Letter to the Editor

Possible Application of Variational Cluster Expansion in Modeling Correlated Neurons Activities

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ABSTRACT

In this letter, we will model neural activities using variational cluster expansion in condensed matter physics. In the model, we will assume that neurons and other brain cells are quantum objects, and thus we merely need to know their interaction, their correlation, and neuron's probability density function. Although it is very difficult to see how application of this formalism could produce anything practical in the current situation when we are still trying to find consensus on ontological and epistemological issues, it will be worth the effort to explore such possible quantum mechanisms.

Key words: Many body theorem, cluster expansion, neural activities, correlated neurons, ground state.

We suggest that variational cluster expansion technique in many-body physics (Clark & Westhaus 1966; Khoshbin-e-Khoshnazar 2001) may be used to model corrected neural activities which may be treated as complex projection amplitudes that do not follow a signal path. It should be noted that this is not related to dissipative quantum model of brain (Vitiello,1995; Freeman & Vitiello, 2006). However, we do assume that neurons and other brain cells are quantum objects, and thus we merely need to know their interaction, their correlation, and neuron's probability density function.

By defining

$$I(\beta) = \langle \Phi | \exp \beta (\mathrm{H}) | \Phi \rangle$$

we will have:

$$E = (\partial / \partial \beta) \ln I(\beta)|_{\beta=0}$$

Now, we consider a 4-point (soma) matter and generalize the above. We define

$$I_{ijkl} = \langle ijkl | F_A^+(1 \ldots A) e^{\beta \mathrm{H}} F_A(1 \ldots A) | ijkl \rangle$$

where i, j, k, l are points fields , *F(1...A)* is correlation function in generally, and maximum of *A* is equal to 4.

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We then will have:

$$I_i(\beta) = \langle i | e^{\beta H_i} | i \rangle = 1$$

$$I_{ij}(\beta) = \langle ij | F_2^+(12) e^{\beta H_{ij}} F_2(12) | ij \rangle$$

$$I_{ijk}(\beta) = \langle ijk | F_3^+(123) e^{\beta H_{ijk}} F_3(123) | ijk \rangle$$

$$I_{ijkl}(\beta) = \langle ijkl | F_4^+(1234) e^{\beta H_{ijkl}} F_4(1234) | ijkl \rangle$$

It is possible to write each of *I*'s using the factor decomposition:

$$I_{ijkl} = \prod_i Y_i \prod_{i \prec j} Y_{ij} \prod_{i \prec j \prec k} Y_{ijk} \prod_{i \prec j \prec k \prec l} Y_{ijkl} = I(\beta)$$

Then, we have:

$$\ln(I(\beta)) = \sum_i \ln Y_i + \sum_{i \prec j} \ln Y_{ij} + \sum_{i \prec j \prec k} \ln Y_{ijk} + \sum_{i \prec j \prec k \prec l} \ln Y_{ijkl}$$

If we write *I*'s using sum product decomposition

$$I_i = X_i$$

$$I_{ij} = I_i I_j (1 + X_{ij}) \quad , \quad X_{ij} = Y_{ij} / Y_i Y_j$$

$$I_{ijk} = I_i I_j I_k (1 + X_{ij} + X_{jk} + X_{ki} + X_{ijk}) \quad , \quad X_{ijk} = Y_{ijk} / Y_i Y_j Y_k$$

$$I_{ijkl} = I_i I_j I_k I_l (1 + X_{ij} + X_{jk} + X_{kl} + X_{ik} + X_{li} + X_{jl} + X_{ijk} + X_{jkl} + X_{lik} + X_{ijkl}),$$

$$X_{ijkl} = Y_{ijkl} / Y_i Y_j Y_k Y_l$$

Now, we will be able to calculate effective two, three, and four-point energy:

$$(\partial / \partial\beta) I(12,\beta)|_{\beta=0} = \partial / \partial\beta \langle ij | F_2^+(12) e^{\beta H_{ij}} F_2(12) | ij \rangle_{\beta=0} = \langle ij | F_2^+(12) H_{ij} F_2(12) | ij \rangle_{\beta=0}$$

$$= \partial / \partial\beta (1 + X_{ij})|_{\beta=0} = \partial / \partial\beta (X_{ij})|_{\beta=0} = W_{ij}(12)$$

$$(\partial / \partial\beta) I_{ijk}|_{\beta=0} = \langle ijk | F_3^+(123) e^{\beta H_{ijk}} F_3(123) | ijk \rangle_{\beta=0} = \partial / \partial\beta (X_{jk} + X_{ki} + X_{ij} + X_{ijk})_{\beta=0}$$

$$= W_{jk} + W_{ki} + W_{ij} + W_{ijk}$$

where

$$W_{ijk} = \langle ijk | F_3^+(123) \mathrm{H}_{ijk} F_3(123) | ijk \rangle$$

In the same way, we obtain:

$$(\partial / \partial \beta) I_{ijk}(\beta)|_{\beta=0} = W_{jk} + W_{ik} + W_{ij} + W_{kl} + W_{li} + W_{jl} + W_{ijk} + W_{jkl} + W_{lik} + W_{ijkl}$$

where

$$W_{ijkl} = \langle ijkl | F_4^+(1234) \mathrm{H}_{ijkl} F_4(1234) | ijkl \rangle$$

If we define

$$F = \prod_{i \prec j} F(l_{ij})$$

F(12)=F(12)

F(123)=F(12)F(23)F(13)

F(1234)=F(12)F(23)F(34)F(13)F(14)F(24)

and

$$W = \sum_{i \prec j} W(l_{ij})$$

W(12)=W(12)

W(123)=W(12)+W(23)+W(13)

W(1234)=W(12)+W(23)+W(34)+W(14)+W(24)

ground state could be calculated via minimization of variational parameters of the model.

Both our model and dissipative quantum model will need the use of electroencephalography data. For example, the textured patterns related to categories of conditioned stimuli, i.e., coexistence of physically distinct synchronized patterns and their remarkably rapid onset into irreversible sequences resembling cinematographic frames.

In dissipative model, each spatial pattern is modeled as a consequence of spontaneous breakdown of symmetry triggered by external stimulus (Freeman & Vittiello, 2007) . In contrast, in our model, each spatial pattern is associated with one of the unitarily inequivalent **ground state** which could be calculated numerically by cluster expansion method. It seems that such idea has also a special role in space-time geometry (Khoshbin-e-Khoshnazar, 2013) as objective reduction in quantum gravity (Hameroff & Penrose 1996; Khoshbin-e-Khoshnazar, 2007).

Although it is very difficult to see how application of this formalism could produce anything practical in the current situation when we are still trying to find consensus on ontological and epistemological issues, it will be worth the effort to explore such possible quantum mechanisms.

The author would like to communicate with researchers who may be able to find the analytical forms of our desired potentials and correlations.

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