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NEURON MODEL SIGMOID ACTIVATION FUNCTION BASED ON MULTI-OPTIONAL FUNCTIONS ENTROPY CONDITIONAL OPTIMIZATION DOCTRINE

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***Abstract*—*It is made an attempt to discover an explainable plausible reason for a neuron activation 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. In the studied case, the input-output mapping is stipulated by the entropy of the activation function conditional optimal distribution in regards with the induced local field of the neuron. It is proposed to evaluate the direction of uncertainty with the combined hybrid relative pseudo-entropy function. This is a new insight into the scientific substantiation of the well-known dependency derived in another way. The developed theoretical contemplations and mathematical derivations are verified with numerical simulation and plotted diagrams.*

Index Terms—Neuron initialization; activation function; sigmoid function; multi-optional doctrine; conditional optimality; hybrid-optional effectiveness function; pseudo-entropy; variational problem.

I. INTRODUCTION

Background I. Through the last decades, the neurosciences have been having a great boom in their emergences, developments, and evolutions. Because of the successes in the adjacent scientific areas, there appeared a number of conjoint sciences. These are scientific areas related somehow to brain studies. Reconfiguration of the theoretical concepts and applied research approaches has been made to the purely biological, medical, physiological, neurological disciplines, as well as genetics under the influence of the successes of the mathematics, statistics, physics, computer sciences, engineering etc [1], [2].

For mathematical modeling processes and systems it is always very important to propose an explainable, apparently the simplest acceptable, scientifically substantiated although, ideological concept describing the most significant properties of the studied processes and systems.

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

Initially, the presented research was submitted to the World Congress on Neurology and Neurosurgery, Vancouver, Canada, March 26-28, 2018, **Neurology** <info@timesmeetings2018.com>. The invitation to participate to the Congress was received on the authors e-mail address on January 27, 2018 at 10:15 AM. The title of the submission was: “A Neuron Model Sigmoid Activation Function Obtained via Multi-Optional Functions Entropy Conditional Optimization Doctrine”, however for some unknown reasons it was not published. Anyway, the author has decided to publish that study, but revised, in the present view.

Background II. The entropy paradigm, likewise the one from the theoretical physics [3] – [5], has already been adopted to the problems of the human being psychological behavior [6]. Generally speaking, the number of research taking into consideration the uncertainty measure in the view of entropy, in both science and social science, investigations has an increasingly high rate [7]. Optimization entropy principle [3] – [5] implemented to the sciences about the laws of human brain work [6] with respect to the social nature and psychological aspects of individuals allows constructing, for example, models of economical systems concerned with the light versus shadow financial components optimality [8], [9].

The canonical view subjective individual preferences functions having been developed, derived mathematically in the explicit view, and described in monograph [6] and recently applied in the prototypic research [8], [9] have the identical mathematical expressions to the used in papers [10], [11] for the probabilities of choice, axiomatically proposed in [12], [13].

The derived preferences functions [6], [8], [9], in the latest works used as the multi-optional hybrid functions, have already been successfully applied to the variety of the different scientific fields solutions [14] – [23]. Amongst those, there are the subjective preferences (multi-optional hybrid functions) of the available alternatives (options) at the processes of:

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1) aircraft maintenance in operation [8], [9], [22], 2) artificial intelligence modeling [18], 3) psychophysics and psychology issues [16], [17], 4) optional operational processes modeling [14], [15], [19], [20] and 5) tribological aspects [21] derivations ways, 6) reliabilities [22], and up to 7) thermodynamic phenomena [23] optimality.

Purpose. Contemplations likewise the described above has instigated the search of a certain kind optimality in substantiations of neural work.

Objective. 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 have the view of a logistic function [1, p. 47, (1.12)]:

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

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

II. Solution of the Problem

A. Hybrid Multi-Optional Functions Optimization Doctrine

Methods I. In order to reveal the optimality of equation (1) [1], it is applied the prototype model of subjective analysis [6], [8], [9]:

$$\Phi_\pi = \alpha H_\pi + \beta\varepsilon + \gamma \mathrm{N}, \quad (2)$$

where Φ_π is objective (purpose) 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 the structural parameters which can be considered at different situations as Lagrange multipliers, weight coefficients or endogenous parameters reflecting some certain properties of psych.

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

$$\partial\Phi_\pi / \partial\pi_i = 0, \quad (3)$$

it yields the so called functions of the individual subjective preferences distributions of the first kind (subject preferences) of the canonical view [6], [8], [9], [14]:

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

Methods II. Now, the evolution of the proposed at this paper approach from the subjective analysis (2) – (4) [6], [8], [9], [14] 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 [16], [19], [21] – [36].

B. 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, [6], [8], [9], [15] – [18], [21] – [23]:

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

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

$$\frac{\partial\Phi_h}{\partial h_i} = -\ln h_i - 1 + \beta v_i + \gamma = 0, \quad \left(\forall i \in \overline{1, n}\right). \quad (6)$$

Then from conditions (6)

$$\ln h_i = \gamma - 1 + \beta v_i,$$

$$h_i = \exp(\gamma - 1 + \beta v_i) = \exp(\gamma - 1)\exp(\beta v_i). \quad (7)$$

The normalizing condition of functional (5) inevitably means

$$\sum_{j=1}^{n} h_j = 1 = \exp(\gamma - 1)\sum_{j=1}^{n} \exp(\beta v_j),$$

$$\exp(\gamma - 1) = \frac{1}{\sum_{j=1}^{n} \exp(\beta v_j)}, \quad h_i = \frac{\exp(\beta v_i)}{\sum_{j=1}^{n} \exp(\beta v_j)}. \quad (8)$$

The obtained equation (8) is the same as (4).

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

$$h_1 = \frac{\exp(\beta v_1)}{\exp(\beta v_1) + \exp(\beta v_2)}, \quad h_2 = \frac{\exp(\beta v_2)}{\exp(\beta v_1) + \exp(\beta v_2)}. \quad (9)$$

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

$$\Phi_{h_{(0,1)}} = -\left(h_{0/1}\ln h_{0/1} + h_{1/0}\ln h_{1/0}\right)$$

$$+\beta\left(h_{0/1}v_0 + h_{1/0}v_1\right) + \gamma\left(h_{0/1} + h_{1/0} - 1\right), \quad (10)$$

$$\Phi_{h_{(0,2)}} = -\left(h_{0/2}\ln h_{0/2} + h_{2/0}\ln h_{2/0}\right)$$

$$+\beta\left(h_{0/2}v_0 + h_{2/0}v_2\right) + \gamma\left(h_{0/2} + h_{2/0} - 1\right), \quad (11)$$

$$h_{0/1} = \frac{\exp(\beta v_0)}{\exp(\beta v_0) + \exp(\beta v_1)},$$

$$h_{0/2} = \frac{\exp(\beta v_0)}{\exp(\beta v_0) + \exp(\beta v_2)}. \quad (12)$$

Making simplest transformations: either multiplying the found expression of (12) by or dividing it into the identical 1, it is possible to get the following equations:

$$h_{0/1} = \frac{\exp(\beta v_0)}{\exp(\beta v_0) + \exp(\beta v_1)}$$

$$= \frac{\exp(\beta v_0)}{\exp(\beta v_0) + \exp(\beta v_1)} \left\{\cdot/\div\right\} \left[1 = \frac{\exp(\beta v_0)}{\exp(\beta v_0)}\right]$$

$$= \frac{\dfrac{\exp(\beta v_0)}{\exp(\beta v_0)}}{\dfrac{\exp(\beta v_0) + \exp(\beta v_1)}{\exp(\beta v_0)}}. \quad (13)$$

The symbol $\left\{\cdot/\div\right\}$ means: "multiply by or divide into"; $\exp(\beta v_0) > 0$ and any $\exp(\beta v_i) > 0$.

$$h_{0/1} = \frac{1}{\dfrac{\exp(\beta v_0)}{\exp(\beta v_0)} + \dfrac{\exp(\beta v_1)}{\exp(\beta v_0)}} = \frac{1}{1 + \exp[\beta(v_1 - v_0)]}. \quad (14)$$

For v_0 and v_2 the same contemplations yield

$$h_{0/2} = \frac{1}{1 + \exp[\beta(v_2 - v_0)]}. \quad (15)$$

In general case, for any v_0 and v_i

$$h_{0/i} = \frac{1}{1 + \exp[\beta(v_i - v_0)]}. \quad (16)$$

Comparing equations (16) and (1) one can notice that

$$\beta = -a, \qquad v = v_i - v_0. \quad (17)$$

The hybrid-optional functions entropy

$$H_h = -\sum_{i=1}^{n} h_i \ln h_i, \quad (18)$$

serves a measure of uncertainty of the hybrid-optional functions h_i. Unfortunately, such measure of uncertainty as expression (18) 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 [14]:

$$\overline{H}_{\max - \frac{\Delta h}{|\Delta h|}} = \frac{H_{\max} - H_h}{H_{\max}} \cdot \frac{\Delta h}{|\Delta h|}. \quad (19)$$

Here in expression (19) $H_{\max}$ is the maximal possible entropy (uncertainty) of the hybrid-optional functions h_i, H_h is the factual entropy (18),

$$\Delta h = \sum_{j=1}^{M} h_j^{+} - \sum_{k=1}^{L} h_k^{-}, \quad (20)$$

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

$$M + L = n. \quad (21)$$

C. Simulation

It is proposed the following numerical simulation to make it visible the theoretical speculations (5) – (21). The calculations data are as follows: $\beta = -0.5$; $v_0 = v_i = -10\ldots10$.

Results. The hybrid-optional functions are shown in Fig. 1. Their traditional entropy is illustrated in Fig. 2.

In Figure 1 it is denoted $\mathrm{h}(\mathrm{v_i},0)$ for $h_{0/i}$ determined with equation (16) at $v_0 = 0$, it coincides with $\mathrm{f_0}(\mathrm{v_i},0)$ calculated by the first equation of (12). The curve of $\mathrm{f_1}(\mathrm{v_i},5)$ is for v_i and optional $v_0 = 5$.

In Figure 2 it is denoted $\mathrm{H}(\mathrm{v_i},3)$ for H_h obtained from equation (18); $\ln(2)$ is the maximal possible entropy (uncertainty) $H_{\max}$ in expression (19) of the hybrid-optional functions h_i.

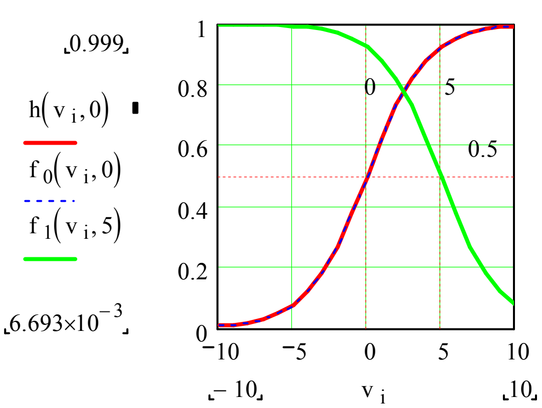

Fig. 1. Hybrid-optional functions

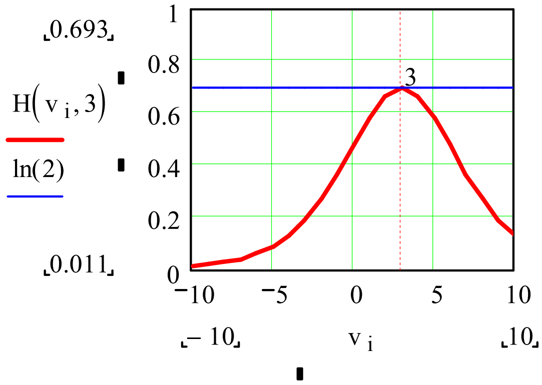

Fig. 2. Hybrid-optional functions entropy

The entropy (measure of uncertainty) of the hybrid-optional functions 3-D surface plot and its contour plot are shown in Figs 3 and 4 respectively.

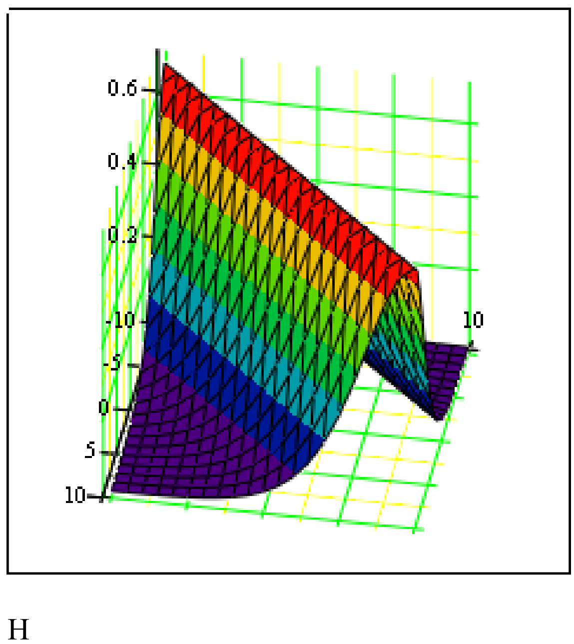

Fig. 3. Hybrid-optional functions entropy 3-D surface plot

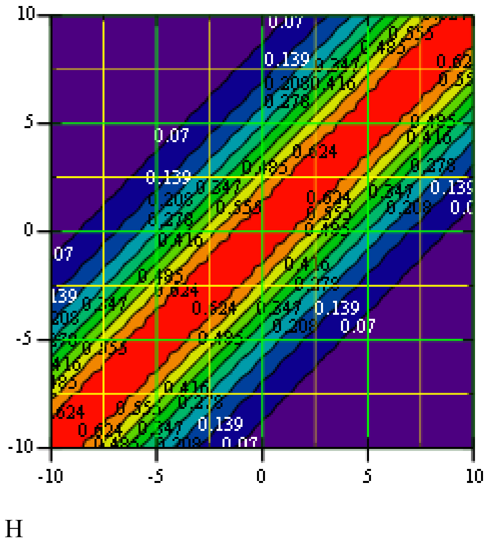

Fig. 4. Hybrid-optional functions entropy contour plot

The hybrid combined relative pseudo-entropy function $H_r(v_i,3)$ as $\overline{H}_{\max - \frac{\Delta h}{|\Delta h|}}$ (19) – (21) is plotted in Figs 5 – 7.

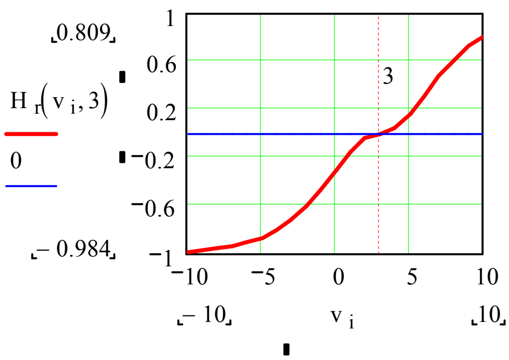

Fig. 5. Hybrid combined relative pseudo-entropy function

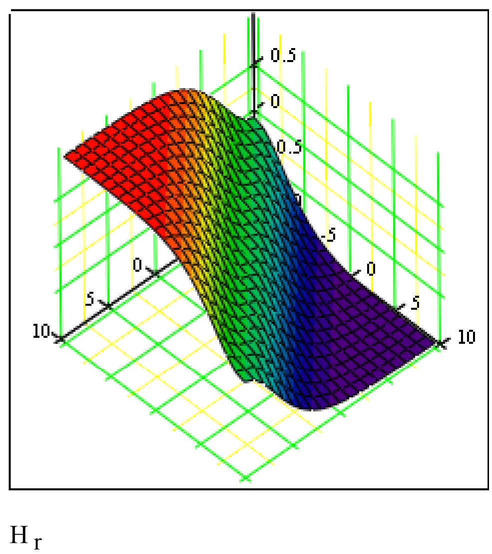

Fig. 6. Hybrid combined relative pseudo-entropy function 3-D surface plot

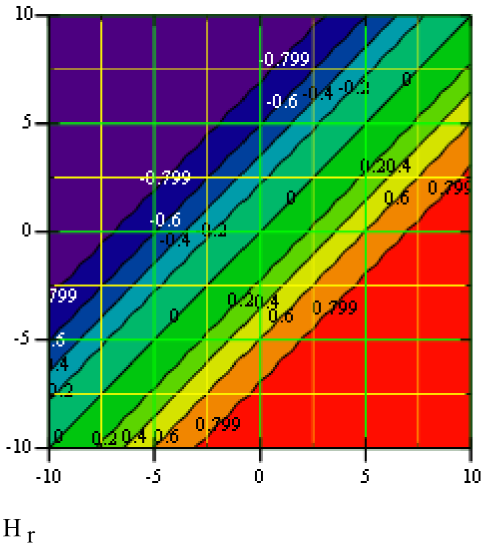

Fig. 7. Hybrid combined relative pseudo-entropy function contour plot

D. Discussion

The proposed approach can be used for the purposes of the threshold activation potential v_0 determination.

Entropy characteristics (see Figs 4 and 7) have the view of the induced local fields' dependence upon the linear combiner output with the effect of the affine transformation ensured by the threshold presence [1, p. 44, Fig. 1.6].

The traditional view entropy (see Figs. 2 – 4) figuring out in the objective functional expression (5) is incapable to catch the positive, negative, or neutral properties of the uncertainty of the activation functions distributions, whereas the developed in reference [14] hybrid combined relative pseudo entropy function (19) – (21) (see Figs 5 – 7) helps with such a problem of the hybrid-optional functions h_i (activation functions) uncertainty direction determination.

III. Conclusions

It is discovered an explanation for the neuron model activation function considering the sigmoid function like a logistic function in terms of the multi-optional conditional optimality doctrine for the special hybrid-optional effectiveness functions uncertainty. Parameters of the hybrid combined relative pseudo entropy function need further investigation.

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А. В. Гончаренко. Сигмоїдальна функція моделі активації нейрону на основі доктрини умовної оптимізації ентропії багатоопційних функцій

Здійснено спробу відкрити правдоподібну причину, що пояснює обґрунтування функції активації моделі нейрону, типа сигмоїдальної функції подібної до логістичної функції, в термінах доктрини багатоопційної умовної оптимальності для невизначеності спеціальних функцій гібридно-опційної ефективності. У випадку, що вивчається відображення вхідної інформації у вихідну обумовлене ентропією умовно оптимального розподілу функцій активації стосовно індукованого локального поля нейрону. Запропоновано оцінювати спрямування невизначеності комбінованою гібридною псевдо-ентропійною функцією. Це є новим поглядом на наукове пояснення добре відомої залежності виведеної іншим шляхом. Теоретичні міркування, які розвиваються, а також математичні викладки підтверджуються числовим моделюванням та побудованими діаграмами.

Ключові слова: активація нейрону; функція активації; сигмоїдальна функція; логістична функція; доктрина багатоопційності; умовна оптимальність; гібридно-опційна функція ефективності; псевдо-ентропія; варіаційна задача.

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Освіта: Одеський інститут інженерів морського флоту, Одеса, Україна, (1984).
Напрям наукової діяльності: багатоопційна оптимальність, варіаційні принципи, експлуатація та керування в активних системах, безпека польотів.
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А. В. Гончаренко. Сигмоидальная функция модели активации нейрона на основе доктрины условной оптимизации энтропии многоопционных функций

Осуществлена попытка открыть правдоподобную причину, поясняющую обоснование функции активации модели нейрона, типа сигмоидальной функции подобной логистической функции, в терминах доктрины многоопционной условной оптимальности для неопределенности специальных функций гибридно-опционной эффективности. В изучаемом случае отображение входной информации в выходную обусловлено энтропией условно оптимального распределения функций активации по отношению к индуцированному локальному полю нейрона. Предложено оценивать направление неопределенности комбинированной гибридной псевдо-энтропийной функцией. Это является новым взглядом на научное пояснение хорошо известной зависимости выведенной другим путем. Развиваемые теоретические соображения, а также математические выкладки подтверждаются численным моделированием и построенными диаграммами.

Ключевые слова: активация нейрона; функция активации; сигмоидальная функция; логистическая функция; доктрина многоопционности; условная оптимальность; гибридно-опционная функция эффективности; псевдо-энтропия; вариационная задача.

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