Prof. Philip Koopman

Carnegie Mellon University

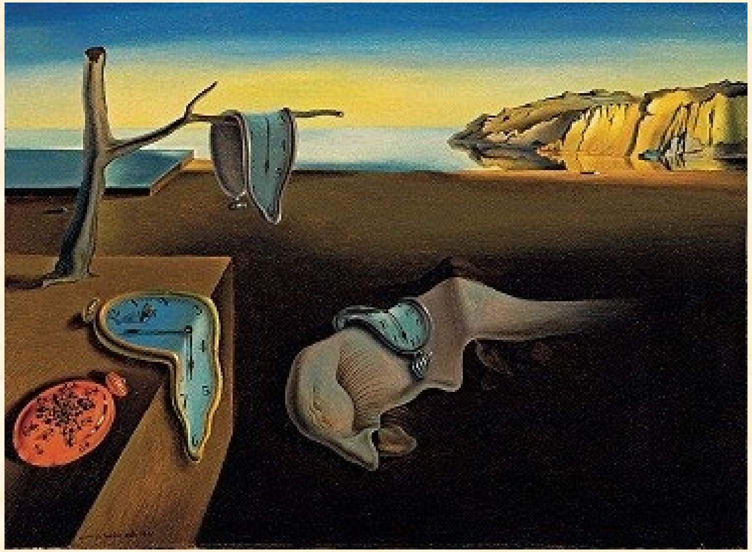
Electrical & Computer ENGINEERING

Date & Time

"Daylight saving time: Only the government would believe that you could cut a foot off the top of a blanket, sew it to the bottom, and have a longer blanket."

– *Origin Unclear*

Date and Time

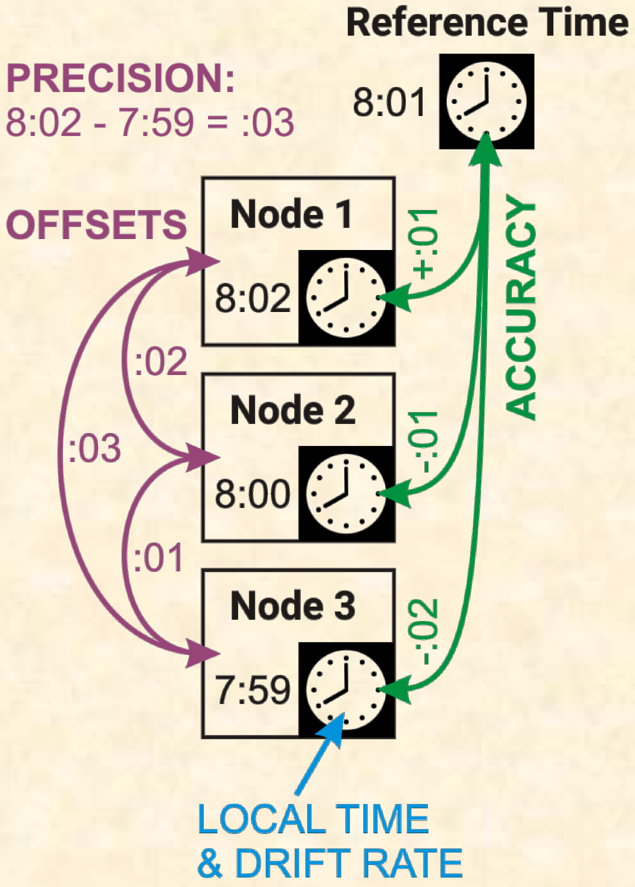


- Anti-Patterns for Date and Time:
  - Daylight saving time hard-coded
  - Time kept without handling time problems
    - Daylight saving time, time zones, mobility
  - Internationalization not considered
- Date and Time issues
  - Keeping time is tricky
    - Leap years, leap seconds, DST changes
  - Determining and displaying local time is tricky
    - Where are you?   Time zone, local DST rules, local display rules
  - Reconciling time is tricky
    - No two computers ever agree EXACTLY on time; updating time has tradeoffs

Keeping Time

Carnegie Mellon University

- **Local time:** based on local microcontroller clock rate
  - System clock oscillator & timer interrupts ➔ software time
- **Drift rate:** local clock rate vs. perfect time
  - Example, 0.002% is 0.00002 seconds/sec drift rate
- **Accuracy:** local clock value vs. perfect time
  - Example: Node#2 is 1 second slower than true time
  - Every local clock has a different accuracy
- **Offset:** difference between two different clocks
  - Example: Node#1 is 3 seconds faster than Node#3
  - Every pair of local clocks has a different offset
- **Precision:** maximum offset between any two local clocks
  - Example: Node#3 is slowest in system; Node#1 is fastest in system. Precision is their offset = 3 seconds
  - There is only one precision value for a system



Clock Synchronization

Carnegie Mellon University

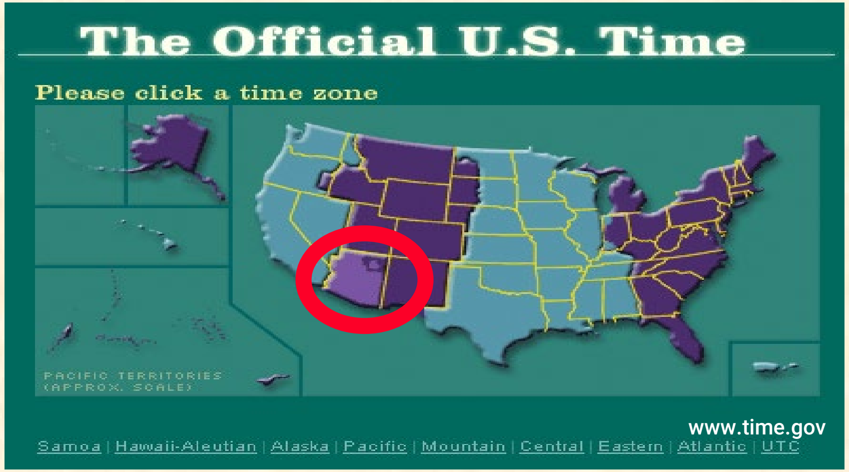
- How do you fix an incorrect clock?
  - Typically only periodic access to clock server
  - State correction
    - Fast forward/reverse to correct time
    - Time jumps or even flows backwards
  - Rate correction
    - Speed up/slow down local tick rate
    - Rate of time is slightly incorrect for a while

- Network Time Protocol (NTP)
  - Time maintenance service
    - Uses Internet access to estimate and track time
  - Complex, and behavior depends upon options

Time Zones & Daylight Saving Time

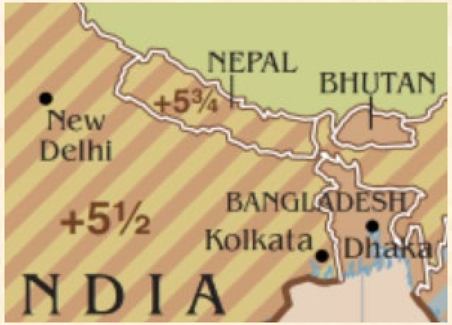
Carnegie Mellon University

- Original time zones for UK rail schedules
  - Not necessarily whole hours
- DST changes arbitrary via governments
  - WW II permanent DST ("War Time")
  - Arizona does not observe DST
    - Navajo reservation within Arizona <u>does</u> DST
    - Hopi reservation does <u>not</u> do DST
- DST Dates differ by location
  - US and Europe differ since 2007
    - Europe to discontinue DST in 2021
  - Northern vs. Southern hemisphere:
    - Fall and Spring are reversed!


The Official U.S. Time

Please click a time zone

PACIFIC TERRITORIES (APPROX. SCALE)
www.time.gov
Samoa | Hawaii-Aleutian | Alaska | Pacific | Mountain | Central | Eastern | Atlantic | UTC



https://goo.gl/XuWhMB

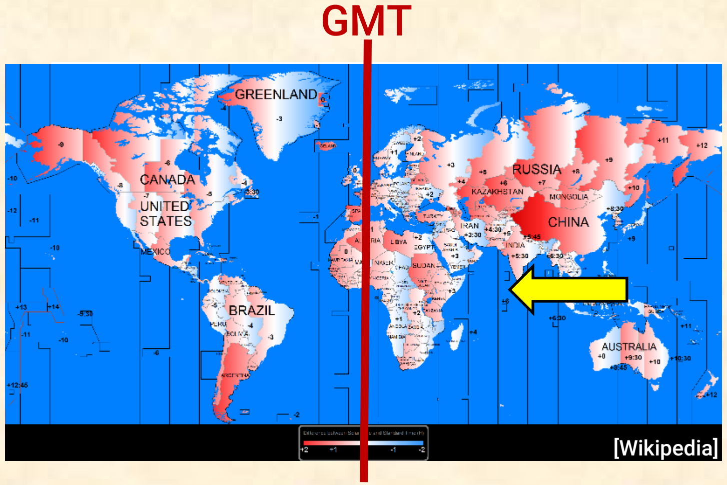
https://goo.gl/bXRScY

Time At Your Location

- Types of time:
  - Solar time: Based on mean sun position
  - Local time: Time in your time zone
  - GMT: Greenwich Mean Time / time zone zero
    - Official time is Universal Coordinated Time (UTC)

https://goo.gl/uP6Wki

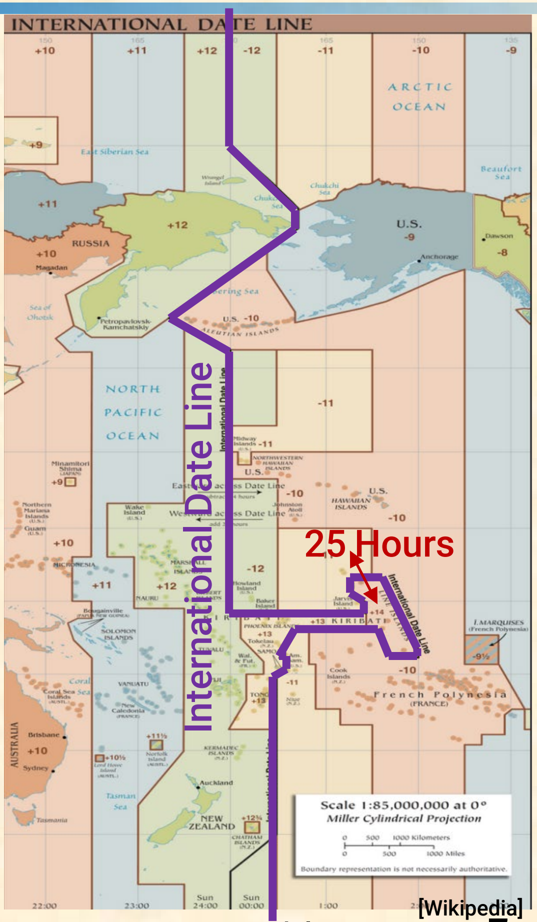
- Sunrise/Sunset depends on where you are
  - Sun rises earlier at eastern end of time zone
  - Depends upon latitude & longitude
    - Sun angle, length of day (including "midnight sun")
    - Length of day increases slightly with altitude
  - "Mean Sun" differs from actual sun
    - Depends on date and year
    - "Equation of time" calculation



[Wikipedia]

Mobility and Time

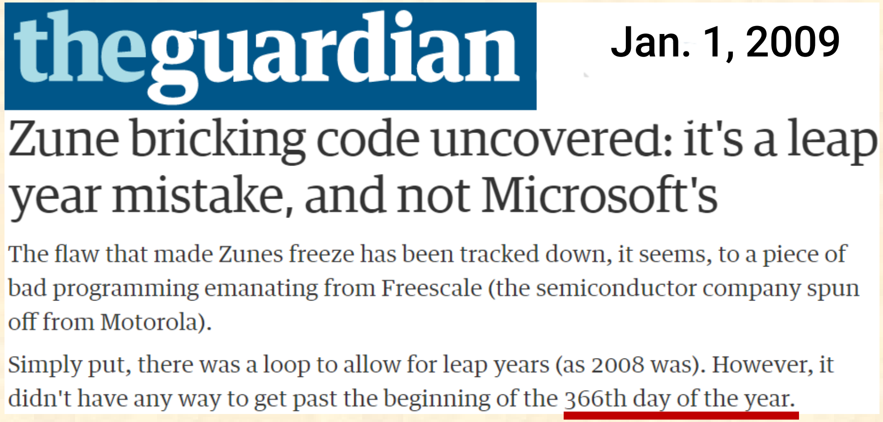
- Time depends upon your location
  - What time is it? Which event happened earlier?
- Date line (+1 day in Asia)
  - It is very far from a straight line; and it changes
- Potential issues:
  - System with multiple users in different time zones
  - System moves between time zones
    - While powered on; while powered off
  - What if system is turned off during DST change?
    - Common bug: fall back too many times for Fall DST
- Best practice: keep time with GMT/UTC
  - Keep time globally in GMT/UTC
  - Display time locally (add in effects of DST, time zones)



[Wikipedia]

Time Leaps

- Leap years: about 365.25 days/year
  - February 29th is leap day every 4 years, …
    - except every 100 years, …
      - except every 400 years
    - 1900, 2100 are NOT leap years
      - 2000 was a leap year
- Leap seconds added to UTC:
  - Earth's rotation is not constant
  - Every once in a while, an extra second is inserted:
    - 61 second minute: 23:59:00, .., 23:59:59, 23:59:60, 00:00:00 (+1day)
    - Theoretically could have negative leap second
- Local rule changes can cause time leaps
  - Changing time zone of a location
- Time rollovers can appear as a huge backward leap
  - Y2K/Millenium Bug: 99 ➔ 00 rollover on 2-digit years
  - Unix cron rollover: 03:14:07 UTC on 19 January 2038



theguardian Jan. 1, 2009

Zune bricking code uncovered: it's a leap year mistake, and not Microsoft's

The flaw that made Zunes freeze has been tracked down, it seems, to a piece of bad programming emanating from Freescale (the semiconductor company spun off from Motorola).

Simply put, there was a loop to allow for leap years (as 2008 was). However, it didn't have any way to get past the beginning of the 366th day of the year.

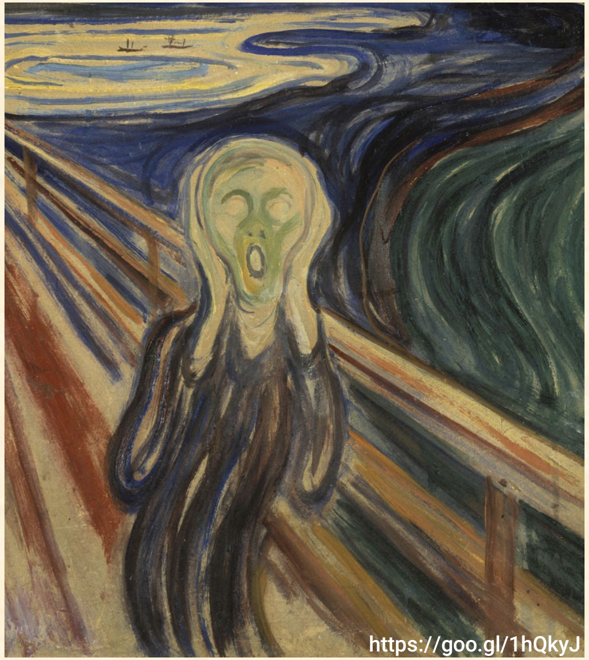
```
year = ORIGINYEAR; /* = 1980 */
while (days > 365)
{ if (IsLeapYear(year))
  { if (days > 366)
    { days -= 366; year += 1;
    }   // MISSING ELSE!
  } else
  { days -= 365; year += 1;
  }
}
```

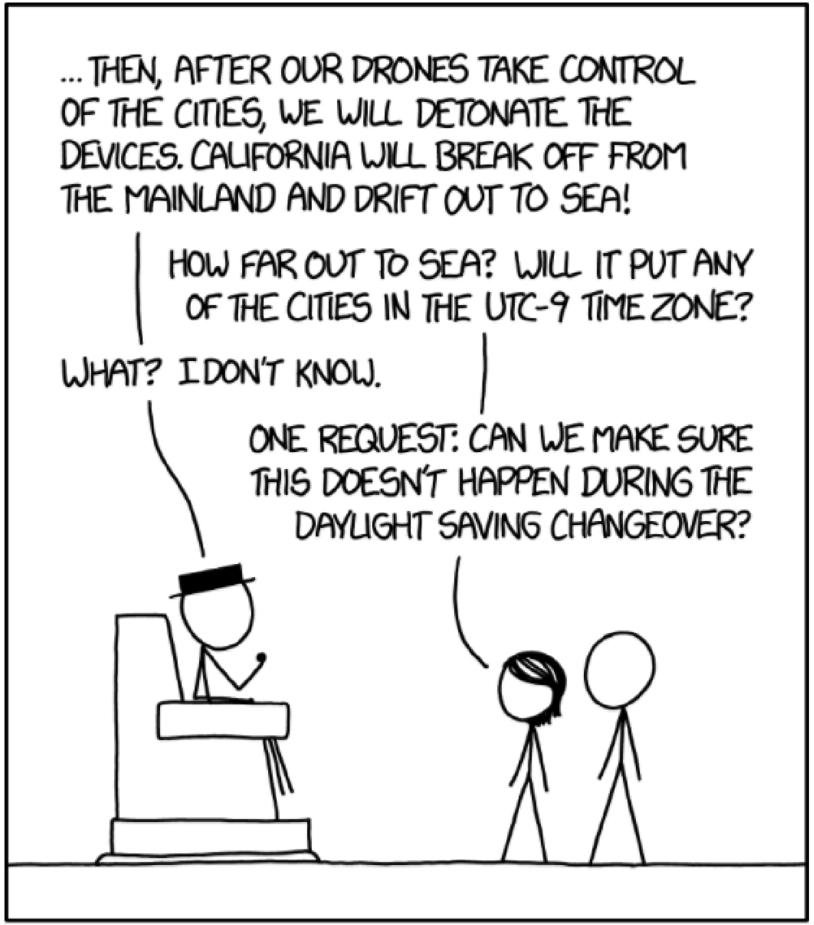
Internationalization

- What day is 02/03/16?
  - US: Feb 3, 2016; Europe: 2 March 2016; or 1916?
    - What day does a week start on? (Sunday or Monday?)
  - Mapping to traditional Chinese Lunisolar calendar?
    - Complete with Leap Month(s)
- Example internationalization issues:
  - AM/PM vs. 24 hour clock
  - English vs. Metric (F/C, ft/meter, mph/kph, miles/km, …)
  - Currency signs, numeric notation (decimal vs. comma)
  - Character sets (e.g. ASCII vs. unicode), word lengths
  - Keyboard data entry (e.g., ASCII vs. Asian character entry vs. Arabic)
  - Left to right, right to left, top to bottom text flow
  - Gender in language, gender identification

Time Best Practices

- Use validated time-keeping libraries
  - It is complicated to get this right
  - Need a way to change DST, time zones, etc.
  - Consider mobility & multi-site coordination
- Think through internationalization
  - What do you support/not support?
- Pitfalls:
  - In general, relying on accurate distributed time (“before”/”after”)
  - Hard-coding changeable time rules (DST dates, time zones)
  - Not considering internationalization needs




...THEN, AFTER OUR DRONES TAKE CONTROL OF THE CITIES, WE WILL DETONATE THE DEVICES. CALIFORNIA WILL BREAK OFF FROM THE MAINLAND AND DRIFT OUT TO SEA!
HOW FAR OUT TO SEA? WILL IT PUT ANY OF THE CITIES IN THE UTC-9 TIME ZONE?
WHAT? I DON'T KNOW.
ONE REQUEST: CAN WE MAKE SURE THIS DOESN'T HAPPEN DURING THE DAYLIGHT SAVING CHANGEOVER?

YOU CAN TELL WHEN SOMEONE'S BEEN A PROGRAMMER FOR A WHILE BECAUSE THEY DEVELOP A DEEP-SEATED FEAR OF TIME ZONE PROBLEMS.

https://xkcd.com/1883/