CARLETON UNIVERSITY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
BLDG 5301 – FALL 2022
BUILDING ENERGY MANAGEMENT AND OPTIMIZATION

Instructor: Burak Gunay, PhD, PEng
Office: CB 5206
Office Hours: Monday 4:30 pm to 5:30 pm
Email: Burak.Gunay@carleton.ca

Lectures on Monday 6:05 pm to 8:55 pm at SA 615

Learning Objectives:
1. Basic understanding on statistical analysis and modelling using sensor and metering data from building energy management systems
2. Basic understanding on building energy management systems
3. Fundamentals of exploratory data mining
4. Fundamentals of linear and generalized linear models
5. Familiarity about optimization methods
6. Basic understanding about model selection and validation procedures
7. Introductory knowledge about inverse modelling in building applications
8. Introductory knowledge about classification and clustering
9. Ability to apply basic data analysis and modelling concepts to tackle problems in building operation and maintenance
10. Ability to use Matlab for basic data wrangling and analysis

Textbook: Reddy, A., 2011. Applied data analysis and modeling for energy engineers and scientists. Springer.
Software: Matlab

Course Plan:

Lecture 1: Introduction (Sep 12)

- Energy sector landscape
- Building energy systems
- Challenges in managing energy use in buildings
- Methods to optimize energy use in buildings
- Energy audits

Lecture 2: Inverse modelling - part 1 (Sep 19)

- Multiple linear regression models
- Change point models
- Matlab tutorial - 1 (estimating retrofit energy savings through multiple linear regression and change point model-based baselines)

- Case study

Lecture 3: Inverse modelling - part 2 (Sep 26)

- Neural network models
- Regression trees
- Matlab tutorial - 2 (estimating retrofit energy savings through neural net and regression tree model-based baselines)
- Case study

Lecture 4: Remote envelope characterization (Oct 3)

- Estimating building envelope properties through inverse modelling
- Matlab tutorial - 3 (estimating R value and air permeance)
- Case study

Lecture 5: Fault detection and diagnostics - hard faults (Oct 17)

- Detecting hard faults affecting HVAC systems
- Matlab tutorial - 4 (detecting hard faults in VAV AHU systems)
- Case study

Lecture 6: Fault detection and diagnostics - soft faults (Oct 31)

- ASHRAE Guideline 36 and best practice sequences of operation
- Approaches to detect and interpret sequencing logic faults
- Matlab tutorial - 5 (detecting soft faults in VAV AHU systems)
- Case study

Lecture 7: Virtual metering and end-use disaggregation (Nov 7)

- Inverse modelling applications to complement existing submetering network
- Matlab tutorial - 6 (disaggregating end-uses in VAV AHU systems)
- Case study

Lecture 8: Load forecasting (Nov 14)

- Time-series modelling and decomposition approaches
- Matlab tutorial - 7 (arima models for short-term electricity demand forecasting)
- Case study

Lecture 9: Optimization (Nov 21)

- Optimization algorithms for data-driven building energy management
- Matlab tutorial - 9 (boiler plant equipment sequencing optimization)
- Case study

Lecture 10: Model-based predictive controls (Nov 28)

- Controls-oriented modelling, RC thermal networks
- Real-time optimization of control decisions
- Matlab tutorial - 10 (optimal start time optimization)
- Case study

Lecture 11: Demand response (Dec 5)

- Critical and coincident system electricity demand
- Sequences of operation for demand management
- Comfort and rebound considerations in demand management
- Matlab tutorial - 11 (Simulating the indoor temperature and demand profile of a building)
- Case study

Lecture 12: Project presentations (Dec 9)

Grade Distribution:
Assignment 1 – Change point models 12%
Assignment 2 – Multiple linear regression and artificial neural networks 12%
Assignment 3 – Load forecasting 12%
Assignment 4 – Optimal sequencing for plant equipment 12%
Assignment 5 – Optimal start of AHUs 12%
Project – Establish an energy use baseline and identify abnormalities 40%

Letter Grade Distribution:

>= 90.00	A+
85.00 - 89.99	A
80.00 - 84.99	A-
77.00 - 79.99	B+
73.00 - 76.99	B
70.00 - 72.99	B-
67.00 - 69.99	C+
63.00 - 66.99	C
60.00 - 62.99	C-
57.00 - 59.99	D+
53.00 - 56.99	D
50.00 - 52.99	D-
<= 49.99	F

Accommodation Statement The Paul Menton Centre for Students with Disabilities (PMC) provides academic accommodations and support services to students with Learning Disabilities (LD), mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision.
If you have a permanent, persistent/prolonged, or temporary disability requiring academic accommodations in my course, please contact the PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation.
If you are already registered with the PMC, please request your accommodations for this course through the Ventus Student Portal at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). Requests made within two weeks will be reviewed on a case-by-case basis. For final exams, the deadlines to request accommodations are published in the University's Academic Calendars.
After requesting accommodations through the Ventus Student Portal, please meet with me to discuss your accommodation needs and how they will be implemented in my course.
For Religious Obligations Students requesting academic accommodation on the basis of religious obligation should make a formal, written request to their instructors for alternate dates

and/or means of satisfying academic requirements. Such requests should be made during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist, but no later than two weeks before the compulsory event. Accommodation is to be worked out directly and on an individual basis between the student and the instructor(s) involved. Instructors will make accommodations in a way that avoids academic disadvantage to the student. Students or instructors who have questions or want to confirm accommodation eligibility of a religious event or practice may refer to the Equity Services website for a list of holy days and Carleton's Academic Accommodation policies, or may contact an Equity Services Advisor in the Equity Services Department for assistance.

For Pregnancy Pregnant students requiring academic accommodations are encouraged to contact an Equity Advisor in Equity Services to complete a letter of accommodation. The student must then make an appointment to discuss her needs with the instructor at least two weeks prior to the first academic event in which it is anticipated the accommodation will be required.

Plagiarism Plagiarism is the passing off of someone else's work as your own and is a serious academic offence. For the details of what constitutes plagiarism, the potential penalties and the procedures refer to the section on Instructional Offences in the Undergraduate Calendar.

What are the Penalties for Plagiarism? A student found to have plagiarized an assignment may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; and/or a reprimand; a refusal of permission to continue or to register in a specific degree program; academic probation; award of an FNS, Fail, or an ABS.

What are the Procedures? All allegations of plagiarism are reported to the faculty of Dean of FASS and Management. Documentation is prepared by instructors and/or departmental chairs. The Dean writes to the student and the University Ombudsperson about the alleged plagiarism, the Dean reviews the allegation. If it is not resolved at this level then it is referred to a tribunal appointed by the Senate.

Plagiarism and cheating at the graduate level are viewed as being particularly serious and the sanctions imposed are accordingly severe. Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy. The Policy is strictly enforced and is binding on all students. Plagiarism and cheating – presenting another's ideas, arguments, words or images as your own, using unauthorized material, misrepresentation, fabricating or misrepresenting research data, unauthorized co-operation or collaboration or completing work for another student – weaken the quality of the graduate degree. Academic dishonesty in any form will not be tolerated. Students who infringe the Policy may be subject to one of several penalties including: expulsion; suspension from all studies at Carleton; suspension from full-time studies; a refusal of permission to continue or to register in a specific degree program; academic probation; or a grade of Failure in the course.

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