Aligning Temporal Data by Sentinel Events: Discovering Patterns in Electronic Health Records

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LifeLines: Overview of Patient Record

10 years ago

Lifelines
Single patient record

CHI96 AMIA98 - www.cs.umd.edu/hcil/lifelines
Measured benefits over tabular display

www.cs.umd.edu/hcil/lifelines
Single record ➔ Millions of records

- Large databases of Electronic Health Records (EHRs)
- Observational studies (i.e. using EHRs for clinical research - rather than clinical trials)
- Recruitment for clinical trials
- Hospital performance monitoring
- Alarm design and testing
- etc.

Often involve temporal comparison relative to an important event (e.g. heart attack, start of a treatment, 1st diagnosis of cancer)
LifeLines: Overview of Patient Record

10 years ago
Lifelines
Single patient record
Lifelines 2
Sets of patient records
All medical data shown had been de-identified (drawback: it was small)

Lifelines 2
Sets of patient records
Today

• Introduce powerful combination of simple operations
  Align Rank and Filter
  • Multiple records simultaneously visible
  • Align by sentinel events
  • Rank by frequency
  • Filter by events

• Measure benefit of alignment

• Explore representation of intervals of validity
Focus on categorical point data

- **Examples**
  - Diagnoses
  - Admission to hospital
  - Complaints: Shortness of breath
  - Tests (e.g. type: creatinine serum, low/normal/high, value)
  - Exams (e.g. type=xray, normal)

- **Point data (not interval)**
  
even if some implicit interval of validity exist

**NOT:**
- Images
- Full text of notes
- Continuous numerical data (e.g. EKGs)
Focus on categorical point data

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Pneumonia
Focus on categorical point data

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Pneumonia  Hospital discharge

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Pneumonia
Context

Search
millions of records

Interactive
visualization of results

LifeLines2

Selected subsets of the records of multiple patients
Context

Search millions of records

Interactive visualization of results

Writing SQL not an option!

LifeLines2

Selected subsets of the records of multiple patients
Context

SELECT TOP 200 *
FROM
contrast contrast_1,
contrast contrast_2,
contrast contrast_3
WHERE
1=1 AND
[contrast_1].[Lab Test] = 'CREAT' AND
[contrast_2].[Value] BETWEEN '0.6' AND '1.2' AND
[contrast_2].[Lab Accessioning Time] < [contrast_1].[Radiology Exam Time] AND [contrast_2].[Lab Accessioning Time] > dateadd(Day, -2, [contrast_1].[Radiology Exam Time]) AND
[contrast_1].[Account] = [contrast_2][Account] AND
[contrast_3][Value] > ([contrast_2][Value] * (1 + 50 * .01)) AND
[contrast_3][Value] > ([contrast_2][Value] + 1) AND
[contrast_3][Lab Accessioning Time] > [contrast_1][Radiology Exam Time] AND [contrast_3][Lab Accessioning Time] < dateadd(Day, 5, [contrast_1][Radiology Exam Time]) AND
[contrast_2][Account] = [contrast_3][Account]

Writing SQL not an option

LifeLines2

Selected subsets of the records of multiple patients
• Related work
• Quick demo
• Report on studies
• Ongoing & Future work
Sample of Related Work

• Many tools... because many types of time series, and needs

• Recent survey paper: Aigner et al, TVCG 2008

• Many static displays

• Numerical vs. Categorical data
  • Numerical
    • Single one (e.g. VizTree looking at patterns in an EKG)
    • Multiple series (e.g. TimeSearcher)
  • Categorical
    • Many modeling and query tools
    • Queries

• Alignment
  • Many examples of use
    • Manual specification of alignment point
    • Periodical data (e.g. spiral displays)
Static views

Powsner & Tufte, 1994

Lexis diagrams (Bertin)
TimeSearcher
Dynamic queries on numerical temporal data

Hochheiser Infovis04

Buono VDA05

www.cs.umd.edu/hcil/timesearcher
Lifelines and improvements
Overview of categorical and/or numerical data (semantic zoom)

Plaisant CHI 96, AMIA 98
Lifelines and improvements
Overview of categorical and/or numerical data (semantic zoom)

I2b2 (Murphy AMIA 07)
Lifelines and improvements
Overview of categorical and/or numerical data (semantic zoom)

Plaisant CHI 96, AMIA 98

Bade CHI 2004
Spiral Graph: Weber 01 (based on Carlis UIST 89)
Periodic data

ThemeRiver (Havre, Infovis00)

Experiscope (Guimbretiere, CHI07)
One of many example of manual alignment
Specification of temporal abstractions
To reason/query with them

Shahar 1999

Post 2007

No focus on UI, or presenting results
Patients with increasing dosages of Remeron followed by a heart attack within 180 days

[Fail et al. VAST06]

www.cs.umd.edu/hcil/patternfinder VAST 06 paper
PatternFinder
Specification of complex temporal queries on categorical data

Ball and chain display of matches

[Fail et al. VAST06]
• Related work
• Quick demo LifeLines2
• Report on studies
• Ongoing & Future work
Scenario: Study relationship between asthma and pneumonia
1) Run query
Scenario: Study relationship between asthma and pneumonia

1) Run query Find all patients who have both Asthma and Pneumonia diagnoses
Scenario: Study relationship between asthma and pneumonia

1) Run query Find all patients who have both Asthma and Pneumonia diagnoses

2) Review results
• Lifelines2
  
  elements
  scroll
  open close
  align
  rank
  filter
  sequence

  interval of validity

switch to demo
User Studies
Two user studies

• Controlled experiment (some training, measure speed and error)
  • Benefit of alignment  YES  (between 0 to 60% improvement)
  • Benefit of interval of validity  NO
  • 20 participants: grad students
    Data: synthetic student record data

• Domain expert qualitative study (no training, think aloud, discussion)
  •
  •
  •
  •
Example tasks

- **1:** How many students submitted a paper within 1 month after proposal? 5 records
- **2:** same with more 20 records
- **3:** How many students published at least 3 papers between PhD proposal and defense?
- **4:** What occurred most often within a month of a student’s 1st paper submission?
Task completion time

Not really useful if data fit in one screen
or if still learning i.e. best strategy not immediate
Task completion time

**Task Completion Time**

ALSO:
- fewer, smaller errors
- rated helpful
  - (8.3 on scale of 1-9)
Observations

• In general with alignments users
  • First reduce data with filters
  • Align
  • Eye-ball temporal relationships
  • Zoom/Inspect data with potential

• Best strategy not found for task 3
  (they aligned on proposal instead of defense)

When no alignment they filtered by sequence:
  “proposal < paper < defense”
Intervals of validity: NO Significant differences

(1) Without intervals of validity

- 1000000002
  - Asthma
  - Rheumatism, exclu prednisone

- 1000000054
  - Asthma
  - Rheumatism, exclu prednisone

(2) With intervals of validity

- 1000000002
  - Asthma
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Two user studies

• Controlled experiment (some training, measure speed and error)
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  • Benefit of interval of validity  \textbf{NO}

  • 20 participants: grad students
    Data: synthetic student record data
    Tasks checked as domain independent

• Domain expert qualitative study (no training, think aloud, discussion)
  • Learnability (visual presentation, UI)
  • General feedback and suggestions

  • 4 participants: nurse, physician, 2 prof. of nursing
  • All experienced with EHR and medical research
Domain expert qualitative study

• 3 scenarios
  • Picking subjects for a clinical trials
    - Patients who took steroids for asthma
  • Trends
    - Asthma attacks seem more likely to follow or precede pneumonia?
    - What events seem to co-occur with acute myocardial infarction?

• Zero training
• Review data
• Think aloud
Domain expert qualitative study

- Visual representation and Align-rank-filter understood without training
  - One user had initial problem seeing that 1 facet = 1 patient (but figured out on his own)
  - One user learned every single feature entirely on her own, others asked demonstration of some features.

- But even experts get confused about data available (e.g. asthma interpreted a flare)
Interpreting intervals of validity

(1) Without intervals of validity

(2) With intervals of validity

May only add more confusion? Is it realistic to count on adequate training?
Future work

- Summaries:
  - temporal distribution of event type(s)

- Comparison of populations grouped by
  - patient characteristic (e.g. men/women)
  - presence/absence (e.g. had stroke or not)
  - ordering relative to sentinel
Future work

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- Integration in operational systems
Context

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LifeLines2
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PatternFinder in Amalga

LifeLines2
PatternFinder (in Azyxxi/Amalga)

Complex temporal queries:

- Patients discharged from ER admitted again within a week
- Patients with radiology exam using contrast, and a normal creatinine level at most 2 days before the exam, and creatinine increase of at least 50% and more than 0.1mg within 5 days of the exam
• radiology exam with contrast
• normal creatinine level at most 2 days before the exam
• creatinine increase of at least 50% and more than .1mg within 5 days of the exam)
Combine alignment with PatternFinder

Collaboration with Washington Hospital Center
(original developers of Azyxxi, now Microsoft Amalga)

- Alignment integrated
- Put on desk of first users last week
- Connected to real time database
- Search UI was designed to match style of existing search interface
Integrate Align-Rank-Filter in i2b2

by early summer
In summary...

- **Align Rank and Filter**
  Powerful combination of simple operations to explore temporal categorical data

- **Performance benefit of alignment** significant

- Integration in 2 large operational EHR systems

- Many applicable domains:
  - Highway incident log
  - Student records
  - Web logs
  - Vehicle fleet records

- Interval of validity? Not clear
www.cs.umd.edu/hcil/lifelines2

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Still a few spots at our workshop:
“Interactive Visual Exploration of Electronic Health Records” at HCIL Symposium (May 30)

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