Integration of Neural Networks and Knowledge-Based Systems in Medicine

Ultsch, A.[1], Korus, D.[1], Kleine, T.O.[2]

[1]Department of Mathematics / Informatics
[2]Department of Neurochemistry, Center of Nervous Diseases
University of Marburg
Hans-Meerwein-Straße / Lahnberge
D-35032 Marburg

Abstract Knowledge-Based Systems are used in medical diagnoses. They have the advantage to give an explanation of a diagnosis. But a main problem when dealing with Knowledge-Based Systems is the acquisition of knowledge. Artificial Neural Networks deal with knowledge in a subsymbolic form. Incomplete and imprecise data can be processed by approximating not linear relations in data. In a laboratory or medical system the integration of the neural network system into the decision making process may be required. We realised this by building a hybrid system consisting, first, of graphical visualisation methods and second, a machine learning module generating rules out of the neural network. The rules are presented in a form, which can be understood by humans and used in Knowledge-Based Systems.

Keywords: Knowledge-Based System, Neural Network, decision making, visualisation, machine learning.

Integration of Neural Networks and Knowledge-Based Systems

Knowledge-Based Systems are used in medical diagnoses. They have the advantage to give an explanation of a diagnosis. This is very important especially in the domain of medicine where the user wants to have the diagnosis proved. But a main difficulty when dealing with Knowledge-Based Systems is the acquisition of the domain knowledge. There are several problems with it. It is difficult to transform the explicit and implicit knowledge of the expert's domain, which also partly consists of own experience, in a form which is suitable for a knowledge base. The knowledge can also be inconsistent or incomplete. A second problem is that Knowledge-Based Systems are not able to learn from experience or to operate with cases not represented in the knowledge base.

Artificial Neural Networks deal with knowledge in a subsymbolic form. They can solve non-linear problems often better than conventional methods and are capable to approximate non linear relations in data. In addition, incomplete and imprecise data can be processed. Neural networks learn in a massively parallel and self-organising way. Unsupervised learning neural networks, like Kohonen's self organising feature maps [Kohonen89], learn the structure of high-dimensional data by mapping it on low dimensional topologies, preserving the distribution and topology of the data. But large neural networks can only be interpreted with analysing tools. We developed a visualisation method, the so called U-Matrix methods, to detect the structure of large two-dimensional Kohonen maps. It generates a three-dimensional landscape on the map, whereby valleys indicate data which belongs together and walls separate subcategories [Ultsch/Siemon90].

In a laboratory or medical system the integration of the neural network system into the decision making process may be useful. The knowledge of neural networks, however, is in this form not communicable; i.e. it is necessary to transform the knowledge into a form, which, first, can be understood by humans and second, can be processed by knowledge based systems. Knowledge based systems have the advantage that they can give an explanation of a diagnosis. By integrating both paradigms, knowledge based systems and neural networks, the disadvantages of both approaches can be redressed.

We are developing a hybrid system REGINA (rule extraction and generation in neural architecture) which consists of several parts. An unsupervised learning neural network maps the (preprocessed) data space onto a two-dimensional grid of neurons, whereby it preserves the distribution and topology of the input space. But only together with a visualisation module, called U-Matrix methods, we are able to detect structure in the data and classify it. A three-dimensional coloured landscape will be generated in which walls separate distinct subclasses and subcategories are represented by valleys. A machine learning algorithm sig* extracts rules out of the learned neural network [Ultsch/Li93]. In distinction to other machine learning algorithms like ID3 our algorithm considers the attributes by selecting those which are relevant for the classification. This corresponds to the proceeding of a medical expert. The rules can be used as a knowledge base for an expert system. Also fuzzy rules can be extracted out of the neural network.

5th Conf. on Artificial Intelligence in Medicine Europe AIME’95, Pavia, Italy, in: Barahona, P.; Stefanelli, M.; Wyatt, J. (eds.) Artificial Intelligence in Medicine, Lecture Notes in Artificial Intelligence 934, Springer 1995, pp. 425-426.

Application in Medicine

In order to test our hybrid system we applied it to two medical applications. First, we used it to diagnose acidosis diseases. The data set consists of 11 attributes originating from the blood analysis. Several classification methods according to [Deichsel/Trampisch85] were used to explain these data. The Neural Network together with the U-Matrix method was able to classify the data into the subcategories healthy, lacacidemia, metabolical acidosis, respiratory acidosis and one patient with cerebral deficiency (Fig.1a). With our rule generation module

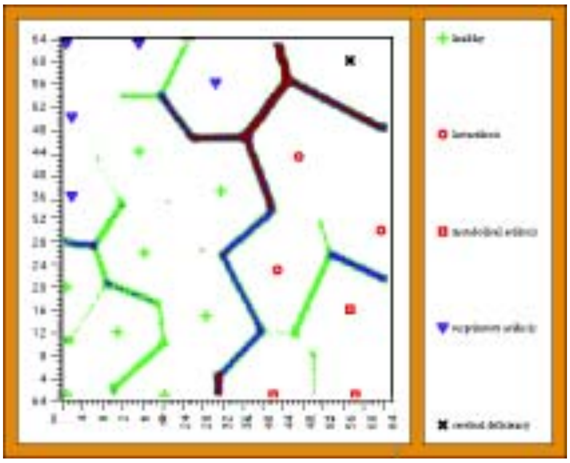

Fig. 1 U-Matrix and classification of acidosis data

sig* we extracted rules out of the Neural Network, which were described by 4 or 5 attributes resembling more closely the decisions made by medical experts [Ultsch/Li93]. Second, we used a data set with patients suffering from different types of the blood disease anaemia. Here no classifications were known a-priori. Deviations of blood values were indicators for a diagnosis of anaemia diseases (Fig.1b). The extracted rules are quite similiar to the diagnosis rules in a medical text book [Müller/Seifert89]. But additional rules were also found and could be verified by medical experts [Ultsch92].

In near future results from CSF analysis [Kleine89] to diagnose different forms of meningitis will be presented. The problems of the course of disease (time series) and multi-diseases (multi-clustering, pattern segmentation) will be also considered in this application. Further applications of our system lie in the area of environment and in the area of industrial processes.

References

[Deichsel/Trampisch85] Deichsel, G.; Trampisch, H.J.: Clusteranalyse und Diskriminanzanalyse, Fischer 1985.

[Kleine89] Kleine, T.O.: New diagnostic methods for inflammation of the human central nervous system by cerebrospinal fluid analysis, J. Clin. Chem. Clin. Biochem. 27, 1989, 895-932.

[Kohonen89] Kohonen, T.: Self-Organization and Associative Memory, Springer 1989.

[Müller/ Seifert89] Müller, F.; Seifert, O. Taschenbuch zur medizinisch-klinischen Diagnostik, Springer 1989.

[Ultsch92] Ultsch, A.: Self-Organizing Neural Networks for Knowledge Acquisition, Proc. Europ. Conf. Artificial Intelligence, Wien 1992, 208-210.

[Ultsch/Li93] Ultsch, A., Li, H.: Automatic Acquisition of Symbolic Knowledge from Subsymbolic Neural Networks, Intl. Conf. Signal Proc., Beijing 1993, Vol.2, 1201-1204.

[Ultsch/Siemon90] Ultsch, A., Siemon, H.P.: Kohonen's Self Organizing Feature Maps for Exploratory Data Analysis, Proc. Intern. Neural Networks, Kluwer Academic Press, Paris 1990, 305 - 308.

5th Conf. on Artificial Intelligence in Medicine Europe AIME'95, Pavia, Italy, in: Barahona, P.; Stefanelli, M.; Wyatt, J. (eds.) Artificial Intelligence in Medicine, Lecture Notes in Artificial Intelligence 934, Springer 1995, pp. 425-426.