VI International Conference on Mathematics and its Applications in Science and Engineering (ICMASE 2025)

THE LANA MODEL: AGENT-BASED MODEL USED FOR SIMULATION OF SIGNAL TRANSMISSION IN NEURONS

Sanja Kapetanovic[1],
Drazena Gaspar[2],
Samra Mededovic[3],
Mile Dzelalija[4],
Nina Bijedic[5]

[1]*Department of Physics, Faculty of Science, University of Split, Croatia*
[2]*Faculty of Economics, University of Mostar, Bosnia and Herzegovina*
[3]*Healthcare, University "Dzemal Bijedic" Mostar, Bosnia and Herzegovina*
[4]*Department of Physics, Faculty of Science, University of Split, Croatia*
[5]*Faculty of Information Technologies, University "Dzemal Bijedic" Mostar, Bosnia and Herzegovina*

ABSTRACT

Since the Hodgkin-Huxley model was published, the differential equation has been applied to describe the dynamics of signal transmission in the brain. Various scientists are working on simplifying it, taking into consideration the demonstration's assurance of accuracy for the biophysical process in the brain.

Regarding the interaction of millions of neurons in the brain, one of the convenient ways to modulate and simulate their interaction is through agent-based modeling due to its possibility to adjust received parameters. The advantage of the agent-based model is that it allows adjusting one parameter while keeping the other parameters fixed, enabling the investigation of individual effects and testing scientific hypotheses related to signal transmission in the brain. In this study, the agent-based model, the Lana model, is presented, which is based on the generalization of undergoing bio-physical processes during signal transmission in the brain. In the Lana model, processes are grouped into two subsets (agents) describing either the signal (agent Signal) or the neuron-related processes necessary for the signal transmission (agent Neuron). Moreover, the neuron is observed with all bio-physical properties using the mathematical equation, the modified Hodgkin-Huxley model. The Agent neuron in the Lana model has the following properties: functionality, trigger threshold, number of functional accesses (dendrites), output range (axons), number of functional outputs (telodendrions), predisposition of the receiving signal, and recovery time. In addition, the Agent signal in the mentioned model has the following properties: signal identification, current strength, repeated signal frequency, initial position, and radius of the affected neuron. Using these two agents, the Lana model enables the simulation of neuron signal transmission in the brain, as well as the flexibility that enables it. The signal transmission is modulated using both agents while the agent Neuron simulates changes in flexibility. The Lana model is considered successful if it can produce the spike graph or pathway from the MRA image.

The purpose of the Lana model lies in the application and regulation of neurons in both physiological and pathological states. The mentioned type of application and regulation of the signal in neurons can play a significant role in understanding neurological diseases, such as stroke, Multiple sclerosis, and Parkinson's disease, as well as in future treatments for pathological brain states.

***K*eywords** Signal Transmission · Agent-based model · Neurons

References

[1] Garg N, Balafrej I, Stewart TC, Portal JM, Bocquet M, Querlioz D, Drouin D, Rouat J, Beilliard Y, Alibart F. Voltage-dependent synaptic plasticity: Unsupervised probabilistic Hebbian plasticity rule based on neurons membrane potential. Front Neurosci. 2022 Oct 21;16:983950. doi: 10.3389/fnins.2022.983950. PMID: 36340782; PMCID: PMC9634260.

[2] Grider MH, Jessu R, Kabir R. Physiology, Action Potential. [Updated 2023 May 8]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK538143/.

[3] Gerstner, Wulfram Wulfram, Kistler, M., Werner. (2002). Spiking Neuron Models: Single Neurons, Populations, Plasticity. 10.1017/CBO9780511815706.

[4] Oost, W., Huitema, A.J., Kats, K. et al. Pathological ultrastructural alterations of myelinated axons in normal appearing white matter in progressive multiple sclerosis. acta neuropathol commun 11, 100 (2023). https://doi.org/10.1186/s40478-023-01598-7.

[5] Hassabis D, Kumaran D, Summerfield C, Botvinick M. Neuroscience-Inspired Artificial Intelligence. Neuron. 2017 Jul 19;95(2):245-258. doi: 10.1016/j.neuron.2017.06.011. PMID: 28728020.

[6] Akella, S., Ledochowitsch, P., Siegle, J.H. et al. Deciphering neuronal variability across states reveals dynamic sensory encoding. Nat Commun 16, 1768 (2025). https://doi.org/10.1038/s41467-025-56733-w.