Part 2
Planning ↔ Plan Management

Temporal Data Abstraction - TDA

View A: Data Oriented
Huge numbers of data
Comprehend data effectively!

View B: Task Oriented
Persons with tasks
Support their data analyses!

TDA: Data
Different Observation Frequencies
High / Low Frequency Data

Different Regularities
Continuously / Discontinuously

Different Data Types
Quantitative / Qualitative

Underlying Models Poorly Understood
Vague Data
TDA: Overview

Data Transformation
Data Validation
Visualization

Check Data
Get New Data

Users
& Tasks

Abstracted Values

Detailed Description on Demand

TDA: 5 Tasks

**Temporal-Context Restriction**
Creation of relevant interpretation contexts

**Vertical Temporal Inference**
Contemporaneous propositions → high-level

**Horizontal Temporal Inference**
Similar-type propositions → over time periods

**Temporal Interpolation**
Join of disjoint points or intervals

**Temporal Pattern Matching**
Creation of intervals by matching of patterns

TDA: Types

**State Abstraction**
Classification of the value of a parameter
e.g., LOW, HIGH

**Gradient Abstraction**
Direction of the parameters' change
e.g., DECREASING, INCREASING

**Rate Abstraction**
Classification of the rate of change of a parameter
e.g., FAST, SLOW

**Pattern Abstraction**
Classification of a parameter within a time period
e.g., CRESCENDO

Example: TDA Tasks

<table>
<thead>
<tr>
<th>SaO2</th>
<th>PtcO2</th>
<th>PaO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>30</td>
<td>H[0]</td>
</tr>
</tbody>
</table>

Controlled Ventilation

Artificial Ventilation


0  30  90  60

time
Expected qualitative trend descriptions moving one qualitative step within 10'-30' (towards target range)

1. C ... dangerous increase
2. ZA ... zero change
3. A3 ... decrease too slow
4. A2 ... normal decrease
5. A1 ... decrease too fast
6. B1 ... increase too fast
7. B2 ... normal increase
8. B3 ... increase too slow
9. ZB ... zero change
10. D ... dangerous decrease

[Expected trend-curve-fitting Schemata: Miksch, et al. 1996]

Trend-curve-fitting Schemata

Actual development of PtcO2 in the past

Therapeutic actions
- increase ventilation
- no change of the ventilation setting
- decrease ventilation

[Miksch, et al. 1996]
Examples: Plan Management

Examples

Asgaard / Asbru Project

CareVis

Asgaard / Asbru Project

Asbru’s Key Features

Hierarchical Decomposition of Plans
Temporal Annotations & Uncertainty
Knowledge Roles

Preferences
Intentions
Conditions
Effects
Plan Layouts

Asgaard / Asbru Project:
Designing Task-Specific Problem-Solving Methods to Support the Design and the Execution of Time-Oriented Skeletal Plans

Peter Johnson
Silvia Miksch
Yuval Shahar

Stanford University
Stanford Medical Informatics
(SMI)

international cooperation

- Vrije Universiteit Amsterdam
- University of Aberdeen
- University of Augsburg
- CBO, Dutch - Healthcare Improvement

W. Aigner, K. Kaiser,
K. Hamermüller
R. Kosara, A. Seyfang,
P. Votruba

and students
Vienna University of Technology
Vienna, Austria

Yuval Shahar

and students
Ben-Gurion University of the Negev
Beer-Sheva, Israel
Hierarchical Decomposition of Plans

Asbru's Time Annotation

Definition: \([\text{ESS}, \text{LSS}], [\text{EFS}, \text{LFS}], [\text{MinDu}, \text{MaxDu}], \text{Reference}\)

Example: \([_., .], [_., .], [180 \text{ MIN}, .], *\text{self}*\)

Asbru's Knowledge Roles (1/2)

Asbru's Knowledge Roles (2/2)
I-RDS Example in Asbru 6.5

(PLAN controlled-ventilation)
(PREFERENCES (SELECT-METHOD BEST-FIT))
(INTENTION:INTERMEDIATE-STATE (MAINTAIN STATE(BG) NORMAL controlled-ventilation *))
(INTENTION:INTERMEDIATE-ACTION (MAINTAIN STATE(RESPIRATOR-SETTING) LOW controlled-ventilation *))
(SUPPORT-PRECONDITIONS (PP (<= 20) I-RDS *)
(BG available I-RDS [[..],[..],[1 MIN, ]ACTIVATED initial-phase])
(ABORT-CONDITIONS ACTIVATED)
(OR (IP (<= 30) controlled-ventilation [[..],[..],[30 SEC, ], *self*])
(RATE(BG) TOO-STEEP controlled-ventilation [[..],[..],[180 MIN, ], *self*]))
(SAMPLING-FREQUENCY 10 SEC)
(COMPLETE-CONDITIONS
(FO2 (<= 50) controlled-ventilation [[..],[..],[180 MIN, ], *self*])
(IP (<= 23) controlled-ventilation [[..],[..],[180 MIN, ], *self*])
(STATE(BG) OR NORMAL ABOVE-NORMAL) controlled-ventilation [[..],[..],[180 MIN, ], *self*])
(SAMPLING-FREQUENCY 10 MIN)
(CO-ALL-SEQUENTIALLY
(one-of-increase-decrease-ventilation)
[observation])

Problem Solving Methods (PSM)

Selected PSM

Authoring Protocols
AsbruView - SopoView
Guideline Markup Tool
Advanced Editors: PIXEE
Information Extraction & Integration
Plan Verification
Monitoring and Execution
Information Visualization

I-RDS Example in Asbru 7.1d

(PLAN controlled-ventilation)
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[observation])
AsbruView

Interface to the Plan-Representation Language Asbru

Metaphor Graphics

AsbruView’s Dimensions

1. Flow of Time
2. Parallel Plans
3. Subplan Levels
4. Color

Anatomy of a Plan

Sequential Plans

Topological View

Temporal View
AsbruView

Evaluation

Metaphors
Colors
Two Views
Time Annotations

Speed
(Plan Placement)

SOPOs

SOPOs
**SOPOs**

**SOPO** = Set of Possible Occurrences

**Pro:**
- Temporal Uncertainty
  - Evaluated in Small User Study

**Con:**
- Hard to Understand (not Intuitive)
- No Hierarchical Decomposition (Unmodified)
- No Facets (Very Difficult)

**DELT/A:** Document Editing & Linking Tool with Add-ons

Working with Guidelines’ & Protocols’ Versions

**2 Main Features**

**Links**
- Linking between the textual guideline and its formal representation
  - Connect related parts in different versions of the same guideline

**Macros**
- Applying design patterns in the form of macros
  - Combine multiple XML-elements to facilitate construction of an XML file

[Votruba, et al. 2004]
**DELT/A: Tasks**

- Authoring GL
- Designing FR
- Augmenting GL
- Annotating FR
- Understanding GL & FL
- Using Links & Navigation
- Structuring GL & FL
- Using Macros

**Living Guidelines**

- Using Macros, Links & Navigation

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**Sample DELTA – Feature: Filtering/Folding**

**Problem**
Files complex & large
Focus on partial aspects necessary

**Solution**
Define filters on the fly
Show/hide parent nodes
Show/hide child nodes

**Example:** Show all data usage elements

---

**Evaluation**

**Qualitative Study**

[Votruba, et al. 2004]

**3 Phases**

A questionnaire: assessing participant's skills
An exploration session: examining functionality
A questionnaire: assessing the three views

**Results**

Homogeneous sample
Three views are very appropriate
Linking features necessary
Markros help to structure and understand
Conclusion (Benefits)

**Tool** for maintaining knowledge in clinical guidelines & protocols

- **Linking** two representations of same guideline
- **Cross-checking** for errors and inconsistencies
- **XML-Macros**: Simple construction of new XML guidelines
- **Full-featured XML-Editor**: No need to switch to standard XML-editor for post-processing of guideline

Information Extraction & Integration

**Semi-Structured Data & Information**

- Knowledge Engineers
- Domain Experts

**Semi-Formal Representation**

**Intermediates Representations**

**Knowledge-Based Methods**

More Details ...

... Katharina Kaiser‘s parts
**The Protocure Project**

**Overall Objective**

“Support guideline developers in the health-care profession in the construction and maintenance of high-quality and up-to-date living guidelines and protocols.”

**Metaphor:**

Guideline & Protocol Development ≈ Software Engineering

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**Verification: Protocure Project**

Improving Medical Protocols by Formal Methods (KIV)

- **Informal Protocol**
  - Modeling
  - Asbru Plans
  - KIV Representation
  - Satisfies?

- **Informal Properties**
  - Intentions, Effects, ...
  - Formal Semantics
  - Translation
  - Satisfies?

- **Formal Semantics**
  - Satisfaction

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**Multi-level Plan Verification**

Check for Anomalies Within Several Layers

- Level 1: Within a Single Component
- Level 2: Within a Single Plan
- Level 3: Within a Plan Hierarchy

- **Modeling**
- **Validation & Testing**
- **Verification**
- **Process model**
- **Deployment**
- **Maintenance**

**Goal:**

to arrive at legal or meaningful plans

<table>
<thead>
<tr>
<th>Decomposition</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
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<tbody>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Cond. A1</td>
<td>✔️</td>
<td>✔️</td>
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</tr>
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<td>Cond. A2</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Cond. A3</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>...</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td>Plan A2</td>
<td>✔️</td>
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Problem Solving Methods

Selected PSM

Authoring Protocols
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Plan Verification
  Monitoring and Execution
  Information Visualization

Overview: Run-Time Modules

Design - Execution - Time

Information Communication

What is the problem?
  Visualization support for patient data analysis is mostly limited to the representation of directly measured data

Why is it important?
  Contextual information on treatment steps could enhance the analysis process

Our solution
  Integrated visualization of medical treatment steps and patient data
  Use visual representations familiar to domain experts

Current Visual Analysis Methods

“data visualization” - no explicit integration of information about the treatment process
The Problem

[Aigner, et al. 2003-2006]

Conceptual Design

Two-view approach:

[Aigner, et al. 2003-2006]

Data Characteristics

Treatment Plan Specification Data
Treatment plan execution data
Patient Data
(measured parameters & variables)

Time-oriented Data (incl. Uncertainties)
Logical Sequences
Hierarchical Decomposition
Flexible Execution Order
Non-uniform Element Types
State Characteristic of Conditions

[Aigner & Miksch 2004-2006]

Our Solution: CareVis

QuickView Panel

Logical View

Temporal View

Interactive and Integrated Visualization of Computerized Protocols and Temporal Patient Data
Logical View

AsbruFlow
based on clinical algorithm maps / flow chart algorithms
[Society for Medical Decision Making, 1992]

Fisheye Approach
Overview+Detail

Temporal View
PlanningLines
based on LifeLines [Plaisant et al., 1998]

View Coupling
common color palette for plans
synchronous selection
user triggered navigation propagation
User Centered Design

3-step evaluation process
qualitative
scenario-based

Prototype Evaluation

5 physicians
Semi-structured interview
Feedback very positive
Clear
Intuitive
Easy to understand
Mental model for PlanningLine glyph very helpful
Increased interest in contrast to User Study

Conclusion

Two-view approach
Working hand-in-hand
Helpful interaction patterns for coupling of views
Making complex data easier to understand
Using visualization techniques familiar to domain experts (physicians)
Development of two novel glyphs
User involvement

LinkVis: Multiple Views

[Aigner, et al. 2003-2006]
LinkVis: Multiple Views

Connecting Time-Oriented Data and Information to a Coherent Interactive Visualization

Ragnar Bade, Stefan Schlechtweg
Silvia Miksch

The Midgaard Project
Aims

Data
High-Dimensional and Time-Oriented Data and Information

Interactive Visualization Techniques
Reveal the Data at Several Levels of Detail and Abstraction, Ranging from a Broad Overview to the Fine Structure

Time Visualization and Navigation Technique
Connects Overview+Detail, Pan+Zoom, and Focus+Context Features to one Powerful Time-Browser

Midgaard Approach
Visualizing Time-Oriented Data
Qualitative Scales
Qualitative/Quantitative Hybrids
Quantitative Scales
Data Points & Their Dimension
High-Frequency Data

Interacting with Data
Browsing Data
Browsing Over Time

Qualitative Scales
Color-Coded Timelines

\[
\begin{align*}
^\circ\text{C} &> 41.0  &> 38.5 &< 38.5 \\
^\circ\text{F} &>105.8 &>101.3 &<101.3
\end{align*}
\]

Height-Coded Timelines

\[
\begin{align*}
^\circ\text{C} &>41.0 &+ &+ &+ &< 38.5 \\
^\circ\text{F} &>105.8 &>101.3 &<101.3
\end{align*}
\]

Mark Regions without Colors

\[
\begin{align*}
^\circ\text{C} &>41.0 &>38.5 &+ &+ &< 38.5 \\
^\circ\text{F} &>105.8 &>101.3 &<101.3
\end{align*}
\]
Quantitative Scales
Read Exact Values
Include Knowledge of Qualitative Scales

Points and their Dimensions
Occurrence Time & Uncertainty

Valid Time

High-Frequency Data
Abstract vs. Expressiveness
Information Mural [Jerding & Stasko, 1998]

Tukey's Box-Plot Redesign

Interacting with Data & Time
The Interactive Stardinates

[Lanzenberger, et al. 2003]

'Stars and Coordinates'
Axes, Scales, Labels
Data Lines, Data Bundles
Pre-attentive Features:
• Shape
• Size
• Relative Position
• Diversity and Accumulation of Lines
**Aims & Tasks: in2vis Project**

Explore & Compare Different Methods to Ease the Understanding

Find their Strengths & Limitations

Estimate How Combinations of these Methods can Contribute to More In-Depth Reasoning Processes

Develop Guidelines How to Explore & Visualize Data & Information Task- and User- Appropriately

---

**Fokus: Explorative Methods of Data Analyses**

Interactive & Explorative Features

Abstract & Highly Structured Data Context

Task-specific & User-oriented (Personalized)

Interactive Information Visualization

Explorative Data Analyses (EDA) supervised Maschine Learning

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**Study**

Psychotherapeutic Data Acquired during Cognitive Behavioural Therapy of Anorectic Girls

Data

Complex, Different Data Types & Time-oriented

Task

Find Predictors
Data Characteristics

Data from Questionnaires
Each about 40 Questions
Filled out by Patients, Parents, and Therapists
Answers Range from 0 to 6
5 Time Steps (pre, eval1-3, post)

- Explore Highly Structured, Temporal Data

Gravi++

Overview Visualizations

TableVis
Overview Visualization

Spring-based Core Visualization

Visualize data by positioning, color, and size of icons

Positioning of persons with spring-based Method

Movement and finding clusters and outliers

Gravi++: Demo
Gravi++

Tooltip
Details on Demand for questions and persons (on mouse over).

Toolbar
Quick access to the most important options.
Traces: Visualize Movement Over Time

Star Glyph: Visualization of Exact Values

Study - Evaluation

Usability Study
Informal Usability Inspection/
Guideline Review
Heuristic Evaluation
Focus Groups

Contribution Study between
Gravi++
Exploratory Data Analysis
Machine Learning Techniques

Guidelines: Explore & Visualize Data & Information
Task- and User- Appropriately
## Study

<table>
<thead>
<tr>
<th>Stage</th>
<th>Method</th>
<th>Subjects</th>
<th>Aim</th>
<th>Outcome</th>
</tr>
</thead>
</table>

### Usability
- Usability expert identified 31 usability problems.
- 27 students (semi-experts in usability) participated in in-depth testing.
- 447 reports documented 576 problems (221 different).
- Focus groups conducted additional usability assessment, no new problems but a different perspective.

### Insight Study
- 33 students (domain novices) participated, 909 reports generated for patterns of insight & cognitive strategies.
- Log files used to analyze visualization, 5605 log file entries collected.
- Focus groups were used to relativize findings and correct interpretation.

### Case Study
- Interviews conducted with 2 clinicians (real users) to assess feasibility & usefulness in real-life scenarios.
- 20 experts from other domains interviewed to assess usefulness in other domains.

## Conclusion

**Interactive Information Visualization**

Part of a comparison study with machine learning and statistical methods.

Time is visualized with animation and traces.

Find predictors and analyze data.

**GOT: Guideline Overview Tool**

(Wolfgang Aigner, 2001)

**GOT: Interactions: Plans & Data**

(Wolfgang Aigner, 2001)
Conclusion

Classical Planning not sufficient in Medicine
  Plan Management
    Time-Oriented Skeletal Planning
  Methods & Tools Supporting the Tasks

User-Oriented Design

Cite-Specific Adaptions

Usability Studies