MAS113: Introduction to Probability and Statistics
Semester Year, 2019/20; 20 credits

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The module provides an introduction to the fields of probability and statistics, which form the basis of much of applicable mathematics and operations research. The theory behind probability and statistics will be introduced, along with examples occurring in such diverse areas as medicine, finance, sport, the environment, law and so on. Some of the computational statistical work will make use of the statistics package R.

Outline syllabus.

Aims.
- Introduce students to the theory of probability, including applications to practical examples;
- To develop the students’ knowledge and understanding of statistics.

Learning outcomes.
- interpret and perform calculations involving random variables and distributions;
- recognise important standard distributions;
- apply the idea of conditional probability via the law of total probability and Bayes’ rule;
- use the software package R for simple calculations, handling data, plots, and working with standard distributions;
- calculate standard errors and properties of sampling distributions in simple problems;
- understand the formulation of inference problems in terms of data and model parameters;
- understand the form and logical basis of significance tests, and be able to interpret such tests;
- understand the concept of a confidence interval and the relationship between confidence intervals and tests;
- understand the basis of simple inference procedures for normal expectations and binomial proportions, and be able to use the procedures in R.

Teaching methods. In both semesters 1 and 2, there will be two formal lectures per week, which will involve the formulation of new theory and worked examples. Each week students will also attend one tutorial, where they will work through set exercises. Areas of common difficulty may be explained on the board by the tutorial leader. Students will also submit homework for marking (but these will not count towards the assessment).

44 lectures, 22 tutorials, 0 practicals.

Assessment. A formal, closed book, two hour examination at the end of the second semester (80%), online tests (6%), R practical assignments (14%).

Full syllabus.

1. Introduction. Statistical and probabilistic modelling, and the need for a mathematical theory of chance.

Expectation and variance and their properties (e.g. \( E(X + Y) = E(X) + E(Y) \), \( E(aX + b) = aE(X) + b \), \( Var(aX + b) = a^2Var(X) \).)
Bernoulli, binomial, Poisson and geometric random variables. Calculations of laws, means and variances.
The Poisson distribution as the limit of a binomial. The binomial and Poisson distribution in R.
Multivariate discrete random variables. Covariance and correlation between two discrete random variables.
The multinomial distribution.

4. **Continuous Random Variables.** Area under a curve as a measure. Probability via integration. Continuous random variables and their pdfs.
Examples. Uniform and exponential distributions.
Mean and variance as integrals.
The normal distribution. The normal distribution in R. The standard normal \( Z \). Mean and variance in general case via \( X = \sigma Z + \mu \).


7. **Summarising and plotting data using R.** Working with data in R using the ”tidyverse”; calculating summary statistics; plots for visualising data.

8. **A short introduction to machine learning.** Classification with the nearest-neighbour algorithm.

8. **Introduction to statistical modelling.** Using probability distributions to model data; parameters of probability distributions as population characteristics.


10. **Interval estimation.** Confidence intervals for means, variances and proportions.


**Recommended books.**

A Applebaum, David “Probability and information : an integrated approach (2nd ed)” (Shelfmark 519 (A), ISBN 9780521899048)
A Dekking, FM, Kraaikamp, C, Lopuhaa, HP and Meester, LE “A modern introduction to probability and statistics: understanding why and how” (Shelfmark 519.2 (D), ISBN 9781852338961)
A Ross, Sheldon M. “A first course in probability (8th ed)” (Shelfmark 519.2 (R), ISBN 9780136079095)
A Trosset, Michael W. “An introduction to statistical inference and its applications with R” (Shelfmark 519.50285 (T), ISBN 9781584889472)
B Grimmett, Geoffrey, and Welsh, Dominic “Probability : an introduction ” (Shelfmark 519.2 (G), ISBN 0198532725)
C Blastland, Geoffrey, and Welsh, Dominic “Probability : an introduction ” (Shelfmark 519.2 (G), ISBN 0198532725)
C Pruim, Randall “Foundations and Applications of Statistics”
C Schoenberg, Frederic P. “Introduction to probability with Texas hold’em examples” (Shelfmark 519.2 (S), ISBN 9781439827680)
C Silver, Nate “The Signal and the Noise: The Art and Science of Prediction” (Shelfmark 303.49 (S), ISBN 9781846147524)