Course Syllabus - Online
Spring 2008 - Section 4218

SUR3520: Measurement Science

Catalog Description
Theory of measurement errors, error propagation, variance and covariance, polynomial curve fitting, regression analysis, correlation and least-squares adjustment

Credits: 3 (LT: 3 + LB: 0)

Timeline:	**LT**	MWF	5 (11:45 am - 12:35 pm) and online
	LB	N/A	
	OF	MWF	3 and online

Instructor:
Dr. Ahmed Mohamed
Office: 406A Reed Lab, Phone: 392-3465 Email: amohamed@ufl.edu

Teaching Assistant:
Sowmya Selvarajan
sselvarajan@ufl.edu

Objective
This course teaches the principles of measurement analysis and adjustment of spatial data. After completing this course, the student is expected to have understanding of fundamental statistical measures, statistical testing, error propagation, survey measurement errors, least squares adjustments, and precision of adjusted quantities.

Pre-requisite(s): MAC 2233, STA 2023, and SUR 2101 or equivalents
Course attendees are assumed to have successfully completed introductory courses on mathematics, statistics, and basic surveying.

Co-requisite(s): None

Course Text (Required)

Ghilani, Charles D, and Paul Wolf 2006. ***Adjustment Computation – Spatial Data Analysis**..4th edition – John Wiley & Sons, Inc.* ISBN: 0-471-69728-1

Lab Text N/A

Software
Textbook CD

Facilities
Lecturing: online and Reed Lab room # 302
Lab: N/A

Website - http://lss.at.ufl.edu/ and log to e-learning

Course Evaluation

10	Assignments	30%
2	Quizzes	30%
	Final Exam	40%
	Total	100%

- Assignments are available to students at the end of each week.
- Assignments are due on the Monday of the following week; cut-off day is 4 days after the due date.
- Quizzes are a full lecture period closed-book exam.
- Final theory exam is closed book for a 2-hour period.

Grading System

90-100	**A**		
85-89.9	**B+**	80-84.9	**B**
75-79.9	**C+**	70-74.9	**C**
65-69.9	**D+**	60-64.9	**D**
		0-59.9	**F**

Academic Honesty:
The University of Florida requires all members of its community to be honest in all endeavors. Cheating, plagiarism, and other acts diminish the process of learning. When students enroll at UF they commit themselves to honesty and integrity. Your instructor fully expects you to adhere to the academic honesty guidelines you signed when you were admitted to UF. As a result of completing the registration form at the University of Florida, every student has signed the following statement: *"I understand the University of Florida expects it students to be honest in all their academic work. I agree to adhere to this commitment to academic honesty and understand that my failure to comply with this commitment may result in disciplinary action up to and including expulsion from the University."* Furthermore, on work submitted for credit by UF students, the following pledge is either required or implied: "*On my honor, I have neither given nor received unauthorized aid in doing this assignment.*" It is to be assumed all work will be completed independently unless the assignment is defined as group project, in writing by the professor. This policy will be vigorously upheld at all times in this course.

Software Use:
All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate.

Campus Helping Resources:
Students experiencing crisis or personal problems that interfere with their general wellbeing are encouraged to utilize the university's counseling resources. Both the Counseling Center and Student Mental Health provide confidential counseling services at no cost for currently enrolled students. Resources are available on campus for students having personal or lacking clear career and academic goals, which interfere with their academic performance. The Counseling Center is located at 301 Peabody Hall (next to Criser Hall). Student Mental Health is located on the second floor of the Student Health
Services in the Infirmary.

1. *University Counseling Center*, 301 Peabody Hall, 392-1575; personal and career counseling: w**ww.counsel.ufl.edu**
2. *Student Mental Health*, Student Health Care Center, 392-1171, personal counseling: **www.hsc.ufl.edu/shcc/smhs.htm**
3. *Sexual Assault Recovery Services (SARS)*, Student Health Care Center, 392-1161, sexual assault counseling; and
4. *Career Resource Center*, Reitz Union, 392-1601, career development Assistance and counseling.

Students with Disabilities Act:
The Dean of Students Office coordinates the needed accommodations of students with disabilities. This includes the registration of disabilities, academic accommodations within the classroom, accessing special adaptive computer equipment, providing interpretation services, and mediating faulty-student disability related issues. *Dean of Students Office*, 202 Peabody Hall, 392-7066, **www.dso.ufl.edu.**

Time Guidelines

Subject to change, the following section times are a suggested guide in order to meet learning goals…

LECTURE Wk		Module	Lecture Topic	Reading
1	Jan 7th	1. Statistical & Mathematical Foundation	Introduction and Course Outline	This document
	Jan 9th		Measurements and Errors	Ch. 1 pp. 1-10
	Jan 11th		Observations and Their Analysis	Ch. 2 pp. 12-30
2	Jan 14th		Random Error Theory (1/2)	Ch. 3 pp. 33-47
	Jan 16th		Random Error Theory (2/2)	Ch. 3 pp. 33-47
	Jan 18th		Confidence Intervals	Ch. 4 pp. 50-65
3	Jan 21st		NO CLASS - Holiday	-
	Jan 23rd		Review of Matrices	Appendices A & B pp. 520-545
	Jan 25th		Review of Matrices	Appendices A & B pp. 520-545
4	Jan 28th		Linearization of Non-Linear Equations - Taylor's Theorem	Appendix C pp. 546-555
	Jan 30st		Statistical Testing (1/2)	Ch. 5 pp. 68-80
	Feb 1st		Statistical Testing (2/2)	Ch. 5 pp. 68-80
5	Feb 4th	2. Propagation of Random Errors	Fundamentals (1/2)	Ch. 6 pp. 84-94
	Feb 6th		Fundamentals (2/2)	Ch. 6 pp. 84-94
	Feb 8th		Error Propagation in Angle and Distance Observations (1/2)	Ch. 7 pp. 99-122
6	Feb 11th		Error Propagation in Angle and Distance Observations (2/2)	Ch. 7 pp. 99-122
	Feb 13th		Error Propagation in Elevation Observations	Ch. 9 pp. 144-156

	Feb 15th		**Quiz 1 – online** Weil Hall 410 and 412	All of the Above
7	Feb 18th	3. Principles of Least Squares	Weights of Observations	Ch. 10 pp. 159-170
	Feb 20st		Fundamental Principle of LS: Stochastic and Functional Models	Ch. 11 pp. 173-199
	Feb 22nd		Observation Equation Functional Model and its Solution (1/3)	Ch. 11 pp. 173-199
8	Feb 25th		Observation Equation Functional Model and its Solution (2/3)	Ch. 11 pp. 173-199
	Feb 27th		Observation Equation Functional Model and its Solution (3/3)	Ch. 11 pp. 173-199
	Mar 29th		Conditional Equation Functional Model	Ch. 11 pp. 173-199
9	Mar 3rd		Example (Adjustment of Level Nets)	Ch. 12 pp. 205-216
	Mar 5th		Precision of Adjusted Quantities	Ch. 13 pp. 221-229
	Mar 7th		Analysis of Adjustments	Ch. 25 pp. 492-502
10	Mar 10th -14th		**Spring Break**	
11	Mar 17th	4. Adjustment Computations - Applications	Adjustment of Horizontal Surveys: Trilateration (Distance)	Ch. 14 pp. 233-250
	Mar 19th		Adjustment of Horizontal Surveys: Triangulation (Angle)	Ch. 15 pp. 255-275
	Mar 21st		Adjustment of Horizontal Surveys: Traverses	Ch. 16 pp. 283-301
12	Mar 24th		Adjustment of Horizontal Surveys: Networks	Ch. 16 pp. 283-301
	Mar 26th		Adjustment of GPS Surveys: Basics	Ch. 17 pp. 310-333
	Mar 28th		Adjustment of GPS Surveys:	Ch. 17 pp. 310-333

			Baseline Solution	
13	Mar 31st		Adjustment of GPS Surveys: Network Solution (1/2)	Ch. 17 pp. 310-333
	Apr 2nd		Adjustment of GPS Surveys: Network Solution (2/2)	Ch. 17 pp. 310-333
	Apr 4th		**Quiz 2 – online** Weil Hall 410 and 412	All of the Above
14	Apr 7th	5. Reliability Analysis	Error Ellipse (1/2)	Ch. 19 pp. 369-386
	Apr 9th		Error Ellipse (2/2)	Ch. 19 pp. 369-386
	Apr 11th		Constraint Equations	Ch. 20 pp. 388-405
15	Apr 14th		Blunder Detection (1/2)	Ch. 21 pp. 409-432
	Apr 16th		Blunder Detection (2/2)	Ch. 21 pp. 409-432
	Apr 18th		Survey Design	Ch. 21 pp. 409-432
16	Apr 21st	6. General Least Squares	General Least Squares Method (1/2)	Ch. 22 pp. 437-451
	Apr 23rd		General Least Squares Method (2/2)	Ch. 18 pp. 345-364 & Ch. 22 pp. 437-451
	Apr 25th		Reading Day	All of the Above
	Apr 28th		**Final Exam** - online	All of the Above
12:30 – 2:30 pm			Weil Hall 410 and 412	

Course Content

Below is a list of the learning outcome(s) for this course, the topics, and the instructional objectives used to achieve the learning outcome(s) …

1. STATISTICAL AND MATHEMATICAL FOUNDATION

Learning Outcome:
Furnish foundation of statistical and mathematical principles pertaining to the theory of errors and its applications in survey adjustment computations

Topics:
1. **Measurements and Errors**: Direct and indirect measurements, error types and their sources, precision vs. accuracy
2. **Observations and Their Analysis**: Sample vs. population, range and mean, variance
3. **Random Error Theory**: Probability, normal distribution, standard error, probable error
4. **Confidence Intervals**: Sampling distribution (t, chi, F), confidence intervals
5. **Statistical Testing**: Hypothesis testing, tests
6. **Matrices**: Revision of matrices and matrix algebra
7. **Matlab Primer**: Introduction to matrix-based computational environment
8. **Taylor's Theorem**: Linearization of non-linear equations

Instructional Objectives:
- Distinguish between direct and indirect measurements
- List the different types of errors
- List the different sources of errors
- Define precision and accuracy as they pertain to survey data
- Differentiate between the population and sample of a data set
- Compute range, mean, and variance of a sample
- Describe the normal distribution curve
- Compute standard and probable errors
- Define (t, chi, F) distribution as applied to survey data
- Set hypothesis testing and analyze their outcomes
- Perform tests of hypotheses for the mean, variance, and ratio of variances
- Solve linear equations using matrices
- Perform basic matrix algebra using Matlab
- Construct a linear form of non-linear equation using Taylor's theorem

---

2. PROPAGATION OF RANDOM ERRORS

Learning Outcome:
Describe the process of random error propagation into indirect survey measurements and use it in survey analysis

Topics:

9. **Basic Equations**: Basic error propagation equation
10. **Frequently Encountered Specific Functions**: Sum, series, and mean
11. **Error Sources in Horizontal Angles**: Reading errors, pointing errors, centering errors, levelling errors, azimuth errors
12. **Errors in Electromagnetic Distance Observations**
13. **Systematic Errors in Differential Leveling**: Collimation Error, Earth Curvature
14. **Random Errors in Differential Leveling**: Reading errors, instrument levelling errors, rod plumbing error
15. **Error Propagation in Trigonometric Leveling**

Instructional Objectives:

- Describe the basic error propagation equation
- Construct error propagation models for the specific cases of sum, mean, and series of observations
- List sources and calculate the value of horizontal angle errors
- List sources and calculate the value of EDM observation errors
- List sources and calculate the value of differential leveling systematic errors
- List sources and calculate the value of differential leveling random errors
- Evaluate error propagation model for trigonometric leveling

---

3. PRINCIPLES OF LEAST SQUARES

Learning Outcome:

Examine the founding principle of the concept of Least Squares and its use in survey analysis

Topics:

16. **Weights of Observations**: Weighted mean, weights and variances, statistics of weighted observations
17. **Fundamental Principle of Least Squares**: Equal-weighted, weighted
18. **Stochastic Model**
19. **Functional Model**
20. **Observation Equations:** Systematic formulation of the normal equations using matrices, linear, non-linear cases, curve fitting
21. **Conditional Equations**
22. **Adjustment of Leveling Nets by Least Squares**: Observation equation vs. conditional equation techniques
23. **Precision of Adjusted Quantities**: Development of covariance matrices
24. **Analysis of Adjustment**: residual analysis, goodness-of-fit test

Instructional Objectives:

- Calculate weighted mean
- Examine the relationship between weights to variances and calculate the statistics of weighted observations

- Describe the underlying concept of Least Squares in both equal-weight and weighed cases
- Recognize the stochastic model as it is used in the context of Least Squares
- Recognize the functional model and its role in Least Square
- Systematically formulate the normal equations using the observation equation functional model with Least Squares for the linear and non-linear cases and for curve fitting
- Systematically formulate the normal equation using the conditional equation functional model with Least Squares
- Assess the observation equation and conditional equation functional models as it applies to the adjustment of leveling nets
- Relate the covariance matrices to the precision of adjusted quantities from Least Squares
- Analyze the result of a Least Squares adjustment through the residuals

4. ADJUTMENT COMPUTATIONS - APPLICATIONS

Learning Outcome:
Solve survey problems involving redundant measurements using the method of Least Squares Adjustment

Topics:
25. **Trilateration**: Distance observation equation, formulation of normal equations, iterations
26. **Triangulation**: Azimuth observation equation, angle observation equation, intersection, resection
27. **Traverses:** Distance and angle observation equations, LS solution
28. **Networks:** Trilaterated and triangulated (braced) quadrilaterals
29. **GPS:** Basics, errors, observation equation for single point positioning, baseline, and network solution

Instructional Objectives:
- Evaluate the observation equation of distance measurement
- Evaluate the observation equation of azimuth measurement
- Evaluate the observation equation of angle measurement
- Solve survey problems involving distance-only (trilateration), angle-only (triangulation), distances and angles (traverse or network) observations using the method of Least Squares adjustment
- Examine GPS sources of errors
- Evaluate the observation equation of GPS measurements in case of single point positioning, baseline, network of baselines of GPS measurements
- Solve GPS survey problems using Least squares

5. RELIABILITY ANALYSIS

Learning Outcome:

Examine topics in reliability analysis for survey problems

Topics:

30. **Error Ellipse**: Computation, standard error ellipse, confidence regions, survey network design
31. **Constraint Equations**: Elimination, Helmert, overweighting methods
32. **Blunder Detection in Horizontal Networks**: loop closure, covariance matrix for the residual vector, detection of outliers and data spoofing
33. **Internal and External Reliability**
34. **Survey Design**

Instructional Objectives:

- Define the error ellipse for survey networks
- Compute error ellipse parameters from adjustment covariance matrix
- Compute the standard error ellipse and define confidence region and their use in survey network design
- Describe the constraint equations by the methods of elimination, Helmert, and overweighting
- Calculate loop closure, covariance matrix of the residual vector
- Examine ways of detecting outliers and spoofing of survey data
- Define and calculate internal and external reliability for survey networks
- Describe the process of survey design

---

6. GENERAL LEAST SQUARES

Learning Outcome:

Examine the method of general least squares and its application in coordinate transformation

Topics:

35. **General Least Squares**: Principle, normal equation solution, curve fitting
36. **Coordinate Transformation – Least Squares**: Observation equations, solution
37. **Coordinate Transformation – General Least Squares**: combined observation-unknown equations, solution

Instructional Objectives:

- Examine the need for and describe the principle of general least squares
- Formulate the normal equations in the case of general least squares and use it to solve the curve fitting problem as example
- Write observation equations and solve the problem of 2D conformal coordinate transformation, as example, using least squares
- Write combined observation-unknown equations and solve the problem of 2D conformal coordinate transformation, as example, using general least squares