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AGGREGATION OF ENTER VARIABLES IN NEURON MODEL OF POWER REQUIRED FOR THE SEAGOING VESSEL BY MEANS OF DIMENSIONAL ANALYSIS

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Abstract

The following article presents the possibility of enter variables aggregation in neuron models required power for the seagoing vessel by means of dimensional analysis. Such aggregation simplifies significantly the model, on the basis of which, the required power for ship propulsion is defined. The algebraical diagram of dimensional analysis constructed by S. Drobot is a good instrument for this goal. What is more, such diagram allows to control, in respect of mathematics, the correctness of conclusion rules used in neuron models.

Keywords: *aggregation of variables in conclusion rules, neuron models, dimensional analysis*

1. Introduction

Power for ship propulsion is selected on the basis of hull resistance analysis in different conditions of sailing. At present it is possible to observe more and more the use of artificial neuron networks in selecting power for ship propulsion [1,2].

In diagram 1 we can see an exemplary structure of neuron network allowing to determine power for ship propulsion in different conditions of sailing.

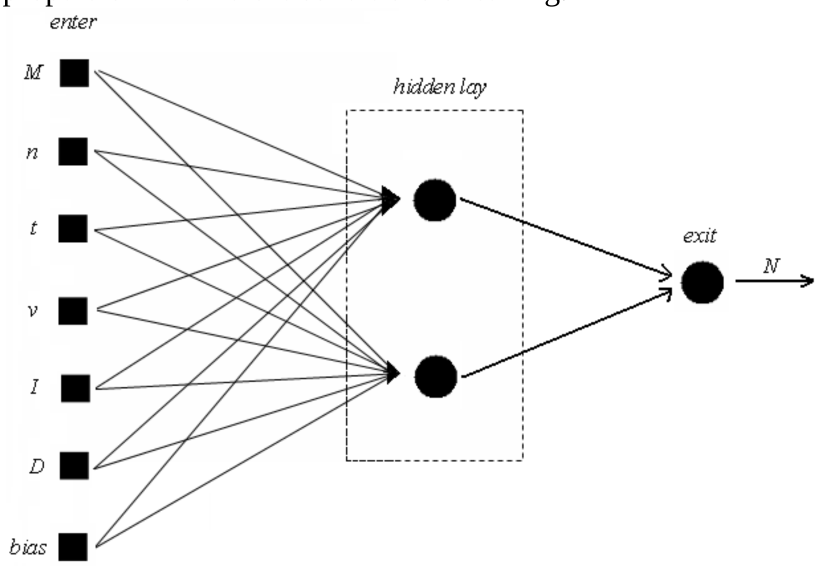

Fig.1 Structure of neuron network determining required power for ship propulsion in different conditions of sailing: M- torque of the propeller tail-end, n- revolution of the propeller, t- time of change of respective parameters, v- speed of ship, I- inertia moment of whirling propulsion elements, D-mass of ship

Therefore ship models are created using activity of neuron networks. Such networks have a complex structure putting into practice power selection for ship propulsion on this basis in a very wide range of variable parameters. The power of ship propulsion depends on dimensional quantities given to enter part of network which is put into activities respective practice. These activities involve checking premises of rules enclosed in respective bases of measurement data.

Conclusions of rules concerning power selection for ship propulsion are defined by neuron network. The number of power selection rules for ship propulsion increases violently according to the increase of the number of entrances [3].

In order to reduce the number of enter signals being dimensional quantities it is possible to use their aggregation by means of dimensional analysis. Aggregation involves the replacement of enter signals by the signal which is a respectively selected product, and their functional combination.

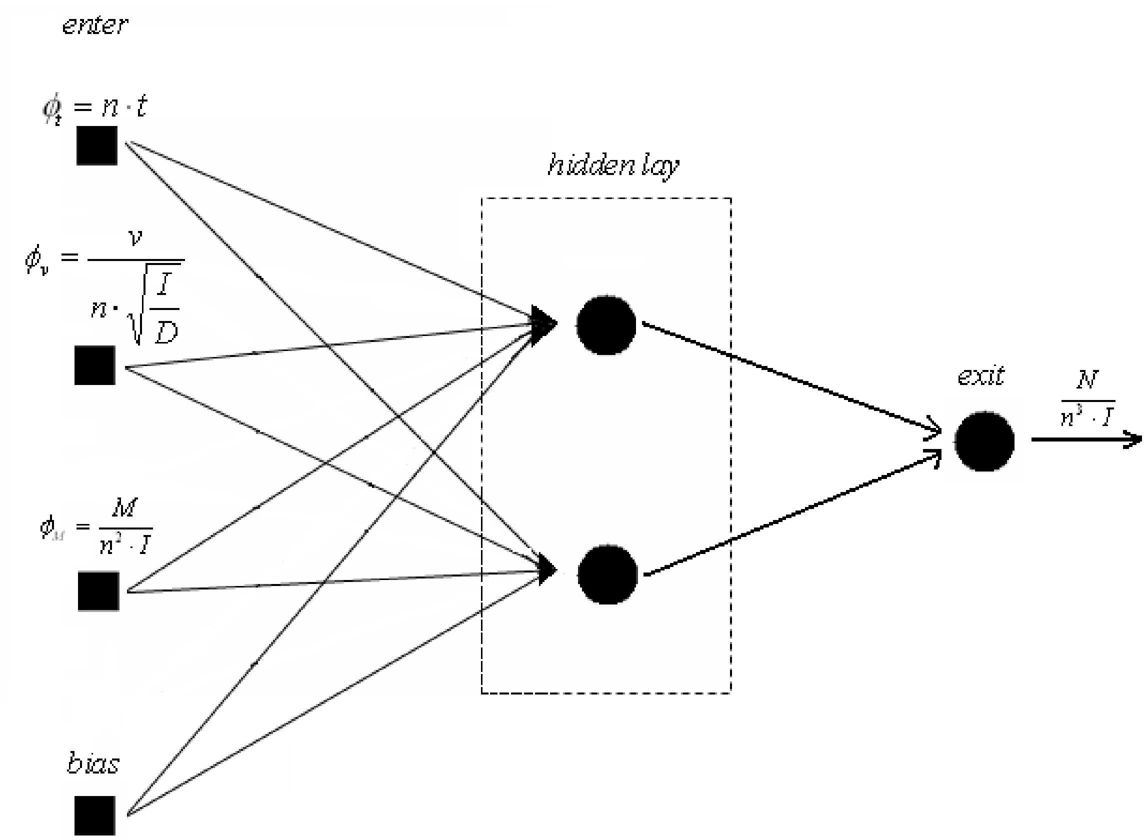

Fig.2 Structure of neuron network determining ship propulsion power followed by their aggregation of enter quantities: φ_t-nondimensional number of time,, φ_v–nondimensional number of speed, φ_M–nondimensional number o propeller torque, $\varphi_N = \frac{N}{n^3 \cdot I}$ -nondimensional number of power requirement

To achieve good results from aggregation it is primary important to select proper dimensional function combining enter variables. At the same time full use is being made in physical relations between power required for ship propulsion and ship resistance. Ship's hull resistances in different conditions of sailing are enter quantities into neuron network. In fig.2 the diagram of neuron structure network determining propulsion power of the ship after aggregation of its enter quantities, has been presented.

2. Aggregation of dimensional quantities describing requirement of power for ship propulsion

Power requirement for ship propulsion can be described by means of the following dimensional function [4,5] :

$$N = \Phi(M, n, t, v, I, D) \tag{1}$$

where:

N – required power for ship propulsion in [kg m^2 s^{-3}],
M – torque at the tail-end of the propeller in [kg m^2 s^{-2}],
n- rotational speed of the propeller in [s^{-1}],
t – time of change of respective parameters in [s],
v – speed of the ship in [m s^{-1}],
I – inertia moment of whirling mass of the ship propulsion system in [kg m^2],
D – mass of the ship in [kg].

The function defined by the formula (1) is a dimensional function in a dimensional space, whose arguments are its quantities. Such function cannot be treated as ordinary numerical function in the set of real numbers. Dimensional function (1) fulfils the conditions of invariance and dimensional homogeneity (6). Such conditions do not limit the form of numerical function where arguments as well as the value of the function are nondimensional quantities.

Six argument of dimensional function of required power for ship propulsion (1) have respective dimensions in an adopted system of measurement units SI. The matrix of exponents of the dimensions in this case, has the form:

	Kg	m	S
M	1	2	-2
N	0	0	-1
T	0	0	1
V	0	1	-1
I	1	2	0
D	1	0	0

The above matrix is of the third order, which means that among arguments of dimensional function three arguments are dimensionally independent.

Dimensional analysis does not provide any method which could make it possible to ascertain which quantities can be chosen as dimensionally independent. Generally, if six quantities define propulsive power of the ship and three quantities are dimensionally independent so the number of possibilities of their selection equals three elements combination out of the six elements set resulting in the number of twenty. Those combinations are, by way of example, the following quantities dimensionally independent of the remaining ones:(n, I, D), (t, v, D), (n, I, t), ... etc. After selection of arguments dimensionally independent of the remaining ones, we can, on the grounds of Buckingham's theorem (tw Π) write down the dimensional function (1) in the following forms:

$$N = f\ (\varphi_t, \varphi_v, \varphi_M) \cdot n^a \cdot I^b \cdot D^c \qquad (2)$$

where:

f – numerical function defined in the domain of real numbers,
φ_t, φ_v, φ_M – nondimensional element of respective dimensional quantities,
a,b,c,d – real numbers,
- the remaining denotations as in the formula (1).

Exemplary relations between dimensional quantities dependent: t, v , M on independent quantities: n, I, D have the following form:

$$t = \varphi_t \cdot n^{\alpha} \cdot I^{\beta} \cdot D^{\gamma} \qquad v = \varphi_v \cdot n^{\alpha_1} \cdot I^{\beta_1} \cdot D^{\gamma_1} \qquad M = \varphi_M \cdot n^{\alpha_2} \cdot I^{\beta_2} \cdot D^{\gamma_2} \qquad (3)$$

where:

α, α_1,α_2,β, β_1, β_2, γ, γ_1, γ_2 – real numbers,
- the remaining denotations like in the formulas (1) and (2).

Real numbers being the exponents of dimensional quantities are determined by comparison of dimensions of quantities taking part in relations (3) and (2) in the following way:

$$[\,s] = [\,s^{-1}\,]^{\alpha} \cdot [\,kgm^2\,] \cdot [\,kg\,]^{\gamma} \quad \Rightarrow \quad \alpha = -1; \quad \beta = 0 \quad \gamma = 0$$
$$[\,ms^{-1}\,] = [\,s^{-1}\,]^{\alpha_1} \cdot [\,kgm^2\,]^{\beta_1} \cdot [\,kg\,]^{\gamma_1} \quad \Rightarrow \quad \alpha_1 = 1; \quad \beta_1 = \frac{1}{2}; \quad \gamma_1 = -\frac{1}{2}$$
$$[\,kgm^2s^{-2}] = [\,s^{-1}]^{\alpha_2} \cdot [\,kgm^2]^{\beta_2} \cdot [\,kg]^{\gamma_2} \quad \Rightarrow \quad \alpha_2 = 2; \quad \beta_2 = 1; \quad \gamma_2 = 0$$
$$[\,kgm^2s^{-3}] = [s^{-1}]^{a} \cdot [\,kgm^2]^{b} \cdot [kg]^{c} \quad \Rightarrow \quad a = 3; \quad b = 1; \quad c = 0\,.$$

Calculated values of numerical exponents taking part in equations (2) and (3) allow us to write down the equation (2) in the following way:

$$\frac{N}{n^3 \cdot I} = f\left(n \cdot t; \frac{v}{n \cdot \sqrt{\frac{I}{D}}}; \frac{M}{n^2 \cdot I} \right) \qquad (4)$$

where:

- denotations like in formulas (1).

The formula (1) proceeding in the same way as above we can obtain different numerical forms of dimensional functions (1) while selecting other quantities as dimensionally independent. So, selecting the quantities: t, v, D as dimensionally independent of the remaining ones, we can obtainces:

$$\frac{N \cdot t}{v^2 \cdot D} = f\left(\frac{M}{v^2 \cdot D}; n \cdot t; \frac{I}{t^2 \cdot v^2 \cdot D}\right) \tag{5}$$

where:

- denotations like in formulas (1) and (2).

Forms of numerical dimensional function (4) and (5) with the same exactness define power required for ship propulsion. There are as many such forms as there are possibilities of selecting quantities dimensionally independent, correct in respect of mathematical precision.

In the case under investigation there are twenty of them. That means that during selecting numerical form of dimensional function we should concentrate on the way which makes it possible to carry out an experiment and train of the network on the set of measuring data. Definition exactness of such functions depends on evaluation of constant coefficients during experimental research by means of regression.

Form of above named numerical function define base for perennial day and night data recording the state parameters of vessel movement in task: ,, Realization of systematic investigations of ship energy propulsion demand ” government department problem [8]. An exponential form of numerical function in which constant coefficients determine measuring data by means of least square method is selected.

Demand of power for ship propulsion determined by means of neuron model taking advantage of dimensional function (1) is in possession of six enter quantities and the same number of conclusion rules. Neuron model of ship propulsion system contains bases of rules making use of numerical form of dimensional functions which can be easily interpreted and modified.

Application of algebraical scheme of dimensional analysis constructed by S. Drobot allows to aggregate conclusion rule defined by the function (1) to form (4) or (5) in which three enter signals take place. So we can see that by means of dimensional analysis it is possible to reduce in an essential way the number of entrances into the neuron model of ship propulsion system and thus considerably simplify its structure. In the model under investigation there are only three enter variables instead of six.

At the time of identification and also estimation of enter signal in the mode on-line of such models there is the Reed preliminary calculation of the value of aggregated variables.

3. Conclusions

Determining power required by the ship means of neuron models allows to train the network in the set of measuring data. Such models are represented by the base of rules for which algebraical scheme of analysis can be used.

It allows to aggregate the model in different ways depending on the need aggregation of neuron model by means of dimensional analysis leads to a considerable reduction of the number of its entries.

In this way the structure of neuron networks is simplified and used in aggregated neuron models.

Precision of numerical function estimation (5) used in aggregated neuron models equals the exactness of determination of its parameters by way of experiment.

Besides the dimensional analysis allows to ascertain the structure of conclusion rule, and being numerical function, it is properly constructed in respect of mathematical correctness.

References

[1] Abramowski T., *Application of artificial neural networks for determination of propeller´s crash-ahead, crash-back, banking performance*. Ship Technology Research, Vol. 48, pp154-160, 2001.

[2] Mesbahi E., Atlar M., *Artificial neural networks: applications in marine design and modelling*. 1st International Conference Computer Applications and Information Technology in the Maritime Industries. Potsdam 2000.

[3] Horikawa S., Furuhashi T., Uchikawa Y., Tagawa T., *A study on fuzzy modelling fusing fuzzy neural networks*. Fuzzy engineering toward human friendly systems IFES′91, pp 562-573, 1991.

[4] Roslanowski J., *Modelling of ship movement by means of dimensional function*. Radom University of Technology, Transport No 3(23), pp 443-448,2005.

[5] Roslanowski J., *The methodology of energetical process model construction in ship propulsion systems by means of dimensional analysis defining their dynamical features*. International Conference Technical, economic and environmental aspects of combined cycle power plants. Gdansk University of Technology2004, pp 59-66.

[6] Drobot S., *On the foundation of dimensional analysis*. Dissertation Mathematic, Vol. XIV,1954.

[7] Drobot S., Warmus W., *Dimensional analysis in sampling inspection of merchandise*. Mathematic, Vol. 5, 1954.

[8] Research Works of Marine Power Plant Institute Merchant Marine College in Gdynia: ,, *A day and night recording of state movement parameters of training vessel m/s A. Garnuszewski* “ (work task No. 106.5.03.05).