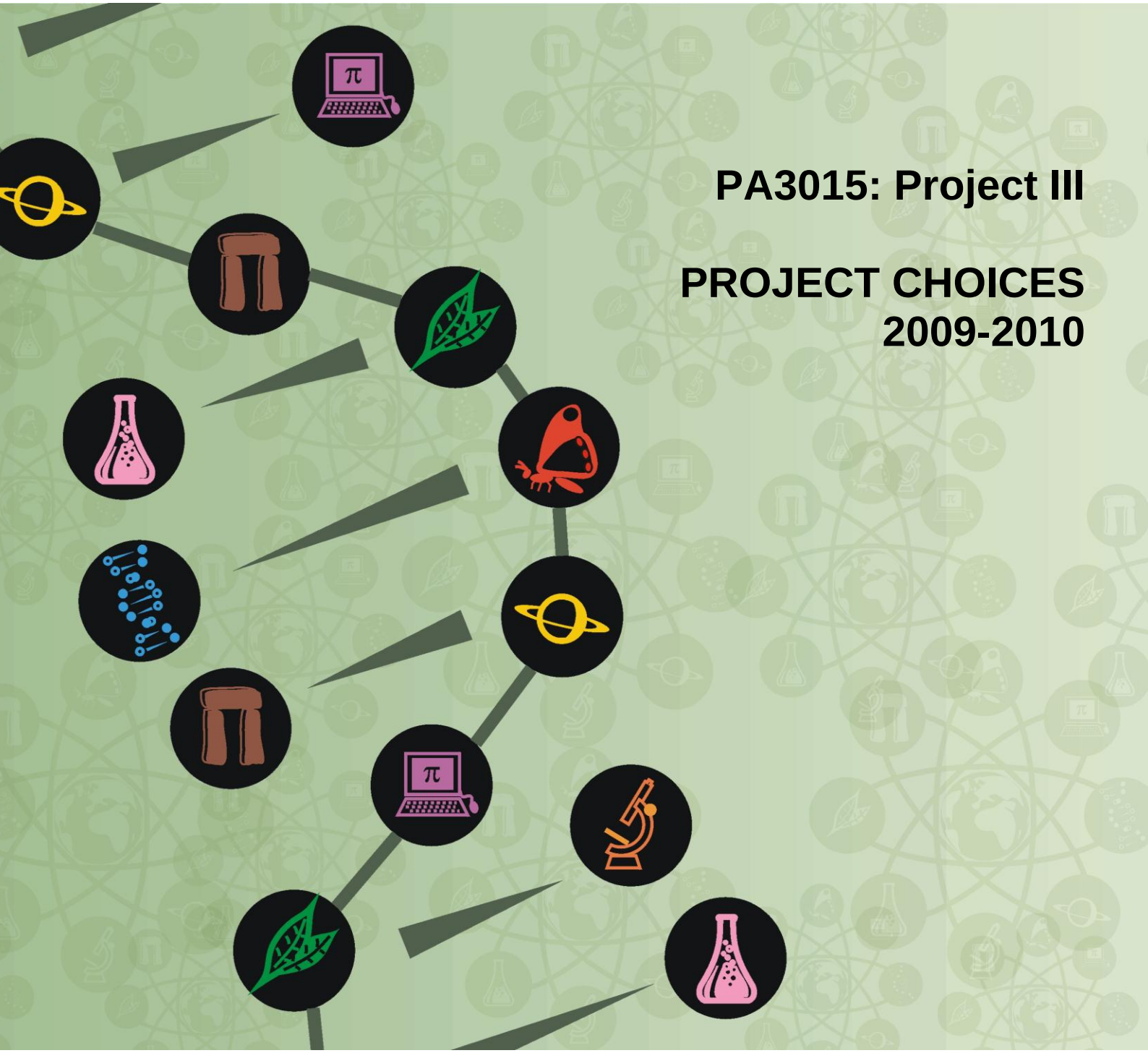
INTERDISCIPLINARY SCIENCE



PA3015: Project III

PROJECT CHOICES 2009-2010

University of Leicester

Contents

Complex Systems – Agent based modelling with NetLogo

Supervisor: Derek Raine

Introduction
Netlogo is a computer programme (and programming language) that is used to model interacting 'agents', that is objects that can receive and process information and act on it independently. An interesting application in physics is to magnetic systems (the agents are the spins on a lattice), but these methods have been extended to other sciences (including social sciences). The project will investigate the use of NetLogo in the context of various complex systems, depending on the interests of the students.

Examples
- 'SugarScape' – Investigating artificial societies
- Magnetic systems
- Evolution of Altruism in artificial societies
- Technological innovation and wealth distribution in artificial societies

Project Aims
To investigate agent-based models using NetLogo

Pre-biotic Ecology

Supervisor: Derek Raine

Introduction
Pre-biotic ecology is a new approach to the origin of life. One particular highly simplified but tractable model of pre-biotic ecology envisages 2D-'cells' inhabiting a torus. The cells contain molecules (the 'food set') that can attach themselves to the cell boundaries where they can polymerise according to certain rules. The boundaries between cells can be removed (fusion of cells) or added (fission of cells) according to various rules. The idea is then to develop a computer model of the evolution of the molecules in this picture, to see how spatial and chemical structures can develop which will represent the first steps towards molecular coding. Previous projects have produced a code in the NetLogo programming language which is ideally adapted to agent-based modelling of complex systems. (A guide to programming in NetLogo will be provided.) The code implements a simplified form of the model and shows how a pre-genomic coding can arise which allows inheritance of the information for an autocatalytic network of reactions. (See e.g. Segre and Lancet (2000) Proc Nat Acad Sci., 97, 4112).

Project Aims
This project will investigate the range of behaviour for different rules for polymerisation, for attachment and detachment of molecules, and for fission and fusion of cells in order to extend the model to more complex reaction networks. The project will look at the relationship between the model and recent developments in the "RNA World" approach to the origin of life (See Scientific American, Sept 2009)

Cosmology

Supervisor: Dr E G Thomas

Introduction
In the standard model of the universe that has emerged over the past decade matter contributes about 26% to the overall mass density with the rest made up of so called dark energy – a mysterious fluid possessing positive mass density but exerting a negative pressure.

Project Aims
The aim of this project is to investigate the effect of this dark energy on the rate of expansion of the universe and to discover how its future will differ from that of a universe containing matter only.

Characterizing Archaeological Materials By Pebble Composition

Supervisor: Dr Jan Zalasiewicz

Introduction
The extensive medieval fortifications at Wallingford, Oxfordshire are currently being investigated by an archaeological team in a major project led b the University of Leicester. Among the questions arising from the research is the relation between the geological substructure of this area, and the various human structures built on top of it, and in some case it is uncertain what is 'natural' (more or less undisturbed geological deposit and its subsoil and soil, and what has been extensively modified and transported by human activity.

To help resolve such questions, a series of samples from different layers uncovered in the excavations has been collected has been collected over the summer. The material includes mud-grade sediment, sand and pebbles. This project will mainly focus on the pebbles, though there is potential also to look at the other grades of sediment.

Project Aims
The pebbles will be analyzed in terms of their composition, by standard 'pebble-counting' techniques involved in clast lithological analysis. That is, the pebbles will be separated into different size categories and then, with the help of a binocular microscope, will be placed into different lithological categories (vein quartz, quartzite, flint, sandstone, granite etc). This will then generate a series of distribution diagrams that can be statistically examined.

Comparison will be made of the pebble populations of the different size fractions (to show the effect of clast size). Then, comparison will be made of the different pebble populations in the various layers uncovered in the excavations, thus helping to characterize or 'fingerprint' the layers.

Further comparison will then be made between these clast populations and those of known geological formations, both of the 'solid' geology (the local strata are Cretaceous in age) and of the glacial and post-glacial 'drift' deposits. The results will then be used to demonstrate how pristine or how mixed (by human action) are the various archaeological layers.

Training and support will be given in the necessary geological techniques, and in the archaeological context.

Characterizing Archaeological Materials By Pebble Shape

Supervisor: Dr Jan Zalasiewicz

Introduction
The extensive medieval fortifications at Wallingford, Oxfordshire are currently being investigated by an archaeological team in a major project led b the University of Leicester. Among the questions arising from the research is the relation between the geological substructure of this area, and the various human structures built on top of it, and in some case it is uncertain what is 'natural' (more or less undisturbed geological deposit and its subsoil and soil, and what has been extensively modified and transported by human activity.

To help resolve such questions, a series of samples from different layers uncovered in the excavations has been collected has been collected over the summer. The material includes mud-grade sediment, sand and pebbles. This project will mainly focus on the pebbles, though there is potential also to look at the other grades of sediment.

Project Aims

The pebbles will be analyzed in terms of their shape and surface texture. That is, the pebbles will be separated into different size categories and then, with the help of a binocular microscope, will be classified according to their shape (i.e. how rounded or angular the pebbles are); their roundness (i.e. how close they are to spheres, as opposed to how elongated they are); and their surface texture (are they smooth, or do they have a rough, abraded or scratched surface). This will then generate a series of distribution diagrams that can be statistically examined.

Comparison will be made of the pebble populations of the different size fractions (to show the effect of clast size). Then, comparison will be made of the different pebble populations in the various layers uncovered in the excavations, thus helping to characterize or 'fingerprint' the layers.

Further comparison will then be made between these clast populations and those of known geological formations, both of the 'solid' geology (the local strata are Cretaceous in age) and of the glacial and post-glacial 'drift' deposits. The results will then be used to demonstrate how pristine or how mixed (by human action) are the various archaeological layers. In addition, evidence of abrasion (say during ploughing, or by having wheeled vehicles pass over the pebbles) will be assessed.

Training and support will be given in the necessary geological techniques, and in the archaeological context.

Interannual variability of the global atmosphere-biosphere CO_2 exchange

Supervisor: Dr J Kaduk

Introduction

The aim of this project is to determine the variations of the global atmospheric CO_2 concentration and relate the observed variations to the variability of temperature and precipitation as well as to determine those geographical regions which are most relevant for the observed variations.

This project builds on 18 years of NDVI and 20 years of global climate data. The task is to analyse these large data sets and to use appropriate simple mathematical operations to determine the relevant characteristics of the global variations in temperature, precipitation, CO_2 and NDVI and relate them to the atmosphere- biosphere CO_2 exchange

Project Aims

- ability to develop small models in matlab or maple
- using basic statistics
- working with large data sets

Communicating ethics

Supervisor: Dr Chris Willmott

Introduction

Recent years have seen unprecedented developments in biomedicine. "Designer babies", transplant organs from animals, personalised medicine, stem cells and cloning are - to varying

degrees - stepping from science fiction to science fact. Whilst the technology has made great strides, the ethical discussion has often failed to keep up.

Project Aims
This project will look at the development of resources for teaching about ethics at secondary and/or undergraduate level. In particular, the project will involve producing and evaluating study guides focussed around pre-existing online Reusable Learning Objects such as news footage streamed on the BBC website or YouTube videos.

Science for Sustainability. Case Studies in environmental problem-solving in the semi-arid tropics - East African Rift Valley.

Supervisor: Dr D Harper

Introduction
Sustainability is a word coined in 1992 by the UN Convention on Sustainability in Rio de Janeiro. It means utilising the earth's resources in the present without compromising their ability to provide for generations in the future. The concept is extremely hard to meet in a modern, industrialised country - one only has to compare the inconsistencies from different Government Departments, or different nations' attitudes to global warming, to see this. In the semi-arid regions of a developing country like Kenya, where human life is almost totally dependent upon the natural resources of the area, the term has a direct meaning. Most people who inhabit the area where the course is based - Lake Bogoria - are aware of the meaning of the term but are unable to put it into practice because the needs of the present - survival - outweigh the needs of the future. The fundamental concept of this course is that the intellect and different experience of a small group of individuals, applied to a problem intensively over 10 days, can produce progress towards solutions that would not otherwise be available. The course fee includes a contribution towards a project fund which will be used for expenditure of small items to implement the solution.

Project Aims
1. To learn the principles of Sustainability, as an increasingly-important issue in everybody's life (by pre-course seminars and reading, early January).
2. To understand and respect the way of life of a different culture, sharing knowledge and experience.
3. To appreciate the sustainability issues of rural people, who may be poorer in monetary goods but richer in spiritual ones.

Sustainability issues
a) freshwater springs, used to provide irrigation water for agriculture and domestic use. Are they wisely apportioned? Could they be better used?
b) fish ponds; as an alternative source of protein. Are they adequately managed? Could there be more?
c) woodlands which provide nectar for bees as well as wood for cooking; Are they sustainably exploited? Is there scope for plantations? If so, of what species?
d) community lands which provide grazing for livestock, including swamps which provide dry season grazing, are they sustainably shared or overgrazed?
e) eroded soils. There has been an increase in erosion in the last 5 years. Is this due to greater overgrazing, climate change altering rainfall intensity, or is it a natural consequence of soils which are young and fragile?
f) eco-tourism camps, which provide additional income. Are they effectively located, maintained and marketed? What other opportunities are there?
g) sales to tourists - profit on sodas; carving; reed products from wetlands, which provide extra income, are they adequately marketed and are there more opportunities?

h) schools and teaching aids. Do the teachers have adequate support to teach sustainability issues, can it be improved?
i) rain water harvesting. Is it effectively used?
j) village centres; social and social communications. Do they work well? Can they be improved?
k) renewable energy sources. To what extent is solar, water, wind power exploited? Can it be improved?

Note: this project involves a 2 week field trip to Kenya in the Easter vacation. If you have any questions please contact Dr Harper at dmh@le.ac.uk

Breeding behaviour of Marsh Harriers

Supervisor: Dr D Harper

Introduction
Marsh Harrier is a rare bird of prey which has been increasing in numbers on wetland protected areas over the past few years in East Anglia. Last year, for the first time ever, a telecam was placed successfully at a nest in a reed bed in Norfolk.

Project Aims
This project would analyse the footage from the cam to measure types of prey, delivery rates and other aspects of breeding behaviour. As this has never been done before, the project is very significant and could result in a scientific publication.

Eco-hydrology of Narborough Bog, Leics.

Supervisor: Dr D Harper

Introduction
Narborough Bog Nature Reserve which contains a small reedbed, which is on a layer of peat lying over several metres of gravel. Rain water runs through the peat and into the gravels which once there travels straight to the river. No water is being retained in the peat and therefore it is drying out.

Two ideas that were suggested were to pump water from the River Soar (which runs along the boundary) onto the reedbed. The second option is to put a borehole into the underlying gravels roughly in the centre of the reedbed to pump water from the underlying gravels back onto the reedbed.

Project Aims
The project is to find out whether there is a water table under the gravels and how much there is in it.

An Ultrasound Radar Simulator

Supervisor: Prof Tim Yeoman

Introduction
Radar systems have a wide variety of uses in industry and commerce, as well as environmental and geo-science and space exploration. Ultrasound has with a frequency of tens of kHz and a wavelength of order one cm, Such a wavelength is similar to those used in a number of radar systems, although the frequency and wave speed are very different. Ultrasound can thus be used to simulate the operation of radar systems in the laboratory.

Project Aims
In this project a simple ultrasound radar simulator will be constructed and tested, using both individual transducers and a phased array of transducers to form the transmitted and received beams. The use of continuous wave, pulsed and chirped transmitted signals will be investigated. The performance of the radar in beamforming and steering, and in the location, identification, and tracking of objects will be investigated and optimised.

The design and construction of the basic elements of a radar system using ultrasound. The driving signals will be produced by a flexible signal generator, while an analogue-to-digital conversion system will log the transmitted and received signals on a computer. This digital output will then be used to test, quantify and optimize the performance of the system under a number of configurations. The performance of the system will be compared to the expected performance of radar systems using basic radar theory.

Basic skills required
Design of suitable experimental configurations, collection of digital data, quantitative analysis of collected data, comparison with theory

Fractal Dimensions In Nature

Supervisor: Prof Terry Robinson

Introduction
Self similarity is one of the most powerful symmetry principles in physics and many important phenomena, from earthquakes to the structure of living organisms are governed by such laws. Fractals are the basic building blocks of self-similar systems and provide a systematic way of characterising and explaining them. This project is concerned with the fractal structure of trees, which provide a readily accessible and familiar example of self similarity in action. This project aims to explore the fractal structure of trees experimentally and to examine the physical models which underly it. One of the oldest models of tree morphology is due to Leonardo da Vinci. He formulated the first example of a continuity law of fluids in devising his theory of trees. The student will devise his or her own experimental strategy to test this theory and to uncover the fractal dimensionality of a number of tree forms.

Project Aims
The aims of this project are

(i) to assess quantitatively Leonard da Vinci's theory concerning the morphology of trees - you will need to devise your own experiment - there are two restrictions : (a) you may not climb trees [your safety], (b) you may not cut down any trees [the trees' safety] - remote sensing is the only option!
(ii) to interpret the theory in terms of the hydraulics involved [This is probably the earliest formulation of the continuity principle]
(iii) to explore the fractal basis of tree morphology.
(iv) Identify the Hausdorf dimensionality of tree branching geometry

Measuring and modelling soil respiration and its spatial and temporal distribution

Supervisor: Dr Jörg Kaduk

Introduction
This project aims at identifying the patterns of soil respiration (soil CO_2 efflux) and its dependence on environmental conditions and relationships to soil carbon content and fine root biomass. It is well

known that soil respiration responds to temperature in an exponential fashion. However, less is known about its spatial distribution and its response to soil moisture.

Project Aims
The project should comprise measuring soil moisture at a large number of locations as well as soil temperature and moisture. In the lab fine root biomass and soil carbon content should be determined for a representative number of soil cores. Optionally the soil and root nitrogen concentrations can be determined in addition. The analysis should determine relationships between measured soil respiration, soil temperature and moisture, fine root biomass and soil carbon content as well as examine the question whether there are spatial patterns in soil respiration and possible causes for these patterns.

Required for project
- learning to use the IRGA
- ability to develop small models in matlab or maple
- using basic statistics
- field work in Wicken Fen (no public transport, no hotel, if no own transport, then significant flexibility to visit the site whenever somebody else goes (about once a month), potentially cattle and ponies on site)

The carbon and water fluxes of South Africa

Supervisor: Dr Jörg Kaduk

Project Aims
The aim of this model is to use a land surface model to simulate the carbon and water exchange of South Africa and compare the simulations to observations at selected locations as well as regional estimates. The project builds on 15 years of climate data available to drive the model. The task is to analyse the simulation results and compare them to observations. Some observations are available, some however need to be extracted from the literature.

Required for project
- ability or willingness to learn quickly to work with very large data sets
- ability to work efficiently in a software environment, some computing experience (linux, bash, linux file system concept) desirable
- willingness to learn and program in the Data Visualization and Analysis tool ferret.