Time

Lecture 39
Interval vs Point

- Different questions:
  - “How long did it take to run 5k?”
  - “When is our final exam?”

- Answering “how long?” is easy
  - Count the number of elapsed seconds
  - Easy to code

- Answering “when?” is tricky
  - 4 pm (May 2, 2017) is not sufficient
  - Meaning depends on geolocation!
  - Even dates (May 2\textsuperscript{nd}) have this problem
Solving Time/Place Problem

- Fix one place on earth, and use that location's time
  - We agreed (in 1884): Greenwich, England
  - Same location as used for longitude
  - “Prime Meridian” of longitude (ie 0°)
    - Aside: What are the co-ordinates of the oval?
  - Once called “Greenwich Mean Time” (GMT)
    - Now called “Coordinated Universal Time” (UTC)

- Example
  - CSE 3901 final exam is at 7 pm on May 2, 2017
  - So why does it say 3 pm on SIS?
Time Zones

- People want their clocks to show 12:00 when the sun is high in the sky

- Solution: Time zones
  - Geographic region that uses the same offset from Greenwich
  - Politically defined

- Abbreviations
  - EST = UTC-5:00 ("Standard", i.e. winter)
  - EDT = UTC-4:00 ("Daylight savings" summer)

- To report a time, append time zone
  - 2017-05-02 15:00:00 EDT
  - 2017-05-02 15:00:00 UTC-4:00
  - 2017-05-02 19:00:00 UTC
Notation: Encoding Date/Time

- Computer scientists understand the importance of representation/encoding
- Big Endian
  - `year-month-day hour:minute:second`
    - `2017-05-02 15:00:00`
  - Benefit: lexicographic = chronological
- Start at 0, not 1
  - Non-CS folks call this a "24-hour clock"!
  - CS folks call this... normal
  - 00:00 is midnight, 12:00 is noon
  - Benefit: Avoids am/pm ambiguities
Mixing Intervals and Points

- Mapping between these is tricky
- *E.g.* run a task *every day at 9 am*
  - Naïve solution: `java.util.Timer`’s schedule
    - `schedule(TimerTask t, Date first, long period)`
  - Period is an interval (number of milliseconds)
    - `schedule(job, noonToday, 86400000);`
- Problem?
From Intervals to Points

- Measure interval from a fixed point
  - Called “epoch”
  - Needed for both date (BC/AD) and time

- Unix: chose Jan 1, 1970
  - long time_t, count of elapsed seconds
  - What time is it? Approx. 1,492,015,000
    - See http://www.unixtimestamp.com
End of the World
From Intervals to Points

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- Unix: chose Jan 1, 1970
  - `long time_t`, count of elapsed seconds
  - What time is it? Approx. 1,492,015,000
    - See [http://www.unixtimestamp.com](http://www.unixtimestamp.com)
  - Stored as a (signed!) 32-bit integer
    - “max time” = $2^{32}-1 = 2.1$ billion = 68 years!

- Will overflow on Jan 19, 2038

- Solution: use 64 bit!
  - Postpones the problem for 290 billion years...
This hour has ?? minutes...
Seconds, Minutes, Hours, Days

- Days *do not* divide years evenly
  - About 365.242199 days/year
- But seconds *do* divide days evenly!
  - Exactly $24 \times 60 \times 60 = 86,400$ s/day

Why?
- Days & years are set independently by nature
- Seconds are our invention

How long is a second?
- Defined to be $1/86,400^{th}$ of a day
- SI second = $9,192,631,770$ oscillations of a caesium-133 atom (at rest, sea level, 0 Kelvin)
- Just one problem... how long is a day?
Problem: Solar / Sidereal Day
Problem: Apparent / Mean Solar

- We are closest to the sun in winter
  - Speed of orbit $\propto$ distance to sun
- Also, Earth's axis is tilted
  - Sun (appears to) move along ecliptic
  - But Earth rotates along celestial equator
- Result: Each apparent solar day (24 hrs?) varies in length!
  - Can be +/- 30 seconds of average length
- Even worse: Variation is correlated!
  - Long days are consecutive during the year
  - Difference (local noon vs watch) accumulates
- Result: Net difference of +/- 15 minutes
Equation of Time
Do We Care?

- The equation of time lets you correctly convert time to/from position of sun
  - At what time will be “local noon” today?
  - See: www.timeanddate.com/sun

- This only matters if you care about the exact position of the sun any given day!
  - Eg sundials and sextants
  - So (mostly) no one cares

- All we need is average length of full day
  - A “mean solar day”
  - Horizontal axis in graph of equation of time
  - Measure it, super accurately, then divide by 86,400
Now For the *Really* Bad News
The Earth is Slowing Down

- Planet has been slowing down (and will continue to slow down)
- Today's "mean solar day" is longer than it was 200 years ago!
  - We use the mean solar day of 1750-1892 (averaged)
- Bad news: There are a bit more than 86,400 SI seconds / mean solar day
- *Really* bad news: We can't predict the size of this effect very far into future
Leap Seconds

- Mean solar day is longer than 86400 SI seconds
  - Tidal forces have slowed the rotation of the earth
  - Must correct clock time to stay synched with solar days

- Leap second: 1 second insertion/deletion
  - Irregular occurrence, UTC decides
  - Based on observation, impossible to predict
  - Since 1972, there have been 27 additions, no deletions
  - Most recent: Dec 31, 2016 (an addition)
# Leap Second Episodes

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**Total**

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**Current TAI - UTC**

37
1 minute ≠ 60 seconds

- Addition/removal occurs during the last minute of Dec 31 or Jun 30
- Those minutes have 61 or 59 seconds!
  23:59:58, 23:59:59, 23:59:60, 00:00:00...
- Screen capture of the clock at time.gov during a leap second:
More Complications

- GPS satellites don’t reset their clocks
  - GPS time was equal to UTC time in 1980
  - Since then, has missed 18 leap seconds
  - [http://leapsecond.com/java/gpsclock.htm](http://leapsecond.com/java/gpsclock.htm)

- Unix time *decrements* during leap second
  - Monotonic timer provided by NTP protocol

- Not all countries have adopted UTC

- Leap seconds will become more frequent
  - Proposals to abolish, replace with leap *hours*
GMT vs UT1 vs UTC

- GMT: Greenwich mean time
  - Antiquated: Should not be used today
- UT1: Universal time
  - Time at prime meridian
  - Determined by celestial movements
- TAI: Atomic time
  - Was equal to UT1 in 1958
  - Ticks in SI seconds
- UTC: Universal Coordinated Time
  - Ticks in SI seconds, like TAI
  - Periodically *modified* to match UT1
And we care because...

The Inside Story of the Extra Second That Crashed the Web

BY ROBERT MCMILLAN AND CADE METZ 07.02.12  7:54 PM
Summary

- Intervals vs points
  - Intervals are easy, points are tricky
  - Unix time: Seconds from 01/01/1970
  - Date/time is coupled to geolocation
- Interval between 2 points is hard
  - Number of days/year can vary
  - Number of hours/day can vary
  - Number of seconds/minute can vary
- Standardization
  - Mean solar day, SI seconds
  - They don't match: need leap seconds
- UT1, UTC, TAI