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SLIP Ph.D. Course in
Stochastic Modelling in Marine Biology

Svendborg, 26-31 May 2002

PARTICIPANTS

12 students attended the course. A couple of these were in the final stage of Master programs, but the majority were in Ph.D. programs. The students were enrolled in programs in Denmark (7), Sweden (3), Norway (1) and Iceland (1).

Four of the students were female.

In addition, five senior researchers attended the course, three of whom were from DIFRES while two were visiting DIFRES from USA.

A list of participants and teachers is enclosed as Annex 1.

ORGANIZERS

The course was organized by Dr. Uffe Høgsbro Thygesen from the Danish Institute of Fisheries Research (DIFRES) and by Prof. Bo Friis Nielsen from the Dept. of Informatics and Mathematical Modelling, Technical University of Denmark (IMM/DTU).

TEACHERS

In addition to the organizers, invited teachers were Senior Scientist Andy Visser (DIFRES), Prof. Per Grove Thomsen (IMM/DTU), Prof. Henrik Madsen (IMM/DTU), Prof. Allan Aasbjerg (IMM/DTU), Senior Scientist Jan E. Beyer (DIFRES) and Prof. George Jackson (Texas A&M University).

A number of students contributed talks.

The list of all talks is given in Annex 3.

CONTENT

The course gave introductions to and surveys of topics in stochastic dynamics of relevance to applications in marine biology. Focus was on temporal dynamics although spatial dynamics were also dealt with. Special emphasis was on Markov models and diffusion models. A description of the day-to-day program is given in Annex 2.

The first day, Monday, gave introductions to Markov chains in discrete and continuous time, and to Markov Arrival Processes. Lectures were in the morning and early afternoon; computer exercises were in the late afternoon in the form of a demonstration to a Matlab library for Markov Arrival Processes.

The second day, Tuesday, introduced diffusion with emphasis on combining the stochastic and the physical points of view. A survey of turbulence in the ocean was also given. Again, the day started with lectures and ended with computer exercises.

The third day, Wednesday, started with introduction to numerical analysis of advection-diffusion transport equations, using discretisation of the partial differential equations. After a survey lecture the students solved problems using the Femlab software package.

After lunch on Wednesday, an introduction to grey-box modelling and parameter estimation in diffusion models was given. The material was illustrated with an exercise in which parameters in a diffusion model were estimated using the software package CTSM.

An excursion was planned for Wednesday evening: a cruise of the scenic waters around Svendborg aboard the veteran ferryboat *Catrine K*. The evening also included dinner and a walk around Valdemar Slot.

On Thursday morning there was a lecture on approximation techniques related to diffusions: time-scale separation leading to diffusion approximations of Markov processes, and low-noise approximations. The lecture was followed by a Matlab exercise illustrating the techniques on the run/tumble motion of bacteria performing chemotaxis.

On Thursday afternoon there was a lecture on spatial statistics, including software demonstrations.

Friday morning started with a Matlab exercise on dynamic optimisation, concerning optimal feeding strategies in situations with a trade-off between mortality and expected feeding success. The exercise was followed by a lecture on the theoretical approaches to dynamic optimisation, and by a case study.

On Friday afternoon the course ended with an evaluation session.

EVALUATION

The course was evaluated by a questionnaire (Annex 4) followed by a general discussion. In general there was satisfaction with the course. Of 13 respondents, six gave an overall evaluation of "Excellent", six rated the course "Good" and the last person rated it "OK". The impression was that the level had been high and progress had been fast, and that the course had offered inspiration and overview.

A considerable part (4 out of 13) thought that the level of the lectures was too high. In contrast, all but one found the exercises useful, and several would have preferred more time for exercises.

It appeared that participants with stronger mathematical prerequisites appreciated the course more. In particular, there was one student with a weak quantitative background who was not overly positive about the course.

A number of possible follow-up activities were proposed and will be considered more carefully.

Recommendations

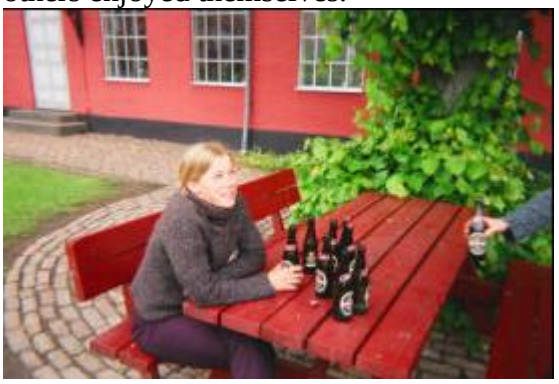
Based on our own impression and the response of the students we offer the following recommendations should a similar course be planned in the future:

In an interdisciplinary course like this, it is important that the target audience is specified in detail. This includes in particular the required background knowledge, but also the learning objective. For this specific course the critical issues were mathematical knowledge and the balance of interest between general understanding and operational skills.
When several speakers are responsible for their own tracks, care should be taken that the tracks are placed within the same context and can cross-reference each other. This requires co-ordination between the speakers, which means much work.
Exercises should be well-planned. When successful, they may contribute more to understanding than lectures do. The distinction between what is taught in lectures and what is taught through exercises deserves attention.
A default teaching model is often "Theoretic lecture followed by hands-on exercises". This model poses problems for groups with diverse backgrounds. Other teaching models – reversing the order or project-based learning – should be considered.
A workshop element where students bring their own problems could be considered. There are both pros and cons to this idea.
In this course we had long lunch breaks and relatively short days. The students appreciated this. They used the breaks to catch up on difficult points, finish exercises, discuss science, or simply to get to know each other.
We used a UNIX network and Matlab for the computer exercises. This worked very well, even though only a minority of the students were familiar with UNIX and Matlab beforehand.
If students make presentations of their own work (which is a very good idea!) these should be placed at the beginning at the course.

Snapshots from the course

The course was hard work for some, while others enjoyed themselves.

A lecturer demonstrating run-tumble motion



Some students from Northern Scandinavian countries took advantage of more liberal Danish alcohol taxes.

“So,” the organizers were asked, “will you teach this course again next year?”

Annex 1.
PARTICIPANTS

	Nationality	Affiliation	SLIP stud	Other students	DIFRES teachers	IMM teachers	Guests
Uffe Thygesen	Denmark	DIFRES			1		
Bo Friis Nielsen	Denmark	IMM/DTU				1	
Henrik Madsen	Denmark	IMM/DTU				1	
Per Grove Thomsen	Denmark	IMM/DTU				1	
Allan Aasbjerg Nielsen	Denmark	IMM/DTU				1	
Andy Visser	New Zealand	DIFRES			1		
Jan Beyer	Denmark	DIFRES			1		
George Jackson	USA	Texas A&M Uni					1
Ellen Toby	USA	Texas A&M Uni					1
Henrik Gislason	Denmark	DIFRES					1
Peter Lewy	Denmark	DIFRES					1
Fredrik Nilsson	Sweden	DIFRES, IMM/DTU	1				
Anders Nielsen	Denmark	DIFRES/KVL	1				
Eva Aagard	Denmark	KVL		1			
Claus Sparrevohn	Denmark	DIFRES		1			
Louise Dahl	Denmark	DIFRES	1				
Michele Casini	Italy	Fiskeriverket		1			
Signild Nerheim	Norway	Göteborg Uni		1			
Sigrunn Eliassen	Norway	Bergen Uni		1			
Stefan Gudmundsson	Iceland	Uni Iceland		1			
Patrick Jonsen	Sweden	Fiskeriverket		1			
Stefan Neuenfeldt	Germany	DIFRES		1			
Søren Loophaven	Denmark	IMM/DTU		1			
Total			3	9	3	4	4

Abbreviations:

DIFRES: Danish Institute for Fisheries Research
IMM/DTU: Informatics and Mathematical Modelling, Technical University of Denmark
KVL: Royal Veterinary and Agricultural University

Annex 2.
PROGRAMME AT A GLANCE

	Morning	Afternoon	Evening
Sunday			Welcome/Introduction
Monday	Markov Chains	Markovian Arrival Processes	
Tuesday	Diffusions: Physics vs. Stochastics	Turbulence	
Wednesday	Numerical Analysis of diffusions	Grey-box modelling of dynamic systems	Excursion
Thursday	Diffusions: Approximations	Spatial statistics	
Friday	Dynamic optimization		

Annex 3.
ABSTRACTS

MONDAY: MARKOV CHAINS AND ARRIVAL PROCESSES

Bo Friis Nielsen

TUESDAY: DIFFUSIONS IN PHYSICS AND STOCHASTICS

Diffusion: Relating the physical and the stochastic view

Uffe Høgsbro Thygesen

From a physical point of view, diffusions are large-scale descriptions of the motion of small particles (e.g. molecules) embedded in a flow. The stochastic translation of this is that diffusions are Markov process the p.d.f.'s of which are governed by advection-diffusion equations. In this talk we relate this to the Itô diffusions, i.e. the solutions to stochastic differential equations. In doing so we recap some basics from the analysis of diffusions: the dual forward and backward equations of Kolmogorov, the relationship between Itô and Stratonovich calculus, and discrete approximations to diffusions. We illustrate with a number of examples of diffusion models from marine biology.

Turbulence in the ocean

Andy W. Visser

Turbulence affects a whole range of physical and biological processes in the ocean. Indeed, one of the most conspicuous features of the annual production cycle in temperate shelf seas - the spring bloom - is mediated by turbulence. At the micro-scale, turbulence directly influences planktonic processes; from how efficiently nutrients are taken up by phytoplankton to the trophic interactions of zooplankton.

The dynamics of turbulence are encapsulated in the Navier Stokes Equations. Traditional methods of incorporating these effects in numerical simulations are through turbulence closure schemes that parameterize sub-grid processes. The simplest of these is the Reynolds decomposition, although more sophisticated schemes such as those based on 'K-epsilon' theory are now commonly employed.

However, recent advances in biophysics recognise that these closure schemes often fail for detailed analysis of biological interactions. The problem lies in the non-linearity of these interactions so that descriptions based on spatially or temporally averaged fields fail to capture the underlying dynamics. As a result, direct numerical simulations coupled to individual based models are finding increased currency.

This talk will cover these topics as they relate to marine ecology, both through illustrative examples, and current theoretical understanding.

WEDNESDAY: DIFFUSIONS; THE TECHNIQUES

Grey-box modelling of dynamic systems

Henrik Madsen

Numerical analysis of diffusion (preliminary title)

Per Grove Thomsen

THURSDAY: DIFFUSION APPROXIMATIONS. SPATIAL ANALYSIS

Diffusion approximations of Markov processes

Uffe Høgsbro Thygesen

One reason why diffusions are so useful is that they often arise as approximations to Markov processes when there is a separation of time scales. For instance, for molecular diffusions, the time scale of intermolecular collisions is often much shorter than that of the embedding flow and that of the observer. Mathematically, this time scale separation is used to perform perturbation analysis of the Kolmogorov equations. In this talk, we briefly review the machinery of regular perturbation analysis, which is used in standard text-books to approximate simple random walks with Brownian motion. Then, we go into some detail with the machinery of

singular perturbation analysis which is necessary in diffusion approximations of e.g. random flights. Finally we illustrate with an example: diffusion approximation and analysis of bacteria performing run-tumble chemotaxis.

Geostatistics and analysis of spatial data
Allan Aasbjerg Nielsen
This lecture discusses geostatistical measures for spatial correlation, viz the autocovariance function and the semi-variogram, as well as deterministic and geostatistical methods for spatial interpolation, viz distance weighting and kriging. A number of models for the semi-variogram are mentioned, in particular the spherical, the exponential and the Gaussian model. The systems of equations for simple and ordinary kriging are derived. Other forms of kriging are mentioned, and references to international literature, web-sites, and state-of-the-art software within the area are given. A very simple example to illustrate the computations is shown as well as more realistic examples. A number of attractive properties of kriging are listed, as well as a simple sampling strategic consideration based on the kriging variance being dependent of the distance to nearest observations. Finally, multivariate techniques for orthogonalization of spatial data with the purpose of reduction of dimensionality are mentioned. The application of these methods on geochemical data from Greenland is demonstrated.

FRIDAY: DYNAMIC OPTIMIZATION

The classical techniques of dynamic optimization
Uffe Høgsbro Thygesen
This lecture surveys the basic classical approaches to dynamic optimization. First, we introduce the problem of dynamic optimization - i.e. finding some function which minimizes a given "cost" functional. We briefly review the history of the problem, and its importance in ecology. One approach to the solution is to find stationary points; this requires a generalization of differentiability to functionals, i.e. the calculus of variations. We also describe the dynamic programming approach developed by Bellman.

Applying calculus of variations to ecology: A case study
Jan E. Beyer

Contributed talks

Horizontal dispersion of juvenile freshwater in the Baltic
Signild Nerheim

Prey availability for cod in a heterogeneous environment
Stefan Neuenfeldt

Application of diffusion theory in biology: A case study with diffusion of fish from a single release point
Claus R. Sparrevohn

The dispersive migration of herring and sprat, and optimal behaviour
Fredrik Nilsson

Spatiotemporal Reconstruction of marine monitoring data
Søren Lophaven

Spatial variability in the distribution of marine plankton
Louise Dahl

Annex 4.

EVALUATION OF THE
SLIP SUMMER SCHOOL ON STOCHASTIC MODELLING IN MARINE BIOLOGY
MAY 26-31, 2002

Please give us your opinion related to the following questions. Do not hesitate to include supplementary comments that you may find relevant. Do not write your name, the questionnaire should be anonymous.

Overall evaluation

What is you overall opinion of the course

Excellent 6
Good 6
OK 1
Not very good 0
Poor 0

Course content

Did the course provide a reasonable overview of the subject?

Yes 12
To some extent 1
No, important items missing 0

Comments (e.g. missing topics)

Where the topics included adequately covered?

Yes 7
To some extent 5
No 0

Comments (e.g. topics receiving insufficient/too much attention)

- ?? A lot was new to me (and still is) so I can't really say
- ?? The topics were covered as well as possible in a fast course like this.
- ?? A bit too few examples.
- ?? Dynamic optimisation was insufficient due to lack of time.

Lectures

How was the level of the lectures?

Too low 0
Adequate 9
Too high 4

Comments

- ?? It was high
- ?? For a biologist, some lectures were too heavy. Some of the engineers were talking like to an audience of engineers (students). However, most were very good and interesting.

Were the lectures well prepared and easy to understand?

Yes 7.5
To some extent..... 5.5
No 0

Comments

- Well prepared, yes! Easy to understand – well, depends on previous knowledge!
- Sometimes too high
- Uffe is a really good teacher
- They were well prepared but again one needs time to digest some of items
- Some were very good, others could have been better prepared

Exercises

Were the exercises useful for understanding the theory?

Yes 12
To some extent..... 1
No 0

Comments

- Some of the exercises had a too high threshold for understanding; could have been better prepared or the problems been posed more precisely.
- I picked up some new Matlab skills, thanks.
- Mostly very good and instructive exercises, but too short time to go into details.

Logistics

How was the physical framework – accommodation, lecture room, food, etc?

Excellent 4
Good 9
OK..... 0
Not very good 0
Poor 0

Comments

- Nice place, excellent food. To noisy around the lecture room sometimes. Nice boat trip.
- It was a bit hard for an internetaholic to out of “contact” most of the time.
- Acoustics were quite bad in the computer room

Overall balance and timing

Was the balance between lectures and exercises right?

Yes 9
To some extent..... 4
No 0

Comments

- Good to go through!
- More time to exercises would have been nice
- More time to exercises

Was the time assigned to each subject appropriate?

Yes 7
To some extent.....4
No 2

Comments

- Some too big
- Personally I would have appreciated more about spatial statistics.
- Maybe a narrower focus would have been better for learning more. BUT this might make the course less interesting for some participants.

Was the overall duration of the course appropriate?

Too short 4
Yes 9
Too long.....0

Comments

- Of course we could spend a lot of time on further exercises, discussion and working on our own data with the new methods – during, say, another week. But I think one week is appropriate, then we can keep in contact with each other and continue the work at home. Most important we have created a new network and got to know each other! ✍

Relevance

Do you think the course will be relevant for your future studies and career?

Yes 10
Don't know.....3
Probably not 0
Not at all.....0

Comments

- The course was an eye-opener and I really got some new ideas for my future work! Very good with long breaks for interesting discussions. Very interesting group of people – further networking will probably arise.

Etc.

How did you receive information about the course?

- E-mail, co-supervisor
- Work
- From my supervisor who received info. On e-mail
- On the internet through fishnet
- Personal com/through DIFRES-emails
- Via the network
- By internet, Fishnet web site
- Internet
- By e-mail
- UHT & BFN
- SLIP-homepage

?? My supervisor got an e-mail about it

Do you have suggestions that might help us to advertise future courses?

?? Mailing lists
?? Maybe give students with non-mathematical background an introduction text/lecture before the actual course
?? Longer time before, mailing lists
?? Another idea would be a kind of workshop where we could go into detail with practical data, especially our own, and exchange ideas and knowledge with each other

Please give any additional comments on the course – frustrations, suggestions for improvements in similar courses, etc.

?? Maybe introduce mathematics through biology instead of the opposite
?? There is only one drawback to this course, i.e. a terrible lack of respect to the world cup ✍
?? In general a very good and inspiring course
?? Opportunities for people having their own data analysed