Combining business process & data discovery techniques for analyzing and improving integrated care pathways

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Integrated care pathway (ICP): Definition

- Structured multidisciplinary care plan
- Details essential steps in the care process
- To achieve well defined goals
- For a patient with a specific clinical problem
- Description of the expected progress over a certain time period
Healthcare 1.0: Pitfalls

Traditional Business Process Model:

• Do not capture process variations, process exceptions or root causes of the exceptions and variations
• Only delta analyses to find impact on key performance indicators
• Models the most standard frequent pathway
• High workload for care process manager
• Retrospective analysis (every 6 months)
• Evaluation over the first semester of each year only
Innovation: Process Discovery

Bottom up approach:

• To discover process inefficiencies, exceptions and variations immediately
• To gain sufficient understanding of the existing process and its outliers
• Evaluation of the care process of all the patients
• To search for the root causes of inefficiencies or improvements
What is Process Discovery about?

C

- Hidden Markov Models
- Complemented with FCA-based grouping of events

ANALYSIS
Of
HMM Artefacts

- Clustering
- Normalisation
- Robustness

Build
HMM Artefacts

K

- Actor-Event-Object data logs
- Informal Process Descriptions
- Implicit Knowledge
- Training materials
- Definition & Rules

Reviews to Improve Existing Knowledge

- Hotspots for Process Improvement
- Root causes for Process Deficiencies
- Process Variations

Manual Inspection of Clusters
- Validation of Process Anomalies & Discovered Rules

Knowledge Iterations
C/K-Theory: Innovative Discovery

Disjunction: Conceptualisation, Tagging & Mining

Discovery & Exploration

The C/K Design Square

Validation & Learning

Conjunction: Activate & Experiment
What is Data Discovery about?

Build FCA & ESOM Artefacts

- FCA Lattices (= normalized concept map)
- ESOM Maps

ANALYSIS Of FCA/ESOM Artefacts

• Anomalies
• Concept Gaps
• Outliers/Exceptions

Knowledge Iterations

- Manual Inspection of Anomalies & Outliers
- Validation of Concept Gaps & Discovered Rules

Reviews to Improve Existing Knowledge

• Unstructured Data Sources (e.g. Reports)
• Metadata/Tags
• Implicit Knowledge
• Training materials
• Definition & Rules

Confusing terms
• Faulty Classified Cases
• New Terms & Attributes
• Missing Values
Combination of process & data discovery (1)

• to gain deeper understanding of existing breast cancer care process & actual activities performed on work floor

• discover process inefficiencies, exceptions and variations immediately

• search for root causes of inefficiencies
Combination of process & data discovery (2)

• Hidden Markov Models to discover process models from event sequences.

• Formal Concept Analysis:
  • analyze characteristics of clusters of patients that emerged from process discovery.
  • find groups of patients to feed into the process discovery methods.
Previous process mining research in healthcare

• mostly Petri-Net models

• Example: process models were built from simulated process logs of hospital-wide workflows containing events like "blood test" or "surgery"

• Hidden Markov Model approach: model workflow inside Operation Room
Hidden Markov Model

- Probabilistic model with greater degree of flexibility
- Better option for healthcare where traditional process mining does not work well,
- Many (open source) algorithms have been published for analyzing and understanding HMMs
- Micro patterns of actor behavior can be easily aggregated in one state
- HMMs can be annotated with a variety of attributes such as probabilities, time duration, variances, etc.
Dataset


- 469 activity identifiers in total

- care trajectory Primary Operable Breast Cancer

- breast cancer care process: 4 phases, 34 doctors, 52 nurses and 14 paramedics
Breast cancer care process (1)

- every activity performed to a patient is logged in a database
- dataset includes all activities performed during surgery support phase
- data was turned for each patient into a sequence of events
- activities with a similar semantic meaning were clustered to reduce complexity of lattices and process models
Breast cancer care process (2)
Quality of care analysis

• initial process model: 148 patients and 469 activity codes

• length of stay in hospital < 10 days: linear process

• length of stay > 9 days: 12 patients for which process was very complex
FCA analysis of 12 patients (1)

- pain score reaches highest point on day 1 and 4 of hospitalization.

- FCA lattice: overlooked connection between removal of wound drains and insufficient pain medication.

- pain medication should be administered before removing the drains
FCA analysis of 12 patients (2)
FCA analysis of 12 patients (3)

• main reason of increased length of stay: neurological / psychiatric problems, wound infection, subsequent bleeding.

• cancer care process more complex resulting in more investigative tests.

• since additional morbidities are a root cause for this increased length of stay: treatment should be anticipated on & optimalized during preoperative phase
Process variations (1)

• 5 types of breast cancer surgery:
  • mastectomy
  • breast conserving surgery
  • lymph node removal
  • combination of mastectomy and lymph node removal
  • combination of breast conserving surgery and lymph node removal
Process variations (2)

• For each surgery type:
  • process model was built
  • FCA lattice for analyzing characteristics of patient groups

• Mastectomy vs. breast conserving surgery
  • more complex surgery type
  • FCA lattices were less complex for mastectomy than for breast conserving surgery.
Breast conserving surgery (1)
Breast conserving surgery (2)

• less uniformly structured care process

• essential care interventions are missing
  • 3 patients did not receive consultation from social support service
  • 15 patients did not have appointment with physiotherapist & did not receive revalidation therapy.
  • 1 patient did not receive pre-operative preparation
  • 2 patients were missing emotional support before and after surgery
Breast conserving surgery (3)

- original pathway was written for certain length of stay
- length of stay was significantly reduced over past years without modifying the care process model
- became impossible to execute prescribed process model in practice
- patients are receiving suboptimal care
Breast conserving surgery (4)

• Solution:
  • activities performed to patients should be reorganized
  • care pathway taking into account this time restriction should be optimalized
Mastectomy (1)
Mastectomy (2)

• less complex lattice structure although care is more complex

• most patients received all key intervention prescribed in clinical pathway

• 2 patients with quality of care issue:
  • 1 patient did not receive emotional support
  • 1 patient did not receive a breast prosthesis before discharge
Workforce intelligence (1)
Workforce intelligence (2)

• 25 patients with LOS < 4 days are treated by surgeon 9.

• patients treated by other doctors have longer LOS

• process models were constructed for patients with
  • LOS smaller than 4 days
  • LOS equal to 4 days
  • LOS larger than 4 days.

• extract best practices.
Process models

ML LOW

ML AVG

ML HIGH
Data entrance quality problems

• some patients for who activities were registered after day of discharge

• reason: error in computer program combined with sloppy data entry by nursing staff

• semantically identical activities that had different activity numbers
Data entrance quality problems (2)

• process models have ordering of events that does not correspond to ordering in real life
  • reason: error in computer system which sometimes imposes certain sequences of events

• discrepancy between built-in top-down developed model and reality
  • reason: insufficient insight into reality of working floor
Questions ?