Section A: questions & application areas

Questions 1/4
1. When are the doors going to be installed and what is done afterwards?
2. Was arthritis diagnosed while a period of tobacco consumption?
3. When did "Olson" write the Technical Report for the "DELTA" project?
4. What do I have to do tomorrow?
5. When do I have to leave the office in order to catch my bus?
6. Are 7 days really 7 days?
7. For how long do I need to apply the therapy at minimum?
8. Until when can corticosteroids be given?
9. Can "Controlled Ventilation" and "Crisis Management" overlap temporally?
10. Who logged into my server at 3pm yesterday?

Questions 2/4
11. At what time did Fidel Castro talk most about "oil"?
12. What kind of food do chimpanzees prefer in winter?
13. Do the stocks of "Microsoft" and "Sun Microsystems" have a similar price history?
14. Is my software project likely to fail?
15. What parts of my software project are stable?
16. How does Beethoven’s "Bagatelle" sound and look like?
17. Which stocks increased in a similar way during the year?
18. Who are the main contributors in an online environment?
19. Which meeting is going to happen on August, 17?
20. How did the prices of various MP3 players change over the last months?
Questions 3/4

21. How is time represented in paintings?
22. How did the ozone concentration in Los Angeles change over the last decade?
23. Can the same pattern of value increase be found in other sessions of dialysis? (MOVIE)
24. How did various authors contribute to the wikipedia entry on "Islam" over time?
25. How did the blood pressure of Jane Doe evolve over the last hours? (MOVIE)
26. What did Isaac Newton do in 1667 and where did he do it?
27. How do the top 100 news topics during the last day look like?
28. What were the main events in my life so far? (MOVIE)
29. How does an hour worth of "Simpsons" look like in one picture? (MOVIE)
30. Which parts of my website were visited during the last hours? (MOVIE)

Applications 1/3

1. project plans (2 DEMO)
2. juvenile justice records, patient records (DEMO)
3. document/file collections
4. personal and/or corporate time management (2)
5. time management (DEMO)
6. events on different granularities
7. medical treatment planning (2, 3, 4)
8. network intrusion detection

Questions 4/4

31. When did Philipp Glass write his fastest songs? (Online-DEMO)
32. Who are my main e-mail communication partners?
33. How does the history of photography look like?
34. Are there any critical portions in my project plan? (DEMO)
35. How is Mary's course of therapy? (DEMO)
36. What treatment step should be performed next?
37. Are there differences in the trends of sold items on different weekdays?
38. What are the patterns of deployed police forces in a city?

Applications 2/3

9. document collections (MOVIE)
10. chimpanzees food consumption
11. internet movie database
12. stock prices
13. software evolution (2)
14. music visualization (MOVIE)
15. stock prices (DEMO)
16. microarray data (DEMO)
17. discussion group activity
18. visual arts
Applications 3/3

19. ozone concentration in Los Angeles
20. medical data (MOVIE) (MOVIE) (DEMO)
21. Wikipedia document evolution
22. historical events (2)
23. news
24. personal history (MOVIE)
25. webpage hit evolution (MOVIE)
26. music collection (Online-DEMO)
31. e-mail history
32. retail (sold items)
33. police unit deployment

Section B:

time & arts

Renaissance

[Masaccio and Masolino, Scenes from the Life of St. Peter, c.1426-7, Brancacci Chapel, Florence]
Multiple appearances of the same person within a single scene

Cubism

The first documented occurrence of the fourth dimension being used in art appeared in 1910 in Paris.

Origin: mathematics + physics
(n-dimensional spaces)

At this point, the fourth dimension was thought as time.

Person walking down stairs -->

Fourth dimension in the painting by picturing different stages of the person’s descent

[Marcel Duchamp, Nude Descending a Staircase, 1912]
Cubism

New ideas about the fourth dimension into the static domain of pictures.

Overlays many different observations.

Emphasizes process of looking and recording over time.

[Picasso, Portrait of Vollard, 1910]

Comics

Visual story telling over time.

Many interesting techniques / paradigms.

If you want to know more, start here:
[Scott McCloud, Understanding Comics, 1994]

Section C: visualization techniques

TimeSearcher

[Hochheiser, 2002; Hochheiser and Shneiderman, 2002]

visualization tool for time-series data

timebox query model
rectangular regions that specify constraints over time series data sets
x-axis extent: time period of interest
y-axis extent: constraint on the range of values
combinations of multiple timeboxes
data + query envelope

http://www.cs.umd.edu/hcil/timesearcher/
Interactive Parallel Bar Charts (IPBC) [Chittaro et al., 2002]

- Basic visual technique: bar charts
- Bar charts only suitable for 1 time series; more --> 3D
- Analysis of medical data
- Occlusions can be removed by flattening occluding elements
  --> Matrix visualization
- Tide mode (highlighting areas)
- Smooth transitions

Midgaard 1/2 [Bade et al., 2004]

- Visualization of medical intensive care data
- Qualitative scales
- Quantitative scales
- Qualitative / quantitative hybrids
- Semantic zoom
  Smoothly integrated

Midgaard 2/2

- Different granularities
- Visualization of measurement deviation,
  Trustability of data points,
  and missing data

TimeWheel / Zeitrad 1/2 [Tominski et al., 2003]

- Time axis in the center
- Variable axis arranged circularly
- Lines connecting time and feature values
- Similar to parallel coordinates
- Variables parallel to time axis (upper and lower) can be explored most effectively
- Focus + Context by shortening of rotated axis and color fading
**TimeWheel / Zeitrad 2/2**

User interaction:
Rotation of variable axes (moving axes of interest into a position parallel to the time axis)

**MultiCombs**

[Müller and Schumann, 2003]

Axis based technique
Multiple parameters on multiple time axis, circularly arranged
Outward from the center of star-shaped
Aggregated view of “past” values in the center

**Temporal Star**

[Noirhomme-Fraiture, 2002]

radial bar graph --> 3D over time
visualizing an object at different epochs
central axis represents time
transparent veil to enhance evolution
not suited for nominal data

**Serial Periodic Data 1/6**

[Carlis and Konstan, 1998]

Visualize both, serial + periodic properties to reveal certain patterns
Time continues serially, but weeks, month, and years are periods that reoccur
Map time onto a spiral + spokes for orientation
Data values are mapped to blots on spiral
Area of blot proportional to value
**Serial Periodic Data 2/6**

**Pure serial periodic data**
- Periods with constant durations

**Event-anchored serial periodic data**
- Periods with different durations
- Start of a new period is indicated by an event

**Examples:**
- Multi day racing data
- Project based time tracking

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**Serial Periodic Data 3/6**

**Extension to 3D:**
- Z-axis for different sets of data
  - No quantitative meaning of z-axis
- Color coding of data sets
  - Lidless, hollow “cans”
  - Instead of blots
  - Prevent occlusion
- Volume of can is proportional to data value

**Pro:** good overview

**Cons:**
- Occlusion
- Clutter
- Z-position meaningless
- Double mapping (z-pos + color)

---

**Serial Periodic Data 4/6**

**User control:**
- Rotation, zoom, pan, tilt

**Annotation features:**
- Align different spirals vertically
- Definition of data derived border lines

**Display of several data sets simultaneously**
- Using bar charts
- Color coded

**Multiple, linked spirals**

---

**Serial Periodic Data 5/6**

**Interval data**
- Only duration of element

**Periodicity unknown**
- Animation
Serial Periodic Data 6/6

User experience findings:
+ Users quickly accept the notion of serial periodic data on a spiral
+ Users react to the spiral displays
  When they saw patterns, they tried to explain them by telling stories
+ Users want more
  Visualization sparked interest for further investigation
- Tool not self explanatory
  Trained operator needed

Spiral Graph 1/3

Main intention: detection of periodic behavior
Mapping data onto a spiral
Mapping of data values to
- color and
- thickness of line
Nominal + ordinal + quantitative data
1 cycle = period length

Spiral Graph 2/3

Two possibilities to detect periodic behavior:
1. Computational:
   Compute frequencies with higher amplitudes via Fourier Transformation
2. Visually:
   Utilize the visual system of a human observer to discover structures
   Spiral is animated by continuously changing the cycle length
   Periodic behavior becomes immediately apparent
   (changing from unstructured to structured)
   User can stop animation when period is spotted

Spiral Graph 3/3

Extensions:
Multi Spirals
   Compare a data set with cyclic patterns in other data.
   Rendering intertwined Spiral Graphs.
3D extension
   Problem: space
   ➔ mapping onto a helix.
   Brushing integrated.
   Selected region is displayed in 2D spiral.
   3D helix best used for navigation only.
GANTT charts 1/2

Project management, project planning
Tasks and their temporal attributes (location, duration)
Milestones
Past + present + future
Hierarchical decomposition

GANTT charts 2/2

Pros:
- Well known representation
- Collapsible hierarchical decomposition
- Easy to comprehend
- Hundreds of tools available (i.e. MS Project)

Cons:
- No uncertainty
- Space consumption (diagonal layout)

LifeLines 1/2

Based on Time Lines
Facets
Visualizing personal histories and patient information
Horizontal bars showing temporal location and duration of data elements
Past + Present

[Plaisant et al., 1996, Plaisant et al., 1998]


LifeLines 2/2

Pros:
- Simple and easy to comprehend
- Better layout than GANTT
- Use of vertical dimension
- Interactive time scale (zoom, pan)

Cons:
- No hierarchical decomposition (only Facets)
- (Just past and present)
**Perspective Wall**

Large collections of documents
Focus + Context of elements over time
Intuitive 3D metaphor for distorting 2D layout
Color coding
Smooth transitions, 3D interactive animation

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**Dynamic Timelines**

3D presentation of historical information
history of photography
seamless micro and macro readings
semantic zoom
translucency
animated visual transition
F+C by selective transparency (queries)

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**Timeline Cinematic**

Temporal Ride

3D representation
timelines are created from date, image and text data
subjective reshaping and repositioning
animation / ride along an individual timeline

http://acg.media.mit.edu/projects/timelines/

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**The Historical Event Markup and Linking Project (HEML)**

marking up web documents
different representations
- table
- timeline
- map
- animated map
XML-Schema for historical events
- participants, dates, location, keywords, evidence (ref)
web service
- use of open technologies
  - XSLT, SVG, Servlets,...

http://www.heml.org/
Temporal Objects 1/2

Depict data with different granularities
Starting instant (earliest start, latest start)
Ending instant (earliest end, latest end)
Maximum duration
Minimum duration

Based on LifeLines
Two encapsulated bars with caps at each end

Temporal Objects 2/2

Pros:
- Simple representation for complex time attributes
- Different granularities
- Easy to comprehend

Cons:
- Only presentation, no interaction
- No direct manipulation

Time Annotation Glyph 1/2

Definition: [[ESS, LSS], [EFS, LFS], [MinDu, MaxDu], Reference]

Characteristics:
- Time points are relative (Reference point)
- Notion for temporal granularity
- Notion for missing values / incomplete specifications
- Metaphor of bar lying on diamonds (preventing invalid constellations)
- User interaction / can be manipulated

Time Annotation Glyph 2/2

Definition: [[ESS, LSS], [EFS, LFS], [MinDu, MaxDu], Reference]

MinDu and LFS defined to higher precision than time axis

Example: [[2 d, 3 d], [__, 11 d], [6 d, __], Diagnosis]

MinDu and LFS defined to lower precision than time axis

Diagnosis 2 d
3 d
undef.

6 d
undef.

11 d
**Paint Strips** [Chittaro and Combi, 2001]

Metaphor of **paint rollers**

Paint roller at the end of a line = line can expand

Wall = expansion limit

Smaller set of temporal attributes as “Temporal Objects” and “Time Glyph”

Combination of strips (rope)

Starting and finishing interval can’t be defined independently from duration

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**SOPOs 1/2**

2D technique

Area depicts set of valid (start, end) tuples

Designed for easy graphical propagation of temporal constraints

**Cons:**

- Representation more complicated than LifeLine based ones
- Space consumption

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**SOPOs 2/2**

Start interval: x-axis

End interval: y-axis

Minimum duration, maximum duration: constraining borders parallel to 45° time flow axis

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**Intrusion Detection** [Muniandy, 2001]

Visualization of user access to machines over time.

**Mapping:**

- Time: circumference
- User: cylinder slice
- Machines: cubes on top
- Access: connection lines

**Annotations via tool tips (mouse hovering)**
ThemeRiver™ 1/3 [Havre et al., 2000]

Visualize thematic variations over time.
Across a large collection of documents.

River Metaphor: the “river” flows through time.
Changing width to depict changes.
Themes or topics are colored “currents”.

ThemeRiver™ 2/3

Histogram vs. ThemeRiver™:

Discrete values
Exact values
Hard to follow a single current
Continuous flow
Interpolation, approximation
Easy to follow a single current (curving continuous lines)

ThemeRiver™ 3/3

User interaction:
- Hide or display topic + event labels
data points
- Choose alternate algorithms for line drawing
Pan + Zoom

Color relations
Related themes are associated to the same color family

Improvements:
- Parallel rivers
- Display of numeric values (on demand)
- Total number of documents
- Access documents directly
- User defined ordering

Lexis Pencil [Francis and Pritchard, 1997]

Pencil-like geometric objects
Mapping time-dependent variables onto faces of the pencil
Heterogeneous data

Can be located in 3D space to show the spatial context
Tip allows exact positioning
Problem: Occlusion
Focus + Context
On pencil: by radial arrangement
In 3D space: enlarging pencil in focus
Software Evolution Analysis

- Analyzing evolution of SW-systems / product families
- 3D visualization
- Colors encode versions
- Changes of parts over time
- Hierarchical decomposition
- Pattern analysis
- Not as information rich as Time-wheel

PeopleGarden 1/2

- On-line environment user visualization
- Flower metaphor for individuals
- Garden metaphor for environment
- Visualization of social network / behavior

PeopleGarden 2/2

- Time of posting -> ordering, saturation
- Amount of response -> circles on top of petals
- Whether a post starts a new conversation -> color
- How long a user is on the board -> flower height

History Flow 1/2

- Wiki web visualization (Wikipedia)
- Evolution of entries
- Finding collaboration patterns revealed complex patterns of cooperation and conflict
  i.e. “self healing” - malicious edits were typically repaired within 2 minutes
- Show relationships between multiple document versions
**PostHistory 1/2**

visualizing email activities
dyadic email relationships (people)
time
uncover email patterns
social networks
e-mail exchange rhythms
the role of time in these patterns
mail traffic vs. content
aggregates
  - Daily email averages (send / receive)
  - Daily "quality" of e-mails (directly / copy / mailing list)
  - Frequency of e-mail exchanges with contacts
  - Comparative frequency of e-mail exchanges with contacts

**PostHistory 2/2**

calendar panel
  - intensity of e-mail exchanges over time
  - each square represents a single day
  - row --> week; one year at a time
  - amount of received e-mails --> size of square
  - personal or directed (mailing-list) --> color
  - (average is calculated)

contacts panel
  - names of the people who have sent messages to the user
  - different layouts
  - interaction by highlighting and animation through time

**Anemone**

organic information design
evolution of webpage usage (visited pages)
branches are created when visited for the first time
branches that are visited often, grow
pages that aren’t visited slowly fade away
user interaction

http://acg.media.mit.edu/people/fry/anemone/
**Music Animation Machine (M.A.M.) 1/2**

Visualization of music

Dynamic representation

Relate audio to visual structure

Simple representation for music extremely complex system

Complex patterns

Online:
http://www.well.com/user/smalin/mam.html

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**Music Animation Machine (M.A.M.) 2/2**

Each note is represented by a colored bar

Each bar lights up as its note sounds

The length of each bar corresponds exactly to the duration of its note as performed

The vertical position of the bar corresponds to the pitch

The horizontal position indicates the note’s timing

---

**Calendar Tools**

Past + present + future

Calendar scale

Events over time, repeating events

Icons, Reminder

Very well known (MS Outlook, iCal, …)

Interactive Techniques:

Overview + Detail
Zoom
Filter
Details on Demand
Multiple Views
Focus + Context

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**SpiraClock 1/2** [Dragicevic and Huot, 2002]

Visualization technique for nearby events.

Intention: fill gap between static calendar and pop-up reminders.

Continuous and non-intrusive feedback.

Analog clock with white spiral inside representing near future.
SpiraClock 2/2

Interaction:
- Change time by moving hands.
- Adjust number of spiral revolutions (visibility of future events)

Range: 1 hour - several days

Not suited for all kinds of events
- i.e. conference, 20. - 25. October

Java applets and applications:
- http://www.emn.fr/spiraclock
- Bus schedule, MS Outlook and vCal import

Spiral Calendar

individual schedule
- 3D spiral layout
- behaviour: clicking, animation
- animated transitions

TileMap / Matrix Vis.

visualization of quantitative histories
- histories whose values are numbers
- each square represents one day
- good for displaying data with a seasonal pattern

Time-wheel 1/3

Visualization of software projects over time
- Multiple time-series placed in a circle
- Data attributes are color coded
- Global trends
- Helps to examine different trends within one object
- Easy recognition of two trends:
  - Increasing trend
  - Tapering trend

[Mackinlay et al., 1994]

[Chuah and Eick, 1997]
**Time-wheel 2/3**

- Increasing trend
- Tapering trend

**Time-wheel 3/3**

*Extension to 3D:*
- Encodes the same attributes as the Time-wheel
- Uses height dimension to encode time
- Variables are encoded as slices of a base circle

**Pro:** Easier to identify overall trends

**Cons:**
- Occlusion
- Perspective

---

**10x10**

- [J. Harris, 2004](http://www.tenbyten.org/10x10.html)

100 words and pictures that define the time

RSS news feeds are scanned + linguistic analysis --> top 100 words

fisheye menu for selecting words

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**Glass Engine**


music of Philipp Glass

navigation along various attributes
**Last Clock**

“Last’ is a clock that is a record of its own history”

Video input data

Different zoom levels / display of

- Last minute
- Last hour
- Last 12 hours

http://www.edleader.co.uk/last/

**PlanningLines 1/2**

Begin and end are intervals rather than instants

Complex set of attributes presented “at a glance”

**PlanningLines 2/2**

Complex set of attributes presented “at a glance”

**GRAVI++**

Spring-based questions/ questionnaires patients attraction field star glyph time steps traces

[Cooper and Ångeslevä, 2002] [Aigner et al., 2005] [Hinum et al., 2005]
CareVis

integrated visualization of computerized protocols and temporal patient data

Cycle-Plot

Multi Scale 1/3

Multi-Scale 2/3
We employ the structure of time to solve our problems: Week of month, day of week, hour of day, 5-minute-block of hour.

This visualization uses the available space much better. The user is guided by the structure of time. Patterns become visible, the overview provides a prospection for regions of interest.