

GEOL 4733

Geological Applications of GPS Geodesy Study Guide for Midterm Exam#1

Glen Mattioli

Course overview, introduction to 4 case studies

- Goals of the course
- General overview of statistical concepts
- Basic components of GPS
- Possible geological and geophysical applications
- Review of case studies
 - Puerto Rico Virgin Islands microplate kinematics
 - Deformation cycles at Soufriere Hills volcano, Montserrat
 - Forearc/arc/backarc kinematics of the Nicaraguan and NE Lesser Antilles subduction systems
 - Noise in GPS time series for the New Madrid Seismic Zone

GPS components and their function

- Need for navigational information and historical development
- Costs, basic structure, and DoD mission for GPS
- 3 segments of GPS
 - Space
 - Control
 - User
- GPS SV constellation
 - Number and distribution of SVs
 - Orbital planes
 - Ground tracks
 - Block I vs. Block II
- Conceptual components to yield a GPS position estimate
 - Using satellite ranging
 - Measuring distance between SV and RCVR
 - Improving timing control – eliminating clock errors
 - Location of SVs in space
 - Discussion of error sources
- Good vs, excellent clocks
 - Quartz oscillators
 - Cesium atomic clocks
- Basic introduction to GPS signal structure
 - Codes
 - Carrier phases
- Code generation and correlation in RCVR
- GPS RCVR component block diagram
- Navigation message and its structure
- Measured range and clock bias
- Graphical illustration of clock error and its impact on position estimate

- Satellite ephemeris and SV control segment
- Error sources
 - Ionosphere – use of L1/L2
 - Troposphere water vapor
 - Multipath
 - Receiver and satellite instrument noise
 - SA and bias
 - Blunders
 - Dilution of Precision
- Earth Centered Earth Fixed coordinate system and its relationship to LLH and ellipsoid of revolution
- Relationship of HAE and HAMSL
 - Actual topography
 - Geoid
 - Ellipsoid
- Global Geoid anomaly map
- Ellipsoid and datum comparisons and conversions
- Differential (double difference) positioning
- Carrier phase tracking and its utility for GPS kinematic positioning
- Receiver characteristics and costs comparison

Introduction to Statistics and Probability

- Elementary concepts and definitions
- Variable type and information content
- Systematic and random errors
- Accuracy vs. precision
- Parent vs. Sample populations
- Univariate statistical terms
 - Mode
 - Mean
 - Median
 - Range
- Discrete distributions vs. sample size
- Histograms and sample distributions
 - Symmetric
 - Uniform
 - Bimodal
 - Skewed
- Deviations
 - Definition
 - Average deviation
 - Variance
 - Standard deviation
- Mathematical definitions
 - Sample mean
 - Sample variance

- Binomial Distribution
 - Permutations
 - Combinations
 - Conditional probability
 - Mean
 - Variance
- Other probability distributions
 - Poisson distribution
 - Gaussian distribution
 - Lorentzian or Cauchy distribution
- Discrete and integral probability functions for a Normal distribution
- Percentage of observation vs. standard deviation
- Confidence intervals

GPS signal structure and DSP techniques

- Signal requirements
 - SV identification
 - SV location
 - Timing information
 - Clock health & status
- Important Issues
 - Coding methods
 - Signal power
 - Frequency allocation
 - Security
- L1/L2 chipping rate and fundamental frequency
 - Carrier phases
 - C/A and P(Y) codes
- Summary characteristics of codes and messages
- Digital modulation methods
 - Amplitude
 - Frequency
 - Phase
- Modulo-2 arithmetic and GPS code recovery
- Code superposition
- Phase and quadrature
- Formal mathematical definition of codes on L1/L2
- GPS signal characteristics in the frequency domain
 - sinc function and its relationship to a square wave
 - Bandwidth requirements and definition
- DSP techniques
 - Low pass filter
 - High pass filter
 - Band pass filter
 - Up conversion
 - Down conversion

- Spread spectrum methods
 - FDMA
 - TDMA
 - CDMA -> GPS
- PRN codes and cross-correlation
- C/A code acquisition and locking
- Coping with Anti-spoofing
 - Signal squaring
 - Code-aided squaring
 - Cross-correlation
 - Z-tracking
- AS technologies summary and relationship to UARK GPS equipment

GPS observables

- Geometric description of pseudoranges
- Definition of pseudorange
- Full mathematical description of pseudorange with propagation errors included
- Definition of topocentric position and approaches to its solution
- The Navigation solution
- Dilution of precision factors and their definition
 - VDOP
 - HDOP
 - PDOP
 - TDOP
 - GDOP
- Undifferenced carrier phase observable equation
- Relationship of carrier phase observable to topocentric range
- Single difference solution geometry
- Double difference solution geometry
- Triple difference solution geometry
- Benefits and common-mode cancellations for difference solutions
- Doppler observation, geometry, and relationship to carrier phase

Possible Exam questions

- Describe in detail the components of the GPS system
- How are SV clocks different from RCVR clocks?
- How are the geoid and ellipsoid related to actual topography?
- Discuss the characteristics of a Gaussian distribution.
- Give two examples of the geological and geophysical application of GPS geodesy; discuss the relative merits of GPS over other techniques.
- What is the binomial distribution and why is it important in physical sciences?
- How is digital information encoded on GPS carrier phases?
- Define Selective Availability and Anti-spoofing. What techniques may be used to deal with these in GPS processing?
- Describe the steps necessary to acquire, process, and obtain a geodetic quality position estimate using GPS.