

# ETC3250/5250: Introduction to Machine Learning

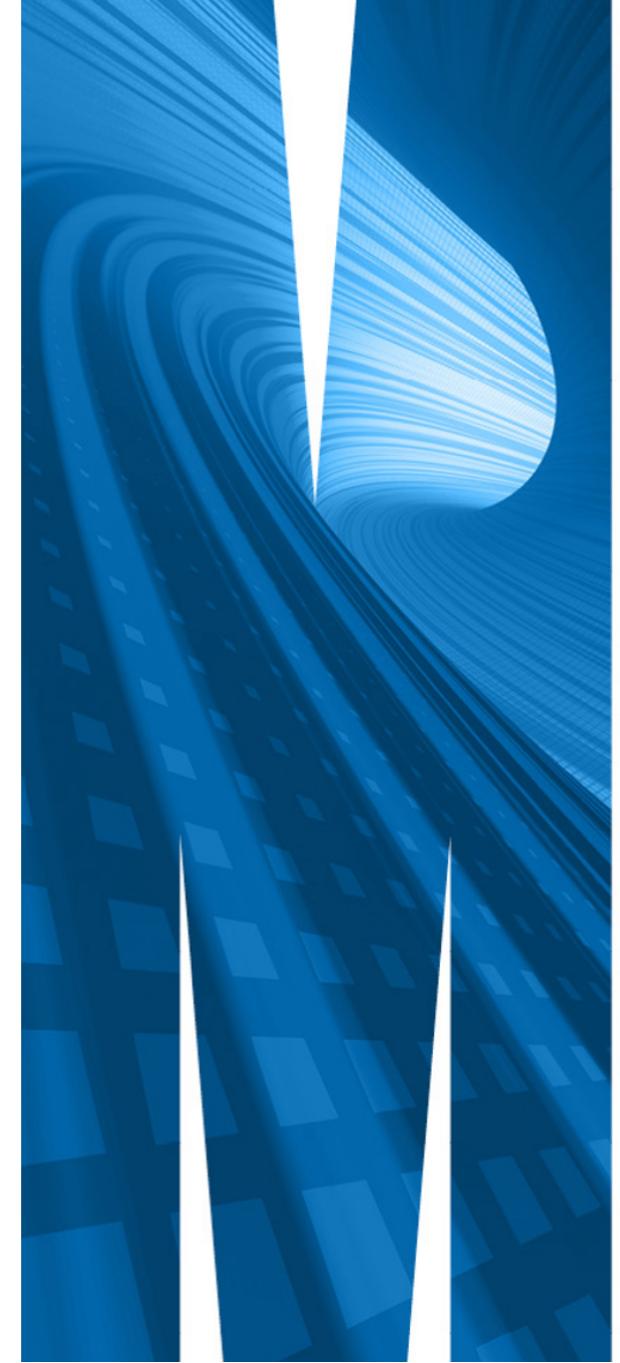
## Getting started

Lecturer: Professor Di Cook

Department of Econometrics and Business Statistics

✉ ETC3250.Clayton-x@monash.edu

CALENDAR  
Week 1a



# About this class

# Meet the team

Me - Hi!  
Responsible for  
everything.



Patrick - 2nd year  
PhD student -  
Tutoring two  
sessions - and  
lead tutor.



Harriet - 1st year  
PhD students -  
Tutoring two  
sessions.



Brenwin - MBAt  
graduate -  
Tutoring three  
sessions.



Brendi - MBAt  
graduate -  
Tutoring three  
sessions.



# Where to find things

- **Moodle**: zoom links, quizzes, assignments, marks, discussion forum, and announcements.
- **Website** (<https://iml.numbat.space>) has the schedule, lecture slides, and tutorial instructions.
- **Textbook** (<https://www.statlearning.com>) free pdf online, and some data.  
Code will be primarily from [Emil Hvitfeldt's site](#).
- Got questions? **Post in the moodle discussion forum**. Of a [private nature](#) (e.g. about marks) you can send email to [etc3250.clayton-x@monash.edu](mailto:etc3250.clayton-x@monash.edu). No response will result from emailing tutors or the instructor.

# Computing

- Using R (4.1.2 (2021-11-01) -- "Bird Hippie") and the RStudio (RStudio 2021.09.0+351 "Ghost Orchid")
- If you are new to R or need a refresher work yourself through the materials at <https://learnr.numbat.space> by the end of week 2.
- Slides are made in Rmarkdown, xaringan style, using a monash theme made by [Emi Tanaka](#), best viewed as html.
- The code for running examples in the lecture slides can be found in the Rmd file. Look for the chunks of R code, and run from them from the start to end.
- We will also be utilising the tidymodels way of thinking and structuring the code. You can see textbook lab code that uses tidymodels at <https://emilhvifeldt.github.io/ISLR-tidymodels-labs/statistical-learning.html>.
- If you have computing problems, follow the guidelines at <https://learnr.numbat.space/chapter3> for making a reproducible example of what you are trying to do and the error you are getting.

# Assessment

- 60% final exam, 9% for the project, and each assignment, and 4% total from weekly quizzes.
- Your final total quiz mark will be based on your best 10 of the 12 scores. Quizzes will be due each Tues 9am, starting in week 1.
- Assignments are due weeks 4, 7, 9. Project due week 11. ETC5250 will also need to make a short video of their project modeling, as part of project mark.
- All three assignments and the project need to be completed. Instructions are provided two weeks ahead of the due date, so plan ahead. If you miss submitting an assignment or the project, through illness, or personal difficulty, the procedure to follow is (1) notify the CE within seven days of the due date, ETC3250.Clayton-x@monash.edu, (2) your score will be the lowest score from the other assignments/project for the missed work. Failure to submit and notify the CE accordingly will result in a zero score.
- These flexibilities in assessments should mean that there is no need to request special consideration.

# Learning objectives

- **Select and develop** appropriate models for regression, classification or clustering
- **Estimate and simulate** from a variety of statistical models, and measure the uncertainty of a prediction using resampling methods
- Manage large data sets in a modern software environment, and **explain and interpret** the analyses undertaken clearly and effectively
- **Apply** business analytic tools to produce innovative solutions in finance, marketing, economics and related areas

# How to do well in this class



Come to class



Work through tutorial exercises



Bring questions to consultation



Read ahead in the textbook, and attempt some of the questions



Start assignments early!



Ask and answer questions in the discussion forum



Do the weekly quizzes



Don't procrastinate - if you don't understand something or can't work how to do a problem, ask, get help, no question is too simple or stupid!



# Where this material fits in your career skills development

“

*See the **Math and Statistics** box: machine learning, statistical modeling, supervised and unsupervised learning.*

“

*And also the **Communication and Visualisation** box: Translate data-driven insights into decisions and actions, plotting using ggplot2.*

# If you like this course, what others could you do

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**ETC3555/5555 - Statistical Machine Learning:** This unit covers the methods and practice of statistical machine learning for modern data analysis problems. Topics covered will include recommender systems, social networks, text mining, matrix decomposition and completion, and sparse multivariate methods. All computing will be conducted using the R programming language.

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**ETC3580/5580 - Advanced Statistical Modelling:** This unit introduces extensions of linear regression models for handling a wide variety of data analysis problems. Three extensions will be considered: generalised linear models for handling counts and binary data; mixed-effect models for handling data with a grouped or hierarchical structure; and non-parametric regression for handling non-linear relationships. All computing will be conducted using R.

# Introduction to machine learning

# Notation

- These slides provide the glossary of math notation used in the lectures slides, and an explanation of main math elements.
- Math notation is useful for concise description of methods and for how to think about the methods conceptually.



# Notation 1/6

$n$  number of observations or sample points

$p$  number of variables or the dimension of the data

A data matrix is denoted as:

$$\mathbf{X}_{n \times p} = (\mathbf{x}_1 \ \mathbf{x}_2 \ \dots \ \mathbf{x}_p) = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1p} \\ x_{21} & x_{22} & \dots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{np} \end{pmatrix}$$

## Notation 2/6

The  $i^{th}$  observation is denoted as

$$x_i = \begin{pmatrix} x_{i1} \\ x_{i2} \\ \vdots \\ x_{ip} \end{pmatrix}$$

The  $j^{th}$  variable is denoted as

$$x_j = \begin{pmatrix} x_{1j} \\ x_{2j} \\ \vdots \\ x_{nj} \end{pmatrix}$$

And we will also use  $X_j$  abstractly represent independent (predictor or input) variable  $j$

## Notation 3/6

The response vector, when it exists, is denoted as

$$\mathbf{y} = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix}$$

And we will also use  $\mathbf{y}$  abstractly represent the response, or output variable.

An observation can then be written as

$$\mathcal{D} = \{(v_i, x_i)\}_{i=1}^n = \{(v_1, x_1), (v_2, x_2), \dots, (v_n, x_n)\}$$

where  $x$  is a vector with  $p$  elements.

## Notation 4/6

A transposed data matrix is denoted as

$$\mathbf{X}_{p \times n}^T = \begin{pmatrix} x_{11} & x_{21} & \dots & x_{n1} \\ x_{12} & x_{22} & \dots & x_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ x_{1p} & x_{2p} & \dots & x_{np} \end{pmatrix}$$

and

$$x_i^T = (x_{i1} \quad x_{i2} \quad \dots \quad x_{ip})$$

## Notation 5/6

If  $\mathbf{y}$  is categorical, with  $K$  levels, it can be useful to write it as a binary matrix

$$\mathbf{Y}_{n \times K} = \begin{pmatrix} 1 & 0 & \dots & 0 \\ \vdots & \vdots & & \vdots \\ 1 & 0 & & 0 \\ 0 & 1 & \dots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 1 & \dots & 0 \\ 0 & 0 & \dots & 1 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \dots & 1 \end{pmatrix}$$

# Matrix multiplication

Suppose that

$$A_{2 \times 3} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{pmatrix}$$

$$B_{3 \times 4} = \begin{pmatrix} -1 & -2 & -3 & -4 \\ -5 & -6 & -7 & -8 \\ -9 & -10 & -11 & -12 \end{pmatrix}$$

Using R as a matrix calculator

```
a <- matrix(c(1,2,3,4,5,6),  
            ncol=3, byrow=T)  
b <- -1*matrix(c(1,2,3,4,5,6,  
                7,8,9,10,11,12),  
                ncol=4, byrow=T)
```

then

$$AB_{2 \times 4} = \begin{pmatrix} -38 & -44 & -50 & -56 \\ -83 & -98 & -113 & -128 \end{pmatrix}$$

Pour the rows into the columns.

Note: You can't do **BA**

# Inverting a matrix

Suppose that  $A$  square

$$A_{2 \times 2} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$$

then the inverse is (if  $ad - bc \neq 0$ )

$$A_{2 \times 2}^{-1} = \frac{1}{ad - bc} \begin{pmatrix} d & -b \\ -c & a \end{pmatrix}$$

and  $AA^{-1} = I$

$$I_{2 \times 2} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

## Notation 6/6

~~$d_s$~~  used to denote the number of variables in a lower dimensional space, usually by taking a projection.

As a ~~orthonormal~~ basis,  $A^T A = I_d$

The projection of  $\mathbf{x}_i$  onto  $A$  is  $A^T \mathbf{x}_i$

# Different types of learning

1. Supervised learning:  $y$  is available for all  $x_i$ 
  - Regression: quantitative  $y_i$
  - Classification: categorical  $y_i$
2. Unsupervised learning:  $y$  unavailable for all  $x_i$
3. Semi-supervised learning:  $y$  available for some  $x$  (not covered in this unit)



Being able to recognise the type of problem is an important skill.

# What type of problem is this? (1/3)

Food servers' tips in restaurants may be influenced by many factors, including the nature of the restaurant, size of the party, and table locations in the restaurant. Restaurant managers need to know which factors matter when they assign tables to food servers. For the sake of staff morale, they usually want to avoid either the substance or the appearance of unfair treatment of the servers, for whom tips (at least in restaurants in the United States) are a major component of pay.

In one restaurant, a food server recorded the following data on all customers they served during an interval of two and a half months in early 1990. The restaurant, located in a suburban shopping mall, was part of a national chain and served a varied menu. In observance of local law the restaurant offered seating in a non-smoking section to patrons who requested it. Each record includes a day and time, and taken together, they show the server's work schedule.

# What type of problem is this? (2/3)

Measurements on rock crabs of the genus *Leptograpsus*. One species *L. variegatus* had been split into two new species, previously grouped by color, orange and blue. Preserved specimens lose their color, so it was hoped that morphological differences would enable museum specimens to be classified. There are 50 specimens of each sex of each species, collected on site at Fremantle, Western Australia. For each specimen, five measurements were made, using vernier calipers.

# What type of problem is this? (3/3)

This data contains observations taken from a high-energy particle physics scattering experiment that yielded four particles. The reaction  ~~$\pi_b^+ p \rightarrow \pi^+ \pi^0 \pi^-$~~  can be described completely by seven independent measurements. Below,  $\mu^2(A, B)$ , where  $E$  and  $P$  represent the particle's energy and momentum, respectively, as measured in billions of electron volts. The notation  $(\cdot, \cdot)$  represents the inner product  $PV$ . The ordinal assignment of the two  $\pi$ 's was done randomly. What are the clusters in the data?



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Week 1a

