LASSONDE SCHOOL OF ENGINEERING | YORK UNIVERSITÉ UNIVERSITY

Dept. of Earth & Space Science & Engineering

# LE/ESSE3630 3.0
# Analysis of Overdetermined Systems
# Winter 2016


**Course Director**

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**Lectures**

*Tuesdays and Thursdays*, 10:00 - 11:30
Norman Bethune College, Room 228

**Laboratories**

*Thursdays*, 16:00-17:30
Petrie Science and Engineering Building, Room 020

**Prerequisites**

Introduction to Applied Statistics (MATH2565), Geodetic Concepts (ESSE3610), Adjustment Calculus (ESSE3620)

**Co-requisites**

n/a

**Assessment**

- Laboratories (9): 30%
- Mid-term Exam: 15% (No make-up exam; the 15% will be carried forward to the final exam.)
- Quizzes (4): 10% (No make-up of any quiz and no carry forward of the marks to the final exam.)
- Class participation: 5%
- Final Exam: 40%.

**Grade System**

| | | | |
|---|---|---|---|
| ≥ 90% | A+ | 60-64% | C |
| 80-89% | A | 55-59% | D+ |
| 75-79% | B+ | 50-54% | D |
| 70-74% | B | 40-49% | E |
| 65-69% | C+ | < 40% | F |

# ACADEMIC INTEGRITY AT YORK UNIVERSITY

From York University Secretariat[1]:

> Having **Academic integrity** means that you have adopted appropriate principles or standards that consistently govern how you pursue your school work. A student with academic integrity earns a degree with honest effort, and knows that this degree is a true accomplishment reflecting years of hard work and genuine learning. Furthermore, practicing academic integrity means that you will develop essential lifelong skills that include conducting research responsibly, writing clearly and documenting appropriately.

**You must** familiarise yourself with York's Senate Policy on Academic Honesty[2]. This policy defines and clarifies York's commitment to maintaining the highest standards of academic honesty. The policy:

- Recognizes the general responsibility of all faculty members to foster acceptable standards of academic conduct and of students to be mindful of and abide by such standards
- Defines what are considered academic offenses, including plagiarism, cheating, impersonation, and other forms of academic misconduct
- Defines the penalties that can be given to students found to have committed plagiarism or any other form of academic offense
- Outlines the procedures for dealing with students who are accused of committing an academic offense

While it is recognized that there are many pressures on students that may lead to academic misconduct, such as achieving high grades or meeting deadlines, each student has clear responsibility for his or her academic honesty.

You are strongly advised to visit the Academic Integrity web site for York University[3], to read the section "*For Students*"[4], and to complete the Academic Integrity Tutorial[5]. **There will be zero tolerance for proven academic dishonesty.**

All students are also expected to familiarize themselves with the following Senate policies:

- Student Professional Behaviour
- Research Involving Human Participants
- Academic Accommodation for Students with Disabilities
- Sessional Dates and the Scheduling of Examinations (section 7 on Religious Observances)

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1 http://www.yorku.ca/acadinte/files/beware-sayswho.pdf
2 http://www.yorku.ca/secretariat/policies/document.php?document=69
3 http://www.yorku.ca/academicintegrity
4 http://www.yorku.ca/academicintegrity/students/index.htm
5 http://www.yorku.ca/tutorial/academic_integrity

# General Course Information

This course builds upon the fundamental concepts of the Adjustment Calculus (ESSE3620) course to expand the elemental classes of mathematical models of Least-squares adjustment (parametric, conditional, combined) to more complex methods, such as adjustments with weighted parameters and generalized adjustment methods. The course will systematically develop such methods based entirely on methods discussed in ESSE3620. Subsequently, the more complex models will be reduced appropriately to the elemental models showing their generalized character.

The second major unit of the course will deal with the statistical assessment of the observations (quality of measurements), the simultaneous assessment of the observations and mathematical models (how well the measurements fit the model) and finally establish statistical confidence on the final results (the trust we can place in the adjusted parameters). We will emphasise the importance of the covariance matrices as the basic entities that carry important statistical information on the observations and models. In all the statistical tests, we will be using the fundamental theory of statistics learned in MATH2565 and in particular the Hypothesis Testing methodology.

Finally, we will learn how the generalized adjustments method of least squares can be used in the more general linear system that will lead to sequential least-squares adjustment and the Kalman filtering that is extensively used in kinematic positioning and navigation of any platform, e.g., airborne, land land marine vehicles etc.

**1. Objectives**

- To master the weighted least-squares adjustment of geodetic networks and its applications in Geomatics Engineering practice.
- To establish solid foundation of the generalised approach of least squares adjustment and how it can be reduced to the fundamental adjustment cases (parametric, conditional, combined) learned in the previous course (ESSE3620: Adjustment Calculus).
- To familiarize and become capable of working with large overdetermined systems of geodetic control networks in terms of measurement modeling, parameter selection, practical data processing and using commercial software (GEOLAB, Columbus Best Fit Computing).To learn the fundamental statistical testing methods to assess observations and models, and place a level of confidence on the final results.
- To acquire basic knowledge of building test statistics in Geomatics practice.
- To design solutions to problems with constraints and singularities.
- To expand the generalised method of adjustment to sequential adjustment and the Kalman filter as they are widely used in kinematic positioning and navigation.

## 2. Course Topics

- Adjustment with the weighted least squares
- Generalised adjustment
- Overdetermined systems in regards to different basic adjustment cases (parametric, conditional, combined)
- Statistical tests and their applications for assessment of least-squares solutions
- Optimal accuracy design
- Least-squares problems with constraints and singularities.
- Basis of sequential adjustment technique and Kalman filter.

## 3. Format

Since every individual responds to different stimuli in his or her learning process, the presentation of the material will be done in a variety of ways. All of them will require work on your part to be effective. We will take a participative approach to learning. This means that faculty and students learn **together** by doing. We will learn **with** each other and **from** each other. **Therefore, we are all responsible for being prepared for class:**

- Lecture sessions will be conducted in form of teaching, discussion and participation. Students are required to participate actively, and design and solve problems by synthesizing knowledge, experience and skills from previous courses.
- The course will be closely related to LE/ESSE3620 3.0 "*Adjustment Calculus*" and will be running parallel to LE/ESSE3640 3.0 "*Geodetic Surveys*".
- Each session will normally commence with a brief review of the concepts treated previously. New subject(s) will be presented immediately after the review, according to the tentative lecture schedule provided in this handout. **Participation** is an essential element of learning: It will be **encouraged** and **assessed**. All sessions will based on, but not limited to the advanced topics of the textbook. Technical papers will also be supplied by the instructor for further studies. The students will be required to actively search relevant literature to further their knowledge.

## 4. Laboratories

- Laboratory Reports: You are expected to describe in detail methodologies, data processing and analysis, and results and hand in reports and developed software.
- Laboratory report presentation, structure, clarity, syntax, spelling and grammar will be evaluated.
- Participation in **all** laboratory sessions is **mandatory**.

- Grades for late laboratory reports will be decreased by 20% per day for each day overdue.
- PSE-020 will be our laboratory where all exercises, software development and/or commercial software use will take place.

## 5. Feedback on Progress

Feedback on your progress will be provided in four different ways:

- Each class session should give you a fair idea how well you have understood the material. This is the MOST important and timely form of feedback. You must communicate any concerns to the instructor for immediate remedial action. You may choose to post your views on the course Moodle site, if you so prefer.
- Laboratory Exercises: You will be asked to execute all of the mandatory laboratory exercises, write reports, solve specific computational problems, and perform statistical testing and evaluation of observations and solutions. Your participation is essential and will be assessed.
- Quizzes: You will be asked to write all of the mandatory short quizzes (1-2 questions; 15-20 minutes). The quizzes will be administered during the laboratory sessions (see laboratory session tentative schedule). The quizzes will be based on the class session material discussed during the week of the quiz.
- Mid-term test.

## 6. Announcements

Announcements and information related to the course, such as special lectures, class cancellations, change of due dates, etc. will be made during lecture and laboratory sessions, via e-mail, and on the course Moodle site.

## 7. Required Textbooks

Ghilani, Charles D. (2010), Adjustment Computations: Spatial Data Analysis, 5th Edition, John Wiley &Son, (3rd Edition)

Anderson, M.J., and E.M. Mikhail, (1998). Surveying: Theory and Practice. McGraw-Hill, (7th Edition)

Vaníček P., and E. Krakiwsky (1986). Geodesy: The Concepts. North Holland, Amsterdam (2nd Edition)

The additional written materials will be provided upon needs

## 8. Suggested Bibliography


- Gelb, A. (ed.), (1974), Applied Optimal Estimation, M.I.T. Press, Cambridge, MA
- Hogg, R.V. and A.T. Craig, (1995), Introduction to Mathematical Statistics, Prentice Hall, New

Jersey (5th Edition)

- Mikhail, E.M., (1976), Observations and Least-squares, Thomas Y. Crowell, New York
- Mikhail, E.D., and G. Gracie, (1981), Analysis & Adjustment of Survey Measurements, Van Nostrand Reinhold

## TENTATIVE CLASS SCHEDULE

Winter Class: *Sunday, January 02, 2016 ~ Monday, April 04, 2016*

Reading Week: *February 13 – 19, 2016*

Statutory Holiday(s): *Family Day, Monday, Feb. 15, 2016*

*Good Friday, March 25, 2016 (Makeup-date: Monday, April 4, 2016)*

Winter Exams: *April 06~20, 2016*

| DATE | | SUBJECT |
|---|---|---|
| ***January*** | *05* | Introduction – Course outline and requirements.<br>Review and enhencement of parametric adjustment: math and stochastic models and solution/accuracy assessment and var-covariance propagation/Initial data in different types of geodetic networks /modeling of the most-commonly-used types of measurememnts |
| | *07* | Review and enhencement of parametric adjustment: continued<br>Review and enhancement of conditional adjustment: math and stochastic models and solution/selected condition types/measurement quanlity control |
| | *12* | The generalized adjustment model to least-squares problems. |
| | *14* | The generalized adjustment model to least-squares problems: continued |
| | *19* | *Quiz #1*<br>Case Studies: ***Coordinate Transformations*** from standard parametric adjustment to conditional adjustment with parameters (the general Least-Squares model). |
| | *21* | Continued. Application-oriented discussion. |
| | *26* | A-priori and a-posteriori variance factors and their meaning |
| | *28* | Hilbert spaces and statistics. The covariance matrix as a metric tensor. |
| ***February*** | *02* | Review of the four commonly-applied test statistics |
| | *04* | *Quiz #2*<br>Normal distribution. Statistical properties of the least-squares solution. |
| | *09* | Statistical testing: Statistical hypothesis Ho, testing of Ho, significance and confidence levels. |
| | *11* | *Mid-Term Exam* |
| | *16* | ***Reading Week – No class*** |
| | *18* | ***Reading Week – No class*** |
| | 23 | Testing of Ho against alternative hypothesis; Type I and type II errors; Statistical Tests with direct measurements and in Linear parametric models |

| | | |
|---|---|---|
| | *25* | Assessment of observations: $\chi^2$ goodness-of-fit test; tests on the mean and the variance. |
| ***March*** | *01* | Tests for outliers in the observations. |
| | *03* | *Quiz #3*<br>Simultaneous assessment of observations and mathematical models. |
| | *08* | Assessment of misclosures and residuals. Examples. |
| | *10* | Problem solving exercise |
| | *15* | Assessment of determined parameters. |
| | *17* | Problems with singularities; Rank deficiency in different types of geodetic Networks |
| | *22* | Quiz #4<br>Problems with constraints; Independent and constrained networks. |
| | *24* | *Concept of free geodetic networks and deformation monitoring* |
| | *29* | Sequential adjustment and base of Kalman filter. |
| | *31* | Review |

## TENTATIVE LABORATORY SCHEDULE

| DATE | | ASSIGNMENT |
|---|---|---|
| ***January*** | *07* | Lab #1: Residual equations for the commonly-used measurement types and the complete formulae of parametric adjustment (The outcome of this lab may be adapted for the ESSE3640 project ). |
| | *14* | Lab #2 3D GNSS Baseline Network Adjsutment |
| | *21* | Lab #3: 2D Horizontal Triangulatrition Network Adjsutment |
| | 28 | Lab #3 continued |
| ***February*** | *04* | Lab #4: Measurement Quality Control using the conditions. |
| | *11* | Lab #5: Modeling of Conformal Coordinate Transformation as the combined as the combined adjustment problem |
| | *18* | ***Reading Week – No classes*** |
| | *25* | Lab #5 continued. |
| ***March*** | *03* | Lab #6: Statistical analysis of observations before a least-squares adjustment. |
| | *10* | Lab #7: Statistical analysis of observations after a least-squares adjustment (1). |
| | *17* | Lab #8 Least-Squares Adjustment of A Combined 3D Control Network (A Joint lab with ESSE3640: "*Control Network Data Processing*") |
| | *24* | Lab #9 Statistical analysis of observations after a least-squares adjustment (2). |
| | *31* | Lab #9 continued. |