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| **Project Title** | Virtual Neuron Cloning and Drug Simulation | | |
| **Track** | Digital Healthcare \_Healthcare technologies | | |
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| **Problem Summary** | Because neuron behavior varies from person to person, patients frequently suffer negative side effects from neurological medications. Even when a medication is clinically approved, these differences make it challenging to forecast how a patient's nervous system will react to treatment. Conventional approaches to drug effect research entail intrusive, costly, and time-consuming experiments that frequently call for testing on humans or animals.  To guarantee that patients receive the best medications, a safe, moral, and individualized approach is vital. Without physically testing medications on humans or animals, we must be able to replicate and comprehend the responses of individual neurons.  Our project attempts to address this by digitally cloning neurons and simulating drug effects using actual electrophysiological data (voltage, current, and time). This will enable researchers and medical professionals to virtually forecast a patient's response to different medications, allowing for quicker, safer, and more individualized care without the dangers of invasive procedures. | | |
| **Methodology** | Techniques  1. Reference-Based Parameter Ranges: To ascertain the usual biological range for important neuron parameters like membrane capacitance, threshold voltage, and ion conductances, we reviewed a number of neuroscience references. This provided us with a solid foundation on which to model the behavior of real neurons.  2. Synthetic Data Generation: Since we were unable to perform physical experiments and it is practically impossible to gather all variations of electrophysiological data from a single patient or dataset, we created synthetic data. In order to model the behavior of membrane voltage and current over time, we randomly sampled parameter combinations within the reference range.  3-ODE-Based Simulation: To produce labeled data (V, I, and known parameters), we numerically solved the Izhikevich model, a biologically plausible spiking neuron model, using Euler's method. This strategy aligned with the numerical techniques.  on which we depended during the project.  4-AI Model Training: We developed a CNN-LSTM hybrid model that predicts the corresponding neuron parameters based on inputs of voltage (V) and current (I). The synthetic parameter set used to generate the data was known as the ground truth.  5-Evaluation: To confirm that the model can accurately reconstruct neuron properties within the anticipated physiological range, its accuracy was tested on unseen synthetic data. | | |
| **Achievements and Skills Gained** | Accomplishments and Acquired Competencies  Results:  generated synthetic neuron data using parameter ranges that are biologically valid.  Euler's method and the Izhikevich model were used to simulate realistic spiking behavior.  trained a CNN-LSTM model to use voltage and current signals to predict neuron parameters with accuracy.  created a dependable AI pipeline for neuron modeling that doesn't require actual patient data.  Acquired Proficiency:  Simulation of data from ODE-based neural models  Time-series deep learning (CNN + LSTM)  Numerical techniques and signal preprocessing  Collaboration, scientific research, and Python (TensorFlow/Keras) | | |

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| **Main Results** | High Quality Figures |
| **Discussion and Conclusion** | This project addresses the challenge of forecasting how each person will react to neurological medications, which frequently result in adverse effects because of differences in neuron behavior. Conventional testing techniques are expensive, time-consuming, and intrusive.  To get around this, we created synthetic neuron data using the Izhikevich model and parameter ranges based on neuroscience. Then, using voltage and current signals, we trained a CNN-LSTM model to precisely predict neuron parameters.  This made it possible for us to simulate the effects of drugs and digitally replicate neurons without the need for in-person testing. For drug evaluation and neuroscience research, our system provides a scalable, moral, and customized substitute. |
| **References** | [1] M. N. Rasband et al., “Organization of the axon initial segment and myelin,” Science, vol. 378, no. 6625, pp. 1205–1212, Dec. 2022, doi: 10.1126/science.aau8302.  [2] “Myelin: A specialized membrane for cell communication,” Nature Education, 2010. [Online]. Available: <https://www.nature.com/scitable/topicpage/myelin-a-specialized-membrane-for-cell-communication-14367205/>  [3] “3D SR imaging of myelin structure,” Nikon Instruments. [Online]. Available: <https://www.microscope.healthcare.nikon.com/resources/applicationnotes/3d-sr-imaging-of-myelin-structure-nsparc>  [4] M. H. Oh et al., “Multiscale mapping of cell types and projections in the mammalian spinal cord,” eNeuro, vol. 9, no. 3, May 2022, doi: 10.1523/ENEURO.0012-22.2022.  [5] L. S. Zhou et al., “Myelin plasticity and remodeling in the central nervous system,” Frontiers in Cellular Neuroscience, vol. 17, 2023. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11252274/>  [6] M. D. Weil et al., “Myelin and nodal plasticity modulate action potential conduction in the adult CNS,” Frontiers in Cellular Neuroscience, vol. 17, 2023. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9980892/> |
| **Future Work and Suggestions** | Use Real Data: To guarantee practical reliability, test the model using actual patient V/I data.  Multi-Neuron Networks: To replicate brain-like networks, go beyond single neurons.  Predict alterations in neuronal behavior both before and after drug exposure using drug effect modeling.  Support Additional Models: Include additional neuron models for comparison, such as Hodgkin-Huxley.  Transfer Learning: Adjust the model for uncommon situations or particular kinds of neurons.  Uncertainty Output: To increase the reliability of predictions, include confidence scores.  Improved Performance: Use GPUs or neuromorphic chips to speed up simulation and prediction.  User Interface: Create a graphical user interface (GUI) that makes drug testing, data uploading, and analysis simple. |
| **Group Photo** |  |