Temporal Information Systems

SS 2015

Some General Reflections About Time

Chapter 1

What IS time?

How is time defined? How do we know precisely? Are there any standards?

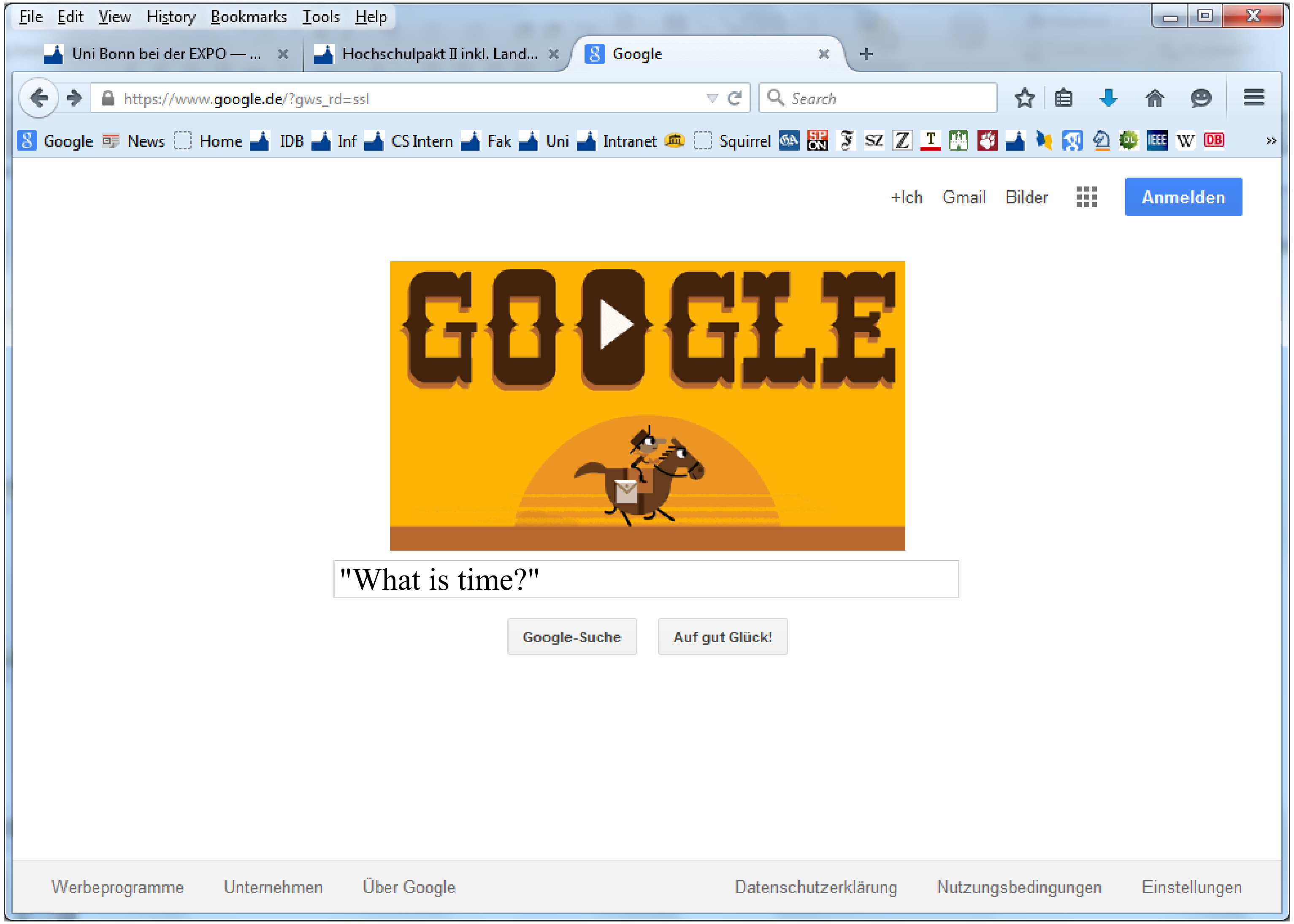
When was time introduced, or did it always exist, even before mankind?

Does time exist independently of its measurements, or not?

Can we „feel“ time, or „understand“ time, or „observe“ time?

How did people „organize“ time?

Ask Google!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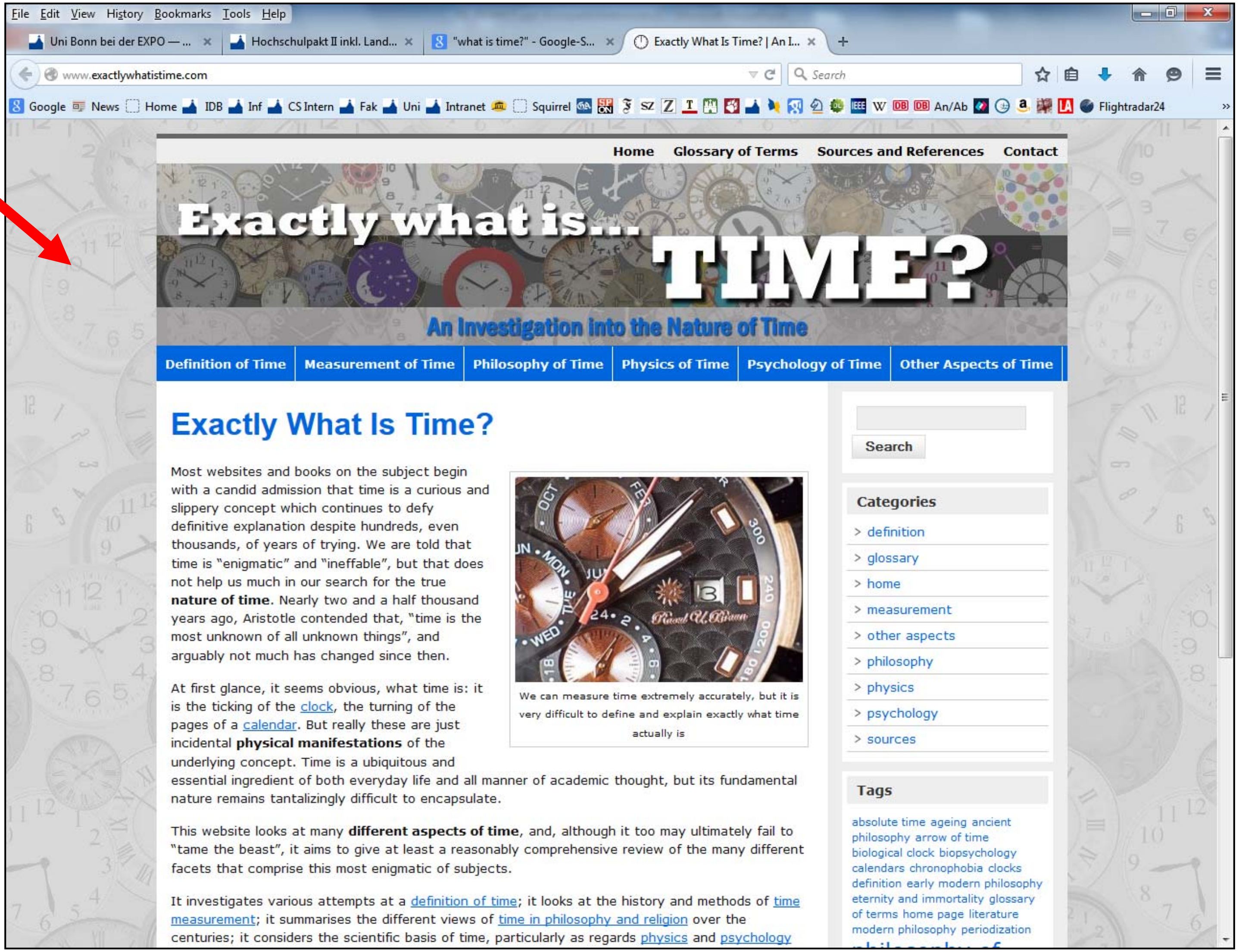


What then is time?

„What then is time?

If no one asks me,
I know what it is;
if I wish to explain to him who asks,
I do not know."

St. Augustine of Hippo (354-430)

Some Very Brief Look at the Philosophy of Time: Newton's View

"Absolute, true, and mathematical time, in and of itself and of its own nature, without reference to anything external, flows uniformly and by another name is called duration.

Relative, apparent, and common time is any sensible and external measure (precise or imprecise) of duration by means of motion; such a measure – for example, an hour, a day, a month, a year – is commonly used instead of true time."

Sir Isaac Newton:
Philosophiae Naturalis
Principia Mathematica (1687)

Newton's famous opponent in 17th century's debate about the nature of time and space,.
Gottfried Wilhelm Leibniz,
is the main proponent of a different „school" of thought,
as he denies the existence of any absolute time.

Philosophy of Time: The Leibniz-Kant View

"Time is not an empirical concept. For neither co-existence nor succession would be perceived by us, if the representation of time did not exist as a foundation *a priori*.

Without this presupposition we could not represent to ourselves that things exist together at one and the same time, or at different times, that is, contemporaneously, or in succession."

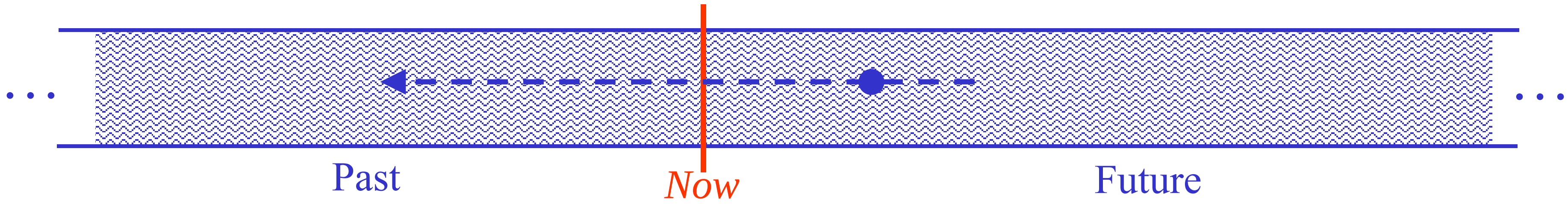
Immanuel Kant:
Critique of Pure Reason (1781)

Kant – like Leibniz – does not believe in time „flowing" as such which we could sense or observe independently from events happening in some order measured according to some representation system.

Time Perception (1): Flow of Time, Past, Present, Future, Begin and End of Time

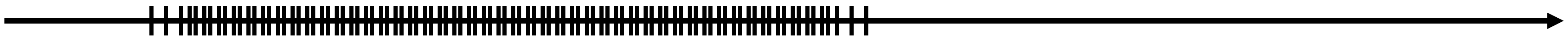
- We will outline here the basic assumptions shared by most people today about our common (?) perception of time and of its properties. Whether these principles are really commonly shared is debatable, but they can be seen as a set of „axioms“ for the remainder of this lecture.

- Here are some of the basic „axioms“:
  - Time flows continuously, with constant speed.
  - The flow of time is directed from future to past, it never reverses or stops.
  - Every current observation or action takes place at a uniquely defined moment in time, called *now* (or, the present time). *Now* has no duration.
  - What was *now* a moment ago, already belongs to the past: *Now* is like a fixed point of observation,„under“ which time flows by.
  - We have no way of telling whether or when there was any begin of time, or whether or when there will be an end of time – thus perceiving the flow of time as an infinite process (and time as unbounded) seems reasonable.

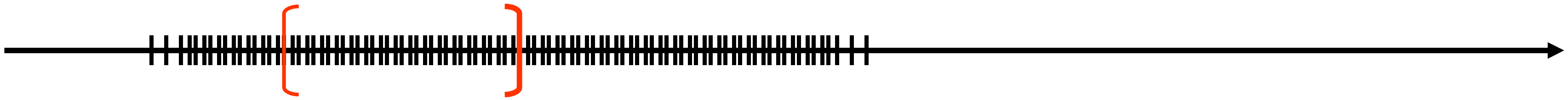


Time Perception (2): Continuous Time Axis, Points and Intervals

Absolute time, being continuous, is modeled by many as isomorphic to the real numbers, i.e., as a totally ordered (linear) sequence of points which is dense, visualized as a line in one dimension (the time axis):



- totally ordered:
  Foreach two points t_1 and t_2, either $t_1 < t_2$ or $t_1 > t_2$ holds.
- dense:
  Foreach two points t_1 and t_2 there is at least one point t_3 s.t. $t_1 < t_3 < t_2$, i.e., there are no gaps on the time axis.



Contiguous sections of the (time) axis are called intervals. An interval is a set of points such that each point, which is between two points in the set, belongs to the set, too.

Time Perception (3): Instant, Period, Duration

- In connection with time, an alternative temporal (non-mathematical) terminology is frequently used for the basic concepts – we will use this system in the following:

point in time:	instant
interval of time points:	period
length of a period:	duration

- An instant has no duration, only periods do.
- These terms are often used inconsequently, or according to different systems – be aware!
- As an example, a (slightly, but significantly) different usage of notions for basic temporal concepts can be found in the book by Snodgrass:

> „An instant is an anchored location on the time line. .. An instant occurs but once, and then is forever in the past.“
> „An interval is an unanchored, contiguous portion of the time line. An interval is relative, an instant is absolute. ... An interval is a .. directional duration of the time line. ... The distance between two instants is an interval.“
> „A period is an anchored duration of the time line. ... A period is a segment of the time line, starting at one instant and terminating at a later instant.“

Time Perception (4): ISO Terminology

- The International Standards Organisation (ISO) has standardized many temporal terms in the International Standard 8601 (last revised 2004). There you find, e.g.:

> time axis:
> mathematical representation of the succession in time of instantaneous events along a unique axis
> instant:
> point on the time axis
> time interval:
> part of the time axis limited by two instants

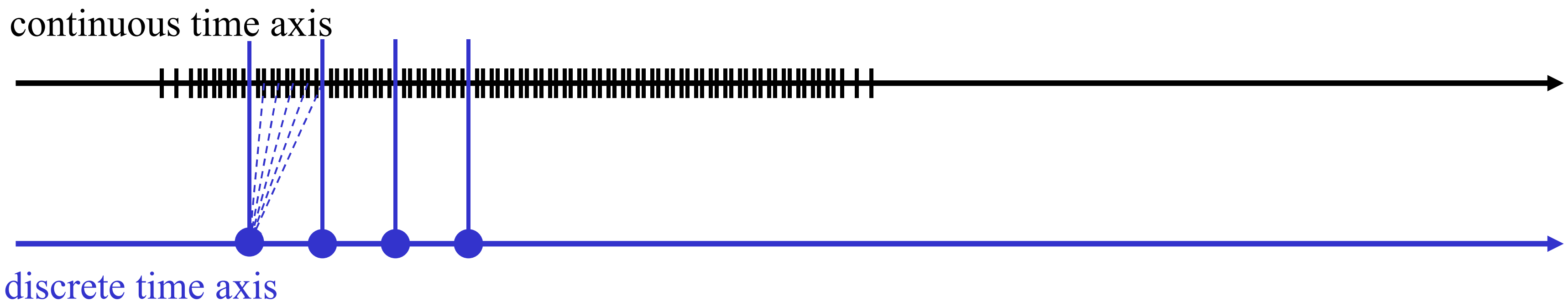
- After that, IS 8601 turns to systems of measuring time, and defines other temporal concepts in the measuring context only:

> time scale:
> system of ordered marks which can be attributed to instants on the time axis, one instant being chosen as the origin
> time point:
> date-time mark attributed to an instant by means of a specified time scale
> duration:
> non-negative quantity attributed to a time interval, the value of which is equal to the difference between the time points of the final instant and the initial instant of the time interval, when the time points are quantitative marks

Time Scales, Granularity and Discrete Time

- As soon as time points are „marked“ (in the sense of IS 8601) by means of a system of identifiers arranged on a time scale, it is no longer possible to keep up the illusion (?) of continuous time.

- Instead, a smallest measurable or recordable duration (in terms of continuous time) has to be chosen, and the time scale used for measurements is to be divided into units of equal length. This division is called discretization, we call the system used for measurements a discrete time system.



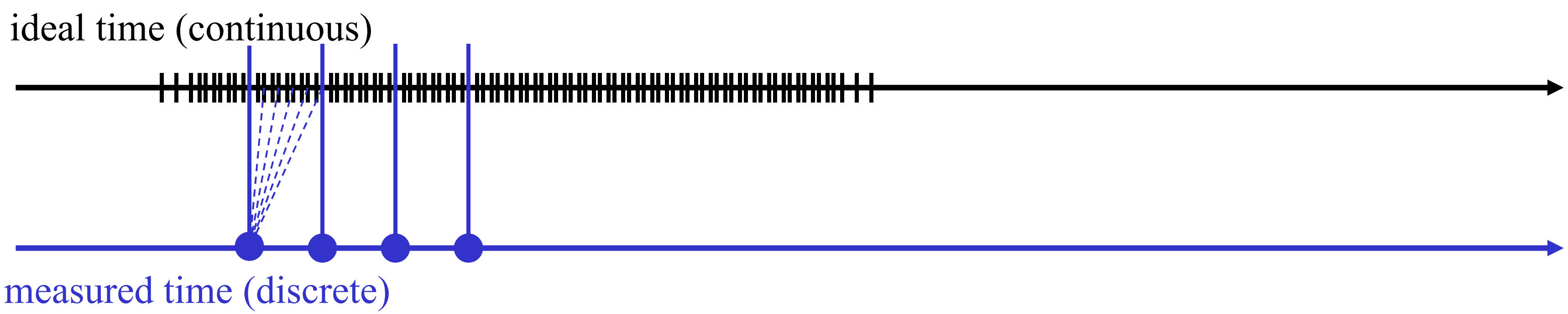
- The length of the units on which the discrete system is based is called its granularity (lat.: granum = grain).

- All points on the continuous axis contained in the interval corresponding to a „granum“ of the discrete system are mapped to the same instant of the discrete system.

Ideal vs. Measured Time: Idea

- There are various reasons motivating the use of discrete scales for working with time measures:
  - It may be impossible to measure more precisely than a certain unit.
  - It may is necessary to choose a certain minimal unit for storing and processing the data representing the measurements in a computer or on paper.
  - Measurements may be communicated with a restricted precision only.

- It is fundamental to consciously accept the necessity to work with a different time scale for managing temporal data as for „perceiving“ time naturally. We thus introduce a two new notions for emphasizing this dichotomy: ideal time vs. measured time



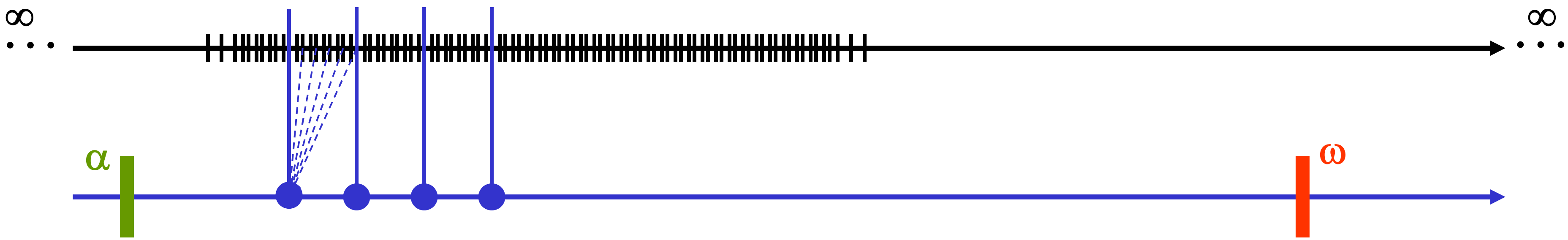
- From the perspective of ideal time, the measured time axis has gaps. However, relative to the discrete time system of measured time its instances are dense again!

Ideal vs. Measured Time: Alpha et Omega

- Whether ideal time is bounded or not, remains an eternal debate for philosophers and theologists. Maybe the „Big Bang“ was the begin of time – who knows! We don‘t know the date of the „Big Bang“ anyway, and we don‘t know the day of Armaggedon, so „practically“ ideal time is unbounded in both directions.

- However, each discrete system of measuring – and thus recording data about – time necessarily is bounded at every moment of observation. There is always a largest (and thus a smallest) value representable wrt the chosen granularity and precision of recording. There are always just finitely many values expressible in such a system.

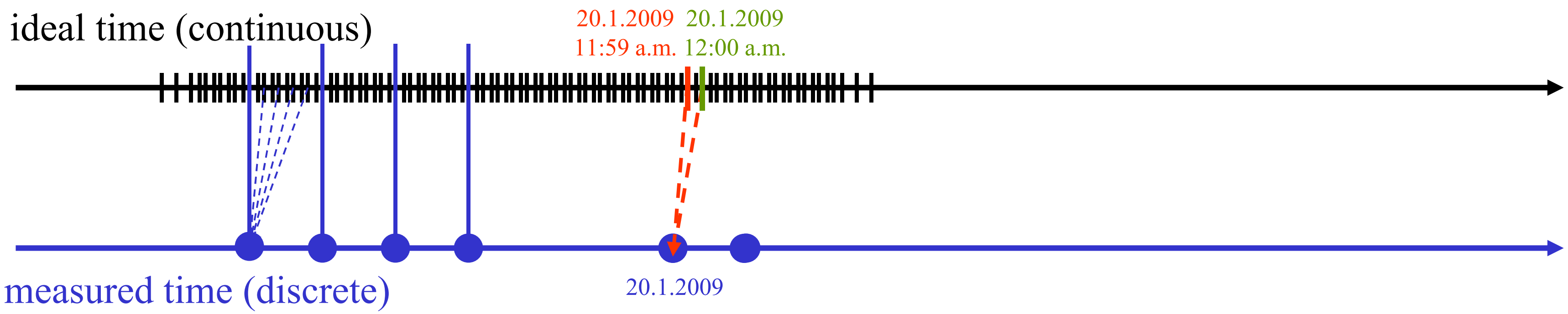
- <u>Example</u>: With dates represented using two digits each for day and month, and four digits for years, the time axis begins on 01.01.0001 and ends on 31.12.9999 (if respecting the necessary constraints such as „No year 0!“, „No day over 31, no month over 12!“).



Ideal vs. Measured Time: The Presidency Anomaly

Did the USA have two presidents at any time during 2009?

Presidency	President	Birthday	From	To	Term
1	George Washington	22.2.1732	30.4.1793	4.3.1798	1
...					
43	George W. Bush	6.7.1946	20.1.2005	20.1.2009	55
44	Barack Obama	4.8.1961	20.1.2009		56



In „real life", i.e., according to ideal time, they didn't – Bush's presidency ended a moment before 12 noon on inauguration day. In our measured time (day granularity) they did!

Units for Measuring Durations

- Durations (i.e., lengths of periods) are traditionally measured in two different systems of specially introduced temporal units, based on astronomical observations:
- Longer periods are measured according to calendar units based on three types of units:
  - Year: Period of time during which the Earth moves around the Sun once.
  - Month: Period of time during which the Moon moves around the Earth once.
  - Day: Period of time during which the Earth rotates once.
- Shorter periods are measured by clock units based on the hour and on fractions of it:
  - Hour: 1/12 of the period of time between sunrise and sunset. (from latin: hora)
  - Minute: 1/60 of an hour.
  - Second: 1/60 of a minute.

(Babylonian sexagesimal system of fractions based on 1/60;
Latin: 1/60 called *pars minuta prima*, 1/3600: *pars minuta secunda* ,
from minuere=making smaller, pars=part, prima=1st, secunda=2nd)

All of these „definitions“ are intricate, there are various versions of them around. Moreover, their lengths due not correctly „add up“, therefore various compensations had to be included (e.g., „leap seconds“, „leap days“, 28-31 days/months)

Measuring Durations vs. Locating Instants and Periods

- There is another fundamental difference worth considering consciously:
  - Measuring durations of periods always returns a value relative to that period.
  - Locating a period (or an instant) on the time axis returns an absolute value (wrt to the particular time scale and, but relative to its „anchoring point“ in ideal time).

- Example:
  a) John arrived at 12 a.m. by train.
  b) John arrived 12 hours later than Mary.

- In case a), the instant at which the event of John‘s arrival took place is „marked“ on the time axis of a measured time scale – here the „mark“ 12 a.m. is to be interpreted relatively to the beginning of the very day on which the statement has been made (the „anchor“).

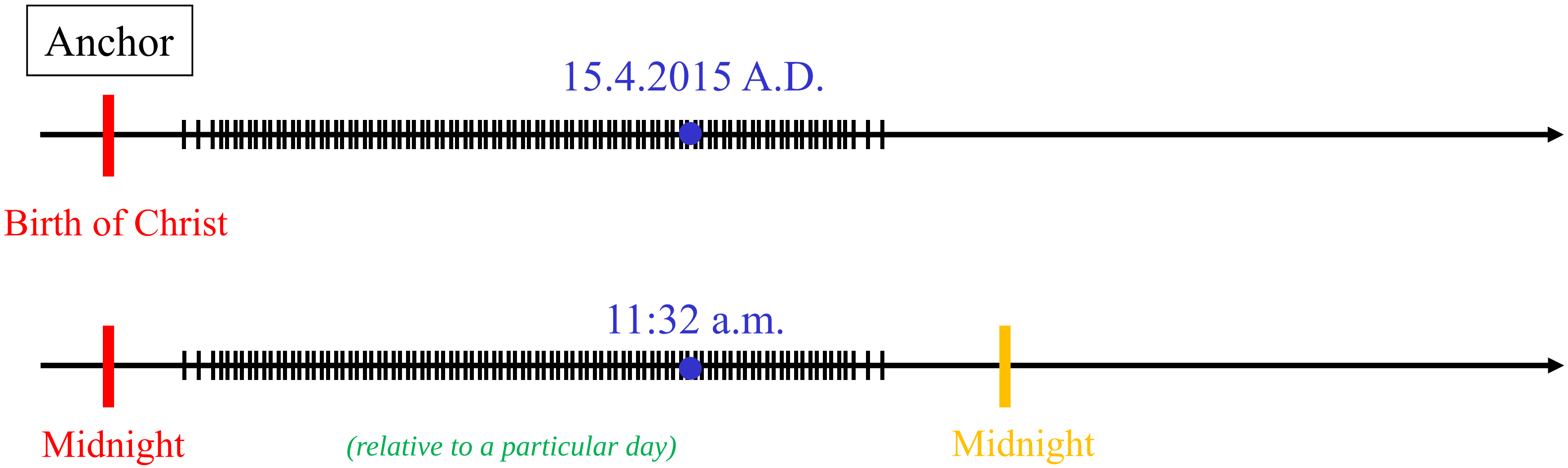
- In case b), the duration of a particular period is measured instead. Even though we cannot locate this period absolutely on our measured time axis (because we don‘t know when Mary arrived), we get sufficient information about the length of this particular period.

- Consequence: In IS 8601, units for duration and location are carefully distinguished, e.g., *calendar day* (location) vs. *day* (duration)!

Anchoring Time Measurement for Locating Instants

- Up till now, we mainly talked about the general nature of our time perception and representation systems. We talked about instants, periods and durations without mentioning any means of distinguishing instants and periods from each other.

- Identifying individual time points means assigning „timestamps“ to these instants, e.g., times of the day or dates. In order to do so, a fixed reference system is needed which usually starts at some instant in the past (the „anchor“ of the system) and fixes a granularity of measuring and a notation for naming the individual instants:



Calendar: Some Basics and „Definition“

A **calendar** is a system of organizing days for social, religious, commercial or administrative purposes. This is done by giving names to periods of time, typically days, weeks, months, and years. A date is the designation of a single, specific day within such a system. Periods in a calendar (such as years and months) are usually, though not necessarily, synchronized with the cycle of the sun or the moon.

Many civilizations and societies have devised a calendar, usually derived from other calendars on which they model their systems, suited to their particular needs.

A calendar is also a physical device (often paper). This is the most common usage of the word. Other similar types of calendars can include computerized systems, which can be set to remind the user of upcoming events and appointments.

…

The English word *calendar* is derived from the Latin word *kalendae*, which was the Latin name of the first day of every month.

(from: Wikipedia, engl., 16.4.2014)

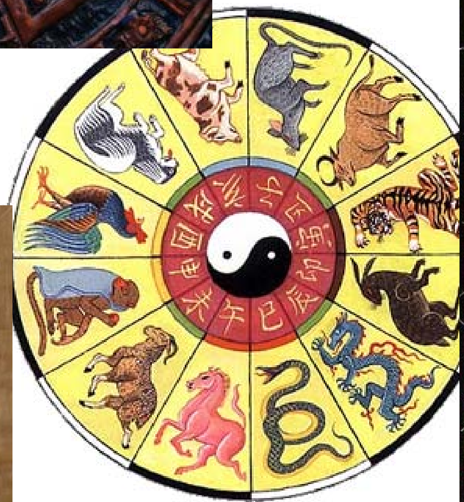
Calendars: Variants and Visualizations

Aztec

Julian

Maya

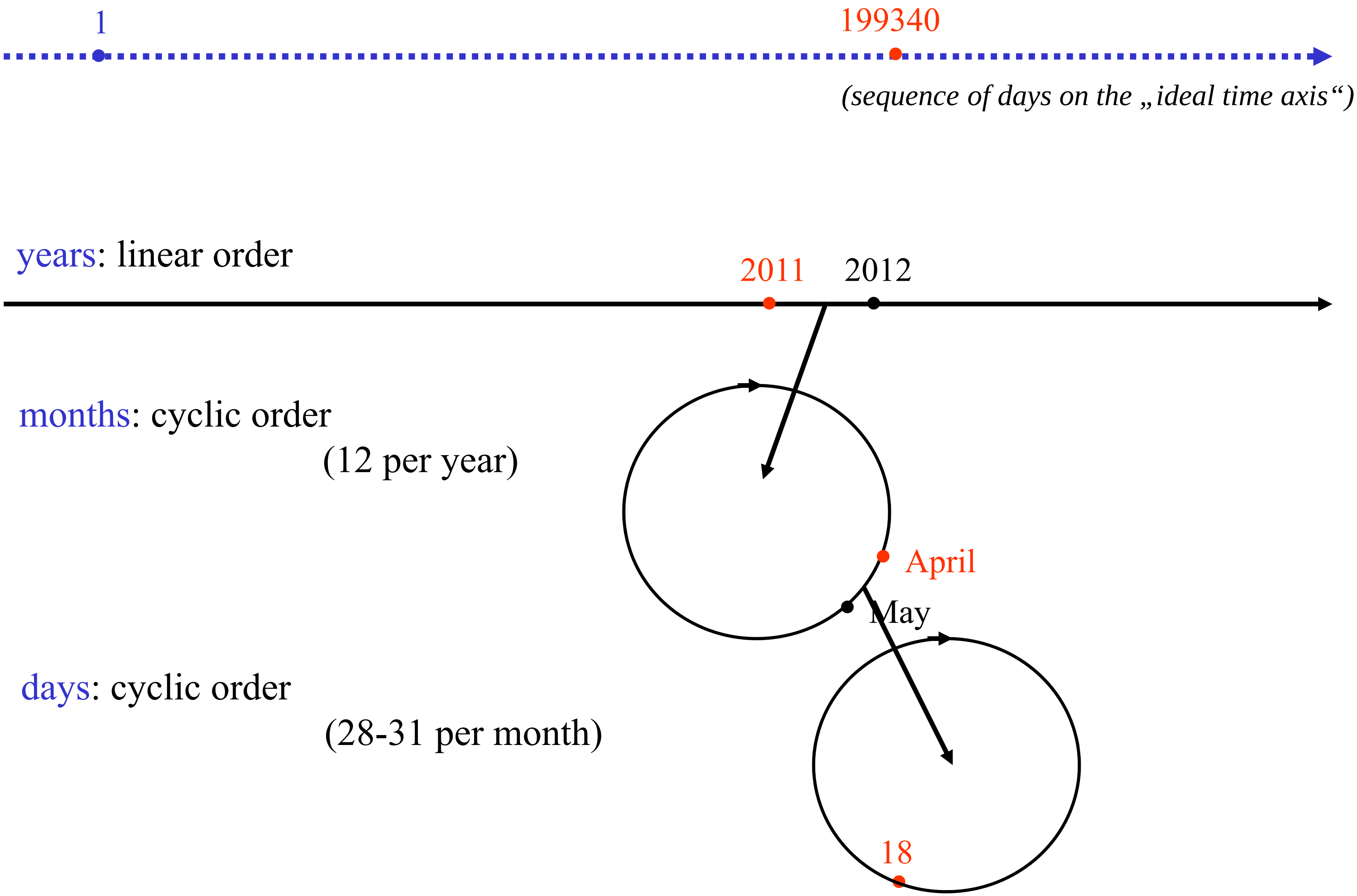
Egyptian



Chinese

Hindu

Modern Calendars: Mixed Organisation Based on Astronomic Units



Calendar Eras and Epoch of the Christian Era

- A calendar era is the year numbering system used by a calendar. The date or year from which time is marked (or: to which the era is anchored) is called the epoch of the era.

- There are many different calendar eras that have been proposed in history, and many of them are still in use today.

- The most widely used such era in the world today, however, is the Christian calendar era, introduced in the year 525 by the Scythian monk Dionysius Exiguus. It is anchored to the year when Jesus Christ is supposed to have been born according to religious tradition. It has therefore been called the Anno Domini era (lat.: annus=year, dominus= the Lord, i.e., God; shorthand A.D.). It is also called the Common Era (short: C.E.) nowadays.

- Dionysius chose the year 754 *ab urbe condita* (lat.: after the founding of the city, i.e., of Rome) as the year 1 after Christ‘s birth. There is no year 0 A.D.! Years before the birth of Christ are counted as years B.C. (*before Christ*), thus there is 1 B.C., 1 A.D, 2 A.D., etc.

- The first day of a year according to A.D. initially varied between different religious feasts, e.g., Christmas. It was fixed to January 1st in 1691.

Gregorian Calendar and Leap Years

- The calendar in use today according to the A.D. era has been introduced on February 24, 1582 by Pope Gregory XIII, and has thus been called the Gregorian Calendar.

- Previously, the so-called Julian Calendar was in use, which dates back to Julius Cesar, the Roman emperor, who introduced it in 45 B.C. in order to come close to the cycle of seasons (the tropical year), known since ancient times to be close to 365.25 days. The Julian Calendar made use of 365 days/year with one leap day introduced every 4 years (the leap years) at the end of February.

- However, the tropical year is actually about 11 minutes shorter than the Julian year. Thus, the Julian calendar was ahead about 3 days every century. Gregor introduced the following exceptions to the leap year computation (normally every year divisible by 4):

  - A year divisible by 100 is (normally) not a leap year, however, ...
  - ... every year divisible by 400 is a leap year again.

- The last day of the Julian Calendar was October 4, 1582, directly followed by October 15, 1582, thus dropping ten days in order to bring the calendar back in tune with the tropical year.

Pope Gregory XIII (1502-1585)

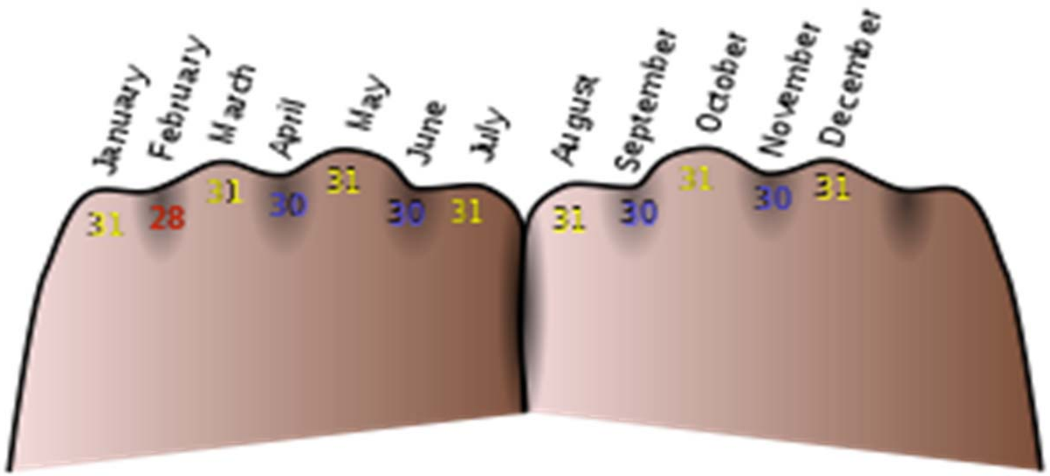
Lengths of Months According to the Gregorian Calendar

- Many students coming from outside Europe – and thus possibly used to non-Gregorian calendars – have problems with the rather irregular system of lengths of months. The alternation between long (31 day) and short months (<31 days) is broken twice!

- Here is the full list:

January	31		July	31
February	28 (or 29 in leap years)		August	31
March	31		September	30
April	30		October	31
May	31		November	30
June	30		December	31

- A convenient (and always accessible) way of remembering uses the knuckles of your two hands:



Variants of Date Representation in Different Regions

"A **date** … is a reference to a particular day represented within a calendar system."

en.wikipedia.org: Calendar date

- There are three different conventions for ordering the three components in dates (according to the Gregorian calendar):
  - Day – Month – Year (DMY), e.g.: 15. April 2015
  - Year – Month – Day (YMD), e.g.: 2015, April 15
  - Month – Day – Year (MDY), e.g.: April 15, 2015

- Different regions in the world use different orderings, e.g.:
  - DMY is used in most of Europe, South America, southern Asia, Australia
  - YMD is used in northern Asia (China, Japan, Corea, Iran)
  - MDY is used in the USA

  (for details see *en.wikipedia.org: Date format by country*)

- For each component (D, M, Y) as well as for the delimiters between the components there are various representation variants, e.g. (in DMY style):

  15. April 2015, 15.4.2015, 15-Apr-2015, 15/04/2015

Clock: Some Basics and a „Definition“

A **clock** is an instrument to indicate, keep, and co-ordinate time.

The word *clock* is derived ultimately (via Dutch, Northern French, and Medieval Latin) from the Celtic words *clagan* and *clocca* meaning "bell". A silent instrument missing such a mechanism has traditionally been known as a timepiece. In general usage today a "clock" refers to any device for measuring and displaying the time.

Watches and other timepieces that can be carried on one's person are often distinguished from clocks.

The clock is one of the oldest human inventions, meeting the need to consistently measure intervals of time shorter than the natural units: the day; the lunar month; and the year. Devices operating on several physical processes have been used over the millennia. The evolution of the technology of clocks continues today.

The study of timekeeping is known as horology.

(from: Wikipedia, engl., 16.4.2014)

Clocks: Variants

Clocks: Nowadays Based on Seconds Defined in Atomic Terms

Modern systems of timing have been relieved from the inaccuracies of astronomical units and are now based on atomic clocks. In 1967, the International System of Units (SI) has chosen the second as the basic unit of time measurement defined as ...

… the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.

1 min =	60 secs
1 hour =	3600 secs
1 day =	86.400 secs
1 (Julian) year =	31.557.600 secs

10^{-3} s = 1 ms (millisecond)
10^{-6} s = 1 µs (microsecond)
10^{-9} s = 1 ns (nanosecond)

FOCS 1, a continuous cold caesium fountain atomic clock in Switzerland, started operating in 2004 at an uncertainty of one second in 30 million years
(from Wikipedia)

Variants of Time Representation

- There are two different kinds of clocks in use in different regions of the world:
  - a 24-hours clock, where hours range from 00 to 23
  - a 12-hours clock, where hours range from 01 to 12, based on a division of the day into two periods: a.m. (latin: „ante meridiem“, before midday) and p.m. (lat.: „post meridiem“, after midday)

- The 12-hour clock is mainly used in English speaking countries, but is also in use as informal/colloquial alternative in many countries preferring the 24-hour system, e.g., in Germany.

- Again, there are different notation variants in use:
  - The hour component is either written with two digits (01, 02, ..., 12, ..., 24) or in mixed style with one or two digits (1, 2, ..., 12, ..., 24).
  - The delimiter between hour and minute is either a colon (:)or a full stop (.).
  - The period of day in 12-hour style is either written a.m./p.m. or AM/PM.

- Midnight is denoted by 00:00 in 24-hour style, not by 24:00! Midnight is denoted by 12:00 p.m. in 12-hour style, whereas 12:00 a.m. denotes midday – this is strictly speaking a contradiction (midday being after midday), but fits well with 12:01 a.m. In 12-hour notation, 12:59 a.m. is followed by 1:00 a.m.!

Calendar and Clock in the Following

For the rest of this lecture, we don‘t „worry“ about different calendars and different time zones: We take the „Germanocentric view“ (as we are in Bonn), i.e., Gregorian calendar, CET (Central European Time), German conventions for representing dates and times!