

Time Series Data



CS 4460 – Intro. to Information Visualization
November 27, 2017
John Stasko

Learning Objectives



- Identify different types of temporal data
 - discrete, interval, linear, cyclic, continuous, ordinal, branching
- List potential tasks for temporal data analysis
- Familiarity with basic temporal representations
 - Line graph, stacked graph, stream graph, bubble tracks, connected scatterplot
- Familiarity with specific temporal representation techniques and systems
 - Lifelines 1-2 & EventFlow, ThemeRiver, Cluster/calendar view, MieLog, LiveRAC,
- Discuss the benefits & limitations of all the techniques
- Be able to apply learned knowledge and examples to the design of visualizations for new data and problems

Time Series Data



- Fundamental chronological component to the data set

75 % of 4000 samples of graphics from newspapers and magazines ('74-'80) were time-series data!

Tufte Vol. 1



Data Sets



- Each data case is likely an event of some kind
- One of the variables can be the date and time of the event
- Examples:

sunspot activity
baseball games
medicines taken
cities visited
stock prices

How about events with a duration?
Discrete vs. Interval

Data Mining



- Data mining domain has techniques for algorithmically examining time series data, looking for patterns, etc.
- Good when objective is known a priori
- But what if not?
 - Which questions should I be asking?
 - InfoVis better for that

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Tasks



- What kinds of questions do people ask about time series data?

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Time Series Tasks

(from class)



- Is there an order that things occur in?
- How long do events last?
- Is there a cycle?
- How does an event change over time?
- How often does an event happen?

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Time Series User Tasks



- Examples
 - When was something greatest/least?
 - Is there a pattern?
 - Are two series similar?
 - Do any of the series match a pattern?
 - Provide simpler, faster access to the series

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Other Tasks



- Does data element exist at time t ?
- When does a data element exist?
- How long does a data element exist?
- How often does a data element occur?
- How fast are data elements changing?
- In what order do data elements appear?
- Do data elements exist together?

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Muller & Schumann '03
citing
MacEachern '95

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Taxonomy



- Discrete points vs. interval points
- Linear time vs. cyclic time
- Ordinal time vs. continuous time
- Ordered time vs. branching time vs. time with multiple perspectives

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Muller & Schumann '03
citing
Frank '98

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Classical Presentation



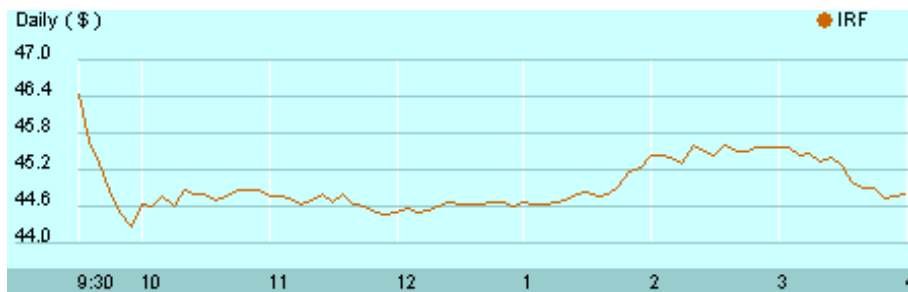
- What is the tried and true, most common way of representing time series data?
 - Focus here is measuring some value over time

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Line Graph



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Classic Views



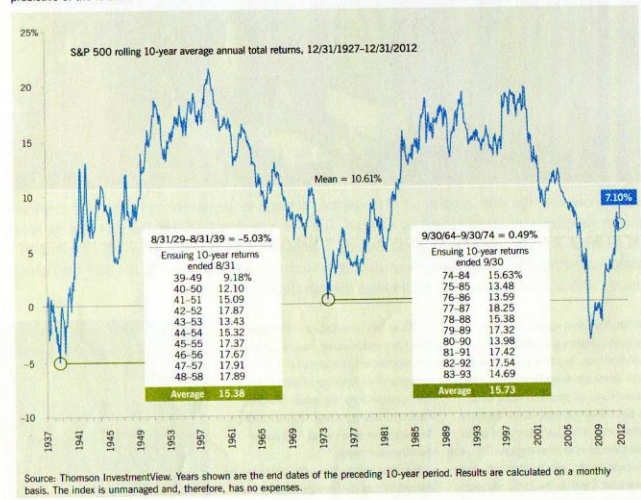
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After big declines, opportunities followed

A look back at market history shows that the U.S. stock market, represented here by Standard & Poor's 500 Composite Index, demonstrated strength after big declines. Even after three steep drops, the S&P 500 still provided an average 10-year annualized return of nearly 11% as of December 31, 2012. However, it's important to note that past results aren't predictive of the future.



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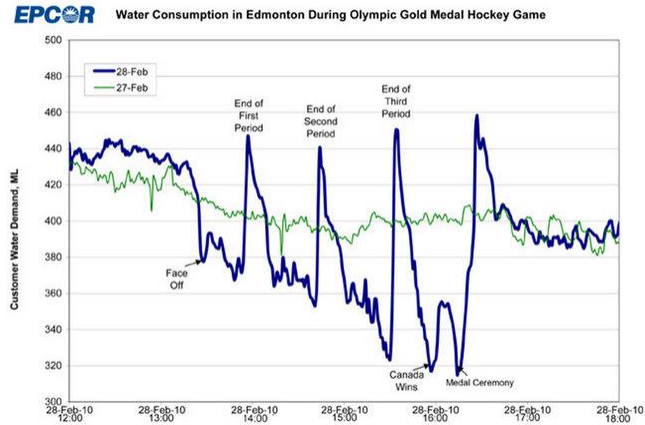
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Fun One



What If Everybody in Canada Flushed At Once?



http://www.patspapers.com/blog/item/what_if_everybody_flushed_at_once_Edmonton_water_gold_medal_hockey_game/

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Data?



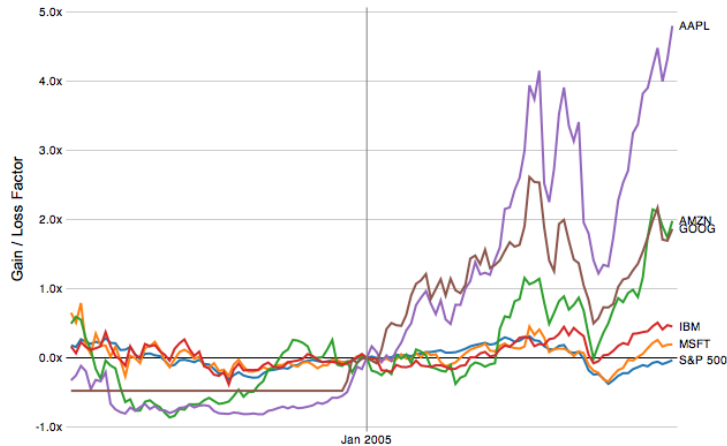
- What are these presenting?
 - One continuous quantitative value over time (time on x , variable on y)
- What if there are multiple values to track?

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Multiple Lines



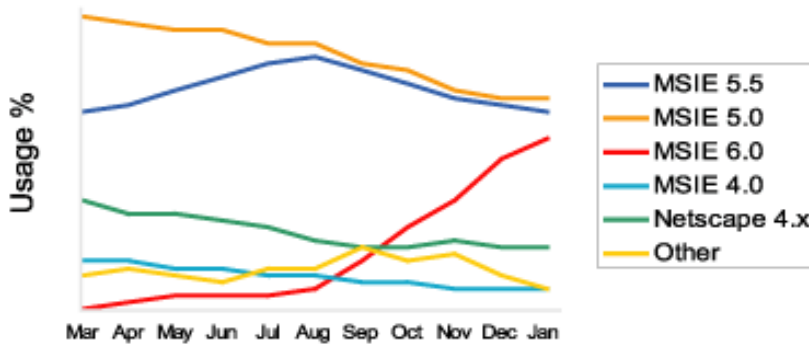
<https://homes.cs.washington.edu/~jheer//files/zoo/index.png>

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Proportions of Total



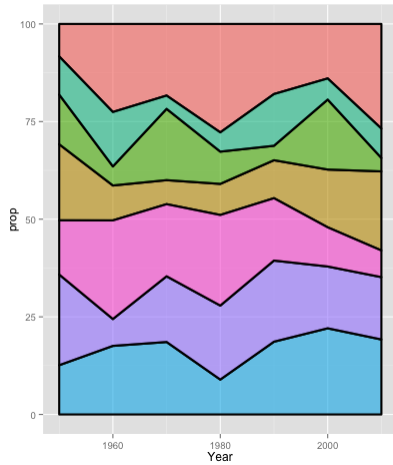
Alternative?

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Stacked Graph



Strengths?

Weaknesses?

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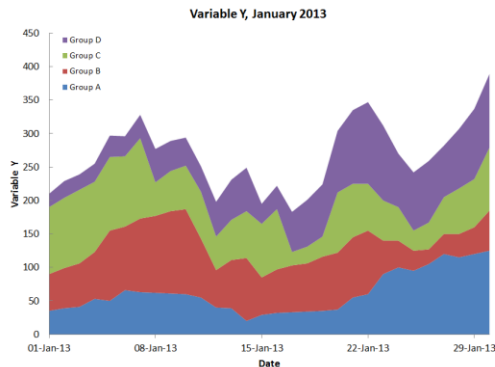
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Data?



- What if the different values don't comprise a whole?
 - Don't add up to 100%



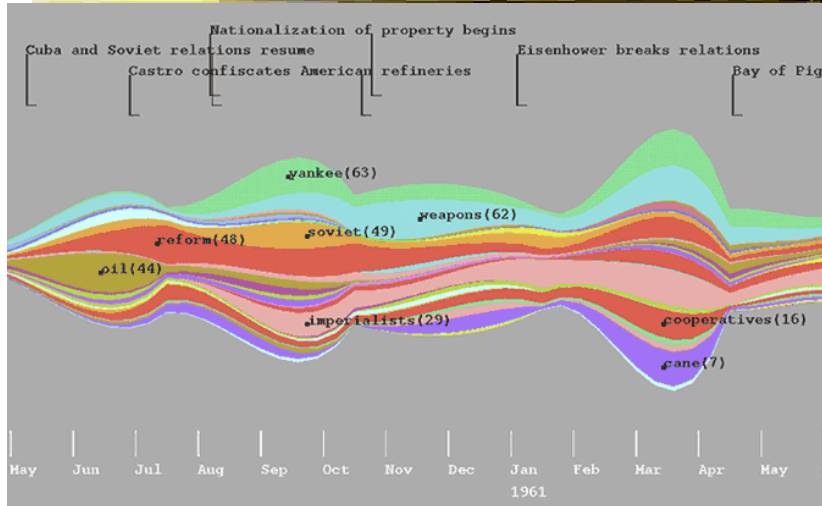
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ThemeRiver

Havre et al
InfoVis '00



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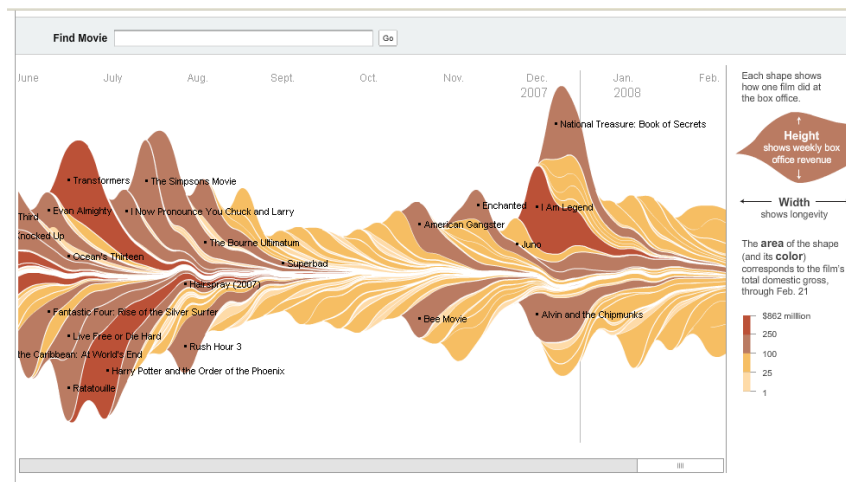
Recall

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Streamgraph

Movie
revenues

Byron & Wattenberg
TVCG '08



http://www.nytimes.com/interactive/2008/02/23/movies/20080223_REVENUE_GRAPHIC.html

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Design Issues



- Curve shape
 - Wiggle, symmetry, balance
 - Definitely some interesting math to do it
 - Color choice
 - Labeling
 - Layer ordering
-
- Paper provides very nice discussion of this

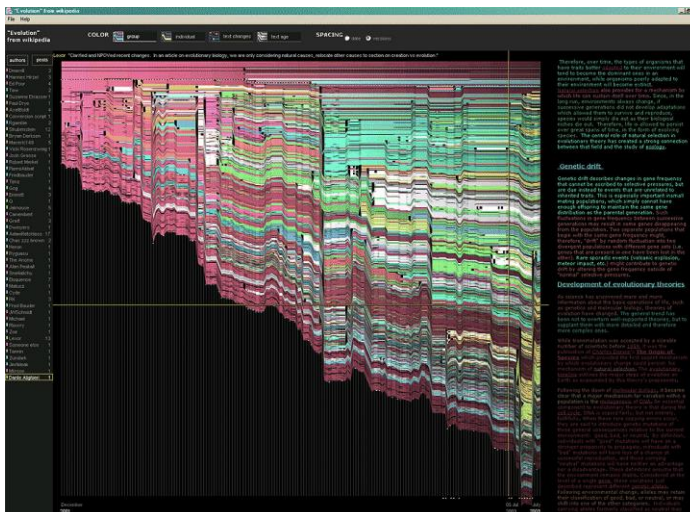
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<http://researchweb.watson.ibm.com/history/>

Document Edits



Flow of changes across electronic documents

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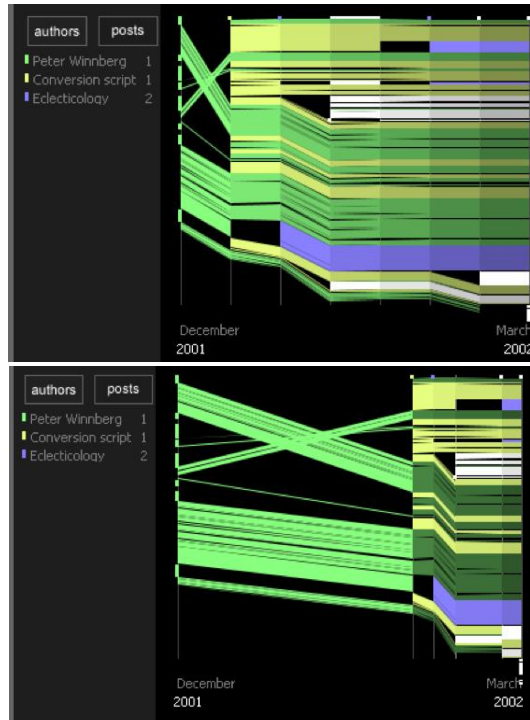
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Brightness indicates text age
Registered authors color-coded
Anonymous authors in white

Spacing by revision #

Spacing by time

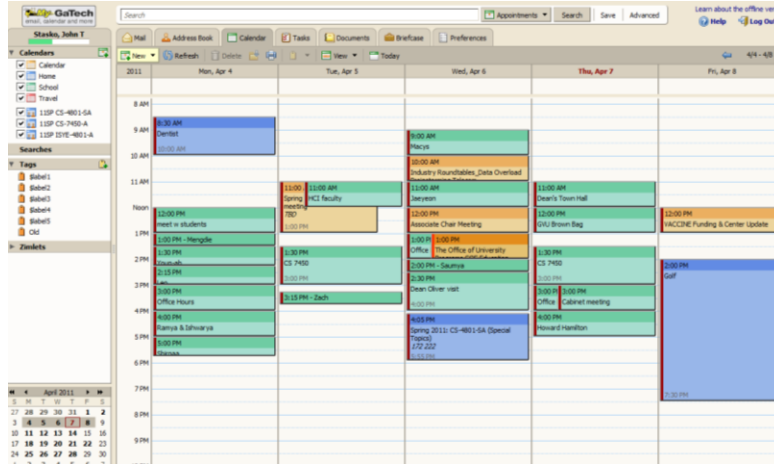


Different Data



- Nominally-typed events occurring over time with durations
- Do days/weeks/months/years matter?
 - If yes, then...

Calendar View



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More Context



- How do we see more context/overview?

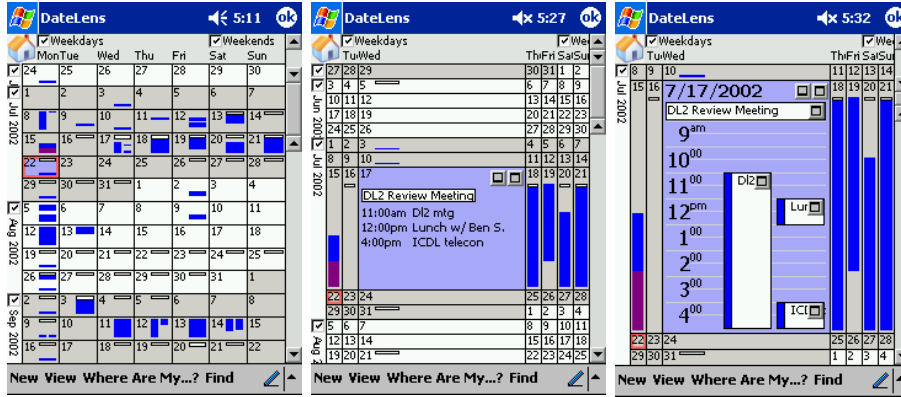
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DateLens

Recall



Fisheye approach

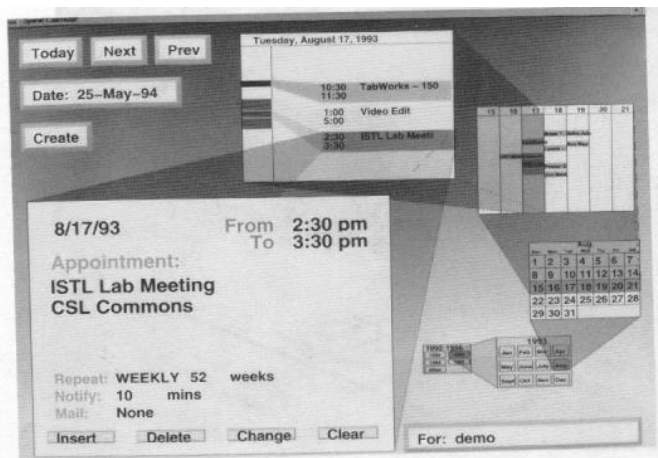
Bederson et al
ACM ToCHI '04

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Alternative



Spiral Calendar

Mackinlay, Robertson & DeLine
UIST '94

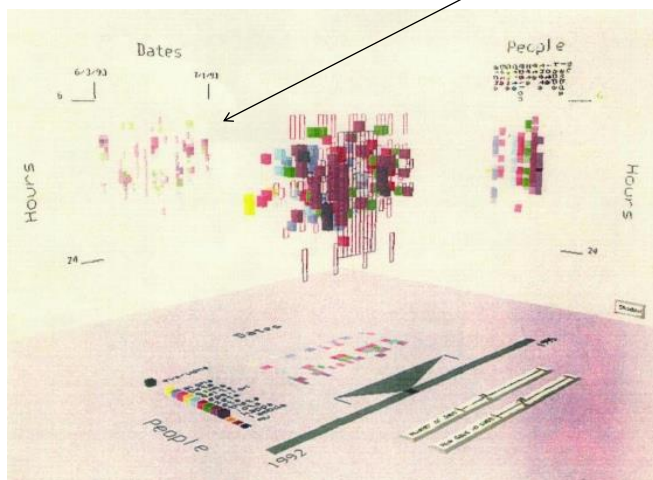
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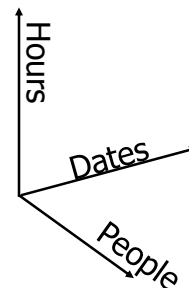
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Alternative

Empty spots on back wall show good times



Time Lattice



Uses projected shadows on walls

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Different Data

Revisit



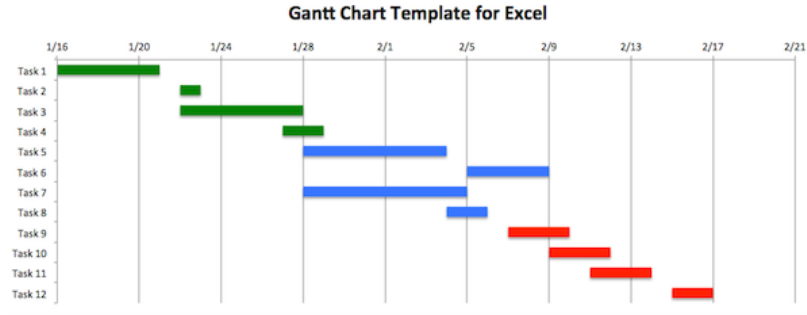
- Nominally-typed events occurring over time with durations
- Do days/weeks/months/years matter?
 - If no, then...

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Gantt Chart



Potential tasks:

- Put together complete story
- Garner information for decision-making
- Notice trends
- Gain an overview of the events to grasp the big picture

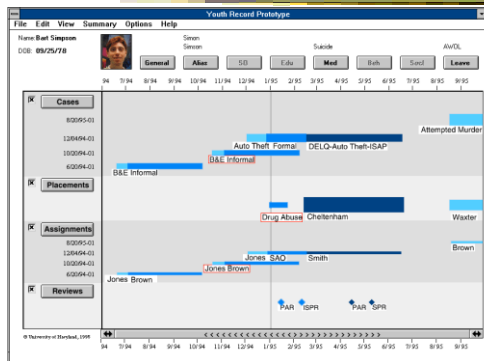
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Lifelines Project

Plaisant et al
CHI '96



Video



Visualize personal history in some domain

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Challenges



- Scalability (could be thousands of tests)
- Can multiple records be visualized in parallel (well)?
 - Comparisons
 - What trends do you see in the last 8 EKGs?
 - Compare the 8 people who all seem to have the same problem
- Support (reg-ex text) queries
- Support alignment, rank, and filter
- Medical application:
 - Look for temporal coincidence of two events
 - First pneumonia and asthma attack
 - Medical professionals don't want to fool with zooming and panning

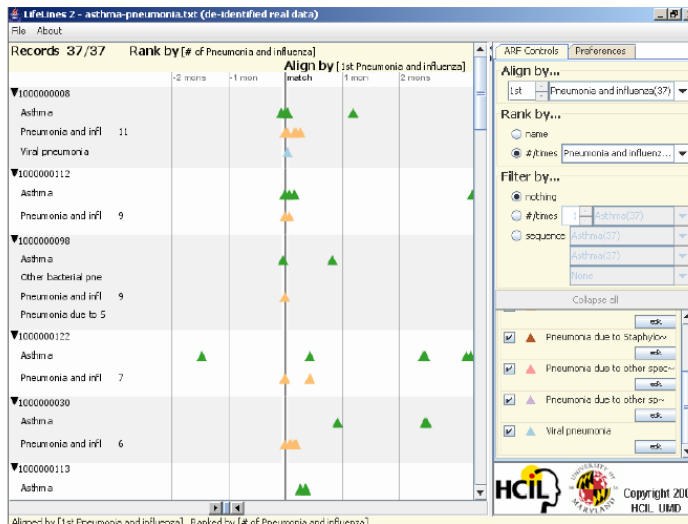
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LifeLines2: Focus on alignment along events

Follow-on



Video

Wang et al
CHI '08

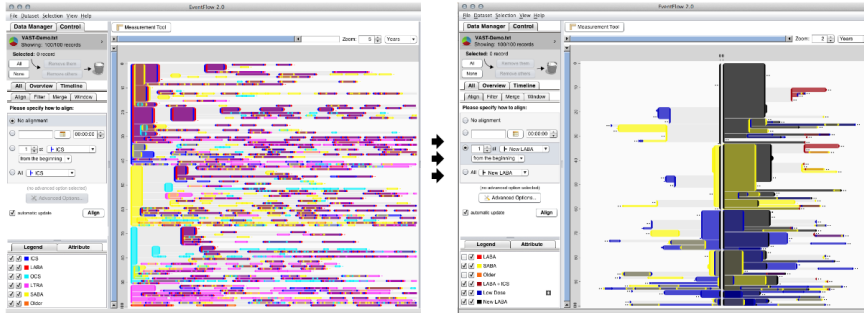
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More Follow-on

EventFlow



Transform

Smart aggregations to show overviews of large collections of events

Monroe et al
TVCG '13

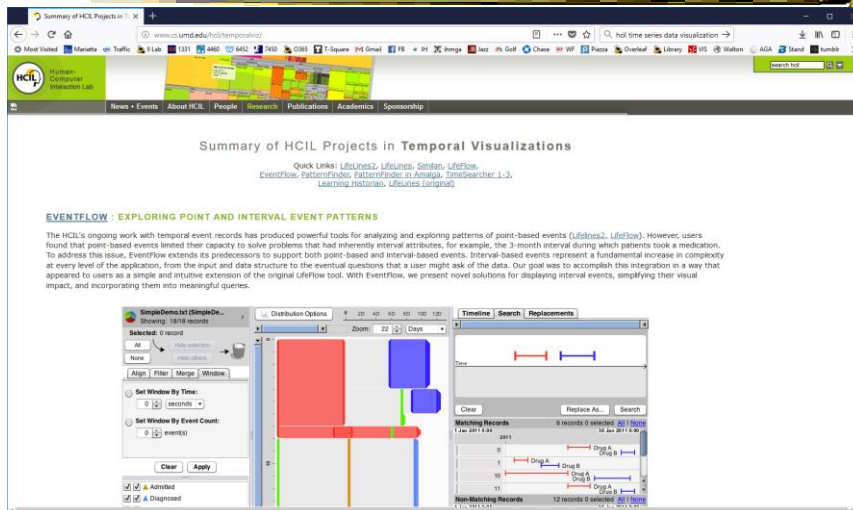
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<http://www.cs.umd.edu/hcil/temporalviz>

HCIL Projects



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Data?



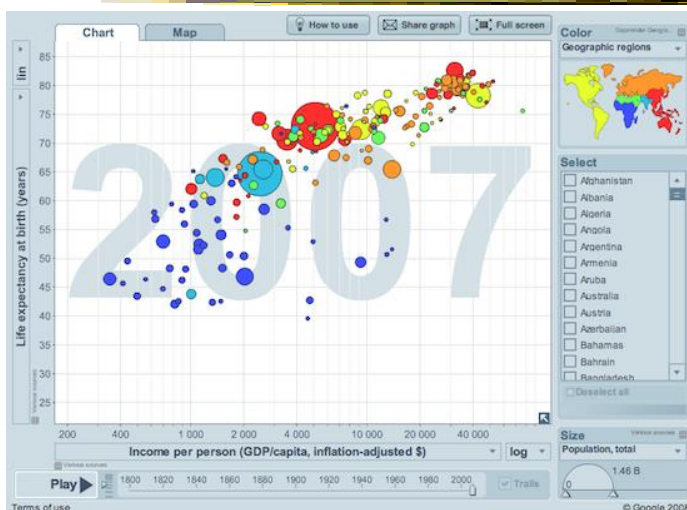
- What if you want to show two continuous variables over time?
 - And not just use two lines

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Bubblechart Animation



Strengths?

Weaknesses?

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GapMinder

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Alternative



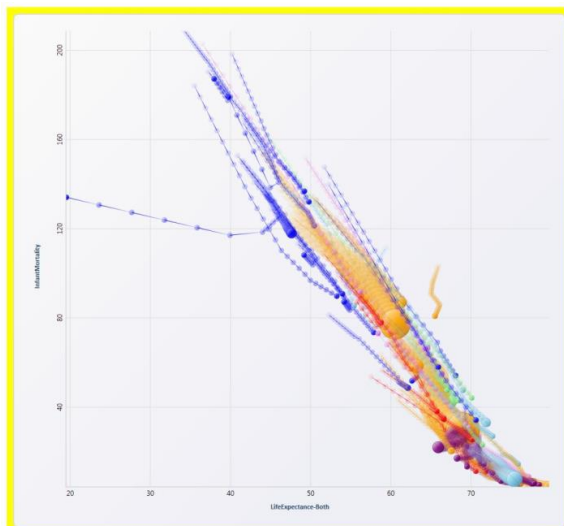
- How do we address weaknesses?
 - How to get rid of time slider?

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Trace View



Color Legend (continent)

- Africa
- Asia
- Europe
- Middle East
- North America
- Oceania
- South America

Task

Select two countries whose InfantMortality dropped first, then increased later.

Tip: Click on a country (in chart) to set an answer.

Answers set: 0/2

Next

Click on "Next" when finished (or "Give Up" if you cannot find all the answers)

"Traces" in
Gapminder-style
visualization

Robertson et al
TVCG (InfoVis) '08

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Connected Scatterplot



- Showing two variables over time
 - Use standard scatterplot
 - Plot the two values at different points in time
 - Connect those points, in order, with a line
 - Label key times (e.g., years)

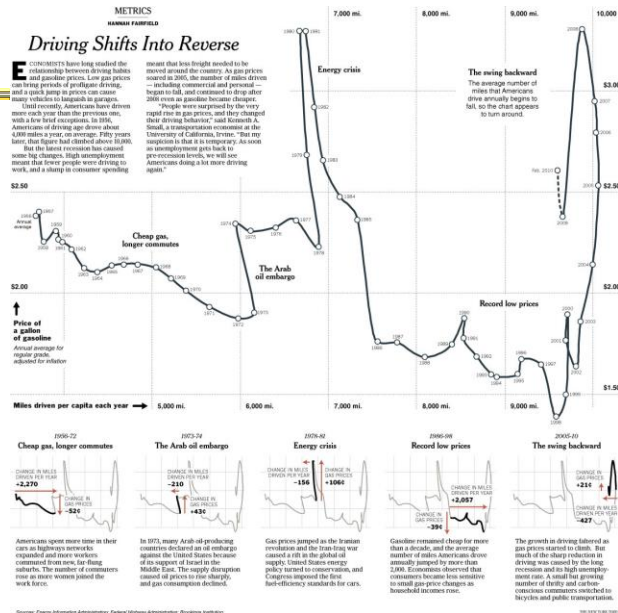
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Hannah Fairfield
NY Times

Notice the narrative elements too



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Janet L. Yellen, on the Economy's Twists and Turns

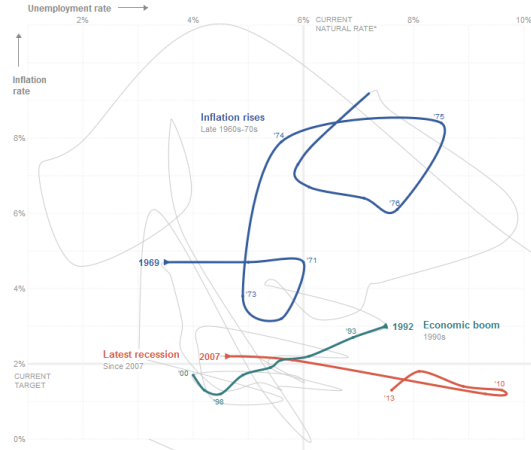


1 2 3 4 5 6 7 NEXT >

Inflation and unemployment

The Federal Reserve is said to have a "dual mandate": keeping inflation in check and the unemployment rate low. These measures, which tend to change cyclically and in concert with each other, are charted for every year since the Great Depression.

In speeches and in meetings, Ms. Yellen, the nominee for the next Fed leader, has commented on the Fed's actions during significant periods, providing a window into her views and priorities.



*The natural rate of unemployment is defined as the lowest sustainable level of unemployment over the long term. If the rate is pushed any lower than the natural level, wages and prices would rise.

<http://www.nytimes.com/interactive/2013/10/09/us/yellen-fed-chart.html>

<http://www.dundas.com/blog-post/in-praise-of-connected-scatter-plots/>

Nice Article



Fundamental Tradeoff



- Is the visualization time-dependent, ie, changing over time (beyond just being interactive)?
 - Static
 - Shows history, multiple perspectives, allows comparison
 - Dynamic (animation)
 - Gives feel for process & changes over time, has more space to work with

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InfoVis to the Rescue



- What about some more unique data sets?
- Can we come up with good individual solutions?

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Case Study 1



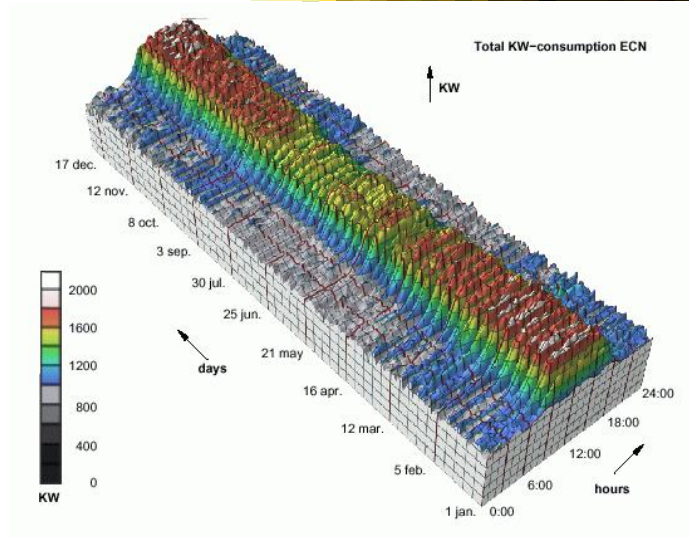
- Understand patterns of presence/resource usage/events over time
- Show this large amount of data in an easily understandable and query-able manner
- Scenarios:
 - Workers punch in and punch out of a factory
Want to understand the presence patterns over a calendar year
 - Power plant electricity usage over a year

Ideas



- Any ideas on what we could do here?

One Idea



Good
Typical daily pattern
Seasonal trends

Bad
Weekly pattern
Details

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Approach Taken



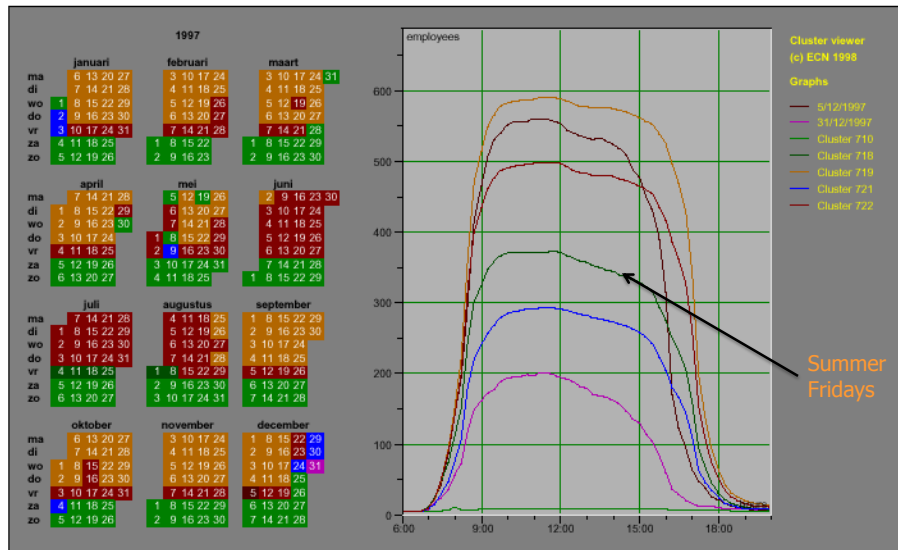
- Cluster analysis
 - Find two most similar days, make into one new composite
 - Keep repeating until some preset number left or some condition met
- How can this be visualized?
 - Ideas?

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Display



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Characteristics



- Unique types of days (individual or cluster) get their own color
- Contextually placed in calendar and line graph for it is shown
- Stop clustering when a threshold met or at a predetermined number of clusters
- Interactions
 - Click on day, see its graph
 - Select a day, see similar ones
 - Add/remove clusters

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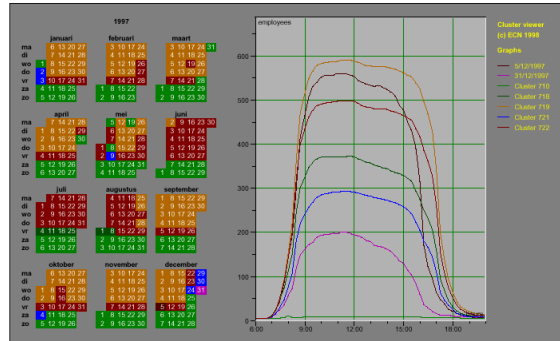
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Insights



- Traditional office hours followed
- Most employees present in late morning
- Fewer people are present on summer Fridays
- Just a few people work holidays
- When the holidays occurred
- School vacations occurred May 3-11, Oct 11-19, Dec 21-31
- Many people take off day after holiday
- Many people leave at 4pm on December 5
 - Special day in Netherlands, St. Nicholas' Eve



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Case Study 2



- Computer system logs
- Potentially huge amount of data
 - Tedious to examine the text
- Looking for unusual circumstances, patterns, etc.

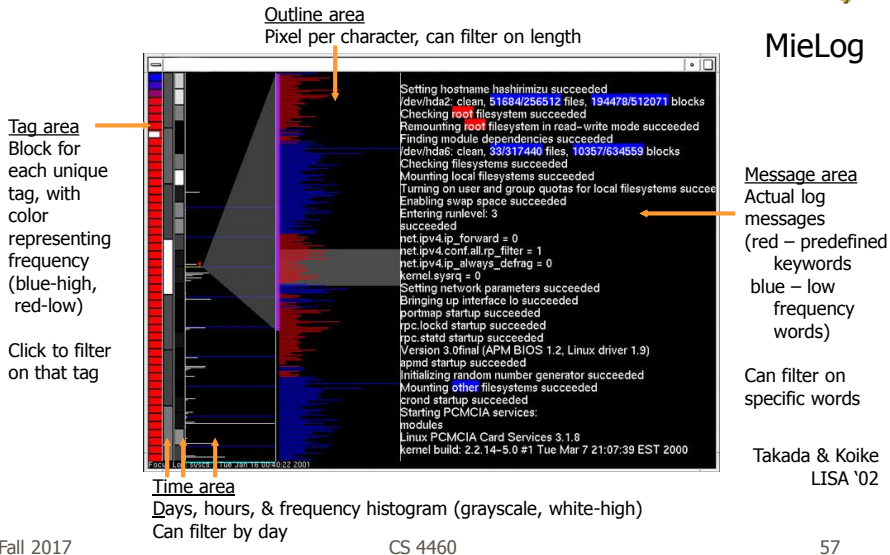
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System View

What kind of display (technique)?



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Takada & Koike
LISA '02

Case Study 3



- Domain: Computer systems management
- Very large scale temporal log data
 - Many processes, machines
- Show more context of what else was going on at that time
 - Likely have to abstract some then
 - Allow several different levels of detail at once
- Allow drill-down for details

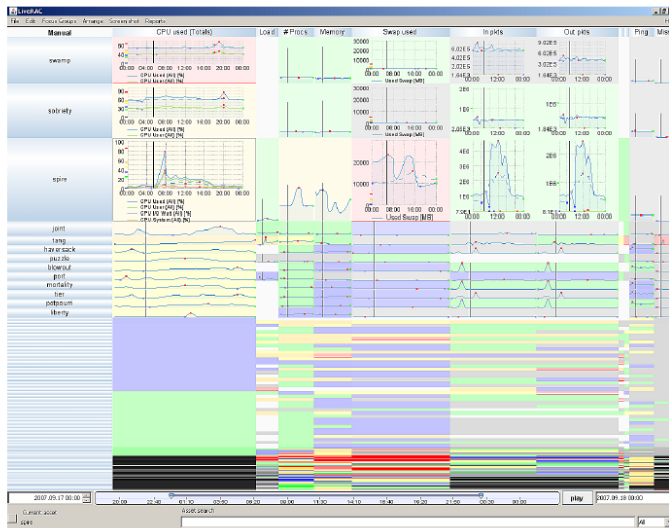
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LiveRAC: Computer system management data

Video



Interaction is vital
Semantic zooming

McLachlan et al
CHI '08

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Case Study 4



- How about events in time and place?
 - Many applications of this problem

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GeoTime



- Represent place by 2D plane (or maybe 3D topography)
- Use 3rd dimension to encode time
- Object types:
 - Entities (people or things)
 - Locations (geospatial or conceptual)
 - Events (occurrences or discovered facts)

Kapler & Wright
InfoVis '04

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Example

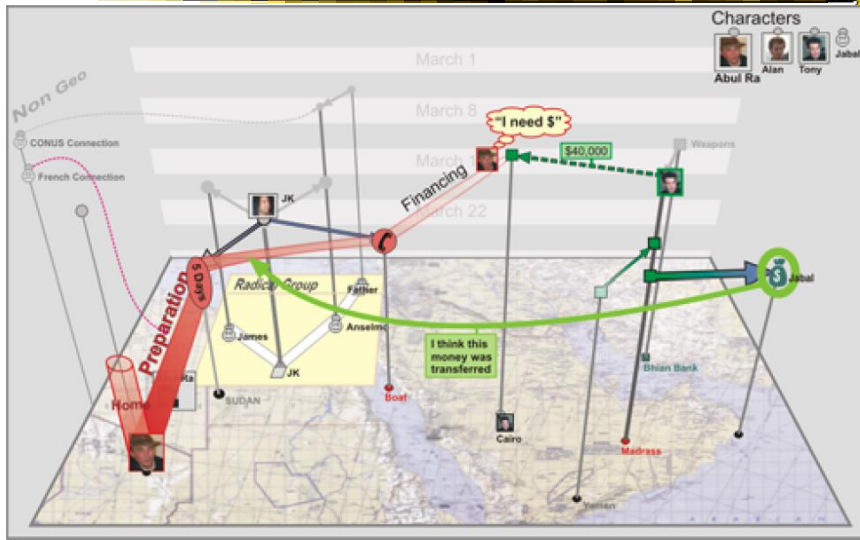


Source: <http://www.oculusinfo.com/>
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Example



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Nice overview

IEEE TRANSACTIONS ON VISUALIZATION AND COMPUTER GRAPHICS, VOL. 14, NO. 1, JANUARY/FEBRUARY 2008 47

Visual Methods for Analyzing Time-Oriented Data

Wolfgang Aigner, Silvia Miksch, Wolfgang Müller, Heidrun Schumann, and Christian Tominski

Abstract—Providing appropriate methods to facilitate the analysis of time-oriented data is a key issue in many application domains. In this paper, we focus on the unique role of the parameter time in the context of visually driven data analysis. We will discuss three major aspects—visualization, analysis, and the user. It will be illustrated that it is necessary to consider the characteristics of time when generating visual representations. For that purpose, we take a look at different types of time and present visual examples. Integrating visual and analytical methods has become an increasingly important issue. Therefore, we present our experiences in temporal data abstraction, principal component analysis, and clustering of larger volumes of time-oriented data. The third main aspect we discuss is supporting user-centered visual analysis. We describe event-based visualization as a promising means to adapt the visualization pipeline to needs and tasks of users.

Index Terms—Time-oriented data, visualization, analysis, user.

1 INTRODUCTION AND MOTIVATION

CONSIDERING the characteristics of data is vital when designing visual representations. A salient characteristic is whether or not data are related to time. That time is an outstanding dimension is reflected by Shneiderman’s Taskby Data Type Taxonomy [1], where temporal data are identified as one of seven basic data types. Nowadays, time-oriented data are ubiquitous in many application domains as, for example, in business, medicine, history, planning, or project management. For a long time, visual methods have been successfully applied to analyze such data. A wide repertoire of interactive techniques for visualizing data sets with temporal dependencies is available. However, many current

- visualization,
- analysis, and
- user.

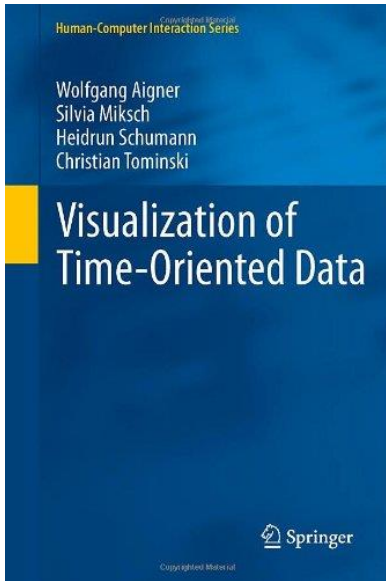
In Section 2, we focus on visualization methods for time-oriented data. We will show that the term *time-oriented data* comprises several types of data with different meanings and applications. Designing or applying visual representations can only be successful if one is aware of these different types. This will be demonstrated with several examples of visualization techniques that stem from our own work or are available in the literature.

Usually, time-oriented data are large—not only in terms of the number of data items but also in terms of the number

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Bigger overview

<http://www.timeviz.net/>

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Useful Widgets

<http://simile-widgets.org/>

Timeline

Web widgets for Visualizing Temporal Data

With this widget, you can make beautiful interactive timelines like the one below. Try dragging it horizontally or using your mouse-wheel. Click on each event for more details.



Timeplot

Web widgets for Visualizing Temporal Data

Timeplot is a DHTML-based AJAX widget for plotting time series and overlay time-based events over them (with the same data formats that [Timeline](#) supports). Here is a live example:

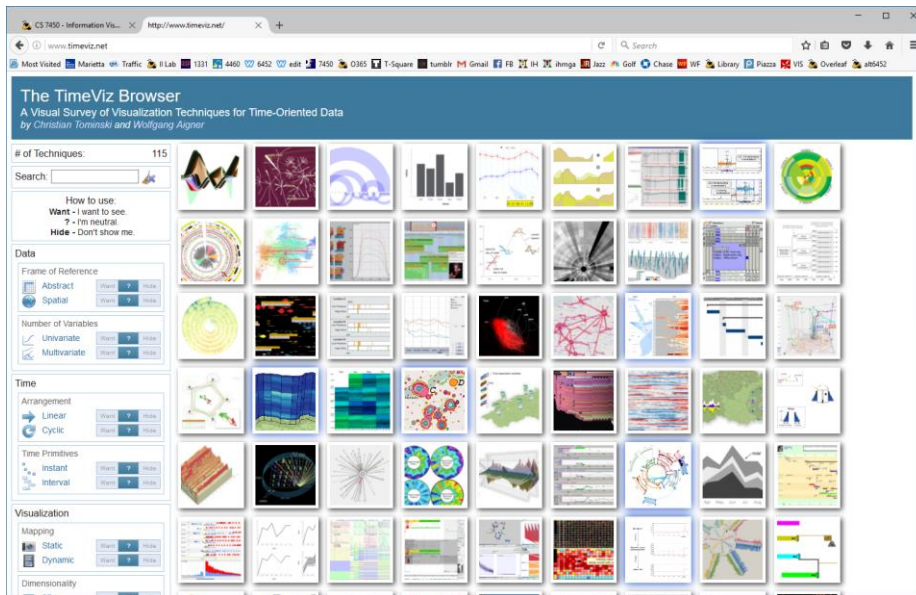


Simile project

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Interactive
survey

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Conclusions



- Think about the data
 - What characteristics?
- Can InfoVis help?
 - Maybe not needed
- Think about the visualization techniques
- Which technique(s) work best for your problem?

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Learning Objectives



- Identify different types of temporal data
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- Familiarity with specific temporal representation techniques and systems
 - Lifelines 1-2 & EventFlow, ThemeRiver, Cluster/calendar view, MieLog, LiveRAC,
- Discuss the benefits & limitations of all the techniques
- Be able to apply learned knowledge and examples to the design of visualizations for new data and problems

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Upcoming



- Visual Analytics
 - Prep: VisMaster video
- Lab: Maps and geo-data
- Review

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References



- Spence and CMS books
- All referred to articles