informations-
visualisierung

visualization of **time-oriented data**

introduction

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Version 3.2
14.12.2009

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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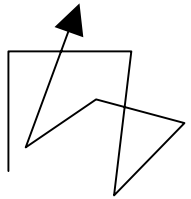
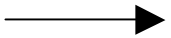
Space can be traversered “arbitrarily”

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

Gives us the ability to…

…travel in time virtually.

Time-oriented data?

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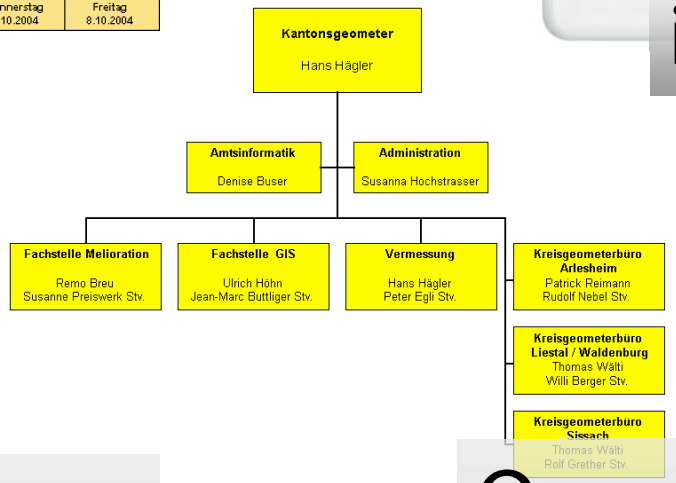
Zeit	Montag 4.10.2004	Zeit	Dienstag 5.10.2004	Mittwoch 6.10.2004	Donnerstag 7.10.2004	Freitag 8.10.2004
		9.00 bis 10.45	Plenar-veranstaltungen 1+2+3	Plenar-veranstaltungen 7+8+9	Plenar-veranstaltungen 13+14	Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen
11.00 bis 13.00	Sektions-sprechertreffen	11.00 bis 12.45	Plenar-veranstaltungen 4+5+6	Plenar-veranstaltungen 10+11+12	Plenar-veranstaltungen 15+16+17	
	Presse-konferenz					Abschluss-veranstaltung
		13.00 bis 14.00	Mittags-vorlesungen 1+2	Mittags-vorlesungen 3+4	Mittags-vorlesungen 5+6	
			Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen	Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen	Sektionen, Arbeitsgruppen, Ad-hoc-Gruppen	
		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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		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	
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Snow height & sunshine hours

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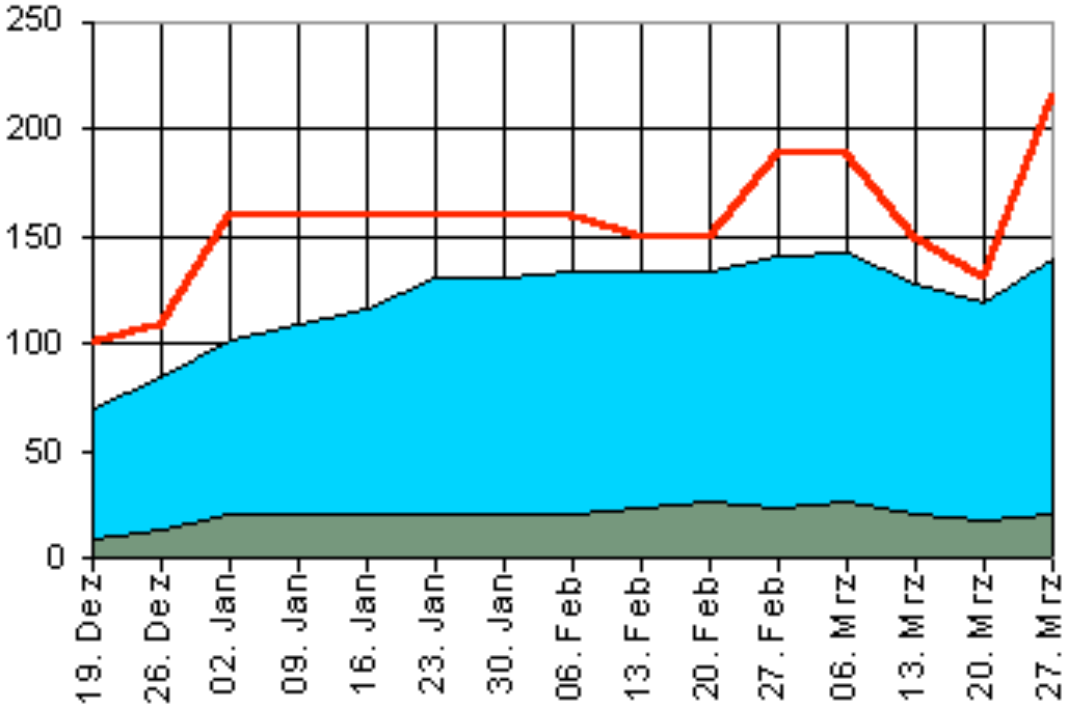

Organization chart

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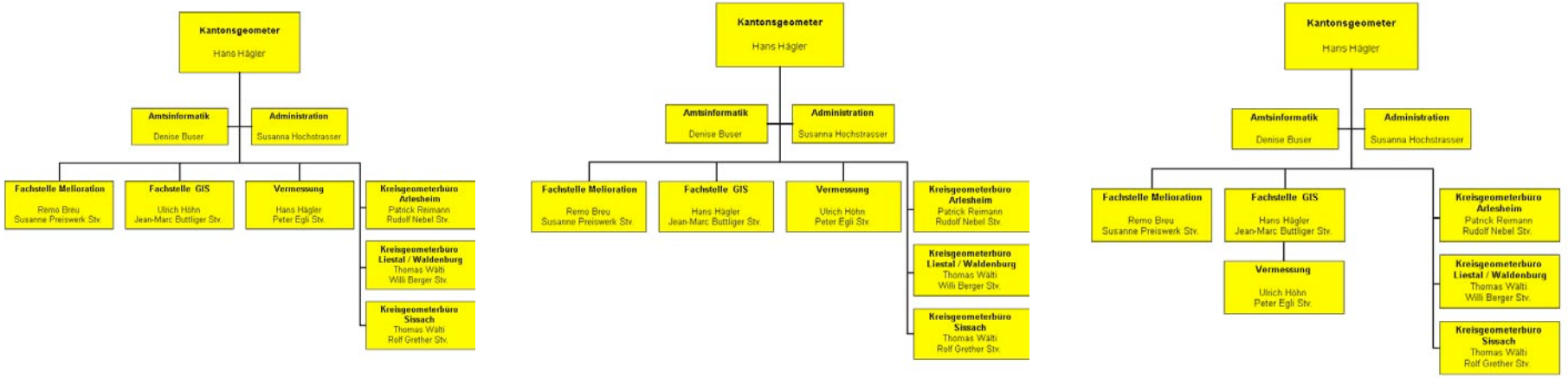

1998 2000 2002

time

iPod price

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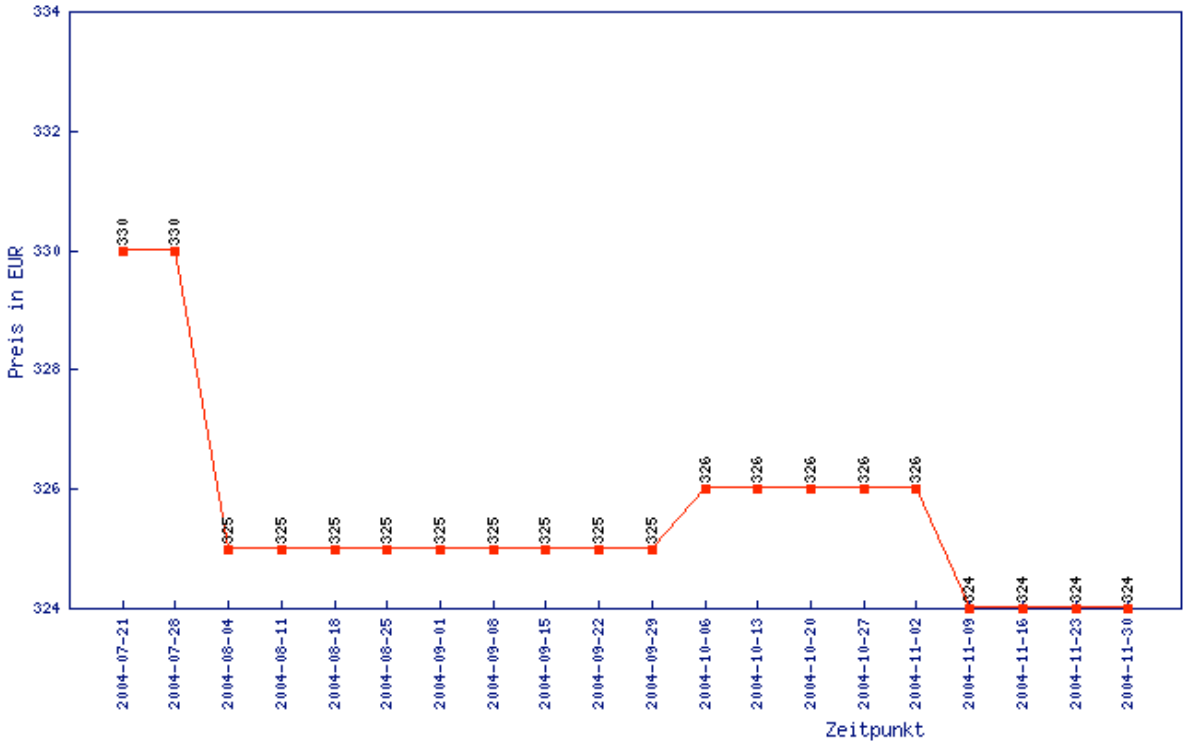
Preis in €	Anbieter	Händler-Bewertung	Verfügbarkeit lt. Händler
			Versand
324,--	T··Online·Shop [zum Shop]	Note: 2,24	Versandfertig in ca. 14 Tagen



	Infos AGB Meinungen	Note: 1,09 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 Design

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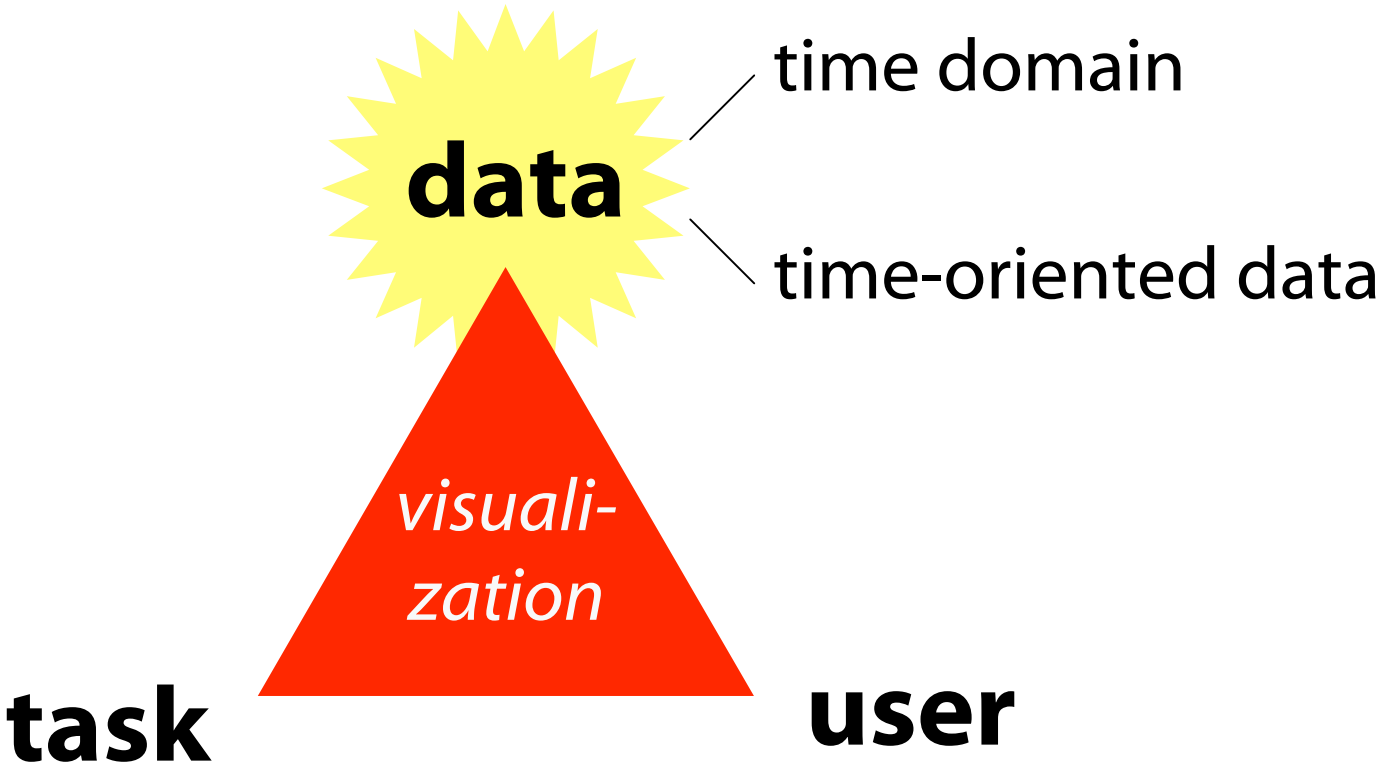

Time domain overview

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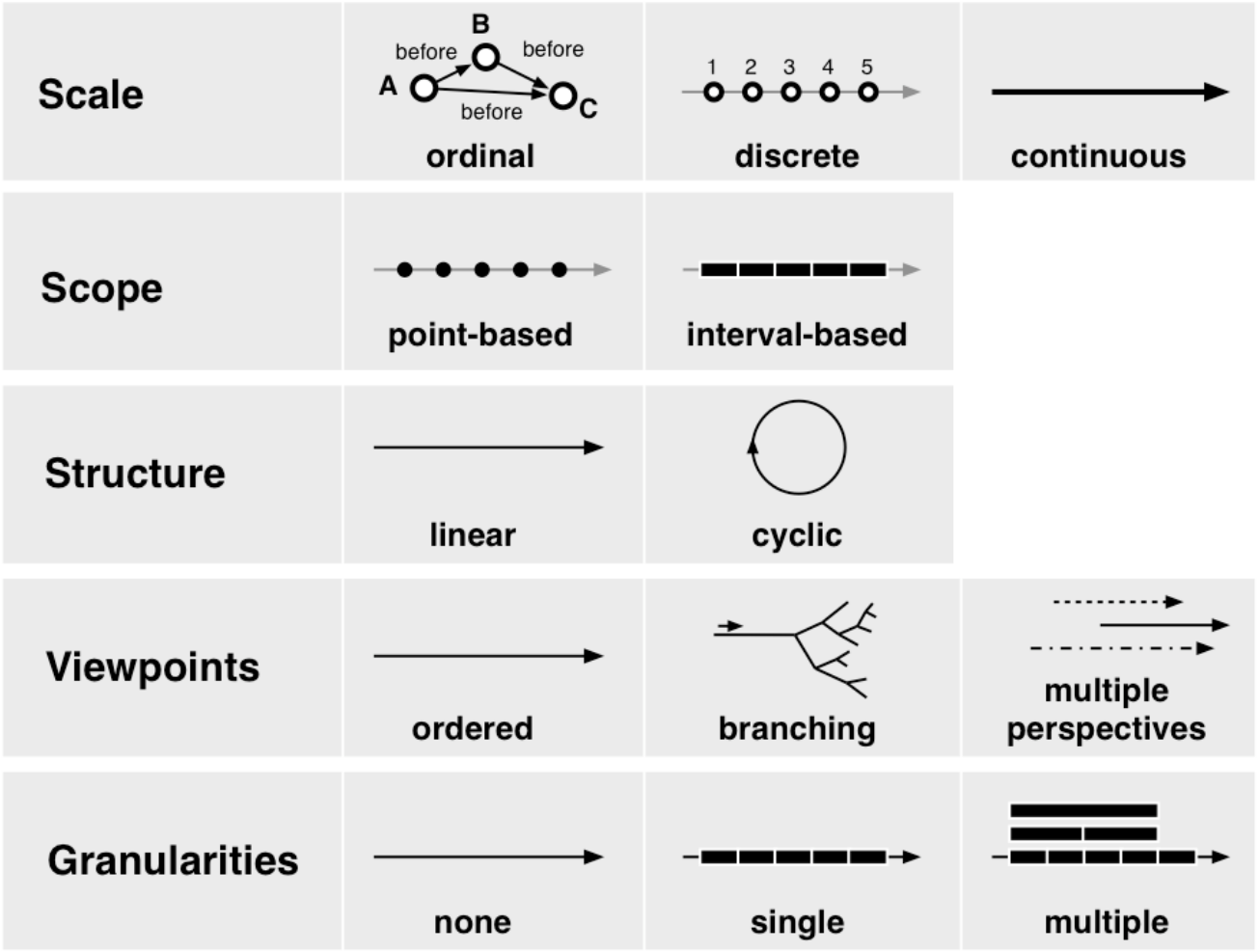
Adapted from [Frank, 1998]



Scale

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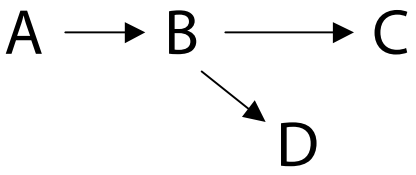
ordinal



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

Structure

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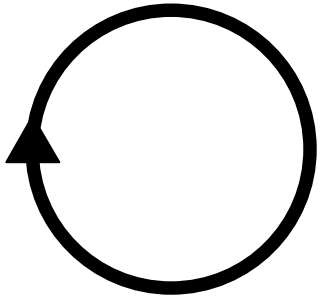
linear

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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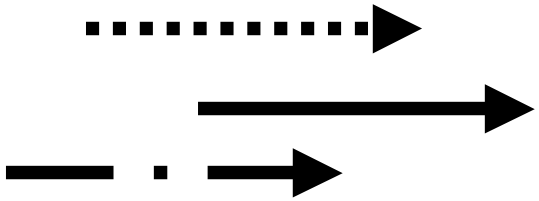
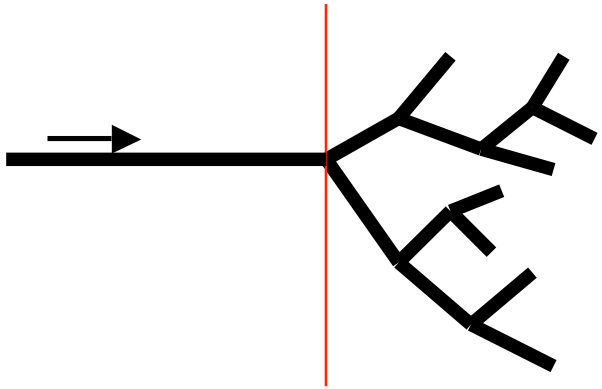
ordered

multiple perspectives



branching



Past

Definite time - data element assignment

Present

Currently valid state

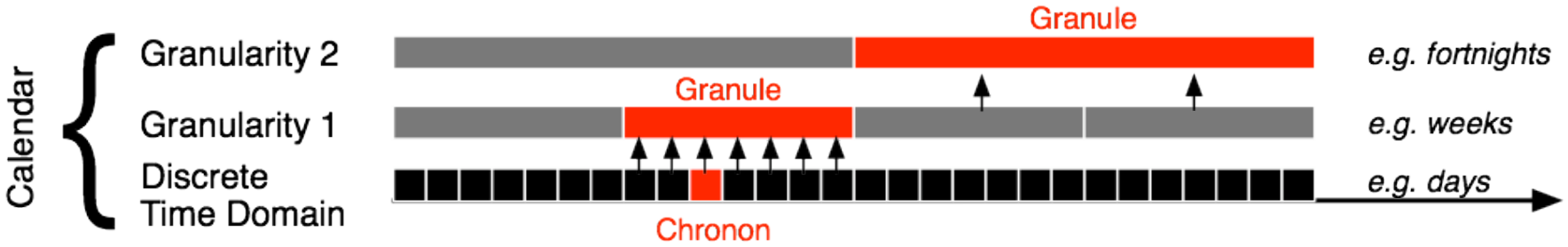
Future

Planning

Temporal uncertainty

Alternative scenarios

Granularity



Calendar

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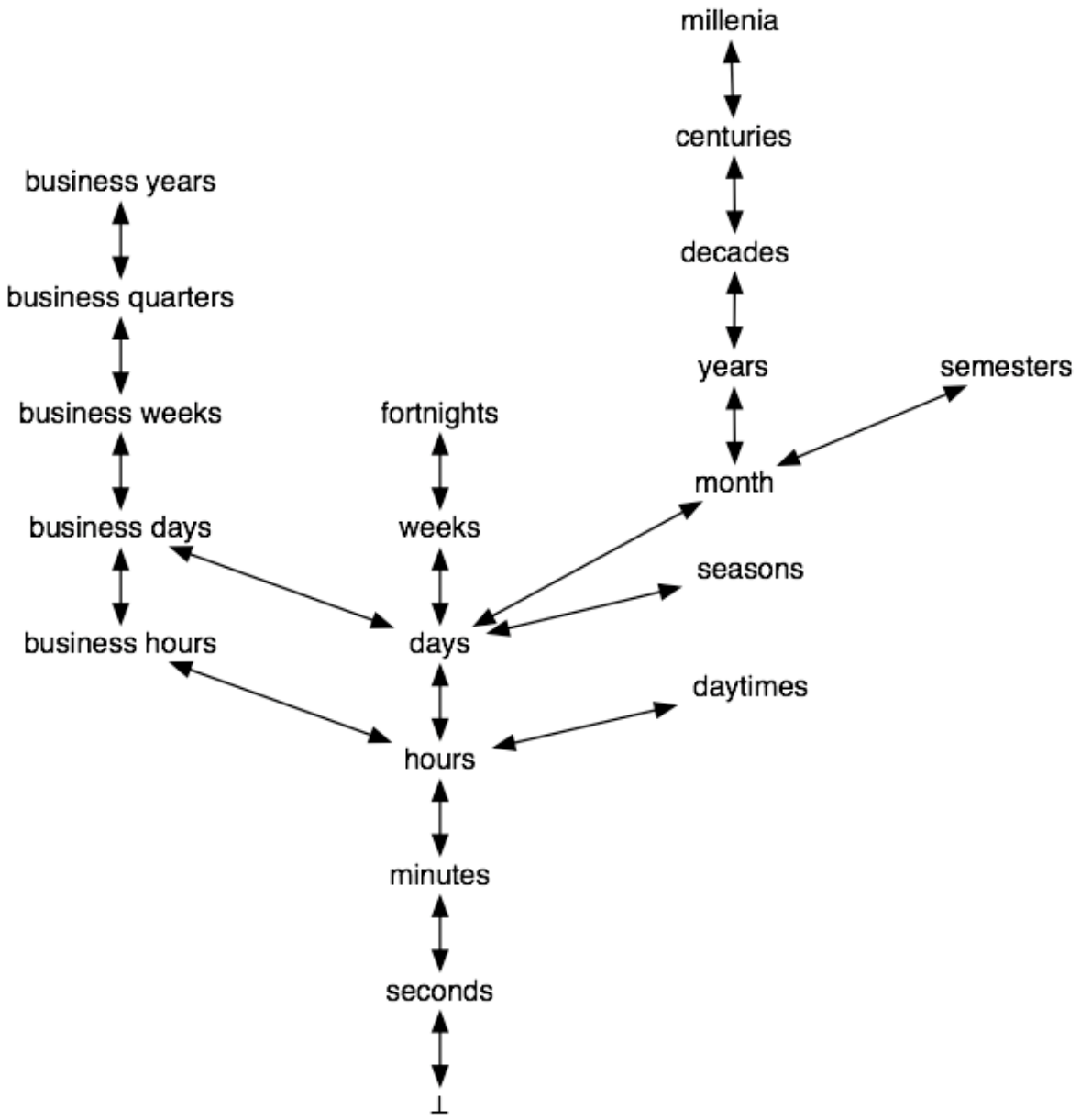

Determinacy

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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

Time primitives

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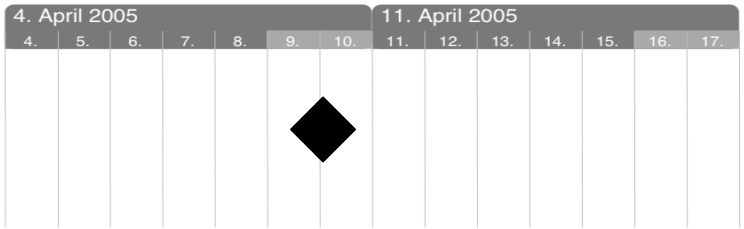
anchored

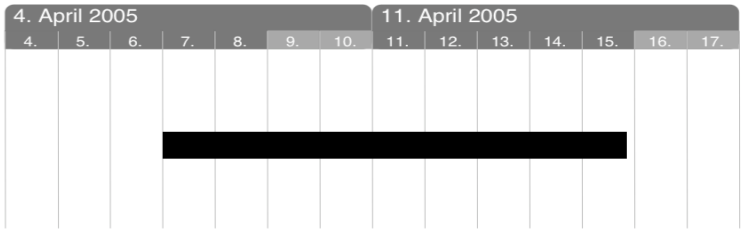
instant - single point in time



unanchored

span - duration of time

interval - duration between 2 instants



Time-oriented data

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Number of variables	 univariate	 multivariate
Frame of reference	 spatial	 abstract
Relation to time	 direct	 indirect
Kind of data	 events	 states

Visualization Design

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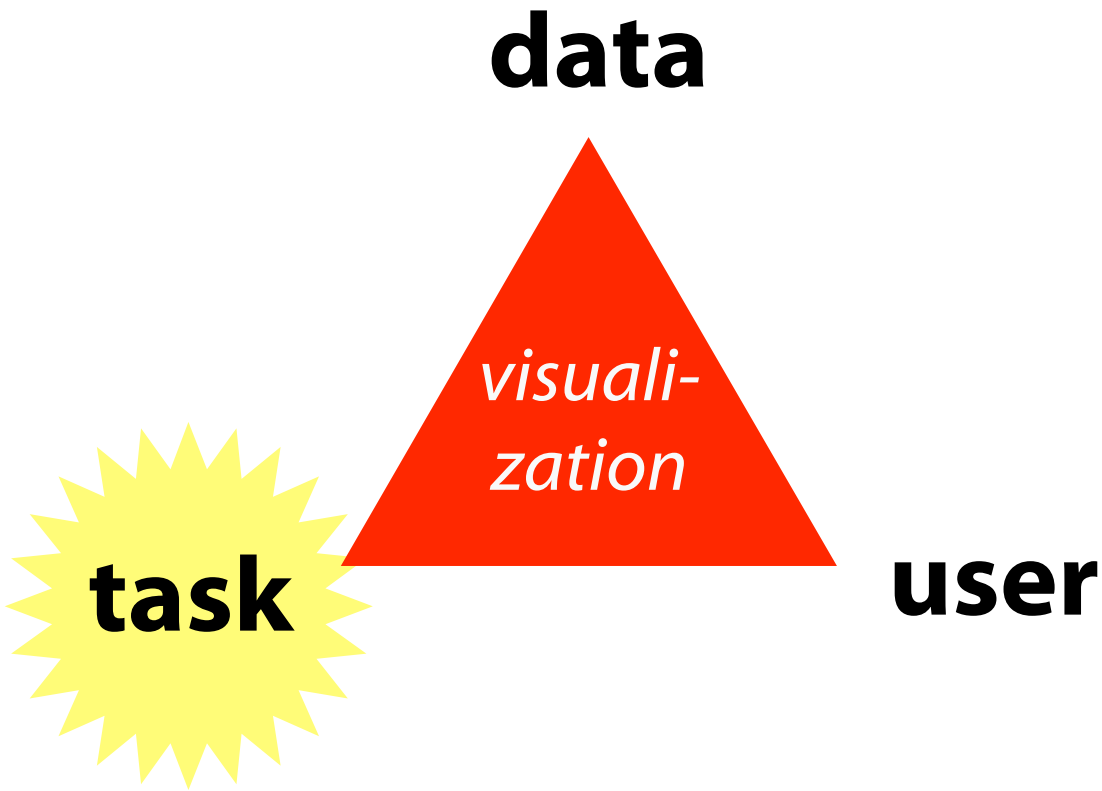

Low-level Task Taxonomy 1/2

[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 Taxonomy 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?

High-level Task Taxonomy

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Navigational Tasks

navigation in time or temporal data

search (implies a specific user-defined target); browse

Observational Tasks

different characteristics of a single temporal history

searching for patterns; detecting disruptions and discontinuities; studying the distribution of the data to identify concentrations of data (or classes of values)

Comparison Tasks

relating multiple temporal histories

comparing of two elements; rearranging; overlaying; studying correlation; searching for effects of causality; comparing evolution relative to a reference value

Manipulation Tasks

manipulation of data values

value aggregation and segmentation

Visualization Design

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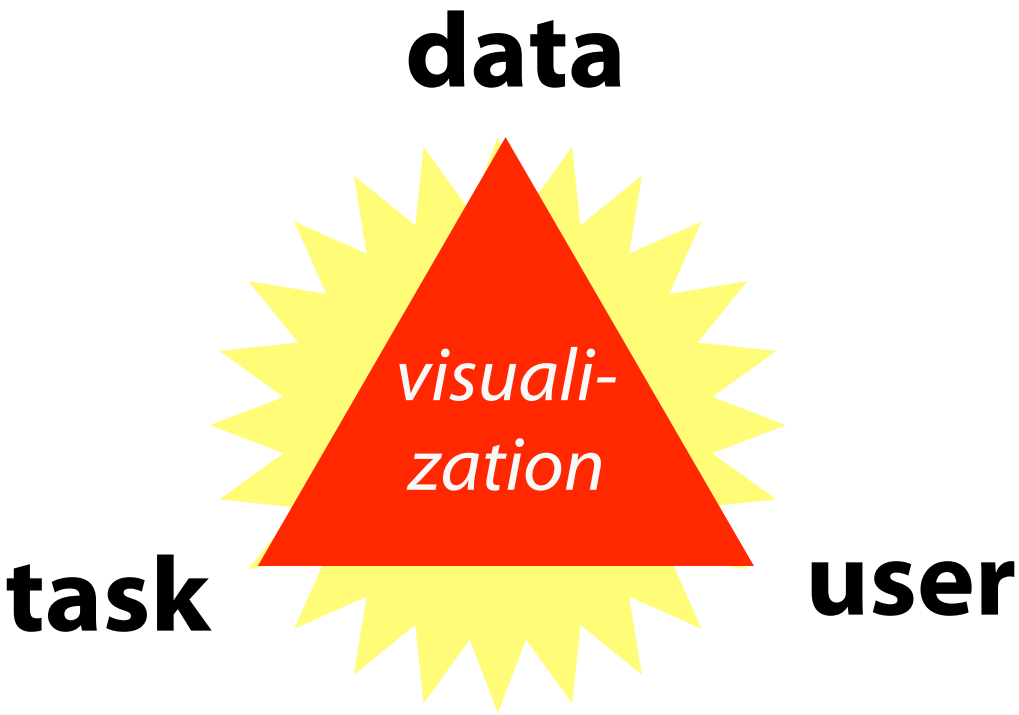

Visual mapping of time

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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

Time → Space

- mapping of time to visual features
- direct comparison of parameters between different points in time is possible

Visual variables

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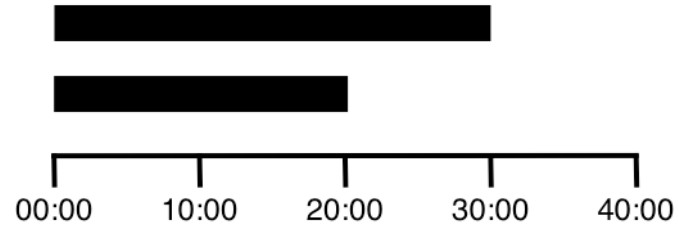
position

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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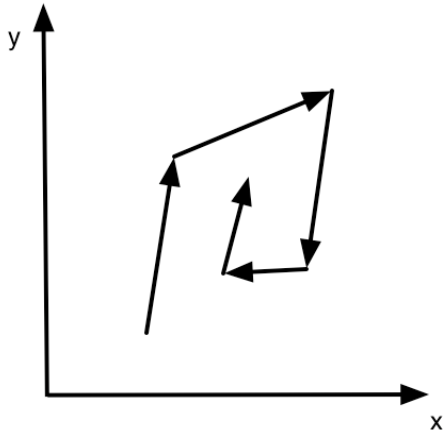
angle, slope

analog-clock-based visualizations

connection

connecting arrows or lines

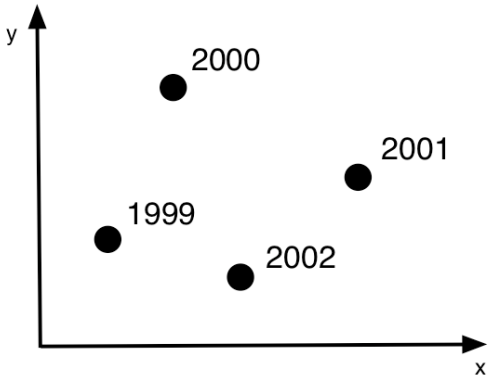
“before element” --> “after element”



text, label

simple text labelling

often combined with “connection”



Visual variables

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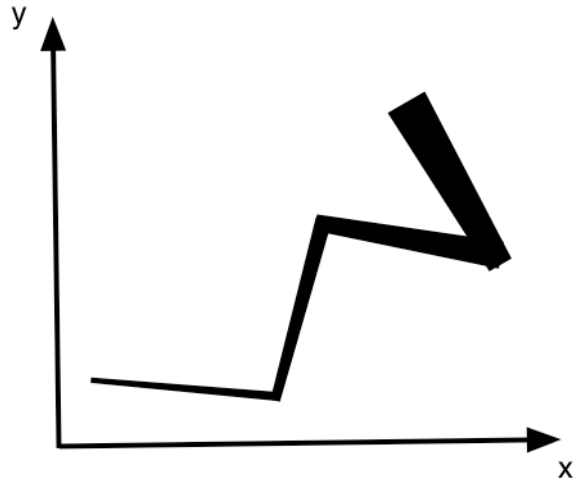
line (thickness)

Increasing or decreasing with time

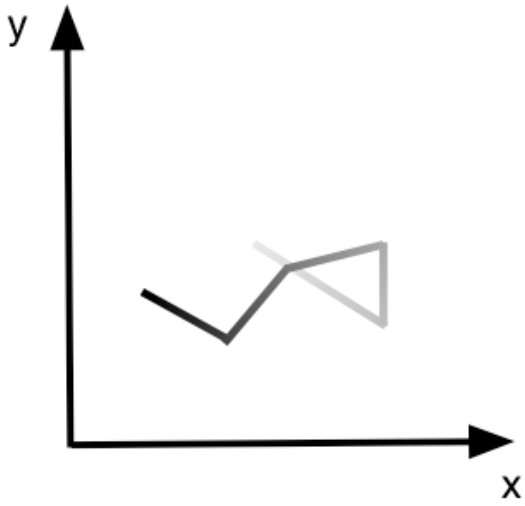


color (brightness, saturation, hue)

brightness most appropriate

“fading away” against the background

transparency



Visual variables

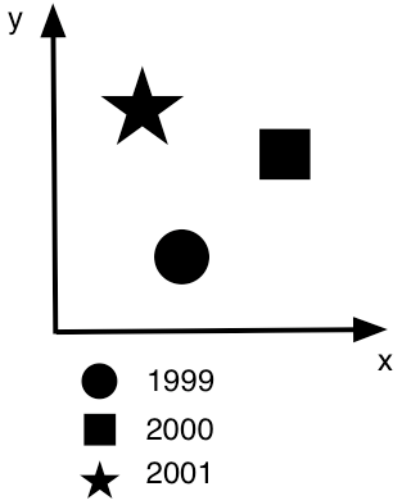
area

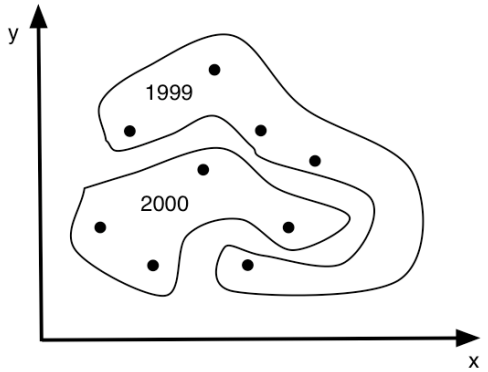
enclosure

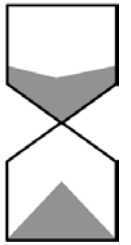
size

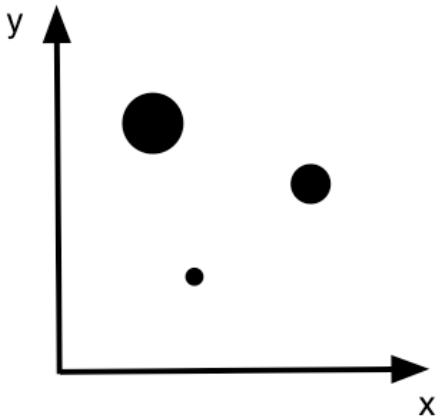
texture

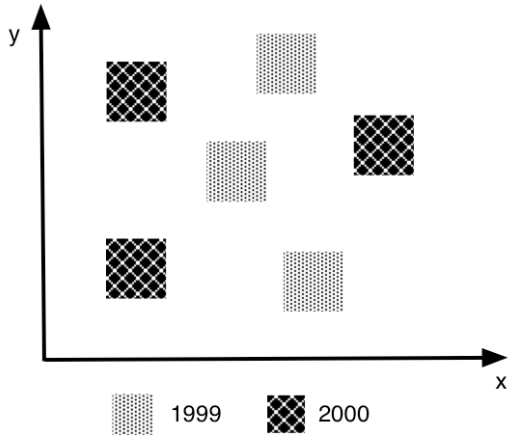
shape











less suited

Visualization roots

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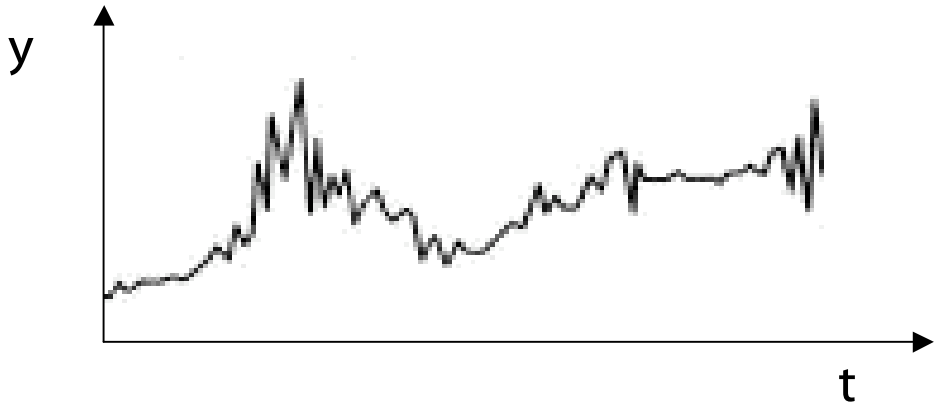
Statistics

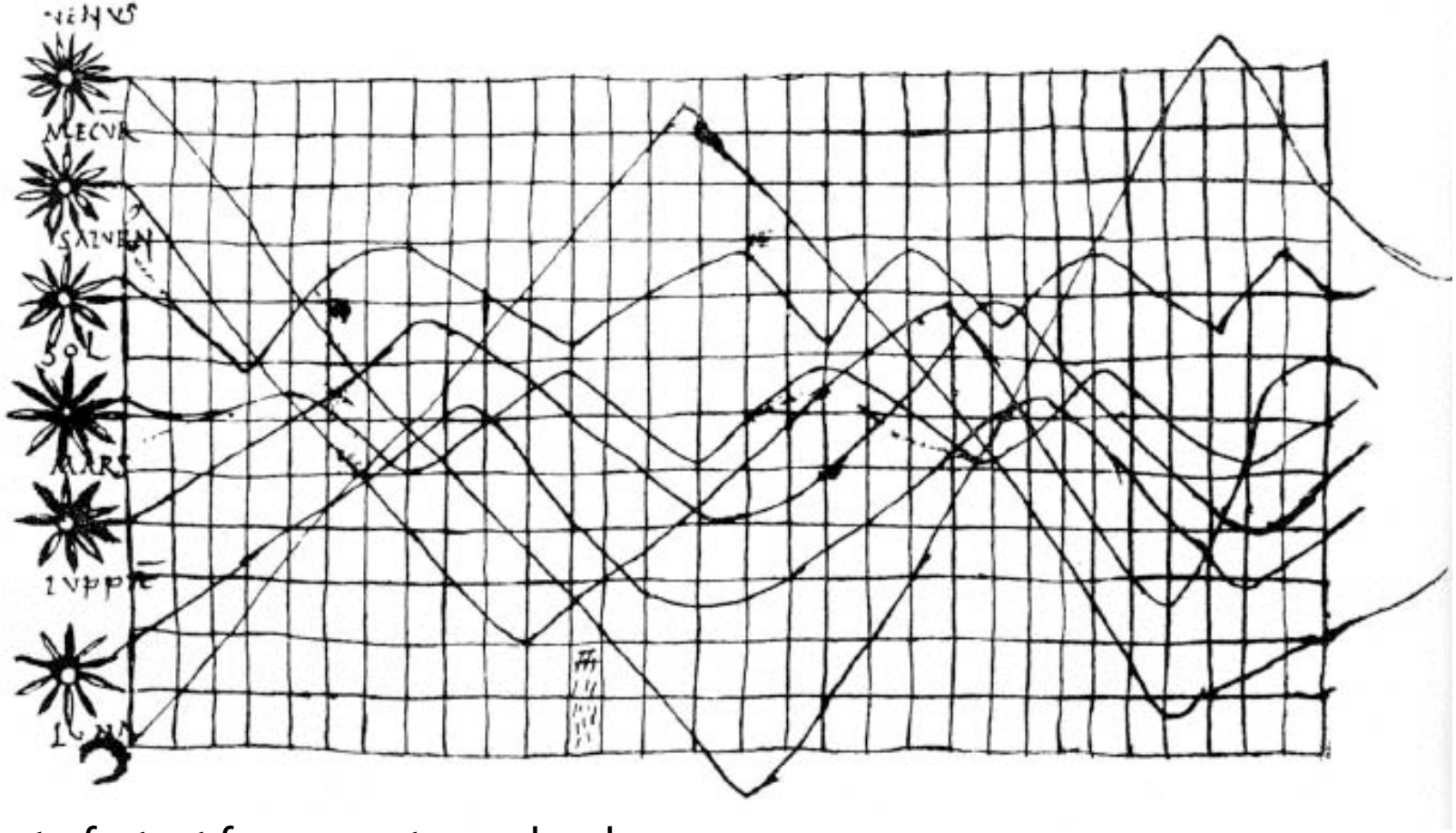
Visualization of time-series.

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

Mostly one parameter over time.

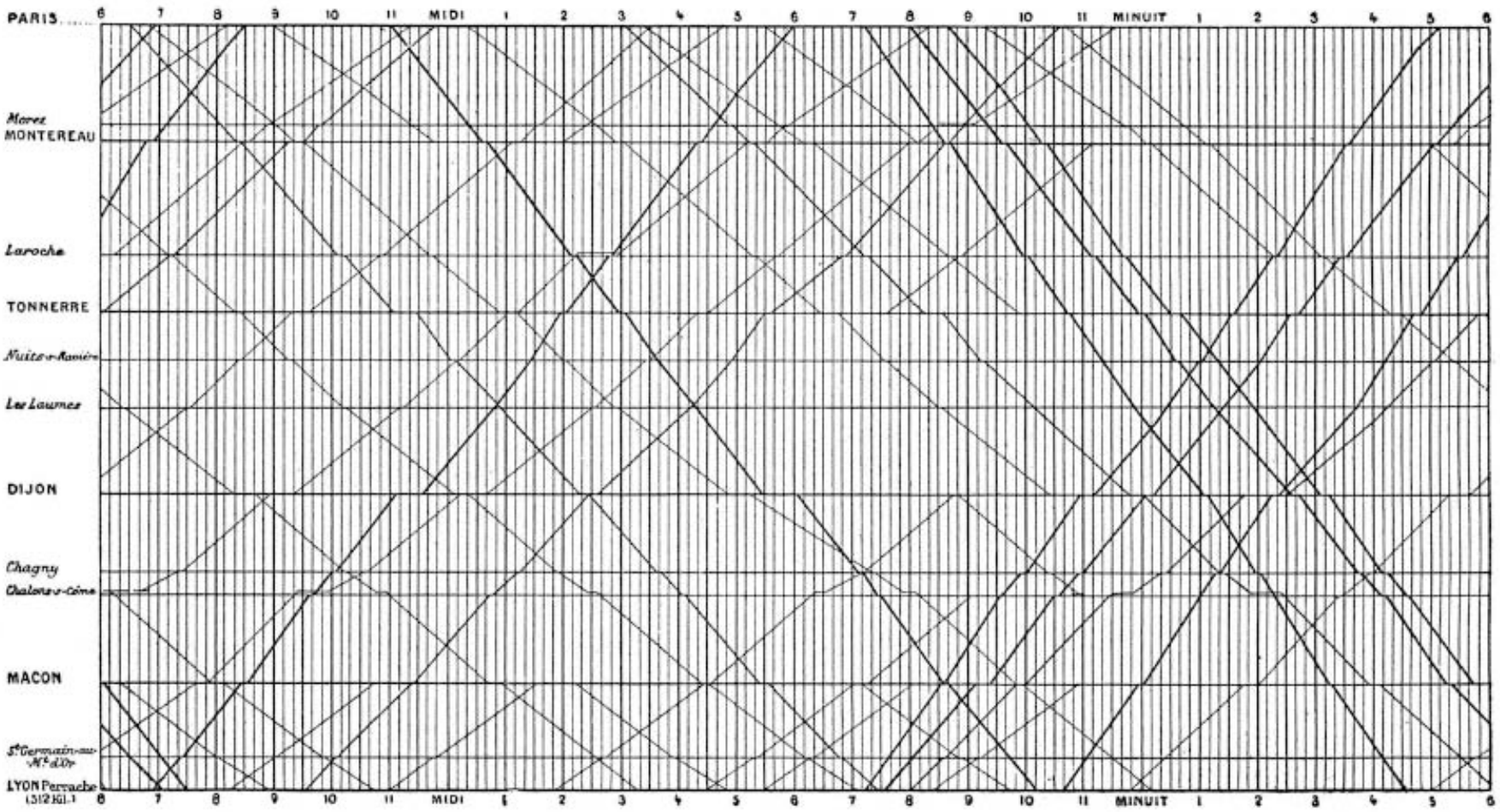


Early time-series plot



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.