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Modelling of Interaction in Environment and Cod using a Neural Network

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Abstract

The domain of fishery hydrography is mainly the analysis of fish-environment relationships. In this paper a software tool is presented that supports „fishery hydrographic pattern recognition“. With other words, complex hydrographical pattern will be used to describe cod distributions in the Baltic Sea.

An artificial neural network is the basis of modelling the interaction in environment and fishes. The artificial neural network is trained with measurements of hydrological and corresponding fishery investigations. The hydrological data were provided by the monitoring cruise of the Institut für Ostseeforschung Warnemünde, the young fish survey data originate from the investigations of the Institut für Ostseefischerei Rostock der Bundesforschungsanstalt für Seefischerei Hamburg. Spatial hydrographical patterns and total biomasses represent the input in the neural network. The output of the net is the distribution of cod.

Annual learning pattern exist from 1978 to 1993. This is the basis of training the neural network.

To get a simplified interpretation of the input and output of the model, we created an interactive graphical user interface. The heart of the simulation environment on the computer is the scientific visualisation of the data.

The visualisation of hydrographical as well as the fishery data results in a 3-D-model of the Baltic Sea.

All inputs of the neural network are graphically interactively modifiable. Therefore, an aimed change of the hydrographical conditions is possible.

How the changed hydrography influences the cod distribution is calculated by the trained neural network. The presentation of changed cod distribution in the 3-D-Baltic Sea topology should allow the user to recognise interactions between environment and fishes.

Introduction

The use of models in fishery research has been the objective to optimise fishery effort. The models that have been developed based on growing rates, natural and fishery mortality, rates of food consumption and influences of the market. The quality of these data seems to be rather acceptable.

On the other hand, the recruitment of fish stocks - as another important factor in the models - is difficult to estimate. It seems that the development in the early stages of the fish stocks is

difficult to understand. Especially, the development of the year classes in dependence on the environmental factors requires further investigations [Nell96].

A step before the investigation of the mentioned relationships between recruitment and environment is the analysis of relationships between distribution of the fish and environment. This means that we have to analyse all relevant data that could be influence the fish distribution. Therefore we are searching for an analysing method that takes complex fishery hydrographic data in to account.

In this publication it will be demonstrated, how data from the fishery biological investigations can be used in connection with hydrographical data to analyse of fish-environment relationships.

The use of scientific visualisation of marine data and computer supported pattern recognition should facilitate the analysis of the data and make the simulation of the distribution of fish possible.

Material and Method

The data used in our investigations originate from different surveys from different institutes. Fishery data originate from the Institut für Ostseefischerei Rostock der Bundesforschungsanstalt für Seefischerei Hamburg. The cod material has been collected during the national Young Fish Survey (YFS) in the western part of the Baltic Sea since 1978. This Young Fish Survey is a bottom trawl survey carried out during the autumn and winter months in the inner part of the Mecklenburger bight and the Arkona Basin. Each area was divided into geographically caused depth strata (10 m intervals). Each strata was covered by a certain number of trawl stations, i.e., 31 stations in the Arkona Basin.

The surveys have been carried out by the RV „Eisbaer“ and the RV „Solea“.

Each tow lasted 30 minutes and the so-called Herring-Bottom-Trawl (HG 20/25) was used.

For our investigations we are using data of the cod distribution.

The hydrological data origin are the monitoring cruises of the Institut für Ostseeforschung Warnemünde. For more details see [Nehr90]. Selected data of the corresponding hydrographic and fishery investigations were used for training an artificial neural network.

In a first step we try to train the artificial neural network with the hydrological pattern of temperature, salinity, oxygen and the numbers of cod in the first four age groups at different trawl stations. Caused by the need of completeness of data sets, we have to select hydrological and trawl stations where data are available during the time of exploration.

Simulation with an Artificial Neural Network

The high performance of the human brain in highly complex cognitive tasks like visual pattern recognition was always a great motivation for modelling the brain and the human way of generalisation.

One of the most successful methods simulating the ability of human pattern recognition seems to be the artificial neural network (ANN).

In these models, knowledge is usually distributed through a net and is stored in the structure of the topology and the weights of the links. The network is organised by training methods. A typical application of ANN is the recognition of hand-written letters. In this case the model is trained by a set of letters, that consists of hand-written and corresponding typed letters. After training the net, the artificial neural network should be able to classify also unknown hand-written letters to typed letters.

Applying the letter recognition to the recognition of fishery hydrographic pattern means that we try to describe the distribution of fishes by means of hydrographic pattern.

However, classical logic is replaced by vague conclusions and associative recall. The model tries to find the best match of fish distribution for a given hydrographic situation. The matching of hydrography and fish distribution can only be as good as the training base. That's why the training pattern have to be selected very carefully.

The Neural Network Simulator

The goal of a neural network simulator that we need is to get an efficient and flexible computer environment for creating neural nets.

The Stuttgart Neural Network Simulator (SNNS) is such a simulator for neural networks. It has been developed at the Institute for Parallel and Distributed High Performance Systems at the University of Stuttgart since 1989 (the SNNS simulator can be obtained via anonymous ftp from host <ftp.informatik.uni-stuttgart.de> in the subdirectory /pub/SNNS).

The SNNS simulator consists of five main components: simulator kernel, graphical user interface, batch simulator, network compiler and an network constructor.

The simulator kernel operates on the internal network data structures of the neural nets and performs all operations on them. The graphical user interface, built on top of the kernel, gives a graphical representation of the neural networks and controls the kernel during run. In addition, the user interface can be used to directly create, manipulate and visualise neural nets in various ways [Zell et. al]. The network compiler compiles an SNNS network file into an executable C source. The network can be used as a function in our own application.

Topology and Configuration of the ANN

The net topology describes how the neurones and their connections are ordered. The network is composed of three layers, the input layer, the hidden layer and the output layer. Each layer consist of a number of units (neurones) which are connected with modifiable connections. In the current example feedforward-networks were used. Here the connections have only one direction, from the input layer to the output layer. Figure 1 shows the topology of the used net.

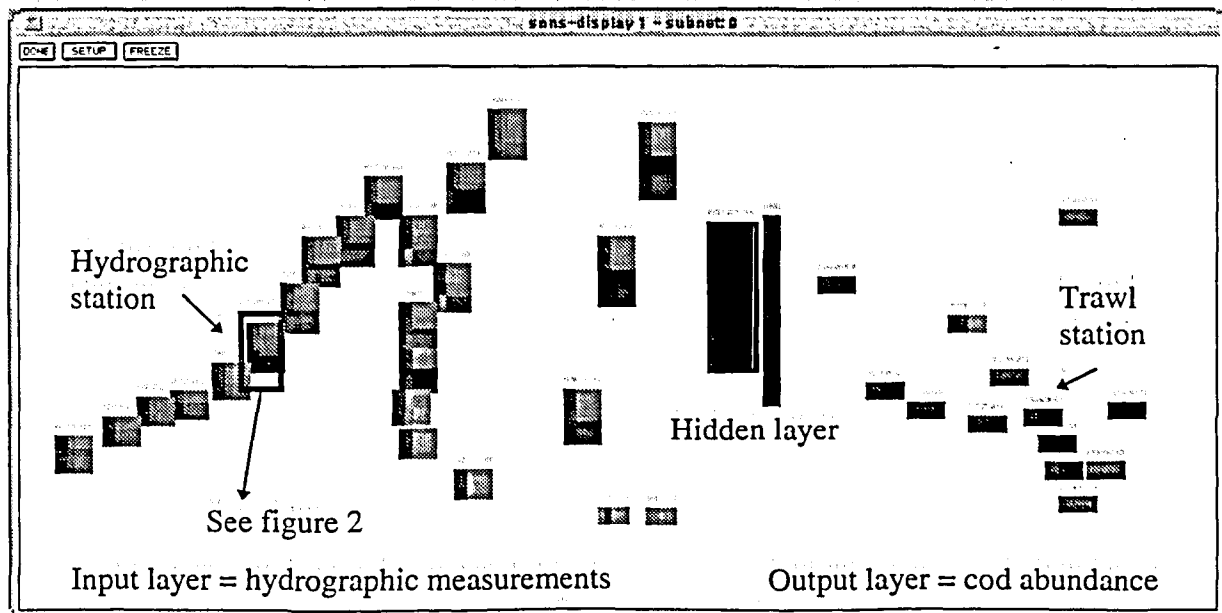


Figure 1: Topology of the artificial neural net (the links between the units are not shown)

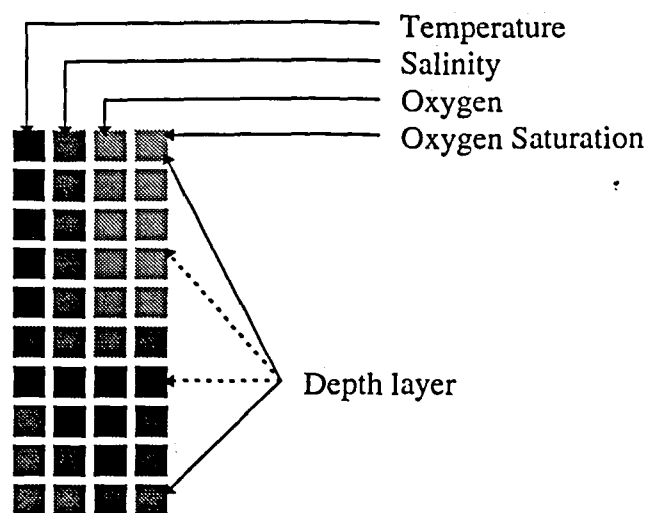


Figure 2: The order of the units at a hydrographic station

In the input layer the hydrographical stations are presented as rectangles and are ordered according to their geographical position. The individual rectangles consist of an amount of neurones. The four parameters temperature, salinity, oxygen and oxygen saturation are ordered vertically. Horizontally, the depth layer can be seen.

In the output layer, there are blocks of four neurones per trawl station. The four neurones represent the abundance of cod at age 0, age 1, age 2 and age 3.

The used artificial neural network has a total of 473 input units (hydrographic data and total biomasses), two hidden layers and 52 output units.

An important focus of a neural network is the question, how to adjust the weights of the links to get a behaviour that describes the real fish distribution with the help of hydrographic conditions. Training a feedforward neural network with supervised learning consists of the following procedure: An input pattern is presented to the network. The input (hydrography and total biomass) is then propagated forward in the net until the activation reaches the output (fish distribution) layer. This constitutes the so-called forward propagation phase [Zell95].

The output of the output layer is then compared to the teaching input. The error, i.e., the difference between the output and the teaching input is the basis to change weights of the links between the units. In this way the errors are propagated backward, so this phase is called backward propagation. How to apply the weight changes of the links to the network, is determined by the learning algorithm. In our investigations we used the most famous learning algorithm, the backpropagation.

After training the network with 144 pattern we got a network that was able to generalise fish distributions from hydrographic pattern. The 144 pattern consists of a mixture of real data and noised copies of the real data.

Combination of the ANN and scientific visualisation

Since now we have built a neural network and trained the network with the learning pattern. The SNNS offers the possibility to compile a C function of the trained network and integrate the C source in an other application. The application where we integrate our compiled ANN is the simulation interface of the fish environment model. The heart of the simulation interface is

a software tool for scientific visualisation. The visualisation is realised on Silicon Graphic computer with IRIS Explorer. The following screen shot shows how it works.

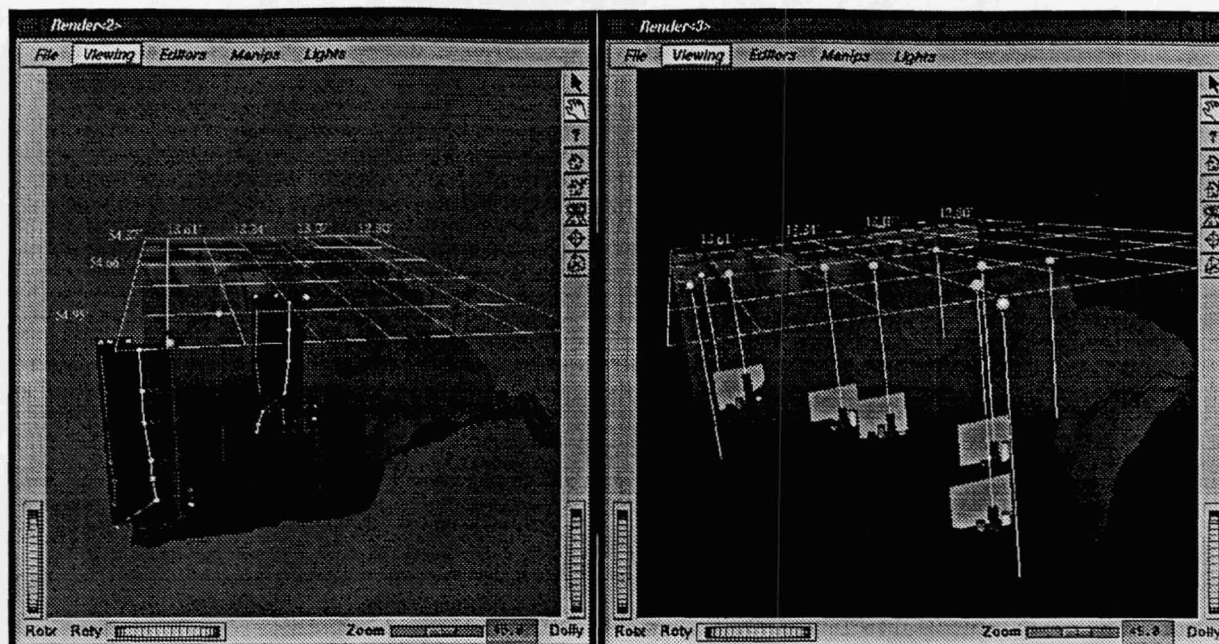


Figure 3: Screen shot of the simulation interface

Interactive Visualisation and Control of the Input and Output of the ANN

For the scientific visualisation of the hydrographic and the fishery data the visualisation software IRIS Explorer is used. IRIS Explorer is a system for creating powerful visualisation maps, each of which comprises a series of small software tools, called modules. A map is a collection of modules that carries out a series of related operations on a dataset and produces a visual representation of the result. We use one map for the hydrographic data and one map for the fishery data.

IRIS Explorer has three main components:

- the Map Editor which is a work area for creating and modifying maps,
- the DataScribe(tm) which is a data conversion utility for moving data between IRIS Explorer and other data formats,
- and the Module Builder which allows us to create our own custom modules.

By means of this software tool a user interface, the import of the data, the possibility of programming special visualisations and the integration of our own simulation modules can be established.

The visualisation environment has two tasks. On one hand, it provides the graphical display of the measurements and their interpretation, on the other hand it gives the possibility to change interactively the input data (hydrography) for the simulation.

It can be seen in figure 3, that hydrographic- and fishery data are presented in separate windows. All basic data will be visualised in the 3-D-model of the Baltic Sea. The data for the 3-D-model of the Baltic Sea originate from the Institut für Ostseeforschung Warnemünde [SeKa95].

The hydrographic data are presented as a profile at the actual geographical position. By the possibilities of navigating in time and space, it is a fast and effective way to consider the hydrographical patterns.

The fishery data are presented in the right window. Bar diagrams showing the amount of the first four age groups of cod at the individual trawl positions.

The analysis of fishery hydrographic data is supported by the visual comparison of the visualised data. The selection of comparably hydrographical and fishery data has to be done by the user of the system.

Simulation

After a detailed visual appraisal of the fish environment relationships, the further analysing procedure of a fishery hydrographer is that now an aimed modification of hydrographical situations is possible. The interactive changing of the hydrography serves the simulation of scenarios "What would be happen if ... ?". The goal is to create a system in which e.g. a hypothetical inflow of salty water of the North Sea could be simulated interactively. The simulation, using the ANN, delivers a decision where and how many cod of an age group are to be met. In future work, it has to be tested that the ANN has been well configured. The objective is a software system that supports the interpretation of statements like the dependence of cod distribution on hydrographical situations through the access of knowledge directly from the data.

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