MITMECHE

2.017 DESIGN OF ELECTROMECHANICAL ROBOTIC SYSTEMS

Fall 2009 Lab 3: GPS and Data Logging

September 28, 2009

Dr. Harrison H. Chin

Formal Labs

1. Microcontrollers
   - Introduction to microcontrollers
   - Arduino microcontroller kit
2. Sensors and Signals
   - Analog / Digital sensors
   - Data acquisition
   - Data processing and visualization
3. GPS and Data Logging
   - GPS receiver and shield
   - Data logging
   - Visualization of data
4. Motor Control
   - Motors
   - Encoders
   - Position control

Lab 3: GPS and Data Logging

- Assemble the GPS logger shield (1:30 – 2:30)
- GPS experiments (2:30 – 4:30)
  - Test your GPS device
  - Determine the accuracy of the GPS receiver
  - Take field data
  - Process GPS data
- Project discussion (4:30 – 5:00)

Assemble The GPS Logger Shield

- Grab a soldering iron and solder
- Power the soldering iron and set the temperature dial to 4
- Follow the on-line instructions on the web site: http://www.ladyada.net/make/gpsshield/solder.html to assemble the board
- Also solder the 9v battery holder
- Take your time. Don’t rush it.

Soldering Guidelines

- Wear safety glasses when soldering
- Do not touch a hot iron
- Never leave your iron turned on while unattended
- Never set the soldering iron down on anything other than an iron stand
- Use needle nose pliers, heat resistant gloves, or a third hand tool to hold small pieces
- Practice a few times if you have not done soldering recently
- Do not use excess amount of solder
- Double check the part you want to solder before you actually do it
- When done soldering, tinning the iron is required to protect the tip from oxidation thereby dramatically increasing its life

Some References on GPS

- References:
  - http://edu-observatory.org/gps/tutorials.html
  - http://www.gpsinformation.org/dale/nmea.htm
  - http://www.cmtinc.com/gpsbook/
  - http://en.wikipedia.org/wiki/NMEA
  - http://vancouver-webpages.com/peter/gpsfaq.txt
  - http://www.trimble.com/gps/index.shtml
  - http://www8.garmin.com/aboutGPS/
  - http://www.nmea.org/
  - …

Global Positioning System (GPS)

- The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. The satellites were placed into orbit by the U.S. Department of Defense. The total cost was around $12B.

- GPS was originally intended for military applications, but in the 1980s, the U.S. Government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day.

- GPS uses these satellites as reference points to calculate positions accurate to a few meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter.

Image by NOAA.

GPS Background

- GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

- A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

GPS Satellites

- NAVSTAR (DoD name for GPS)
- Orbiting the earth about 12,000 miles above us.
- Making two complete orbits in less than 24 hours with a speed of roughly 7,000 miles an hour.
- Powered by solar energy.
- On-board backup batteries to keep them running in the event of a solar eclipse, when there's no solar power.
- Small rocket boosters on each satellite keep them flying in the correct path.
- The first GPS satellite was launched in 1978.
- A full constellation of 24 satellites was achieved in 1994.
- Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.
- A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.
- Transmitter power is only 50 watts or less.

GPS Data (NMEA 0183 Standard)

- The NMEA 0183 Interface Standard defines electrical signal requirements, data transmission protocol and time, and specific sentence formats for a 4800-baud serial data bus.
- Each bus may have only one talker but many listeners. This standard is intended to support one-way serial data transmission from a single talker to one or more listeners.
- This data is in printable ASCII form and may include information such as position, speed, depth, frequency allocation, etc.

NMEA Standard Sentences

Many sentences in the NMEA standard for all kinds of devices that may be used in different environment. Some of the ones that have applicability to GPS receivers are listed below: (all messages start with GP.)

- AAM - Waypoint Arrival Alarm
- ALM - Almanac data
- APA - Auto Pilot A sentence
- APB - Auto Pilot B sentence
- BOD - Bearing Origin to Destination
- BWC - Bearing using Great Circle route
- DTM - Datum being used
- GGA - Fix information
- GLL - Lat/Lon data
- GRS - GPS Range Residuals
- GSA - Overall Satellite data
- GST - GPS Pseudorange Noise Statistics
- GSV - Detailed Satellite data
- MSK - send control for a beacon receiver
- MSS - Beacon receiver status information
- RMA - recommended Loran data
- RMB - recommended navigation data for gps
- RMC - recommended minimum data for gps
- RTE - route message
- TRF - Transit Fix Data
- STN - Multiple Data ID
- VBW - dual Ground / Water Spped
- VTG - Vector track an Speed over the Ground
- WCV - Waypoint closure velocity (Velocity Made Good)
- WPL - Waypoint Location information
- XTC - cross track error
- XTE - measured cross track error
- ZTG - Zulu (UTC) time and time to go (to destination)
- ZDA - Date and Time

```
$GPRMC,135713.000,A,4221.4955,N,07105.5817,W,4.29,258.17,310809,,*16
```

RMC GPS Sentence

Text removed due to copyright restrictions.
Please see Table B-9 in GlobalSat Technology Corporation.
"GPS Engine Board EM-406a."

Conversion

- UTC (Coordinated Universal Time) to local time
- Lat, Long, Alt
- Kts to m/s

GPS Logger Shield & GPS Receiver

- EM-406a GPS engine board by GlobalSat

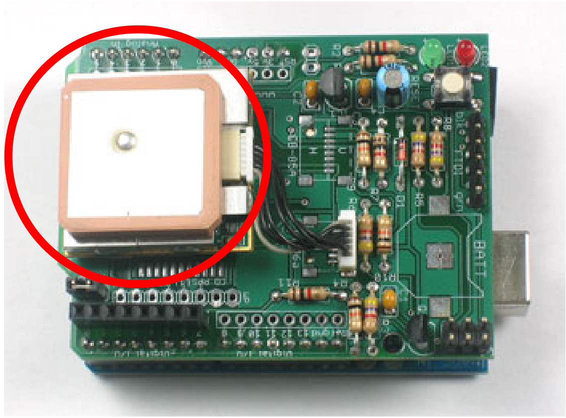
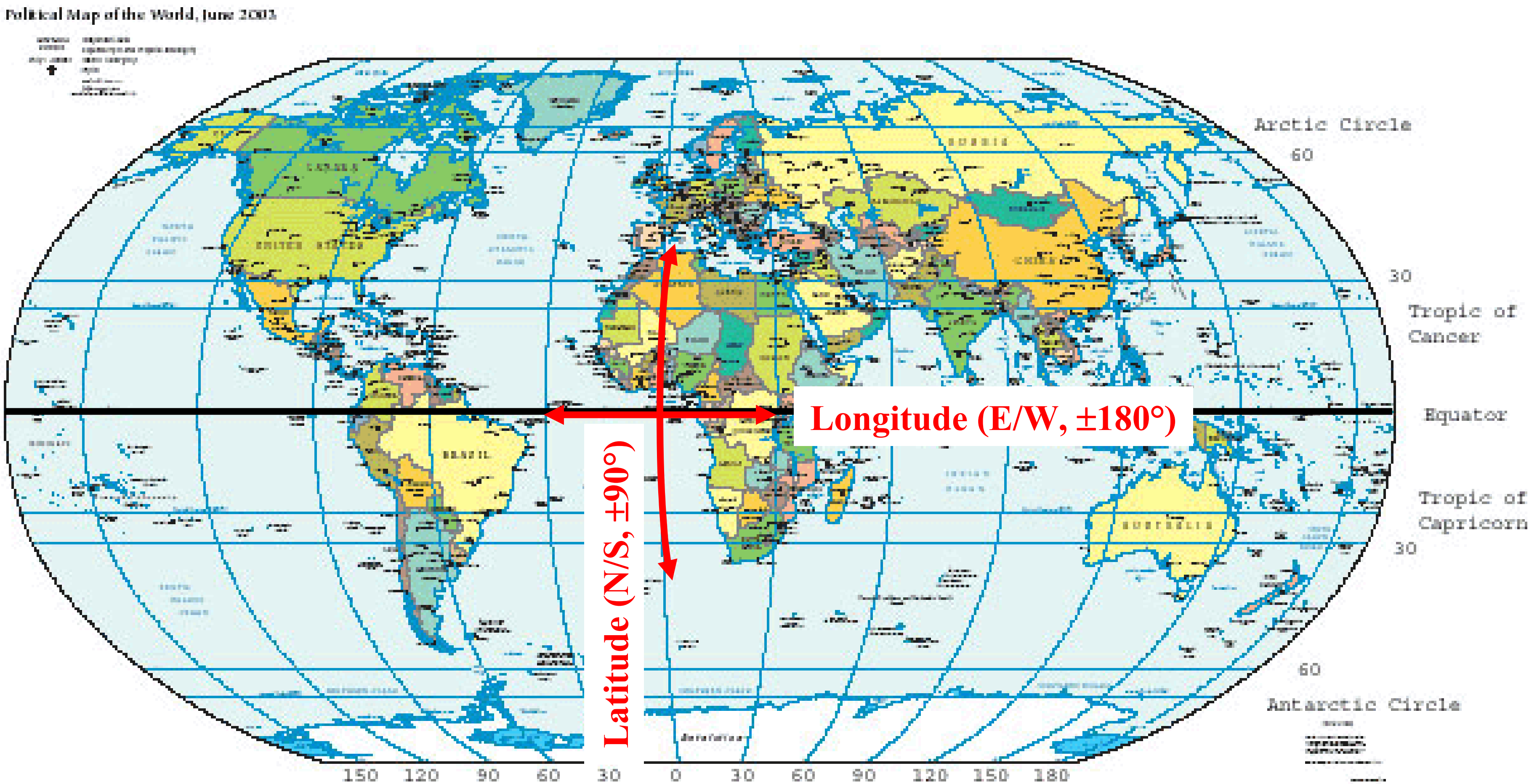


Photo by ladyada on Flickr.

Text removed due to copyright restrictions.
Please see pages 2-3 in GlobalSat Technology Corporation.
"GPS Engine Board EM-406a."

Geographic Coordinate System



Map by CIA World Factbook.

Geocoding w/ GPSVisualizer

Please see GPS Visualizer's Geocode

You can type in a coordinate in Google Map or Yahoo Map and display its location

Calculate Distance Between Two Geographic Coordinates

Haversine formula:

Δlat = lat2− lat1
Δlong = long2− long1
a = sin²(Δlat/2) + cos(lat1)cos(lat2)sin²(Δlong/2)
c = 2atan2(√a, √(1−a))
d = Rc

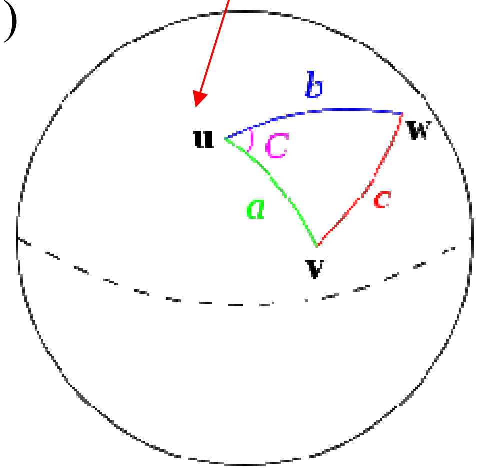
Where R = Earth's radius (mean radius = 6,371km)

Put **u** at the north pole to get this formula

$$\text{haver}\sin(c) = \text{haver}\sin(a-b) + \sin(a)\sin(b)\,\text{haver}\sin(C)$$

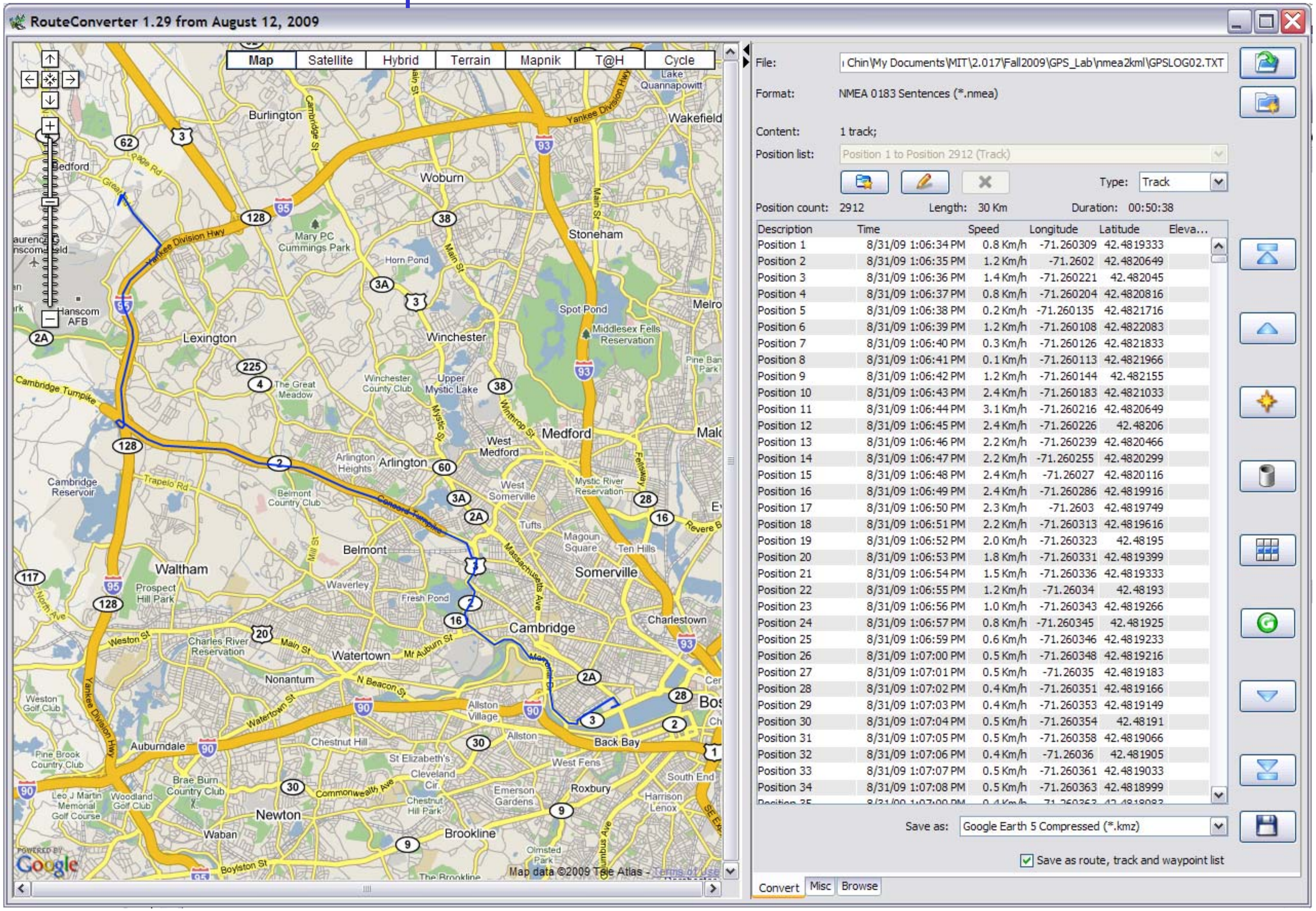
$$\text{haver}\sin(\theta) = \sin^2\left(\frac{\theta}{2}\right)$$

… or use MATLAB's `distance` function to find the arc length in degrees…
(1 arc deg ≈ 69.047 miles ≈ 111.12 km)



RouteConverter Software

http://www.routeconverter.de/



Project Discussion

- Work on the project proposal

Deliverables

- Assembled GPS logger shield and battery holder
- Answer all the questions in the Lab 3 handout
- Data plots
- Estimated GPS data scatter
- Show the teaching staff your lab notebook