A CONCEPTION OF NEURAL NETWORKS IMPLEMENTATION IN THE MODEL OF A SELF-LEARNING VIRTUAL POWER PLANT

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Abstract: The present article focuses on learning methods of self-learning organization (on the example of the virtual power plant), using artificial intelligence. There was multi-module structure of the virtual power plant model presented, in which there were automated chosen learning processes of the organization as well as decision making processes.

1 INTRODUCTION

The article presents the virtual power plant model (Kucęba, 2003), in which chosen decision making processes are automated by application of neural networks. The structure of the proposed model consists of the following modules (Figure 1):

- The Internal Knowledge Components Acquisition Module,
- The External Knowledge Components Acquisition Module,
- The Explaining-Concluding Module,
- The Knowledge Aggregation Module,
- The Individual Units Motion Management Module,
- The Control Module,
- The Heat Demand Prediction Module (for the units producing heat in association).

It should be stressed that three of the above mentioned modules (The Explaining-Concluding Module, The Individual Units Motion Management Module, The Heat Demand Prediction Module), were worked out on the basis of artificial intelligence (Kucęba, 2004). These modules realize self-learning organization's tasks, based on identification of key competence essential to coordinate and manage units in the virtual structures. They were designed with the aid of the neural networks professional simulator "Statistica Neural Networks".

2 FUNCTIONALITY OF THE MODULES IN THE MODEL OF THE VIRTUAL POWER PLANT

After defining structural modules, verification of the acquired and generated information in the aspect of their usefulness in the process of learning of the simulated and determined in the project self-learning virtual power plant was conducted.

The element aiding decision making processes in the environment of dispersed production units of low power is The Individual Units Motion Management Module, based on neural networks. Input variables set of this module is generated by the proceeding Explaining-Concluding Module and The Internal Knowledge Components Acquisition Module. Neural networks implemented in The Individual Units Motion Management Module generate knowledge on the basis of which decisions in the area of correlated units motion management are made. Knowledge is then delivered to The Virtual Power Plant Motion's Central Dispatcher, which on the basis of it and data acquired form The Data Aggregation Module determines among other things work schedule for the next hour or twenty four hours of the virtual power plant and also manages motion of the individual units producing low power energy.
Effective functioning of the proposed organization is conditioned by proper selection of input variables in the individual modules of knowledge components acquisition. To this end there were two different

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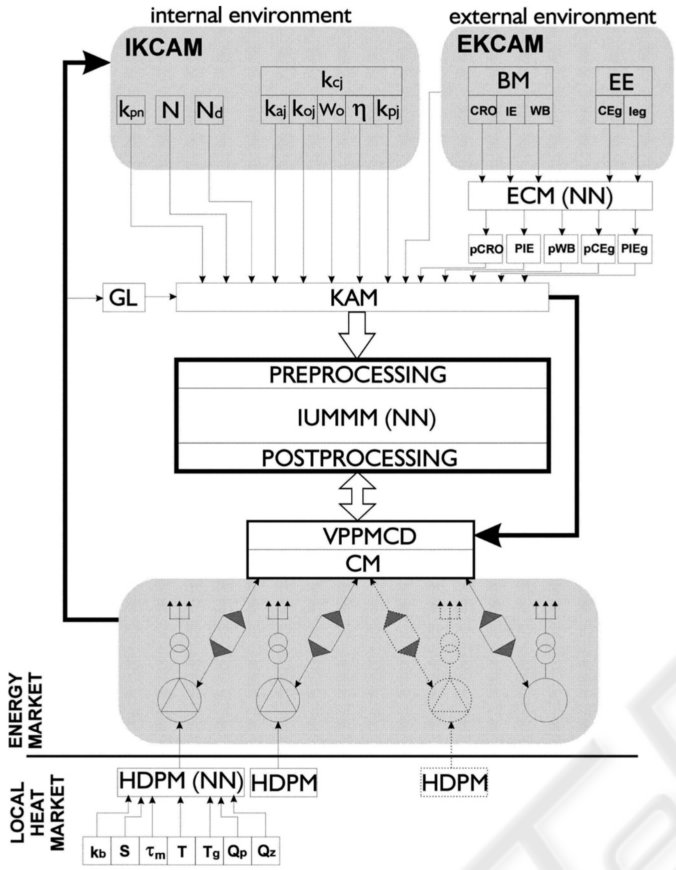

where:

IKCAM - The Internal Knowledge Components Acquisition Module
EKCAM - The External Knowledge Components Acquisition Module
k_{pn} – costs of energy carriers acquisition in the regional perspective
N – electric/heat indicative power of individual units
N_d – discretional power
k_{cj} – unit price of the energy from scattered and dispersed sources
k_{pj} – unit price of fuel in the regional perspective
k_{aj} – depreciation costs of energetic equipment
k_{oj} – unit price of calculable interests
w_o – fuel value of individual energy carriers
η - energetic equipment efficiency
BM – Balance Market
CRO – accounting prices of deviations (APD) on the balance market
IE – energy amount on the balance market
WB – balance index
EE – Energy Exchange
CEg – energy price on the Energy Exchange
IEg – energy amount on the Energy Exchange
ECM – The Explaining-Concluding Module
pCRO – accounting prices of deviations prognosis (APD) on the balance market
PIE – energy amount prognosis on the balance market
pWB – balance index prognosis
pCEg – energy price on the Energy Exchange prognosis
pIEg – energy amount prognosis on the Energy Exchange
GL – Geographical Location
KAM – The Knowledge Aggregation Module
IUMMM – The Individual Units Motion Management Module
NN – Neural Networks
VPPMCD - The Virtual Power Plant Motion's Central Dispatcher
CM – The Control Module
HDPM – The Heat Demand Prediction Module
k_b – cubature of the buildings heated
s- size of centrally heated rooms
τ_m – power usage time
T – extreme temperature in heating period
T_g – heating periods length
Q_p – quantity of heat production
Q_z – quantity of heat consumption

Figure 1: Model of self-learning organization in the virtual management environment (power plant). Source: own analysis

methods of input variables selection used. In case of The Internal Knowledge Components Acquisition Module technical-economical analysis was used.

Verification of the input variables of The Explaining-Concluding Module was based on Crucial Factors Success Analysis. It was conducted in the context of variables selection representing real time changes occurring on the balance market and the Energy Exchange. Effective management of the individual units motion is largely dependent on proper selection of knowledge components used in the process of learning of neural networks allocated in The Explaining-Concluding Module. In connection with that conducted Crucial Factors Success Analysis was limited to minimizing function of errors generated in the structure of neural networks using sensibility analysis, implemented from applied in the research “Statistica Neural Networks” – neural networks simulator. At this stage of the conducted research for balance market and the Energy Exchange there were independent sets of neural networks of diverse typologies defined, with the proper selection of input and output variables.

The main feature of the applied sensitivity analysis was determination of relative influence of the input variables (knowledge components) on neural network capacity by multiple network tests and reduction of time series representing input variables. The aim of this analysis was identifying variables that can be omitted in the process of learning without quality loss of neural network. Applied sensitivity analysis evaluated variables usefulness by giving them proper rank, ordering observed variables according to their importance (decreasing error). Selection determinant of the set elements were values of prognosis errors generated on the outputs of the networks.

As a result of the conducted analysis there was shape of time series representing input vectors of neural networks formulated. Data set structure, the components of which are input vectors and assigned to them input variables, was implied by specificity of information aggregated and processed by individual structural elements of self-learning virtual organization (Duch, Korbicz, Rutkowski, Tadeusiewicz, 2000). Data set of The Explaining-Concluding Module was determined at this stage, the components of which were vectors described by attributes bunch.

In the modules – The Explaining-Concluding Module and The Individual Units Motion Management Module, individual attributes of the vectors represent input and output variables processed by carefully selected at the later stage of research architecture of neural networks. In the first stage of the project there were two independent data sets for The Explaining-Concluding Module worked out, in order to represent phenomena occurring on the balance market and the Energy Exchange. Data sets structure, on the basis of which the process of learning of the presented module implemented in the model of self-learning organization in the virtual environment was implemented, was determined in the following stages:

- Aggregation of information describing external environment of a virtual energetic enterprise. This information included variables such as: energy price, its quality and defined within the confines of research balance index in twenty-four-hour/hour turn on the balance market and the Energy Exchange;
- Division of data set into the following sub-sets: learning, validating and testing (Kiełtyka, Kucęba, Sokołowski, 2004). The structure of these sub-sets was determined by constant number of vectors' attributes, which represented values of input and output variables.

3 INPUT AND OUTPUT VARIABLES AGGREGATION

Selection of neural networks (Kiełtyka, Kucęba, Sokołowski, 2004) was realized in a way separated for information from the balance market and the Energy Exchange. In case of the prediction process on the Energy Exchange there were two complex sets of diverse architecture neural networks determined.

The structure of the learning, validating and testing patterns, was defined here as two-dimensional time series including the following variables:

Input variables:

- Energy price on the Energy Exchange in twenty-four-hour/hour turn (quantity variable),
- Energy amount on the Energy Exchange in twenty-four-hour/hour turn (quantity variable),

Output variables:

- Energy amount (quantity variable),
- Energy price (quantity variable).

The variables were aggregated in time series the range of which was determined from 5 to 10 elements (time series size). Prognosis horizon was set an hour and twenty-four hours in advance.

Table 1: Chosen neural networks typologies implemented in the Explaining-Concluding Module in the process of knowledge components prognosis.

Time moment	Optimum network topology		Number of neurons in hidden layer (1)		Number of neurons in hidden layer (2)		Real value		Estimated value		Relative error [%]		Prognosis quality [%]	
	EP	EA	EP	EA	EP	EA	EP	EA	EP	EA	EP	EA	EP	EA
1st January														
13.00 hour	MLP	MLP	8	4	-	7	94,16	228	89,11	205	5,363	10,087	94,637	89,913
24.00 hour	MLP	MLP	8	4	-	7	100	363	106,54	405	6,54	11,57	93,46	88,43
14th March														
1.00 hour	RBF	MLP	17	9	-	5	102,6	336	100,77	333,42	1,783	0,767	98,217	99,233
16.00 hour	RBF	MLP	17	9	-	5	109	294	106,8	311,28	2,018	5,877	97,982	94,123
2nd June														
6.00 hour	MLP	MLP	9	15	-	11	90,2	177	89,85	193,08	0,388	9,084	99,612	90,916
17.00 hour	MLP	MLP	9	15	-	11	117	225	118,32	279,33	1,128	24,146	98,872	75,854
22nd September														
21.00 hour	RBF	GRNN	41	352	-	2	124	375	123,56	349	0,35	6,933	99,65	93,067
24.00 hour	RBF	GRNN	41	352	-	2	102,32	278	98,68	300	3,557	7,913	96,443	92,087

Table 1 presents specification of the chosen neural networks (MLP, GRNN, RBF) that constitute executive element in the processes of energy price prognosis (EP) and its amount (EA), implemented in the Explaining-Concluding Module. There were chosen days of observation in the year 2003 presented in the table. High quality of neural networks in the process of prognosis (example table 1) determines assumption that the proposed element of information processing increases functioning efficiency of the simulated self-learning organization in the virtual management environment.

At the next stage of data processing aggregated knowledge components (omitting components form the separated layer) were sent to the module that constitutes the decision making aiding element of the proposed model - The Individual Units Motion Management Module. There were sets of neural networks implemented in this module, which aided classification of all the knowledge components in order to generate information facilitating motion management of the virtual power plant.

Input variables:

- costs of energy carriers acquisition in the regional perspective (taking into consideration renewable energy carriers), applied in the production process of final energy,
- electric/heat indicative power of individual units,
- discretional power,
- unit price of the energy from scattered and dispersed sources (heat and electric energy):
  – unit price of fuel in the regional perspective,
  – depreciation costs of energetic equipment,
  – unit price of calculable interests,
  – fuel value of individual energy carriers,

– energetic equipment efficiency,
- accounting prices of deviations prognosis (APD) on the balance market in twenty-four-hour/hour turn,
- energy amount prognosis on the balance market in twenty-four-hour/hour turn,
- balance index prognosis in twenty-four-hour/hour turn,
- energy price on the Energy Exchange prognosis in twenty-four-hour/hour turn,
- energy amount prognosis on the Energy Exchange in twenty-four-hour/hour turn,
- geographical location of individual correlated units,

Output variable:
- dual state variable signaling turning individual unit on/off (quality variable).

On the basis of key competence there were defined priority criteria determining learning process and self-learning of neural networks, which determined proper work control of the correlated production units. The following criteria were formulated: type of energy sources used (renewable sources having the highest rank), unit cost of energy, demand for energy and geographical location. They imply classification type of the processed knowledge components, on the basis of which The Individual Units Motion Management Module generated on output dual state nominal variables, informing of turning on/off individual units within self-learning organization in the virtual management environment. This information was passed to the Virtual Power Plant Motion’s Central Dispatcher. The dispatcher receives all data included in The Knowledge Aggregation Module in the same time unit. Access to data from both modules creates situation where the dispatcher plays the role of decision-maker managing effective functioning of the virtual power plant. The dispatcher also cooperates in the process of learning of The Individual Units Motion Management Module, verifying in real time generated by this module information on the basis of all data components. Decisions controlling motions of the individual production units are passed to The Control Module (switch), which is integrated with it by energetic networks and VPN networks. In addition, VPN networks realize communication among the correlated units transferring internal knowledge components (describing internal environment) to The Internal Knowledge Components Acquisition Module (Kiełtyka, Kucęba, 2003).

4 SUMMARY

The organization, for which the virtual management environment was created, is integrated by the network of mutual connections structure of geographically dispersed low power energy sources.

Implementation of the designed framework model may influence organizational efficiency growth.

This article and its realization were inspired by the research conducted by the author concerning application of neural networks in various business processes. In the author’s opinion creation of self-learning organization in the virtual management environment is not only the future but also the need of the present day.

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