



visualization of **time-oriented data**

visualization techniques

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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 tabacco consume? (DEMO)
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? (DEMO)
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"? (MOVIE)
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 the 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? (MOVIE)
17. Which stocks increased in a similar way during the year? (DEMO)
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)

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?

Applications 1/3

informations-
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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

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) (2 (MOVIE), 3 (DEMO), 4)
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

Section B:
time & arts

Renaissance

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[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

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visualisierung



**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]

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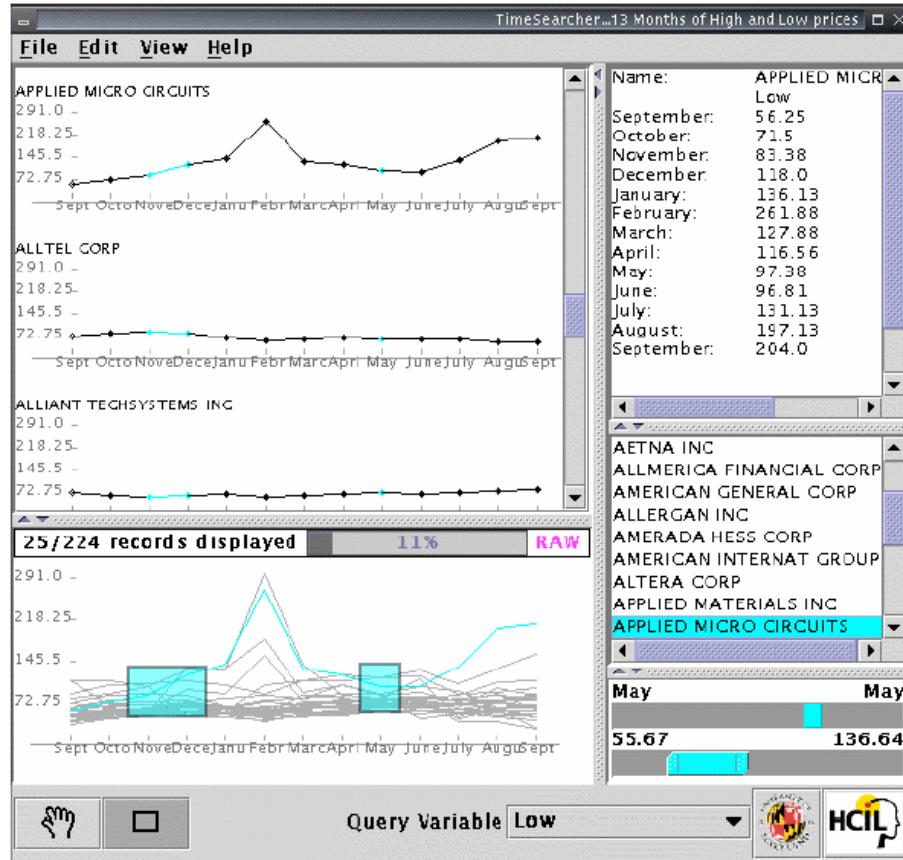


Figure 2: TimeSearcher with graph display and highlight in query window.

<http://www.cs.umd.edu/hcil/timesearcher/>

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

DEMO

Interactive Parallel Bar Charts (IPBC)

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[Chittaro et al., 2002]

basic vis 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

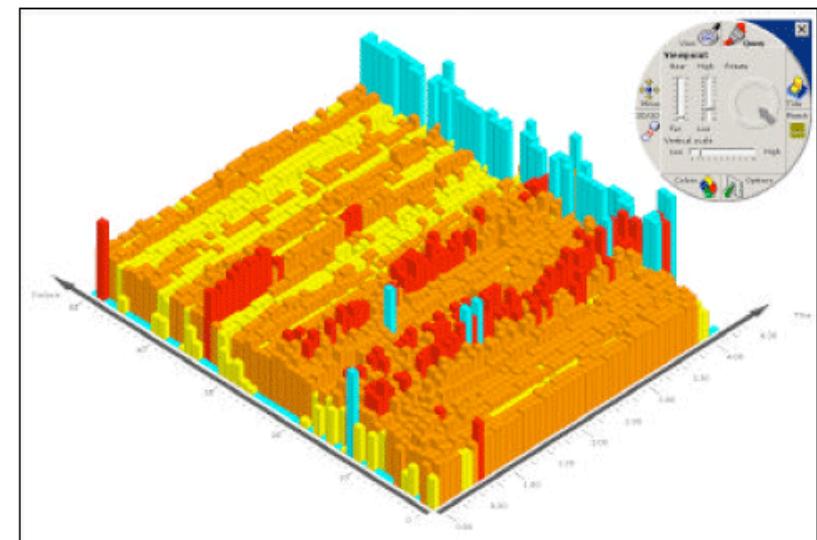


Fig. 1. A Parallel Bar Chart.



Midgaard 1/2

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[Bade et al., 2004]

visualization of medical intensive care data

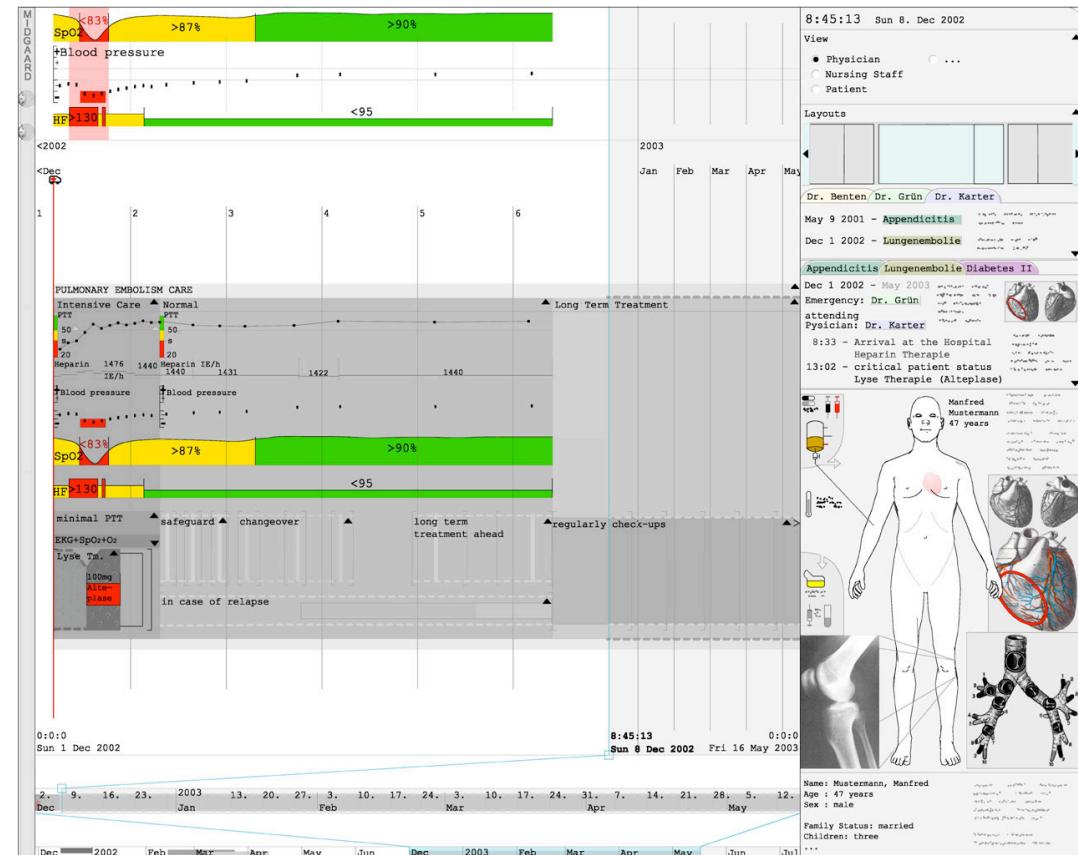
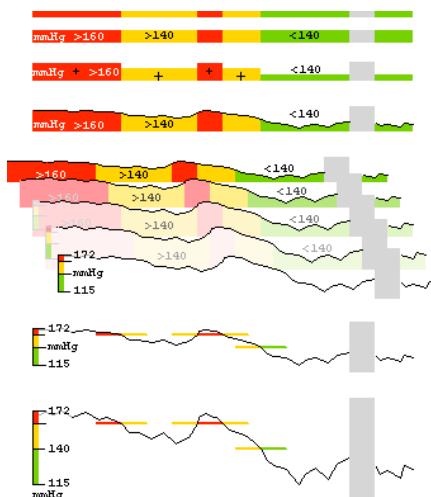
qualitative scales

quantitative scales

qualitative / quantitative
hybrids

semantic zoom

smoothly integrated



Midgaard 2/2

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different granularities

vis of measurement deviation,
trustability of data points,
and missing data

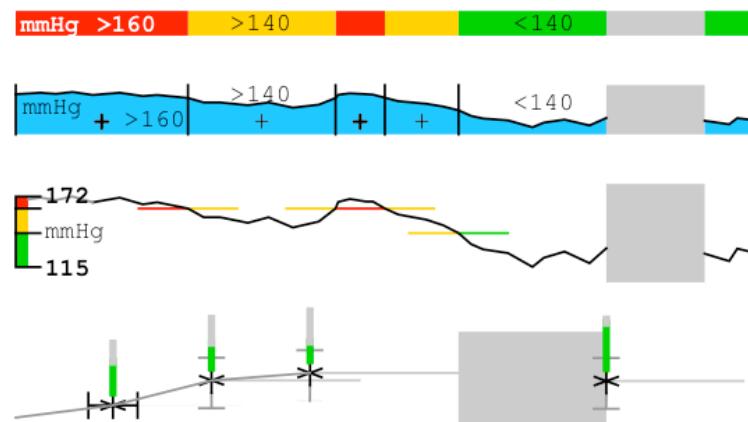


Figure 11. Gray regions indicate missing of valid data values in any representation.



Figure 8. Representation of a data point with a more coarse (left) and a more precise (right) occurrence time than the actual timeline scale. Additionally a horizontal line indicates the valid time of the data point.



Figure 9. Visualization of measurement deviation by extending the representations as shown in Figure 8.



Figure 10. Trustability of data points represented by a green filled bar. (extending Figure 8).



TimeWheel / Zeitrad 1/2

[Tominski et al., 2003]

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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

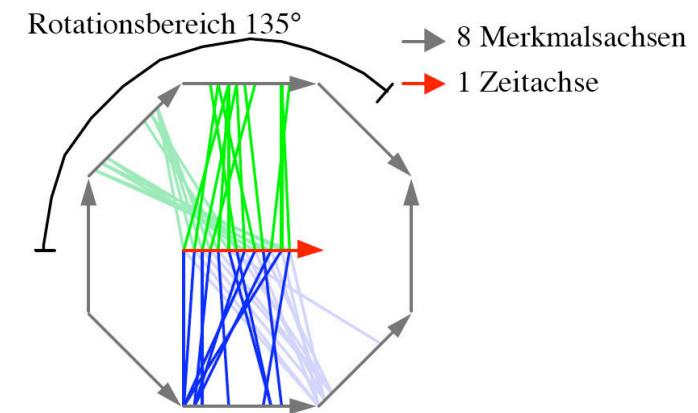
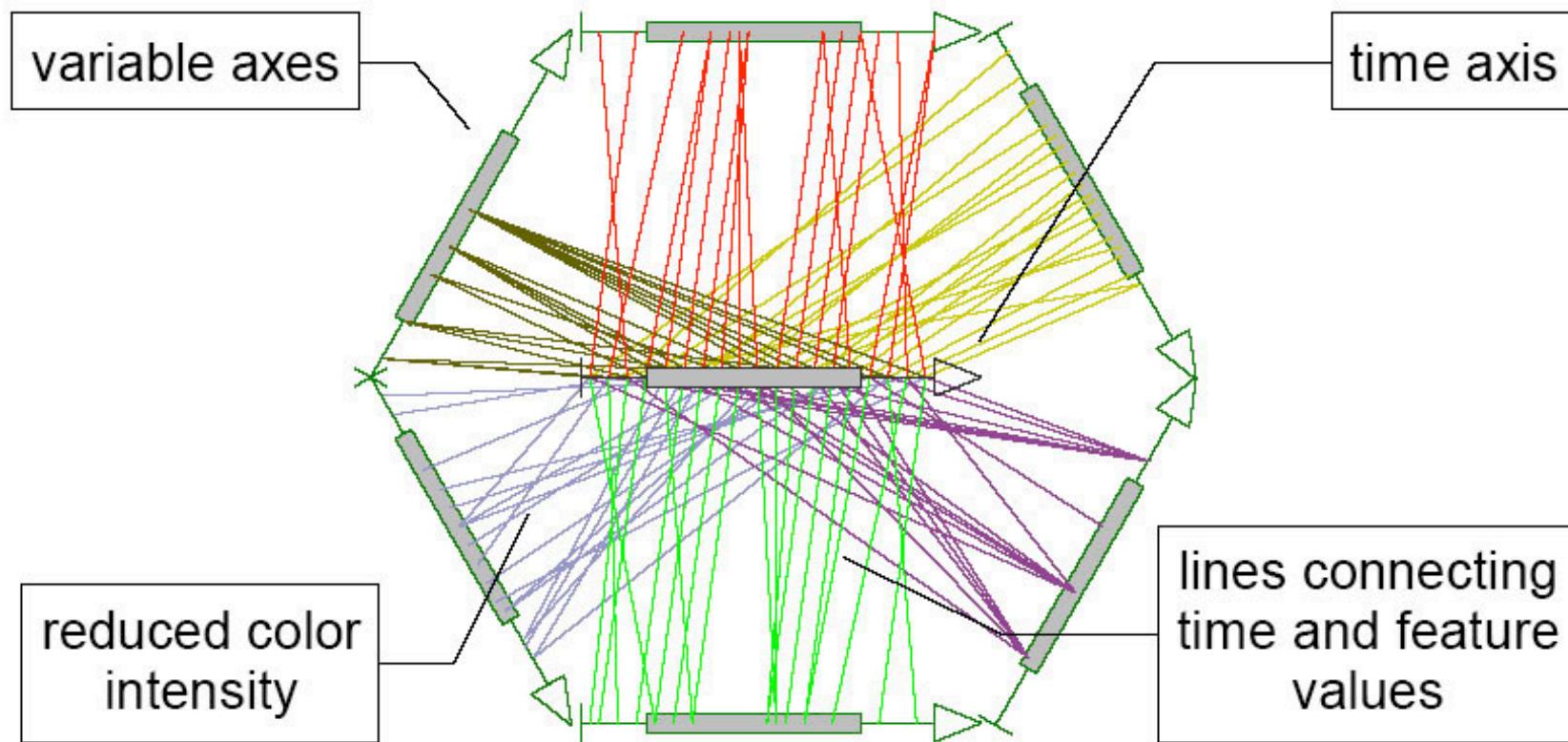


Abb. 9 Das Zeitrad

TimeWheel / Zeitrad 2/2

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User interaction:

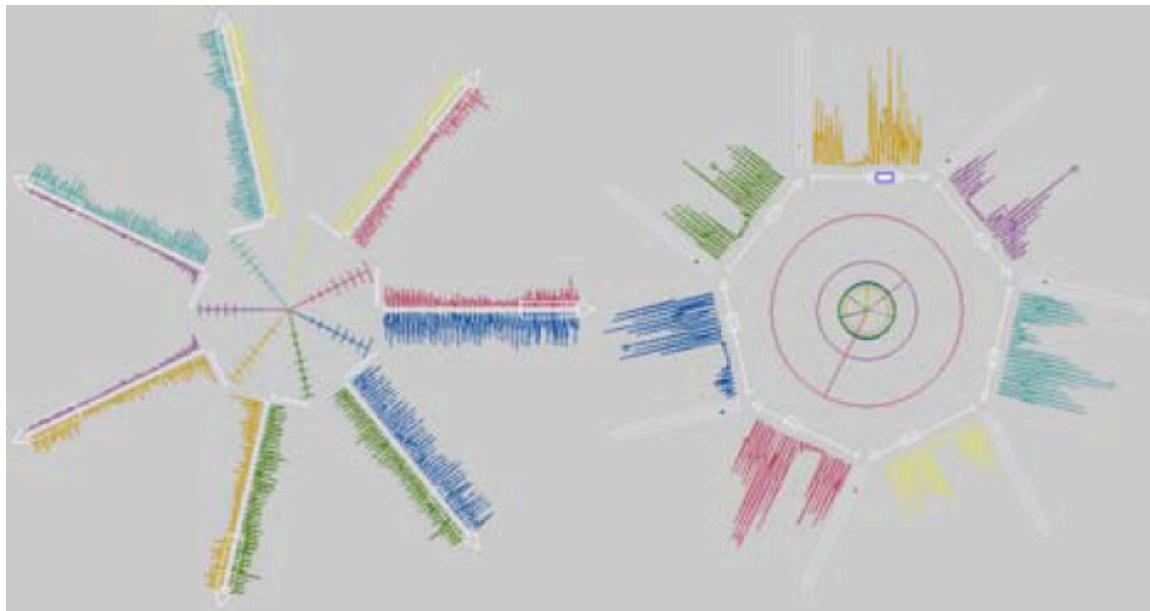
Rotation of variable axes

(moving axes of interest into a position parallel to the time axis)

MultiCombs

[Müller and Schumann, 2003]

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Axis based technique

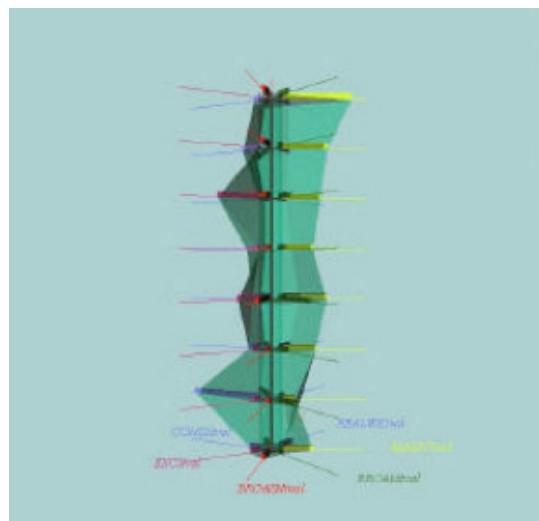
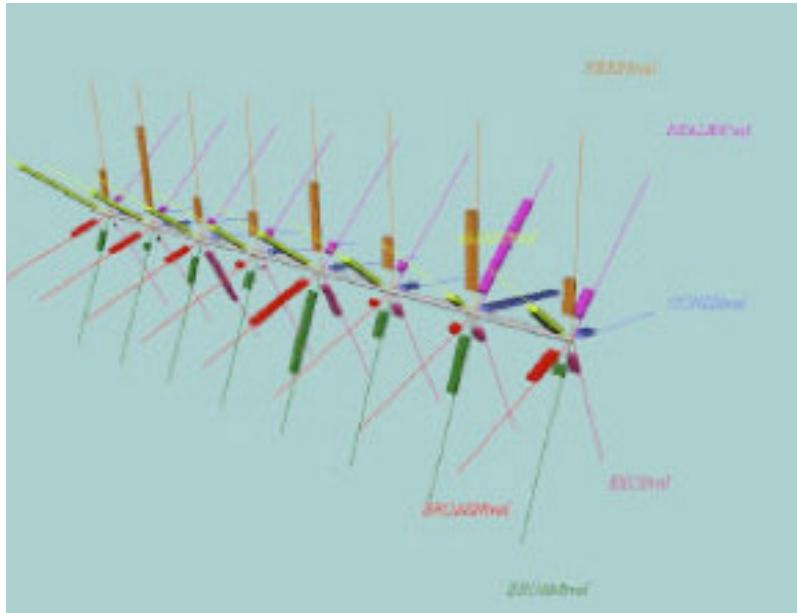
Multiple parameters on multiple time axis, circularly arranged

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

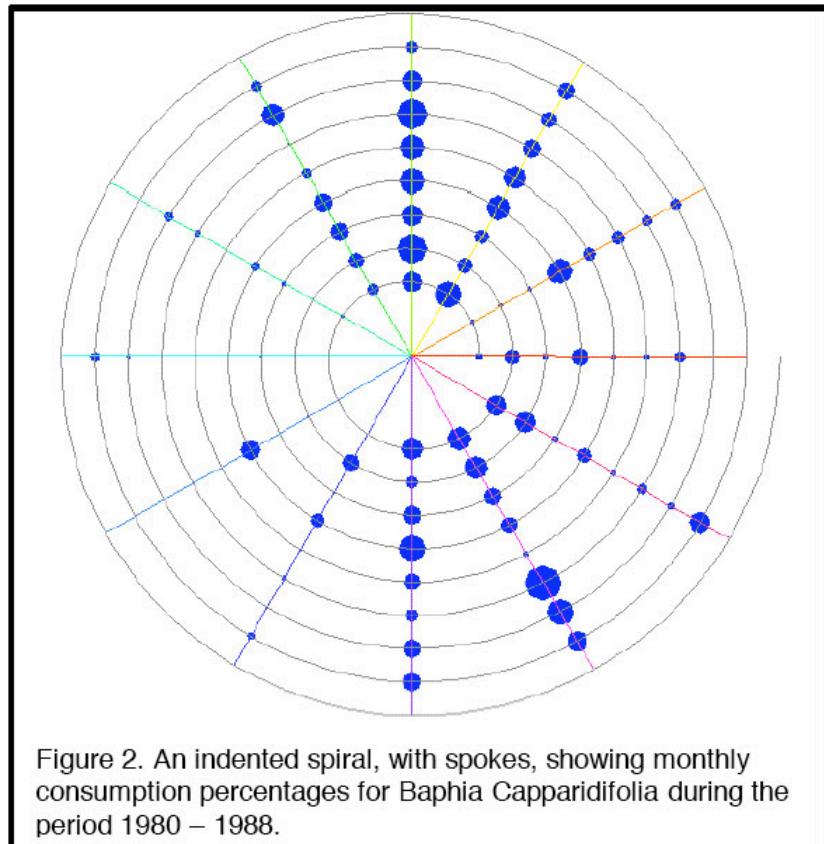
transparent veil to enhance evolution

not suited for nominal data

Serial Periodic Data 1/6

[Carlis and Konstan, 1998]

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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

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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

Serial Periodic Data 3/6



Figure 3. A spiral display of monthly consumption percentages for all 112 foods during the period 1980 – 1988.

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:

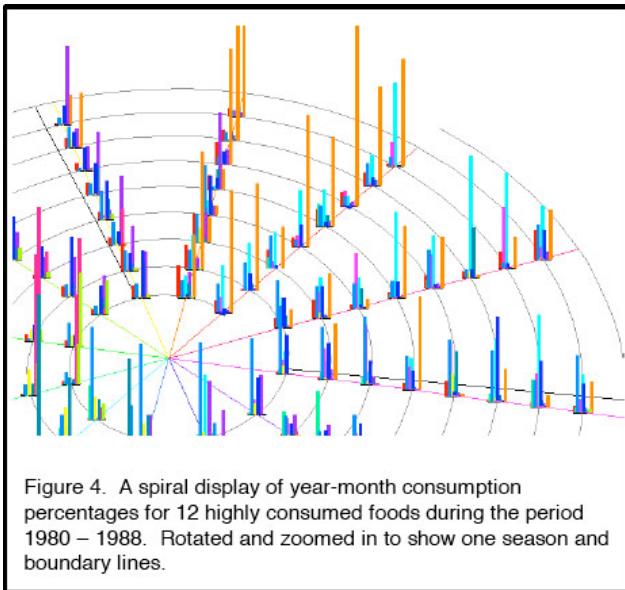
Occlusion

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

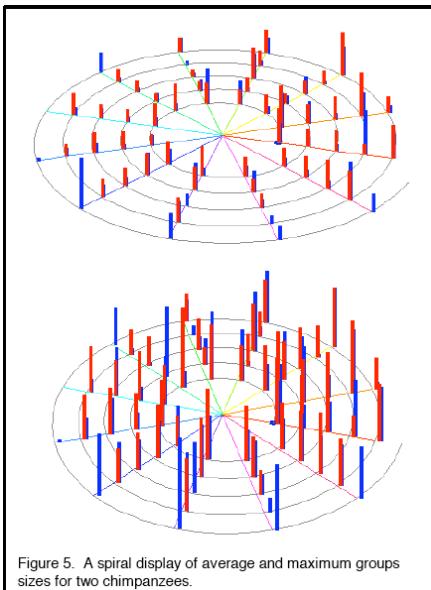
Definition of data derived border lines

Display of several data sets simultaneously

Using bar charts

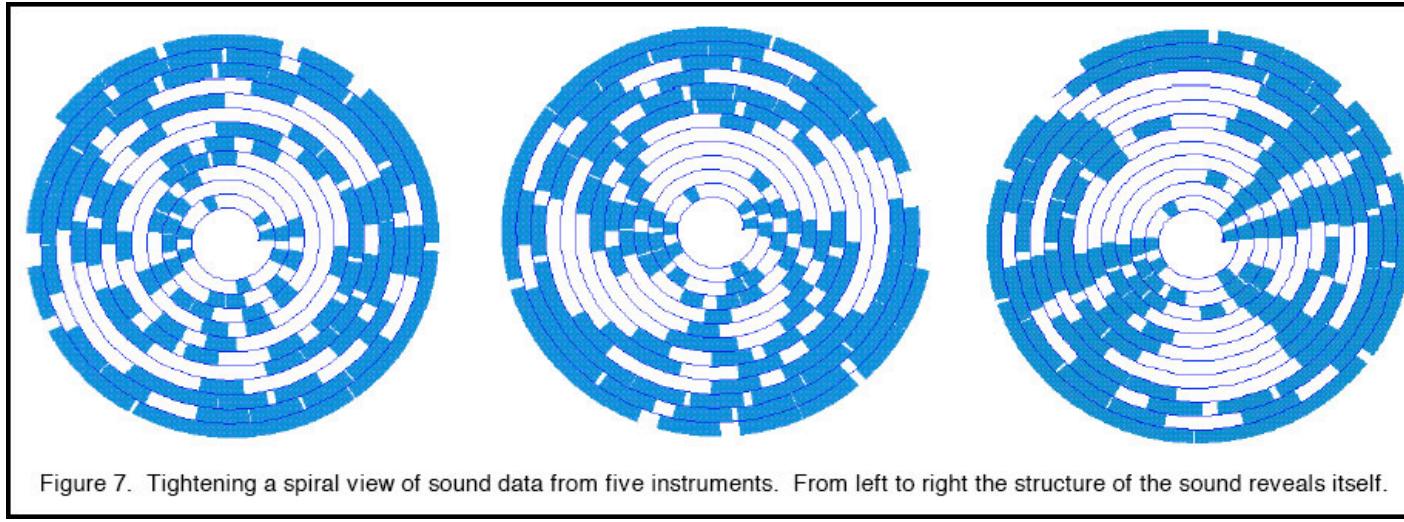
Color coded

Multiple, linked spirals



Serial Periodic Data 5/6

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Interval data

Only duration of element

Periodicity unknown

Animation

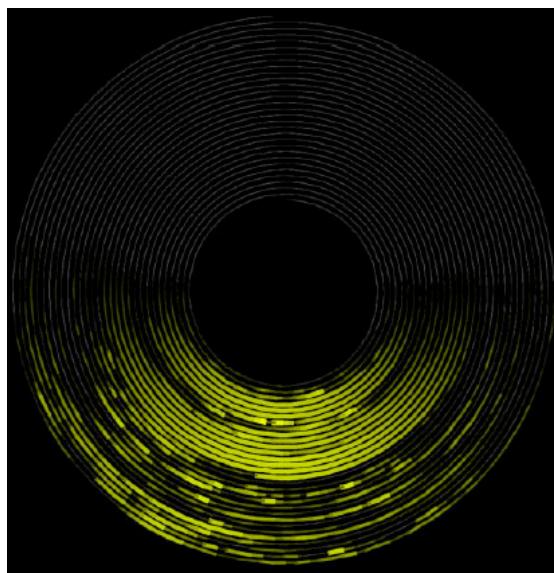
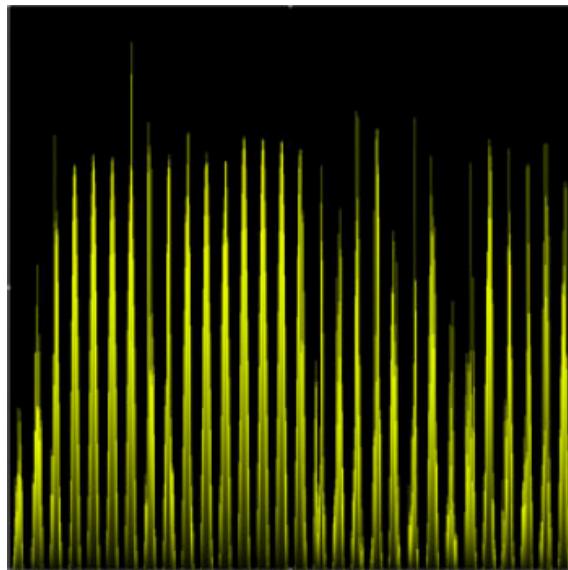
User experience findings:

- + 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

[Weber et al., 2001]

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Main intension: 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

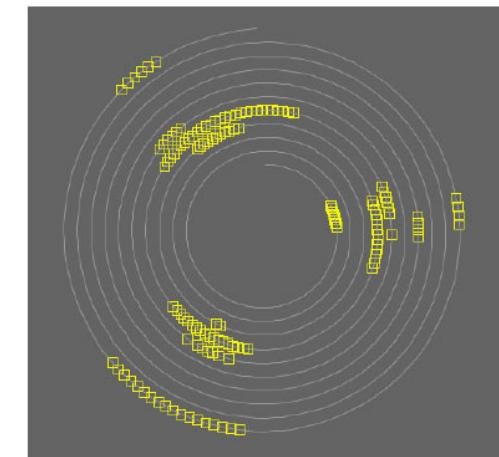


Figure 2: Nominal time-series data presented on a Spiral. The periodic behaviour of the underlying process is revealed.

Spiral Graph 2/3

Two possibilities to detect periodic behavior:

1. Computational:

Compute frequencies with higher amplitudes via *Fourier Transformation*

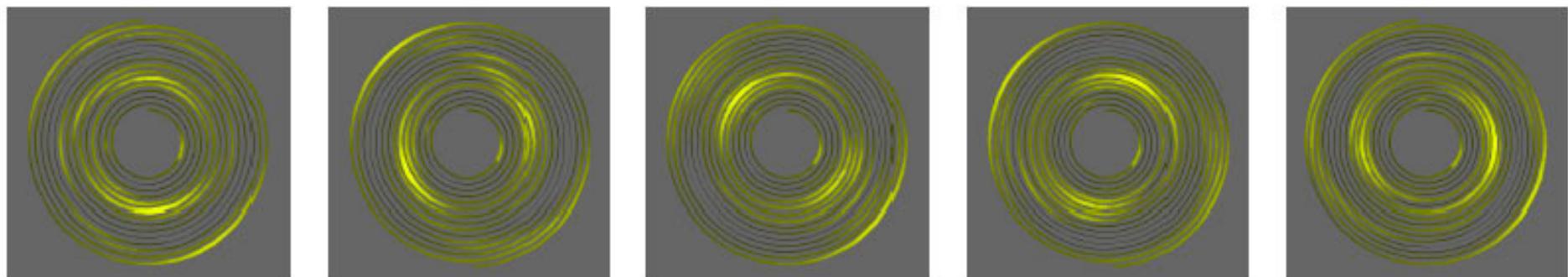
2. Visually:

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

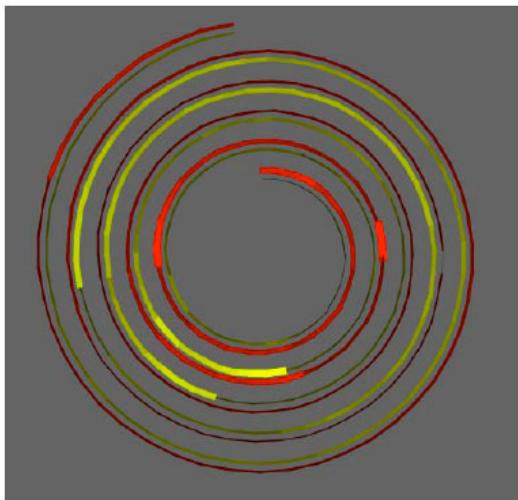


Figure 4: Stock prices of Microsoft (yellow) and Sun Microsystems (red) in five years on parallel spirals.

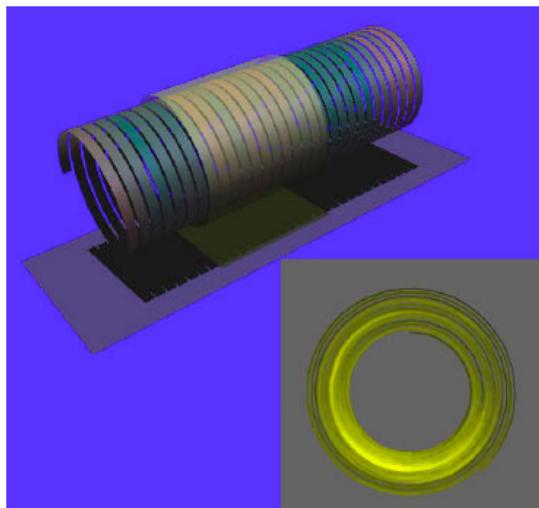


Figure 6: Using a helix in 3D to support intuitive browsing through a large data set.

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.

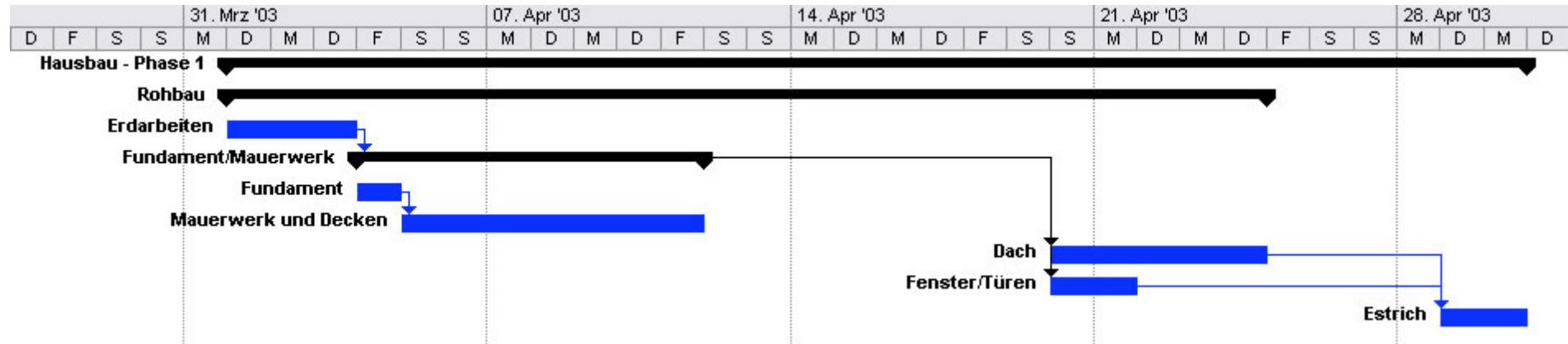
Brushing integrated.

Selected region is displayed in 2D spiral.

3D helix best used for navigation only.

GANNT charts 1/2

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Project management, project planning

Tasks and their temporal attributes (location, duration)

Milestones

Past + present + future

Hierarchical decomposition

GANNT 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

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

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Based on Time Lines

Facets

Visualizing personal histories and patient information

Horizontal bars showing temporal location and duration of data elements

Past + Present

<http://www.cs.umd.edu/hcil/lifelines/latestdemo/kaiser.html>

DEMO

Pros:

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

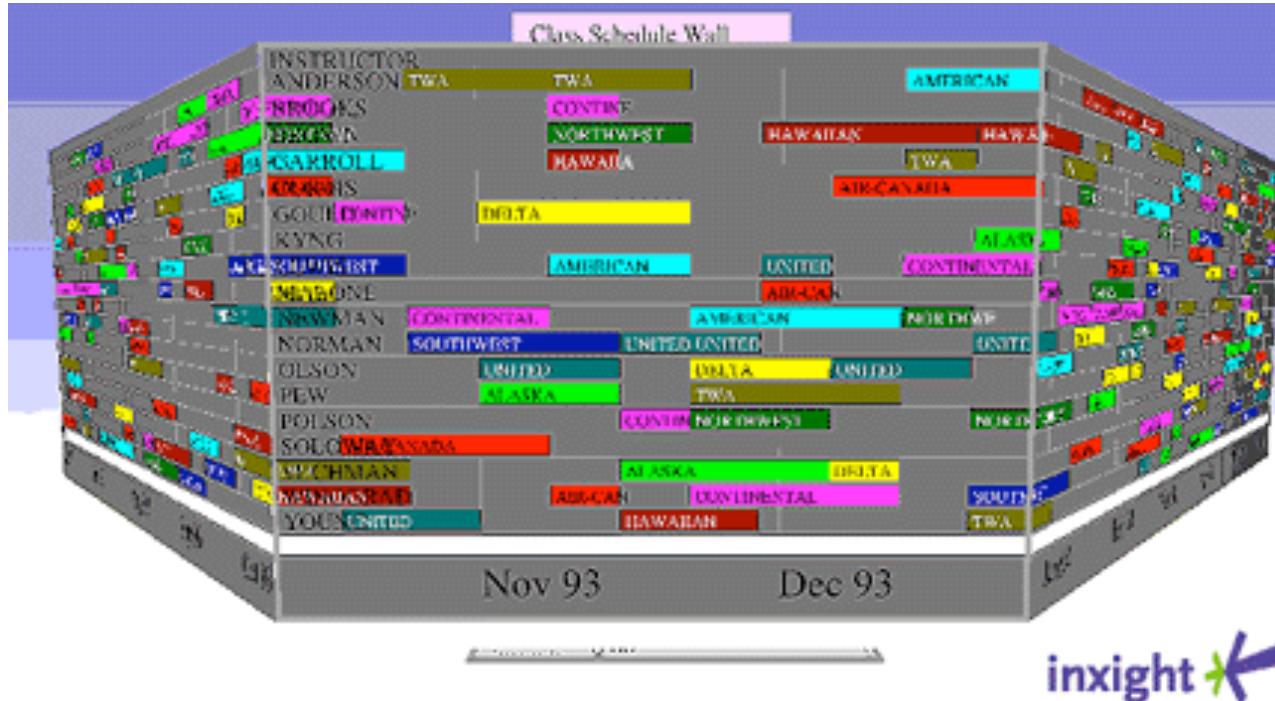
Cons:

- No hierarchical decomposition (only Facets)
(Just past and present)

Perspective Wall

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[Mackinlay et al., 1991]



inxight ↗

Large collections of documents

Focus + Context of elements over time

Intuitive 3D metaphor for distorting 2D layout

Color coding

Smooth transitions, 3D interactive animation

Dynamic Timelines

[Kullberg, 1995; Kullberg, 1996]

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3D presentation of **historical information**

history of photography

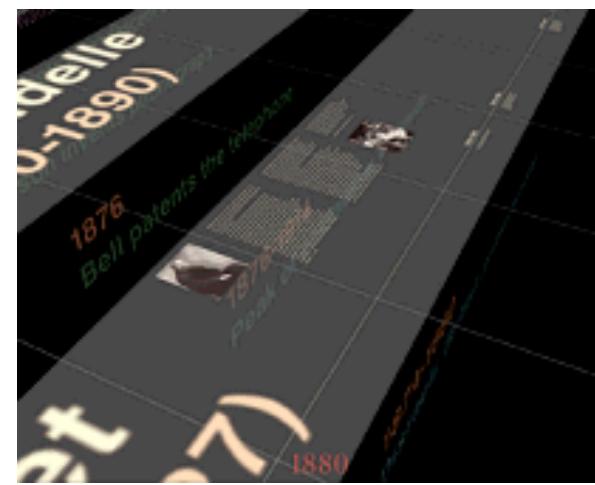
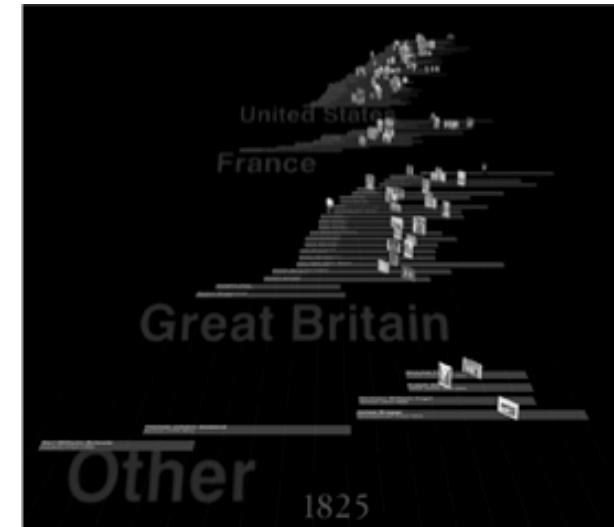
seamless micro and macro readings

semantic zoom

translucency

animated visual transition

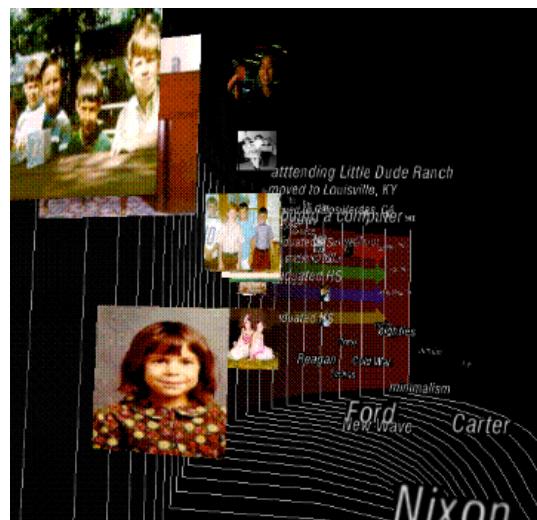
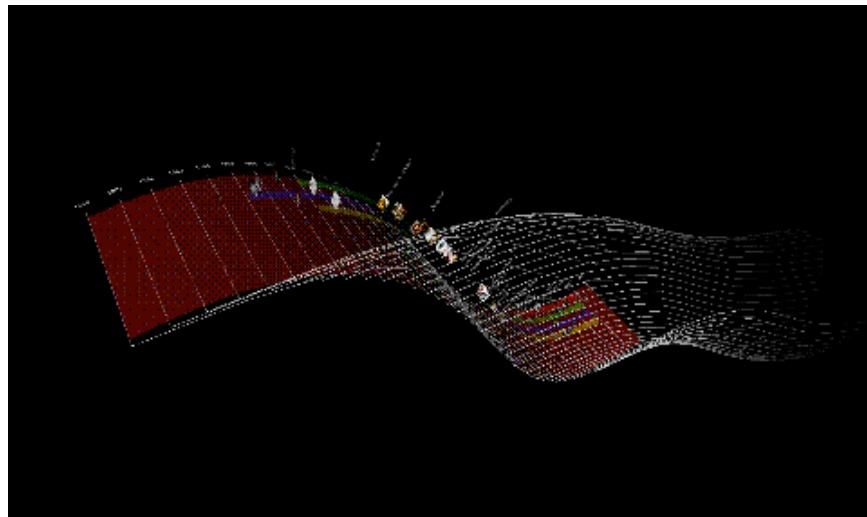
F+C by selective transparency (queries)



Timeline Cinematic Temporal Ride

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[Elise Co, 1997]



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/>



The Historical Event Markup and Linking Project (HEML)

Event	Date	Location
Newton is born	AD 1643 January 4	Woolsthorpe
Newton studies at Trinity College	AD 1661 June 5 -- AD 1668	Cambridge
Newton lays the foundations of calculus	AD 1665 June 1 -- AD 1667	Woolsthorpe
Newton publishes 'Philosophiae naturalis principia mathematica'	[AD 1687 -- AD 1687]	Cambridge
Newton dies	AD 1727 March 31	London



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<http://www.heml.org/>

marking up web documents

different representations

table

timeline

map

animated map

**XML-Schema for historical
events**

participants, dates, location,
keywords, evidence (ref)

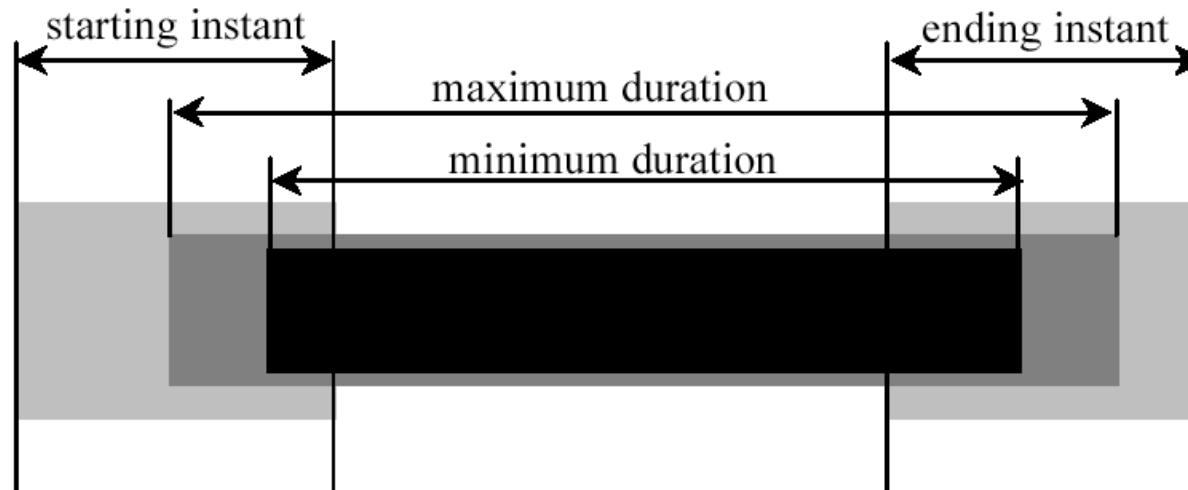
web service

use of open technologies
XSLT, SVG, Servlets, ...

Temporal Objects 1/2

[Combi et al., 1999]

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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

Pros:

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

Cons:

- Only presentation, no interaction
- No direct manipulation

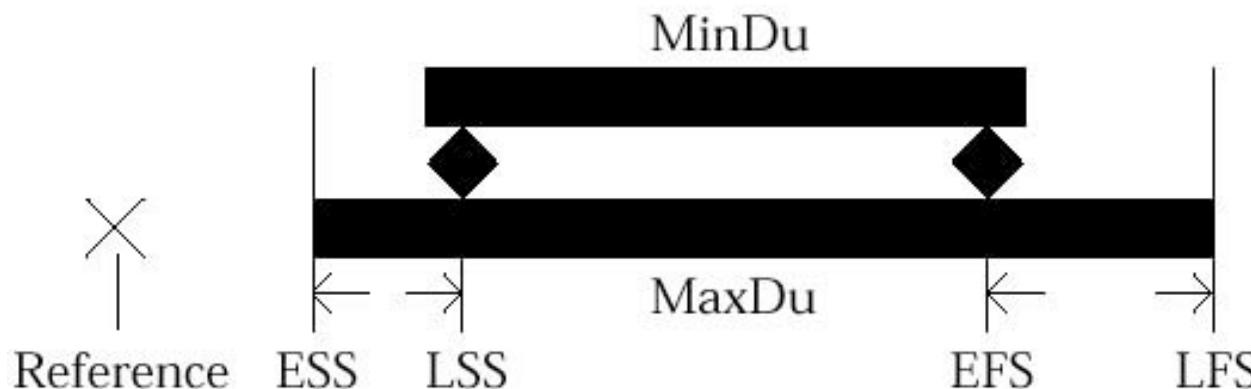
Time Annotation

Glyph 1/2

[Kosara and Miksch, 1999]

Definition:

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



For representation of future planning data (uncertainty / indeterminacy)

Characteristics:

Time points are relative (Reference point)

Notion for temporal granularity

Notion for missing values / incomplete specifications

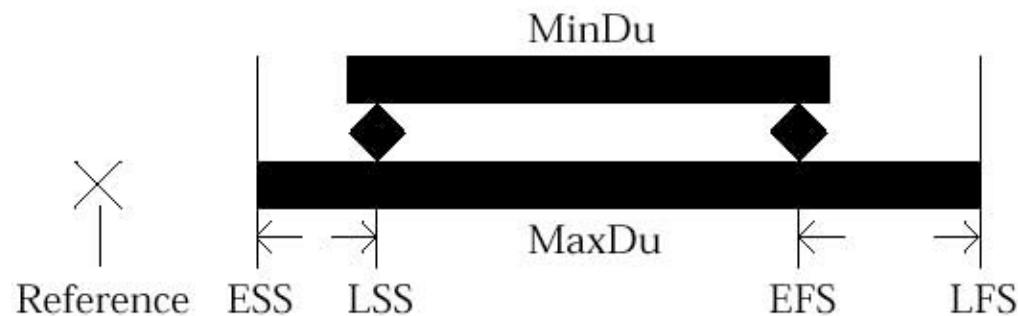
Metaphor of bar lying on diamonds (preventing invalid constellations)

User interaction / can be manipulated

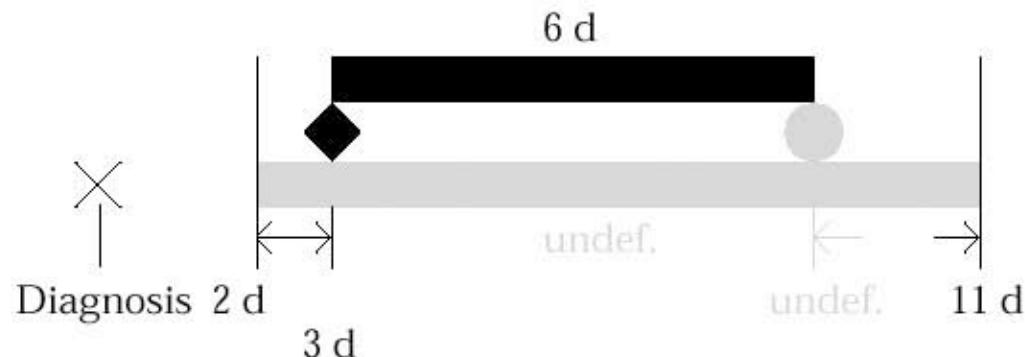
Time Annotation

Glyph 2/2

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



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



MinDu and LFS defined to higher precision than time axis



MinDu and LFS defined to lower precision than time axis



Paint Strips

[Chittaro and Combi, 2001]

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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)

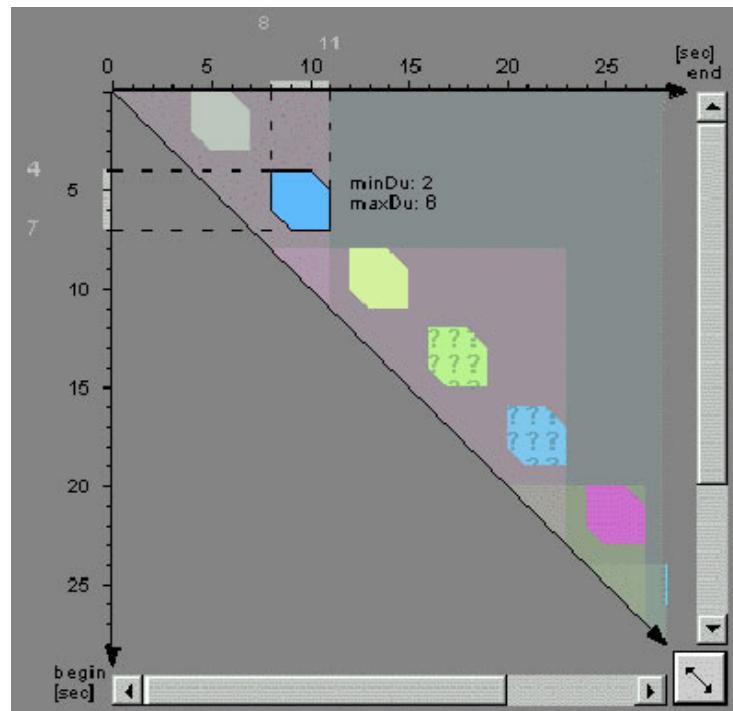
Starting and finishing interval can't be defined independently
from duration

SOPOs 1/2

[Messner, 2000]

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Rit's Set of Possible Occurrences



2D technique

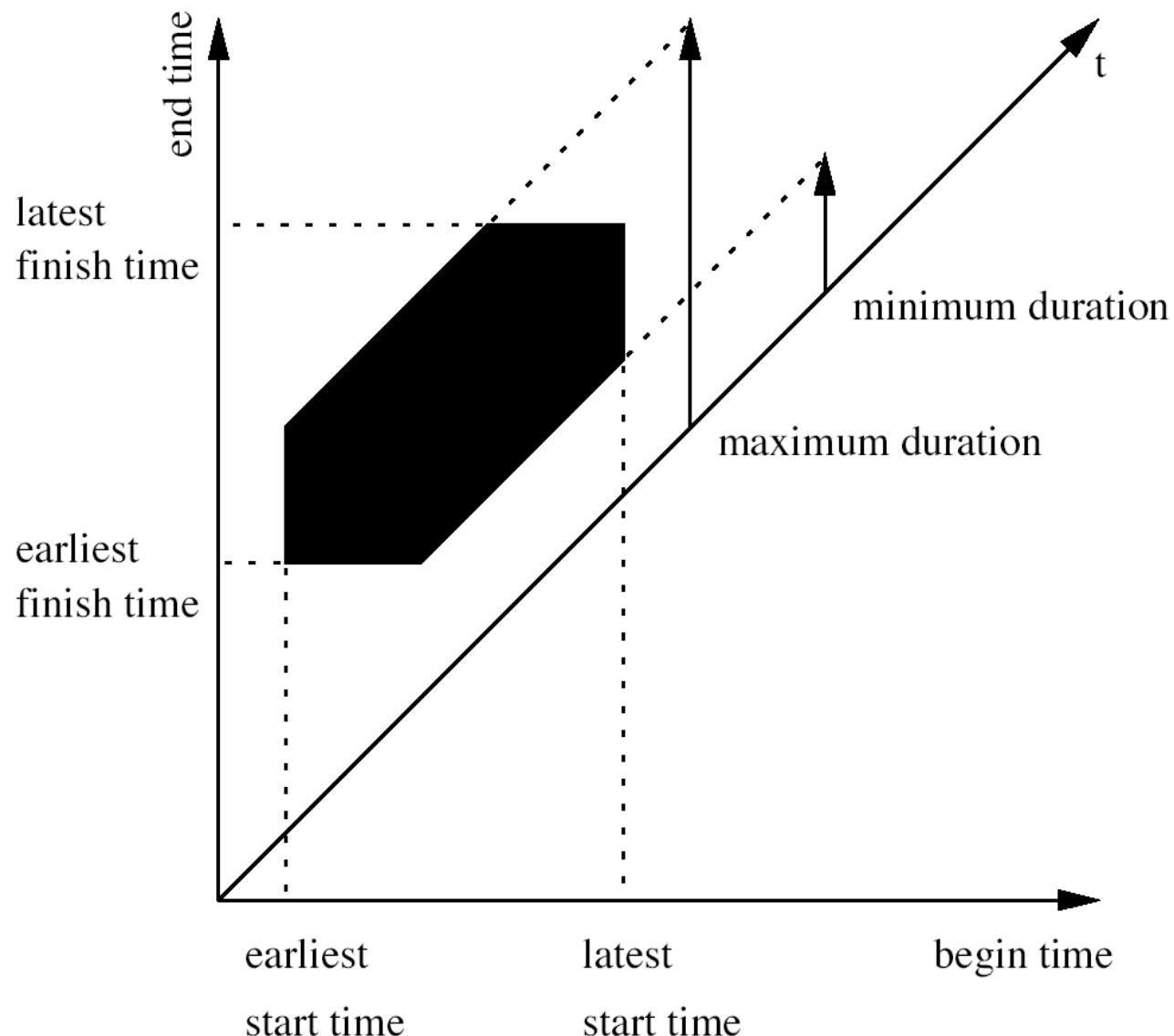
Area depicts set of valid
(start, end) tuples

Designed for easy graphical
propagation of temporal
constraints

Cons:

Representation more
complicated than LifeLine
based ones
Space consumption

SOPOs 2/2



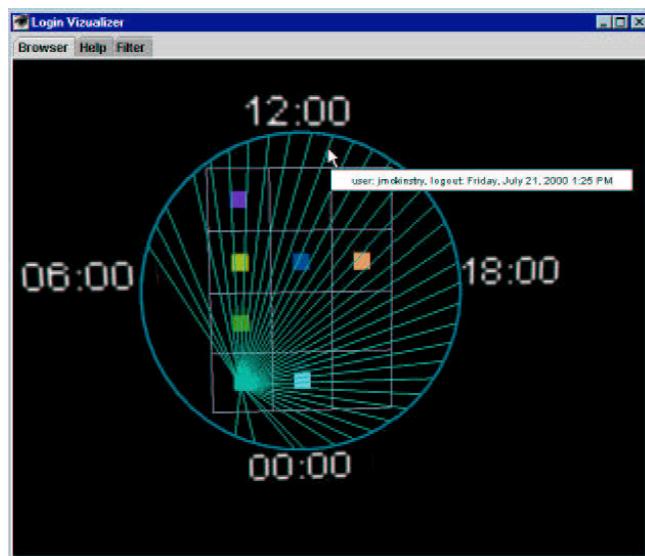
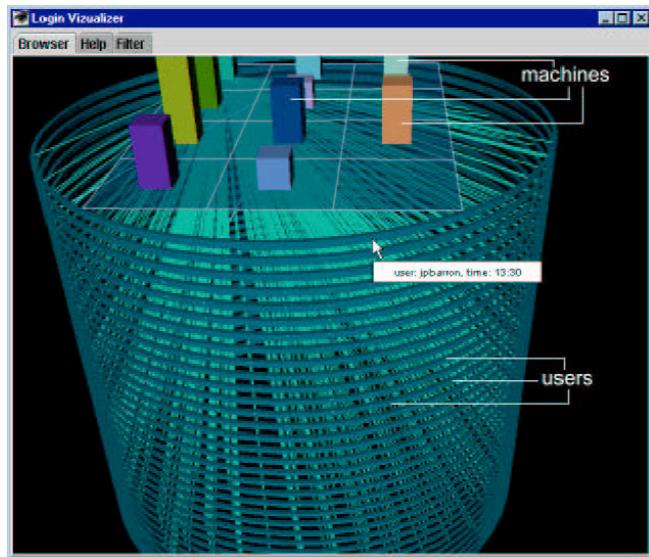
Start interval: x-axis

End interval: y-axis

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

Intrusion Detection

[Muniandy, 2001]



Visualization of user access to machines over time.

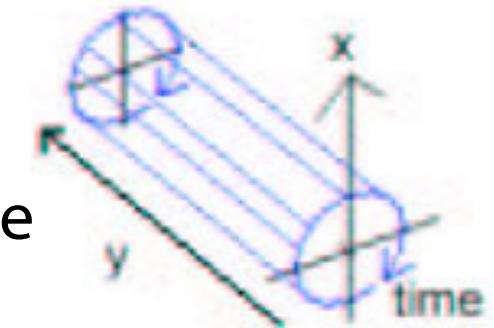
Mapping:

Time: circumference

User: cylinder slice

Machines: cubes on top

Access: connection lines



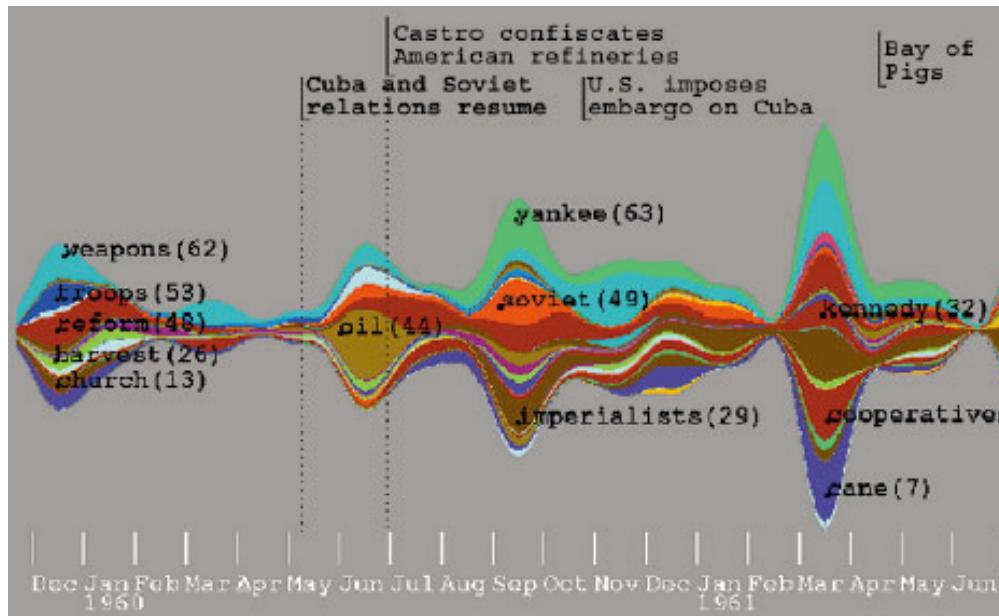
Annotations via tool tips
(mouse hovering)

ThemeRiver™

1/3

[Havre et al., 2000]

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Visualize thematic variations over time.

Across a large collection of documents.

River Metaphor: the “river” flows through time.

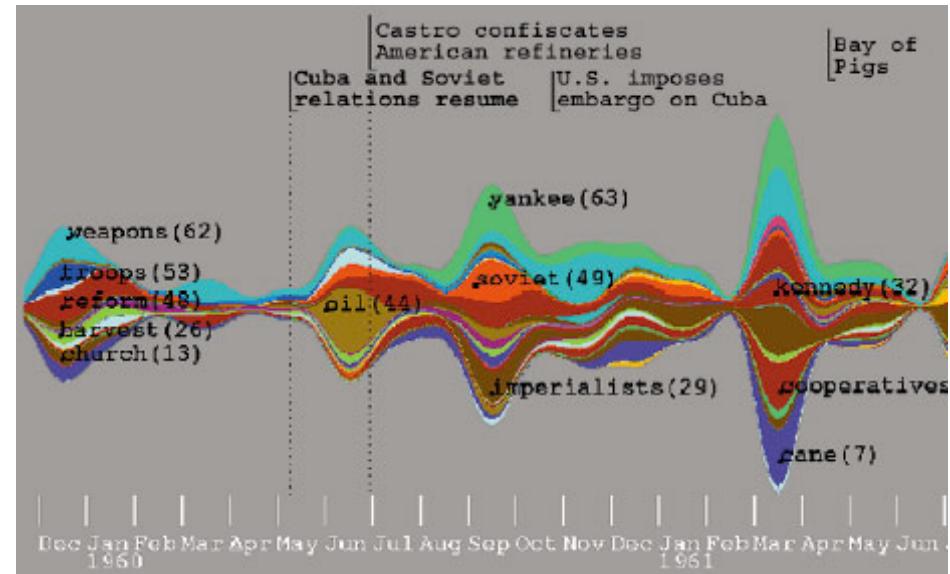
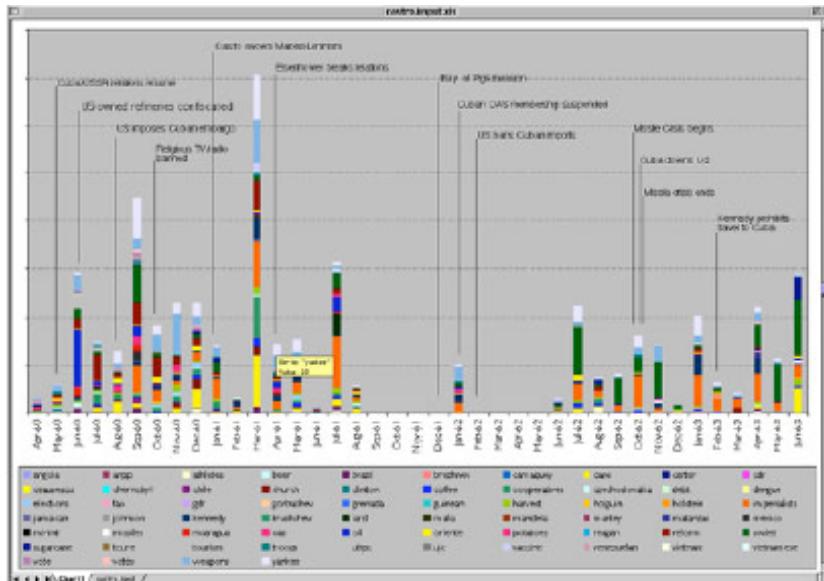
Changing width to depict changes.

Themes or topics are colored “currents”.

ThemeRiver™ 2/3

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Histogram vs. ThemeRiver™:



Discrete values

Exact values

Hard to follow a single current
current

Continuous flow

Interpolation, approximation

Easy to follow a single current
(curving continuous lines)

User interaction:

- Hide or display
 - topic + event labels
 - time + event grid lines
 - raw data points

- Choose alternate algorithms for line drawing

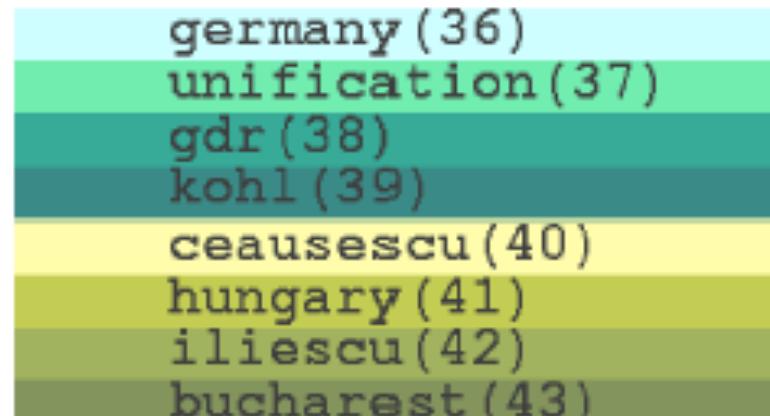
- Pan + Zoom

Color relations

Related themes are associated to the same color family

Improvements:

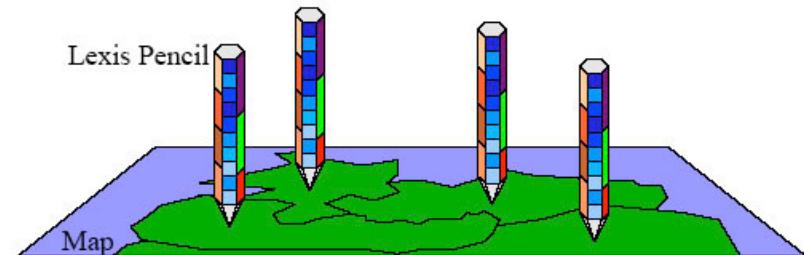
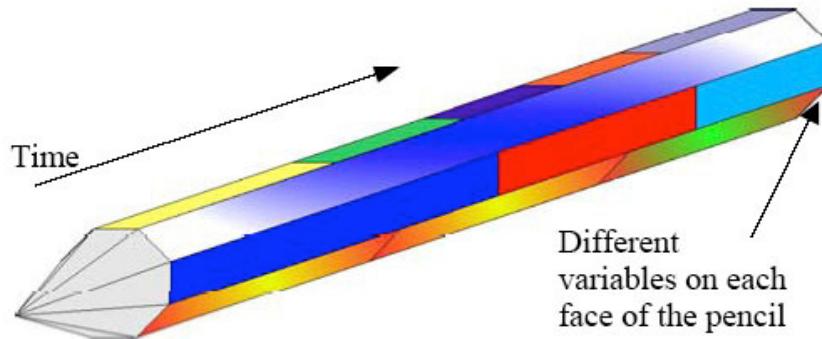
- Parallel rivers
- Display of numeric values (on demand)
- Total number of documents
- Access documents directly
- User defined ordering



Lexis Pencil

[Francis and Pritchard, 1997]

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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

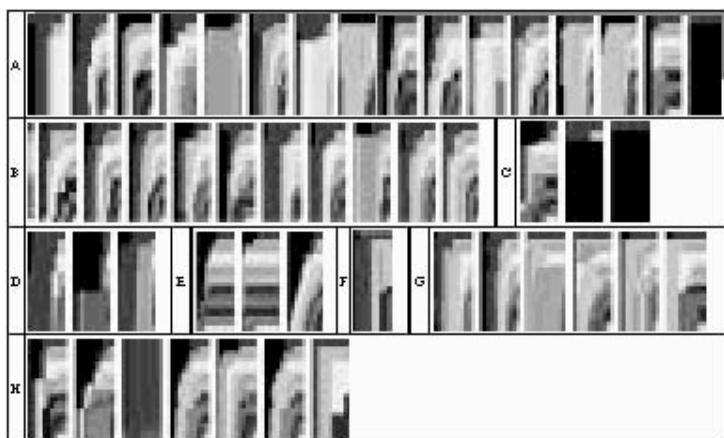
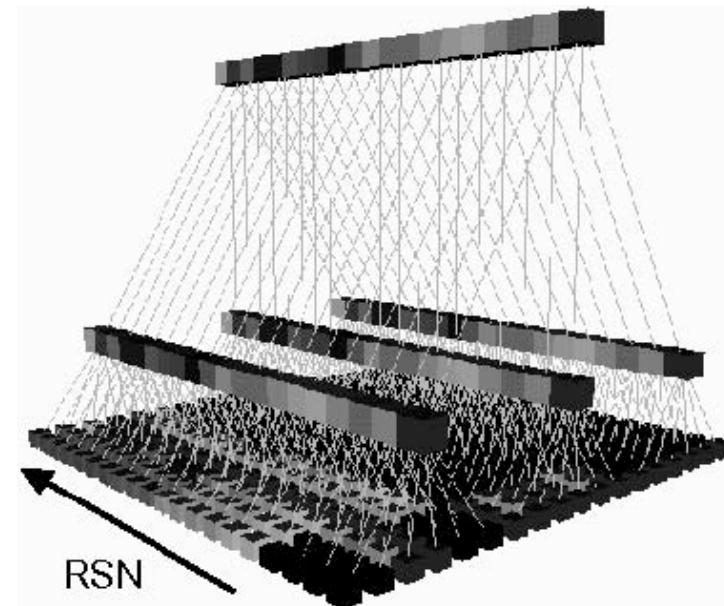
Focus + Context

On pencil: by radial arrangement

In 3D space: enlarging pencil in focus

Software Evolution Analysis

[Jazayeri et al., 1999]



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

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[Xiong and Donath, 1999]



Figure 8. A PeopleGarden showing messages from a message board with 1200 postings over a 2-month period. Height of flower denotes amount of time a user has been at the board.

on-line environment user
visualization

flower metaphor for
individuals

garden metaphor for
environment

visualization of social
network / behavior

PeopleGarden 2/2

[Xiong and Donath, 1999]

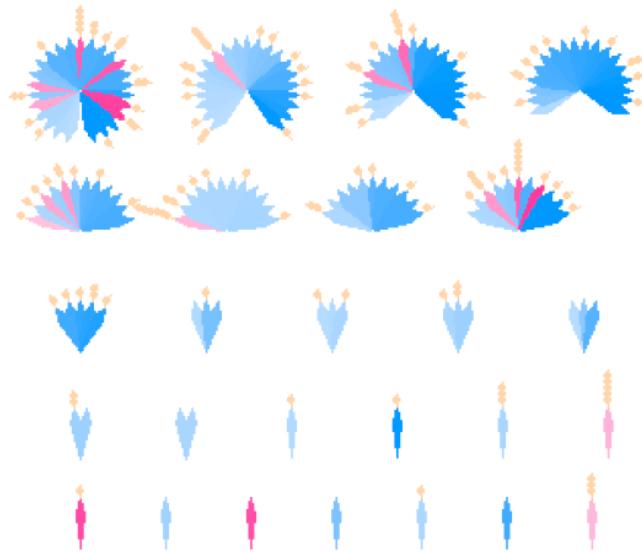


Figure 9. A PeopleGarden sorted by amount of postings. Magenta denotes initial postings, and blue replies. (See <http://graphics.lcs.mit.edu/~becca/papers/pgarden> for colored picture.)

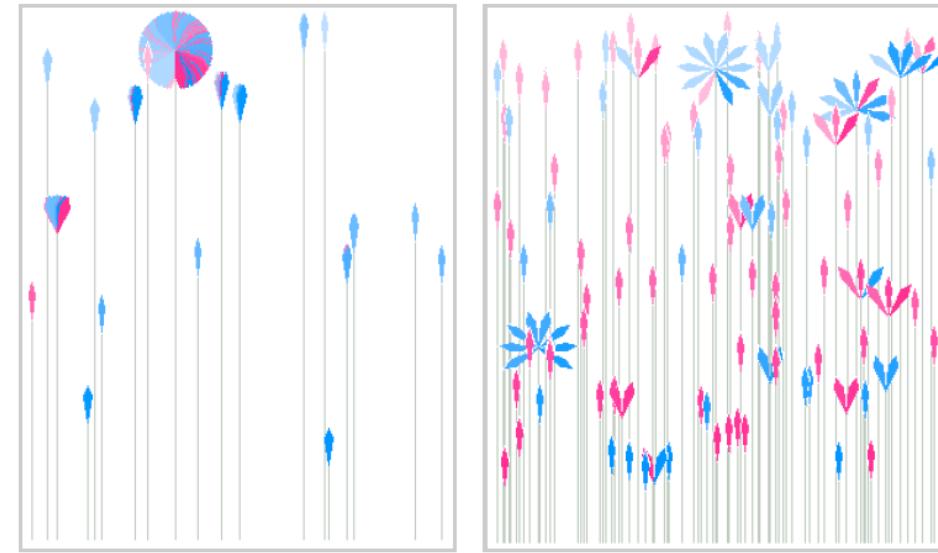


Figure 2. What can data portraits like the ones above tell us about discussion groups? A group with a dominating voice vs. a more democratic group.

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

[Viegas and Wattenberg, 2003; Viegas et al., 2004]

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Wiki web visualization (Wikipedia)

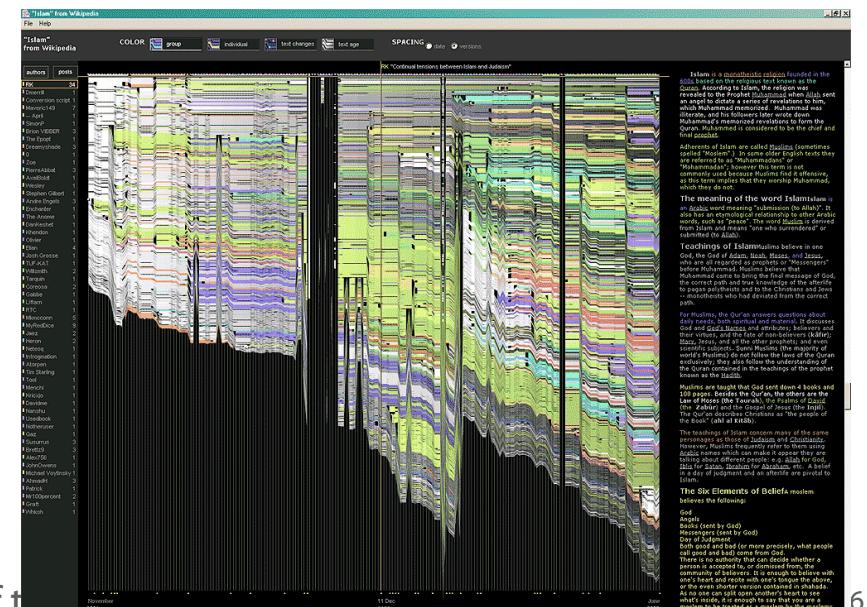
evolution of entries

finding collaboration patterns

revealed complex patterns of cooperation and conflict

i.e. "self healing" - malicious edits were typically repaired
within 2 minutes

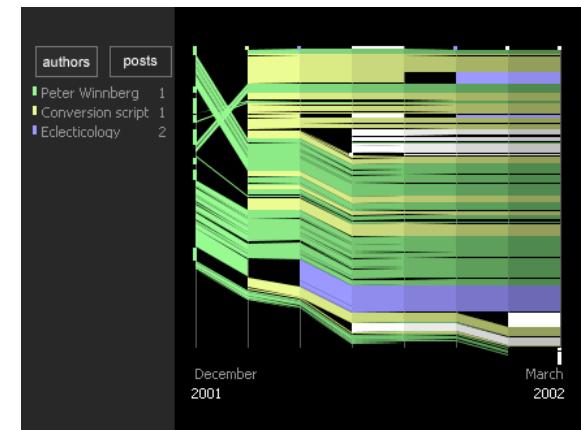
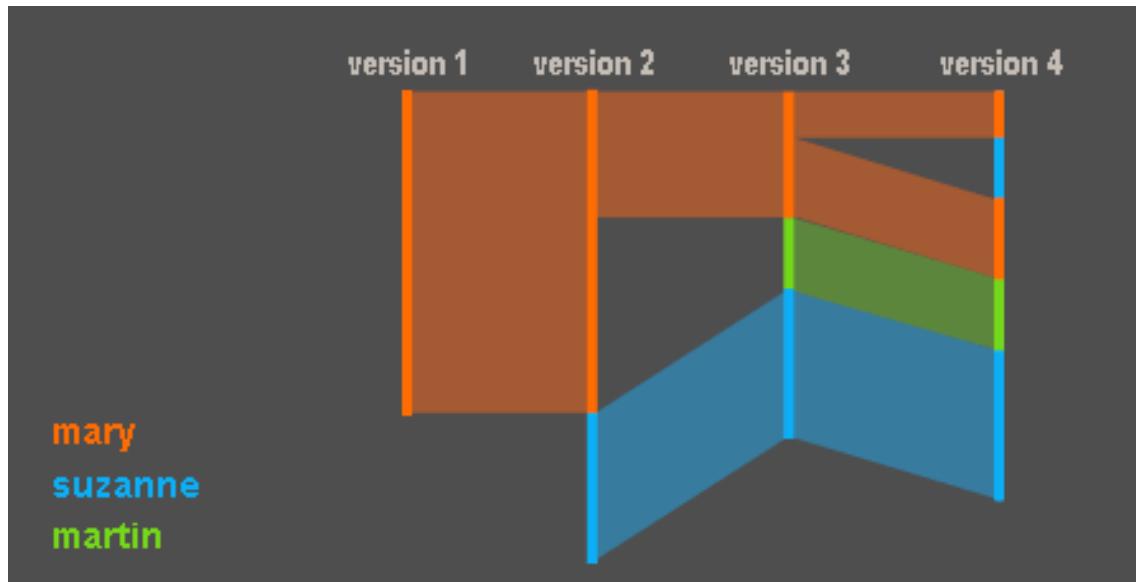
show relationships between multiple document versions



visualization of t

history flow 2/2

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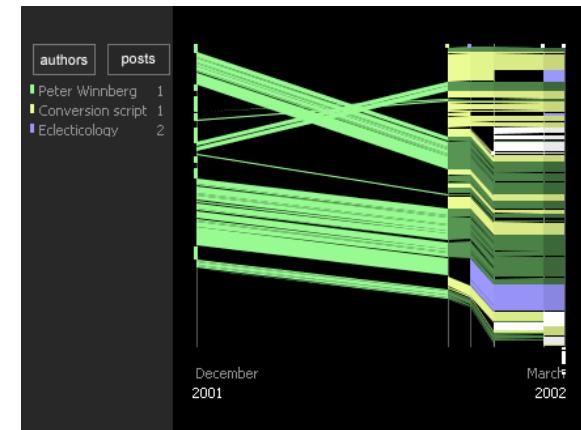
vertical revision lines

length is proportional to text length

different colors for authors (original author)

gaps in connections clearly highlight
deletions and insertions

“space by occurrence” vs. “space by date”



PostHistory 1/2

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[Viegas et al., 2004]

visualizing email activities

dyadic email relationships (people)
time

uncover email patterns

social networks

email exchange rhythms

the role of time in these patterns

mail traffic vs. content

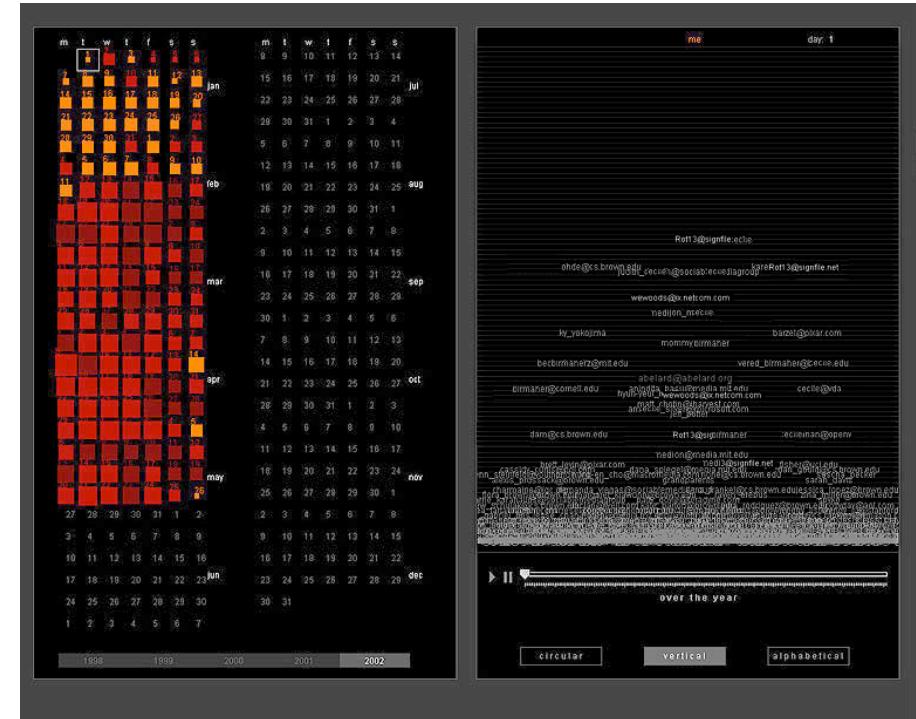
aggregates

Daily email averages (send / receive)

Daily "quality" of emails (directly / copy / mailing list)

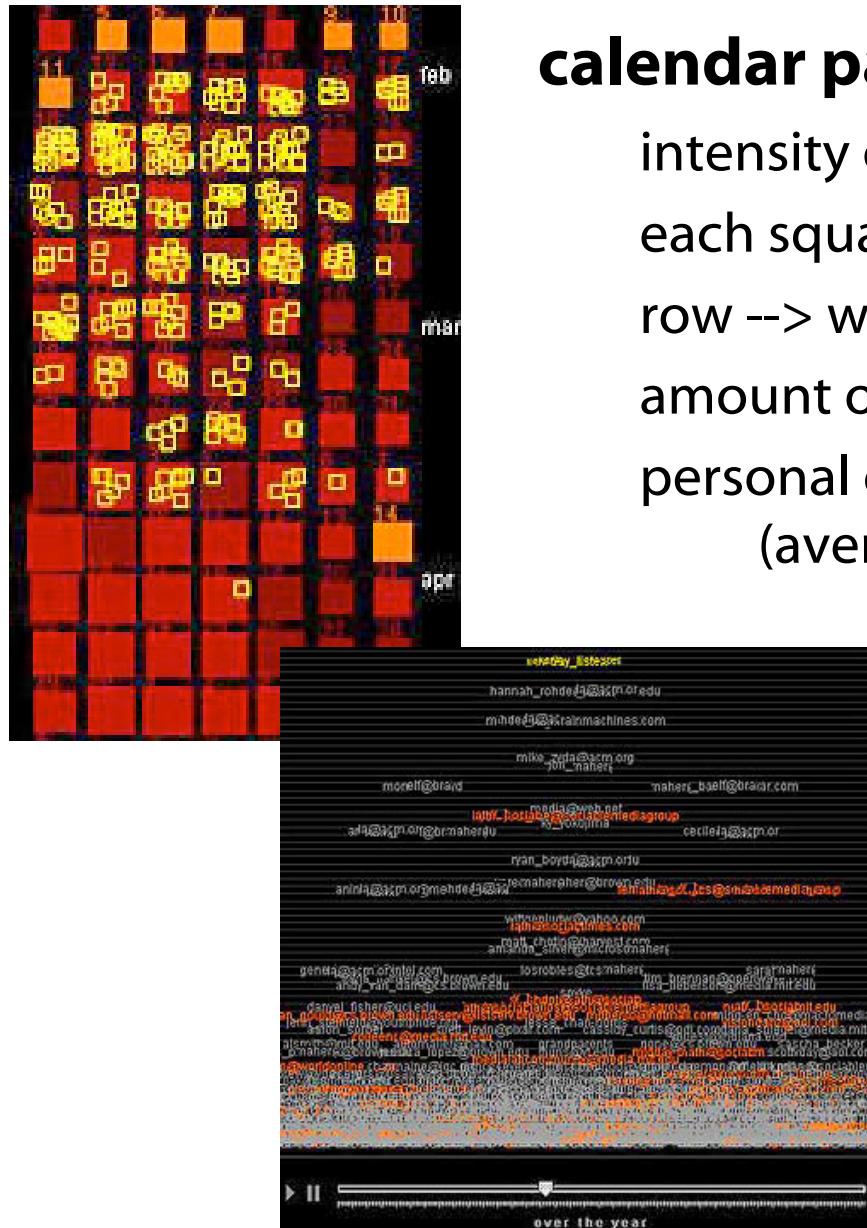
Frequency of email exchanges with contacts

Comparative frequency of email exchanges with contacts



PostHistory 2/2

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calendar panel

intensity of email exchanges over time
each square represents a single day
row --> week; one year at a time
amount of received emails --> 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

[Fry, 1997]

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organic information design

evolution of webpage usage (visited pages)

branches are created when visited for the first time

branches that are visited often, grow

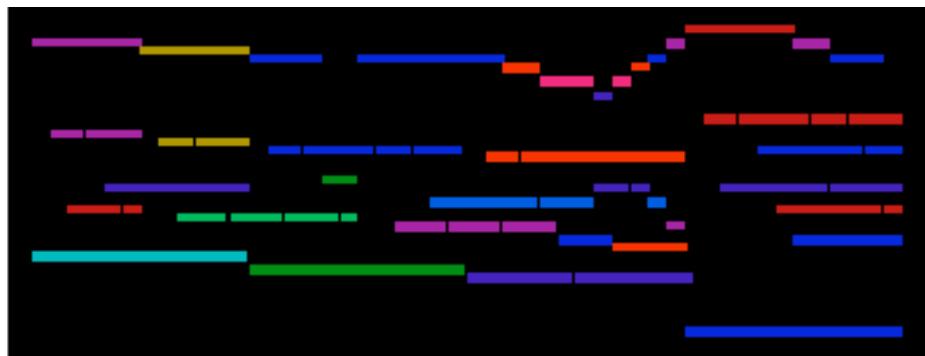
pages that aren't visited slowly fade away

user interaction



<http://acg.media.mit.edu/people/fry/anemone/>

Music Animation Machine (M.A.M.) 1/2



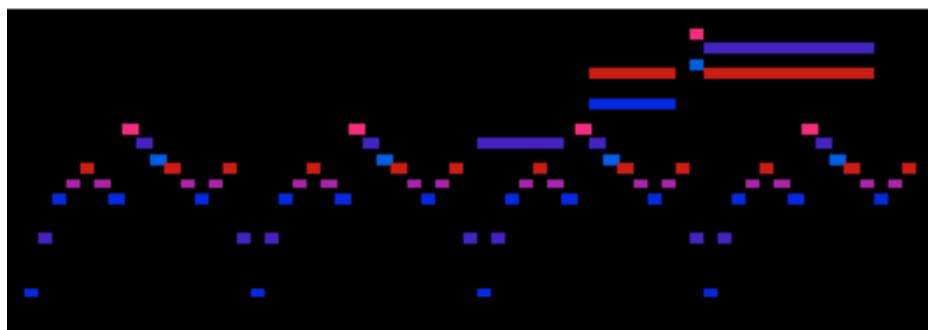
Visualization of music

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>

Music Animation

Machine (M.A.M.) 2/2

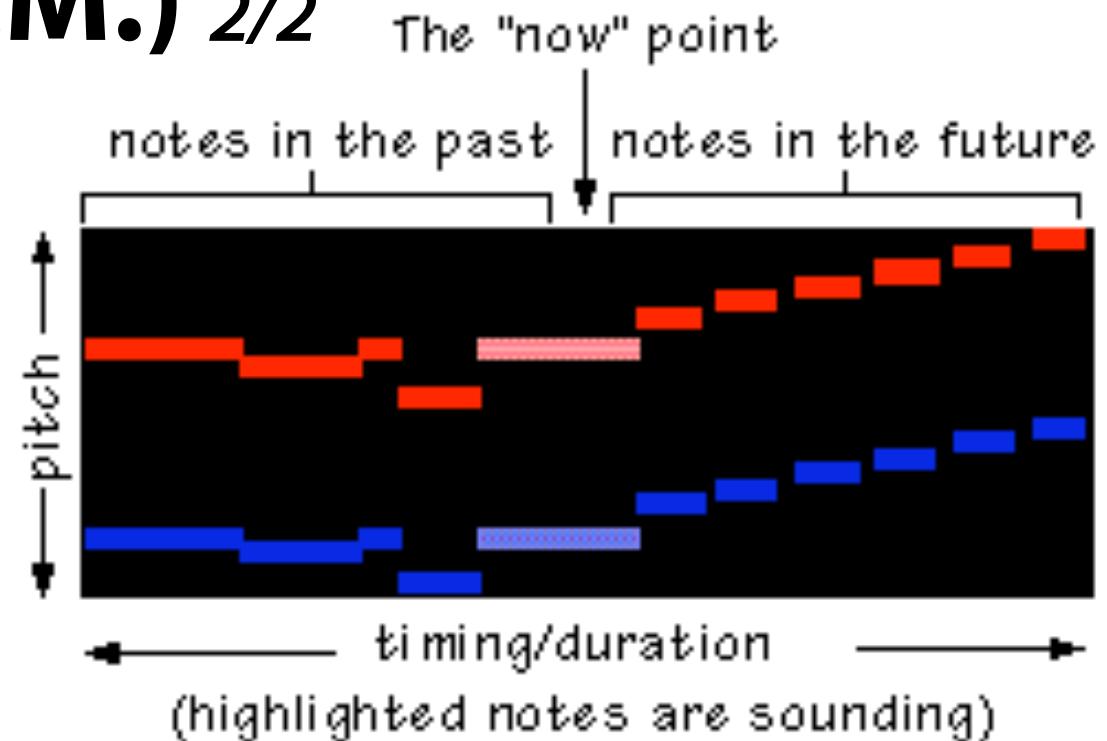
Each note is represented by a colored bar

Each bar lights up as its note sounds

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

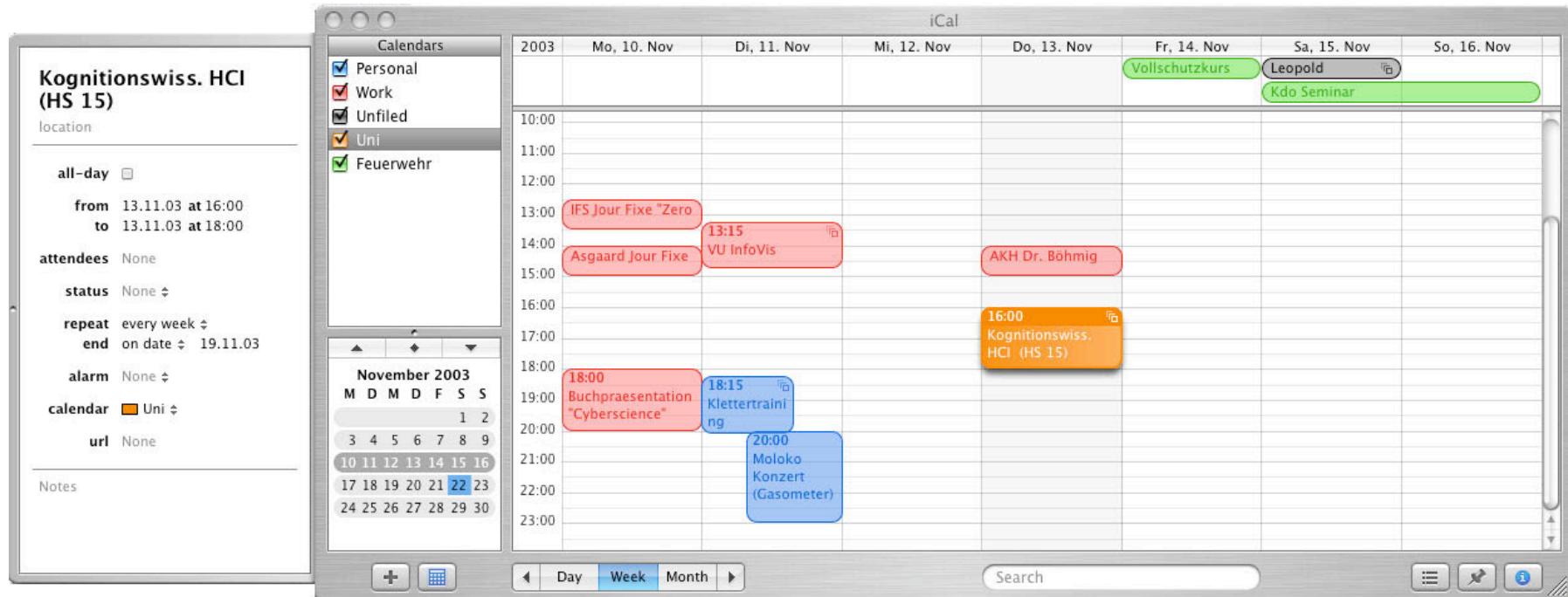
The vertical position of the bar corresponds to the pitch

The horizontal position indicates the note's timing



Calendar Tools

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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

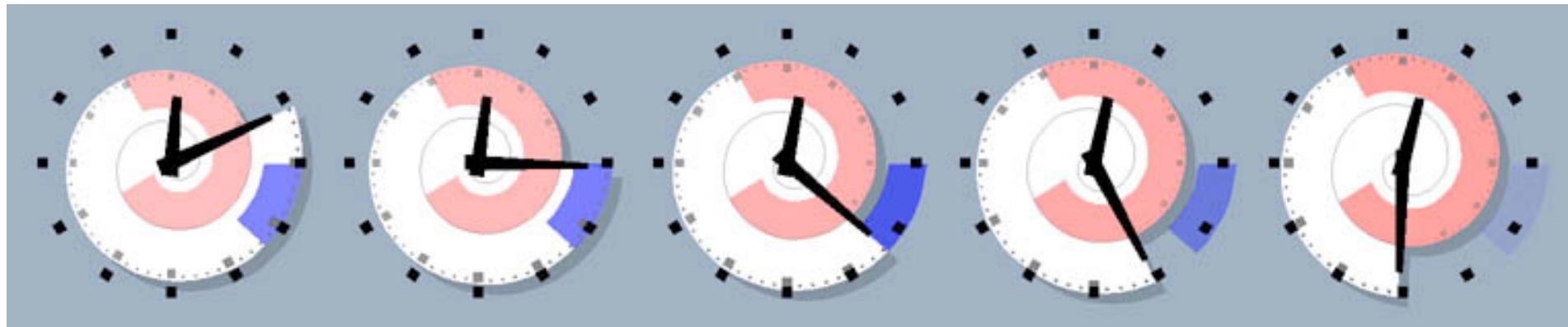
Multiple Views

Focus + Context

SpiraClock 1/2

[Dragicevic and Huot, 2002]

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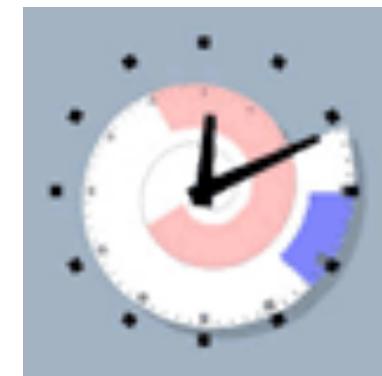


Visualization technique for nearby events.

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

informations-
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Interaction:

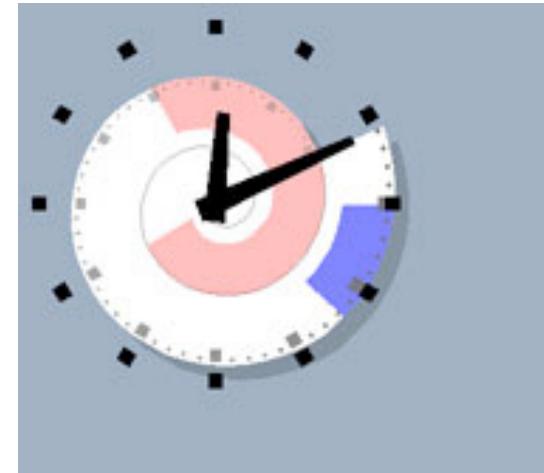
Change time by moving hands.

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>

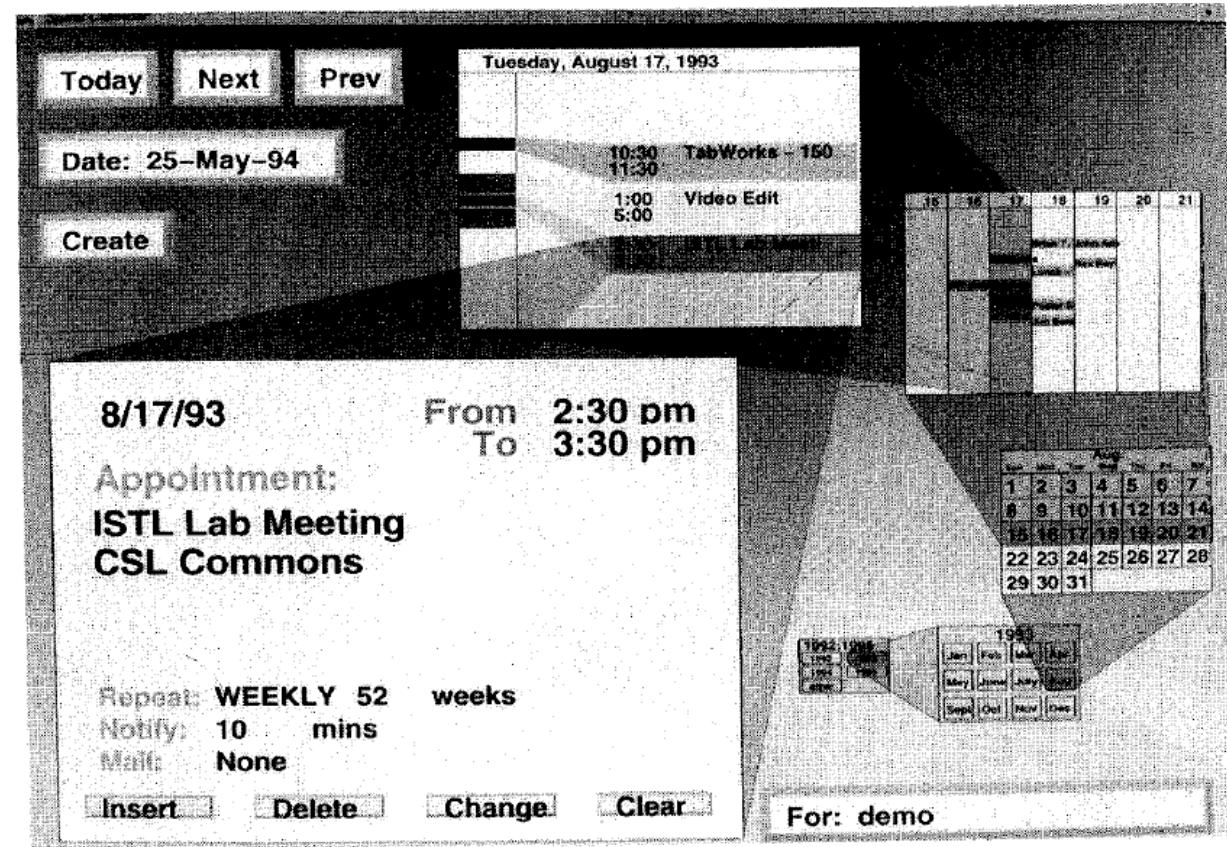
Bus schedule, MS Outlook and vCal import

[DEMO](#)

Spiral Calendar

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[Mackinlay et al., 1994]



individual schedule

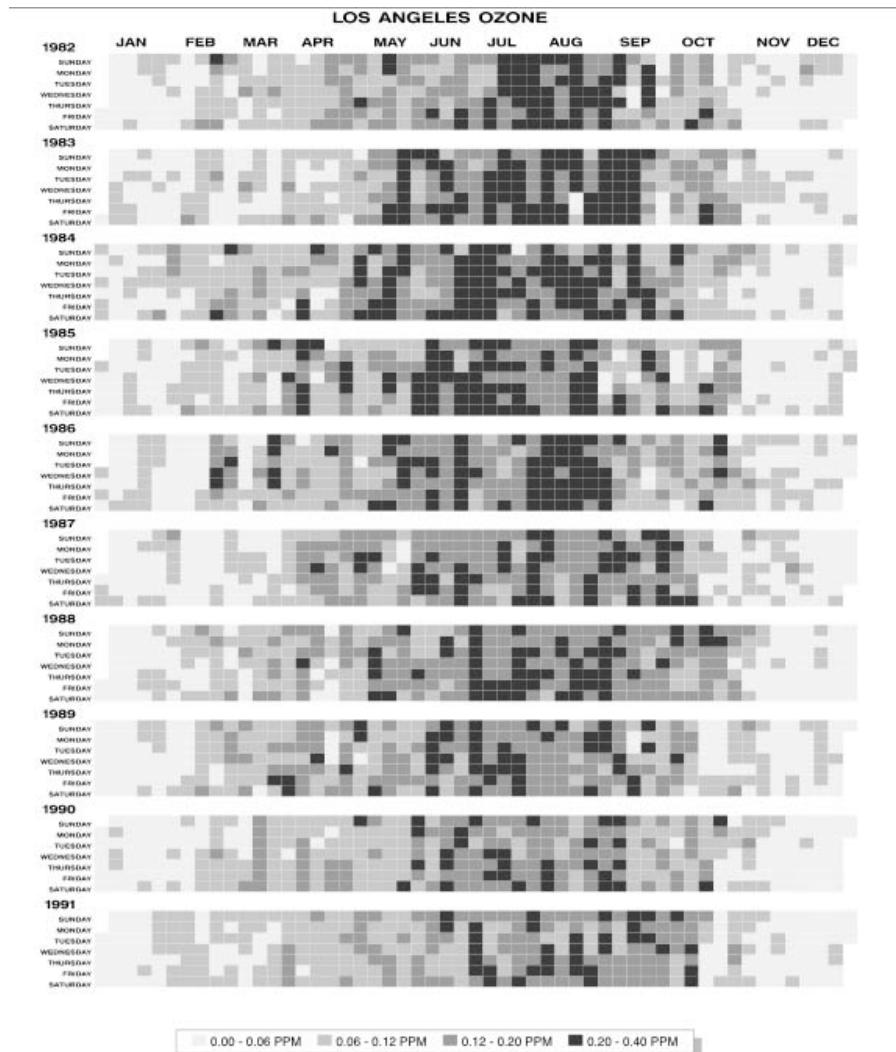
3D spiral layout

behaviour: clicking, animation

animated transitions

TileMap / Matrix Vis.

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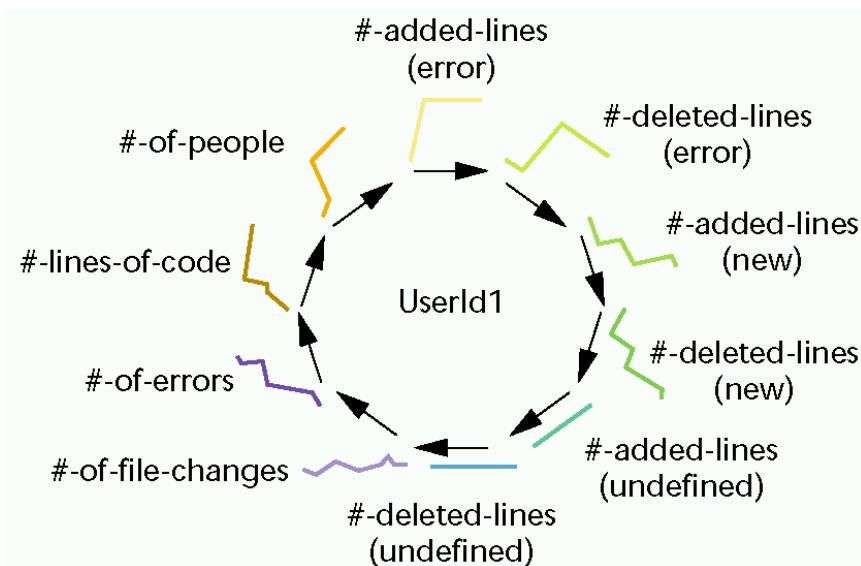
visualization of
quantitative histories

histories whose values are
numbers

each square represents
one day

good for displaying data
with a seasonal pattern

Time-wheel 1/3



[Chuah and Eick, 1997] **informations-visualisierung**

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:

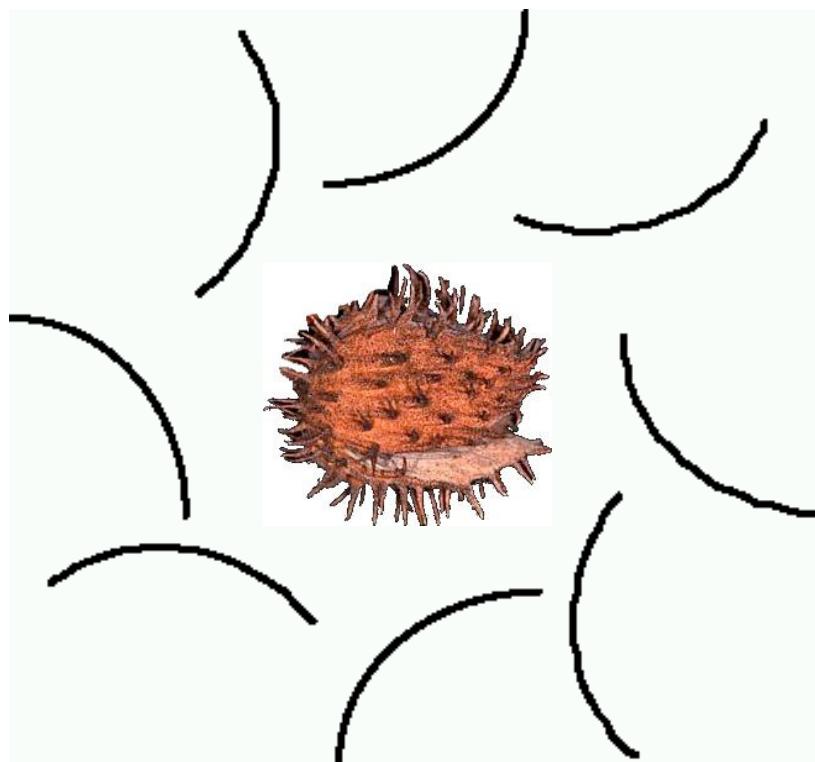
Increasing trend

Tapering trend

Time-wheel 2/3

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Increasing trend



„Prickly fruit“

Tapering trend



„Hairy fruit“

Time-wheel 3/3



Extension to 3D:

Encodes the same attributes as the Time-wheel

Uses height dimension to encode time

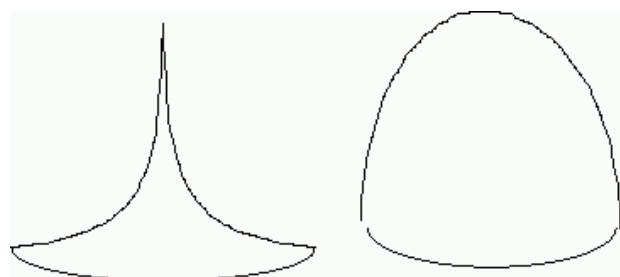
Variables are encoded as slices of a base circle

Pro: Easier to identify overall trends

Cons:

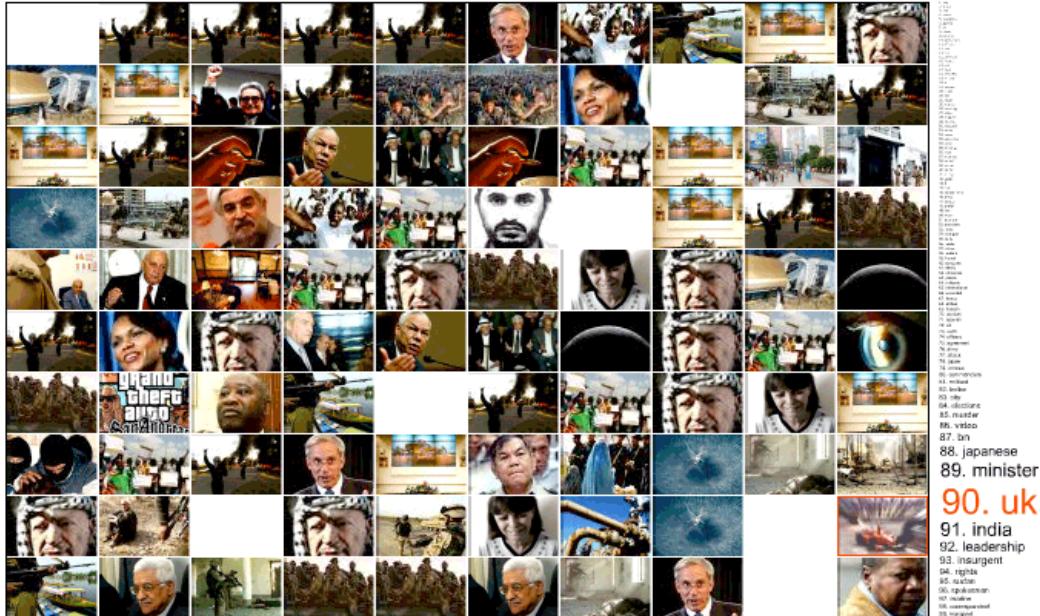
Occlusion

Perspective



10x10

10 x 10



[J. Harris, 2004] informations-
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<http://www.tenbyten.org/10x10.html>

100 words and pictures that define the time

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

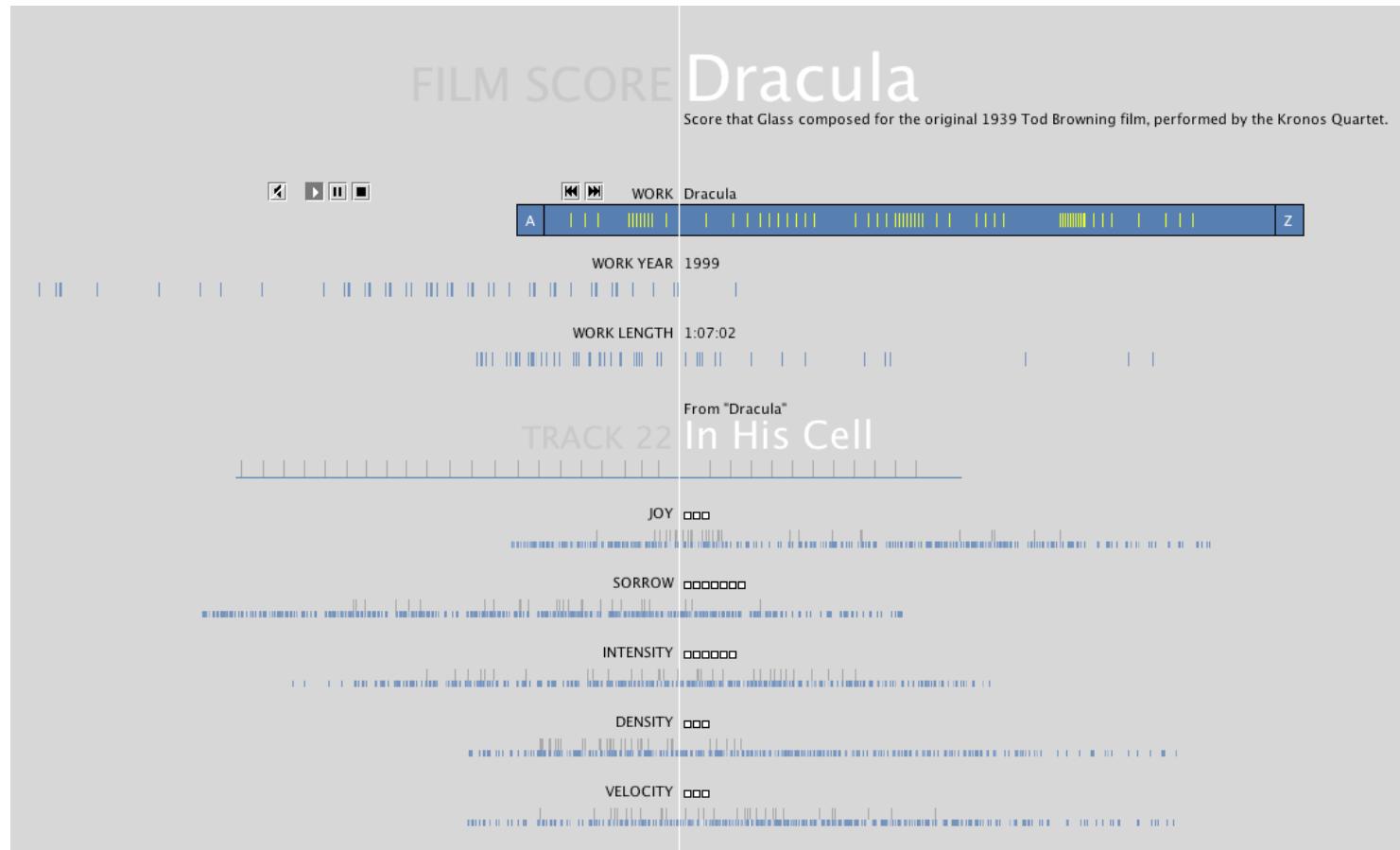
fisheye menu for selecting words

Glass Engine

<http://www.philipglass.com/glassengine/#>

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[IBM T.J. Watson Research Center]



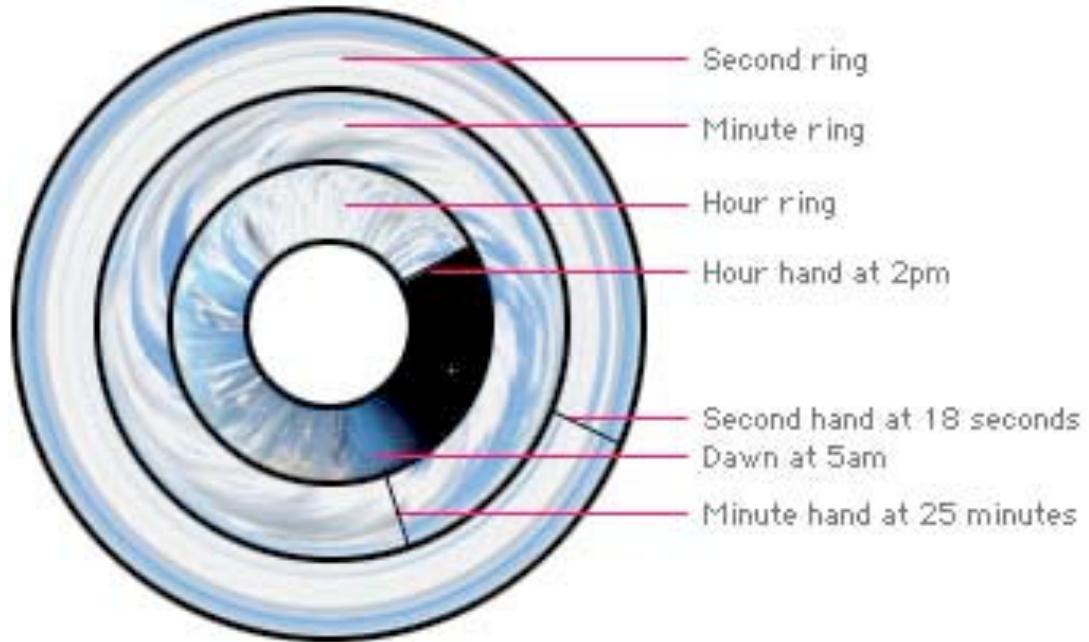
music of Philipp Glass

navigation along various attributes

Last Clock

[Cooper and Ängeslevä, 2002]

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"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/>

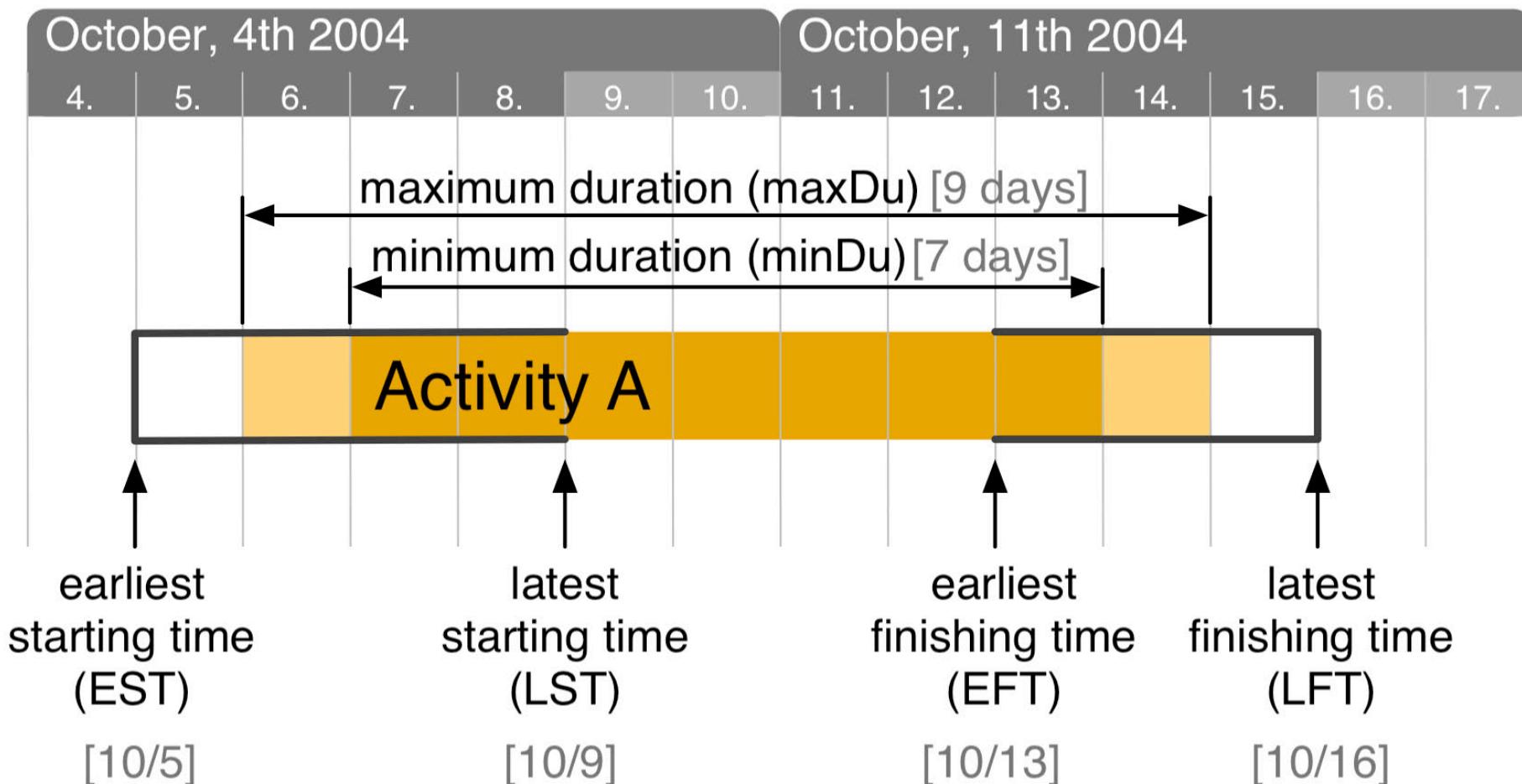
PlanningLines 1/2

[Aigner et al., 2005]

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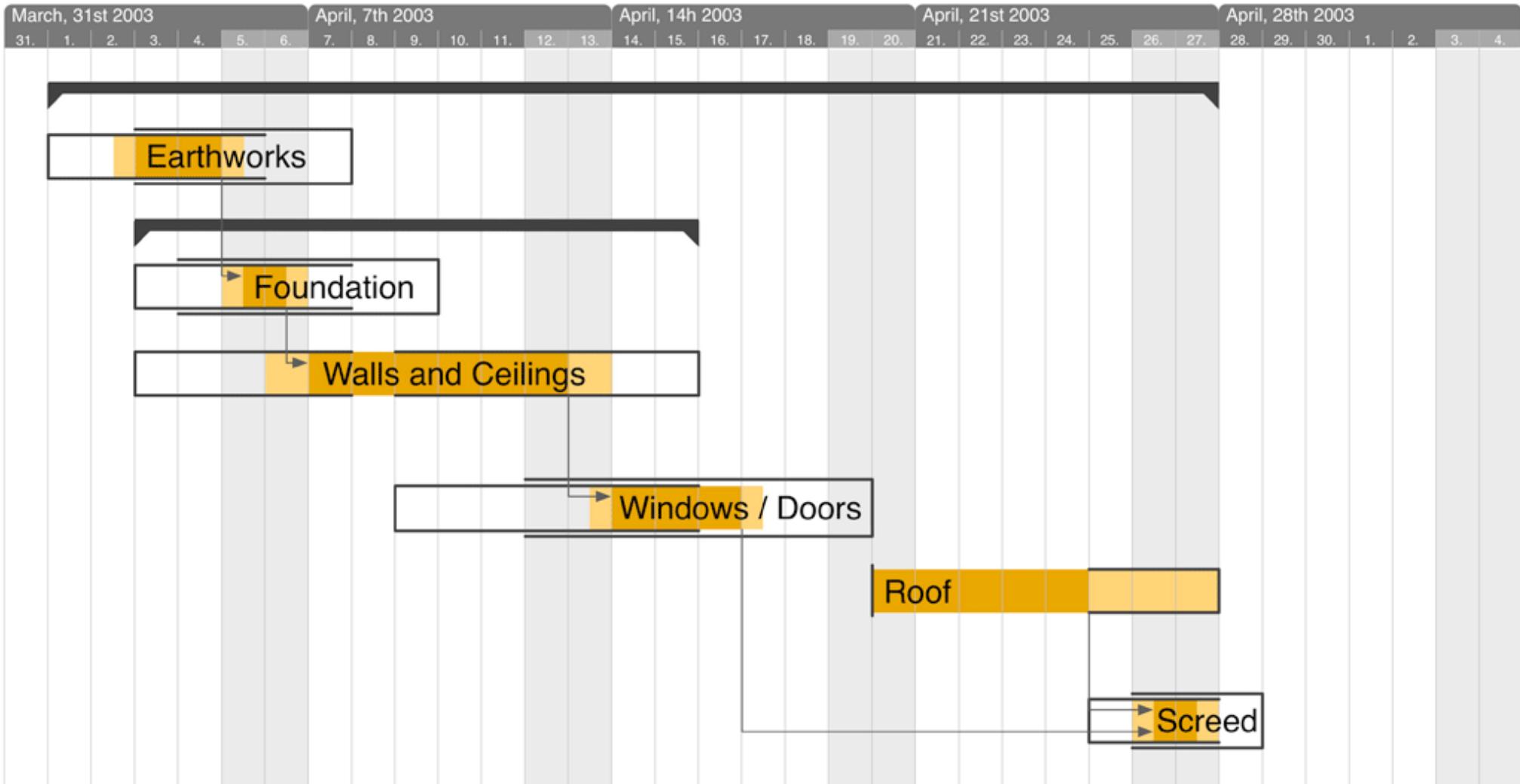
Begin and end are intervals rather than instants

Complex set of attributes presented „at a glance“



PlanningLines 2/2

informations- visualisierung

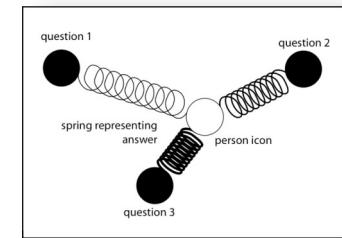
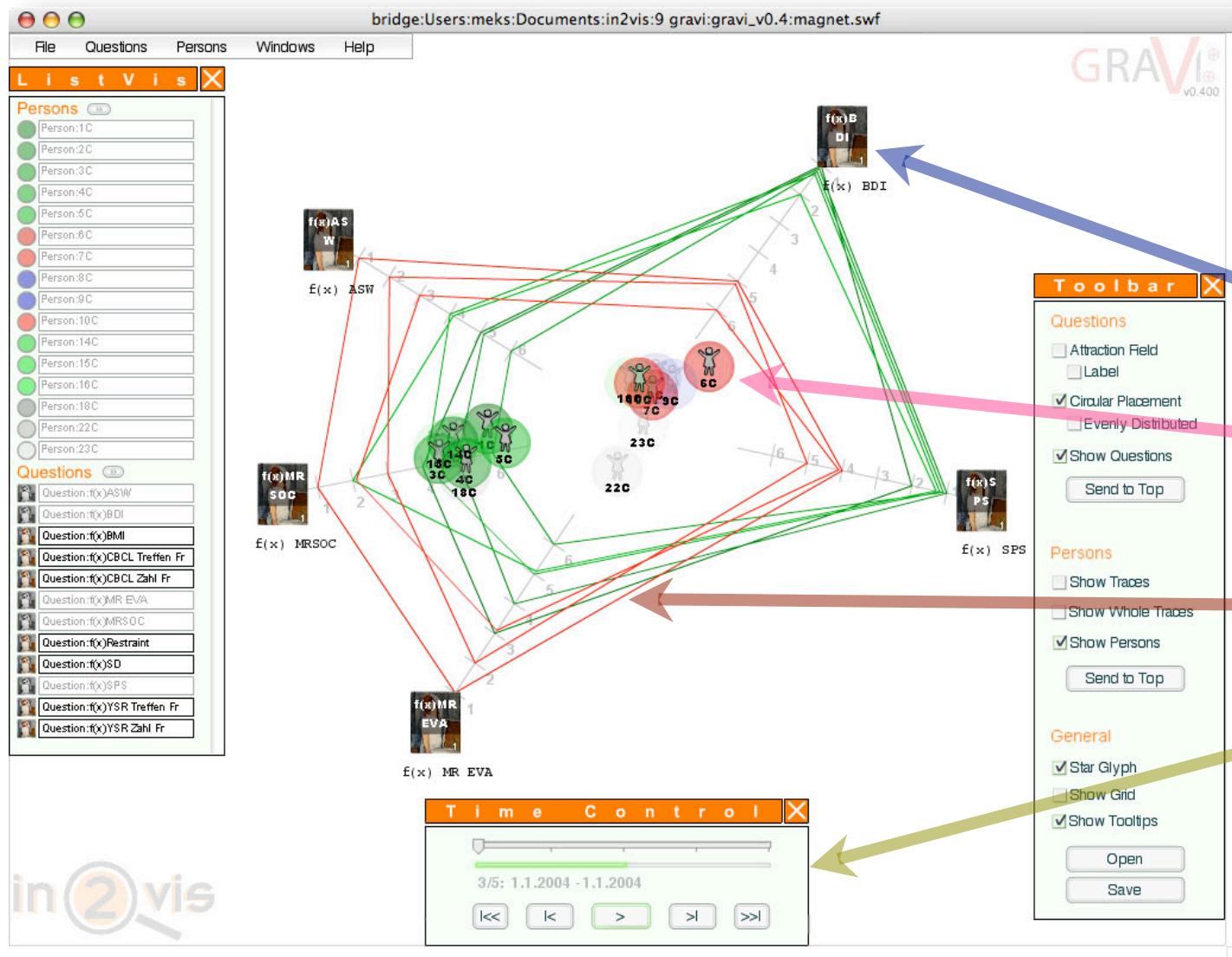


DEMO

GRAVI++

[Hinum et al., 2005]

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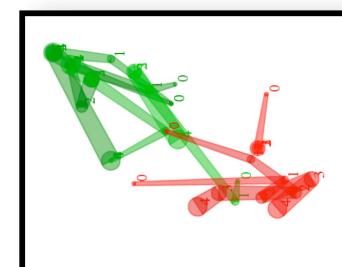
spring-based

questions/
questionnaires
patients

attraction field
star glyph

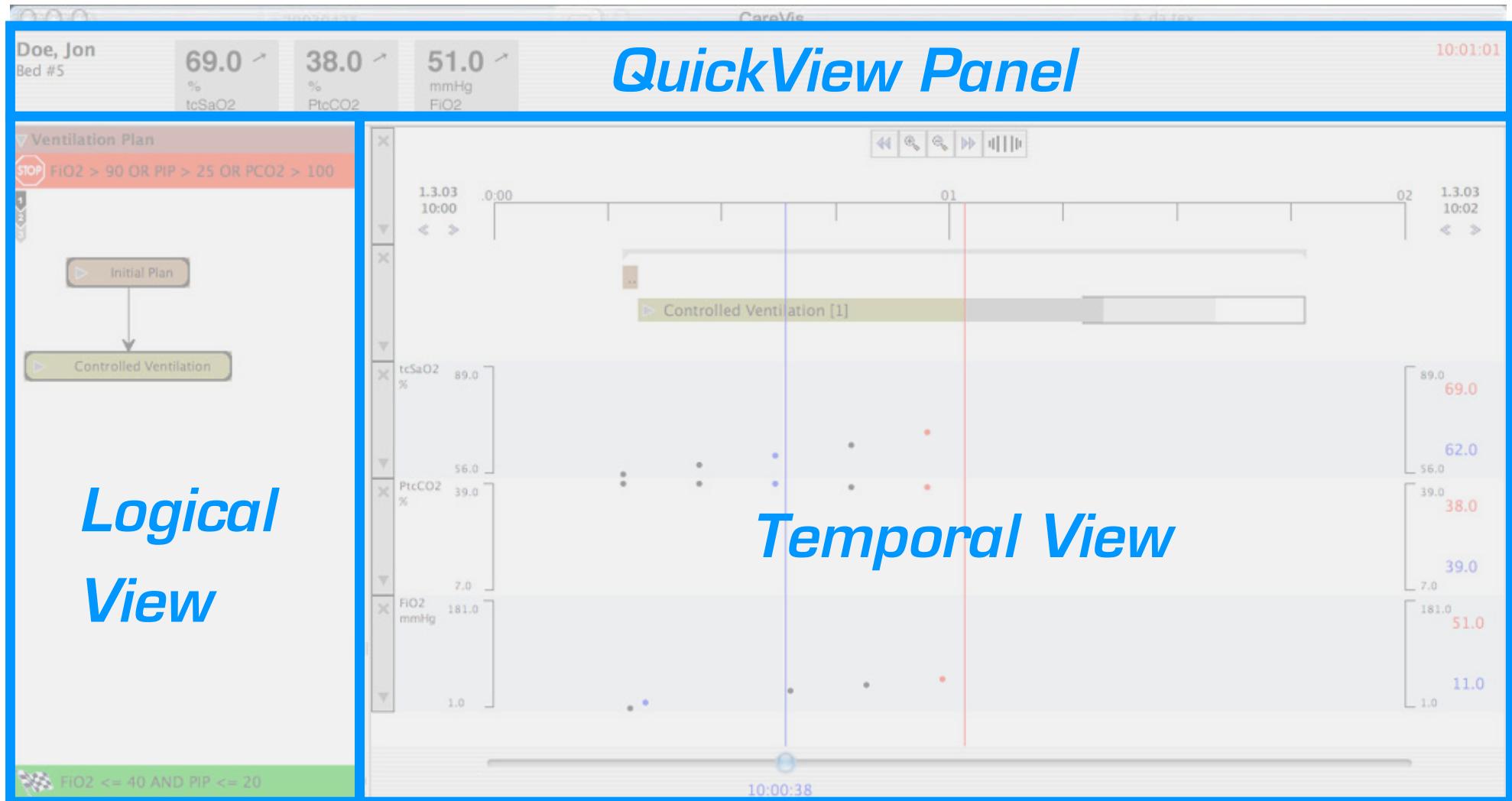
time steps

traces



DEMO

visualization of time-oriented data



integrated visualization of computerized protocols and
temporal patient data