COURSE INFORMATION

Time: Monday 08:30 am - 10:00 am (first slot)
Location: H11
Credit: 4 ECTS credit points

INSTRUCTOR

Name: Islam S. M. Khalil
Office: C7.03
E-mail: islam.shoukry@guc.edu.eg
Office hours: Sunday 01:30 pm - 03:00 pm. Otherwise, by appointment.

TEACHING ASSISTANT

Name: Sarah M. Azzam
Office: C3.337
E-mail: sarah.mostafa@guc.edu.eg
Office hours: Sunday 01:30 pm - 03:00 pm. Otherwise, by appointment.

RESOURCES

Web site: Available through course website. Please check regularly for announcements and updates.
Recommended: Optimization of Dynamic Systems (Agrawal *et al.*) - Nonlinear and dynamic optimization (Chachuat)

PREREQUISITES

Students are expected to have a working knowledge of differential equations, linear and nonlinear systems. Familiarity with programming, especially with Matlab is recommended.

PURPOSE

This course is designed to equip students with fundamental theories and computational methodologies that are used in (computer aided) optimization analysis. Students will learn how to analytically formulate unconstrained and constrained optimization problems as well as how to utilize numerical algorithms to solve such problems.

Students will be introduced to the fundamental theorem of calculus of variation that has a long history of interaction with other branches of mathematics such as geometry and differential equations, and with physics, particularly mechanics.

The emphasis in this course is not on the excessive mathematical abstraction but rather on the ability to formulate an optimization problem and select a proper technique to solve such a problem.

COURSE OBJECTIVES

The goal of this course is to equip each student with the ability to formulate optimization problems By the end of the course, each student should be able to do the following:

- Identify the objective function, the holonomic and nonholonomic constrains.
- Form the Lagrangian function and solve for the optimal variables and Lagrange multipliers.
- Form the Hessian matrix and analyze the second order sufficiency conditions of the optimization problem.
- Compare between optimization techniques such as the gradient descent method, Gauss-Newton method, and the Levenberg-Marquardt method.

TENTATIVE SCHEDULE AND TOPICS

WEEK	TOPICS
1 (Optimization problems formulation)	Objective functions and constrains, system classification, solution of the state equations, Cayley-Hamilton theorem, functions of a matrix
2	Regularization and under-determined systems, over-determined systems, singular-value decomposition
3 (Static optimization)	Minimum and maximum, first order optimality conditions, second order sufficient conditions, linear problems: simplex and primal-dual interior point, holonomic and nonholonomic contstrains
4	Constrained optimization (equality and inequality constrains), Lagrange multiplier method, partition method
5 (Optimization tools)	Hill climbing and Newton-Raphson method, Gradient descent method
6	Gauss-Newton method, Levenberg-Marquardt method
7	Quadratic problems: active-set and interior point
8 (General non-linear optimization)	Dynamic programing
9	The minimum principle of Pontryagin (the calculus of variation)
10	The increment of a functional, the variation of a functional, maxima and minima of a functional
11	The fundamental theorem of calculus of variation
12	Euler equation, Hamilton-Jacobi Bellman equation
13	A number of special optimization problems, ongoing research
14	examples and problems

HOMEWORKS

Homework will be assigned regularly and posted on the course website. Hardcopies will generally not be made available in class, so you will have to produce your own printout.

EXAMS

There will be one mid-term and one final exam. Since the course continually builds upon previous material, all exams will be comprehensive. In class exams are closed book, with one page of personally prepared notes.

LECTURE

Lectures will involve discussions and group activities. Extra lectures and problem solving sessions may be scheduled if necessary. Class participation and cooperation among students are highly encouraged. Student feedback will be collected throughout the semester and adaptation will be undertaken accordingly.

OTHER NOTES

Any student with a disability requiring accommodation in this course is encouraged to contact the instructor during the first two weeks of the semester.

GRADING POLICY

Your course grade is determined from the total points you receive from homeworks, midterm and final exams, and the project. Borderline grades are determined by class participation.

Homeworks and project must be submitted to my office by the end of the date due (midnight). No late problem sets are accepted (Extensions may be granted for special circumstances and only when requested in advance).

You are responsible for all information given in class verbally and/or in writing. Any information about the course on the web may be replaced by the information given in class.

Cooperative efforts at understanding the material and the assignments of the course are encouraged. However, you may only submit work that you have completed individually. For example, you may communicate verbally about methods for solving assigned problems, but sharing of written work is not permitted. Submitting any work that is not the result of a students own effort is considered cheating.

ACTIVITY	WEIGHT [%]
Homeworks	10
Quizzes	20
Midterm exam	30
Final exam	40

Additional Reading

- Van Brunt, The calculus of variations, Springer 2003.
- Kirk, Optimal control theory - an introduction, Dover publications, 1970.