TimeBench: A Data Model and Software Library for Visual Analytics of Time-Oriented Data

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Prazsky orloj by George M. Groutas, four seasons by nalmes.deviantart.com, Calendar card - Design 2 by Joe Lanman
Challenges of Time-oriented Data

e.g., analyzing electronic health records

time-oriented multivariate sampled irregularly

multiple granularities & cycles

different time primitives

temporal indeterminacy

[Aigner et al., 2011]
A Software Library for Visual Analytics

**TimeBench** aims to fulfill the following desiderata:

- expressiveness
- common data structure
- developer accessibility
- runtime efficiency
Aspects of Time-oriented Data

multiple granularities & cycles

- none
- single
- multiple

linear

cyclic

different time primitives

- instant
- interval
- span

temporal indeterminacy

determinate

indeterminate

[Aigner et al., 2011]
Challenging Aspect: Multiple Granularities & Cycles
Calendar Operations for Granularities

- **Years**: 2013
- **Months**: 10
- **Weeks**: 23
- **Days**: 18

Total: 1,382,087,700,000
Calendar Operations for Granularities

granularities ... map time and integer numbers

- years
- months
- weeks: 21, 22, 23, ...
- days

1,382,087,700,000

time

[Bettini et al., 2000]
Calendar Operations for Granularities

granularities … map time and integer numbers

years
months
weeks
days

1,382,087,700,000

18

time

granule … subset of time for a granularity and an identifier

[Bettini et al., 2000]
Calendar package

general classes
  • Granule
  • Granularity

exchangeable calendar backend
  • CalendarManager
Calendar Operations based on Granularities

- anchor data on any granularity
- convert granules to another granularity
  - convert milliseconds (and vice versa)
- group granules by identifier
- shifting granules by a given number
- check qualitative temporal relations
Challenging Aspect: Different Time Primitives

1 time point

period between 2 time points

duration of a period (not anchored in time)
Expressive Data Structure for Primitives

complex primitives built hierarchically
create primitives from granules
object-oriented tuples
Connecting Data to Primitives

temporal object … data tuple with a reference to a primitive

Primitive p = object.getPrimitve();
if (p instanceof Interval)
    print p.getBegin();
foreach (obj : p.getObjects())
    print obj;
Embedded in Software Design Patterns

data column pattern
relational graph pattern
proxy tuple pattern

factory methods
accessor methods

interval index
Challenging Aspect:
Temporal Indeterminacy

[Aigner et al., 2005]
Hierarchy of Primitives for Indeterminacy

- temporal object
- indeterminate interval
  - begin interval
    - earliest begin
  - max. duration
  - min. duration
  - end interval
    - earliest end
    - latest end
Library Components

- Calendar operations
- Data structures
- Data transformations
- Visualization & interaction
Visual Analytics Library
Application Example: PlanningLines

[Aigner et al., 2005]
Application Example: GROOVE
Evaluation

application examples
challenging VA methods
different data characteristics

long-term developer studies
in student & research project

- TiMoVA
- temporal pattern discovery [C&G, 2014]
- high-school graduation project

[Lammarsch et al., 2014; Bögl et al., 2013]
Evaluation Results

expressiveness
demonstrate applicability in a range of challenging projects

common data structure
no adaptation of the data structure needed

developer accessibility
tested with university and high-school students

runtime efficiency
examples run smoothly with thousands of temporal objects
Future Work

- extend with new transformations and visualization methods
- integrate with data sources
- add freely configurable calendars
- support branching time
- extend for spatial & spatio-temporal data
Future Work

TimeBench source code published at GitHub
https://github.com/ieg-vienna/TimeBench

community building
• promotion
• tutorials
• pull requests
**TimeBench.org**

A Software Library for Visual Analytics of Time-Oriented Data

- **multiple granularities & cycles**
  - years: 2013
  - months: 10
  - weeks: 23
  - days: 18
  - time: 1,382,087,700,000

- **different time primitives**
  - $G_1$, $G_2$, $G_3$, $G_6$
  - $\inf(\text{instant}_a) = \inf(\text{interval}_c)$
  - $\sup(\text{instant}_a) = \sup(\text{interval}_c)$

- **temporal indeterminacy**
  - imprecise begin
  - max./min. duration
  - imprecise end

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