Lecture 11: Summaries; Time

Time and Time Series

Time is…

Continuous

But our observations are discrete.
Can be sampled **evenly** or **unevenly**.
Consequence: model time-varying data as a function $\mathbb{R} \to X$ or as $\mathbb{N} \to X$. Latter choice easy to represent as a list.

Ordered

Time is linear: one thing follows another.
But many time-related periods are cyclical and recurrent.

Astronomical Cycles
: day, month, year

Non-astronomical Cycles
: week, quarter, minute, second

Indep. of Location

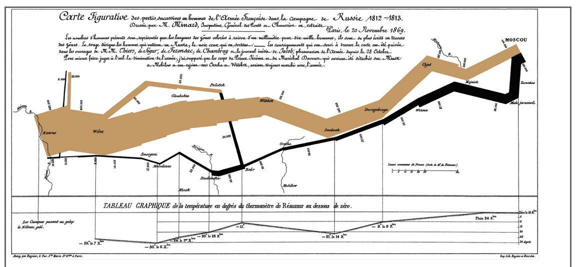
But the ways we denote and represent time are not

Statutory

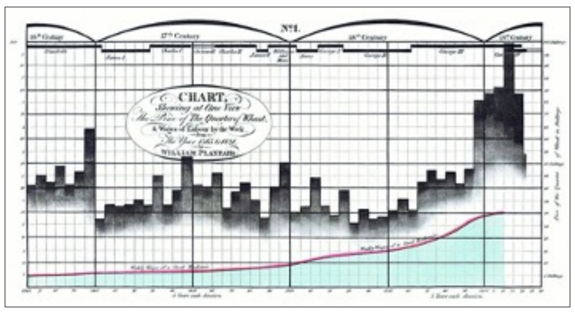
The ways we measure and identify time is regulated, with local

and legislative
variations.
Time Zones
Daylight Savings

Classic Examples

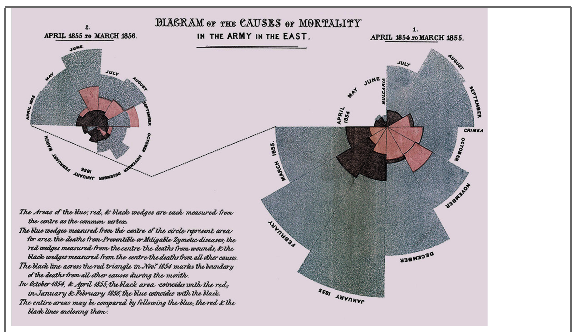


Charles Minard – Napoleon's March on Russia

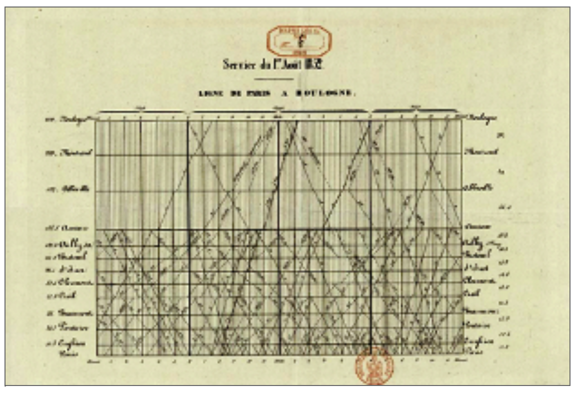


William Playfair - Price of Wheat and Income of a Mechanic

W.E.B. Du Bois - Proportion of freedmen and slaves in America



Florence Nightingale – Causes of Mortality



Ibry - Train Schedules Paris-Boulogne

Homework

Reconstruct one of these graphs

As closely as you can, pay attention to all aspects of the visualization.
Data Sources:

Minard
: You may not repeat the reconstruction of Minard's graph

Playfair
: **https://github.com/friendly/HistData/blob/master/data/Wheat.RData?raw=true** and **https://github.com/friendly/HistData/blob/master/data/Wheat.monarchs.RData?raw=true** (as `.RData`, for CSV see Blackboard)

Du Bois
: **https://github.com/ajstarks/dubois-data-portraits/raw/master/plate51/data.csv**

Nightingale
: **https://github.com/friendly/HistData/blob/master/data/Nightingale.RData?raw=true** (as `.RData`, for CSV see Blackboard)

Ibry
: **https://github.com/michiexile/paris-a-boulogne**

Visual Channels for showing time

Most of these examples use position (cartesian or radial) for the time attribute. Minard uses color (and a very coarse discretization).

- **Other options**
  - Opacity to encode time can make for quite good "trails".
  - Rotation can help association to hands of a clock.
  - If position is not the encoding used, we often assume equidistant sampling - so be clear if this is not the case for your work
- **Channel Choice Questions:**
  - Is time **present** as an attribute?
  - Is time **important** as an attribute?

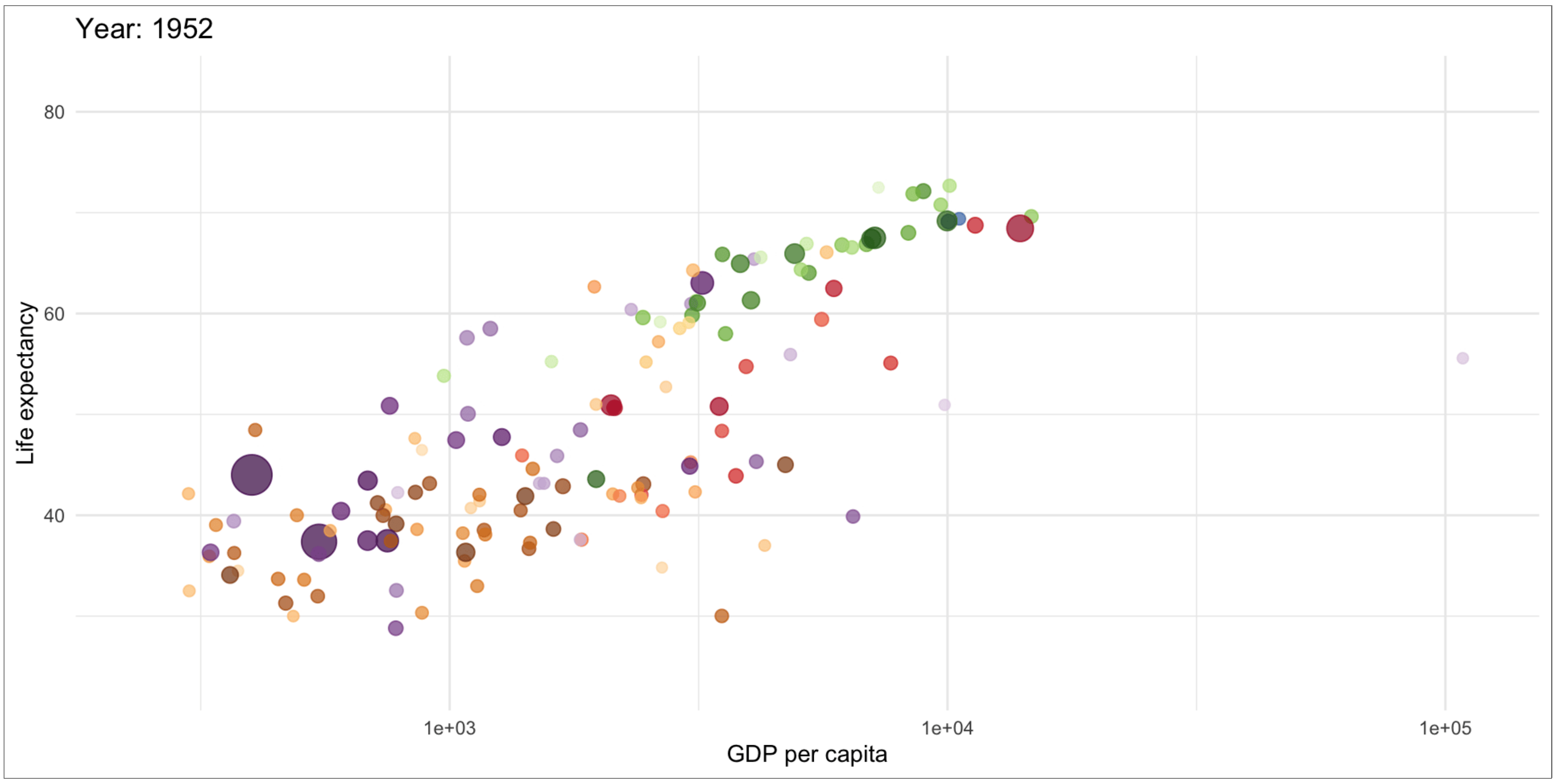
Movement, 3D-position for Time

0:00 / 0:00

Movement for Time

Animation in ggplot2

▶ Code



Movement for Time

Animation in ggplot2

`gganimate` extends `ggplot2` with an **animation grammar**:

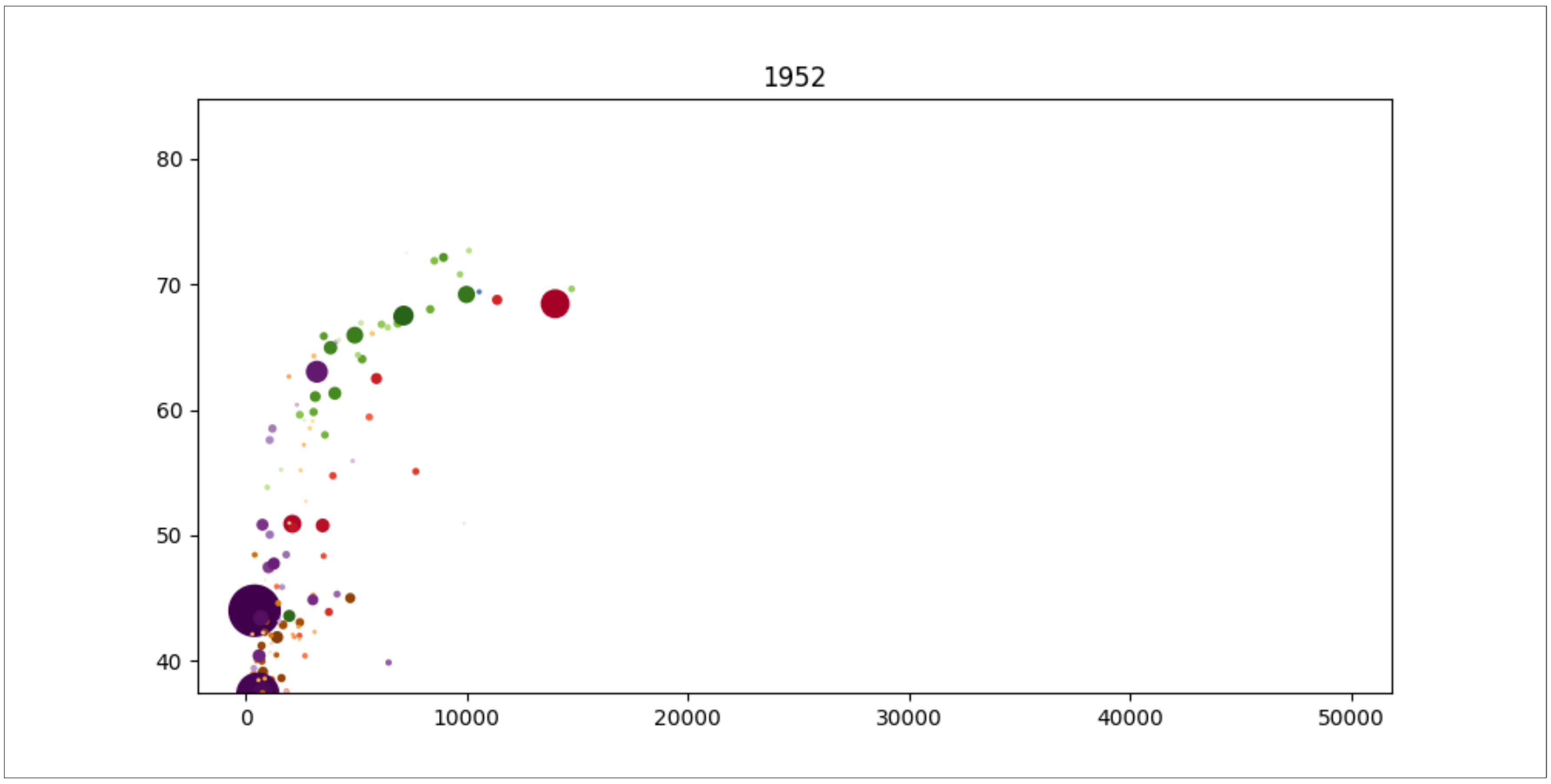
- `transition_*()` - specify how data should spread and relate across time
- `view_*()` - specify how positional scales should change along the animation
- `shadow_*()` - specify how data from other points in time should be present (…maybe you want to leave trails of the last n observations?)
- `enter_*()` and `exit_*()` - specify how new data appears and old data disappears
- `ease_aes` - specify easings for specific aesthetics

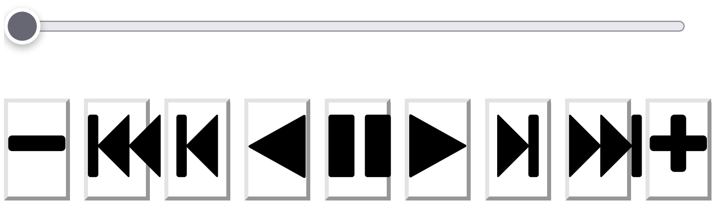
Easing refers to the way you start and stop a motion. You could just interpolate linearly between start and end state, but by using a smoother function, a more fluid and easier to track display may be achieved.
Options include `"linear"`, `"quadratic"`, `"sine"`, `"circular"`, `"elastic"`, `"back"`, `"bounce"`, each with a suffix of `-in`, `-out` or `-in-out` to specify where the easing should happen.

Movement for Time

Animation in matplotlib

▶ Code





Once Loop Reflect

Movement for Time

Animation in matplotlib

- Use **`matplotlib.animation.FuncAnimation`**
  - Write a function that creates (or changes) the plot given a frame-number
  - Instantiate `FuncAnimation` together with an appropriate file writer
  - Run `animationInstance.save("filename.gif", writer=writer)` for one of the file writer options

Movement for Time

Animation in altair

Is not well-supported. Seems like the best option is to generate each frame separately and combine them either with a fairly large amount of javascript work or by exporting each chart to a picture and building an animated gif (or video file) with a python library like `imageio` or `Pillow`

Animation in Visualization

Animation grabs attention

- Even in peripheral vision: excellent for alerting the user

Animation can help maintain object identity across transformations

- Accuracy depends on speed – both too fast and too slow can be harmful

Heer and Robertson (2007) suggest a taxonomy of animated transitions:

- View transformations – zooming, panning
- Substrate transformations – change the spatial canvas where marks are embedded; axis-rescaling, log transforms, fisheye distortions
- Filtering – changing which elements should be visible according to a logical predicate; elements may be added or removed
- Ordering – rearrange ordinal data dimensions; sorting on attribute values, manual reordering
- Timestep – apply temporal changes to data values; eg change from one year to the next
- Visualization change – changes to the visual mappings applied to the data; bar chart to pie chart, or changing palettes and mapping schemes for color, size, shape encodings
- Data Schema change – changes to the data dimensions being visualized; adding additional data columns, roll-up or drill-down operations

Animation in Visualization

Heer and Robertson adapt Tversky et al’s (2002) principles of Congruence and Apprehension for effective animation:

- *Maintain valid data graphics during transitions.* As much as possible, keep all intermediate interpolation states to valid data graphics.
- *Use consistent semantic-syntactic mappings.* Similar transitions should have similar appearances across different underlying types, to increase consistency and learnability.
- *Avoid ambiguity.* Make different operators have noticeably different transitions.
- *Group similar transitions.* Objects that go through similar visual changes are more likely to be perceptually grouped.
- *Minimize occlusion.* Occluding breaks tracking.
- *Maximize predictability.* If the viewer can predict the end state based on seeing parts of the transition, it reduces cognitive load and improves tracking. Slow-in slow-out timings emphasize starting and ending states and improves spatial and temporal predictability.
- *Use simple transitions.* Translation and expansion/contraction motions are easier to understand than rotation.
- *Use staging for complex transitions.* Break up complex transitions into simple components. Example: separate axis rescaling from value changes.
- *Make transitions as long as needed, but not longer.* Transitions must be long enough that we can track changes, but not so long that the viewer grows bored and disengages. Transitions around 1 second have been recommended in the research literature.

Storing Time Information

Notation varies regionally, sometimes drastically, sometimes confusable:

- 7/5/11 - what date does this represent?
- 11:25 pm vs. 23:25
- Week starts on…?

Standards for Dates and Times

Standardized Notation for dates and times is specified in ISO 8601 (also RFC 3339).

- Components ordered by decreasing length
- 24h clock system
- 0-padded to expected precision
- Time Zone denoted with ± UTC offset
- Gregorian (not Julian) calendar
- May or may not include added separators
  - use `-` for the date portion, `:` for the time portion
- May be truncated for reduced precision

`2023-04-03T14:00-05:00` or `230403T1145-0500` both valid.

Computer Storage of Date-Times

Very broadly in use are versions of UNIX Time / epoch time / time stamps. These systems represent time as a count of time units since a specified start date-time. Both resolution (how long is the time unit) and epoch (when does it start) varies with operating system and platform. Fundamental building block for computer time keeping.

UNIX, POSIX
: seconds since 1 Jan 1970
: until 19 Jan 2038 (using signed 32-bit integers; Y2k-type effects visible today)
: until 2 July 2486 (using unsigned 32-bit integers)
: until 4 Dec 292 277 026 596 (using 64-bit integers)

macOS, iOS (Mac computers, iPhone, iPad)
: <1ms steps. 1 Jan 2001 ± 10 000 years

Windows
: 1ms or 100ns ticks
: 1 Jan 1601 to 31 Dec 30827 using a struct with separate fields for components of the date-time

Excel
: epoch is 1 Jan 1900

Java, Android, JavaScript
: 1ms ticks since 1 Jan 1970

SQL
: 3ms steps 1 Jan 1753 - 31 Dec 9999
: 60s steps 1 Jan 1900 - 6 June 2079

Commonly occurring calendars

Solar

Gregorian

Introduced 1582. Adjusts year length from 365.25 days to 365.2425 days. Epoch is claimed to be the birth of Jesus Christ.

Later dates often indicated by **CE** (common era) or **AD** (Anno Domini, referring to the religious source of the epoch). Pre-epoch dates often indicated by **BCE** (before common era) or **BC** (before christ).

Julian

Proposed by Julius Caesar, reforming the Roman calendar.

Pre-Julian calendar had 355-day years and commonly occurring “intercalary” months to catch up; plagued by political meddling and date confusion.

Month names largely preserved from the pre-Julian calendar: **Martius** (for the war-god Mars, start of the year), **Aprilis** (from *aperio* “to open”), **Maius** (for the Greek fertility goddess Maia), **Iunius** (for the goddess queen Juno), **Quintilis**, **Sextilis**, **September**, **October**, **November**, **December** (5th, 6th, 7th, 8th, 9th, 10th), **Ianuarius** (for the god Janus of beginnings and transitions), **Februarius** (for the Februa purification festival [later Lupercalia])

Quintilis was renamed Iulius to honor Julius Caesar. Sextilis renamed Augustus to honor Augustus Caesar.

Coptic, Ethiopian, Indian National, Solar Hijri

Commonly occurring calendars

Lunar

Hijri

Islamic religious calendar, 12 lunar months per year, 354 or 355 days per year. Epoch in 622 CE, the Hijrah, when Muhammad and followers moved from Mecca to Medina to establish a community.

Commonly occurring calendars

Lunisolar

Hebrew

Lunar months, solar year, 19-year cycle of intercalary months every 2-3 years to correct fo the short lunar years. Epoch is the creation of the world, according to Bereshit (Genesis)

Hindu, Bengali, Burmese, Thai Lunar
Chinese, Japanese, Korean, Mongolian, Tibetan

Timezones

And other quirks and pitfalls of working with time data

http://infiniteundo.com/post/25326999628/falsehoods-programmers-believe-about-time **http://infiniteundo.com/post/25509354022/more-falsehoods-programmers-believe-about-time**

A Brief History of European Time

Ancient Egypt, Ancient Rome, etc
: Day is divided into 24 units: 12 in the day, 12 in the night

1200s
: Push towards **equinoctial** hours, and mechanical clocks.

1355
: Equinoctial clock, bells struck every hour, hours even length documented in use in Milano

The Inception of Time Zones

The introduction of railway travel changed time needs: no longer could stops along the railway line run on local times (usually placing **noon** at the time when the sun is at its highest). Within England local times varied with up to 20 minutes before national standardization.

1853
: Train collision in New England due to different train guards having slightly different times

1870
: Dowd proposed time standardization with 4 time zones in the US.

1876
: Sandford Fleming proposed worldwide time zones: 24 time zones, labeled by single letters, each covering 15 degrees longitude, 1h difference between zones.

1880
: United Kingdom standardized time nationally.

1918
: US Congress adopted standard time zones.

Time Zones across the world

Many countries adopted time relative to a local observatory, rather than time relative to Greenwich, UK.

1929
: Most countries had hourly time zones

: Iran, India, parts of Australia had 30-minute offsets wrt Greenwich

1986
: Nepal standardizes to UTC+05:45

Time Zones keep changing

2018
: Volgograd moves from UTC+03 to UTC+04

2020
: Volgograd moves from UTC+04 to UTC+03 (Moscow Time)

2021
: South Sudan changes from UTC+03 to UTC+02

: Jordan changes system for DST

: Samoa abolishes DST

2022
: Iran abolishes DST

: Jordan and Syria both abolish DST and settle on UTC+03

: Mexico abolishes DST - except for areas near the US border

: Fiji probably abolishes DST

2023
: Most of Greenland moves from UTC-03 / UTC-02 to UTC-02 / UTC-01 after almost abolishing DST

Falsehoods Programmers Believe about Time

- There are always 24 hours in a day
- February is always 28 days long
- Any 24-hour period will begin and end in the same day (week, month, …)
- A week begins and ends in the same month.
- A week (or month) begins and ends in the same year.
- Time has no beginning and no end.
- Human-readable dates can be specified in universally understood formats such as 05/07/11.
- Timestamps will always be specified in the same format.
- Timestamps will always have the same level precision.
- A timestamp of sufficient precision can safely be considered unique.
- A timestamp represents the time that an event actually occurred.
- Years have 365 or 366 days

Falsehoods Programmers Believe about Time

- The offsets between two time zones will remain constant.
- OK, but timezone offsets won't change in the future.
- OK, but timezone changes will occur with plenty of advance notice.
- Timezone offsets will always be an integer number of hours.
- …of half-hours?
- Daylight savings happens at the same time every year.
- Daylight savings happens at the same time in every time zone.
- Daylight savings always adjusts by an hour.