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Applicability of the multi-optional uncertainty conditional optimality doctrine to the neuron firing model

It is made an attempt to discover an explainable plausible reason for a neuron model activation function, or a squashing function, of a sigmoid type function like logistic function, substantiation in terms of the multi-optional conditional optimality doctrine for the special hybrid-optional effectiveness functions uncertainty.

Introduction. The most up-to-date research in the area of neural networks deals with the extremely complex processes occurring in the networks neuron connections [1]. The neural network structures of the modeled systems and processes can be of different nature. It is always important to apply a suitable approach for such modeling. In the sphere of the aircraft airworthiness support, a significant influence of the aeronautical engineering maintenance technologies uncertainty is a crucial thing.

State of the problem. The uncertainty measure in the given consideration is the entropy of the special hybrid-optional effectiveness functions. Such kind of entropy originates from the Jaynes' principle [2-4], being adapted to the subjective entropy maximum principle [5], with the implementation possibilities to the applicable fields of aviation industry as that follows the readings of the references [6-34].

The mentioned research scientific gap is the neural networking model that takes into account the significant role of the uncertainty when considering the neuron activation function.

Purpose of the paper. The presented paper is aimed at the sigmoid neuron activation functions modeling on the basis of the developed doctrine about the multi-optional functions entropy conditional optimality.

Problem setting. The problem statement for the current state would be as to find a value extremized with the known view expression used as a neuron model activation function. Consider sigmoid function, for instance, logistic function [1].

It is generally accepted that activation functions or squashing functions have the view of a logistic function [1, p. 47, (1.12)]:

$$\varphi(v) = \frac{1}{1 + \exp(-av)}, \qquad (1)$$

where v is induced local field or activation potential of the neuron, a is slope parameter of the sigmoid function.

Hybrid Multi-Optional Functions Optimization Doctrine. ***<u>Methods I.</u>*** In order to reveal the optimality of equation (1) [1], it is applied the prototype model of subjective analysis [5], being preceded with the Jaynes' principle [2-4]:

$$\Phi_\pi = \alpha H_\pi + \beta\varepsilon + \gamma N, \qquad (2)$$

where Φ_π is objective functional; H_π is subjective entropy; $\varepsilon = \varepsilon(\pi, U, \ldots)$ is the function of subjective effectiveness depending upon preferences π, utilities functions

U, etc.; N is normalizing condition; α, β, γ are structural parameters (Lagrange multipliers, weight coefficients or endogenous parameters of psych).

On conditions of the objective functional (2) extremum existence:

$$\frac{\partial \Phi_\pi}{\partial \pi_i} = 0\,, \qquad (3)$$

it yields the so called functions of the individual subjective preferences [5]:

$$\pi_i = \frac{\exp(\beta U_i)}{\sum_{j=1}^{N} \exp(\beta U_j)}\,. \qquad (4)$$

Methods II. Now, the evolution of the proposed at this paper approach from the subjective analysis (2-4) [5] to the hybrid multi-optional functions optimization doctrine implies the use of the hybrid multi-optional functions, as an objectively existing characteristic of a phenomena, instead of the subjectively preferred by a human functions, since no one chooses the objectively existential reality [11-34].

Neuron Model Sigmoid Activation Function. ***Methods III.*** Accordingly to the introduced hybrid multi-optional functions entropy conditional optimization doctrine, the objective functional is being constructed in the following way, [11-21]:

$$\Phi_h = -\sum_{i=1}^{n} h_i \ln h_i + \beta \sum_{i=1}^{n} h_i v_i + \gamma \left(\sum_{i=1}^{n} h_i - 1 \right), \qquad (5)$$

where h_i is the hybrid multi-optional function (objective fundamental value of the process) deemed to be relevant to the induced local field or activation potential v_i.

The necessary conditions of functional (5) extremum existence, absolutely like (3) for (2) yield

$$h_i = \frac{\exp(\beta v_i)}{\sum_{j=1}^{n} \exp(\beta v_j)}\,. \qquad (6)$$

For any two activation potentials [1, p. 43, (1.3)] v_1 and v_2, at $n = 2$

$$h_1 = \frac{\exp(\beta v_1)}{\exp(\beta v_1) + \exp(\beta v_2)}\,, \qquad h_2 = \frac{\exp(\beta v_2)}{\exp(\beta v_1) + \exp(\beta v_2)}\,. \qquad (7)$$

If each of the induced local fields v_1, v_2, … , v_i is compared with the threshold activation potential v_0,

$$\Phi_{h_{(0,i)}} = -\left(h_{0/i} \ln h_{0/i} + h_{i/0} \ln h_{i/0} \right) + \beta \left(h_{0/i} v_0 + h_{i/0} v_i \right) + \gamma \left(h_{0/i} + h_{i/0} - 1 \right). \qquad (8)$$

$$h_{0/i} = \frac{1}{1 + \exp[\beta (v_i - v_0)]}\,. \qquad (9)$$

Comparing equations (9) and (1) one can notice that

$$\beta = -a , \qquad v = v_i - v_0 . \qquad (10)$$

The hybrid-optional functions entropy

$$H_h = -\sum_{i=1}^{n} h_i \ln h_i \ , \qquad (11)$$

serves as a measure of uncertainty of the hybrid-optional functions h_i. Unfortunately, such measure of uncertainty as expression (11) does not show the direction of the uncertainty and its relative value.

Methods IV. In order to bypass such a difficulty it is proposed to apply the hybrid combined relative pseudo-entropy function developed in reference [22]:

$$\overline{H}_{\max - \frac{\Delta h}{|\Delta h|}} = \frac{H_{\max} - H_h}{H_{\max}} \cdot \frac{\Delta h}{|\Delta h|} . \qquad (12)$$

Here in expression (12) $H_{\max}$ is the maximal possible entropy (uncertainty) of the hybrid-optional functions h_i, H_h is the factual entropy (11),

$$\Delta h = \sum_{j=1}^{M} h_j^{+} - \sum_{k=1}^{L} h_k^{-} \ , \qquad (13)$$

where h_j^{+} and h_k^{-} are positive and negative properties hybrid-optional functions respectively, M and L are numbers of the positive and negative properties options:

$$M + L = n . \qquad (14)$$

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