informations-
visualisierung

visualization of **time-oriented data**

introduction

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Data types [Shneiderman, 1996]

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1-dimensional

2-dimensional

3-dimensional

Temporal

= 4D space

“the world we are living in”

Multi-dimensional

Tree

Network

Spatial + temporal dimensions

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Every data element we measure is related and often only meaningful in context of **space** + **time**

Example: price of a computer

where?

when?

Differences between space and time

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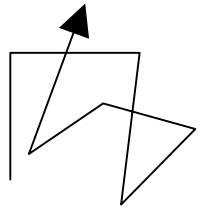
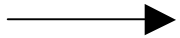
Space can be traversered “arbitrarily”



we can move back to where we came from

Time is unidirectional



we can’t go back or forward in time

Humans have senses for perceiving **space**

visually, touch

Humans don’t have senses for perceiving **time**

Interactive visualization

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Gives us the ability to…

…travel in time virtually.

Time-oriented data?

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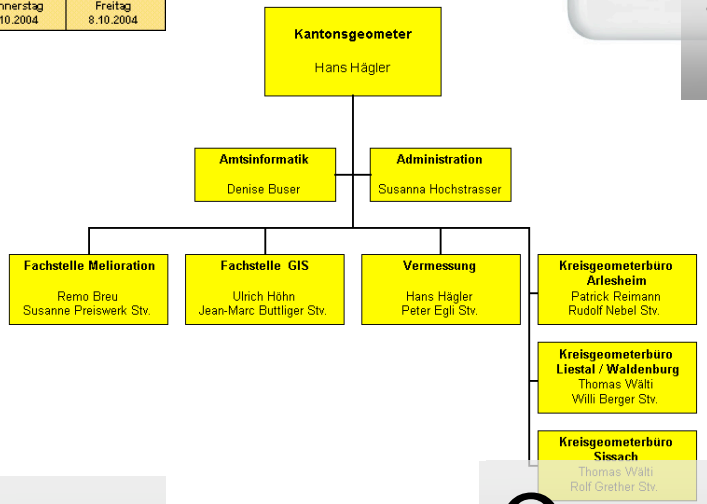
Zeit	Montag 4.10.2004	Zeit	Dienstag 5.10.2004	Mittwoch 6.10.2004	Donnerstag 7.10.2004	Freitag 8.10.2004
		9.00 bis 10.45	Plenar-veranstaltungen 1+2+3	Plenar-veranstaltungen 7+8+9	Plenar-veranstaltungen 13+14	Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen
11.00 bis 13.00	Sektions-sprechertreffen Presse-konferenz	11.00 bis 12.45	Plenar-veranstaltungen 4+5+6	Plenar-veranstaltungen 10+11+12	Plenar-veranstaltungen 15+16+17	Abschluss-veranstaltung
		13.00 bis 14.00	Mittags-vorlesungen 1+2	Mittags-vorlesungen 3+4	Mittags-vorlesungen 5+6	
		17.00 bis 18.00	Authors meet Critics, Foren, Sonder-veranstaltungen	Authors meet Critics, Foren, Sonder-veranstaltungen	Authors meet Critics, Foren, Sonder-veranstaltungen	
		18.00 bis 20.00	Abend-veranstaltungen 1+2	Sonder-veranstaltung DGS Mitglieder-versammlung	Abend-veranstaltungen 3+4	
Ab 20.00	Kongressparty	20.00	Podiums-diskussion	Sonder-veranstaltung	Podiums-diskussion	
Zeit	Montag 4.10.2004	Zeit	Dienstag 5.10.2004	Mittwoch 6.10.2004	Donnerstag 7.10.2004	Freitag 8.10.2004

Event calendar

iPod price

Snow height & sunshine hours



Organization chart

Event calendar

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Zeit	Montag 4.10.2004	Zeit	Dienstag 5.10.2004	Mittwoch 6.10.2004	Donnerstag 7.10.2004	Freitag 8.10.2004
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		13.00 bis 14.00	Mittags-vorlesungen 1+2	Mittags-vorlesungen 3+4	Mittags-vorlesungen 5+6	
14.00 bis 17.00	Eröffnungs-veranstaltung	14.15 bis 17.00	Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen	Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen	Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen	Konzilsitzung Presse-konferenz
		17.00 bis 18.00	Authors meet Critics, Foren, Sonder-veranstaltungen	Authors meet Critics, Foren, Sonder-veranstaltungen	Authors meet Critics, Foren, Sonder-veranstaltungen	
		18.00 bis 20.00	Abend-veranstaltungen 1+2	Sonder-veranstaltung DGS Mitglieder-versammlung	Abend-veranstaltungen 3+4	
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Snow height & sunshine hours

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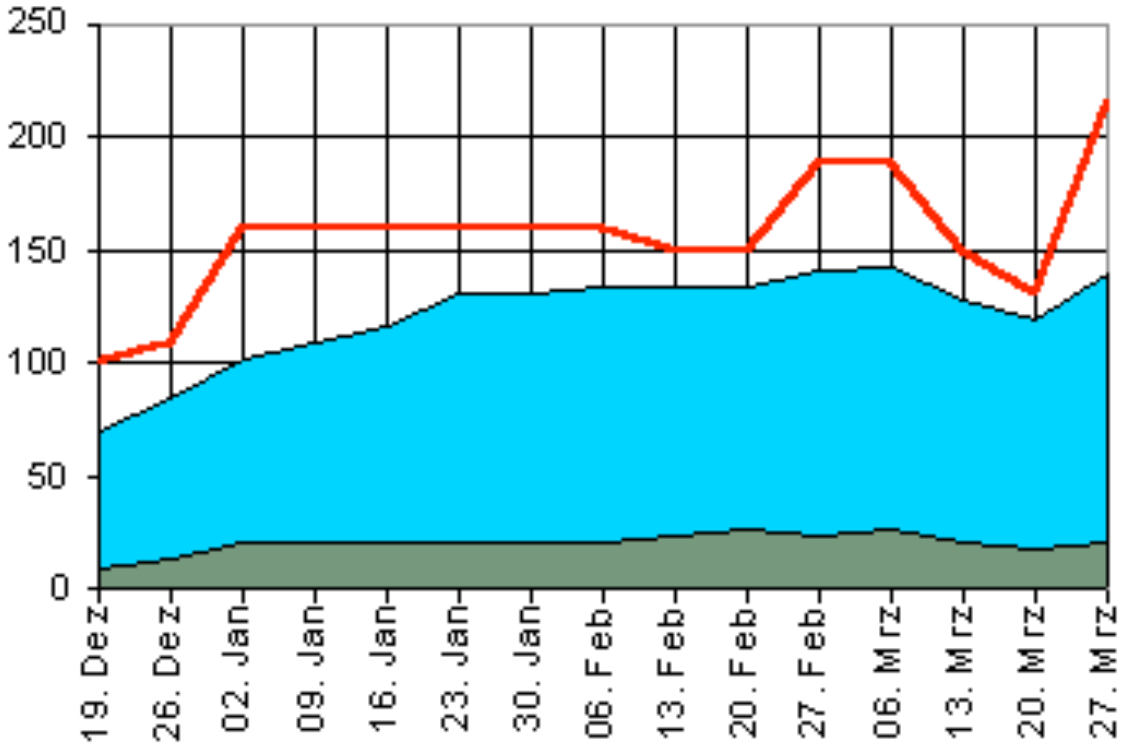
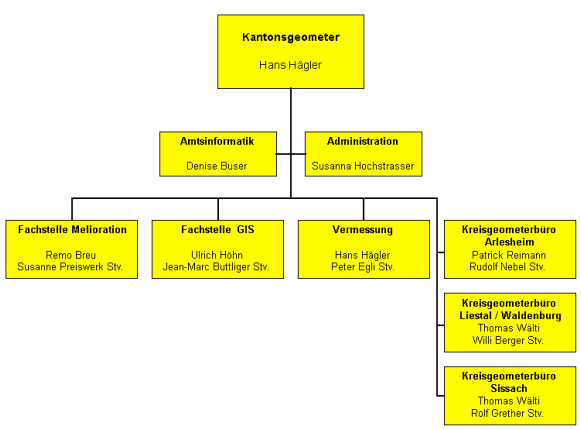
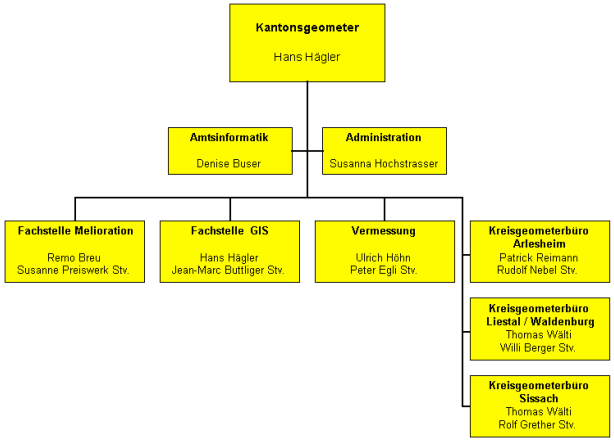


Organization chart

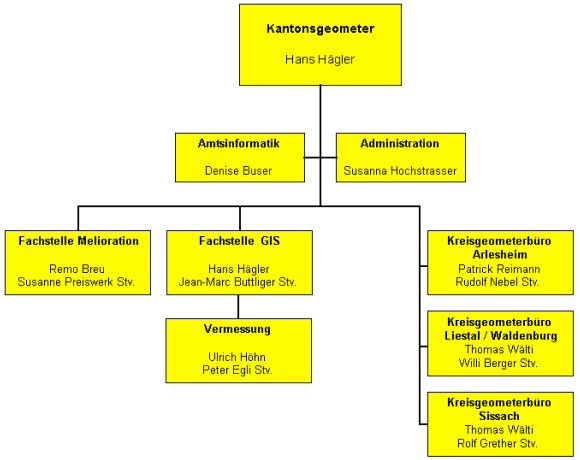
informations-visualisierung



1998



2000



2002

time

iPod price

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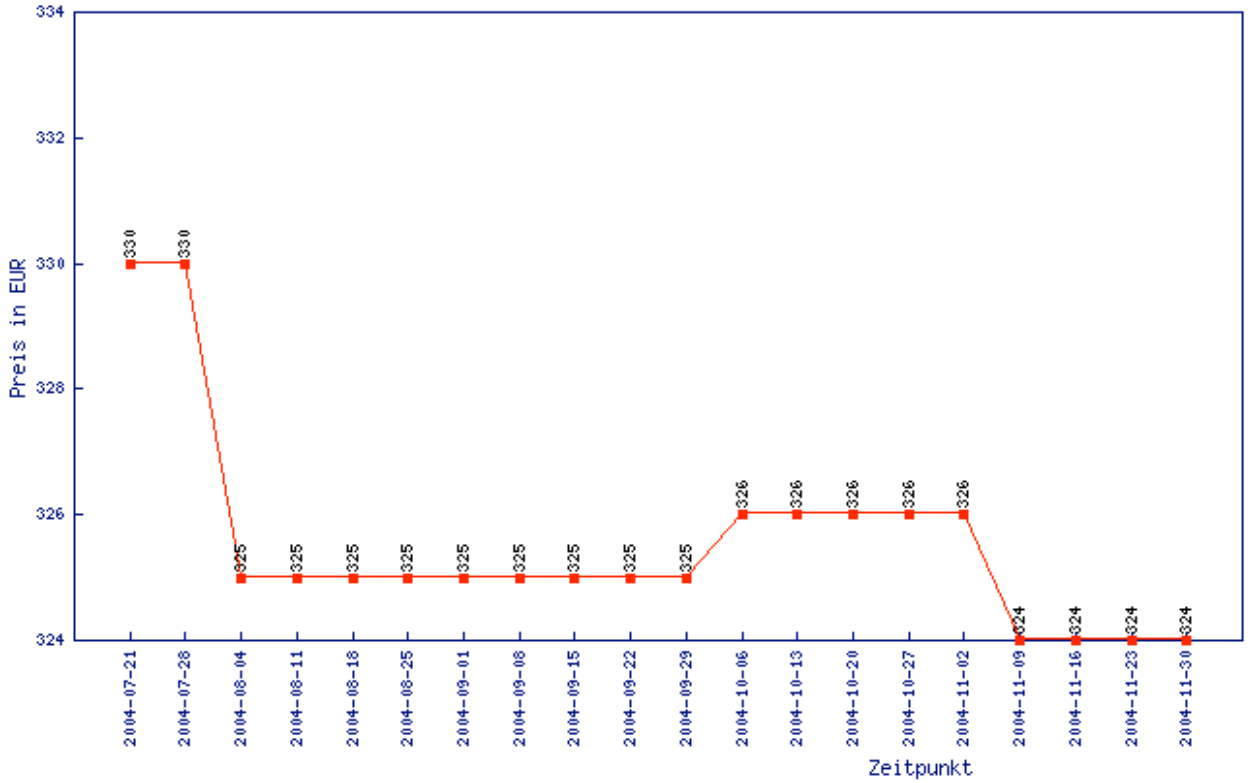
Preis in €	Anbieter	Händler-Bewertung	Verfügbarkeit lt. Händler / Versand
324,--	T-Online-Shop [zum Shop]	Note: 2,24	Versandfertig in ca. 14 Tagen
	Infos AGB Meinungen	14 Bewertungen	Details auf Anfrage Vorkasse: € 5,30 Nachnahme: zzgl. € 4,80 kostenlose Zustellung in



What is time?

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"If no one asks me, I know.
But if I wanted to explain it to one who asks me, I plainly do not know."
-- Augustinus (AD 354-430, The Confessions)

"Die Empfindung der Zeit hängt davon ab, auf welcher Seite der geschlossenen Klotür man sich befindet."
-- Albert Einstein

What is time-oriented data?

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no formal definition

what is considered as time-oriented data depends on the intended **task**

a possible definition:

Data, where **changes over time** or **temporal aspects** play a central role or are of interest.

Visualization of time-oriented data

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What?
time & data
1

Why?
user tasks
2

How?
visualization & interaction
3

Modeling time

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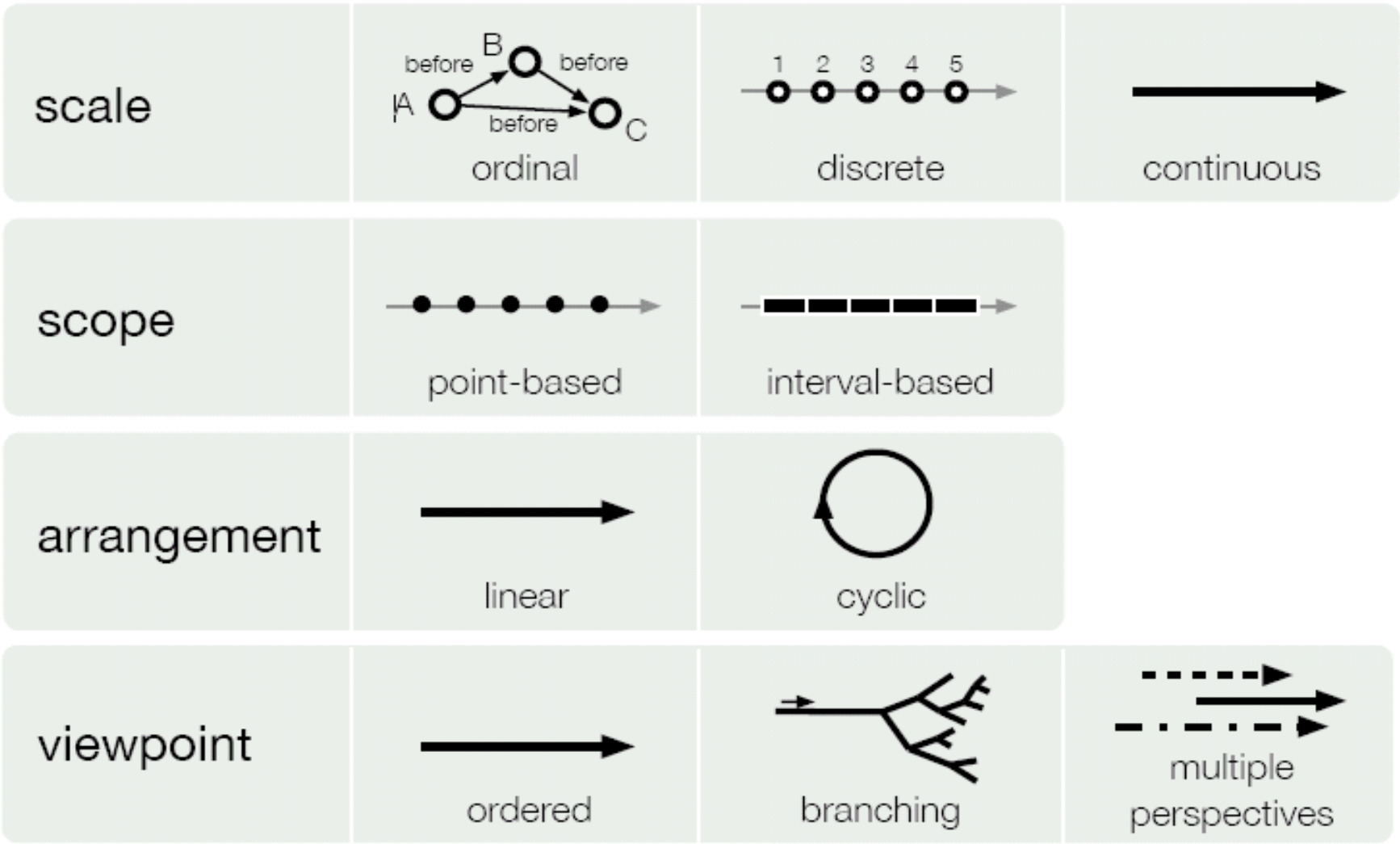

Scale

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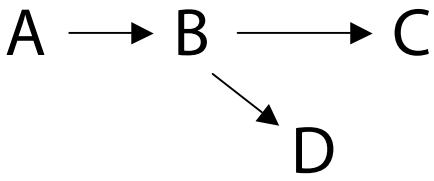
ordinal



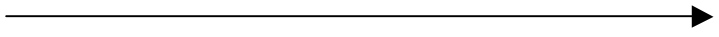
only order is known

discrete

every element of time has a unique predecessor and successor

comparable to Integer

continuous



between any two elements in time there might be another one in between

dense time

comparable to Float

Arrangement

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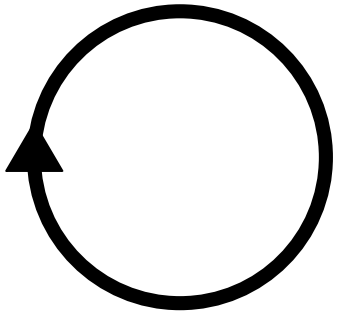
linear

each element of time has a unique predecessor and a unique successor

cyclic



summer is before winter, but winter is also before summer

Viewpoints

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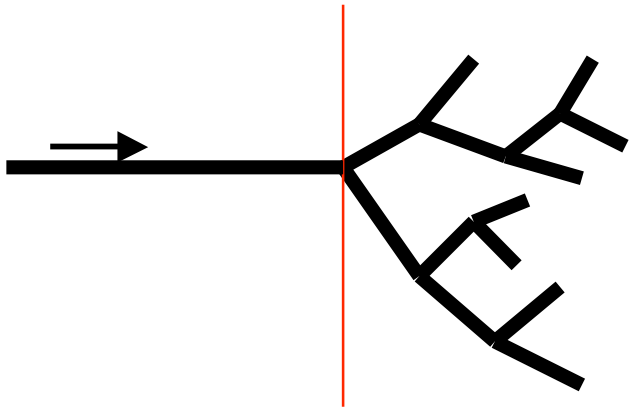
ordered

branching



Past

Definite time - data element assignment

Present

Currently valid state

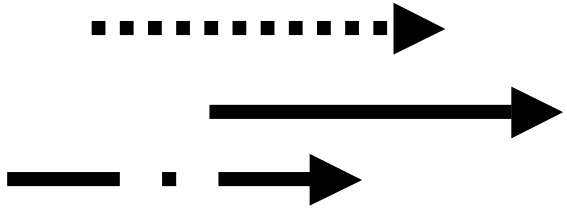
Future

Planning

Temporal uncertainty

Alternative scenarios

multiple perspectives



Modeling time

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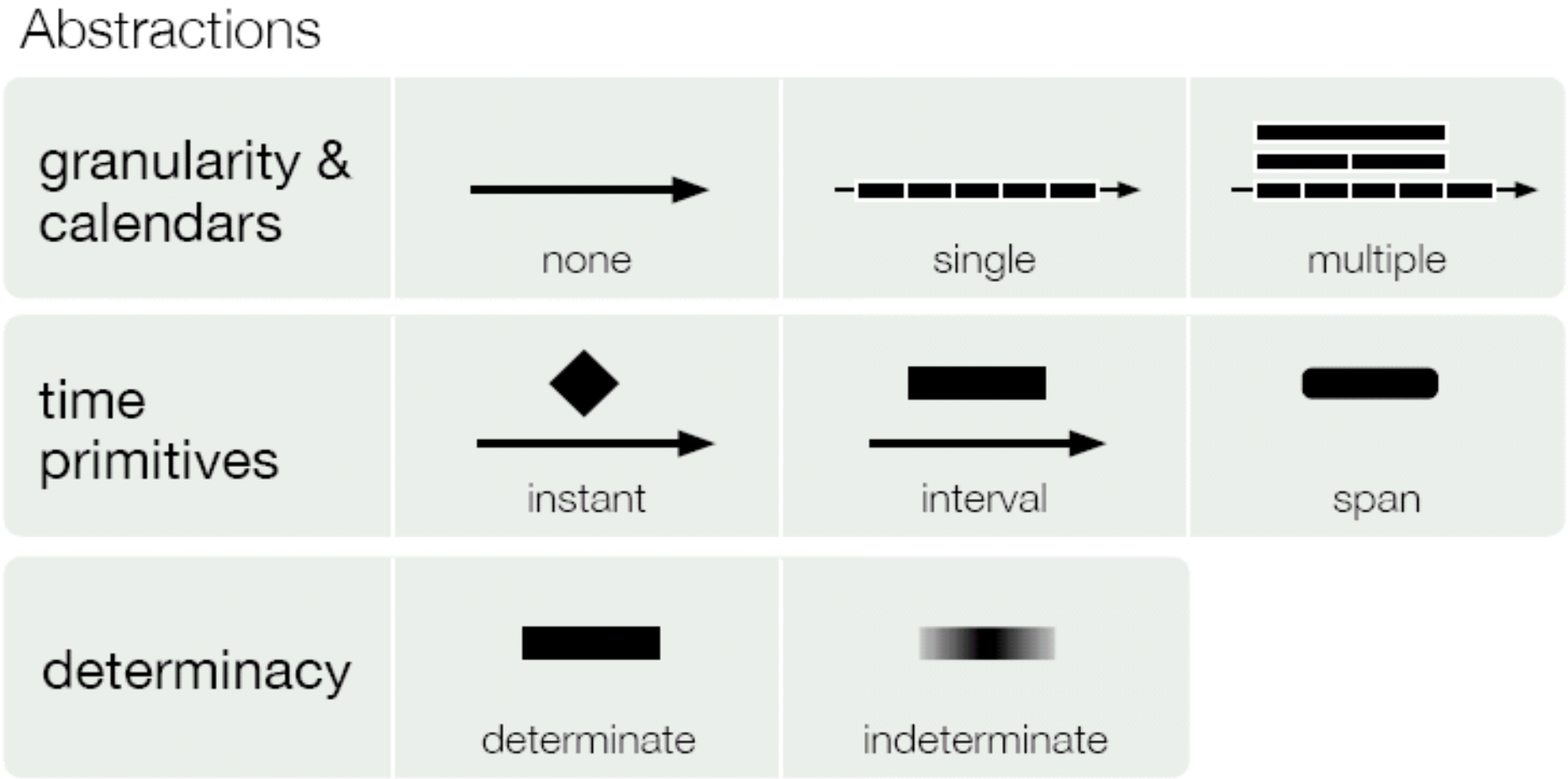
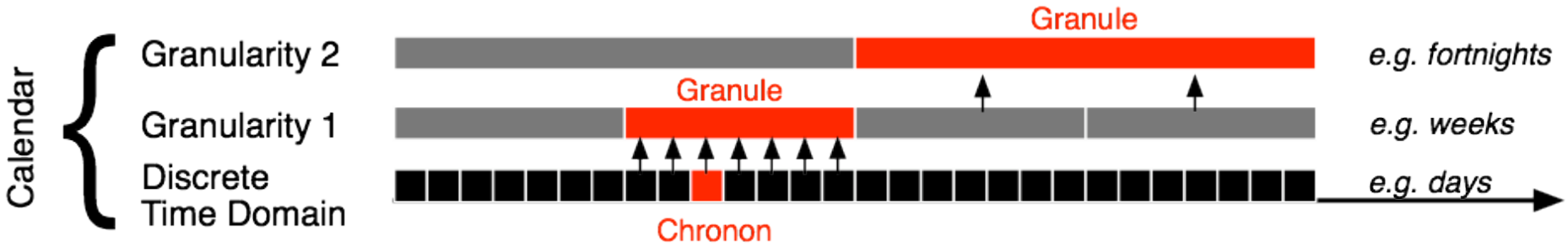


Granularity



Calendar

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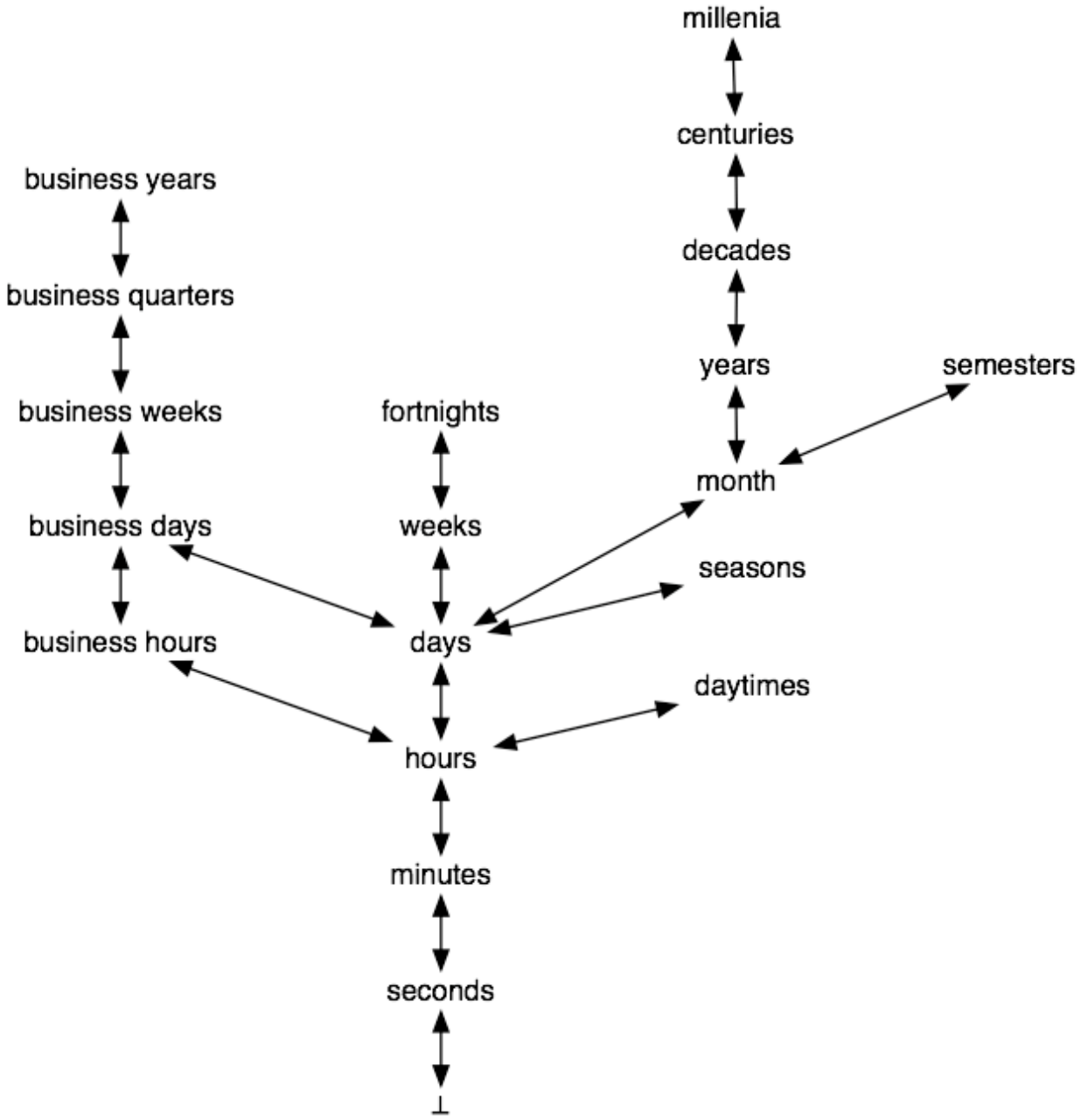

Example: Granularity paradoxon

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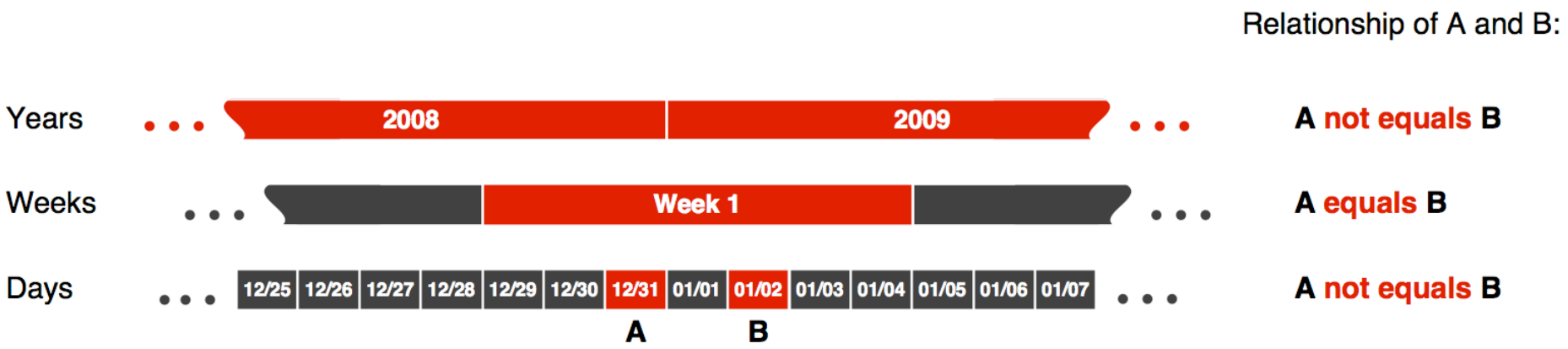

Time primitives

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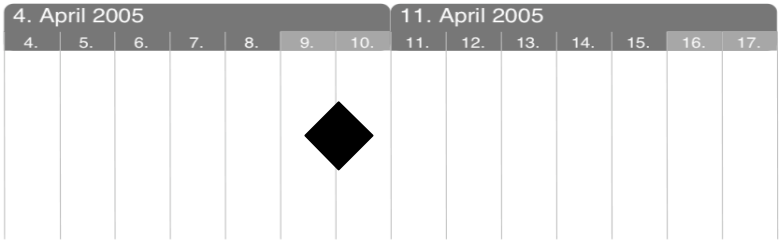
anchored

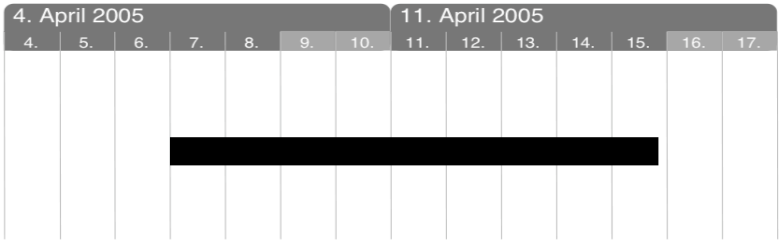
instant - single point in time



unanchored

span - duration of time

interval - duration between 2 instants



Determinacy

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determinate

complete knowledge of temporal attributes

indeterminate

incomplete knowledge of temporal attributes

no exact knowledge

i.e. "time when the earth was formed"

future planning

i.e. "it will take 2-3 weeks"

imprecise event times

i.e. "one or two days ago"

multiple granularities

Characterizing data

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scale	3.14 3.27 4.88 quantitative	coconut banana apple qualitative
frame of reference	 abstract	 spatial
kind of data	 events	 states
number of variables	 univariate	 multivariate

Relating data & time

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internal time inherent in the data model	 non-temporal	 temporal
external time extrinsic to the data model	 static	 dynamic

Visualization of time-oriented data

informations-visualisierung

What?
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Low-level Task List 1/2

[McEachren, 1995]

Existence of a data element

Does a data element exist at a specific time?

Example: Was a measurement made in July, 1960?

Temporal location

When does a data element exist in time?

Example: Is there a lecture taking place on November 24, 2005?

Time interval

How long is the time span from beginning to end of the data element?

Example: How long was the processing time for data set A?

Temporal texture

How often does a data element occur?

Example: How often was Jane sick last year?

Low-level Task List 2/2

[McEachren, 1995]

Rate of change

How fast is a data element changing or how much difference is there from data element to data element over time?

Example: How much did the price of gasoline change since last September?

Sequence

In what order do data elements appear?

Example: Did the explosion happen before or after the car accident?

Synchronization

Do data elements exist together?

Example: Is Jill's birthday on Easter Monday this year?

Task Taxonomy 1/2

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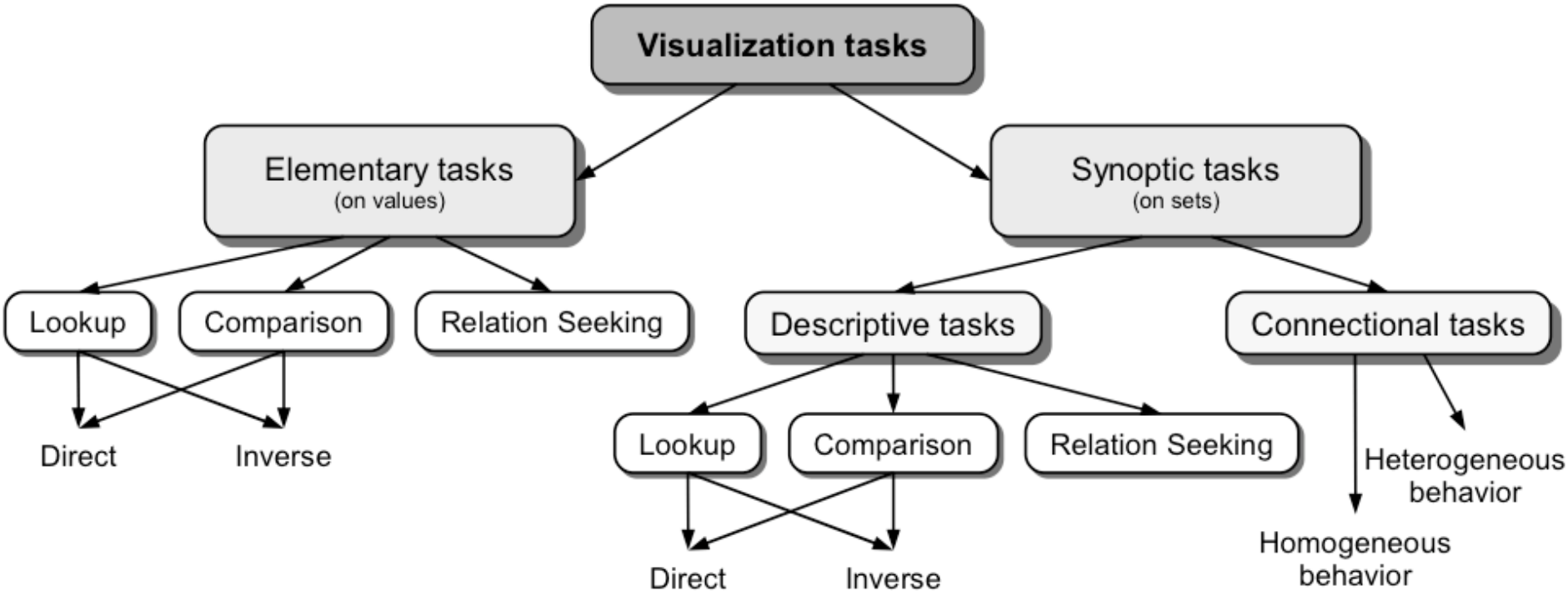
[Andrienko & Andrienko, 2006]



Task Taxonomy 2/2

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[Andrienko & Andrienko, 2006]

Task Type	Example
Elementary	
Direct lookup	What was the price of Google stocks on January 14?
Inverse lookup	On which day(s) was the lowest stock price for Amazon in 2010?
Direct comparison	Compare the stock prices of Yahoo and Microsoft on January 14.
Inverse comparison	Did the price of an Apple stock reach $200 before or after January 14?
Relation seeking	On which days was the price of Adobe stocks higher than the price of AOL stocks?
Synoptic	
Direct lookup (pattern definition)	What was the trend of Oracle stocks during January?
Inverse lookup (pattern search)	Find months in which the price of Novell stocks decreased.
Direct (pattern) comparison	Compare the behavior of the stock price of Hewlett-Packard in January and June.
Inverse (pattern) comparison	How is a decreasing trend of Dell stocks related to the period of summer vacation?
Relation seeking	Find two contiguous months with opposite trends in the stock price of Lenovo.
Homogeneous behavior	Is the behavior of Nokia stocks influencing the behavior of Motorola stocks?
Heterogeneous behavior	Do the phases of the moon influence the behavior of Intel stocks?

Visualization of time-oriented data

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Visualization roots

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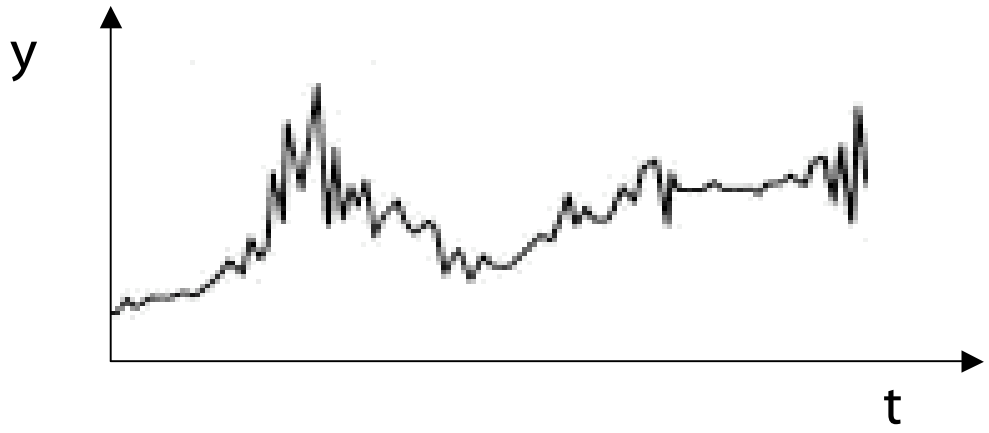
Statistics

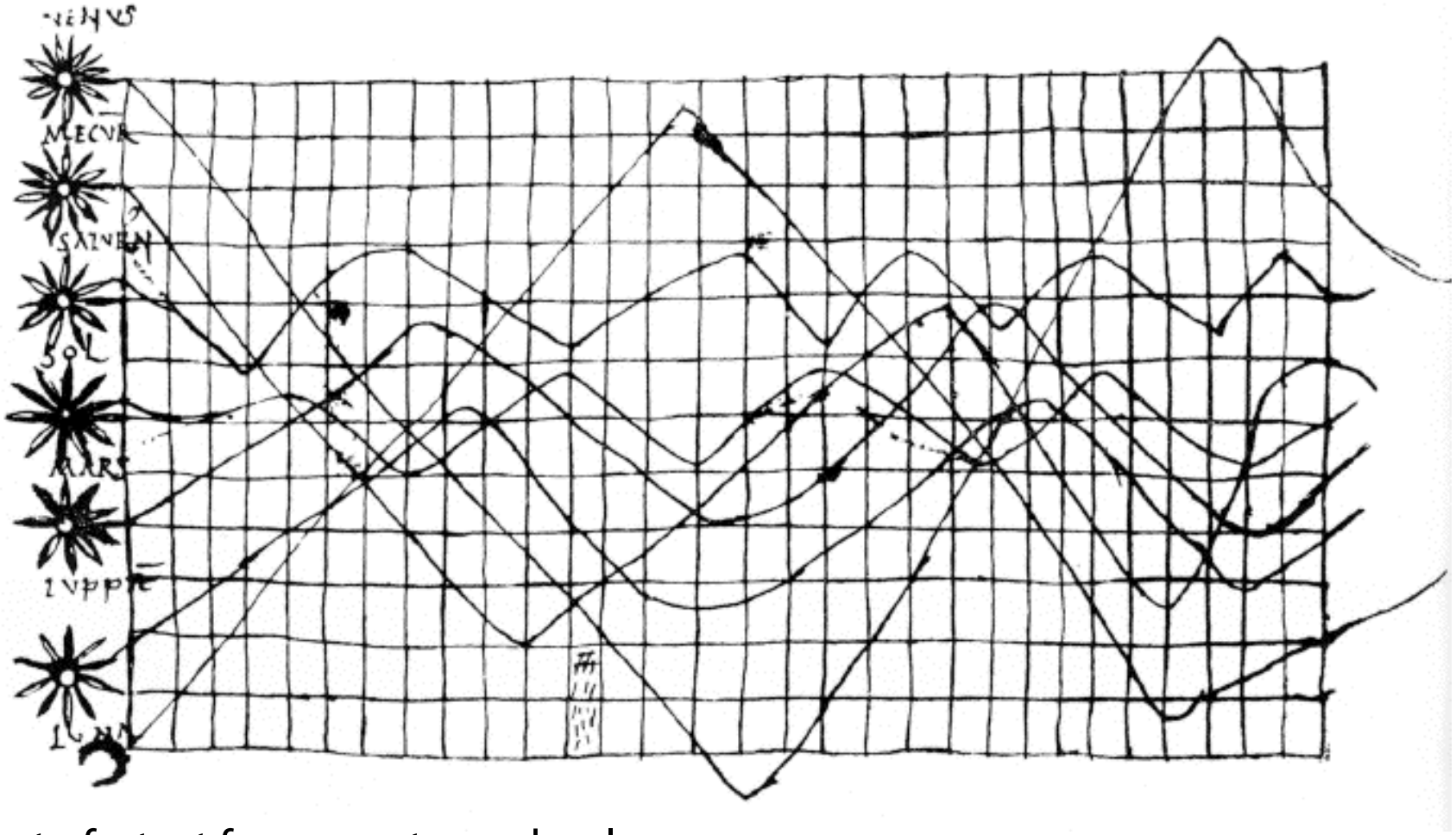
Visualization of time-series.

The time-series plot is the most frequently used form of graphic design. [Tufte, 1983]

Mostly one parameter over time.

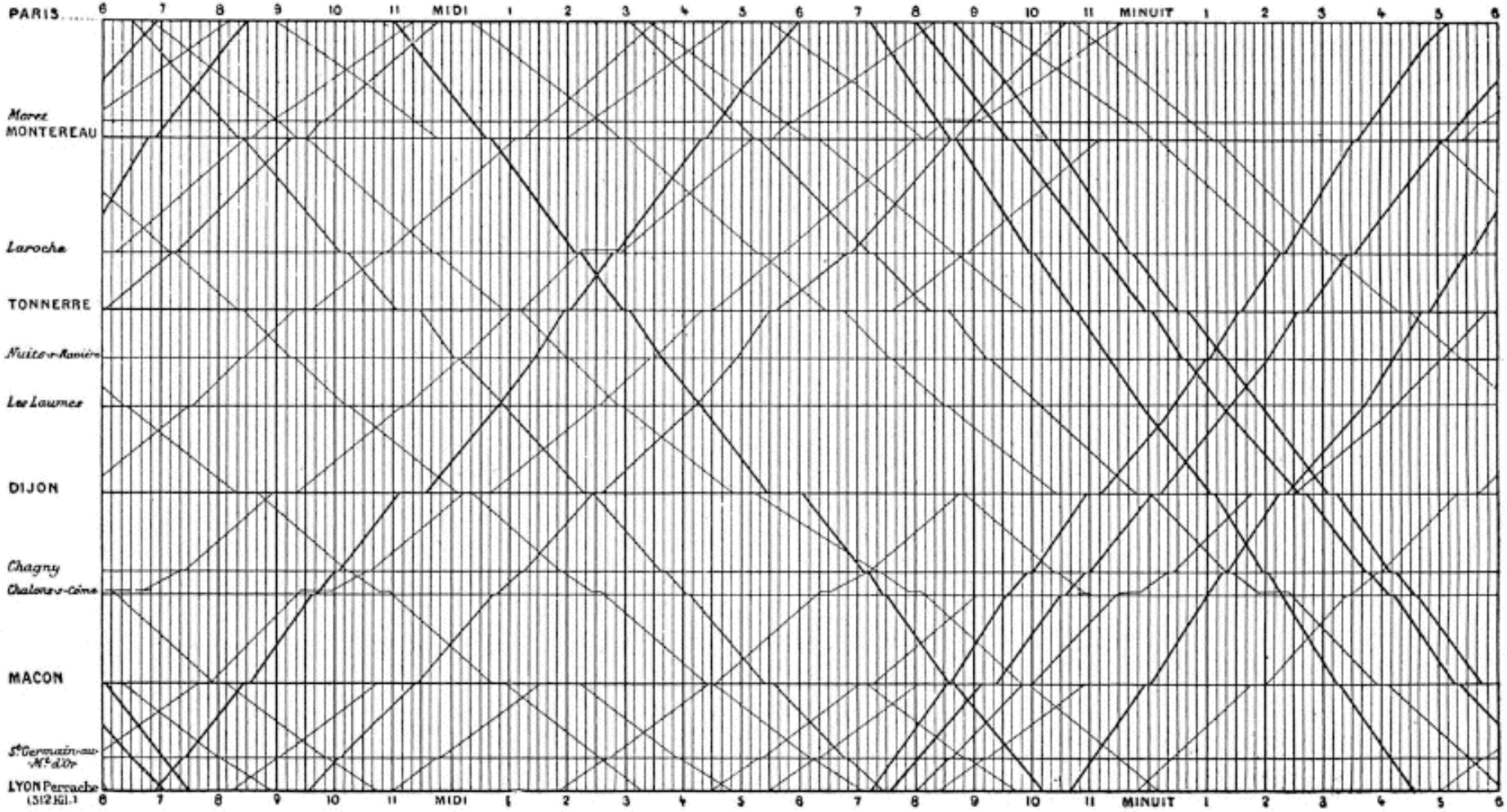


Early time-series plot



Part of a text for monastery schools
10th or 11th century (!)
Inclinations of the planetary orbits over time
800 years before other time-series plots appeared

Train schedule



Paris to Lyon (1880s)

E. J. Marey, *La Méthode Graphique* (Paris, 1885), p. 20. The method is attributed to the French engineer, Ibry.

Visualizing time-oriented data

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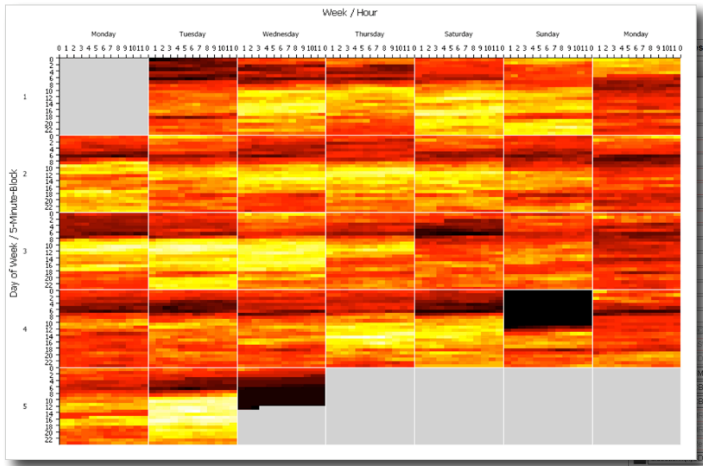

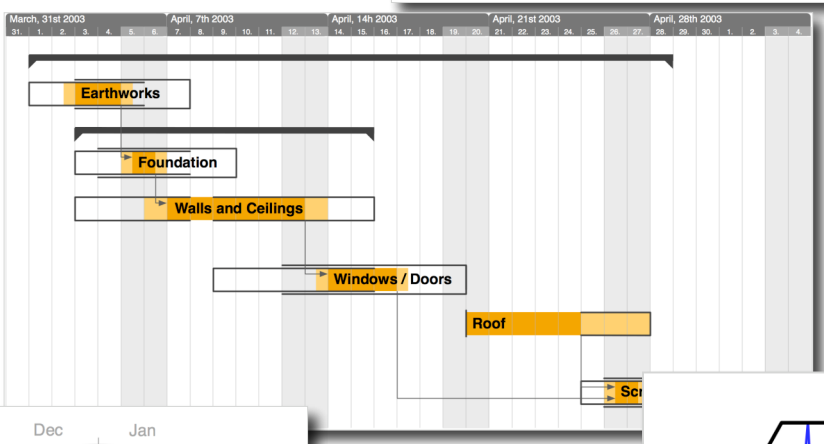

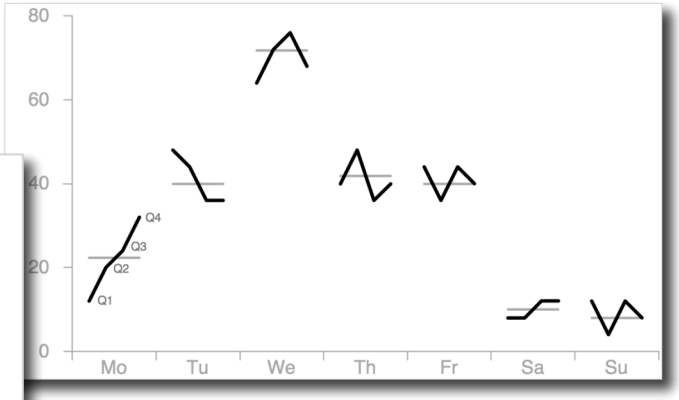

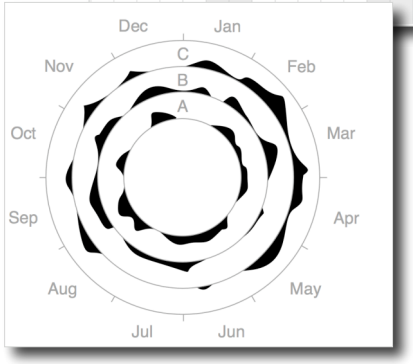

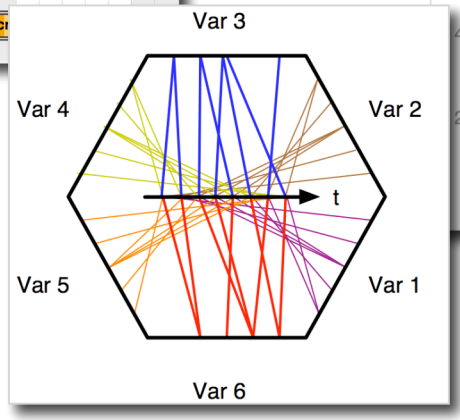

Visual mapping of time

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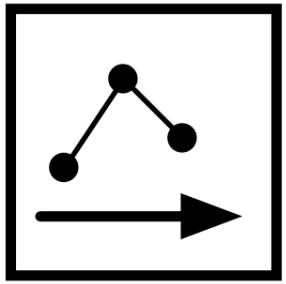
Dynamic: ***Time → Time (Animation)***



probably the most natural form of mapping

no "conversion" of concepts needed in between

well suited for

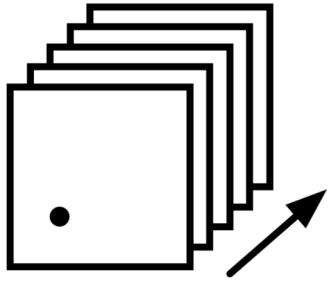
keeping track of changes

following trends and movements

not well suited for

analytic and explorative tasks

no direct comparison of parameters between different points in time is possible



Static: ***Time → Space***

mapping of time to visual features

direct comparison of parameters between different points in time is possible

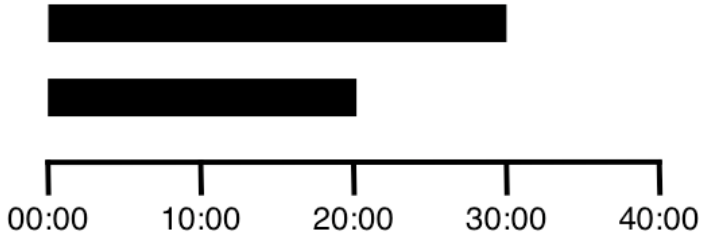
Visual variables

position

most common mapping

the most accurately perceived visual feature

length



second most accurate attribute

typically, the length of an object denotes the duration, as for example in timelines

Visual variables

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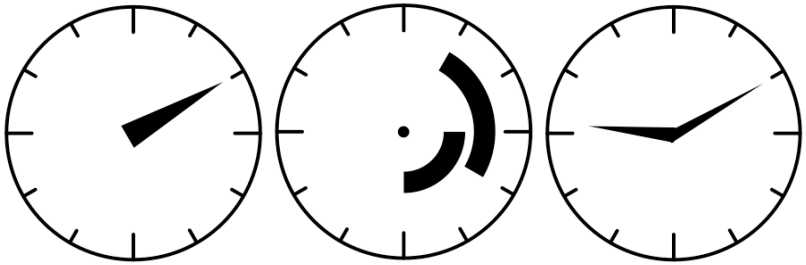
angle, slope

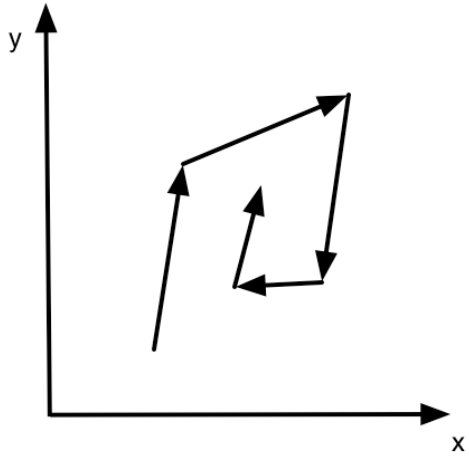
analog-clock-based visualizations



connection

connecting arrows or lines

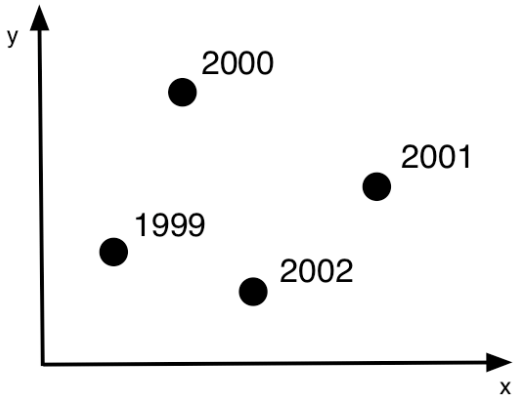
“before element” --> “after element”



text, label

simple text labelling

often combined with “connection”



Visual variables

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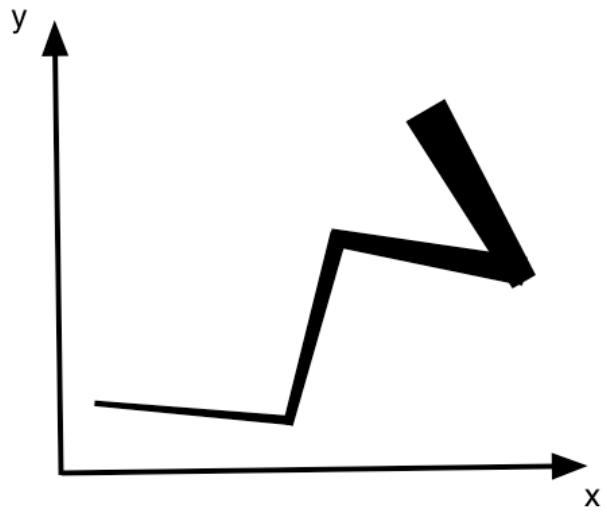
line (thickness)

Increasing or decreasing with time

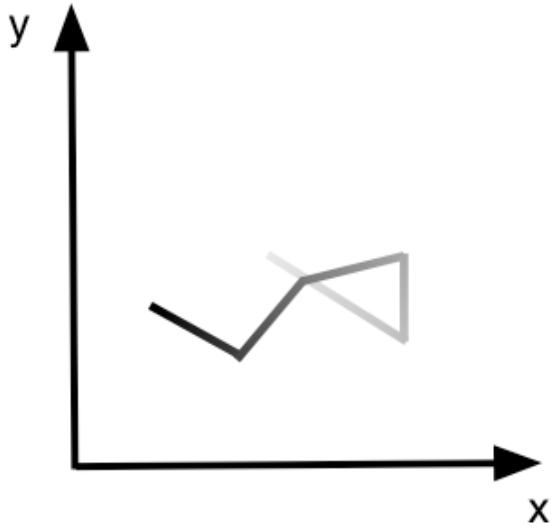


color (brightness, saturation, hue)

brightness most appropriate

“fading away” against the background

transparency



Visual variables

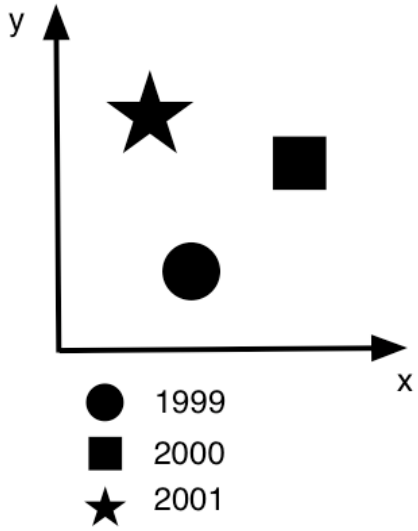
area

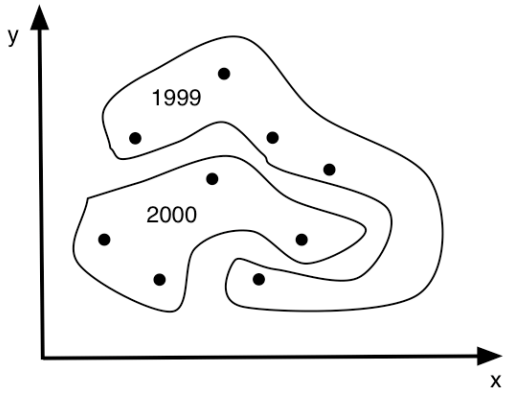
enclosure

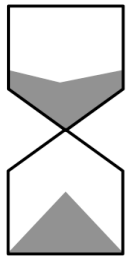
size

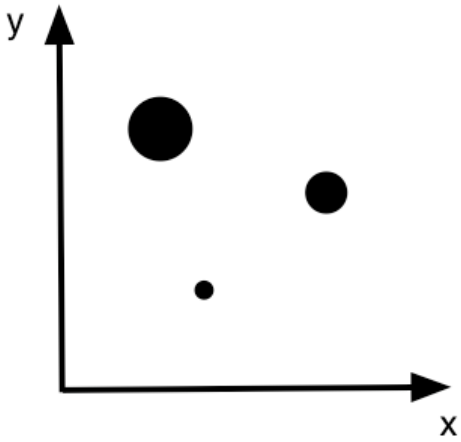
texture

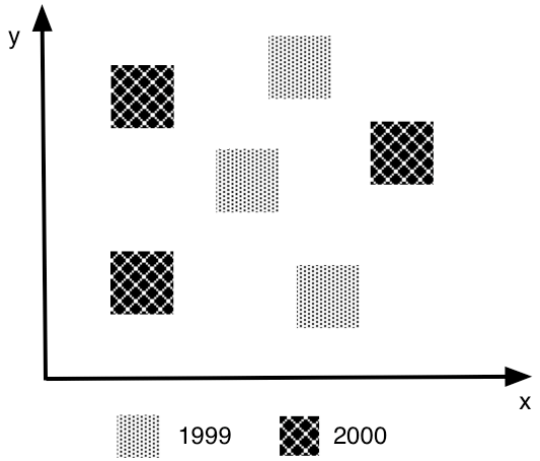
shape











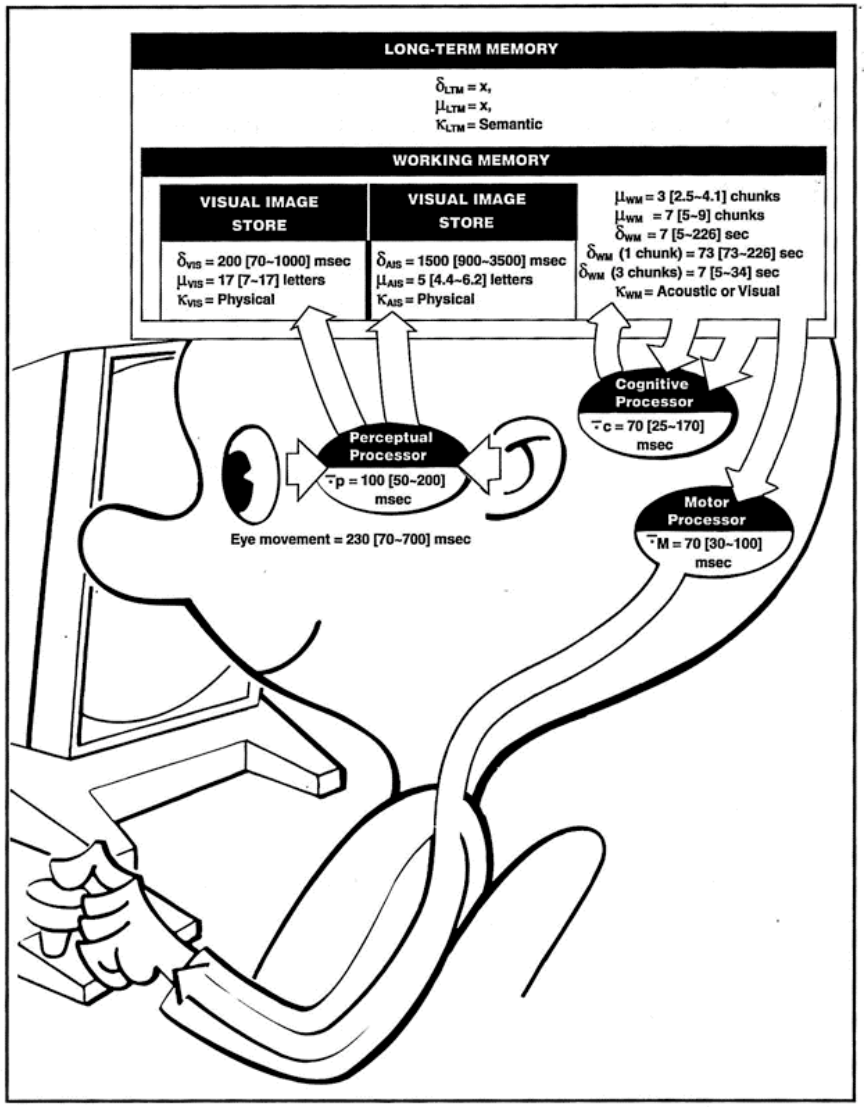
less suited

Interaction facilitates active discourse with the data and visualization

see

think

modify

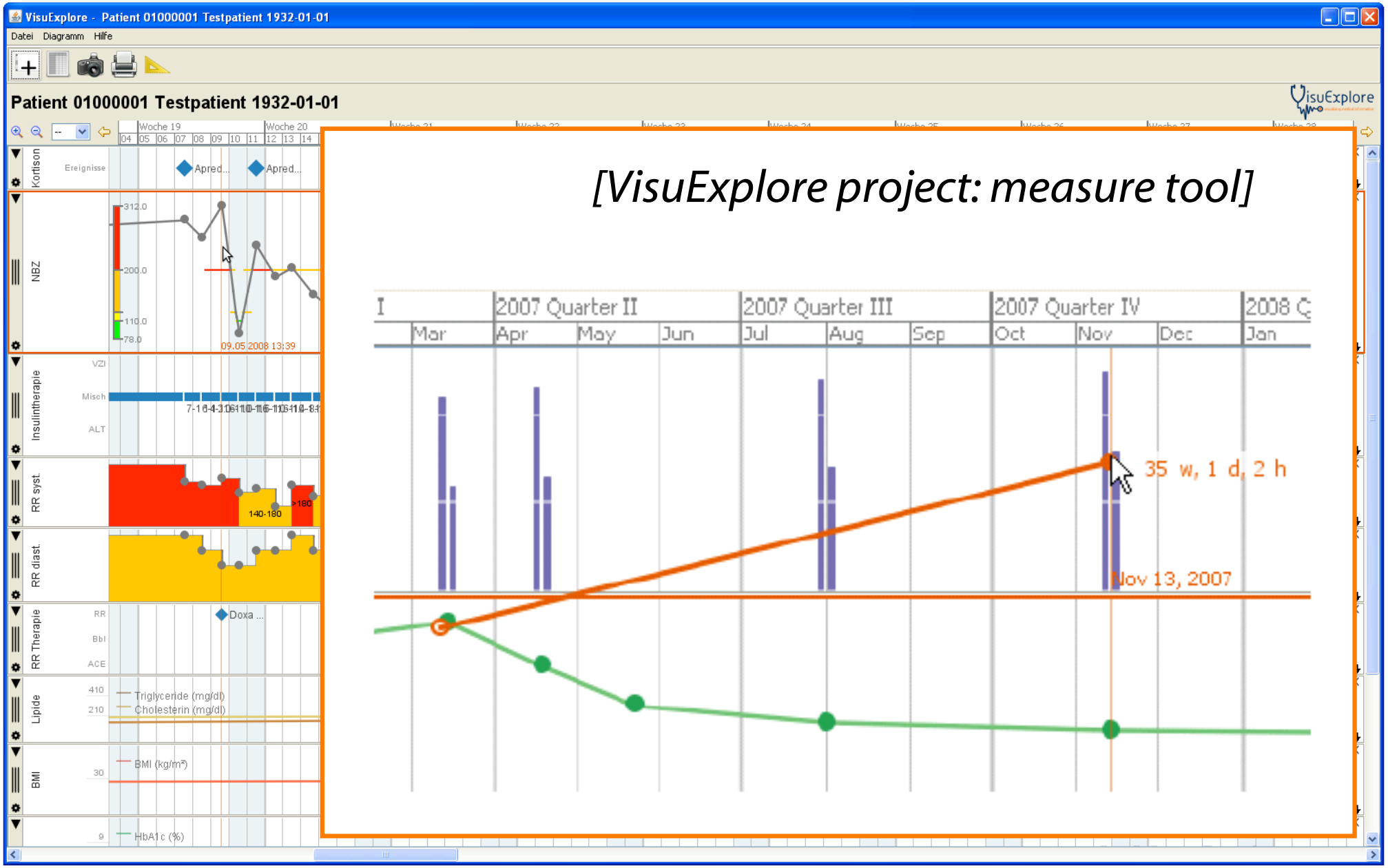


[Card et al., 1983]

Interacting with time

informations-visualisierung

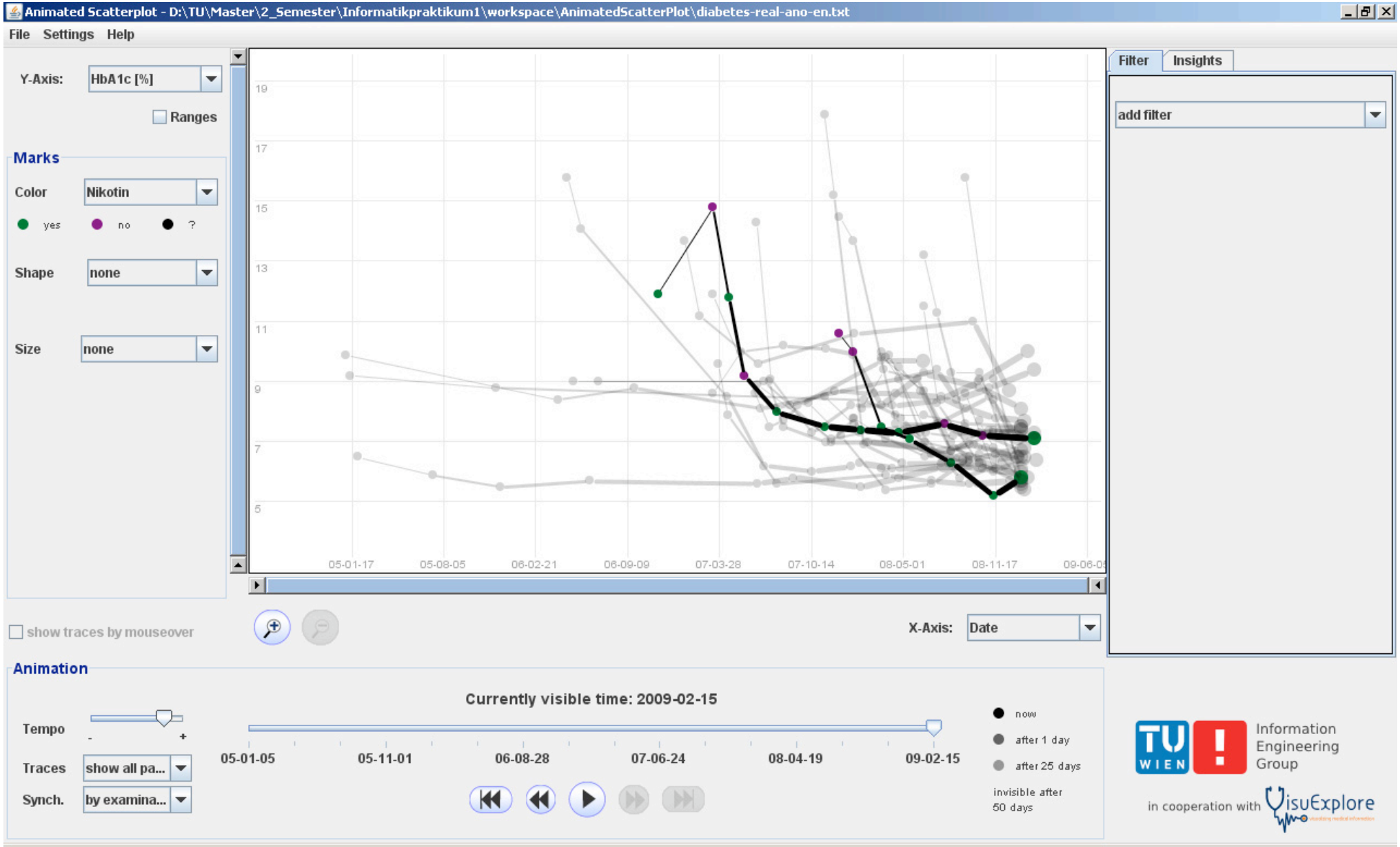
[VisuExplore project]



Interacting with time

informations-visualisierung

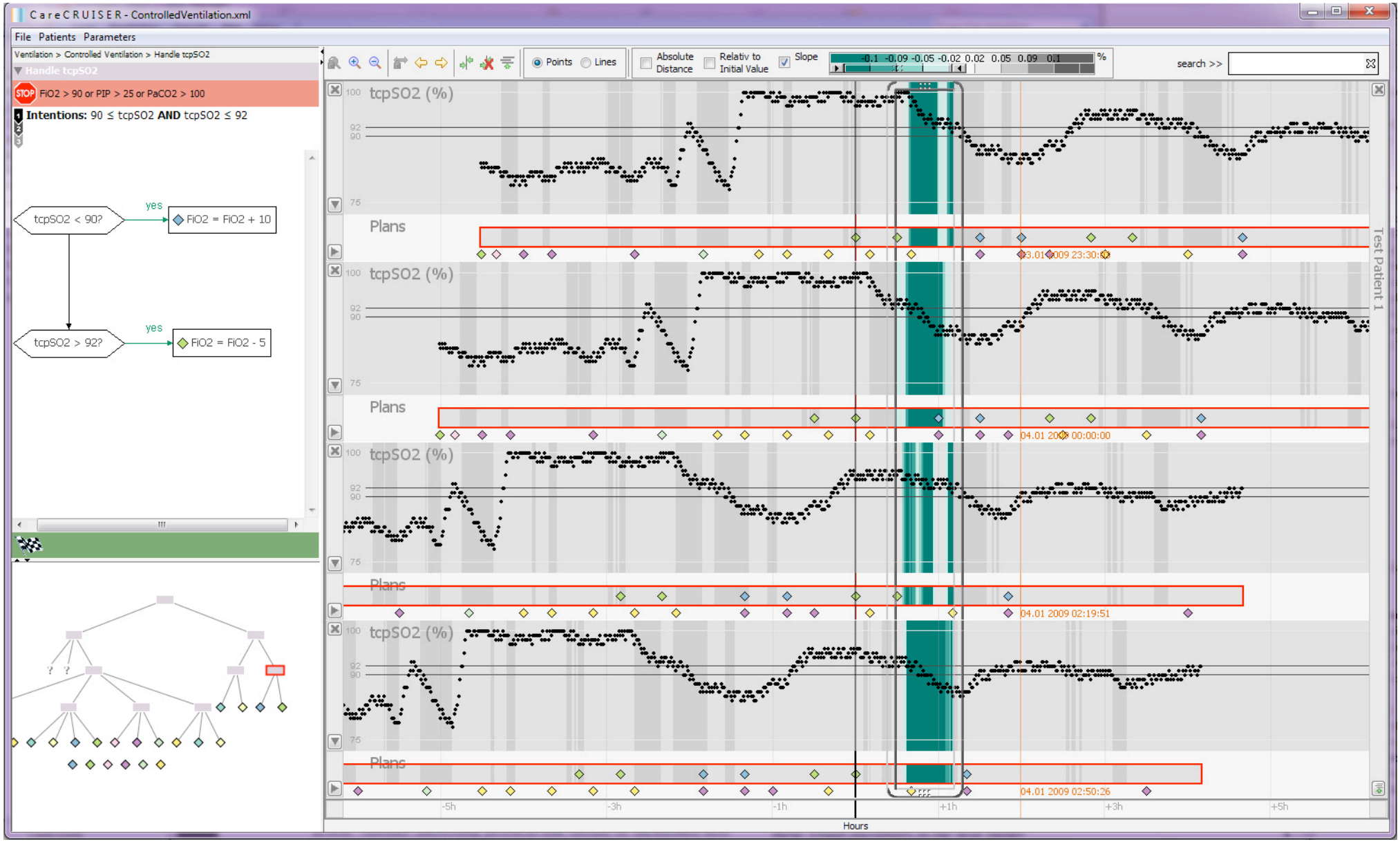
[Animated Scatterplot project]



Interacting with time

informations-visualisierung

[CareCruiser project]



Visualization of time-oriented data

informations-visualisierung

What?
time & data
1

Why?
user tasks
2

How?
visualization & interaction
3

Forthcoming book 2011

informations-visualisierung

Springer

Visualization of Time-Oriented Data

Series: » Human–Computer Interaction Series

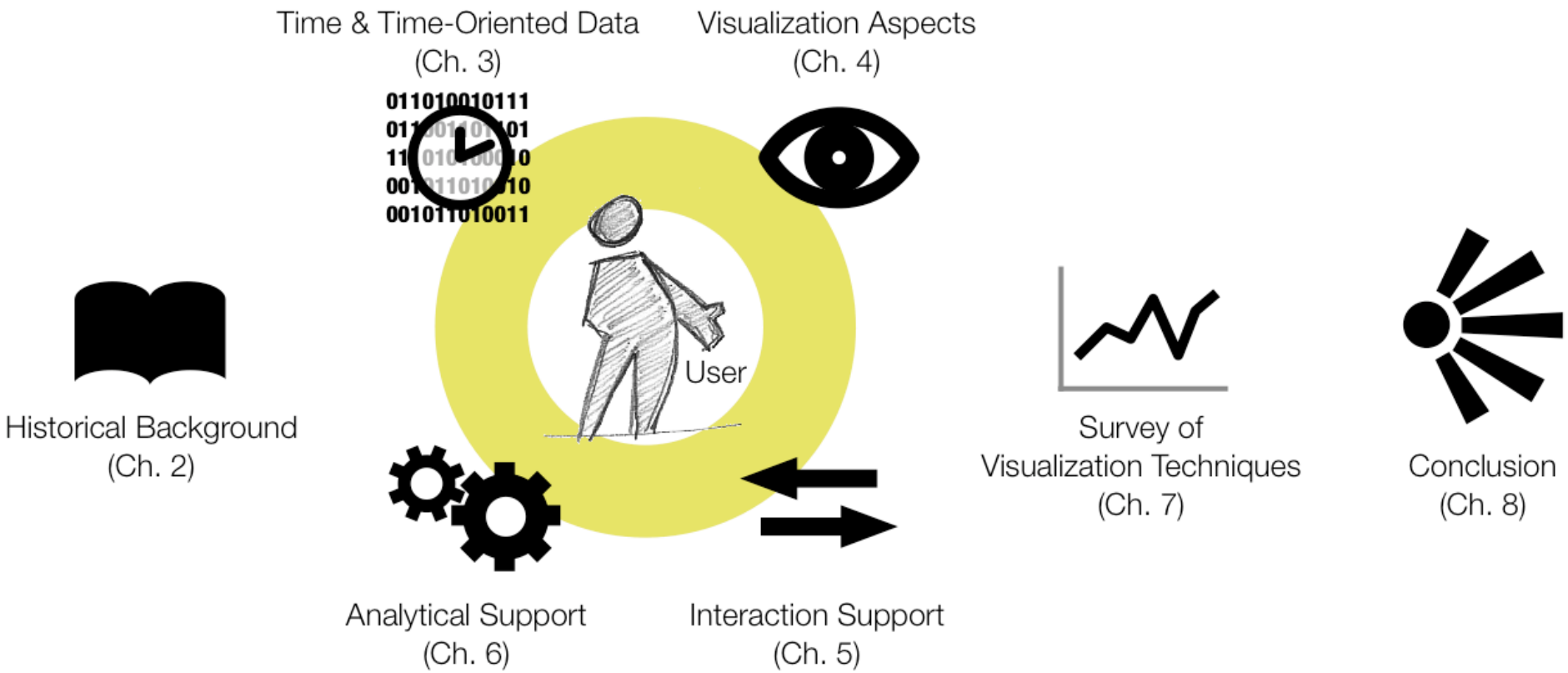
Aigner, W., **Miksch**, S., **Schumann**, H., **Tominski**, C.

1st Edition., 2011, XVI, 184 p. 150 illus. in color., Hardcover
ISBN: 978-0-85729-078-6

Due: May 20, 2011

[Aigner, Miksch, Schumann, Tominski, 2011]

Aigner, Miksch, Schumann, Tominski: **Visualization of Time-Oriented Time (2011)**



[Aigner, Miksch, Schumann, Tominski, 2011]

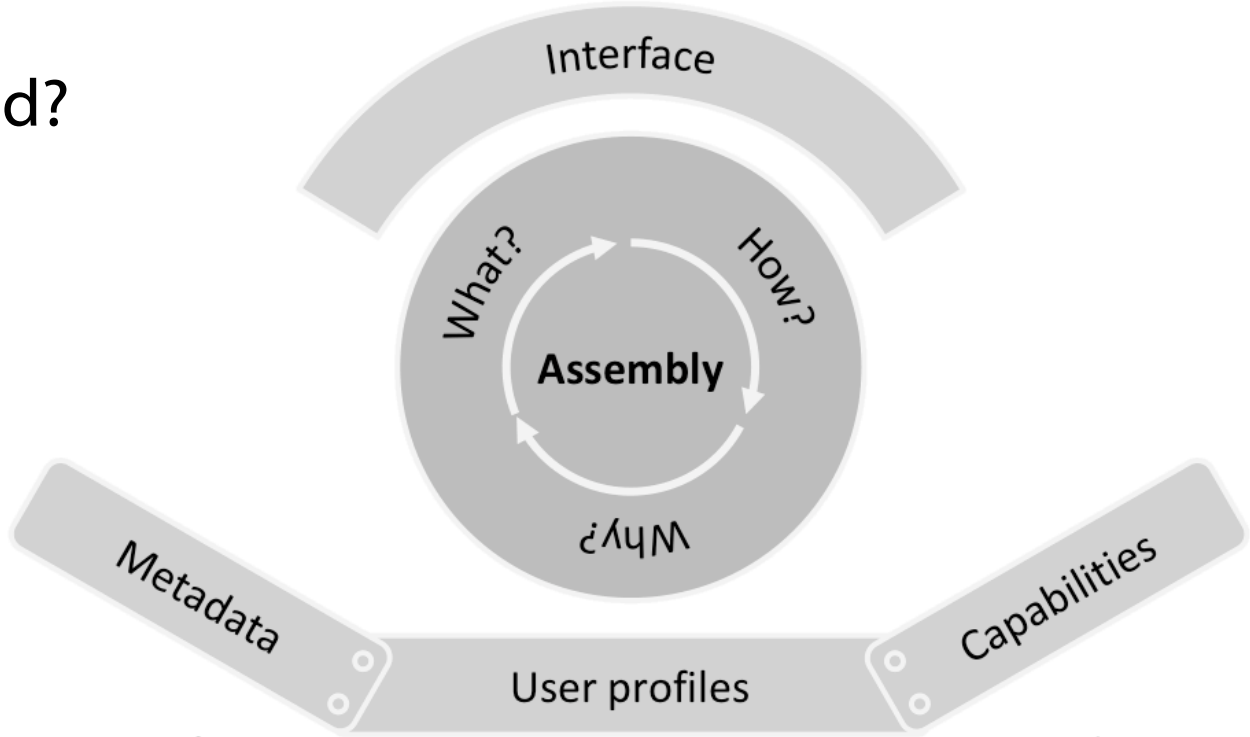
Visualization design

informations-visualisierung

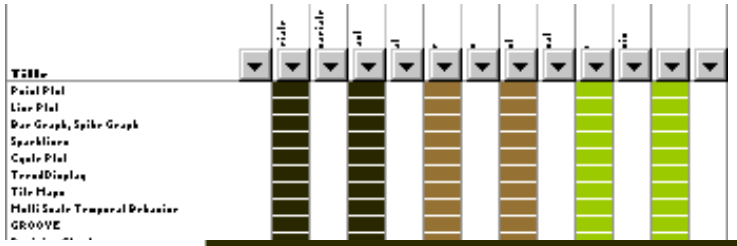
What is presented?
time and data

Why is it presented?
user tasks

How is it presented?
visual representation



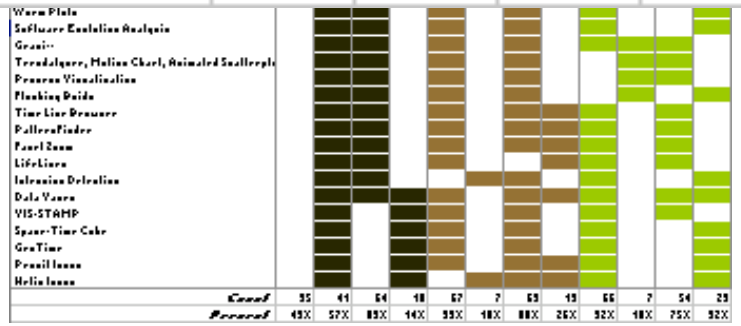
[Aigner, Miksch Schumann, Tominski, 2011]



informations-visualisierung

Compared: *75 methods*

	data				time				vis			
	variables		frame of reference		arrange-ment		time primitives		mapping		dimension-ality	
	univariate	multivariate	abstract	spatial	linear	cyclic	instant	interval	static	dynamic	2D	3D
Count	35	41	64	10	67	7	63	19	66	7	54	23
Percent	49%	57%	89%	14%	93%	10%	88%	26%	92%	10%	75%	32%



[Aigner, Miksch, Schumann, Tominski, 2011]