Weekly Learning Plan — MATH38161

Korbinian Strimmer

1 October 2020

Overview

General plan

This module is taught based on the concept of "flipped learning":

1) First, you study the asynchronous material by yourself:
   i) read the lecture notes,
   ii) watch the lecture videos and
   iii) try to solve the questions and problems given in the worksheets and study their solutions.

For each of the semester weeks 1–11 the following pages provide a detailed list which material you will need to study in a specific week.

2) Subsequently, you attend the live synchronous sessions:
   i) the review lecture and
   ii) the tutorial session.

The review lecture recapitulates the key content from the lecture notes and videos each week. The tutorial session discuss the questions and problems in an interactive fashion.

Links

You can find the course material both on Blackboard and on the MATH38161 course homepage. There can also find the scheduled times and locations for the two weekly live sessions.

Workload

For this course you will need to spend about 6-7 hours study each week:

- 2-3h watching videos, reading and understanding lecture notes
- 2h answering questions and solving and understanding problems in worksheets
- 2h attending live sessions

The in-semester assessment will require about 10h of additional work.

Week 1 (from 5 October 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week first an overview over the course content and course organisation is given. The essentials in matrix theory are reviewed and an introduction to multivariate random variables is given. The tutorial provides information about installing R and R Studio as well as the R packages used later in the course. It also introduces R Markdown for document preparation mixing text, formulas, R code and R output.

Study:

Video 1 Introduction to the course
LN Preface
LN Section 1.1

Video 2 Refresher on matrices and matrix calculus
LN Appendix A

Video 3 Multivariate random variables
LN Section 1.2

Questions and problem solving:

Worksheet 1

Week 2 (from 12 October 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we study the multivariate normal distribution and how to estimate its parameters. In addition, a number of further continuous and discrete multivariate distributions are discussed as generalisation of their univariate counterparts.

Study:

Video 4 Multivariate normal distribution
LN Section 1.3

Video 5 Estimation of multivariate mean and covariance
LN Section 1.4

Video 6 Further multivariate distributions
LN Sections 1.5 and 1.6

Questions and problem solving:

Worksheet 2

Week 3 (from 19 October 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

The focus of this week are linear and nonlinear transformations for random vectors and their properties. As special class we consider general whitening transformations that form the basis of many multivariate statistical models and procedures.

Study:

Video 7 Linear transformations
LN Section 2.1

Video 8 Nonlinear transformations
LN Section 2.2

Video 9 General whitening transformation
LN Section 2.3

Questions and problem solving:

Worksheet 3

Week 4 (from 26 October 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we study properties of five commonly used natural whitening procedures and discuss related methods such as principal component analysis and canonical correlation analysis.

Study:

Video 10 Natural whitening transformations
LN Section 2.4

Video 11 Principal component analysis
LN Sections 2.5 and 2.6

Video 12 Canonical correlation analysis
LN Section 2.7

Questions and problem solving:

Worksheet 4

Week 5 (from 2 November 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we discuss the problem of unsupervised learning and focus on algorithmic methods for clustering such as hierarchical clustering based on trees and the K-means algorithm.

Study:

Video 13 Unsupervised learning and clustering
LN Section 3.1

Video 14 Hierarchical clustering
LN Section 3.2

Video 15 K-means algorithm
LN Section 3.3

Questions and problem solving:

Worksheet 5

Week 6 (from 9 November 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we continue to study unsupervised learning. Specifically, we focus on probabilistic models in the form of (Gaussian) mixture models, and show how to fit these models to observations using the expectation-maximisation (EM) algorithm.

Study:

Video 16 Mixture models
LN Section 3.4

Video 17 Fitting mixture models to data
LN Section 3.5

Questions and problem solving:

Worksheet 6

Week 7 (from 16 November 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we consider supervised learning problems and introduce the general Bayes classifier. Subsequently, three widely used classification methods (QDA, LDA and DDA) are developed and demonstrated how they can be applied to data.

Study:

Video 18 Supervised learning and the Bayes classifier
LN Sections 4.1 and 4.2

Video 19 Normal Bayes classifiers (QDA, LDA, DDA)
LN Section 4.3

Video 20 Training QDA and LDA classifiers from data
LN Section 4.4

Questions and problem solving:

Worksheet 7

Week 8 (from 23 November 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we focus how to select features suitable for prediction in classification and how to evaluate prediction accuracy in supervised learning by cross-validation.

Study:

Video 21 Variable ranking in classification
LN Section 4.5

Video 22 Variable selection and cross-validation
LN Section 4.6 + further reading

Note: in LN Section 4.6.3 you find directions for further reading on cross-validation.

Questions and problem solving:

Worksheet 8

In-semester assessment:

Instructions for the project are available on Blackboard on **Monday 23 November 2020, 12 noon**.

Week 9 (from 30 November 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we study the vector correlation to measure linear association between two random vectors, discuss mutual information to measure nonlinear association and introduce the essentials of graphical models to describe the dependency patterns among random variables.

Study:

Video 23 Vector correlation and RV coefficient
LN Section 5.1

Video 24 Mutual information as generalisation of correlation
LN Section 5.2

Video 25 Graphical models
LN Section 5.3

Questions and problem solving:

Worksheet 9

In-semester assessment:

Work on project! Submission deadline is next week.

Week 10 (from 7 December 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we move away from linear models to nonlinear models and introduce random forests, a nonparametric prediction model.

Study:

Video 26 Limits of linear models and correlation
LN Section 6.1

Video 27 Random forests
LN Section 6.2 + further reading

Note: in LN Section 6.2 you find specific directions for further reading (see also Blackboard).

Questions and problem solving:

Worksheet 10

In-semester assessment:

Project submission deadline is on **Monday 7 December 2020, 12 noon**.

Week 11 (from 14 December 2020)

LN: lecture notes — view online
Video: lecture videos — view online
Worksheets: download worksheets

Topics:

In this week we provide a broad overview of Gaussian processes and neural networks, two commonly used machine learning approaches for nonlinear modeling and prediction.

Study:

Video 28 Gaussian processes
LN Section 6.3 + further reading

Video 29 Neural networks
LN Section 6.4 + further reading

Note: in LN Sections 6.3 and 6.4 you find specific directions for further reading (see also Blackboard).

Questions and problem solving:

No worksheet this week

The tutorial this week is an exam Q & A.