eloise Hopkins (38)

Due in 3 weeks

👁

# Connecare – Medical Case Overview



English Welcome: Simon

Home > My Cases > James Michael

**Groningen CS2 - James Michael** Age: 20 Current Stage: Case Evaluation Case ID: ymjfocu5vyxc Case Actions

Summary **Process** Data Team Notifications 2 Messages 1 Notes

Case Identification Case Evaluation 1 Workplan Discharge

a month ago Stage Actions

Task	State	Due Date	Professional	Completed by	Role	Required
Set Evaluation Due Date	✓	N.A.	Simon Bönisch	Simon Bönisch	Professional	Yes
Charlson	▶	2-Feb-2019	Simon Bönisch	N.A.	Professional	Yes
Groningen Frailty Indicator (GFI)	✓	2-Feb-2019	Simon Bönisch	Simon Bönisch	Professional	Yes
Activities of Daily Living (ADL)	▶	2-Feb-2019	Simon Bönisch	N.A.	Professional	Yes
Instrumental Activities of Daily Living (IADL)	▶	2-Feb-2019	Simon Bönisch	N.A.	Professional	Yes
Nutritional Risk Screening (NRS)	✓	2-Feb-2019	Simon Bönisch	Simon Bönisch	Professional	Yes
Mini Nutritional Assessment (MNA-SF®)	▶	2-Feb-2019	Simon Bönisch	N.A.	Professional	Yes
Hospital Anxiety and Depression Scale (HADS)	▶	Set Date	Simon Bönisch	N.A.	Professional	Yes

Build 2018-12-18



English Welcome: Simon

Home > My Cases > James Michael > Case Evaluation > Nutritional Risk Screening (NRS)

**Groningen CS2 - James Michael** Age: 20 Current Stage: Case Evaluation Case ID: ymjfocu5vyxc Case Actions

Summary **Process** Data Team Notifications 2 Messages 1 Notes

### Nutritional Risk Screening (NRS)

Clinician: **Simon Bönisch**  
 Role: **Professional**  
 Due Date: **2-Feb-2019**  
 State: **✓ Completed**

Professional

**Is BMI <20,5? \***  
Yes

**Has the patient lost Weight within the last 3 months? \***  
No

**Is the patient severely ill? \***  
Yes

**Severity of disease \***  
Major Abdominal Surgery \* Stroke

**Age \***  
< 70 years

**NRS Score 3**

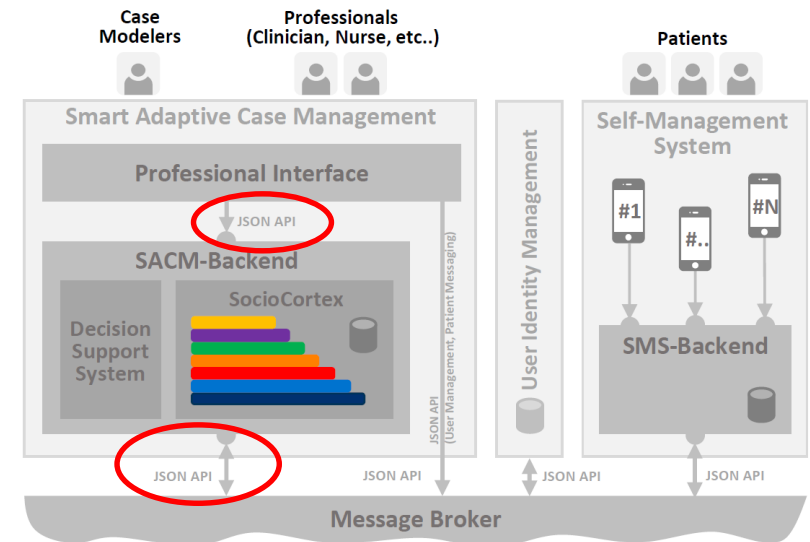
**CORRECT**

Reference: Kondrup, J., Rasmussen, H. H., Hamberg, O. L. E., and STANGA, Z. (2003). Nutritional risk screening (NRS 2002): a new method based on an analysis of controlled clinical trials. Clinical nutrition, 22(3), 321-336.

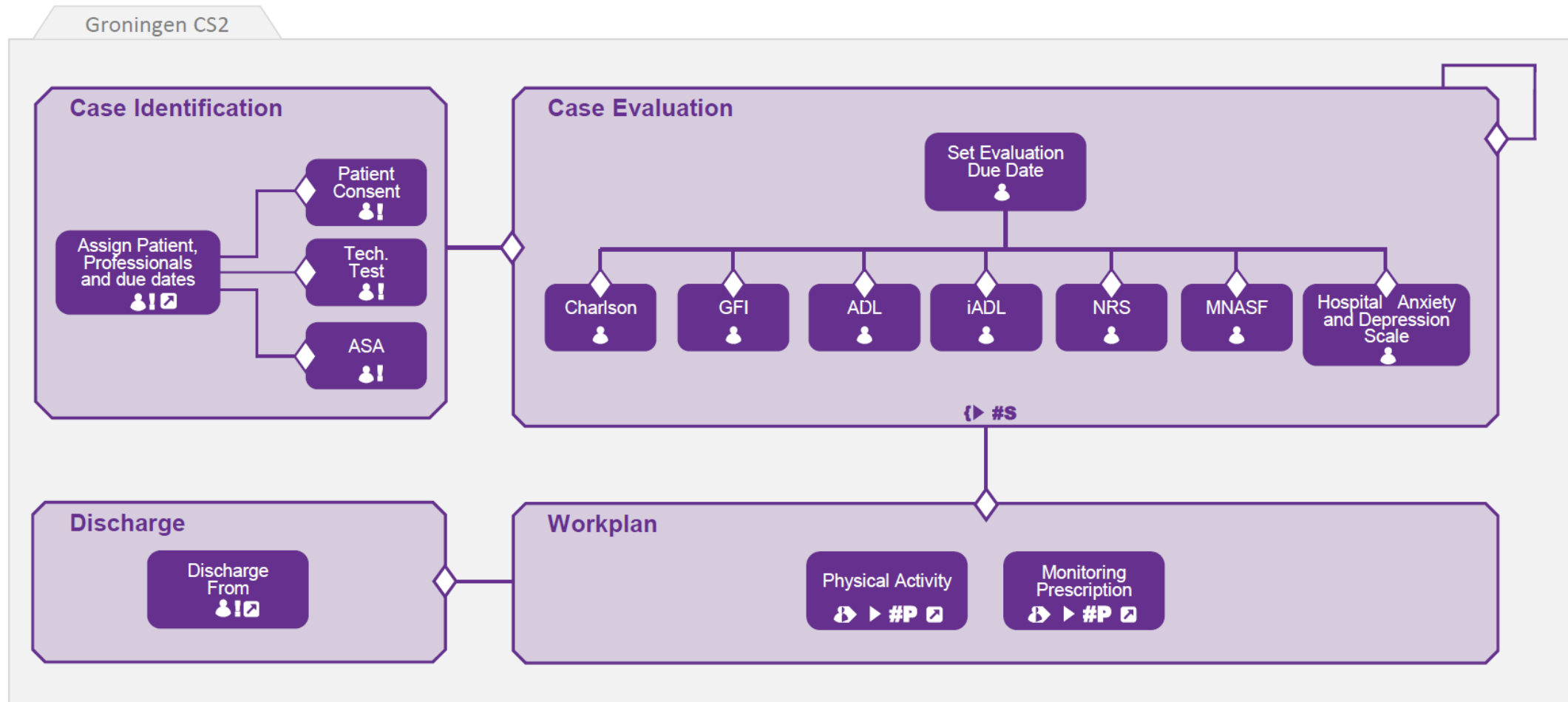
Build 2018-12-18

# Connecare – Why discover clinical pathways?

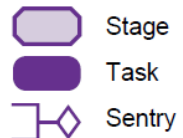
- Clinical Pathway
  - Abstract **model of the treatment of a patient** with a certain condition
  - Used to **manage quality of healthcare**
  - Developed by a medical professional in an objective way
  - Adapted to individual case when put into practice
- Backend of Connecare is called **SACM** and developed at sebis chair
  - Requires high degree of adaptability (high diversity of hospital sites & treatments)
  - Therefore **entirely model-driven** (like a process engine)
  - case model quality is crucial for overall system quality
  - Communication via **RESTful API** featuring request logging
- Case **model verification hard**, due to knowledge-intensive processes
- Verification through **real world execution** necessary
- Discovery of process models from execution logs to enable **comparison of modeled pathway with actual one**



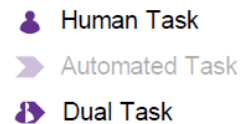
# Connecare – Groningen CMMN Case Model



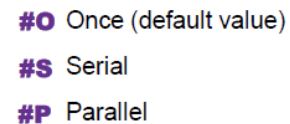
## Process Elements



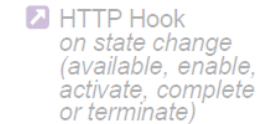
## Task Types



## Repeatable



## Options



RQ1

How is the model-provided flexibility used during the execution?

RQ2

How are User Roles, Alerting and Messaging features used during the execution?

RQ3

What are potential model improvements that can be derived from the execution?



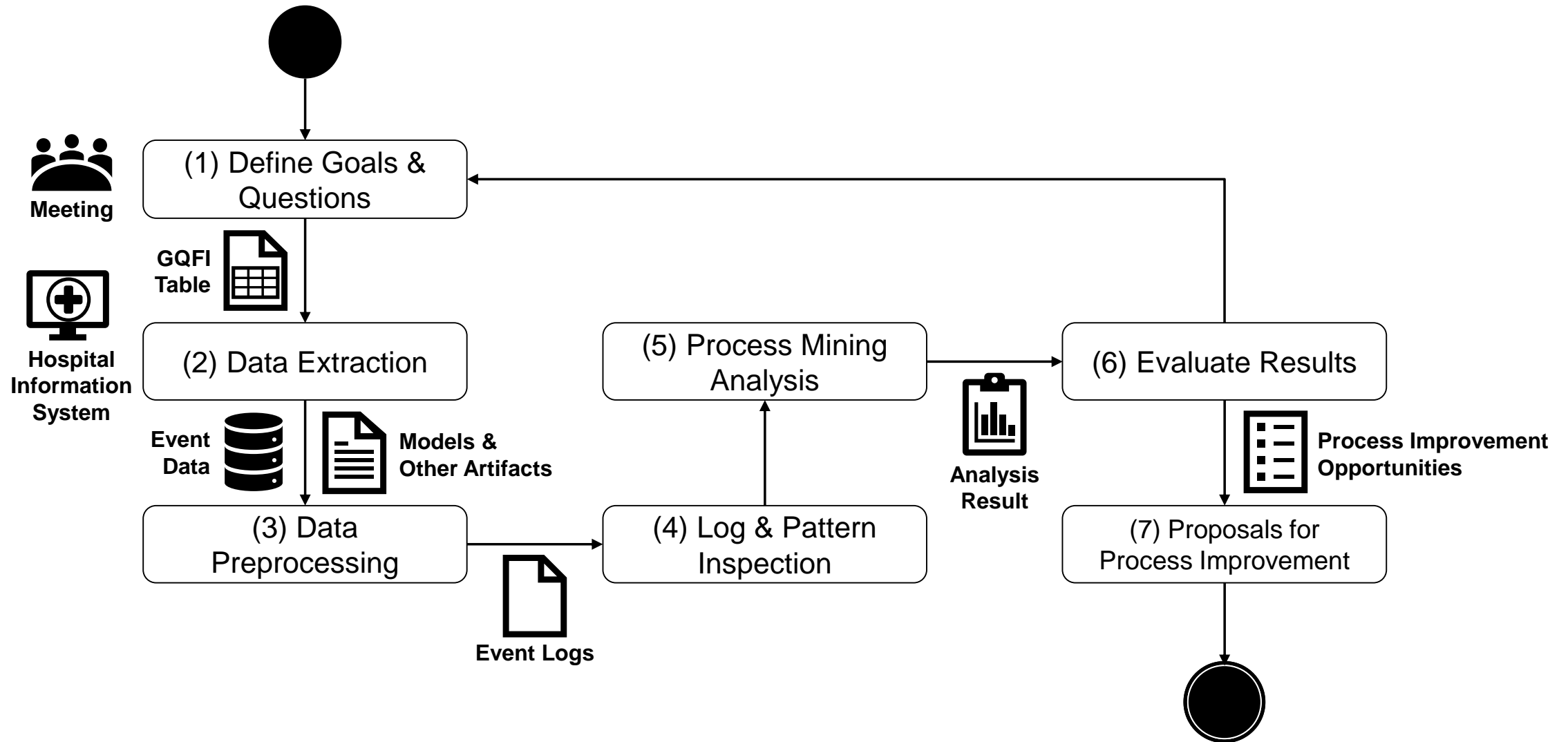
# Research Approach

# Approach: Process Mining in General

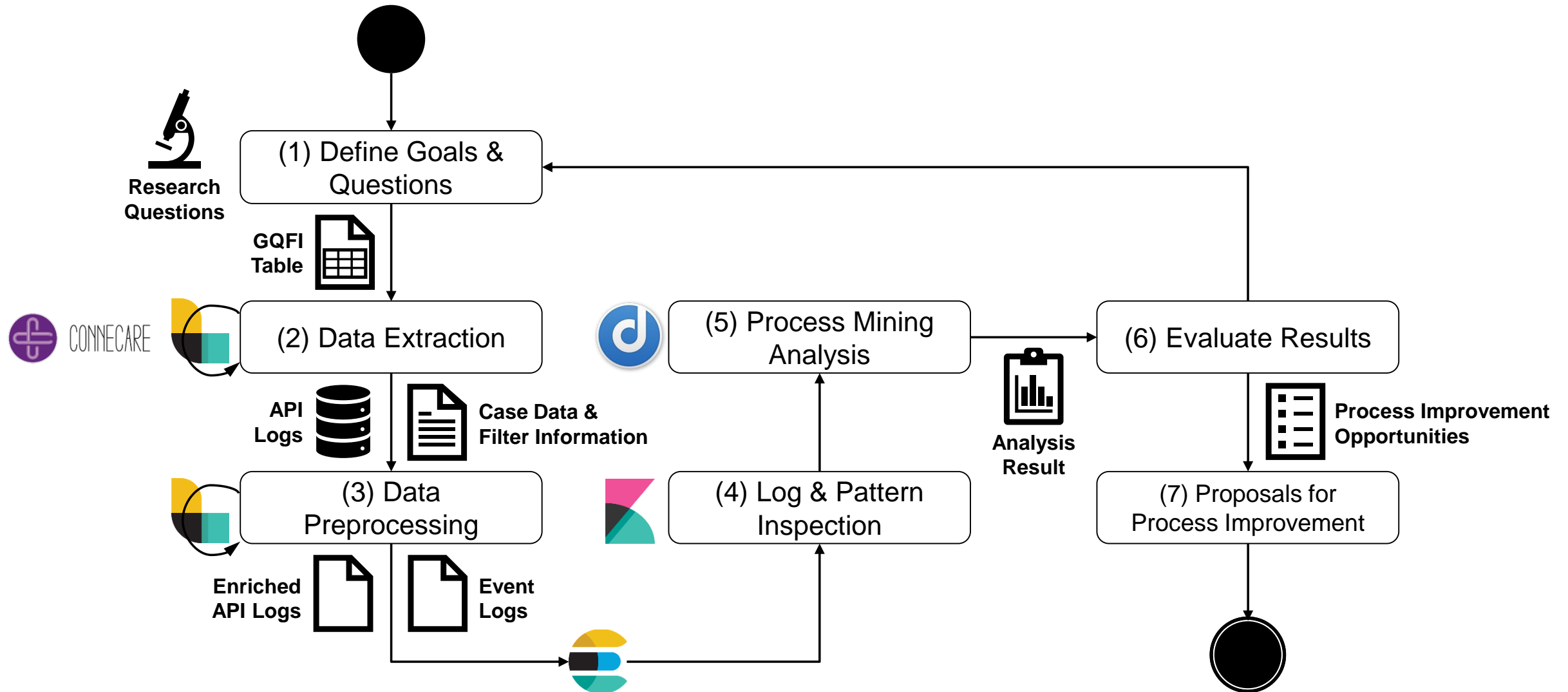
- **Extract knowledge from event logs** to discover, monitor and improve processes
- Many **Process Mining Tools** available (e.g. ARIS, ProM, Disco, Celonis, pMineR, ...)
- Bridge between Data Mining and Business Process Modeling
- Many established methodologies for Data Mining (e.g. CRISP-DM)
- Differences during analysis phase between Data and Process Mining
- Processes in healthcare are **knowledge-intensive**
  - Special Process Mining challenges:
    - Complex processes
    - Highly dynamic executions
    - Multi-disciplinary processes
    - Ad-hoc processes

# Approach: Process Mining in Healthcare

- Separate methodology necessary
- **Systematic Literature Review** conducted in 2018 by T.G. Erdogan and A. Tarhan
  - 172 studies on PM of healthcare processes
  - Publishing frequency increases
  - **Four generic** PM methodologies
  - **Eight healthcare specific** suggestions for PM methodologies (with varying set of PM features)
  - No established, comprehensive methodology for healthcare mining
- Follow-up Paper combines all identified PM features into one single methodology
  - **„Process Mining Methodology for Healthcare“**
- Slightly adapted to fit Connecare use case  
(due to e.g. data that can only be extracted live)

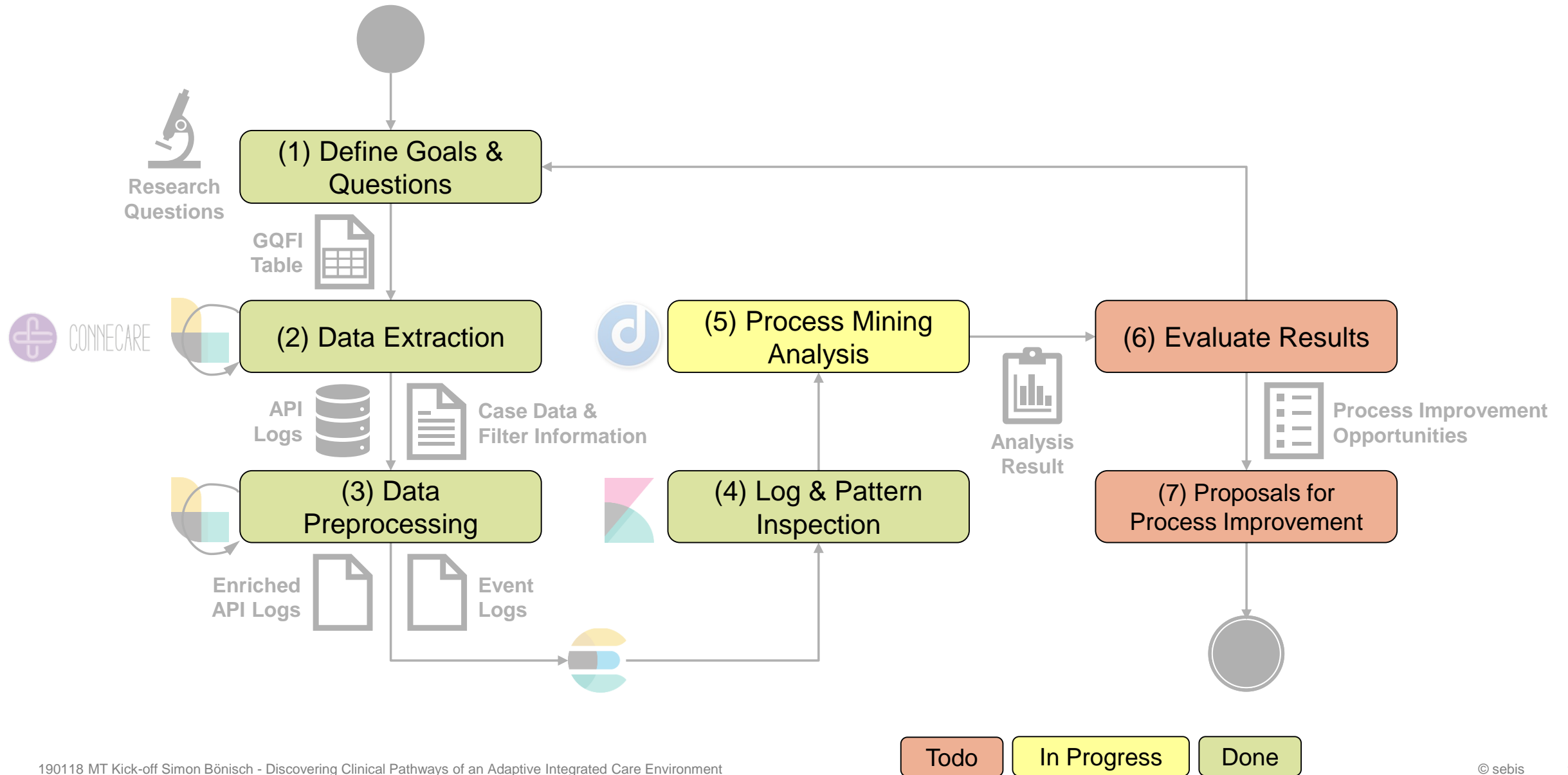


# Process Mining Methodology in Context of Connecare



# State of Implementation

# Current Progress







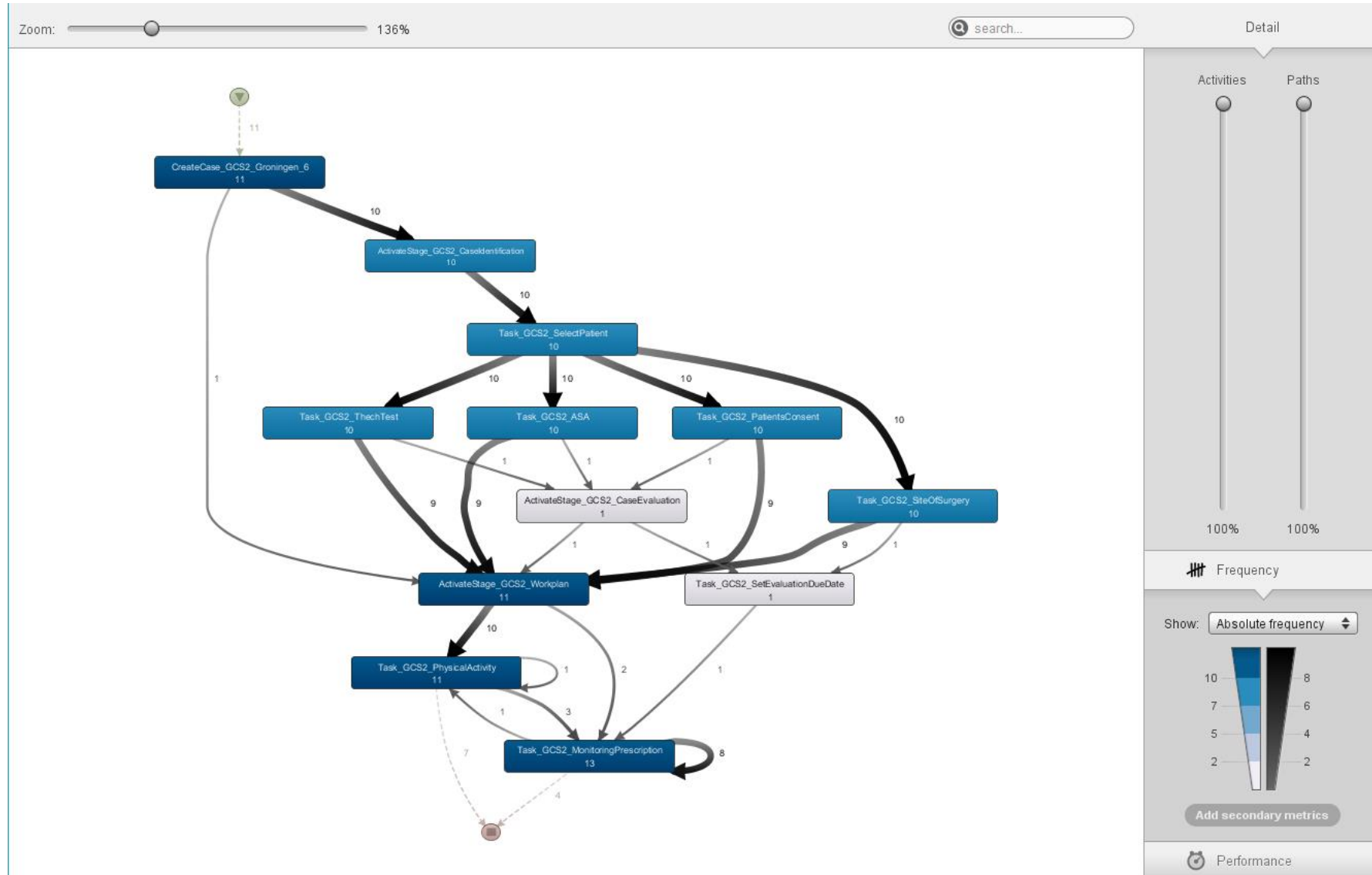
- Connecare deployed in four hospitals and **used with real patients**
  - **Data protection rules** prevent copying data to local system
  - Deployment necessary to access and analyze the real data
- **Single docker container** containing whole ELK stack
  - Simpler to setup, configure and deploy
  - Minimized resource usage (quite heavy infrastructure constraints)
- Authentication through **nginx reverse proxy** with HTTP Basic Auth
- **Early deployments** done to the test and productive environments
- Applications publicly accessible, but login-protected
- Container supports HTTP only, but external reverse proxy enforces HTTPS and translates to HTTP

# Process Mining Analysis

- **High tool flexibility** thanks to customizable data export
- Using **Disco** by Fluxicon
  - Marketed commercially but free for academic use
  - Based on **FuzzyMiner**
  - Generates clear process maps for **knowledge-intensive processes**
  - **Reduces complexity** using techniques known from cartography (Aggregation, Abstraction, Emphasis, Customization) based on calculated significance and correlation metrics
  - Provides **additional metrics** and means for Log Inspection
- Analysis is done **manually**
- Data imported through simple .csv files
- Data **clustered** into files by **case model version**

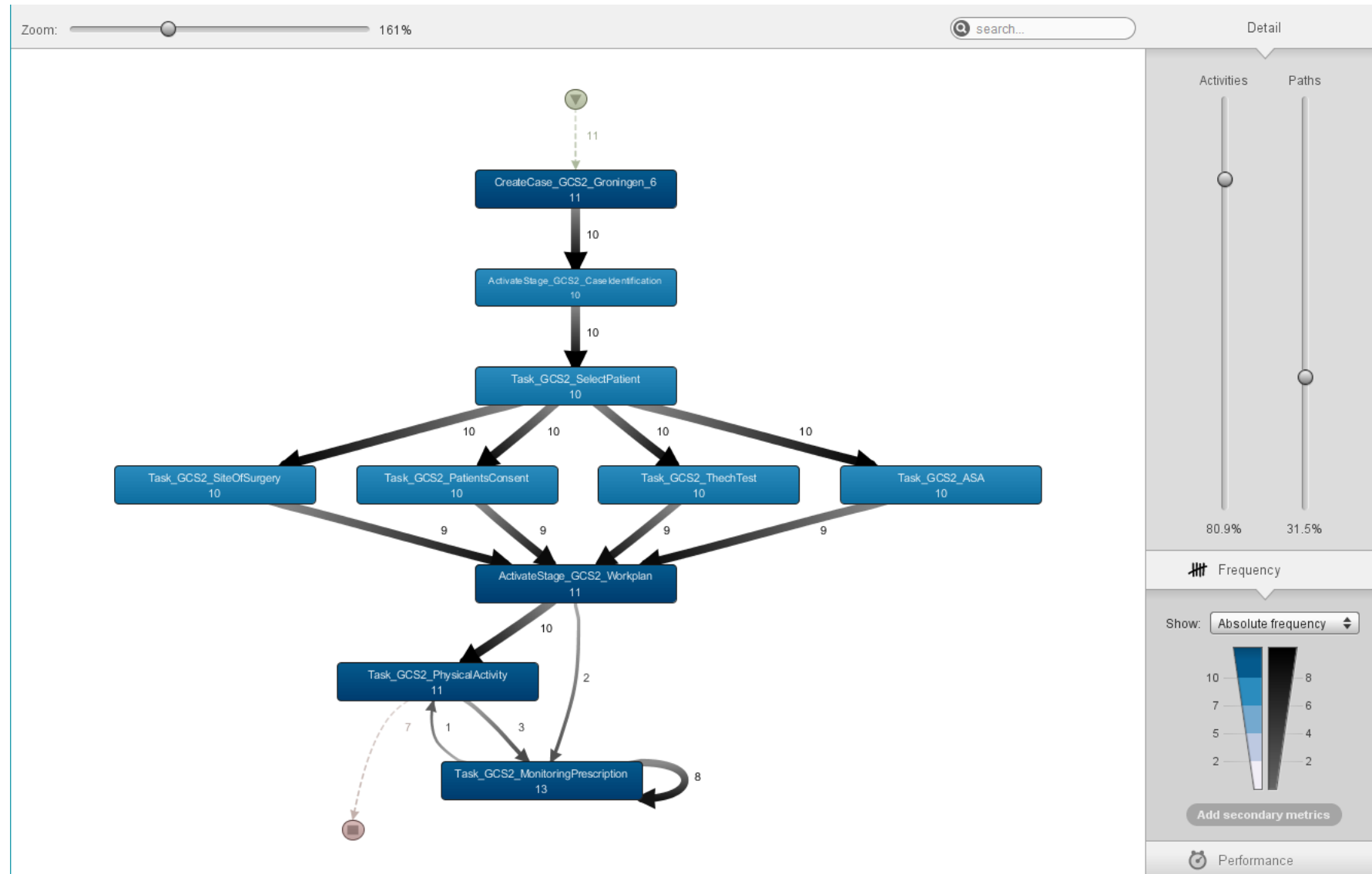
# Process Model: Groningen Case Study 2

## Raw Data View



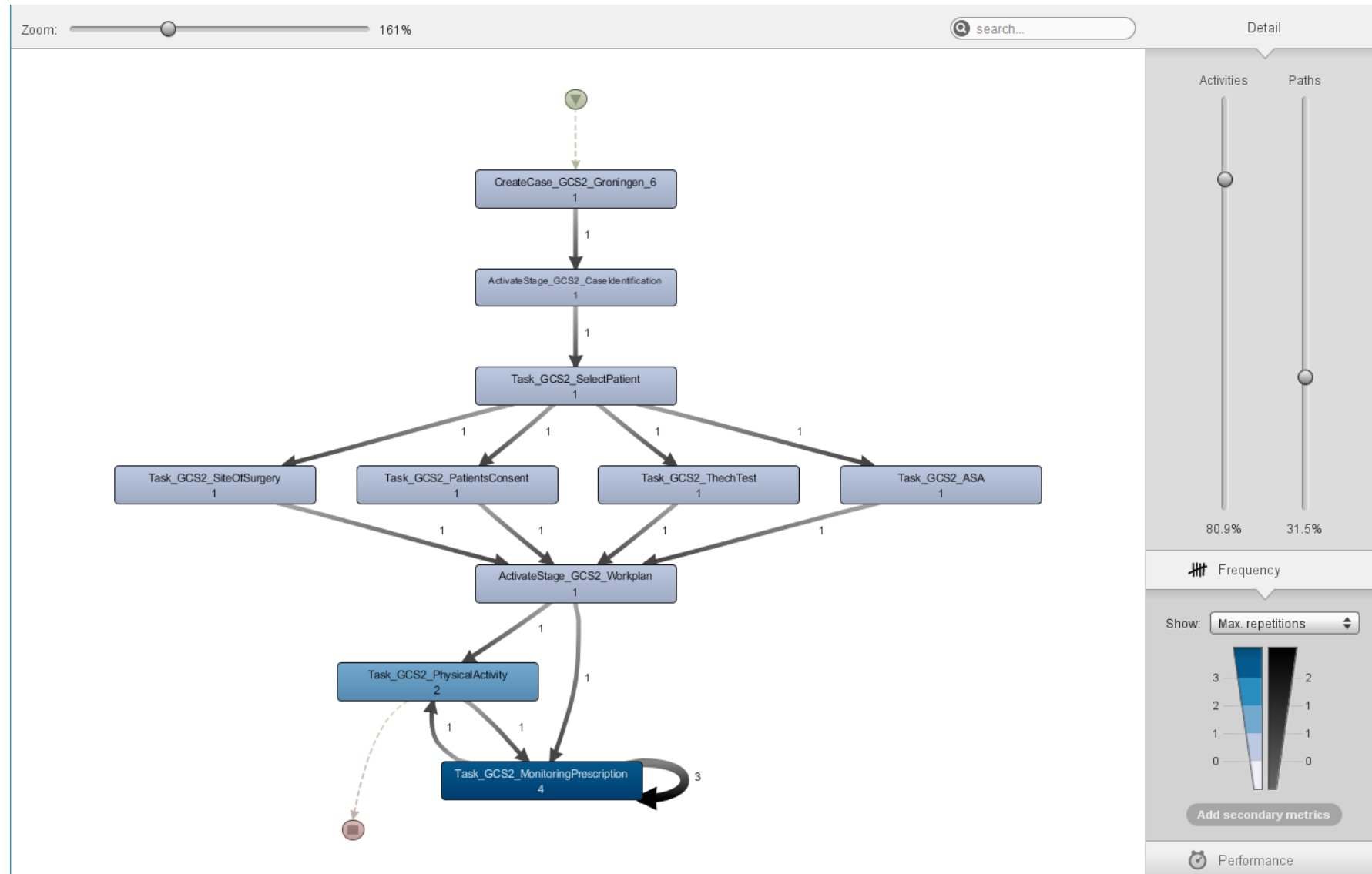
# Process Model: Groningen Case Study 2

## Abstracted View



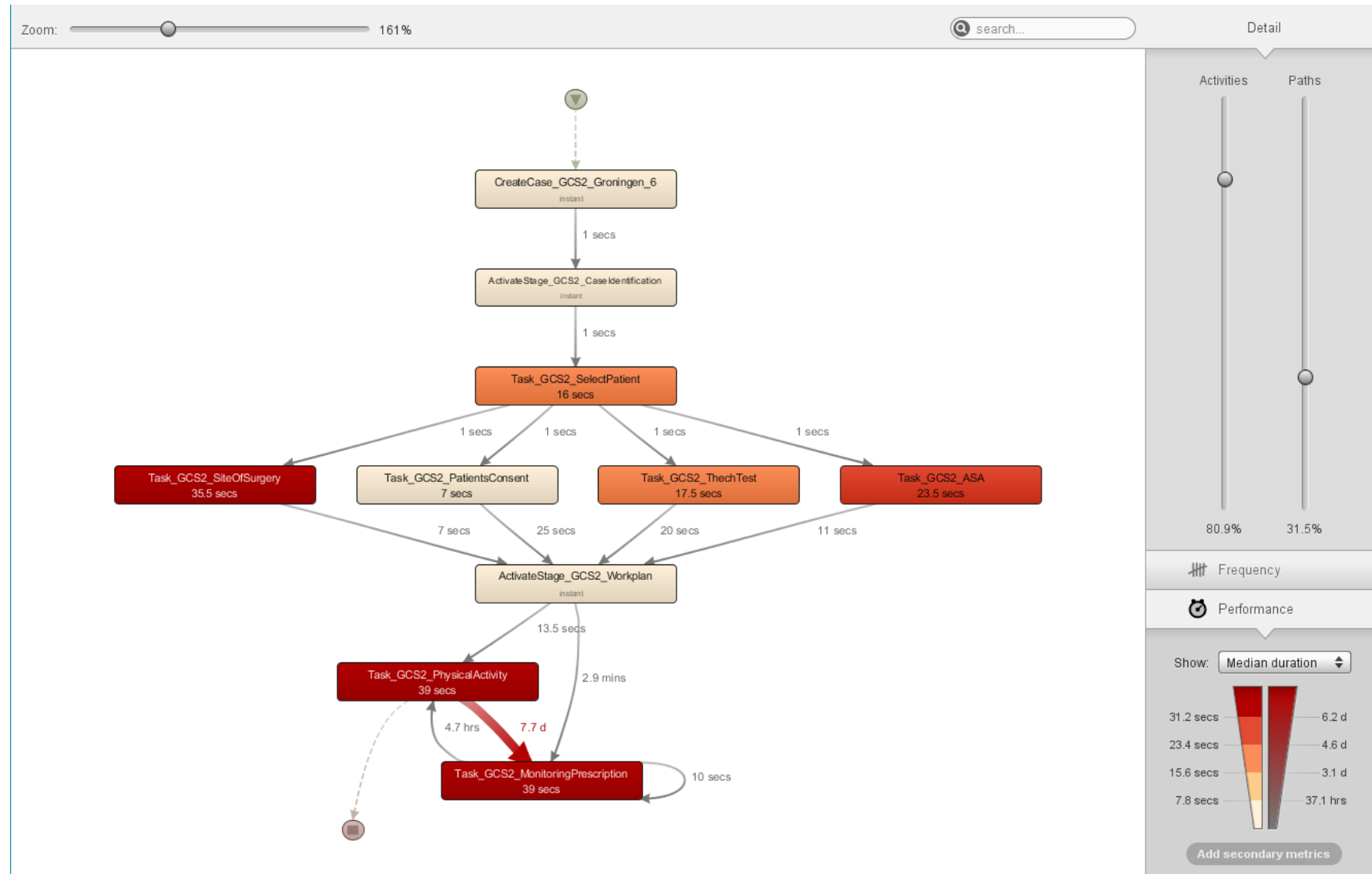
# Process Model: Groningen Case Study 2

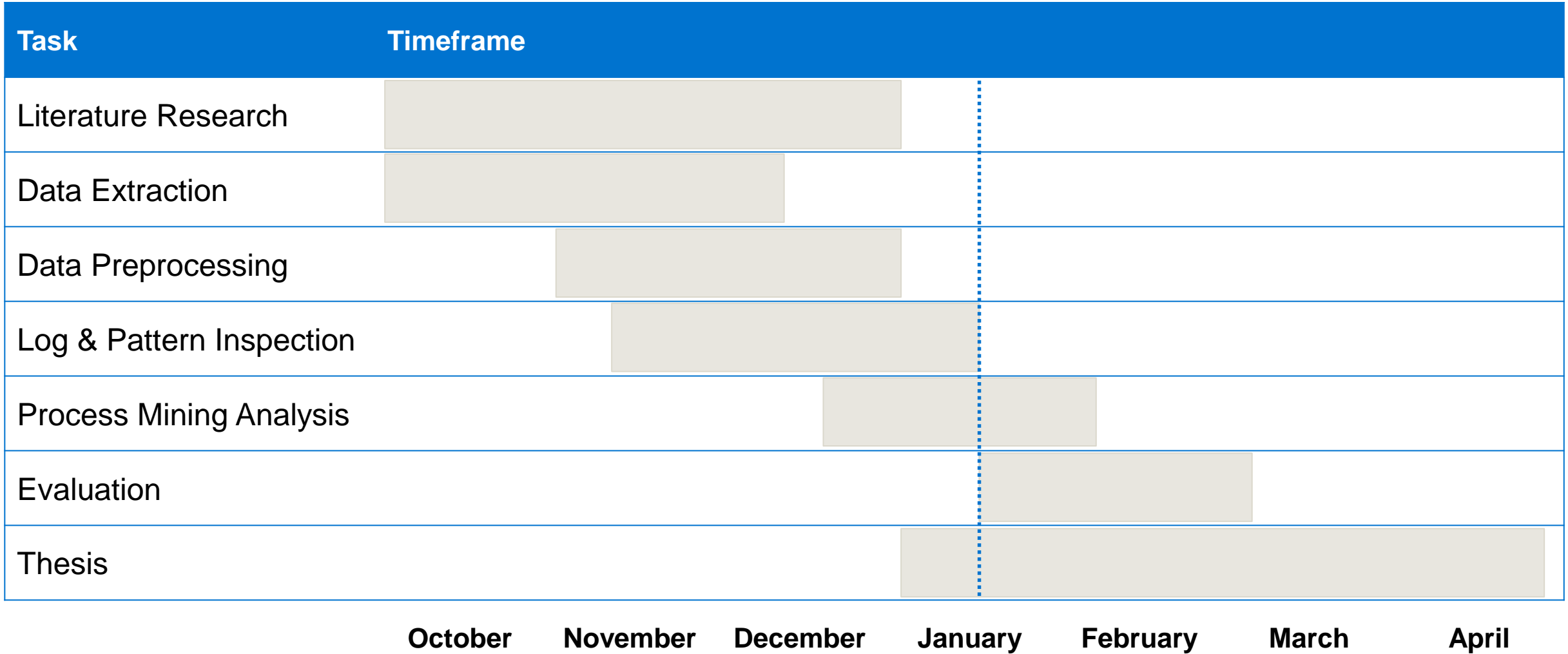
## Maximum Repetitions View



# Process Model: Groningen Case Study 2

## Performance View – Median Duration







B.Sc.

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Backup

# PM Methodology Features Comparison

PM Features and Methodologies	PDM [35]	L* Lifecycle Model [8]	PM2 Project [34]	Process Comparison Methodology [36]	Question Driven Methodology [41]	Declarative PM [19]	The Proposed Method
Defining Goals		✓	✓				✓
Defining Questions		✓	✓		✓		✓
Defining Indicators							✓
Selecting PM Features							✓
Designing de jure model		✓				✓	✓
Data Extraction	✓	✓	✓		✓		✓
Data Preprocessing	✓		✓	✓	✓		✓
Data Modeling							✓
Data Abstraction			✓				✓
Data Filtering			✓		✓		✓
Data Visualization			✓		✓		✓
Clustering				✓			✓
Log and Pattern Inspection	✓		✓		✓		✓
Process Discovery	✓	✓	✓	✓	✓	✓	✓
Process Exploration		✓				✓	✓
Process Variant Analysis				✓	✓		✓
Conformance Checking	✓	✓	✓		✓	✓	✓
Process Enhancement		✓	✓			✓	✓
Decision Point Analysis							✓
Organizational Analysis	✓				✓		✓
Performance Analysis			✓		✓		✓
Performance Target Analysis							✓
Process Comparison				✓			✓
Process Improvement		✓	✓				✓
Operational Support		✓	✓				✓

Nurse

Options

Refresh

- Discover
- Visualize
- Dashboard
- Timelion
- Canvas
- Machine Learning
- Infrastructure
- Logs
- APM
- Dev Tools
- Monitoring
- Management

NOT simulated requests

real users

external IPs

application: "SACM.FRONTEND"

Add a filter +

Actions

sacmlogs\*

Selected fields

? \_source

Available fields

Popular

t case.id

t caseld

@timestamp

t @version

t \_id

t \_index

# \_score

t \_type

t acceptLanguage

t application

case.activeDate

case.availableDate

? case.completedDate

t case.definitionId

t case.description

case.enabledDate

t case.name

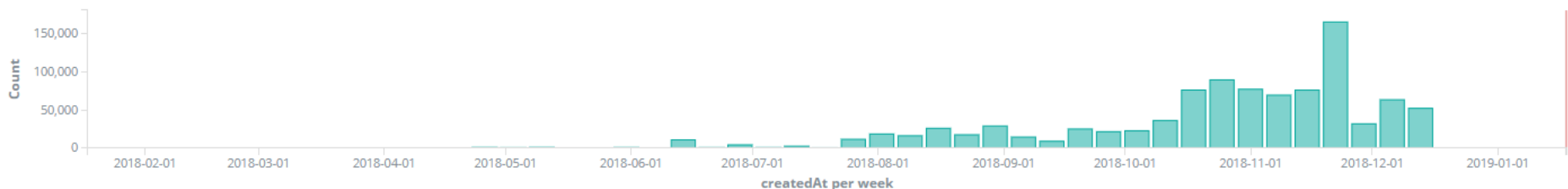
t case.patientId

case.terminatedDate

t case.uniqueName

# case.version

January 17th 2018, 22:43:02.748 - January 17th 2019, 22:43:02.748 — Auto



Time	_source
December 12th 2018, 09:52:50.165	<pre>application: SACM.FRONTEND groups: Anesthesiologist, Nurse, Clinician, Primary Care Nurse, Case Manager, Primary Care Clinician, Physiotherapist resource: cases workspaceId: 2c9480885d1737ef015d74deec7f0002 isGzip: true reqBodySize: - createdAt: December 12th 2018, 09:52:50.165 groupIds: r1teiy147w47, 1hwzu9h0g4vf0, 145k1hlvmfk8x, 1lu3lciit8mvg1, 14sm13utt2yga, e8uzsdsvozn4, 1v3qywhfgfcwk, 1dpqqc5m3s8qc, ke6eyq0wef2e, 1b72d7wp8qvk, 1q3fhjrzrzoqz, rq9jj0djp4xa, y1sczn9t47vb, 1x4am3t5e1nwd, 1t9ggz0xrgc3w, cjes3umclz8m, 1y0lfpfavgkjr, 1x15xlz9plar1, eomkd9m19tdu, cx932rrrvskhg, w0xx17qolpjj, c137c886923911e7bd0c0242ac120002, 1oqnrrovwtcccxk, 1b6u41h5y4lj2, hf2q0o8m309f, qleex3ox5ymt, f143cn8a3oa9, 1ug4n9zt1bjrh, 1v8min4c1susx, c137c880923911e7bd0c0242ac120002, bhjp296897xe, 17ap0uaton5z6, nchdkj686jtk, 1l1cq8ii36pos6, 1xsi40d5kwa</pre>
December 12th 2018, 09:52:49.800	<pre>application: SACM.FRONTEND groups: Anesthesiologist, Nurse, Clinician, Primary Care Nurse, Case Manager, Primary Care Clinician, Physiotherapist resource: cases workspaceId: 2c9480885d1737ef015d74deec7f0002 isGzip: true reqBodySize: - createdAt: December 12th 2018, 09:52:49.800 groupIds: r1teiy147w47, 1hwzu9h0g4vf0, 145k1hlvmfk8x, 1lu3lciit8mvg1, 14sm13utt2yga, e8uzsdsvozn4, 1v3qywhfgfcwk, 1dpqqc5m3s8qc, ke6eyq0wef2e, 1b72d7wp8qvk, 1q3fhjrzrzoqz, rq9jj0djp4xa, y1sczn9t47vb, 1x4am3t5e1nwd, 1t9ggz0xrgc3w, cjes3umclz8m, 1y0lfpfavgkjr, 1x15xlz9plar1, eomkd9m19tdu, cx932rrrvskhg, w0xx17qolpjj, c137c886923911e7bd0c0242ac120002, 1oqnrrovwtcccxk, 1b6u41h5y4lj2, hf2q0o8m309f, qleex3ox5ymt, f143cn8a3oa9, 1ug4n9zt1bjrh, 1v8min4c1susx, c137c880923911e7bd0c0242ac120002, bhjp296897xe, 17ap0uaton5z6, nchdkj686jtk, 1l1cq8ii36pos6, 1xsi40d5kwa</pre>
December 12th 2018, 09:52:49.432	<pre>application: SACM.FRONTEND groups: Anesthesiologist, Nurse, Clinician, Primary Care Nurse, Case Manager, Primary Care Clinician, Physiotherapist resource: cases workspaceId: 2c9480885d1737ef015d74deec7f0002 isGzip: true reqBodySize: - createdAt: December 12th 2018, 09:52:49.432 groupIds: r1teiy147w47, 1hwzu9h0g4vf0, 145k1hlvmfk8x, 1lu3lciit8mvg1, 14sm13utt2yga, e8uzsdsvozn4, 1v3qywhfgfcwk, 1dpqqc5m3s8qc, ke6eyq0wef2e, 1b72d7wp8qvk, 1q3fhjrzrzoqz, rq9jj0djp4xa, y1sczn9t47vb, 1x4am3t5e1nwd, 1t9ggz0xrgc3w, cjes3umclz8m, 1y0lfpfavgkjr, 1x15xlz9plar1, eomkd9m19tdu, cx932rrrvskhg, w0xx17qolpjj, c137c886923911e7bd0c0242ac120002, 1oqnrrovwtcccxk, 1b6u41h5y4lj2, hf2q0o8m309f, qleex3ox5ymt, f143cn8a3oa9, 1ug4n9zt1bjrh, 1v8min4c1susx, c137c880923911e7bd0c0242ac120002, bhjp296897xe, 17ap0uaton5z6, nchdkj686jtk, 1l1cq8ii36pos6, 1xsi40d5kwa</pre>
December 12th 2018, 09:52:49.037	<pre>application: SACM.FRONTEND groups: Anesthesiologist, Nurse, Clinician, Primary Care Nurse, Case Manager, Primary Care Clinician, Physiotherapist resource: cases workspaceId: 2c9480885d1737ef015d74deec7f0002 isGzip: true reqBodySize: - createdAt: December 12th 2018, 09:52:49.037 groupIds: r1teiy147w47, 1hwzu9h0g4vf0, 145k1hlvmfk8x, 1lu3lciit8mvg1, 14sm13utt2yga, e8uzsdsvozn4, 1v3qywhfgfcwk, 1dpqqc5m3s8qc, ke6eyq0wef2e, 1b72d7wp8qvk, 1q3fhjrzrzoqz, rq9jj0djp4xa, y1sczn9t47vb, 1x4am3t5e1nwd, 1t9ggz0xrgc3w, cjes3umclz8m, 1y0lfpfavgkjr, 1x15xlz9plar1, eomkd9m19tdu, cx932rrrvskhg, w0xx17qolpjj, c137c886923911e7bd0c0242ac120002, 1oqnrrovwtcccxk, 1b6u41h5y4lj2, hf2q0o8m309f, qleex3ox5ymt, f143cn8a3oa9, 1ug4n9zt1bjrh, 1v8min4c1susx, c137c880923911e7bd0c0242ac120002, bhjp296897xe, 17ap0uaton5z6, nchdkj686jtk, 1l1cq8ii36pos6, 1xsi40d5kwa</pre>
December 12th 2018, 09:52:48.644	<pre>application: SACM.FRONTEND groups: Anesthesiologist, Nurse, Clinician, Primary Care Nurse, Case Manager, Primary Care Clinician, Physiotherapist resource: cases</pre>

&gt; Nurse

Options

Refresh

NOT simulated requests

real users

external IPs

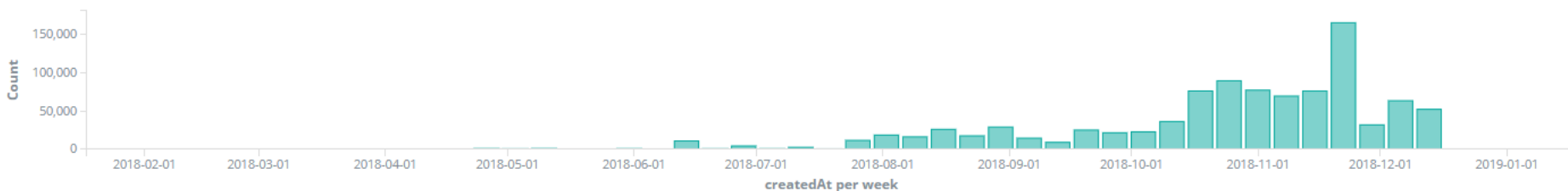
application: "SACM.FRONTEND"

Add a filter +

Actions

sacmlogs\*

January 17th 2018, 22:43:02.748 - January 17th 2019, 22:43:02.748 — Auto



Time  \_source

December 12th 2018, 09:52:50.165 application: SACM.FRONTEND groups: Anesthesiologist, Nurse, Clinician, Primary Care Nurse, Case Manager, Primary Care Clinician, Physiotherapist resource: cases workspaceId: 2c9480885d1737ef015d74deec7f0002 isGzip: true reqBodySize: - createdAt: December 12th 2018, 09:52:50.165 groupIds: r1teiy147w47, 1hwzu9h0g4vf0, 145k1h1vmfk8x, 11u3icit8mvg1, 14sm13utt2yga, e8uzsdsvozn4, 1v3qywhfgfcwk, 1dpqc5m3s8qc, ke6eyq0wef2e, 1b72d7wp8qvk, 1q3fhjrzrqozh, rq9jj0djp4xa, y1sczn9t47vb, 1x4am3t5e1nwd, 1t9ggz0xrgc3w, cjes3umc1z8m, 1y01fqpfavkjr, 1x15x1z9plar1, eomkd9m19tdu, cx932rrrvskhg, w0xx17qolpjj, c137c886923911e7bd0c0242ac120002, loqnrovwtcccxk, 1b6u41h5y41j2, hf2q0o8m309f, qlleex3ox5ymt, f143cn8a3oa9, 1ug4n9zt1bjrh, 1v8min4c1susx, c137c880923911e7bd0c0242ac120002, bhjp296897xe, 17ap0uaton5z6, nchdkj686jtk, 11cq8ii36pos6, 1xsi40d5kwa

Table  JSON  [View surrounding documents](#) [View single document](#)

@timestamp	January 16th 2019, 18:11:53.245
@version	1
_id	A0i1V2gBZbvIVrAR2n6d
_index	sacmlogs-2019.01.16
_score	-
_type	sacm-api-access-log
acceptLanguage	es-ES,es;q=0.9
application	SACM.FRONTEND
caseId	1npwhq337ohzy
createdAt	December 12th 2018, 09:52:50.165
duration	282
email	-
event	CASE_GET
geoip.continent_code	EU

- Discover
- Visualize
- Dashboard
- Timelion
- Canvas
- Machine Learning
- Infrastructure
- Logs
- APM
- Dev Tools
- Monitoring
- Management
- Default
- Collapse

- Selected fields
- ? \_source
- Available fields
- Popular
- t case.id
  - t caseId
- Other fields:
- @timestamp
  - @version
  - \_id
  - \_index
  - \_score
  - \_type
  - acceptLanguage
  - application
  - case.activeDate
  - case.availableDate
  - case.completedDate
  - case.definitionId
  - case.description
  - case.enabledDate
  - case.name
  - case.patientId
  - case.terminatedDate
  - case.uniqueName
  - case.version

&gt; Search... (e.g. status:200 AND extension:PHP)

Options

Refresh

Add a filter +

sacmlogs\*

Data Options

## Metrics

Metric Unique count of case.id.keyword

Add metrics

## Buckets

Split Rows

Terms help

Aggregation

Terms

Field

case.uniqueName.keyword

Order By

metric: Number of Instances

Order

Descendir

Size

35

 Group other values in separate bucket ?

 Show missing values ?

Custom Label

Case Model

Advanced

Add sub-buckets

## Case Model

## Number of Instances

ICS1_Assuta_6	23
ICS2_Assuta_1	20
GCS2_Groningen_6	14
ICS1_Assuta_5	12
LCS1_Leida_3	10
ICS2_Assuta_5	9
LCS2_Leida_5	7
LCS2_Leida_6	6
GCS2_Groningen_4	6
BCS2_Barcelona_1	5
LCS2_Leida_4	4
ICS2_Assuta_4	4
ICS2_Assuta_3	4
LCS1_Leida_5	2
ICS1_Assuta_1	2
GCS2_Groningen_3	2
GCS2_Groningen_1	2
LCS1_Leida_4	1
LCS1_Leida_2	1
ICS2_Assuta_2	1
ICS1_Assuta_2	1
GCS2_Groningen_2	1
GCS1_Groningen_1	1

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caselid: "hosejrmyteb4" Add a filter +

