Syllabus for Programming, Data Science and Statistics, PDSS 3

Disclaimer: This is an indicative syllabus only and may be subject to changes. The final and official syllabus will be distributed by the Instructor during the first day of class.

The School of Collective Intelligence
Master's Program in Collective Intelligence

Module Title:	**Programming, data science and statistics 3**
Module Code:	
Number of hours:	**50 (Lectures:25, Labs:25, Exam:2)**

Pre/Co-Requisites: Basic maths, R and Python, MATLAB or Octave.
Instructor: Jose Segovia-Martin
Second Instructor:
Teacher Assistant:

Module description:

This module covers various scientific computing techniques and is designed to equip the students of the MSc programme in Collective Intelligence with different methods useful in computation, modelling and analysis of complex systems. The module provides students with a broad background in computational and theoretical techniques for describing and understanding complex natural and cultural systems.

The module will consist of four blocks: (1) statistics, (2) equation-based models (3) agent-based models (4) neural networks. The first block will consist of a refresher in basic research methods and statistics (linear models and multiple regression), as well as the study of mixed effects models. The second block will consist of an introduction to modelling with ordinary differential equations (ODEs), PDE's and their numerical resolution using Odeint in Python and MATLAB. The third block will be devoted to the study of agent-based models (ABMs), where students will learn to create their own models using Agentpy. In the fourth block, we will study the basic concepts of neural networks and will learn to use Tensorflow for basic text and image classification.

Learning objectives	
The course embodies in its content and components certain specific objectives; students who have participated fully in the course will: 1. be able to correctly interpret MR models. 2. be able to analyse linear mixed effects models. 3. demonstrate proficiency in programming the numerical solution of ODEs. 4. be able to solve optimization processes. 5. understand basic components of matices, eigenvalues and eigenvectors. 6. learn to programme a basic agent-based model. 7. have a basic understanding of the functioning of a neural network.	
Learning activities	
1. Lectures 2. Practical Labs 3. Student Activities (Individual/group)	
Assessment (adjust as applicable):	
Homework: Problem sets	25%
Coursework: Labs - Assignments	25%
Final exam	50% (pass mark 60%)

Module Schedule

Weeks	Lectures/ Lab / Activities	Concepts	References
Week 1	Lecture: Introduction to the course Lab: Installing R-studio. Review of R, Python, Google Colab. Discussing Models as fables.	-What is in this course? -Models, models and more models…: What are linear models? What are equation-based models? What are agent-based models? -Complex systems, nonlinearity and emergence. -Models as fables.	
Week 2	Lecture: Introduction to R and R studio Lab: Introduction to R	- Numerical vectors, Logical vectors, Factor vectors. Plotting. - Tidyverse	*- An Introduction Using R (Bodo Winter), 2019*
	Lecture: Regression refresher		

Week 3	Lab: Simple regression	- Intercepts and slopes - Fitted values and residuals - Assumptions - Measuring model fit	- *The R book (second edition). Authors: Michael J. Crawley. Publisher: Wiley, 2013* - *Discovering statistics using R. Authors: A. Field, J. Miles, Z. Field. Publisher: Sage, 2012*
Week 4	Lecture: Regression refresher Lab: Multiple regression	- Interpretation in simple regression. - Recap on the main principles of multiple regression. - Interpretation of effects with more than 1 IV. - Refresh Type I and Type III sums of squares. - Recap assumptions. - Talk through a research example.	- *The R book (second edition). Authors: Michael J. Crawley. Publisher: Wiley, 2013* - *Discovering statistics using R. Authors: A. Field, J. Miles, Z. Field. Publisher: Sage, 2012*
Week 5	Lecture : Mixed models Lab: Mixed models	- Analysis of mixed models. - Independence - Convergence - Significance	- *An Introduction Using R (Bodo Winter), 2019.* https://bodo-winter.net/tutorials.html

Week 6	Lecture: Intro to Ordinary differential equations (ODE) Lab: Solving ODE numerically	-SciPy - Order - Dimensions - Autonomy - 1D examples	- *Learning Scientific Programming with Python* by Christian Hill (Cambridge University Press, 2015). - Yang, W. Y., Cao, W., Kim, J., Park, K. W., Park, H. H., Joung, J., ... & Im, T. (2020). *Applied numerical methods using MATLAB*. John Wiley & Sons. -http://sam-dolan.staff.shef.ac.uk/
Week 7	Lecture: ODE and coupled ODE Lab: Solving ODE systems	- 2D autonomous equations - Coupled systems (predator-prey equations, 2 order ODE)	- *Learning Scientific Programming with Python* by Christian Hill (Cambridge University Press, 2015). - Yang, W. Y., Cao, W., Kim, J., Park, K. W., Park, H. H., Joung, J., ... & Im, T. (2020). *Applied numerical methods using MATLAB*. John Wiley & Sons. -http://sam-dolan.staff.shef.ac.uk/
Week 8	Lecture: Optimization	- Quadratic approximation method - Genetic algorithms	- Yang, W. Y., Cao, W., Kim, J., Park, K. W., Park, H. H., Joung, J., ... & Im, T. (2020). *Applied numerical methods using MATLAB*. John Wiley & Sons.
Week 9	Lecture: Matrices, Eigenvalues and Eigenvectors	- Eigenvalues - Eigenvectors - Similarity, transformation and diagonalization.	- Yang, W. Y., Cao, W., Kim, J., Park, K. W., Park, H. H., Joung, J., ... & Im, T. (2020). *Applied numerical methods using MATLAB*. John Wiley & Sons.

Week 10	Lecture: Partial differential equations	- Eliptic PDE - Parabollic PDE	- Yang, W. Y., Cao, W., Kim, J., Park, K. W., Park, H. H., Joung, J., ... & Im, T. (2020). *Applied numerical methods using MATLAB*. John Wiley & Sons.
Week 11	Lecture: Intro to ABM Lab: Building a simple ABM	- Agent-based models: basic concepts -The Wealth model	https://agentpy.readthedocs.io/en/stable/index.html
Week 12	Lecture: ABMs Lab: Virus/culture spread	- Virus spread - Simple and complex contagion.	https://agentpy.readthedocs.io/en/stable/index.html https://ccl.northwestern.edu/netlogo/
Week 13	Lecture: Neural Networks Lab: Image classification	-Introduction to Tensorflow 2.	https://www.tensorflow.org/tutorials/keras/text_classification
Week 14	Working on Assignments	Applying all previous concepts	
Final Week 15 DD/MM/YY	Exam		