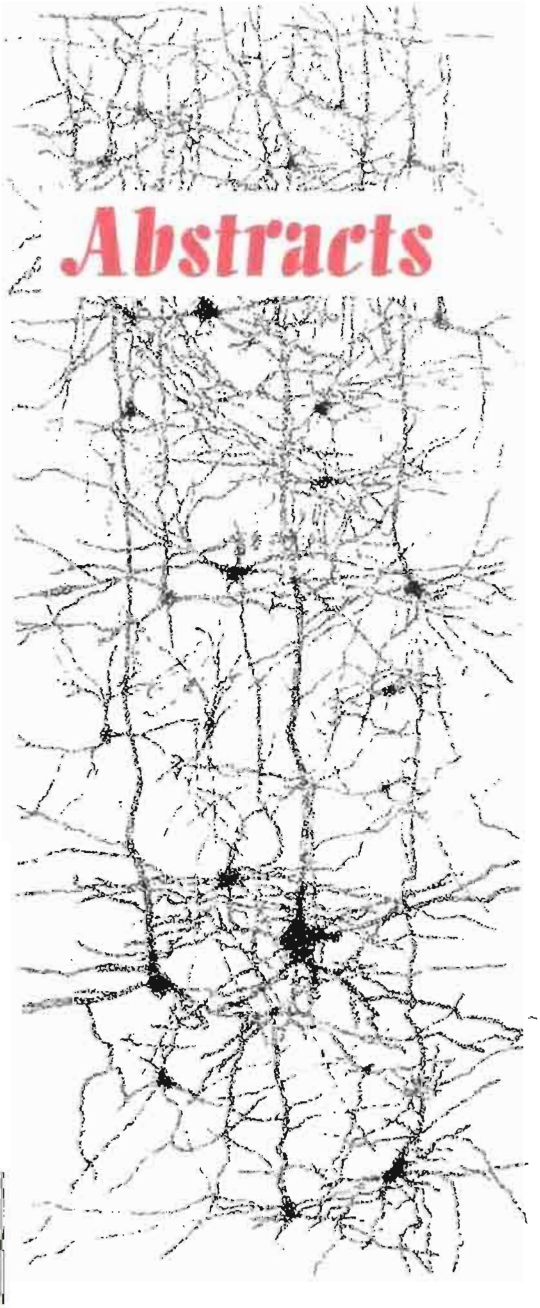
INTERNATIONAL WORKSHOP ON APPLICATIONS OF ARTIFICIAL NEURAL NETWORKS TO ECOLOGICAL MODELLING

Toulouse, France, 14-17th December 1998

Abstracts



Organized by

CESAC, UMR C5576
CNRS-Université Paul Sabatier

Centre d'Ecologie des Systèmes Aquatiques Continentaux

Organizing committee

Sovan LEK
UMR CNRS/UPS C5576
Toulouse

Jean François GUEGAN
UMR CNRS/IRD 9926
Montpellier

International Workshop on the Applications of Artificial Neural Networks to Ecological Modelling

Toulouse (France) - December 14-17 of 1998

It is with great pleasure that we welcome you to the International Workshop on the Applications of Artificial Neural Networks to Ecological Modelling. This meeting was initially inspired during casual conversations the two leader co-organizers had at the end of 1996. Ecological Modelling must be regarded here in its largest expression, and it may include different research areas from evolutionary ecology to human epidemiology, biodiversity research and conservation action world-wide, or environmental sciences and applied ecology as well. This meeting has been imagined to bring together theoretical and applied life-sciences research, and it should promote future collaborations between researchers from different disciplines. The present Proceedings include the corresponding abstracts of different papers which will be published into two separate volumes, i.e. a special issue of the international "***Ecological Modelling***" journal, and a hard book published by ***Springer Verlag***. The contributions look at examples of applications of Artificial Neural Networks in a large diversity of research fields, and we have tried to select for the more convincing and varied examples of what neural networks may permit to imagine today. Indeed, much of our concern when writing this report is that the meeting and its relevant contributions should be viewed as being distinct from routine and cyclic symptoms of pure modelling. If some contributions are judged as being disturbing, controversial, or as far as possible opening new avenues in life-sciences research, at the closure day of the meeting we will be two contented fellows !

Sovan LEK and Jean François GUEGAN

International Scientific Committee

Professor P. AURIOL (Director of CESAC, University Toulouse III, France)
Professor P. AUGER (University Lyon I, France)
Professor R. BARBAULT (University Paris VI, France)
Professor B. GRANDJEAN (University Laval, Canada)
Professor S.E. JORGENSEN (University Copenhagen, Denmark)
Professor A. PAVE (University Lyon I, France)
Professor R. TOMASSONE (INA and University Lyon I, France)
Doctor. P. BOURRET (CERT-ONERA, Toulouse, France)
Doctor. C. TOUZET (University Marseille, France)
Doctor J.F. GUEGAN (CEPM, UMR 9926 CNRS/IRD, Montpellier, France)
Doctor S. LEK (CESAC, UMR 5576 CNRS/UPS, Toulouse, France)

Local Organizing Committee

Dr. Sovan Lek, CESAC, UMR 5576 CNRS/UPS, Bât IVR3, 118 route de Narbonne, F-31062 Toulouse cedex 4, France. Phone: 33-5 61 55 86 87 Fax: 33-5 61 55 60 96
Email: lek@cict.fr

Dr. Jean-François Guégan, CEPM, UMR 9926 CNRS/IRD, 911 Parc Agropolis, B.P. 5045, 34032 Montpellier cedex 1, France. Phone (33) 4 67 41 62 32 Fax (33) 4 67 41 62 99
Email : guegan@cepm.mpl.orstom.fr

Dr. F. Bau (CESAC, UMR 5576 CNRS/UPS)
Dr. R. Céréghino (CESAC, UMR 5576 CNRS/UPS)
Mrs. J. Brabet (CESAC, UMR 5576 CNRS/UPS)
Mrs Y. Durand (CESAC, UMR 5576 CNRS/UPS)
Mrs. D. Galy (CESAC, UMR 5576 CNRS/UPS)
Mr. S. Brosse (CESAC, UMR 5576 CNRS/UPS)
Miss. K. Cever (CESAC, UMR 5576 CNRS/UPS)
Mr. S. Gabas (CESAC, UMR 5576 CNRS/UPS)
Miss. V. Lavandier (Institut Limayrac, Toulouse)
Miss G. Loot (CESAC, UMR 5576 CNRS/UPS)
Miss S. Angelibert (CESAC, UMR 5576 CNRS/UPS)
Miss J. Cowan (CESAC, UMR 5576 CNRS/UPS)

Sponsors

The ANN Workshop acknowledges the help and cooperation of the following:

- Centre National de Recherche Scientifique (CNRS), Département des Sciences de la Vie
- Université Paul Sabatier, Toulouse 3
- Electricité de France (EDF)
- Agence de bassin d'Adour-Garonne
- Ministère des Affaires Etrangères
- Région Midi-Pyrénées
- Mairie de Toulouse
- OKTOS – Paris
- Springer-Verlag, Allemagne
- Oxford University Press, GB
- The monthly Journal "Ecological Modelling"

GENERAL INFORMATION

REGISTRATION

Registration will start on Sunday, December 13 of 1998 between 4.00 p.m. and 7.00 p.m. and will go on the following day between 8.00 a.m. and 9.00 a.m. at the Great Hall of the University of Toulouse 3. Participants will receive their registration materials when they will be registered.

BADGE

The personal badge you will receive is your entrance ticket to all conference sessions. Thus participants are requested to always wear their badge.

RESTAURANT

Individual tickets will be offered with registration materials for three lunches (a ticket colour per day). The Upsidum restaurant is situated 50m from the Conference building. Tickets will be available for people having registered only (delegates and accompanying people), but it will be possible for people not registered to buy supplementary ticket at the registration desk (FF 50). Dinners are not included into the registration fees. Delegates must refer to the different advertisements (numerous restaurants, cafés, etc. available in the city centre) proposed into the delegate pack. For registered people, both lunch and dinner on Thursday (post-congress excursion) will be offered by the organizing committee.

EXCURSION VISITS FOR ACCOMPANYING PEOPLE

Many different excursion programmes will be possible for accompanying people during the Conference. These excursions will be organized during the Monday to Wednesday afternoons (between 2.00 p.m. and 6.30 p.m). They concern different possible visits of monuments, museums and other famous spots of Toulouse city centre. Mrs Véronique Lavandier, who is a Tourism Higher School postgraduate, will be in charge of these excursions. For more details, please contact our registration office.

SERVICE ON-SITE

Located by the main entrance are the following services:

- Public Telephones (telephone cards are sold in different shops)
- Travel Agency (to buy or book an air or railway ticket)
- PC Computer with printer
- Photocopy

Other services (Post office, Bank,...) are available outside the University area.

INTERNET SERVICE

For Email and Internet access, computers will be available in the seminar room.

SMOKING POLICY

Participants are kindly requested to refrain from smoking in all closed areas (Great Hall, session room and restaurant) due to French policies. Smoking is only allowed in the open areas.

POST-CONGRESS EXCURSION

Participants and accompanying people who wish to attend the post-congress excursion to Carcassonne are requested to inform our registration office during the registration process. The organizing committee strongly recommends people to be present at 9.00 a.m. at our meeting point situated just in front of the main University entrance. Please contact our office desk for more details on the post-congress excursion.

Programme of the meeting

Monday, 14th December 1998

8.00 a.m. : Reception and registration.

9.00 a.m.–9.30 a.m.	Opening ceremony (With the President of the University Toulouse 3, the Head of the CNRS regional delegation, the Director of CESAC, and the organizing committee)
Chairman: P. AUGER	
9.30 a.m.–10.15 a.m.	S.E. JORGENSEN **"State-of-the-Art of Ecological Modelling with emphasis on development of structural dynamic models"**
10.15 a.m.–10.45 a.m.	F. RECKNAGEL and H. WILSON **"Elucidation and Prediction of Aquatic Ecosystems by Artificial Neural Networks"**

10.45 a.m.–11.15 a.m. : COFFEE-BREAK

Chairman: F. RECKNAGEL	
11.15 a.m.–11.45 a.m.	R. BARCIELA *et al.* **"Modelling primary production in a coastal embayment affected by upwelling using dynamic ecosystem models and artificial neural networks"**
11.45 a.m.–12.15 a.m.	M. SCARDI and L.W. HARDING Jr. **"Developing an empirical model of phytoplankton primary production: a neural network case study"**
12.15 a.m.–12.45 a.m.	L. GROSS *et al.* **"Neural Networks for Modelling the Transfer Function between Marine Reflectance and Phytoplankton Pigment Concentration"**

12.45 a.m.–2.00 p.m. : LUNCH (It will be offered in the UPSIDUM-University restaurant, 50m far from the Conference Hall)

Chairman: I. AOKI	
2.30 p.m.–3.00 p.m.	F.G.TOMASEL and J.M. PARUELO **" Primary production estimation in grasslands of South and North America by ANN analysis of satellite data"**
3.00 p.m.-3.30 p.m.	A. AUSSEM and D. HILL **"Wedding Connectionist and Algorithmic Modelling towards Forecasting *Caulerpa taxifolia* Development in the North-Western Mediterranean Sea"**
3.30 p.m.-4.00 p.m.	M. SCARDI **"Neural network models of phytoplankton primary production"**

4.00 p.m.-4.30 p.m. : COFFEE-BREAK

Chairman: A. TERIOKHIN	
4.30 p.m.-5.00 p.m.	I.M. SCHLEITER *et al.* **"Assessment of water quality, bioindication and population dynamics in lotic ecosystems with neural networks"**
5.00 p.m.-5.30 p.m.	S. MANEL *et al.* **"The comparative utility of neural networks and logistic regression in predicting the distribution of Himalayan river birds"**
5.30 p.m.-6.00 p.m.	I. MORLINI **"Radial Basis Function Networks With Partially Classified Data"**
6.00 p.m.–6.30 p.m.	J.P. VILA *et al.* **"Neural Network Architecture Selection: New Perspectives"**

Tuesday, 15th December 1998

Chairman: J. SMID	
9.00 a.m.–9.30 a.m.	P. BOURRET **"Unsupervised learning for exhibiting new properties: from observations to assumptions"**
9.30 a.m.–10.00 a.m.	M. BROWN *et al.* **"Support Vector Machines for Optimal Classification and Spectral Unmixing "**
10.00 a.m.–10.30 a.m.	M. DUBOIS *et al.* **"Ultrafast estimation of DBH repartitions from ground based photographs, using neural networks"**

10.30 a.m.–11.00 a.m. : COFFEE-BREAK

Chairman: P. BOURRET	
11.00 a.m.–11.30 a.m.	G.M. FOODY **"Fuzzy Mapping of Coastal Vegetation from Remotely Sensed Imagery with a Feedforward Neural Network"**
11.30 a.m.–12.00 a.m.	M. MASSON *et al.* **"Software Sensor Design Based on Empirical Data"**
12.00 a.m.–12.30 a.m.	J. MANSLOW and M. BROWN **"A Probabilistic Description and Interpretation of Sub-Pixel Area Estimation Procedures"**

12.45 a.m.–2.00 p.m. : LUNCH (University restaurant)

Chairman: G. BALL	
2.30 p.m.-3.00 p.m.	A.T. TERIOKHIN and E.V. BUDILOVA **"Evolutionarily optimal networks for controlling energy allocation to reproduction and repair in men and women"**
3.00 p.m.-3.30 p.m.	J.F. GUEGAN *et al.* **"Global epidemiology and human infectious disease occurrences"**
3.30 p.m.-4.00 p.m.	A.T. TERIOKHIN and J. KOZLOWSKI **"On Neural Networks Capable To Realize Evolutionarily Optimal Animal Strategies Of Growth And Reproduction In A Seasonal Environment"**

4.00 p.m.-4.30 p.m. : COFFEE-BREAK

Chairman: M. SCARDI	
4.30 p.m.-5.00 p.m.	G.M. FOODY **"Applications of the Kohonen Self-Organising Feature Map Neural Network in Ecological Data Analysis"**
5.00 p.m.-5.30 p.m.	D. AURELLE *et al.* **"Microsatellites and artificial neural networks : tools to discriminate natural and hatcheries brown trout (*Salmo trutta fario*, L.) in Atlantic populations"**
5.30 p.m.-6.00 p.m.	P. BOËT. and T. FUHS .**"Predicting local fish species in the seine river basin with artificial neural networks"**

7 p.m. : RECEPTION AND COCKTAIL AT TOULOUSE CITY TOWN HALL

Wednesday, 16th December 1998

Chairman: S.E. JORGENSEN	
9.00 a.m.–9.30 a.m.	P. AUGER *et al.* **"Coupling the ecological levels: from individuals to populations and communities"**
9.30 a.m.–10.00 a.m.	M. DREYFUS. **"A fishery model based on search behaviour of both preys and fishermen represented by neural networks and learning through reinforcement"**
10.00 a.m.–10.30 a.m.	M.A. CISNEROS **" Forecasting sardine biomass using regression and neural network models"**

10.30 a.m.–11.00 a.m. : COFFEE-BREAK

Chairman: G. FOODY	
11.00 a.m.–11.30 a.m.	B.A. MEGREY **"Using Neural Networks to Examine Relationships Between Features of the Environment and Recruitment Variation in Exploited Marine Fish Stocks"**
11.30 a.m.–12.00 a.m.	W. SILVERT and M. BAPTIST. **"Can Neural Networks be used in Data-Poor Situations?"**
12.00 a.m.–12.30 a.m.	M.T. VAN WIJK and W. BOUTEN **"Modelling water and carbon fluxes above European coniferous forests with artificial neural networks"**

12.45 a.m.–2.00 p.m. : LUNCH (University restaurant)

Chairman: H. WERNER	
2.30 p.m.–3.00 p.m.	G.R.. BALL *et al.* **"A Comparison of Artificial Neural Network and Conventional Statistical Techniques for Analysing Environmental Data"**
3.00 p.m.–3.30 p.m.	I. AOKI *et al.* **"Analysis of response of zooplankton biomass to climatic and oceanic changes"**
3.30 p.m.-4.00 p.m.	S. BROSSE *et al.* **"The use of artificial neural networks to assess fish community structure in the littoral zone of a mesotrophic lake"**

4.00 p.m.-4.30 p.m. : COFFEE-BREAK

Chairman: J.P. VILA	
4.30 p.m.-5.00 p.m.	T.S. CHON **"Temporal Patterning of Community Data by Utilizing Artificial Neural Networks"**
5.00 p.m.-5.30 p.m.	J. SMID *et al.* **"A Web based tool for data visualization and analysis"**
5.30 p.m.-6.00 p.m.	P.M. ATKINSON *et al.* **"Patch-based modelling of change in the lowland heaths of Dorset, England using an artificial neural network"**
6.00 p.m.–6.30 p.m.	H.H. WERNER *et al.* **"Neural Network Tools for the Analysis of Ecological Data from Aquatic Systems"**

6.30 p.m.	**Closure session**

POSTER SESSION:

S.A. BORDIGNON and C. GAETAN **"Neural network predictions of air pollution concentrations in an urban area"**

Y.DIMOPOULOS *et al.* **"Neural network models to study relationships between lead concentration in grosses and urban permanent descriptors in Athens city (Greece)"**

J.L. GIRAUDEL *et al.* **"Application of the Self-organizing map method to microsatellite data: how to detect genetic structure in brown trout (*Salmo trutta*) populations"**

M.L GONCALVES **"Land-cover classification of multi-spectral imagery using an advanced neural system"**

D.S. KIMES and R.F. NELSON **"Predicting Ecologically Important Vegetation Variables from Remotely Sensed Optical/Radar Data Using Neural Networks"**

T. KOMATSU *et al.*. **"Analysis and prediction of sardine catch changes in Sagami Bay, Japan, using a neural network"**

R. LAE *et al.* **"Predicting fish yield of African lakes using neural networks"**

N. METOUI **"Inverse problem by neural network : application for wind retrieval from spaceborne scatterometer data"**

F. MOATAR *et al.* **"pH modelling by neural networks. Application of control and validation data series in the Middle Loire river"**

A. SCHULTZ and R. WIELAND **"Derivation and validation of artificial neural networks for spatial agroecological problems"**

R.E. STRAUSS and Ö.K. GRANTHAM **"Using Supervised Neural Networks to Characterize the Length and Structure of Foraging Search Paths"**

C. TOURENQ *et al.* **"Use of artificial neural networks to predicting damages by Flamingos in rice fields"**

D. ZAKARYA and M.A. FROUJI **"Effect of Environmental Parameters on the Bacterial Pollution. Correlation Analysis Using Neural Networks"**

Thursday 17th December 1998

POST-CONGRESS EXCURSION : VISIT OF THE MEDIEVAL CITY OF CARCASSONNE
(Web site: http://www.bc.edu/bc_org/avp/cas/fnart/arch/medieval_fort.html)

- 9.00 a.m. : Departure from Toulouse (in front of the University, at the stop bus n° 2, see included map). During the week, this bus may get into the University area.
- 10.30 a.m. Arrival in Carcassonne.
- 11.00 a.m.-12.30 a.m. : Guided visit of the city
- 1.00 p.m. : Lunch at the restaurant in the city (restaurant "**Au Comte Roger**")
- 2.00 p.m.-3.30 p.m. : Free visit in the city
- 3.30 p.m. : Departure to Limoux (about 50 km from Carcassonne)
- 4.30 p.m. : Visit of cellar and wine tasting
- 7.00 p.m. : Go back to Carcassonne
- 7.30 p.m. : Farewell dinner (restaurant: "**Le Richepin**", with good viewpoint to lighted Medieval city)
- 11.00 p.m. : Return to Toulouse

Contents

Index of authors with pages of contribution

Abstracts

Analysis of response of zooplankton biomass to climatic and oceanic changes

AOKI I.[1*], KOMATSU T.[2] and HWANG K.[3]

[1] Department of Bioscience, Graduate school of Agricultural and Life Science, University of Tokyo, Yayoi, Bunkyo, Tokyo 113, Japan.
[2] Ocean Research Institute, University of Tokyo, Minamidai, Nakano, Tokyo 164, Japan.
[3] National Fisheries Research and Development Agency, Shirang-ri, Kijang, Pusan, Korea.

The northeastern sea area of Japan is well known to be highly productive under the influences of the Kuroshio (Western boundary current of the subtropical gyre in the North Pacific) and the Oyashio (Western boundary current of the subarctic gyre) currents. This paper examined the long-term variation in zooplankton biomass in response to climatic and oceanic changes, using a neural network as a nonlinear multivariate analysis method. Zooplankton data collected from 1951 to 1990 of North-Eastern Japan were analysed. We consider patterns of the Kuroshio and Oyashio, sea surface temperature, and meteorological parameters as environmental factors affecting zooplankton biomass. Back propagation neural networks were trained to generate mapping functions between environmental variables and zooplankton biomass. The performance of the trained network models was measured by cross-validation. Changes in zooplankton biomass could be predicted from environmental conditions. Weights of input variables and sensitivity analysis of networks showed that air pressure, sea surface temperature and sun shine time had consistently a great impact on zooplankton biomass. The patterns of the Kuroshio and Oyashio currents and Southern Oscillation Index had different effects among sea areas.

* Email: aoki@hongo.ecc.u-tokyo.ac.jp

Patch-based modelling of change in the lowland heaths of Dorset, England using an artificial neural network

ATKINSON P.M.[1*], NOLAN A.M.[1] and BULLOCK J.M.[2]

[1]Department of Geography, University of Southampton, Highfield, Southampton SO17 1BJ
[2]Institute for Terrestrial Ecology, Furzebrook Research Station, Furzebrook, Wareham, Dorset BH20 5HA

1. AIMS AND OBJECTIVES

The heathlands of Dorset provide a habitat for many important species such as the Dartford warbler (*Sylvia undata*), the sand lizard (*Lacerta agilis*), the smooth snake (*Coronella austriiaca*) and the lady-bird spider (*Eresus niger*). Further, these heaths are now the only place where all six of Britain's native reptiles are found together. Much of the Dorset heaths have been lost over the last century and a half. The heaths that have survived are considerably fragmented and this has increased the likelihood of loss of heathland and loss of the fauna that the heaths support. The heaths are now a top priority for habitat conservation in Britain. In the present research, the objective was to build an object-based (patch-based) statistical predictive model of heathland change for use by heathland managers.

2. METHOD

In the past, models of ecological change have tended to be applied at a single place. Examples are first-order Markovian models and transitional models. However, increasingly researchers are incorporating more explicitly spatial effects such as spatial context. For the present purpose it was desirable to incorporate variables on context through a patch-based statistical model. The main reason for this was that heathland managers generally do not have access to pixel-based processing, and need to make decisions regarding the patch, the natural spatial unit for management.

Extensive surveys of the Dorset heathlands (data on 200 variables for 3110 cells each of 200 m by 200 m) were carried out in 1978, 1987 and 1996. Initially, bivariate distribution functions were plotted between percentage change in the area of heath in a patch (1978 to 1987) and several transformed 'explanatory' variables, and stepwise multiple regression models obtained. However, when the logorithm of area of heathland was held constant, no other variables were significant at the 95% confidence level. Further, the variance in the y-variable was inversely dependent on x, making regression modelling particularly problematic. A simple feed forward, back-propagation multi-layer perceptron artificial neural network (ANN) was applied to the data with percentage change in heathland as the output and several explanatory variables as the inputs. The ANN, thus, had 10 (N) nodes in the input layer, 21 nodes (2N + 1) nodes in the hidden (data) layer and 1 node in the output layer. The ANN was trained using 2/3 of the available data selected randomly, the remaining 1/3 being used for validation.

3. RESULTS

The results of the ANN were compared with those of regression through the accuracy of the predictions obtained for the validation data. The ANN was found to be marginally more accurate than the regression model in terms of the root mean squared error supporting the view that data-dependent prediction is more appropriate than model-dependent prediction for relations which

* Email: pma@soton.ac.uk

are multivariate non-linear and non-normal. Starting with area of heathland as the only explanatory variable, it was possible to plot the effect of area of heathland on percentage change, and the relation was, as expected, non-linear. Further variables were added iteratively to the ANN input layer and the effect on accuracy recorded. It was found that the area of invasive species in the perimeter of the patch was the second most important variable.

4. CONCLUSIONS

Clearly, ANNs have a useful role to play in modelling and predicting ecological change in heathlands. The authors feel that this applicability should extend to many other ecological dynamical systems such as the spread of bracken and rhododendron in upland Great Britain and regenerating clear-felled patches in tropical forests.

Aggregation and emergence in ecological modelling: integration of the ecological levels

AUGER P.[1*], CHARLES S.[1] VIALA M.[1] and POGGIALE JC[2]

[1] UMR CNRS 5558, Université Claude Bernard Lyon-1, 43 Boulevard du 11 Novembre 1918, 69622 Villeurbanne cedex, France
[2] Centre d'Océanologie de Marseille (O.S.U.), Unité Associée au CNRS (UA 41), Campus de Luminy, Case 901 F 13288 Marseille cedex, France.

Ecological systems are composed of different levels of organization, the individuals, the population, the community and the ecosystem. This hierarchy corresponds to several levels of observation involving different time and space scales. Thus, modelling ecological systems implies to study the relationships between the different levels and raise particular questions: What are the effects of individual decisions on the dynamics and the stability of populations and communities ? What are the effects of environmental changes on the behaviour of the individuals and then on the populations and the community ?

Taking into account a hierarchical organization may lead to build complex models involving many variables and parameters. Such models cannot be easily analyzed and only computer simulations can be realized. However, the existence of different time scales allows to use mathematical methods, aggregation methods, leading to macro-models governing a few number of global variables which vary at a slow time scale. Such aggregated models can be studied analytically and are useful tools for the study of the couplings between the different ecological levels.

We present examples of aggregation methods applied to population dynamics in a heterogeneous environment. We study the influence of individual decisions for migrations at the fast time scale on the dynamics and the global stability of the community in the long term. We consider the example of a fish population (the brown trout) in a hierarchical river network and we study the effects of dams and channels on asymptotic growth rate of the global population.

Neural networks are an alternative approach for the study of the influence of environmental changes on the dynamics of the different ecological levels. We present a comparative analysis of different modelling methods that may be useful for studying the interactions between the ecological levels.

* Email: pauger@biomserv.univ-lyon1.fr

Microsatellites and artificial neural networks : tools to discriminate natural and hatcheries brown trout (*Salmo trutta fario*, L.) in Atlantic populations.

AURELLE D.[1*], LEK S.[2], BERREBI P.[1] and GIRAUDEL J.L.[3]

[1] Laboratoire Génome et Populations, CNRS UPR 9060, Cc063, Université Montpellier II, Place Eugène Bataillon, 34095 Montpellier Cedex 05 France
[2] CESAC, UMR C5576, CNRS-Univ Paul Sabatier, 118 route de Narbonne, 31062 Toulouse cedex 4, France
[3] IUT Périgueux-Bordeaux IV, Département Génie biologique, 39 rue Paul Mazy, 24019 Périgueux Cedex, France

Artificial Neural Network have been applied to classify some populations of brown trout (*Salmo trutta fario*, L.) from south western France with microsatellites data. In this area, several different genetic forms coexist and interact (ancestral Atlantic, wild modern Atlantic and domestic modern Atlantic); nevertheless no diagnostic markers are available, that's why some classification tools are necessary. A classical *Feed-forward* network has been used with three layers: an input layer (corresponding to the different variables necessary for the discrimination: here the alleles of the different loci), an hidden layer, and an output layer (with a number of neurons corresponding to the number of categories where the individuals will be classified). For the training of the network, some reference samples were presented to the network (supervised approach). A back-propagation algorithm was then used to modify the weights of the different connections. In order to test the network we used two procedures: the *Hold-out* and the *Leave-one-out* approaches. The choice of the technique was done according to the problem and to the samples used: this choice is discussed.

Several comparisons have been realised: ancestral versus modern types, comparison of different hatcheries strains, comparison of some river populations with hatcheries. The results of the training gave some high percentages of well classified individuals for the test with the *Hold-out*: up to 95% for the ancestral/modern classification. With the tests using the *Leave-one-out* analysis, we also obtained such high percentages (98% for the same comparison). These good results show that ANN are well suited for such analyses, and they also confirm the distinction among the different forms. The worst results were obtained for the comparison of different domestic strains which are known to be quite homogeneous. We also evaluated the contribution of the different variables (alleles) to the network using the Garson-Goh algorithm: the most informative alleles were found among the more frequent ones.

These results are interesting from a technical (application of ANN) and a more biological point of view (natural differentiation of this species, management of natural populations).

* Email: aurelle@crit.univ-montp2.fr

Wedding Connectionist and Algorithmic Modelling towards Forecasting Caulerpa taxifolia Development in the North-Western Mediterranean Sea

AUSSEM A.* and HILL D.

Laboratoire d'Informatique, de Modelisation et d'Optimisation des Systemes (LIMOS), ISIMA - Universite Blaise Pascal, Clermont Ferrand II, Campus des Cezeaux - B.P. 125, 63173 AUBIERE Cedex FRANCE

We discuss the use of supervised neural networks as a metamodelling technique for discrete event stochastic simulation with a view to reducing dramatically the computational burden involved by the simulations. A sophisticated computer model, coupling a Geographical Information System with a stochastic discrete event simulator, has been developed to anticipate the propagation of the green alga of tropical origin *Caulerpa taxifolia* in the North-Western Mediterranean sea. The model aims to provide reliable predictions, a couple of years in advance, of: i) the local expansion patterns of the alga, ii) the increase of taxifolia biomass and iii), the covered surfaces. Because the algorithmic model accounts for spatial interactions and anthropic dispersion/activities such as eradication, introduction of specific predators etc., simulations are extremely time and memory consuming. In order to reduce the computational burden, a neural network was successfully trained on artificially generated data provided by the simulation runs to provide accurate forecasts 12 years in advance along with confidence intervals thereof. The ability of the neural networks to capture the underlying physics of the phenomena is clearly illustrated on several experiments on a large coastal area. The neural network is able to construct, on this site, estimates of the taxifolia expansion 12 years in advance in nice agreement with the simulation trajectories.

Keywords - *Caulerpa taxifolia*, Invasive species, Neural networks, Discrete event simulation, Discrete spectral analysis, GIS.

* Email: alex@sp.isima.fr

A Comparison of Artificial Neural Network and Conventional Statistical Techniques for Analysing Environmental Data

BALL G.R. [1*], PALMER-BROWN D. [1] and MILLS G.E. [2]

[1] Department of Computing, The Nottingham Trent University, Burton Street, Nottingham, NG1 4BU. United Kingdom.
[2] ITE-Bangor, University of Wales, Deiniol Road, Bangor, LL57 2UP, United Kingdom.

Interactions between plants, tropospheric ozone pollution and environmental factors are complex and non-linear in nature (Balls *et al.* 1995b). Data sets can be generated in a variety of ways, for example exposing clover plants in acrylic chambers to a range of ozone concentrations at a range of microclimatic conditions, allowed to vary with ambient conditions (Balls *et al.* 1995a). During the last 5 years the authors have developed and refined techniques analysing and modelling these data using ANNs (Roadknight *et al.* 1997) This paper presents a comparative assessment using a range of statistical and artificial neural network modelling techniques. These techniques include linear regression, non-linear regression, multiple regression, stepwise regression, principle components analysis (PCA), PCA combined with least squares regression, back propagation ANNs and back propagation ANNs combined with PCA. The statistical approaches were tested for their performance on the training data and on new test data extracted as a subset of the original data set. Results are also presented of analysis of a number of methods used to determine the importance of input variables and patterns within the data set used. These methods help to refine the data analysis as part of an overall strategy for parsimonious modelling. In this study the best performances in terms of modelling test data were produced by PCA combined with the back propagation ANN, back propagation ANNs, and PCA combined with least squares regression, in that order.

* Email: graham.balls@ntu.ac.uk

Modelling primary production in a coastal embayment affected by upwelling using dynamic ecosystem models and artificial neural networks

BARCIELA R.[1*], GARCIA E.[2] and FERNANDEZ E.[1]

[1] Universidad de Vigo, Departamento de Ecoloxia e Bioloxia Animal, Facultad de Ciencias, Campus Lagoas- Marcosende s/n, E-36200, Vigo, Spain.

[2] Universidad de Vigo, Departamento de Linguaxes e Sistemas Inform ticos, Facultad de Ciencias, Campus Lagoas-Marcosende s/n, E-36200, Vigo, Spain.

Two modelling approaches, dynamic ecological simulation and neural network analysis, were used to describe and predict the main patterns of primary production temporal variability in a coastal embayment affected by upwelling (Ria de Arousa, West Coast of Spain). A one dimensional, carbon based, size-dependent dynamic simulation model physically forced by solar radiation, temperature, upwelling index and mixed layer depth was developed using object-oriented programming. The nutrient compartment includes dissolved inorganic nitrogen and labile dissolved organic carbon. The model is defined by six main biological compartments: nanophytoplankton, microphytoplankton, microzooplankton, mesozooplankton, bacteria and cultured mussels. The model was tunned with a three years data series (1992 to 1994) from the region and validated using data collected in the same area in 1995 and 1996. The model reproduces both seasonal and interannual patterns and magnitudes of nutrient concentration and phytoplankton biomass. The correlation coeficient between measured and modelled phytoplankton biomass and nutrient concentration from 1995 to 1996 were 0.17 and 0.49, respectively. Major disagreements observed between modelled results and sea-truth data are largely due to the presence of poleward slope currents not considered in the physical formulation of the model.

Neural network models were also developed using backpropagation networks with one or two hidden layers and sigmoid and sinusoidal activation functions. The correlation between observed and modelled phytoplankton biomass from 1992 to 1994 were 0.99 and 0.71 for daily and weekly predictions, respectively.

Both modelling approaches yield valuable information. The dynamic simulation model contributes to the understanding of cycling of matter through planktonic food webs but, although reproducing the main patterns of large-scale variability, its predictive potential is low due to the large uncertainty associated with parameter estimation. By contrast, the neural network model, although not providing information on ecosystem functioning, has demonstrated to be a powerful predictive tool for short (daily to weekly) time scales.

* Email: rmba@soc.soton.ac.uk

Predicting local fish species in the seine river basin with artificial neural networks

BOËT P.[1♣] and FUHS T.[2]

[1] URE qualité et fonctionnement hydrologique des systèmes aquatiques, Cemagref BP44, 92163 Antony, France.
[2] Laboratoire d'Ingénierie pour les Systèmes Complexes, Cemagref BP44, 92163 Antony, France.

Ichthyological communities are the expression of fundamental biological processes (reproduction, feeding, and shelter) expressed at different scales in time and space. They can be considered to be good indicators of the health of aquatic ecosystems.

The identification, ranking and evaluation of the various key factors responsible for the current state of these communities are essential tools for the conservation or restoration of the populations and environments.

We attempted to model the highly non-linear relationships between the environmental descriptors and the fish species, by the means of neural networks, because of their robustness with respect to noised or incomplete data.

Our work is based on a large database covering the whole Seine River basin (700 fish catches on 583 sampling stations). Those data result of *in situ* electrical fish catches. They are by nature extremely heterogeneous, on the one hand, because they are the result of samplings implemented to meet various objectives, and on the other hand because of the inevitable biases intrinsic to the catch technique used, especially in the case of large waterways.

We used one-hidden layered neural networks, endowed with 2 to 10 hidden neurons, for each of the 26 most frequent species over the Seine river basin. Their inputs are six variables (stream order, river slope and width, water quality, habitat quality, and ecoregion) from the fifteen available covariates describing the characteristics of the river.

Cross-validation estimates of good prediction raise an accuracy from 60% to 85%, depending on the species. The best levels of success were obtained for those species whose ecological profiles are clear, like head-water stream fishes. The poorest ones are supported by ecological explanations, *e.g.* the bimodal repartition of the gudgeon or the limited efficiency of the catchment of bream.

Finally, we discuss methodological improvements, and plead for a sound comparison between neural nets and other non-linear techniques.

♣ Email: philippe.boet@cemagref.fr

Neural network predictions of air pollution concentrations in an urban area

BORDIGNON S.A. and GAETAN C.*

Department of Statistics, University of Padova, via S. Francesco, 33, I-35121 Padova, Italy.

In the context of air quality management, short-term real time prediction of future ambient concentrations is a relevant aspect. In fact, whenever the predicted concentration exceeds the pre-assigned standard, proper actions can be taken or at least an alarm can be given. In view of such use for control or alarm purposes, time series analysis techniques, namely the so-called ARMAX (Auto Regressive Moving Average with exogenous inputs) stochastic models, have been widely employed as an alternative to deterministic models (Milionis and Davis, 1994). However, such models have not been proved always satisfactory, expecially in providing accurate predictions in situations of forthcoming pollution "episodes". In fact, it is widely recognized that (a) pollution concentrations depend heavily on meteorological factors, (b) this relationship may be highly nonlinear and (c) the dynamics itself may be nonlinear. Obviously these nonlinearities can not be adequately captured by linear ARMAX models.

In this paper we adopt a nonlinear point of view in modelling and predicting pollution concentrations. Because there are few physical insights about the dynamic relationship between pollution concentrations and meteorological factors, rather than searching for a specific nonlinear parametric model, we propose a nonlinear black-box structure (Sjoberg et al. 1995) based on neural networks.

More precisely we train multilayer feedforward perceptrons in order to get one-step ahead predictions for some air pollutants (carbon monoxide, ozone and sulphur dioxide). The inputs are lagged values of the pollutants and related meteorological variables, recorded from one site of the monitoring urban area network of the municipality of Venice. Observations are taken on an hourly basis

Some care is dedicated to the network pruning and validation. In order to avoid overtraining we employ jointly statistical significance tests (Cottrell et al. 1995) and BIC-like information criterion in order to eliminate 'superfluous' weights. If the pruned network is adequate, then the one-step ahead prediction error should be unpredictable from all linear and non linear combinations of past inputs and outputs. Thus we use some correlation tests for non-linear models (Billings and Voon, 1986) in order to perform model validation.

Finally we deal with the task of multi-step ahead prediction of the pollutants (up to 24 hours). We consider two different methods: the first and usual one consists in taking successive predicted values as new inputs; the other is a new method based on bootstrap techniques which requires more computation, but can provide predictive confidence intervals. The results show substantially better predictive performances of the last method.

* Email: gaetan@hal.stat.unipd.it

References

Billings S.A. and W.S.F. Woon (1986), 'Correlation based model validity tests for nonlinear models', Int. J. Control, 44, pp. 235-244.
Cottrel M. et al. (1995), Neural modelling for time series: a statistical stepwise method for weight elimination, IEEE Trans. on Neural Networks, 6, pp. 1355-1364.
Milionis A.E. and T.D. Davies (1994), Regression and stochastic models for air pollution - I. Review, comments and suggestions, Atmospheric Environment, 28, 17, pp. 2801-2810.
Sjoberg J. et al. (1995), Nonlinear black-box modelling in system identification: a unified overview, Automatica, 31, pp. 1691-1724.

Unsupervised learning for exhibiting new properties: from observations to assumptions

BOURRET P. [*]

ONERA-DTIM,

A well known drawback of neural networks is to look like a "black box" allowing to exhibit relationships which may be extremely difficult to explain. Moreover, it could seem impossible to discover a new and significant feature describing a phenomenon by using neural networks. The aim of this paper is to prove that unsupervised learning allows a better understanding of a given phenomenon which is described by a set of data. In order to illustrate what we claim, we use a very simple set of data (average temperatures of a set of cities). We show that classification allow us to exhibit several well known properties (like opposite behaviour in the northern and southern hemispheres). Particularly, we show that the interest of unsupervised learning is not only to exhibit families, but also to discover "new" features (like distance to the west coast and east coast of continents), which are the projections on axis like it can be done by using principal component analysis.

We also point out the interest of the study of outlayers. We recall in our conclusion that such a method only allows to exhibit assumptions which must be proved by another way.

[*] Email: bourret@cert.fr

The use of artificial neural networks to assess fish community structure in the littoral zone of a mesotrophic lake

BROSSE S.*, GUÉGAN J.F., TOURENQ J.N. and LEK S.

CNRS, UMR 5576 CESAC - Université Paul Sabatier, 118 Route de Narbonne 31062 Toulouse cedex, France. E-mail: brosse@cict.fr

The present work describes a comparison of the ability of Multiple Linear Regression (MLR) and Artificial Neural Networks (ANN) to predict fish population and community structures in a mesotrophic reservoir. The models were developed and tested using 306 observations with the Sampling Point Abundance method performed by electrofishing in a restricted littoral area of lake Pareloup providing a wide range of topographical characteristics. It is a large mesotrophic reservoir (1250 ha.) located in the South West of France. For each of the 306 samples, the relationships between the physical environment and the abundance of various fish species were studied. For the 15 fish species colonising the lake, 6 main species (i.e. populations) were retained to perform ANN and MLR, explanatory variables being provided by the same data matrix. Each of the 6 MLR and ANN models had 9 independent environmental variables (i.e. depth, distance from the bank, slope of the bottom, flooded vegetation cover, % of boulders, % of pebbles, % of gravel, % of sand and % of mud) and 1 dependent variable (fish density for the considered species). Modelling procedures were run after log (x + 1) transformations of the dependent variable. Principal component analysis was performed on the partial coefficients of the MLR and on the relative contribution of each independent variable of ANN models (determined using Garson's algorithm), to determine the community structure.

The results stress that ANN are better suited to predict fish abundance at the population scale than MLR. In the same way, a higher level of ecological complexity i.e. community scale, was reliably obtained by ANN whereas MLR presented serious shortcomings. The ANN modelling approach used here is a fast and flexible way to incorporate multiple input parameters into a single model. In addition to the predictive value of the model, the combination of ANN and multivariate analysis simultaneously visualise the results provided by several ANN models with the same data matrix at the input. Thus, ANN are more suited than MLR to reproduce the operation of real complex multi-species systems (i.e. community structure) on the basis of the ecological variables introduced in the model.

* Email : brosse@cict.fr

Support Vector Machines for Optimal Classification and Spectral Unmixing

BROWN M.*, LEWIS H. and GUNN S.

Image, Speech and Intelligent Systems Research Group, Department of Electronics and Computer Science, University of Southampton, Southampton, SO17 1BJ, UK

Support Vector Machines (SVMs) are currently attracting a lot of interest in the fields of empirical data classification and modelling, due to their performance on real-world data sets [1]. They are based on the concept of "optimal" linear discrimination which aims to maximally separate two classes. Implicit in this technique is the idea that only the data points which lie on the edge of the class conditional distributions should determine where the discrimination boundary lies, and the remaining data points (the majority) can be discarded. However, the technique is not limited to linearly separable problems and it can be used to model data with overlapping classes, non-linear discrimination regions and for modelling and regression problems. In all cases, the algorithms select a small (typically 3 or 5%) sub-set of the training data which contains the most important information. Only this data is used in the model's/classifier's design.

It can be shown that Linear Spectral Mixture Models (LSMM) have much in common with the linear SVM algorithm, and under certain circumstances, they are equivalent [2]. However, the SVM approach is more attractive as it performs automatic pure pixel selection and it can be extended to deal with spectrally mixed classes and non-linear mixture regions within the more general framework. The techniques are currently being evaluated as part of the FLIERS project [3], which is investigating the use of area modelling for land cover estimation from remotely sensed data. This is an important point, as instead of using binary training data to represent the "true" class for that pixel, an estimate of the mixing proportions must be generated and used to train the system. Often the chosen land cover classes cannot be uniquely discriminated between, hence the variance in the training data may arise from spectral confusion, rather than viewing the variance as arising from the inherent sub-pixel mixing process.

It has been found that the ability of the technique to handle classes which overlap means that it can be applied more easily to the real Landsat TM data (as compared with selecting pure pixels and using LSMM). A precise definition of the performance improvement is difficult as both techniques are similar if appropriate pure pixels are selected, but it is argued that the selection procedure is a difficult process to formulate and optimise. In addition, results will be generated over the summer on using non-linear kernels (polynomials, radial basis function and sigmoidal) and assessing their performance on the real-valued area-based target data.

[1] V. Vapnik, 1995, The Nature of Statistical Learning Theory, Springer-Verlag, New York.

[2] M. Brown and H.G. Lewis, 1998, Support vector machines and linear spectral unmixing for remote sensing, ICAPR-98, November, Plymouth.

[3] H.G. Lewis, M. Brown, A.R.L. Tatnall, M. Nixon and J. Manslow, 1998, Data Analysis and Empirical Classification in FLIERS, Project Report.

* Email: mqb@ecs.soton.ac.uk

Temporal Patterning of Community Data by Utilizing Artificial Neural Networks

CHON T.S.[1*], PARK Y.S.[1] and CHA E.Y.[2]

[1] Department of Biology, Pusan National University, Pusan 609-735, Korea
[2] Department of Computer Sciences, Pusan National University, Pusan, 609-735, Korea

Dynamic feature of community data in sequential samples (e.g. monthly collections) were extracted by the use of spatio-temporal artificial neural networks. A set of sequential data in a given pre- and post-period were provided as matching inputs and outputs for training to the network, and various forms of temporal changes in communities in these sequential periods were patterned in the network. Subsequently new field data for community dynamics were given to the trained network as inputs, and, after recognition, subsequent community data were predicted as matching outputs by the trained network. The field data used in this study were benthic macroinvertebrate communities collected at various study sites with different environmental impacts in the Suyong river in Korea. Densities of selected taxa (number of individuals per square meter) in monthly samples were given as sequential data sets for training. Through learning the network conveyed the general conformational characteristics in community dynamics in the field data in its weights, and it was demonstrated that the complex data of community changes could be comprehensible in a reduced dimension in this study. The sequential patterning by the network generally represented temporal characteristics and other environmental impacts implied to the study sites. Advantages and disadvantages in patterning spatial- and temporal-data in community dynamics were also discussed.

* E-mail: tschon@hyowon.pusan.ac.kr, ecosys@chollian.net

Forecasting sardine biomass using regression and neural network models.

CISNEROS M.A.*

Instituto National de la Persa, Calle 20#605 sur Guaymas 85400 Sonora, Mexico

Small pelagic fish species like sardines and anchovies have complex population dynamics as a result of their close relation to the environment, short life span and variable recruitment. Consequently, their prediction and management are particularly difficult. We evaluated performance of regression and artificial neural network models to forecast one year in advance the annual spawning biomass of Pacific sardine (*Sardinops sagax)* of the California current. Due to high auto-correlation In the series of biomass, extrapolations one year in the future were good up to 1992. After that year, forecasts were satisfactory when mean water temperature, over 3 years prior to the year of the forecast, was included in the models. With the 45 data points we used, regression models performed better than artificial neural networks, which seems to have resulted from shortness of the data series. However, inclusion of parameters other than temperature in the networks resulted in over-training and poor performance, thus indicating a threshold length of the series for good performance.

Key words: Pacific sardine; neural networks; biomass forecasts.

* Email: Mocıta@enlace.com.mx

Neural network models to study relationships **between lead concentration** in **grosses and urban permanent descriptors** In **Athens city (Greece)**

DIMOPOULOS Y.[1], CHRONOPOULOS J.[2], LEK S.[3] and CHRONOPOULOU-SERELIL A.[1]

[1] Laboratory of Physics and Meteorology, Agricultural University of Athens, 75, lera Odos, 11855 Athens, Greece.
[2] Laboratory of Floriculture and Landscape Architecture, Agricultural University of Athens. 75, lera Odos, 11855 Athens, Greece.
[3] CESAC UMR 5576, Bat 4R3, CNRS-Université Paul Sabatler, 118 route de Narbonne, 31062 Toulouse cedex, France.

The aim of the present work is to propose a model for the estimation of lead concentration in grasses using urban descriptors easily accessible and to study the specific effect of each descriptor on lead concentration. Lead concentrations were determined on one grass species, *Cynodon dactylon* (L.) Pers, (Bermuda grass), collected from 30 different locations in Athens city. The proposed model is a multilayer perceptron (MLP) trained by backpropagation. The predictive quality of the, model was judged by two cross-validation methods. The generalization ability of the model is confirmed by a determination coefficient higher than 0.91. The study of the first partial derivatives of the output of the MLP with respect to each input is used to obtain a identification of the factors influencing the lead concentration and the mode of action of each factor.

A fishery model based on search behaviour of both preys and fishermen represented by neural networks and learning through reinforcement.

DREYFUS M.*

Facultad de Ciencias Marinas, U.A.B.C., P.O. Box 189003-70, Coronado CA 92178-9003.

A model of the yellowfin tuna (*Thunnus albacares*) fishery in the Eastern Pacific Ocean is build with emphasis on behaviour of both preys (tunas) and predators (fishermen). In both cases behaviour is decided by neural networks that learn through reinforcement learning techniques, rewarding actions that promote higher fitness through trial and error experimentation with the environment. The feedback is a scalar payoff hence no explicit teacher is needed and little or no prior knowledge is needed. Artificial tunas search for confort areas an adopt a behaviour observed in nature in relation to patchy habitats where position in relation to food patches or there extension is unknown. A higher sinuosity of movement is observed within confort areas augmenting the probability of staying in those patches. The same is true for fishermen in the real world as well as for artificial fishermen (fishermat). A two neural network model is considered for the fishermat. It is assumed that fishermen have some knowledge of fishing grounds extension and location but once there, no knowledge of prey position exist. One neural network deals with decisions to stay or move from areas or fishing grounds while the other neural network is related to search movement decisions within the area chosen.

* Email: dreyfus@cicese.mx

Ultrafast estimation of DBH repartitions from ground based photographs, using neural networks

DUBOIS M. A.[1*], CHAVE J.[1], RIERA B. [2] and COURNAC L.[3]

[1] SPEC, CEN Saclay-Orme des Merisiers, F91191 Gif sur Yvette Cedex, France.
[2] Laboratoire d'Ecologie Générale, MNHN, CNRS, URA 1183, 4 avenue du Petit Château, F91800, Brunoy, France.
[3] Laboratoire d'Ecophysiologie de la photosynthèse, DEVM/DSV, CEN Cararache, F13108, St Paul-lez Durance, Cedex, France.

Obtention of DBH (trunk diameter) data by exhaustive in-situ tree counting and measurement is extremely time consuming; nevertheless it is a very important element to describe and study a forest ecosystem. When data is available, it usually covers a highly localised area, whereas datas covering extensive regions are necessary to understand landscape behaviour.

We have developed a method to derive DBH histogram estimations from standardised ground based photographs, using a neural network (back propagating multi-layer perceptron) . This network has been previously trained on a set of photographs taken on a grid where hand counting was available.

Applications to forest in French Guyana, Cameroon and Madagascar are discussed.

* Email: mad@spec.saclay.cea.fr

Applications of the Kohenen Self-Organising Feature Map Neural Network in Ecological Data Analysis

FOODY G.M.*

Department of Geography, University of Southampton, Highfield, Southampton, SO17 1BJ

The Kohenen Self Organising Feature Map (SOFM) neural network is a powerful technique for data analysis that has attracted relatively little attention in ecological analysis. The SOFM is very dissimilar to the more widely used neural networks, such as the feedforward or multi-layer perceptron, which have proved attractive for applications such as (supervised) classification and prediction. The main differences relate to the network's architecture and approach to learning. The network comprises two layers only, one each for input and output, with each unit in the input layer connected to every unit in the output layer. As indicated by its name, the SOFM is based on unsupervised learning. It is therefore suited to clustering, an important issue in statistical ecology. Relative to other clustering approaches used in ecology the SOFM has a range of advantages, not least the freedom from distribution and linearity assumptions. However, the SOFM represents more than just an alternative clustering algorithm for the ecologists toolbox.

In essence, a SOFM performs a classification by reducing the input data dimensionality by converting the input feature space (e.g. floristic survey data) to a topologically ordered map. Typically the output units of the SOFM are arranged in a low, often one or two, dimensional, array or map. Each output unit in this map receives the input patterns in parallel and the network has lateral unit interaction in this output layer. The SOFM uses a competitive approach to learning that acts to group together similar patterns in a part of the output layer while at the same time distancing them from other, less similar, patterns that belong to other groups. The output of the network is thus an ordered display which can be interpreted to yield useful information. This paper aims to briefly outline the main features of the SOFM network. Although the main focus will be on the network's potential for clustering, particularly in terms of community classification, further possible applications and interpretations of the outputs will be discussed. In particular, the spatial distribution of the clusters in the SOFM output may be used to indicate association. Moreover, since the topological map derived from the SOFM is, in effect, a display of the relative locations of samples along a set of the axes it may be used to provide information on ecological similarities and relations in a manner similar to ordination analyses; the interpretation of relative distances and locations in the output, however, requires caution. These issues will be considered using two data sets. Firstly, for comparative purposes the SOFM will be compared against a range of conventional methods in statistical ecology using published data sets. Secondly, it will be evaluated for the analysis of moorland vegetation data acquired from transect surveys across Exmoor in SW England. The similarities and differences in the of the results obtained will be stressed and future possible research issues presented.

* Email: G.M.Foody@soton.ac.uk

Fuzzy Mapping of Coastal Vegetation from Remotely Sensed Imagery with a Feedforward Neural Network.

FOODY G.M.*

Department of Geography, University of Southampton, Highfield, Southampton, SO17 1BJ

Remote sensing has considerable potential for the mapping and monitoring of vegetation. However, this potential has often not been fully realised. Of the many reasons for this, one major limitation has been the reliance on conventional hard image classification approaches as the tool in mapping. Thus, for instance, a common approach to mapping has been to use a supervised classification such as the maximum likelihood classification. This is only appropriate under a set of stringent circumstances, which include the requirement for the classes to be discrete and mutually exclusive. Often, and particularly for mapping natural and semi-natural vegetation, this is not the case as the classes are continuous and intergrade. A conventional hard classification cannot appropriately represent such classes, especially in the transitional areas, which are often of particular ecological significance, where they may co-exist spatially. An alternative approach to mapping is to use fuzzy or soft methods. With these each image pixel is allowed multiple and partial class membership and so can represent the full range of class membership from pure stands of a particular class to complex mixtures. The output of such an analysis is typically a map or set of maps displaying the spatial variation in the grade of membership to selected classes. A variety of techniques have been developed for vegetation mapping, ranging from softened statistical classifications to fuzzy classification algorithms but here attention is focused on the use of a feedforward neural network. This paper will outline the derivation of a fuzzy vegetation map from multi-spectral remotely sensed imagery of a coastal test site in Wales. At the site there are a range of classes that lie in a complex mosaic of intergrading classes with occasional clumps of relatively discrete (e.g. woodland) classes. The advantages of the neural network approach over other methods will be outlined. This will focus on the freedom from distribution and linearity assumptions as well as issues related to the pre-processing of the remotely sensed imagery and selection of training samples. The derivation of the fuzzy output, through extraction of the output layer unit activation functions, will be explained and the accuracy of the classification evaluated against a map produced from field survey undertaken at a time near the date of the acquisition of the remotely sensed imagery. For comparative purposes the results will be compared against a classification derived from the same data using conventional techniques. The paper will conclude with a discussion of the potential to refine the approach and possible use of other types of neural network, notably radial basis function networks, and neuro-fuzzy methods.

* Email: G.M.Foody@soton.ac.uk

Application of the Self-organizing map method to microsatellite data: how to detect genetic structure in brown trout (*Salmo trutta*) populations

GIRAUDEL J.L.[1*], AURELLE D.[2], LEK S[3] and BERREBI P.[2]

[1] IUT Périgueux-Bordeaux IV, Département Génie biologique, 39 rue Paul Mazy, 24019 Périgueux Cedex

[2] Laboratoire Génome et Populations, CNRS UPR 9060, Cc063, Université Montpellier II, Place Eugène Bataillon, 34095 Montpellier Cedex 05 France. Email: aurelle@crit.univ-montp2.fr, berrebi@crit.univ-montp2.fr

[3] CESAC, CNRS UMR 5576, Bat 4R3, Université Paul Sabatier, 118 route de Narbonne, 31062 Toulouse Cedex, France. Email: lek@cict.fr

The aim of this study was to analyse the structure and the relationships of French river and domestic brown trout (*Salmo trutta*) populations in the western part of French Pyrenees through genetic data. It was known that two wild forms are naturally present: ancestral Atlantic and modern Atlantic; moreover, stocking practices led to the presence of a third form: domestic modern Atlantic trout.

Artificial Neural Network can be an useful tool to reveal the composition of each population. With the potential presence of the three forms of trout in the same river, a unsupervised learning process is convenient to be used. The Kohonen Self Organising Map (SOM) algorithm allows to visualise and cluster high dimensional data without a priori knowledge. To describe the genetic structure, the input data were 4 microsatellites loci analysed for 245 trouts and the output layer is a rectangular grid laid out in an hexagonal lattice of 80 neurones.

Microsatellite are highly variable genetic markers and are expected to give a precise image of the genetic relationships of quite similar trout forms. A SOM analysis was then performed and followed by a Fuzzy-Clustering-Mean (FCM) analysis applied to the Kohonen map in order to classify all the individuals among 6 fuzzy-clusters. This clustering has been analysed according to the origins of the individuals. It confirmed the existence of several wild forms in south-western France, and gave some indications about the impact of stocking with domestic individuals in these rivers. This confirms that ANNs are well suited for population genetics data

Keywords : Trout, Genetic data, Microsatellites, Kohonen maps, Neural networks, Fuzzy clustering

* Email: giraudel@montesquieu.u-bordeaux.fr

Land-cover classification of multiespectral imagery using an advanced neural system

GONCALVES M.L.*

PUC - MINAS Av. Padre Francis Cletus Cox, 1661 Cep 37701-355, Pocos de Caldas - MG - Brasil.

This work presents an Artificial Neural Networks based system for the land-cover classification of multispectral imagery. The system consists of two processing modules: an Image Feature Extraction Module using Kohonen's Self-Organizing Map and a Classification Module using Multi-Layer Perceptron network. The system was developed aiming at two specific goals: to exploit the advantages of unsupervised learning for feature extraction and the testing of techniques to increase the learning algorithm's performance concerning training time. More specifically, this work tests the implementation of a parallel learning algorithm for Kohonen's SOM in a multiprocessing environment and the utilization of a second-order learning algorithm for the MLP network. The experimental results exhibit a much superior performance by both algorithms. To test the applicability of this work, the system was applied to the classification of a LANDSAT/TM image segment from a pre-selected testing area and its performance was compared with that of a Maximum Likelihood Classifier, conventionally used for multispectral images classification. The good results obtained by the neural classification allied to the performance improvement encourage therefore further research efforts in this area.

* Email: marcio@pcaldas.pucminas.br

Neural Networks for Modelling the Transfer Function between Marine Reflectance and Phytoplankton Pigment Concentration

GROSS L.[1*], THIRIA S.[1], FROUIN R.[2]

[1] LODYC (Laboratoire d Oceanographie DYnamique et de Climatologie) Universite Pierre et Marie Curie (Paris 6) Tour 26 - 4eme etage - boite 100 4, place Jussieu 75252 Paris cedex 05., France

[2] Scripps Institution of Oceanography University of California San Diego 9500 Gilman Drive La Jolla, CA 92093-0221, e-mail: rfrouin@ucsd.edu,

Neural networks are now widely used as non-linear models to fit continuous transfer functions. In this study we apply well-known methodology and theoric properties relative to a particular class of neural network, the multilayered perceptrons, to a geophysic inversion: the estimation of the concentration of chlorophyllous pigments in the near-surface of oceans from Ocean Color measurements. This bio-optical inversion is established by analyzing concomitant sun-light spectral reflectances over the ocean-surface and pigment concentration. The relationships are complex, non-linear, and their biological nature implies a significant variability, that we can analyse as a 'biological noise' added to a mean bio-optical relationship. Moreover, the sun-light reflectances are usually measured by satellite radiometers flying at 800 km over the ocean surface, which affected the data by adding radiometric noise and atmospheric correction errors. By comparison with the polynomial fit usually employed to treat this problem, we show the advantages of neural function approximation like the association of non-linear complexity and smoothness. Moreover, as the real problem of ocean color is dealing with noisy data, neural networks appear to be a good solution to decrease the errors of a model calibration made with satellite's reflectances.

* e-mail: lgr@lodyc.jussieu.fr, thiria@cnam.fr

Global epidemiology and human infectious disease occurrences

GUEGAN J.F.[1*], THOMAS F.[1], DE MEEUS T.[1], LEK S.[2], TYBAYRENC M.[1] and RENAUD F.[1]

[1] Centre d'Etudes sur le Polymorphisme des Micro-organismes, Centre ORSTOM de Montpellier, U.M.R. C.N.R.S.- I.R.D. 9926, 911 avenue du Val de Montferrand, Parc Agropolis, F-34032 Montpellier cédex 1, France.

[2] C.E.S.A.C., U.M.R. C.N.R.S. 5576, Bâtiment IVR3, Université Paul Sabatier, 118 route de Narbonne, F-31062 Toulouse cédex 4, France. Email : lek@cict.fr

Desperately, processes governing infectious disease patterns at largest scales have been largely neglected untill now. The prime interest was focused on recognition and determination of spatial patterns of infectious diseases world-wide with modernisation and control programme effort variables accounting for most of their explanation. Accordingly, the key-proximate determinants in human population characteristics are "by tradition" those related to development, modernisation, culture and family planning influences. However, little has contributed to exactly specify what kinds of evolved mechanisms in humans might underlie such variation in disease patterns on Earth. In a former work, we demonstrated that humans may have optimised some of their life-history traits as an adaptative flexibility to variation in parasite pressures across regions. Very scarce studies have selected parasitism as a potential environmental variable having influenced human patterns, and evolutionary theory may probably contribute to a better understanding of human life-history characteristics. Here, we use the potential of two multivariate models, i.e. logistic regression and artificial neural network, in predicting infectious disease occurrences from a set of co-evolved human life-history traits. We then compare the performance of both methods in describing the actual spatial distribution and species occurrence of human diseases at the global level. Both methods converge and adequately describe most of the disease distributions and occurrences world-wide. Our findings point out that infectious disease distribution and occurrence are well designed by human life-history traits which tends to reinforce the importance of an evolutionary explanation to human condition within its environment.

* Email: guegan@cepm.mpl.orstom.fr

State-of-the-art of ecological modelling with emphasis on development of structural dynamic models

JORGENSEN S.E.*

DFH, Environmentai Chemistry, University Park 29 2100 Copenhagen 0, Denmark.

Ecological modelling originates from Lotka-Volterra and Streeter-Phelps in the twenties, while the comprehensive use of models in environmental management started in the beginning of the seventies.

During the seventies we learnt that development of ecological models requires a comprehensive knowledge to the functioning of ecosystems and that it is extremely important to find a balanced complexity considering the available data, the ecosystem and the focal problem. Meanwhile many models have been developed and today we have the experience form more than 4000 ecological models which have been used as tool in research or environmental management. Recently (1995), a book "Environmental and Ecological Modelling" by S.F-. Jorgensen et al., Lewis Publisher, reviewed more than 400 models and gave details about the models. The idea was to give the experience from previous modelling studies to those who want to develop models of similar ecosystems or focusing on similar environmental problems.

In spite of the widely gained experience in ecological modelling, we are still facing serious problems in modelling, which, however, we attempt to overcome. The main problems are in short: 1) usually / often we cannot get sufficient data to develop models which can give reliable prognoses 2) the parameter estimation is often the weakest point in modelling 3) the models don't reflect the real properties of ecosystems, particularly their adaptability and ability to meet change in forcing functions with change in species composition. Several research ideas have been pursued to solve these problems. A review of these ideas is the core of the presentation-. i) fuzzy models ii) use of chaos theory in modelling iii) use of catastrophe theory in modelling iv) use of artificial intelligence in parameter estimation v) estimation methods for parameters vi) data base of ecological parameters vii) more use of ecological properties as constraints for our models, included the use of these constraints for parameter estimation viii) use of fractal theory in modelling ix) development of structural dynamic models.

* Email: sej@mait.dfh.dk

Predicting Ecologically Important Vegetation Variables from Remotely Sensed Optical/Radar Data Using Neural Networks

KIMES D.S.* and NELSON R.F.

Biospheric Sciences Branch, Code 923, Laboratory for Terrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

A number of satellite sensor systems will collect large data sets of the Earth's surface during NASA's Earth Observing System (EOS) era. Efforts are being made to develop efficient algorithms that can incorporate a wide variety of spectral data and ancillary data in order to extract vegetation variables required for global and regional studies of ecosystem processes, biosphere-atmosphere interactions, and carbon dynamics. These variables are, for the most part, continuous (e.g. biomass, leaf area index, fraction of vegetation cover, vegetation height, vegetation age, spectral albedo, absorbed photosynthetic active radiation, photosynthetic efficiency, etc.) and estimates may be made using remotely sensed data (e.g. nadir and directional optical wavelengths, multifrequency radar backscatter) and any other readily available ancillary data (e.g., topography, sun angle, ground data, etc.). Much of the current remote sensing research involves the development of techniques to accurately extract continuous vegetation properties. It is clear from the literature that significant problems exist with the "traditional techniques" being used. These are very topical and truly difficult problems that are being encountered in the remote sensing community.

Neural networks can provide solutions to many of these problems and have significant advantages as compared to traditional techniques when applied to both measurement and modelling studies. Neural networks can be used: 1) to provide accurate initial models for extracting vegetation variables when an adequate amount of data is available; 2) to provide a performance standard for evaluating existing physically-based models; 3) to invert multivariate, physically based models; 4) in a variable selection process to identify those independent variables which best infer continuous vegetation measures; and 5) to incorporate new data sources that would be difficult or impossible to use with conventional techniques. In addition, neural networks employ a more powerful and adaptive nonlinear equation form as compared to traditional linear, index transformations, and simple nonlinear analyses. These neural networks attributes are discussed in the context of two investigations performed to extract the age of secondary growth forests in Rondonia and forest biomass in a Maine forest and other literature studies.

* Email: dan@pika.gsfc.nasa.gov

Analysis and prediction of sardine catch changes in Sagami Bay, Japan, using a neural network

KOMATSU T.[1*], AOKI I.[2], MITANI I.[3] and HWANG K.[4]

[1] Ocean Research Institute, University of Tokyo, Minamidai, Nakano, Tokyo 164, Japan.
[2] Department of Bioscience, Graduate school of Agricultural and Life Science, University of Tokyo, Yayoi, Bunkyo, Tokyo 113, Japan.
[3] Kanagawa Prefectural Fisheries Research Institute, Jyogashima, Misakicho, Miurashi, Kanagawa 238-02, Japan.
[4] National Fisheries Research and Development Agency, Shirang-ri, Kijang, Pusan, Korea.

In Sagami Bay of central Japan, adult sardines are caught by several large set nets in spring. This species is very important for commercial fisheries. Because the set nets are traditional passive fishing method, not only biological but also physical environmental parameters influence the catch. This paper examined the long-term change in sardine catch by the set nets in spring in Sagami Bay in response to biological and physical (hydrographic and meteorological) environmental parameters using a neural network as a nonlinear multivariate analysis method. Sardine catch data collected from 1978 to 1994 were analysed. We consider flow patterns of the Kuroshio (warm current) and Oyashio (cold current), sea surface temperature, meteorological parameters as environmental factors and sardine catch in several regions in the precedent years. Back propagation neural networks were trained to generate mapping functions between environmental variables and sardine catch. The performance of the trained network models was measured by cross-validation. Changes in sardine catch could be predicted from environmental conditions. Weights of input variables and sensitivity analysis of networks showed that catch of sardine by purse seines in the adjacent sea in the precedent autumn and the flow patterns of the Kuroshio had consistently a great impact on the sardine catch. The developed model could predict its change between 600 t/year and 1800 t/year.

* Email: komatsu@ori.u-tokyo.ac.jp

Predicting fish yield of African lakes using neural networks

LAE R.[1*], LEK S.[2] and MOREAU J.[2]

[1] Centre ORSTOM de Brest, B.P. 70, 29280 Plouzané, France.

[2] CESAC UMR 5576, Bat 4R3, CNRS-Université Paul Sabatler, 118 route de Narbonne, 31062 Toulouse cedex, France.

[3] Labo d'Ingénierie Agronomique, ENSAT, INP, Av. de l'Agrobiopole, Auzeville-Tolosane, BP 107, 31326 Castanet-Tolosan cedex. Email: moreau@ensat.fr

Understanding and predicting biological productivity is considered as a key question for lake fisheries scientists because fisheries management should be based on a realistic estimation of the potential fish yield. Several tests were made in the past for determining the abundance of living stocks using some non biotic characteristics of aquatic ecosystems. For the development of predictive models of fish abundance, multiple linear regression and discriminate analysis have remained, the most frequently used techniques. However, these techniques showed serious shortcomings because abundance of fish and environment characteristics show non-linear or non-monotonous relationships. Using techniques based on correlation coefficients is often inappropriate. For this reason we used the artificial neural networks which may be applied to different kinds of problems, e.g. pattern classification, interpretation, generalization or calibration. The aim of this study was to analyse the level of relationships between some physical environmental parameters and the fish yield on African lakes, and also to propose the basis of the development of predictive tools using neural network methodology.

Artificial neural network approaches to modelling and prediction of fish yield as related to the environmental characteristics were developed from combinations of 6 variables: Catchment area over Maximum area, Fishing Effort, Conductivity, Depth, Altitude and Latitude. For a total of 59 lakes studied, the correlation coefficients obtained between the estimated and observed values of abundance were significantly high with the neural network procedure (r adjusted=0.95, $p<0.01$). The predictive power of the ANN models was determined by the leave one out cross-validation procedures. This is an appropriate testing method when the data set is quite small and/or when each sample is likely to have 'unique information' that is relevant to the model. Fish yields estimated with this method were significantly related to the observed fish yields with the correlation coefficient reaching 0.83 ($p<0.01$). Our study shows the advantages of the backpropagation procedure of the neural network in stochastic approaches to fisheries ecology. Using the specific algorithm, we can identify the factor influencing the fish yield and the mode of action of each factor. The limitations of the neural network approaches as well as statistical and ecological perspectives are discussed.

Keywords: Predictive Modelling, Multiple regression, African lakes, Fish yield, Fisheries.

* Email: lae@orstom.fr

The comparative utility of neural networks and logistic regression in predicting the distribution of Himalayan river birds

MANEL S.[1*], DIAS J.M.[2] and ORMEROD S.J.[3]

[1] UPRES 159, Université de Pau et des Pays de l'Adour, UFR Sciences et Technologie, 12 bis avenue de Mounédé, 64100 Bayonne, France.

[2] UPRES-A-5033, Université de Pau et des Pays de l'Adour, UFR Sciences et Technologie, 12 bis avenue de Mounédé, 64100 Bayonne, France.

[3]Catchment Research Group, School of Biosciences, Cardiff University, PO Box 915 Cardiff CF1 3TL, UK.

1. In the largest ever survey of its type, we assessed the occurrence of 6 species of river birds along 180 streams in the Indian and Nepali Himalaya, which have the greatest diversity of river birds on earth. We compared the performance of multiple discrimant analysis (MDA), logistic regression (LR) and artificial neural networks (ANN) in predicting presence-absence from 32 variables describing altitude, slope, stream habitat structure, stream chemistry and aquatic invertebrate abundance.
2. An initial assessment compared model performance using the entire data (= training set) and threshold criteria for accepting predicted species presence set crudely to $p \geq 0.5$. ANN marginally outperformed the other methods, correctly predicting more cases (88-100%) than either LR (75 - 92%) or MDA (78-89%).
3. A more stringent comparison assessed prediction error on independent test data using a 'leave-one-out' (= jack-knife) approach replicated through 180 runs; we avoided possible bias from threshold criteria for accepting species presence by using a threshold inependent method (received operating characteristic = ROC plot). In this case, LR outperformed ANN, although differences in prediction error were greater in some species than others.
4. Reflecting well-known effects by species prevalence, in which each test species occurred at only 12-36% of the sites, all methods predicted true absences (i.e. negative predictive power: 82-97%) better than true presences (i.e. positive predictive power: 5-74%); LR produced the best positive predictions for 4 of the 6 species.
5. ANN was considerably more expensive in computing time, requiring for example one day per species for jackknifing, compared with 15 minutes in LR.
6. Besides illustrating the importance of testing ecological models using independent data, these study reveals that ANN do not yet have major advantages over conventional multivariate methods for assessing bird distributions. LR was also more straightforwad in providing testable hypotheses about effects by altitude and habitat character on species' presence. Higher positive predictive power in LR, if repeated in other studies, would provide benefits is assessing distributions of scarce or threatened species.

* Email: manel@messv1.univ-pau.fr

A Probabilistic Description and Interpretation of Sub-Pixel Area Estimation Procedures

MANSLOW J.* and BROWN M.

Image, Speech and Intelligent Systems Research Group, Department of Electronics & Computer Science, University of Southampton, Highfield, Southampton, SO17 1BJ, UK

This paper reports on work carried out on the European Union funded research project FLIERS (Fuzzy Land Information in Environmental Remote Sensing), the aim of which is to develop algorithms for estimating subpixel land cover area proportion estimates. It is anticipated that due to subpixel mixing of land cover types, such algorithms will yield more meaningful land cover maps than do traditional classifiers.

Traditional approaches to land cover classification using neural networks have involved the creation of classifiers by using a training set of crisply classified example pixels. This procedure is inappropriate for estimating land cover areas since the network predictions represent probabilities that the hypothesis attached to each network output is correct given the current network input, and are hence not area estimates.

To perform area estimation, it is necessary to train a network using training data where the training targets themselves represent area proportions. These may be obtained by coregistering high and low resolution satellite images of the same region, and then counting the proportion of high resolution pixels placed crisply into each target class which fall into each of the low resolution pixels. By doing this, the simple probabilistic interpretation of the network outputs is lost and, as a result, certain design issues, such as choice of activation functions, and objective function for training become less clear. Sum-of-squares and cross-entropy objective functions have both been used, for example, usually without rigorous justification.

This paper presents a frequentist-probabilistic interpretation of area-based fuzzy classifications of mixed pixels. Under this interpretation, Cox's axioms governing the manipulation of probabilities provide insight into the conditions necessary to achieve accurate subpixel area estimates. Specifically, justification is given for the use of the cross-entropy objective function and softmax activation functions on neural network output nodes.

The relationship between class definitions and the upper limit on the achievable accuracy of area estimates is also discussed. In particular, it is argued that the inclusion of classes without crisp spatial boundaries, or which are defined in terms of the spatial relationship between components, inevitably limits area estimation accuracy. In general, accuracy is maximised if classes are defined as a union of spectrally distinct components.

* Email: jfm96r@ecs.soton.ac.uk

Software Sensor Design Based on Empirical Data*

MASSON M.♣, CANU S. and GRANDVALET Y.

Heuristique et Diagnostic des Systèmes Complexes - UMR CNRS 6599, Université de Technologie de Compiègne, BP 529 - F-60205 Compiègne cedex - France

Without measurement there is no possible monitoring. Usually these measurements are provided by physical sensors. These sensors can be broadly classified into two groups: the cheap and reliable ones and the others, the expensive and unreliable ones. Unfortunately, for water. quality monitoring, some key parameters such as the ammonia concentration are given by expensive sensors. This paper is focused on how to use available, cheap and reliable measure to estimate these key parameters. That is to say: how to replace physical sensor by *software sensor.* To do so, some prior knowledge is needed about the relationship between the available measurement and the one to ne estimated. But very often, especially in the case of environmental data, there is no physical model available. In fact, the relations between variables are often non linear, time dependent with important delays and, last but not least, they suffer from a high level of noise and uncertainty. The positive point is that, thanks to the new generation of SCADA system, a lot of data is now available. This allows the model implemented in the logical sensor to be based on empirical data. This problem of retrieving dependencies from empirical data is known as *black box* modelling or *flexible regression.* Many difficulties arise with the use of black box models. First, the relevant inputs are not known. They have to be found among all possible explicative variables. Second, because of uncertainty, missing data cannot be known exactly. Rather than estimating a single value, it can be useful to give an interval where the real value is expected to lie at a given confidence level. Third, since this kind of model is based on empirical data, its validity depends on the nature of this data. If the input pattern is new with respect to the training data, the black box model has to detect it rather to give a wrong prediction.

These principles were applied on a real case. This paper presents the software sensor designed to measure the ammonia to monitor the impact of a waste water treatment plant. The raw data available for this study consist of on-line measurements on a period of 2 or 3 months. A first task was to select from the 18000 data (70 days) a subset of valid data. Only 12 days were selected and divided into a learning set used to determine the model of the data, and a test set used to check efficiency of the model. A data analysis was conducted to select the relevant inputs. A correlation between the ammonium and the temperature, the conductivity, the variations of oxygen between two instants and to some extent the oxygen and the variations of temperature was found. The variables level, pH, and turbidity were not retained for the study. Several prediction models were retained: a penalized least square linear fit (ridge regression), and two black-box models : the Nadaraya-Watson predictor, and a multilayered perceptron. The multilayered perceptron gave the best generalization error. A confidence interval is also given using the Nadaraya-Watson regressor. Special attention is devoted to the notion of validity domain allowing to limit the prediction to known areas of the input space and thus to decrease the generalization error. This application show the feasibility of the replacement of an expensive measurement, such as NH4, by a software or a virtual sensor. The prediction can be used either for the complete replacement of the physical sensor, or for its validation.

---

* This work has been done within the EM'S Esprit Project P-22442. The EM'S consortium is: Suez - Lyonnaise des Eaux, F, VKI Water Quality Institute, DK, Danfoss System Control, DK, Hitec, N, Computas, N and Heudiasyc CNRS, F.

♣ Email: mmasson@hds.utc.fr

Using Neural Networks to Examine Relationships Between Features of the Environment and Recruitment Variation in Exploited Marine Fish Stocks

MEGREY B.A.*

National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA 98115 USA.

Marine ecosystems are notoriously difficult to study. Their trophic relationships are multidimensional and their process linkages are complex and highly nonlinear. Consequently, applied ecological investigations attempting to relate oceanic physics, atmospheric physics, and marine biology to variations in fish stock recruitment are difficult to carry out. In addition, relevant biophysical factors in marine environments vary widely in their spatial and temporal scales of influence. Modelling paradigms and analytical tools that effectively identify environment-dependent recruitment relationships and provide the capability for recruitment prediction are not well established. Yet, recruitment prediction remains a vital information component required by resource management decision makers dealing with exploited marine ecosystems.

The aim of this analysis was to use neural networks as an analytical tool to effectively deal with the problems described above. Specifically the objectives were two-fold: to use neural networks to (1) examine the relative importance of physical and biological variables on year-class strength of an exploited marine fish stock, walleye pollock (Theragra chalcogramma) and (2) to predict future recruitment. Several neural network models were applied to a 33-year recruitment time series and a time series of physical data describing the atmospheric and oceanic features of the North Pacific Ocean off Alaska. Both prediction and classification schemes were investigated using Generalized Regression, Probabilistic, and Recurrent Backpropogation neural networks.

Classification schemes appeared to perform better than prediction schemes. Factors that affected ocean stratification and circulation during the spring and summer of the animals' birth year were identified as being important to recruitment. Neural network models typically explained 65% of the variation observed in pollock recruitment.

Despite the fact that neural networks have not received much attention in fisheries science, results from this study indicate that neural networks appear to hold promise in a marine fisheries recruitment prediction framework. They preclude the need to assume functional relationships a priori before an analysis proceeds or invoke restrictive assumptions that we know are not valid in marine ecosystems.

* Email : bmegrey@afsc.noaa.gov

Inverse problem by neural network : application for wind retrieval from spaceborne scatterometer data

METOUI N.*

CEDRIC - Conservatoire National des Arts et Métiers, 292 rue Saint Martin, 75141 Paris cedex 3

The aim of this work is to modelize the ocean surface wind vector (speed and direction) by using the ERS-1 scatterometer data (the ratio of transmitted versus backscattered power signal, called the normalized radar cross section (σ^{o}) of the ocean surface).

This is an inverse problem which yields ambiguities on to the azimuth of the wind vector : different winds may give the same measure σ^{o}.

A neural method of inversion was developed [1] and permits to compute the wind direction by using the three σ^{o} given by the three antennas of the ERS-1 scatterometer, oriented in different directions.

Moreover, we have a direct function (GMF : Geophysical Modelling Function [2]) which relates the σ^{o} from the wind, this function, F, was realized with a multilayer network which has one hidden layer : $\sigma^{o} = F(v)$.

We will present a method which permits to improve the wind field given by the inverse neural method.

We suggest a variational approach by minimizing the distance C(v) between the prediction of the forward model (defined by F) and measurements given by the satellite.

The initial solution presented in the input of the network (F) is the wind field given by the inverse function. We minimize the cost C(v) with a gradient method.

The computation of $\partial C/\partial v$ needs $\partial f/\partial v$ which is computed by gradient-back-propagation on the direct network, F, whose weights are frozen.

The input adaptation is done following a gradient rule :

$$v(i+1) = v(i) - \varepsilon(i).\partial C/\partial v(i)$$

This method permits to restore the local variability of wind.

The physical validity of the wind field obtained is done by comparison with field of the meteorological model of the European Centre for Medium Range Weather Forecast (ECMWF), and the field of the neural inverse method.

[1] .Thiria S., Mejia C., Badran F., Crepon M., « A Neural Network Approach for Modelling Non linear Transfer Functions : Application for Wind Retrieval from Spaceborne scatterometer Data », Journal of Geophysical Research vol. 98 N° 012 , p. 22,827-22,841 Dec. 15, 1993.

[2] Mejia C., Thiria S., Badran F., Crepon M., « Determination of the Geophysical Modelling Function of ERS-1 scatterometer by the use of Neural Network », accepted at Journal of Geophysical Research.

* Email: metoui@cnam.fr

pH modelling by neural networks.
Application of control and validation data series in the Middle Loire river.

MOATAR F.[1*], FESSANT F.[2] and POIREL A.[3]

[1] LTHE, UMR 5564 : CNRS - INPG - ORSTOM – UJF, BP 53, 38041 Grenoble cedex 9, France.

[2] INRETS-MAIA, 2 avenue du General Malleret Joinville, 94114 Arcueil, France.

[3] EDF - Division Technique Générale, 21, avenue de l'Europe, BP 41, 38 040 Grenoble cedex 9, France.

The French environmental regulations impose continuous monitoring of the aquatic environment at every river site equipped with a nuclear power plant. Therefore «Electricité de France» performs continuous data acquisition of four variables: temperature, electrical conductivity, dissolved oxygen and pH on an hourly basis. This case study concerns a measurement site upstream of a power plant, on the middle Loire river, at Dampierre.

Several different kinds of models were elaborated for each parameter in order to be able to control and validate these data. These tools are based on statistical (probability, autoregressive (AR) or autoregressive model with exogenous inputs (ARX), artificial neural networks (ANNs), statistical fit to physical laws) and physical concepts (water-atmosphere exchange, biology-chemistry connection).

We performed the modelisation of pH at Dampierre using neural networks.

River water pH is affected by numerous processes : biological, physical and geochemical. Examples are: CO_2 pressure equilibrium with the atmosphere, photosynthesis, respiration of plants, organic matter degradation, geological and mineral background, pollution, etc.

Inter-relationships between those processes and pH values are complex, non-linear and not well understood. This is the reason why the neural network approach has been tested.

Since neural networks models require equally spaced data which have been collected over a long time period, and because we want to model pH on a daily basis, the variables included in the models were restricted to discharge and solar radiation. The model is a multi-layer neural network.

To investigate the influence of the previous day's flows and radiation, the criterion of Nash has been calculated in the training and validation set. The best network found to simulate pH was one with 2 input nodes and 3 hidden nodes. The inputs are daily discharge and a variable called « index of anterior radiation », i.e., calculated as an exponential smoothing of the radiation variable.

When calibrated over four years and validated for one year of independent sampling, the model has proved satisfactory on pH simulation with accuracies on the order of 80 %.

* Email: moatar@lthe712b.hmg.inpg.fr

Radial Basis Function Networks With Partially Classified Data

MORLINI I.*

Department of Statistics, University of Parma (Italy), Via J.F. Kennedy, 6 - 43100 Parma, Italy.

One of the major problem related to practical applications in patter classification is the presence of partially classified data. In these situations the population from which the sample is taken consists itself of a number of several homogeneous sub-populations, but the group membership of the training data is known only for some input values. If the quantity of data available is sufficiently large, and the proportion of unclassified observations is small, then the simplest solution is to discard those patterns from the data set. When there is too little data to discard the unclassified one, or when the proportion of unclassified observations is high, it becomes important to use all the information, which is potentially available from the incomplete pattern. The purpose of this work is to show the benefits of using the information contained in the data to the maximum extent. In order to illustrate the importance of using both classified and unclassified data for pattern recognition tasks in radial basis functions networks (Broomhead and Lowe, 1988; Moody and Darken, 1988), an example on a real data set is proposed. The network performances are measured in terms of classification error rate and generalisation to unobserved patterns. The example is based on the classification of two species of voles. The two species, *Microtus multiplex* and *Microtus subterraneus*, differ in the number of chromosomes, but are morphometrically difficult to distinguish. The geographic ranges of distribution of the two species overlap to some extent in the Alps of southern Switzerland and northern Italy. *M. subterraneus* occurs at elevations from 1000 m to over 2000 m, except in the western part of its range, where it is found in lower elevations. *M. multiplex* is found at similar elevations, but also at altitudes from 200-300 m south of the Alps. Much of the data available are in form of skull remains, either fossilised or from owl pellets. Till now, no reliable criteria based on cranial morphology have been found to distinguish the two species. The data set consists of eight variables measured on the skulls of 288 specimens found at various places in central Europe. For 89 of the skulls, the chromosomes were analysed to identify their species: 43 specimens were from *Microtus multiplex* and 46 from *Microtus subterraneus*. Species was not determined for the remaining 199 specimens. Airoldi, Flury and Salvioni (1996) report a discriminant analysis and finite mixture analysis of this data set. Here, we seek to analyse the data with RBF networks and to compare the classification capabilities of different models. The analysis is first performed on the 89 specimens with known group membership, and the trained neural network is then used to classify the remaining 199 specimens. In a second time, unclassified observations are used with classified data only in the pre-processing stage. Finally, classified and unclassified observations are both used to optimise the basis functions parameters.

The results show that the generalisation properties of the network are substantially better when all the available observations are used.

References

Airoldi, J. P., Flury, B. and Salvioni, M. (1996), Discrimination between two species of Microtus using both classified and unclassified observations. *Journal of Theoretical Biology* 177, 247-262.

Bishop, M.C. (1995), *Neural Networks for Pattern Recognition*, Clarendon Press, Oxford.

* Email: morlini@economia.econ.unipr.it

Broomhead, D.S. and Lowe, D. (1988), Multi-variable functional interpolation and adaptive networks. *Complex Sys.* 2, 321.

Moody, J. and Darken, C.J. (1988), Learning with localized receptive fields, in Touretzky, D., Hinton, G. and Sejnowsky, T., *Proceedings of the 1988 Connectionist Models Summer School*, Morgan and Kauffman, San Mateo, pp. 133-143.

Elucidation and Prediction of Aquatic Ecosystems by Artificial Neural Networks

RECKNAGEL F.* and WILSON H.

University of Adelaide, Department of Environmental Science, Roseworthy, South Australia 5371, Australia

Applications of artificial neural networks open up new horizons in the elucidation and prediction of aquatic ecosystems.

In aquatic ecosystems, causal elucidation (the normally domain of deductive deterministic modelling) usually leads to a dead end. However, by contrast, recent results show that inductive modelling based on neural networks can have far reaching outcomes. In the context of phytoplankton dynamics, two methods were used to extract knowledge from trained and validated neural networks: sensitivity analysis and scenario analysis. By means of sensitivity analysis, driving variables are ranked by their weighting for output determination. The application of neural networks to different freshwater systems showed that phytoplankton abundance in rivers was primarily driven by transport processes as indicated by flow (Recknagel et al. 1997a). In lakes by contrast, sensitivity analysis showed that variables related to photosynthesis and grazing determined phytoplankton abundance. Scenario analysis was used to test hypotheses for succession of *Microcystis* by *Oscillatoria* in an eutrophic lake (Recknagel 1997b). Light and temperature conditions triggered species succession rather more than nutrient or grazing conditions. New types of neural networks with recurrent structures and genetic algorithm components promise even further elucidation.

Aquatic ecosystems can be predicted by steady state or transitional behaviour. Steady state models are traditionally identified by inductive regression techniques which have constraints regarding the number of variables and nonlinear relationships. Steady state predictions of fish density and distribution depending on habitat characteristics by artificial neural networks (Lek et al. 1996) and subsequently by genetic algorithms (D'Angelo et al. 1995) clearly overcome constraints of regression techniques and improve in predictivity. Predictive models of transitional ecosystem behaviour are traditionally developed by deterministic techniques which have constraints in complexity, state space and time resolution. Those constraints can be overcome by neural network models too, as demonstrated by Recknagel et al. (1998) in predicting daily abundance and succession of five algae species and three zooplankton groups for two years in an eutrophic lake. The exploration of genetic algorithms for neural network design and training promises further improvements in predictions of very complex and discontinuous ecological patterns.

References:

D'Angelo, DJ, Howard, LM, Meyer JL, Gregory, SV, and LR Ashkenas, 1995. Ecological uses for genetic algorithms: predicting fish distributions in complex physical habitats. *Can J Fish Aquat Sci* 52, 1893-1908.

Lek, S, Delacoste, M, Baran, P, Dimopoulos, I, Lauga, J, and S Aulagnier, 1996. Application of neural networks to modelling nonlinear relationships in ecology. *Ecol. Modelling* 90, 39-52.

Recknagel, F, French, M, Harkonen, P, and KI Yabunaka, 1997. Artificial neural network approach for modelling and prediction of algal blooms. *Ecol. Modelling* 96, 11-28.

* Email: frecknag@roseworthy.adelaide.edu.au

Recknagel, F, 1997. ANNA - artificial neural network model for predicting species abundance and succession of blue-green algae. *Hydrobiologia* 349, 47-57.

Recknagel, F, Fukushima, T, Hanazato, T, Takamura, N, and H Wilson, 1998. Modelling and prediction of phyto- and zooplankton dynamics in Lake Kasumigaura by artificial neural networks. *Lakes and Reservoirs* (in press).

Developing an empirical model of phytoplankton primary production: a neural network case study.

SCARDI M.[1*] and HARDING, Jr. L.W.[2]

[1] Stazione Zoologica "A. Dohrn" di Napoli, Villa Comunale, 80121 Napoli, Italy.
[2] University of Maryland, Horn Point Laboratory (UMCES) and Maryland Sea Grant, Box 775, Cambridge, Maryland 21613, email: larry@kestrel.umd.edu

During the last two years, several models of phytoplankton primary production (PP) have been developed by applying neural networks to shipboard data from Chesapeake Bay. The first models were intended as simple tests of the applicability of neural networks to modelling PP, whereas more recent models have been trained and validated on fairly large data sets encompassing seasonal and interannual variability of PP and environmental variables affecting PP. All the neural network models have a single hidden layer and were trained using the error-backpropagation algorithm with constant learning rate and no momentum term. Our results show that even the simplest neural network models provide superior results to those from more conventional empirical models of PP that are usually based on linear or multilinear relationships.

Phytoplankton biomass, surface irradiance and transparency (expressed as light extinction coefficient or as depth of the photic zone) were always used as predictive variables, whereas an estimate of phytoplankton PP was the only neural network output. Other variables that tend to co-vary with phytoplankton PP were added to this basic set during model development. Specifically, geographical coordinates, julian day, salinity, and depth of the water column were taken into account, as well as a few derived variables (e.g. the depth-integrated phytoplantkon biomass).

The final formulation of the neural network model has a 12-8-1 structure and uses log-transformed phytoplankton biomass and PP data. The model has been trained and validated on the basis of a data set that included 326 observations. One hundred of the observations were randomly selected to create the training set, whereas the remaining 226 observations were used as a validation set. Several techniques have been applied to obtain a generalized model and to prevent overfitting (training set sub-sampling, white noise addition, etc.). Finally, a sensitivity analysis of the neural network model was conducted to evaluate the relative importance of each predictive variable. Some examples of the neural network model application will be presented and compared with the results of more conventional models and with those of a simplified neural network model that only uses a subset of the predictive variables that can be obtained by remote sensing.

* Email: mscardi@mclink.it

Neural network models of phytoplankton primary production.

SCARDI M.[*]

Stazione Zoologica "A. Dohrn" di Napoli, Villa Comunale, 80121 Napoli, Italy

Empirical models of phytoplankton primary production play an important role in oceanographic research, mainly because direct measurements of this variable are difficult and time consuming. First of all, they are needed to fully exploit the large phytoplankton biomass data sets that are obtained by remote sensing, but they are also necessary to carry out instrumental estimates of primary production (e.g. by pump and probe fluorometers) and to post-process the field data.

Many empirical models have been developed and several of them provided useful results, but the oceanographic data sets are growing larger and demand more effective approaches. In this framework, artificial neural networks have been recently proposed as empirical models of phytoplankton primary production. Even though only very simple error back-propagation neural networks were used, they provided very good results and always performed better than conventional empirical models.

Some examples of neural network-based empirical models of phytoplankton primary production will be presented and their results will be compared with those provided by conventional models. These examples will represent a wide spectrum of complexity and of spatial scales, ranging from the local to the global ones. All the models will have a single hidden layer and a single output, whereas hidden and output nodes will have sigmoid activation functions. The neural network training will be performed with a constant learning rate and no momentum term.

One of the main problems in the application of neural networks to ecological modelling is their tendency to overfit the training data patterns. Several strategies will be applied in order to obtain a good generalization (i.e. to train neural network that act as models rather than as memories) and thoroughly discussed.

A major advantage of neural network models of phytoplankton primary production is their capability of incorporating information that is difficult to manage with conventional models (e.g. binary or nominal data, geographical coordinates, etc.), but that tends to co-vary with the output variable. The covariation has not to be linear, because neural networks can deal with non-linear relationships more easily than other empirical models. Some examples of the exploitation of such additional information will be presented.

Finally, the role of sensitivity analysis of the neural network models will be discussed. In particular, sensitivity analysis makes possible to assess the strength of the links between predictive variables and phytoplankton primary production in the observed data sets rather than in the framework of an *a priori*, simplified theoretical model. Therefore, it can provide a deeper insight into the dynamics of phytoplankton primary production under real world conditions.

---

[*] Email: mscardi@mclink.it

Assessment of water quality, bioindication and population dynamics in lotic ecosystems with neural networks

SCHLEITER I.M.[1*], BORCHARDT D.[1], DAPPER T.[2], SCHMIDT H.-H.[3] and WAGNER R.[3]

[1] Dept. of Sanitary and Environmental Engineering, University of Kassel, Kurt-Wolters-Str. 3, D-34125 Kassel, Germany
[2] Dept. of Mathmatic/Informatic, University of Kassel, Germany
[3] Max-Planck-Inst. of Limnology, Schlitz, Germany

The assessment of states and processes of running waters is a major issue of aquatic environmental management. Because system analysis and prediction with deterministic and stochastic models is often limited by the complexity and dynamic nature of these ecosystems, supplementary or alternative methods have to be developed. We tested the suitability of various types of artificial neural networks for system analysis and impact assessment in different fields: a) temporal and spatial dynamics of water quality as influenced by the weather, urban storm-water run-off and waste-water effluents b) colonisation patterns of benthic macro-invertebrates in relation to water quality and habitat structure c) prediction of population dynamics of aquatic insects. Specific pre-processing methods and neural models were developed and allowed the assessment of relations among complex parameters (weather, discharge, water-quality, habitat-structure, benthic community structure) with high levels of significance. Special data processing employing a dynamic evaluation of data fed into the network improved the performance of the networks. Sensitivity studies with a special back-propagation-variant allowed a quantitative assessment of the input data which was not possible with standard neural modelling techniques. Time dependent neural networks, which allow for a consideration of past events, proved rewarding and compensated for investment into the analysis and prediction of time series.

The results demonstrate that neural networks can conveniently be applied to running water ecology and sanitary engineering including the prediction of effects in the community. In particular neural networks can be used to reduce the complexity of data sets by identifying important (functional) inter-relationships and key variables. Thus, complex systems can be visualised in easily surveyed models with low measuring and computing effort. Examples for this are the diurnal variation of oxygen concentration (modelled from precipitation, water temperature and oxygen concentration of the preceding day; $r^2 = 0.79$), population dynamics of emerging aquatic insects (modelled from discharge, water -temperature and abundance of the parental generation; $r^2 = 0.78$), and water quality as indicated by a few "sensitive" benthic organisms (e.g. conductivity, using 5 out of 248 species; $r^2 = 0.86$).

Estimation of the influence of complex environmental stress variables and prediction of the course of development of running waters from given conditions can be developed to greater detail than in conventional methods. Future studies on artificial neural networks and their applicability to bioindication and monitoring in running water systems are intended.

Keywords: Modelling, prediction, artificial neural networks, cause-effect relations, bioindication, monitoring, freshwater ecology, pollution control

* Email: schleit@hrz.uni-kassel.de

Derivation and validation of artificial neural networks for spatial agroecological problems

SCHULTZ A.*, WIELAND R.

ZALF e.V., Institute for Landscape Modelling, Eberswalder Straße 84, D-15374 Müncheberg, Germany

Agroecological modelling means creating models to reflect matter, energy and informatic interactions between and among abiotic (weather, physical and orographic characteristics, landscape structure, soil conditions, nutrients, ...) and biotic (appearance, growth and density of plants, animals and microorganisms) components of agricultural landscapes. Most of the agroecological problems are of spatial character, either with a direct area relation or reasonable at all only within an implicit spatial connection. Generally the basis for agroecological modelling is empirical knowledge in form of measured, observed or "experienced" environmental variables from actual, and reported qualitative dependencies from former investigations. Despite of a permanently increasing amount of agroecological knowledge and of an unparalled level of detail in selected problems the fundamental understanding of many agroecological processes is not as good as it should be in order to ascertain reliable valuations of current situations and to derive forecasts of consequences of a changing environment. So it is an important task of agroecological modelling to develop, validate and finally apply conceptual tools to organize the detail knowledge and to arive a better understanding of agroecological dependences.

Especially in such cases, where the theoretical background of the considered agroecological phenomenon is not sufficiently known, the derivation and application of artificial neural network models (ANNMs) tries to combine data analysis with an implicit systems analysis and to find appropriate nonlinear model structures. In agroecology perfect or general experimental equipment does not exist. Agroecological measurements and observations are always to be considered in a concrete spatial, temporal and experimental connection. All measured, observed or estimated quantities and qualities have errors in "y"- as well as "x"-data. This is the reason that models developed at one spatial and temporal scale cannot be arbitralily applied at others because implicit site conditions usually change. So model validation becomes difficult.

In order to analyze approaches, to ascertain problems, to derive general guidlines for creating "optimal" architectures for agroecological ANNMs, to improve network learning with input data preprocessing and to realize substitutes for input and parameter sensitivity as well as to check various validation criteria a number of investigations is carried out with ANNMs for different practical goals, with different attributes and properties of input information, and for different spatial scales. The following groups of ANNMs are used:

- ANNMs for determining the quality of a landscape as habitat for animals and plants (creates normalized values between 0 = very bad and 1 = excellent),

* Corresponding author. E-mail: aschultz@zalf.de

- ANNMs for calculating the course of soil moisture and biomass growth under winter cereal standing crops dependent on standard meteorological inputs (quantitive values in natural measure units),
- ANNMs for the classification of site properties to preprocess and to reduce the number of input values for spatialization approaches.

A Web based tool for data visualization and analysis

SMID J.[12*], KURZ L.[1], LEVINE E.[3], Glucksmann I.[1], SMID M.[1] and VOLF P.[4]

[1] SKS Enterprises, Greenbelt, MD, USA
[2] Morgan State University, Dept. Of Mathematics, Baltimore, MD 20771 USA.
[3] NASA/GSFC, Biospheric Sciences Branch, Greenbelt, MD 20771 USA.
[4] UTIA and TU Liberec, The Czech Academy of Sciences, Prague 180 00, Czech Republic.

Currently, massive amounts of data are being received, collected, and compiled from field campaigns and remote sensing satellites. These data provide the basis for analysis of global natural and anthropogenic effects on the environment. In order to use both ground based and satellite image information, calibration and visualization of the data must be done in addition to data analysis to answer specific questions. Web based tools can provide a simple and accessible means to interpret and work with the large amounts of data already available and planned for the future. WebGraph is a data visualization and analysis tool designed to be accessed via the World Wide Web. With WebGraph, scientists and engineers working together can use neural network algorithms, data mining and discovery techniques to better understand patterns and relationships within data. The purpose of WebGraph is threefold:

(1) to stimulate research,
(2) to provide data exchange and a depository for group working ideas, and
(3) to provide tutorials for both general information and specific mathematic and scientific concepts.

Two case studies are presented which demonstrate the use of WebGraph for both science and engineering applications.

In the first example, the problem of calibration of Landsat 5 and Landsat 7 sensors is considered. Calibration of these sensors is critical to provide images that can be used to developing algorithms relating the imagery to ground based measurements. The calibration procedure used in this study consists of finding the best automatic fit to the calibration data. The best fit features low complexity, change point detection and flexible basis functions. We have chosen quadratic splines and a lead trend function. The problem leads to a nonlinear incremental fitting procedure.

The second example deals with the prediction and characterization of the amount of organic carbon in soil using Thematic Mapper data. The assessment of soil carbon dynamics at regional and global scales is difficult because it requires repeated sampling with depth to monitor changes over time. By using a surrogate measurement, such as remotely sensed data, that could provide an estimate of soil organic carbon status, repeated field sampling would not be necessary. This nonlinear problem is solved using regression trees and the results are compared to results of neural-like approaches.

* Email: smid@gsfc.nasa.gov

Using Supervised Neural Networks to Characterize the Length and Structure of Foraging Search Paths

STRAUSS R.E.* and GRANTHAM Ö.K.

Department of Biological Sciences, Texas Tech University, Lubbock TX, 79409-3131, USA

The analysis of search paths plays a key role in optimal foraging theory. We have considered a simplified model of resource acquisition in which N points ("food items") of equal value are dispersed randomly within a square arena, and consider only the search path needed to find and consume the N items (assuming no satiation and no learning during the search). For a given point configuration, the lower and upper bounds on the path length are given by the globally optimal shortest and longest paths (the former being analogous to the "traveling salesman" problem), which we estimate via genetic algorithms. In addition, we have characterized the lengths and shapes of search paths produced under five probabilistic and one rule-based search patterns; in order of decreasing mean path lengths these are: random point choice, Pearson random walk, Levy random walk, reciprocal-distance preference, inverse-squared-distance preference, and nearest neighbor. In addition to its length, each search path was characterized geometrically by its vector autocorrelation function, distribution of angular deviations, and number and spacing of path intersections; canonical variate analysis was used to discriminate paths produced by the different models on the basis of these geometric descriptors.

The objectives of this study were (1) to evaluate the performance of neural networks under supervised training, as measured by mean path length under repeated testing; and (2) to determine what characteristics of point configurations the trained networks are "perceiving" in order to find a short path. The factors affecting the performance of supervised networks were investigated by systematically varying the number of points (prey abundance), the degree of clustering of the points (patchiness), and the architecture of the networks.

In general, trained networks were able to find paths among random point configurations that were slightly shorter than nearest-neighbor paths. The characteristics of point configurations that were "perceived" by trained networks can be evaluated by presenting the networks with idealized sets of points and recording patterns of nodal activity.

This basic model can be extended by varying domain shape, number of spatial dimensions, number of simultaneous paths (predators), and allowing for satiation, variation in search rate and handling time, revisitation of prey, search-strategy switching, and learning during the search.

* Email: REStrauss@ttu.edu

Can Neural Networks be used in Data-Poor Situations?

SILVERT W.[1*] and BAPTIST M.[2]

[1] Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2
[2] Delft Hydraulics, Marine and Coastal Management, P.O. Box 177, 2600 MH Delft, Netherlands

A major limitation on the use of neural networks is that they require large amounts of data for training. This is a serious problem in most ecological applications, because data are usually very scarce. It is therefore essential to find ways of making the training of neural networks more efficient so that they can be used in situations where the number of data is small. We explore several ways of doing this, including constraining the system on the basis of prior information and the use of transformed variables to reduce the effective number of degrees of freedom. The more successfully we can integrate neural networks with other analytical procedures based on scientific understanding of how ecosystems function, the more effective neural networks will be in dealing with ecosystems for which only limited data are available.

* Email: SilvertW@mar.dfo-mpo.gc.ca

On The Structure Of Networks Realizing Evolutionarily Optimal Strategies Of Individual Survival

TERIOKHIN A.T.*, BUDILOVA E.V.

Moscow State University, Dept. of Biology, Moscow 119899, Russia

The purpose of this presentation is to show how neural networks can be applied for elucidiating the way an animal uses when it divides energy between its basic needs: maintenance, repair, growth, and reproduction. Our specific goal will consists in understanding the mechanisms of lifetime scheduling of energy allocation to individual survival as opposed to the survival of the species which it belongs to.

We assume that the process of energy partition in organism should be evolutionarily optimal in the sense that it should lead to maximization of some criterion of Darwinian fitness. As such a criterion can be used the intrinsic rate of population growth which is reduced to the lifetime reproductive success of individual when the size of population is stable. We apply the mathematical theory of optimal control (maximum principle, dynamic programming) to solve this evolutionary optimization problem.

An essential feature of optimal control approach consists in dividing the system variables into two parts: state variables and control ones. The optimization problem is solved when we are able to indicate for any admissible point in the state variables space a point in the control variables space i.e. to indicate an optimal behaviour (in our case optimal energy partition) for any state of an individual and its environment. This conforms perfectly to the ideology of multilayered neural networks. Namely, state variables correspond to inputs of the first layer (layer of sensors) and control variables correspond to the outputs of the last layer (layer of effectors). The intermediate (associative) layers perform mapping of inputs to outputs. We could say that in this interpretation the goal of the evolution consists in adjusting interneuronal weights in such a way that an optimal output (energy partition) should correspond to any given input (sensor information about the physiological state of the individual and about the state of its environment).

So, our procedure consists of two steps: first, we find an optimal strategy of energy partition for a given problem statement, and second, we try to construct a biologically plausible neural network scheme which could realize the optimal strategy found.

* Email: AT@ATeriokhin.home.bio.msu.ru

On Neural Networks Capable To Realize Evolutionarily Optimal Animal Strategies Of Growth And Reproduction In A Seasonal Environment

TERIOKHIN A.T.[1*], KOZLOWSKI J.[2]

[1] Moscow State University, Dept. of Biology, Moscow 119899, Russia.
[2] Institute of Environmental Biology, Jagiellonian University, Oleandry 2A, 30-063 Krakow, Poland. Email: KOZLO@eko.uj.edu.pl

In (Kozlowski J., Teriokhin A.T. Energy allocation between growth and reproduction: The Pontryagin maximum principle solution for the case of age- and season-dependent mortality. Evolutionary Ecology, 1998, in press) we built an evolutionariry optimization model in order to explain the postmaturation growth observed in most of fish, reptiles, amphibians and many invertebrates. Optimal allocation of energy to growth and reproduction was studied with dynamic optimization method for long-lived animals inhabiting seasonal environment. It was proved that it is optimal to grow after maturation either several years or asymptotically. In the work presented here we propose a neural (or rather neuroendocrine) network capaple to realise the optimal strategy of energy allocation so found. Formally, the problem could be solved if we construct a multilayered network approximating the switching curve on the plane age - size. However, this straightforward approach leads to the necessity to have separate groups of neurons for each season because the switching curve has a complex saw-shaped form. It does not seem realistic from the physiological point of view. In (Budilova E.V., Kozlowski J., Teriokhin A.T. Neural network models of life history energy allocation. Proceedings of the First National Conference on Application of Mathematics to Biology and Medicine. Zakopane, September 26-29, 1995, p.13-18) we proposed and here develop an alternative approach which allows to reduce significantly the complexity of the neural network controlling energy partition between growth and reproduction. This is made at the cost of introducing of a third sensor - that of season - in addition to the sensors of age and size. We are also forced to deviate from the classical multilayred neural scheme of perceptron type and admit direct action of sensors on interneuronal links. The biological plausibility of proposed schemes is discussed.

* Email: AT@ATeriokhin.home.bio.msu.ru

Primary production estimation in grasslands of South and North America by ANN analysis of satellite data

TOMASEL F.G.[1*] and PARUELO J.M.[2]

[1] Depto. Fìsica. Facultad de Ingenierìa. Universidad Nacional de Mar del Plata, J.B. Justo 4302 (7600) Mar del Plata. Argentina. E-mail: ft818710@engr.colostate.edu
[2] Depto. Ecologìa. Facultad de Agronomìa. Universidad de Buenos Aires, Av. San Martìn 4453 (1417) Buenos Aires. Argentina. E-mail: paruelo@ifeva.edu.ar

We used artificial neural networks (ANNs) to investigate the relationship between environmental variables and functional characteristics of grassland and shrubland ecosystems. Estimates of the seasonal dynamics of the primary production were derived for sites distributed across a precipitation gradient in both North and South America. We used four attributes of the seasonal curves of the Normalized Difference Vegetation Index (NDVI) as estimator of the primary production and its seasonality: the annual integral of the NDVI curve (NDVI-I), the difference between maximum and minimum NDVI (MM), the start of the growing season (SGS) and the date of the maximum NDVI (DM).

The multi-layer network used for this analysis consisted of two layers of nodes fully interconnected. The network was trained using the error back-propagation training algorithm. Training was based on the minimization of the total error by using the gradient descent technique. The ANNs were trained using 15 years of monthly precipitation and temperature data as inputs and the values of each of the four traits derived from the satellite data as known outputs. To reduce the overfitting problem, we carried out an optimization on two parameters of the network: the number of nodes of the hidden layer and the error goal used to stop the training process.

The ANNs developed performed better than other predictive techniques such as multiple regression models. Using the ANNs, we explored the main determinants of the primary production and its seasonality. For example, the NDVI-I was mainly controlled by a linear combination of spring and summer precipitation. The climatic controls of the date of maximum NDVI varied among sites. Based on a limited set of input data, ANNs were able to predict the start of the growing season and the date of maximum NDVI up to three months ahead, depending on the site.

* Email: ft818710@engr.colostate.edu

Use of artificial neural networks for predicting rice crop damages by greater flamingos in the Camargue, France

TOURENQ C.[1,2*], AULAGNIER S.[3], MESLÉARD F.[1], DURIEUX L.[1], JOHNSON A.[1], GONZALEZ G.[3] and LEK S.[4]

[1] Station Biologique de la Tour du Valat, Le Sambuc, 13200 Arles, France.
[2] Centre d'Ecologie Fonctionnelle Evolutive, Université de Montpellier II, route de Mende, 34000 Montpellier, France.
[3] Institut de Recherche sur les Grands Mammifères, INRA, BP 27, chemin de Borde-Rouge, 31326 Castanet Tolosan, France.
[4] CESAC UMR 5576, Bat 4R3, CNRS-Université Paul Sabatler, 118 route de Narbonne, 31062 Toulouse cedex, France.

Rice crops damage by shorebirds, ducks or passerines has been mostly studied in Africa, Australia, North and South America where there is extensive rice cultivation; with crop losses estimated at several million dollars annually. Since the eighties, incursions of Greater Flamingos (*Phoenicoterus ruber roseus*) into rice plots have been reported almost every year in the Camargue, southeastern France, and more recently in Spain.

We surveyed the performances of artificial neural networks (ANN) in predicting presence or absence of flamingo damage from 11 variables, describing landscape features of paddies: surface, distance from the colony, from natural marshes and from human constructions (habitation, electric lines and roads), number of sides with hedges and height of hedges, and proximity to regularly visited fields.

With the whole set of 1978 records, we produced 11 working sets subdivided in a training part and a testing part, including of "presence" and "absence" records randomly sampled. The model was first fitted for predicting both types of records, then training and testing was repeated 10 times for a working set, and 3 times for the other ones. At last, the whole set with the 1996 "presence" was used to predict damages one year later.

The larger number of "absence" records (1771) induced very bad performances for predicting damages when the training part was the two thirds of the working set. The best test results were obtained when equilibrating the number of records of the two types. Moreover the best scores for the testing set were obtained for intermediate number of hidden neurons.

The models can be considered relatively stable end pretty good. Percentage of classification (learning and prediction) were relatively homogeneous, giving a standard deviation for the tests very small within repeats for one working set, and small between working sets.

Of the 11 variables that all contributed to the models, three can be distinguished for their higher contributions: distance from natural marshes, contiguity with damages fields, and distance from electric lines.

Predictibility from one year to the following one also supports that ANN can be an alternative or a supplement to actual scaring methods in identify potential damaged fields and propose agricultural management plans or concentrate scaring actions on these high-risk areas.

* Email: tourenq@tour-du-valat.com

Modelling water and carbon fluxes above European coniferous forests with artificial neural networks

VAN WIJK M.T.* and BOUTEN W.

Landscape and Environmental Research Group, University of Amsterdam, Nieuwe Prinsengracht 130, 1018 VZ Amsterdam, The Netherlands

Models for predicting water and carbon dioxide fluxes above forest ecosystems are usually developed, calibrated and validated for a specific forest. Recently the Euroflux project provided flux measurements from a large of range of forests across Europe. These measurements give the opportunity to model ecosystem fluxes along a range of biotic and abiotic system inputs, and to investigate which processes and variables determine short term forest ecosystem responses to the environment.

In this paper artificial neural networks are used to select a minimal set of input variables to model forest ecosystem water and carbon fluxes. The goal is to model the ecosystem fluxes independently of tree species and to analyse the model performance over different forest sites without detailed physiological information. A two layered backpropagation neural network is used because of its power to fit highly non-linear relations between input and output variables. A sensitivity analysis is performed with the neural network model to get insight in the relations that the network has found. This is done for one variable, but also for two variables together to investigate the way in which the value of one variable influences the response-curve of the another variable, the so called interaction effects. The model performance is tested by predicting ecosystem fluxes of forest sites that are not included in the calibration dataset and that have intermediate characteristics. The results are compared to deterministic models describing ecosystem fluxes.

The variables that determine ecosystem water and carbon fluxes were radiation, temperature, vapour pressure deficit, leaf area index and time of the day (ToD). The sensitivity analysis showed that the first four variables were interacting in their responses, but that the response on the variable ToD was independent of the other input variables. Predictions of forest ecosystem fluxes of sites not included in the calibration set were satisfying and comparable with more traditional deterministic models specifically calibrated for the individual sites.

The results show that both latent heat and carbon dioxide fluxes above coniferous forest ecosystems can be modelled satisfactory without detailed physiological information. Artificial neural networks showed to be a very powerful tool for non-linear model derivation. A quantitative insight in the model relations that the neural network has found was gained by the use of fuzzy logic, of which a preliminary example is given.

* Email: m.t.wijk@frw.uva.nl

Neural Network Architecture Selection: New Perspectives

VILA J.P.*, WAGNER V. and NEVEU P.

I.NRA, laboratoire de Biométrie, 2 Place Viala,, 34060 Montpellier France

The aim of this paper is to present to the community of ecologists concerned with predictive modelling by feedforward neural network, a new statistical approach to select the best neural network architecture (number of layers, number of neurons per layer and connectivity) in a set of several candidate networks.

As a matter of fact, the question of determining the correct network topology is crucial in multilayer feedforward network function approximation and is one of the most debated problems in the neural network community (see for example the recent survey by [9]) . As pointed out by several authors ([15], [8], [3]), oversized networks learn more rapidly since they can more easily monitor local minima, but exhibit poor generalization performance because of their tendency to fit the data noise with the true response.

Specific on-line and off-line techniques have been developed to choose the right architecture by incremental or decremental procedures. Constructive algorithms, as for example *Cascade Correlation* ([5], [9]), start with a small network and try to increase it step by step, while pruning algorithms as *Optimal Brain Damage* [10] or *Optimal Brain Surgeon* [7], start, with a large network and try to eliminate unnecessary connections [14]. But reaching the best topology by this step-by-step evolution is not guaranteed and termination criteria lack clear statistical meaning. Among off-line techniques *cross-validation* [6] is one of the most favored selection procedures, because of its apparent objectivity, even though it can be time consuming.

Statistically-based comparison techniques divide themselves in two main groups:
- *asymptotic* comparison tests (Wald test, likelihood ratio test, Akaïke criteria,. . .) [16]
- comparison procedures based on an *approximate* Bayesian analysis ([11], [17]).

Neither of these two approaches is definitely satisfying. The first one relies upon samples of sufficiently large size and is often restricted to the comparison of embbeded networks. The second one assumes the disposal of a pertinent probability prior distribution for the network parameters (weights) and more seriously, suffers from several controversial points and drawbacks: treatments of the hyperparameters (integrated out or not [19], [12]), questionable Gaussian approximation of the posterior weight distributions [11] or recourse to heavy Monte Carlo estimations [13].

However, the Bayesian approach could appear as the most promising, since some of these critical points could be handled more satisfactorily from a Bayesian point of view, by respecting more faithfully the general Bayesian approach of model comparison ([1], [2]), in particular with regard to the choice of priors and the possibility of exact posterior computation. *It is this precise framework that we consider the question of the selection of a neural network topology in a regression problem.* The heart of our approach [18] is the determination and the validation of a specific network parameter prior distribution *conjugate*

* Email: vila@helios.ensam.inra.fr

to the postulated likelihood of the data (the training set), which allows computation of a parameter posterior and a network response posterior distributions. From these posterior distributions, several selection procedures can be built. Following [2], we consider more particularly a Bayesian *predictive* sample *reuse* procedure, which selects the network under which the training set achieves the highest level of some kind of internal consistency.

This *pure* Bayesian network architecture selection approach will be briefly described and illustrated with some artificial and real neuro-modelling problems.

References

[1] BERGER, .I.O. (1985). Statistical Decision Theory and Bayesian Analysis. New York: Springer-Verlag.

[2] BERNARDO, J.M., SMITH, A.F.M. (1994). Bayesian Theory. New York: John Wiley.

[3] CASTELLANO G.C., FANELLI, A.M., PELILLO, M. (1997). .An iterative pruning algorithm for feedforward neural networks. IEEE Trans. Neural Networks, 8: 519-531.

[4] CHEN, A. M., LU, H., HECHT-NIELSEN, R. (1993). On the geometry of feedforward neural network error sulfaces. Neural Computation 5: 910-927.

[5] FAHLNIAN, S.E., LEBIERE, C. (1990). The cascade correlation learning architecture. in Advances in Neural Information Processing systems 2. San Mateo, CA: Morgan Kaufmann, pp.521-532.

[6] GOLUB, G.H., HEATH, M., WAHBA, G. (1979). Generalized cross-validation as a method for choosing a good ridge parameter. Technometrics, 21: 215-223.

[7] HASSIBI, B., STORK, D.G., WOLFF, G., WATANABE, T. (1994). Optimal Brain Surgeon: extensions and performance comparisons. in Advances in Neural Information Processing Systems 6. San Mateo, CA: Morgan Kaufmann, pp. 263-270.

[8] KUNG, S.Y., HWANG, J.N. (1988). An algebraic projection analysis for optimal hidden units size and learning rates in backpropagation learning. in Proc. IEEE Int. Conf Neural Networks, San Diego, CA, vol. 1 pp. 363-370.

[9] KWORK, T.Y; YEUNG, D.Y. (1997). Constructive Algorithms for Structure Learning in Feedfoward Neural Networks for Regression Problems. IEEE Trans. Neural Networks, 8: 630-645.

[10] LE CUN, Y. DENI , J.S., SOLLA, S.A. (1990). Optimal Brain Damage. in Advances in Neural Information Processing Systems 2. San Mateo, CA: Morgan Kaufmann, pp. 598-605.

[11] MACKAY, D.J.C. (1992). A practical Bayesian framework for backpropagation networks, .Neural Computa., 1: 448-472.

[12] MACKAY, D.J.C. (1995). Hyperparameters: Optimize or integrate out ? in Maximum Entropy and Bayesian Methods. The Netherlands: Kluwer.

[13] NEAL, R.M. (1996). Bayesian Learning for Neural Networks, Springer: New York.

[14] REED, R. (1993) Pruning algorithms- A review. IEEE Trans. Neural Networks 4: 740-747.

[15] RUMELHART, D.E., HINTON, G.E., WILLIAMS, R..J. (l986). Learning representations by backpropagating errors. Nature 323: 533-.536.

[16] SEBER, C.A.F; WILD, C.J. (1989). Nonlinear Regression. New York: Wiley.

[17] THODBERG, H.H.T. (1996). A review of Bayesian neural networks with an application to near infrared spectroscopy. IEEE Trans. Neural Networks 7: 56-72.

[18] VILA, J.P., WAGNER, V., NEVEU, P. (1998). Bayesian nonlinear model selection and neural networks. Rapport Technique, Laboratoire de Biométrie INRA Montpellier, 22p.

[19] WOLPERT, D.H. (1993). On the use of evidence neural networks, in Advances in Neural Information Processing Systems 5. San Mateo, CA: Morgan Kaufmann, pp. 539-546.

Neural Network Tools for the Analysis of Ecological Data from Aquatic Systems

WERNER H.H.[2*], DAPPER T.[2], SCHMIDT H.-H.[3], BORCHARDT D.[1], SCHLEITER I.M.[1] and WAGNER R.[3]

[1] Dept. of Sanitary and Environmental Engineering, University of Kassel, Germany.
[2] Dept. of Mathmatic/Informatic, University of Kassel, Germany.
[3] Max-Planck-Inst. of Limnology, Schlitz, Germany.

In data analysis for aquatic systems we face the problem of a very large number of relevant parameters (meteorological, physical, chemical, biological) with widely unknown interdependencies. For several reasons the use of statistical methods reaches its limits. Firstly, the high dimensionality of the parameter space (several hundred parameters) makes standard statistical programs very slow, so that results can't be obtained in acceptable time. Secondly, most of the statistical procedures assume some kind of independence and normal distribution of the parameters in use, but the parameters in question are highly interdependent and by no means normally distributed. However, not much is known about the kind of dependencies. Thirdly, statistical methods are linear in nature and nonlinearities can only be handled by a priori models, but without knowledge about the dependencies it is next to impossible to create a sensible a priori nonlinear model.

In this situation neural networks provide an interesting alternative approach for data analysis. The main advantageous properties of neural networks are nonlinearity, adaptivity (learning from examples), generalization (reasonable response on new untrained data), and model freeness (no a priori model needed). The price for these good features is high training effort (training a large network is very time consuming), intrinsic modelling (the networks act as black boxes and resist a thorough analysis of their behaviour), and uncertain training success (it is not guaranteed that a network will learn a given lesson, or, in case it learns, that it will have decent generalization abilities). The networks used in these investigations are Backpropagation Networks (BP), Radial Basis Function Networks (RBF), Feature Maps (FM) in several variants (Learning Vector Quantisation: LVQ, Kohonen feature maps, motoric maps), and Jordan Nets (JN i.e. a BP with "states") especially for time series modelling. In these network types the training effort can be reduced considerably by splitting the task up into several subtasks. Of main interest is a pre-processing step to reduce the input dimension, since the training success heavily depends on the ratio of input dimension and number of samples in the training set. Several classical and neural dimension reduction methods are presented and compared with respect to different problems.

The above neural network methods have been applied to the following aqua-ecological problems:

- Dependence of selected physico-chemical parameters from weather conditions and other physico-chemical parameters
- Dependence of physical parameters from weather conditions
- Modelling of changes of selected physico-chemical parameters as time series

* Email: werner@neuro.informatik.uni-kassel.de

- Interdependencies of water-conditions (index of saprobity) and community (macroinvertebrates)
- Prognosis of species abundance
- Dependencies between the distribution of macroinvertebrates and selected physico-chemical parameters

Reference:

Borchardt e.al.: Modellierung ökologischer Zusammenhänge in Fließgewässern mit Neuronalen Netzen Wasser & Boden 49 (1997), 38-50.

Effect of Environmental Parameters on the Bacterial Pollution. Correlation Analysis Using Neural Networks.

ZAKARYA D. [1*♣] and FROUJI M.A.[2]

[1] Faculty of Science and Technology, Mohammadia, Morocco.
[2] Faculty of Science and Technology, Settat, Morocco.

Wastewater is one of the most important sources of urban and industrial pollution due to the chemical and biological pollutants that it contains. The effect of a set of environmental parameters on pollution indicators bacteria in high rate oxidation pond has been studied using neural networks (three layers and backpropagation algorithm).

The best models established were found to be non-linear. The obtained results show that neural networks may be used as a practical tool to control the wastewater treatment. The predicted pollution factors values were well correlated to the observed ones ($r > 0.96$).

Contributions of variables were estimated according to a simple method allowed the evaluation of the importance of each variable.

$Cont\% (V_i) = (100.\ Vi \,.\cdot\, W_{ij}) \,/.(\cdot\, {}^{n} Vi \,.(\cdot\, W_{ij}))$

n : number of variables, V_i : variable considered, $Cont\%(V_i)$: contribution of a variable V_i. W_{ij}: weights of connections between V_i neurons j of the hidden layer.

The parameters used are the acido-basicity of the water, solar radiation, water temperature, dissolved oxygen concentration , algal activity, organic matter concentration, nutrient enrichments, grazing by zooplankton, wind and residence time.

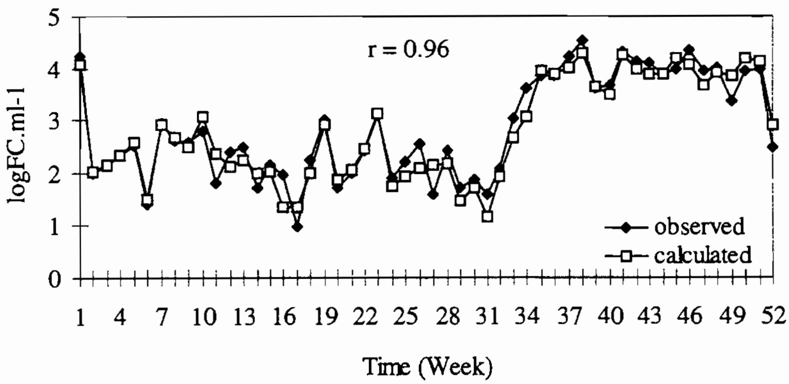


Figure : Evolution of the abundance of fecal coliforms at the outflow of pond. Comparison between observed and calculated values.

Chastrette M., Zakarya D. and Peyraud J.F., Structure-Musky Odour for indan and tetralin derivatives using neural networks. *Eur. J. Med. Chem.* **29**, 343-348 (1994).

♣ Email: zakaria@deneb.uh2m.ac.ma

International Workshop on the Applications of Artificial Neural Networks to Ecological Modelling

Toulouse (France) - December 14-17 of 1998

It is with great pleasure that we welcome you to the International Workshop on the Applications of Artificial Neural Networks to Ecological Modelling. This meeting was initially inspired during casual conversations the two leader co-organizers had at the end of 1996. Ecological Modelling must be regarded here in its largest expression, and it may include different research areas from evolutionary ecology to human epidemiology, biodiversity research and conservation action world-wide, or environmental sciences and applied ecology as well. This meeting has been imagined to bring together theoretical and applied life-sciences research, and it should promote future collaborations between researchers from different disciplines. The present Proceedings include the corresponding abstracts of different papers which will be published into two separate volumes, i.e. a special issue of the international "***Ecological Modelling***" journal, and a hard book published by ***Springer Verlag***. The contributions look at examples of applications of Artificial Neural Networks in a large diversity of research fields, and we have tried to select for the more convincing and varied examples of what neural networks may permit to imagine today. Indeed, much of our concern when writing this report is that the meeting and its relevant contributions should be viewed as being distinct from routine and cyclic symptoms of pure modelling. If some contributions are judged as being disturbing, controversial, or as far as possible opening new avenues in life-sciences research, at the closure day of the meeting we will be two contented fellows !

Sovan LEK and Jean François GUEGAN

OXFORD UNIVERSITY PRESS

Springer

Science de la Vie

EDF Electricité de France

Oktos
La Conquête De l'Univers Clientèle