Artificial Neural Networks - Classification and Technical Applications *

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Abstract: - **The paper is a review of the classification and applications of the artificial neural networks. The basic properties of these networks are viewed thus pointing to the governmental programs for their research and applications.**

Keywords - **artificial neural networks; artificial neural network properties; artificial neural network applications.**

I. Classification of Neural Networks

According to [1], neural networks (NN) may be divided in two large groups: *feed-forward networks* and *recurrent/feedback* networks.

1.Types of feed-forward networks:

One-layer perceptron. All inputs are connected to each of the output neurons.

Multilayer perceptron, NN with radial basis functions. Outputs from all neurons of a layer are connected to each of the neurons of the next layer.

2.Recurent networks (feedback networks). According to the type of the links between their neurons, the NNs can be classified as:

NNs with competitive training. Each neuron from a given layer is connected to all other neurons of the same layer.

Kohonen's self-organizing maps (SOM). Each neuron from a layer is connected his nearest neighbors from the same layer.

Hopfield network. Each neuron from a layer has as an input all outputs of all other neurons of the same layer.

Adaptive Resonance Theory Networks (ART). Each output neuron is connected to all other output neurons as well as with all input neurons.

Training algorithms

The NNs training rules may be classified according to the following features: training paradigm, training rule, training algorithm, NN architecture and application area [1].

1.Training paradigm: supervised learning, unsupervised learning, hybrid.

2.Training rules:

Error correction;

Competitive training;

Hybrid training – competitive and error correction;

Rules based on principles from physics. On their part they are classified as: Hebb's training (supervised and unsupervised), Boltzman's training (supervised).

3.Architecture: NN's architecture is closely dependent upon its training rule.

With error correction: multiplayer perceptrons are used. In case of supervised learning, perceptrons may be multiplayer as well as one-layer.

Competitive training: in this case the following architectures are possible- architecture for standard competitive training, SOM (unsupervised), ART-networks (supervised or unsupervised).

With error correction and competitive (for hybrid training) - NNs with radial basis functions.

Rules based on principles from physics: Hebb training (feed-forward networks architecture is used. In case of supervised learning, it is possible that the number of layers is more than 1. For unsupervised learning Hebb's rule competitive structures and Hopfield networks are possible); Boltzman's training (it has it's own unique architecture).

4.Training algorithm: it depends on the area of application, i.e. on the type of the given problem. First two points listed next describe the specific algorithms used with the two main types of training; the third point lists the most popular algorithms used with NNs:

Supervised learning. Characteristic algorithm is the within-class categorization. It is realized with adaptive vector quantization; ART-networks.

Unsupervised learning. The specific training algorithms are chosen according depending on the area of application: associative memories (on boundary between automats and NNs; trained according to a unique principle); classification (realized with vector quantization, SOM-networks, ART1- and ART2-networks).

Popular training algorithms (starting from most widely-used); perceptron algorithms (supervised) (perceptron

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training, back-propagation, Adaline/Madaline); competitive training algorithms (supervised or unsupervised)(algorithms for vector quantization or ART networks; SOM are also allowed, provided the training is unsupervised); radial basis functions algorithms; algorithms for networks based on physical rules. Hebb's rule for supervised learning is realized with linear discriminant analysis, and for unsupervised learning – with principal component analysis (in addition to associative memories training). Boltzman's rule for unsupervised learning has its own training algorithm.

II. Applications of Neural Networks

Survey shows, that NNs are one of the most-actively researched and most perspective fields in artificial intelligence. They are object of massive research in EEU (Eureka) and in some of the most developed countries, such as Germany (ITR-8800-G9, Ministry Of Science), France (DGA/DRET/SDR), USA, Japan.

The areas of application of NNs, according to [2] are known as "soft computing" for badly defined problems, in which constant adaptation and evolution are necessary. They are successfully used for diagnostics, image recognition, classification, optimization and control.

Types of NNs applications

Generally speaking, the applications of NNs can be classified using three different criteria, depending upon: whether the grouping follows the natural NN paradigm, whether the classification is done in view to use in industry or some very complex applications are envisaged.

Natural applications

1.Function approximation. A special place in this group is held by the radial basis functions, which synthesize in their structures supervised and unsupervised NN learning [1]; this class NNs, have their own specific training algorithm [1].

2.Associative memories (AM). The distinction between NNs and Ams is not strict and often is a question of personal favor: many NNs work as Ams (for example Hopfield network associates images with themselves, while some Ams function as NNs. Some of the more popular Ams are [3]: Willshaw associative memory, Advanced Distributed Associative Memory (ADAM), Sparse Distributed Memory (SDM), Bidirectional Associative Memory (BAM).

3.NNs for coding. Not depending upon its concrete technical implementation, coding is used in image compression. NNs are used for finding an effective field of samples, represented through hidden neurons, coding a great number of input-output samples.

4.Data compression.

5.Image compression. It is based upon the low transmitting capacity of TV channels (beside intensity and pixel color, there is also big information surplus during video signal transmission). This is why, before transmission, the picture is compressed by coding and after transmission it is decoded in the receiver. In those cases NNs are used (Kortel, for exmpl.) for coding by the sensors and the hidden layer and for decoding by the hidden layer and output layer; the NN is trained by teacher using the bach-propagation method.

6.Image and speech recognition.

7.Cell NNs. Used in hardware for modeling electrical circuits.

Application of NNs in the industry

1.Synthesis and prediction of time sequences. [4, 5]

2.Identification and modeling of dynamic no stationary processes. [6-8]

3.Optimization and control of dynamic systems. These NNs are used in economy, ecology, industry, etc. For example in the industry, NNs have two main applications – improvement of technology and application on control level. NNs improve technology if they are used in computer vision (for automatic quality control), in robot control systems, inspection of difficultly accessible areas. On the control level, NNs are very effective in optimization of production schedules, etc.

Complex applications

1.Image recognition with NNs

-Problems in image recognition:

1)Image analysis – an image is input to the NN and its output is a combination of image description parameters (feature vector). The problem which image analysis solves is classification of the object in the input image.

2)Synthesis of artificial images – input is the feature vector of an image (see p.1)). Classical optics and computer graphics are problems of visual synthesis. An important term is the field of optical flow. It takes part in the synthesis of new images, with known transformation parameters and given input image.

-Visual perception and recognition:

1)Object representation: through lines or photographic representation (through arrey of values, corresponding to levels of grey), most realistic or closest to human vision.

2)Main problems: separating image from background, and visualizing object independently of its position.

Typical applications of visiual perception and recognition are criminology, banking, communications and medicine; image editing, video editing, virtual reality, multimedia databases, computer graphics; human-computer interaction (HCI) interfacesface and object recognition; image animation for cartoons; mdelling of visual processes in humans and animals; character recognition [9]; signature classification for identification; greyscale image segmentation.

A HCI interface for example is described with 10 parameters, more or less, plus several global parameters. In medicine, NNs are used for obtaining and storing of medical data, from specialized medical technology (for example computer tomograph, etc), which is eventually processed in certain way (ex. Diagnose formulation, visualization of scanned images, etc). In banking and finances a main problem is the risk evaluation and this is why for the moment only straight, small-sized NNs are used.

-NNs for image recognition – applications:

1)Pose-independent face recognition. 15 different poses of a face are used.

2)Classical approach to visual perception. In this approach the information is divided in two parts – position independent –"what" and viewpoint for object representation – "where". The NN has an input layer , a hidden layer and an output layer. The two parts of the output layer characterize the object position. The training of the network is realized through random image sequence.

3)Segmentation. (Kienker) Specific parts of the network are described – a layer represents object's boundaries in the image, a layer defines if a pixel belongs to the object. Training is done according to Bolzman-machines rule and the test forms vary from triangle to spiral. The NN interprets correctly even figures which are represented only with their angles.

4)Problems of computer vision (Koch). They are solved through standard regulation theory by minimization of quadratic energy functions corresponding to Hopfield networks. For example when only some of the points are provided or if there is noisy data, a smooth surface is reconstructed by linear processes.

5)Object position and orientation independence (Logotetis and Pauls). The different object's views are recognized by three, instead of one, neurons.

6)Nondeformable 3d object generation. (Pojo, Bauhmer, Shashua).One of the samples if set to serve as reference. The optical field flow defines the correspondence between the pixels of the base and the other samples. From some input data – pose parameters – multiple output data is received. Each output data corresponds to an attribute for a given pixel in the image.

7)Face template construction. Templates are applied for the different parts of face – eyes, nose, mouth.

8)View-tuned and view invariant neurons; setting of the form of psychophysical recognition fields (Pojo, Brokolo, Logotetis). The input image data is passed through filters, after which is compared with patch of the target object.

9)Training by line drawings (Pojo, Brunelli, Librand).

10)Face verification (Romano, Bauhmer)

11)Face recognition using several views.

2.Speech recognition

-General scheme for speech recognition (SR). The SR process basically consists of two parts: noise reduction of the input signal and linguistic processing of the cleared signal. Noise can be either specific for the sound input (empl. Microphone) or a part of the sound background. The process of noise reduction is realized through acoustic modeling. Linguistic modeling includes word recognition, choosing of most probable word candidate and word processing of the recognized words; word recognition is composed of acoustic modeling and linguistic modeling. The acoustic analysis produces a list of words, having similar sounds, and linguistic modeling defines the probability that a given word is among, before or after other words, so that the list of most probable words may be reduced in size.

-Sound and speech characteristics.Vowels (different harmonics of one frequency can be distinguished; this base frequency is defined from the tone of talking); voiceless consonants (no harmonics can be distinguished, though noise appears in certain frequency intervals); voiced consonants (a combination of light harmonics and nose in some frequency intervals).

-Difficulties in speech recognition

1)speech is a key to human memory

2)subjective factors (pronunciation, etc)

3)speech intermittency (often no pauses between words)

4)contextual dependency of word meaning [10, 11]

-Speech recognition with NNs

1)General settings. SR with NNs can be divided into following stages: preprocessing, selection of most probable candidates, postprocessing. During preprocessing the input signal cleared from noise or the dimentions of the input vector are reduced. Postprocessing allows, the cleared signal to be saved in suitable form and to be integrated with other applications. The role of NN here is in the process of noise reduction as well as in the formation of robust to noise representations and similarity functions and in the construction of methods describing classes in case of badly structured data. [12,13]

2)Basic scheme of SR with NN. NN solve two types of problems in SR. The first one is the minimization of the topology of the NN through matrix-vector representation of the NN and synthesis of fast converging methods and algorithms for training of NN with minimized topology. For the solution of the second problem, systems of NN are used, modeling various subtasks of the SR task, rather than one single NN for recognition [14].

-Types of NN for SR:

1)Straight networks for separation of different words with limited dictionaries (have restricted use)

2)Recurrent networks

-Use temporal structure of language

-Store the contextual history of a sequence in natural language

3)Systems of NNs:

-The input NNs have to cluster / classify input vectors according to tone, so that similar sounds can be recognized

-On upper level are NNs for letter recognition, with temporal processing output

-On highest level are NNs for word recognition, with context reference for better recognition.

IV. Conclusions

The paper is a review of the classification and applications of the artificial neural networks. The basic properties of these networks are viewed thus pointing to the governmental programs for their research and applications.

References

[1] A. Jain, A. K., Artificial neural networks: a tutorial, *IEEE Computer*, Mar. 1996, pp. 31-44, 1996.

[2] R. R. Yager, L. A. Zadeh, Fuzzy sets, neural networks, and soft computing, N.Y., Van Nostrand Reinhold, 1994.

[3] R. Beale, T. Jackson, Neural computing: an introduction, Dptmt. of Comp. Sci., Univ. of York, Adam Hilger, 1990.

[4] M. J. Cosculluela, *et al.*, Day type identification for electric hourly load demand forecasting using SOM, Prepr. of the 6-th Int. Conf. on NN - NEURO NIMES'93, France, 25-29, 1993.

[5] A. Jain, A. K., Artificial neural networks: a tutorial, *IEEE Computer*, Mar. 1996, pp. 31-44, 1996.

[6] A. Jain, A. K., Artificial neural networks: a tutorial, *IEEE Computer*, Mar. 1996, pp. 31-44, 1996.

[7] K. S. Narendra, K. Parthasarathy, Identification and control of dynamic systems using neural networks, *IEEE Transactions on*

Neural Networks, V. 1, 4-27, 1990.A. Jain, A. K., Artificial neural networks: a tutorial, *IEEE Computer*, Mar. 1996, pp. 31-44, 1996.

[8] S. A. Billings, *et al.*, Properties of NN with application to modelling nonlinear dynamical systems, *Int. J. Control*, V. 55, No. 1, 13-224, 1992.

[9] S. Mori, *et al.*, Historical review of OCR research and development, *IEEE Proc.*, V. 80, No. 2, 1029-1057, 1992.

[10] M. Zeidenbeerg, Neural network models in AI, Ellis Horwood, 1990.

[11] R. Reilly, N. Sharkey, Connectionist approaches to natural language processing, Lawrence Erlbaum Associates, Publishers, 1992.

[12] H. Hattori, Text-independent speaker recognition using neural networks, Proc. of the ICASSP'92, V. II, 153-156, 1992.

[13] M. Hunt, C. Lefebvre, A comparison of several acoustic representation for speech recognition with degraded and undegraded speech, Proc. of ICASSP'89, 262-265, 1989.

[14] Artieres, T., *et al.*, Connectionist and conventional models for free-text talker identification tasks, Universite de PARIS-SUD, Rapport de Recherche No 677, 1991.

[15] D. Williams and J. B. Gomm, “The introduction of neural network projects in a degree of electrical and electronic engineering”, *12th Int. Conf. on Systems for Automation of Engineering and Research SAER'98, Proc*. 19-20 September 1998, Varna - St. Konstantin resort, Bulgaria, pp. 102-106, 1998.

[16] I. Baruch, A. Martinez and B. Nenkova, “Adaptive Neural Control with Integral-Plus-State Action”, *Cybernetics and Information Technologies*, Vol. 2, No. 1, Sofia, pp. 37-48, 2002