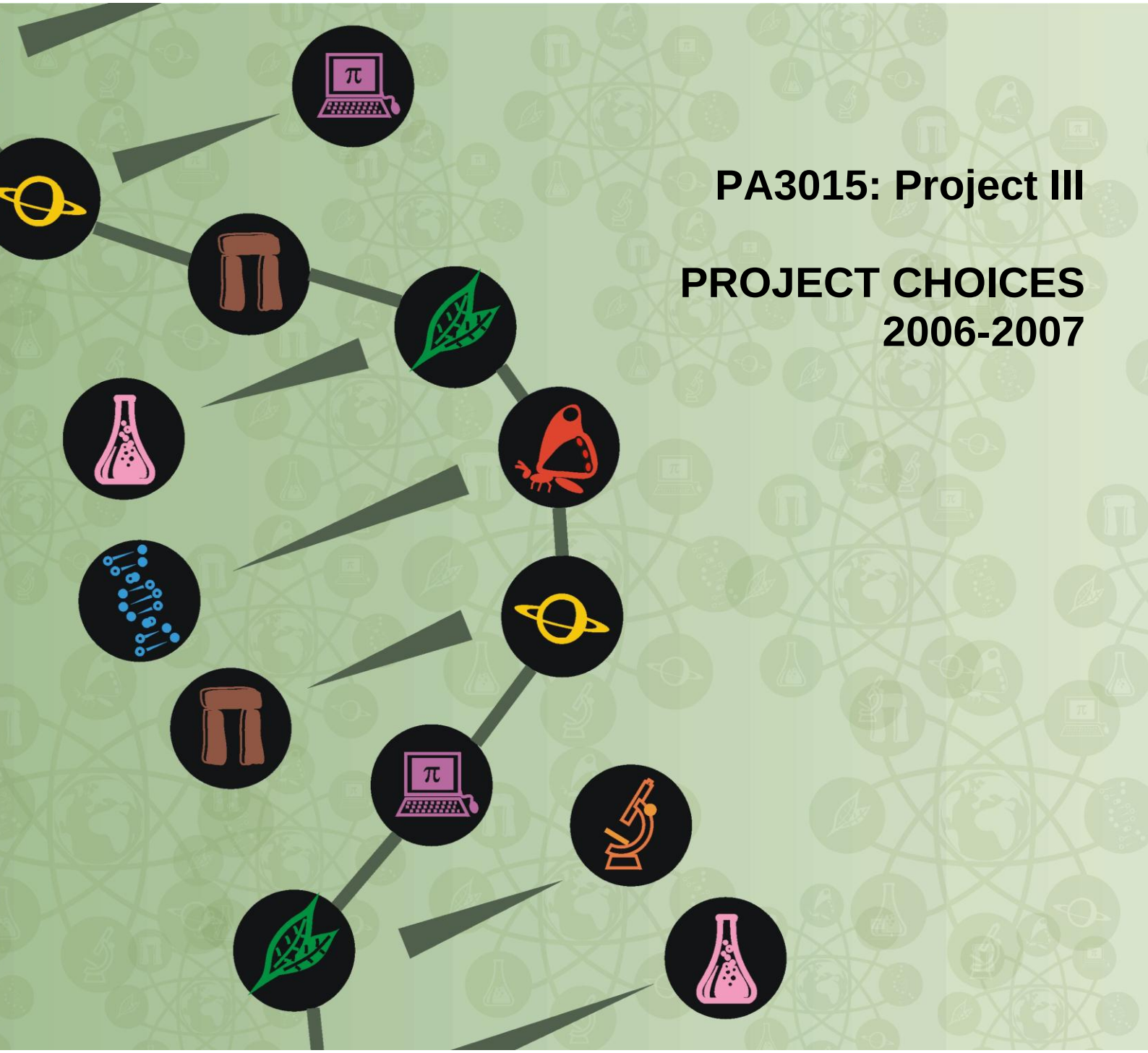
INTERDISCIPLINARY SCIENCE



PA3015: Project III

PROJECT CHOICES 2006-2007

University of Leicester

Contents

Measuring and modelling photosynthesis and its distribution in the canopy

Supervisor: Dr J Kaduk

Introduction
This projects aims at identifying the patterns of photosynthetic capacity and their dependence on environmental conditions and relationships to nutrient status. For example it is well known that sun leaves have a higher photosynthetic capacity than shade leaves. However, it is not clear how exactly the photosynthetic capacity changes within the canopy for closed and open canopies as well as with orientation to the sun. The project should comprise measuring light saturated photosynthesis and incident light levels in the field in different canopy locations and for different canopy geometries. Leaf nitrogen concentrations should be determined in the lab. The analysis should determine relationships between measured light levels, N concentration, light saturated photosynthesis and leaf position in the canopy.

For safety reasons this project should be conducted together with Measuring and modelling soil respiration and its spatial and temporal distribution with which it also shares the main equipment. The idea would be to obtain the field measurements for both projects in a team of two students.

Project Aims
- Use of the IRGA
- ability to develop small models in matlab or maple
- using basic statistics
- field work

Measuring and modelling soil respiration and its spatial and temporal distribution

Supervisor: Dr J Kaduk

Introduction
This projects aims at identifying the patterns of soil respiration (soil CO2 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. 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.

Project Aims
- Use of the IRGA
- ability to develop small models in matlab or maple
- using basic statistics
- field work

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.

Palaeoecology of extinct planktonic colonies

Supervisors: Dr J Zalasiewicz, A Snelling, Dr M Williams

Introduction

The oceans of the early Palaeozoic Era, some 400-500 million years ago, differed from modern oceans in a number of fundamental aspects. Firstly, the bottom waters were frequently devoid of oxygen and hence lacked multicellular animal and plant communities, reflecting a time in the Earth's history when the carbon cycle operated differently to today's. However, the sediments that accumulated on these stagnant sea floors preserve parts of a planktonic ecosystem that thrived in the surface waters, the members of which drifted to the sea floor after death.

The most striking constituent of this ancient planktonic community is a group of organisms, the graptolites, that have no counterpart in the plankton of today. The graptolites were highly organised, colonial animals thought to be related to the living pterobranchs (that live, though, attached to the sea floor), that evolved rapidly and seemingly 'built' their own skeletons, much as termites or wasps build their nests today.

Our knowledge of the ecology of these enigmatic organisms is slight, as they are only preserved as death assemblages divorced from their original living habitat. However, detailed study of their relation to the enclosing rock strata can yield clues to their lifestyles, such as tantalising glimpses of predation and community structure.

This project comprises detailed study of exquisitely preserved examples of graptolites from the early Silurian (ca 436 million years old) rocks of Llanidloes, central Wales. Blocks of this material commonly show graptolite specimens seemingly deformed prior to burial (perhaps due to predation or to physical damage from turbulence in the water in which they lived) and preserved at 'odd' angles to the sedimentary stratification.

Project Aims

The object of this exercise is to analyse and interpret the precise morphology of these unusual fossil specimens and their geometrical relations to the rock layering; this should help shed light on the nature of the environmental parameters that affected them in life, and reconstruct the manner of their death and burial in the mudrock that now encloses them.

The work will involve detailed examination of the fossils using a high-power binocular microscope, making photographs and camera lucida drawings, physically extracting specimens from the rock, making 3-D X-Ray images of the fossils within the rock slabs and analysing and interpreting the forces that seemingly distorted these fossils. Optionally, some field collecting of further material and/or scanning electron microscope analysis to show microstructure might be involved.

The work is associated with a current PhD project (Andrea Snelling) funded by the British Geological Survey into the evolutionary and paleoenvironmental history represented by these fossils in Wales and Scotland. It may well provide scientific results of publishable quality.

An Antarctic climate palaeothermometer from fossil molluscs

Supervisors: Dr M Williams and Dr J Zalasiewicz

Introduction
Global climate is warming. This change is seen most dramatically on the Antarctic Peninsula, where temperatures have risen several degrees over the past few decades. This has resulted in a retreat of the seaborne ice shelves which might lead to instability of the land based ice sheet.

Molluscs record a signal for seasonal changes in climate through the isotopic composition of their shells. When ice melts, it alters the oxygen isotopic composition of seawater and this is recorded in the mollusc shells. Ice melt in the Antarctic is linked to air temperature, and this has been calibrated with the isotopic composition of living mollusc shells. So air temperature can be estimated from shell composition.

We seek to apply this methodology to fossil material, to find out if seasonality on the Antarctic Peninsula has differed markedly in the past. This is important to developing a model of the effects of long term climate change on the Peninsula sea ice. Fossil material from James Ross and Cockburn islands has already been collected by the British Antarctic Survey, and will be supplemented by new collections in January. But before the analysis for isotopes we must check the preservation integrity of the fossil material, to be sure that we are tracking an original and not overprinted signal.

Project Aims
This project will use a range of analytical techniques to check the mollusc preservation. The material will be thin sectioned and studied with the scanning electron microscope (element maps and crystal textures). Thin sections will also be studied with cathode ray luminescence, a technique which distinguishes primary from secondary (altered) carbonates. The fossils will also be studied for ultrastructure with the SEM. Following this work we hope to undertake isotope analytical work at the NERC Isotope Geosciences Laboratory in Nottingham.

This project is part of a broader collaboration with the British Antarctic Survey in Cambridge, and we envisage the candidate visiting and having contact with the scientists there. The work may ultimately be published.

Environmental monitor for schools

Supervisor: Dr N F Arnold

Introduction
As part of the second/third year group research project, students are designing a system to measure atmospheric nitrogen dioxide and other environmental parameters, such as temperature and wind velocity that ultimately will be made available to schools/colleges. For this venture to be successful, it must meet the curriculum requirements for science/ICT.

Project Aims
Learn about the basic principles of environmental monitoring.
Interact with the teams responsible for developing the hardware and software and influence the specifications that are being drawn up.

Generate documentation and study materials that would support learning and teaching for a range of school ages and abilities.

Dynamic MRI

Supervisor: Dr M R Horsfield

Introduction
Magnetic resonance imaging often uses injectable contrast agent to enhance the appearance of a particular tissue - known as dynamic contrast-enhanced MRI (DCE-MRI). An analysis of the time course of signal enhancement can lead to a better understanding of the type of disease within a tissue. However, such an analysis requires measurement of the rate at which contrast agent enters the tissue (the 'input function'). This is difficult to measure accurately. This project will develop a model-based approach to measuring the input function, such that assessing the input function will be reduced to one of model parameter estimation. This has the potential to improve the reliability of the technique.

Project Aims

- Literature survey of DCE-MRI and input function estimation.
- Literature survey of model-based input function estimation.
- Implementation of a model-based approach and evaluation of the quality of the model.
- Refinement(s) of the model in (c), re-implementation and re-evaluation.

Software will be developed using the Java programming language.

Three-Dimensional Tensor Field Visualisation

Supervisor: Dr M R Horsfield

Introduction
The pathways of the major nerve fibres in the brain can be estimated from diffusion-weighted magnetic resonance imaging (MRI) data. The pathways can be modelled as a second-order tensor field. However, visualising these three-dimensional pathways is difficult. This project will develop and evaluate methods for displaying the pathways, displaying the properties of the tissue along the pathways and for interacting with the data.

Project Aims

- Literature survey of methods for displaying second-order tensor field data, particularly in the context of diffusion tensor imaging.
- Development of a graphical user interface for the display of the nerve fibre pathways from MRI data.
- Software developments will be coded using the Java programming language, and the "Java-3D" - the extension to Java for displaying three dimensional graphics.

Complex systems as models for the teaching of mathematical modelling

Supervisor: Dr D Raine

Introduction
In the standard school curriculum applied mathematics, if it means anything at all, consists of some rather dry applications of statistics and what are largely perceived as irrelevant problems in mechanics. Results from the study of complex systems provide a much richer variety of engaging problems that can be tackled using elementary mathematics and computers. These therefore have

the potential to provide a much more interesting approach to mathematical modelling for a wider range of students. One can model for example the arms race (history of WW1), the prison population (sociology and politics) the stock exchange (economics), cellular automata (computer science and biology), chaos in chemical reactions, percolation (physics) and fractals (mathematics). I call this approach 'social maths' because the idea is to show the relevance of mathematical models to understanding relevant problems in society. The idea of the project is to develop a module of social maths for A-level students that might take the place of mechanics as a way to teach modelling, in order to illustrate the concept and to help to progress it.

Project Aims

- Understanding of self-organised criticality and complex systems
- Programming in any high level language

Models and tools for the facilitation of inter-institutional Science Education research.

Supervisor: Dr D Raine/Dr T Barker

Introduction

This proposal is set in the context of a research project funded by the Higher Education Academy to examine the role of Science for Sustainability (SfS). The Sustainable Development (SD) agenda provides both a globally pressing concern for humanity and a potential means of interesting more students in Science and particularly Physics. The SfS project sets out to examine the SD agenda for its relevance to Science education and to develop appropriate sample curricula materials in collaboration with partners. These partners currently include the African Virtual University in Nairobi, Kenya who, in turn collaborate with partners all over Africa and potentially include the Science Learning Centres and Institute of Physics. Hence for the project to work a communications and organisational infrastructure is required which can work 'at a distance' such as those provided by current Content Management Systems (CMS) incorporating Weblogs, Wikis and Discussion Boards. Therefore this project will examine such inter-institutional collaboration, examining issues relevant to educational research. These issues may include the appropriate analysis of social as well as technological needs, for instance, thus deriving models for collaboration is such inter-institutional Science Education research projects. This rationale is currently being explored in the United Nations Global Alliance for ICT and Development as well as forming the basis for international conferences. The student may reasonably be expected to contribute to both should they so wish.

Project Aims

Skills expected to be gained would include a basic knowledge of educational research methods, knowledge of current tools and pedagogies for online collaboration and education and a broader understanding of the issues concerning the current reality of collaborative and interdisciplinary research and particularly in the context of SfS.

Pre-biotic Ecology

Supervisor: Dr D 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 regions of a cylindrical surface. The cells contain molecules (the 'food set') that can attach themselves to the boundaries of the region where they can polymerise according to certain rules. The boundaries between regions 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 C code, which implements the model structure and shows how a pre-genomic coding can arise which allows inheritance of the information for an autocatalytic network of reactions. 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.

See e.g.
Segre and Lancet (2000) Proc Nat Acad Sci., 97, 4112

Project Aims

- Some basic aspects of molecular evolution leading to genetic coding
- Understanding of self-organisation and emergent behaviour in complex systems
- Programming in C or C++

Tracking Systems for Humans and Animals

Supervisor: Prof M Simms

Introduction
In a number of experiments position and status of animals or humans are required. Space type examples include astronauts in a space station, animals in a test facility. Although complicated tracking techniques have been proposed simple positioning techniques using fluorescent type markers (e.g. quantum dots) are possible.

Project Aims
Examine position and location methods. Look at non-intrusive methods using fluorescent markers e.g. quantum dots. Derive a conceptual design of such a system and model its performance.

An ultrasound radar simulator

Supervisor: Dr T K 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. 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.

Project Aims
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.