Dynamic DBS & Levodopa Optimization Model: Predicting and Optimizing Dopaminergic Response from Levodopa Intake

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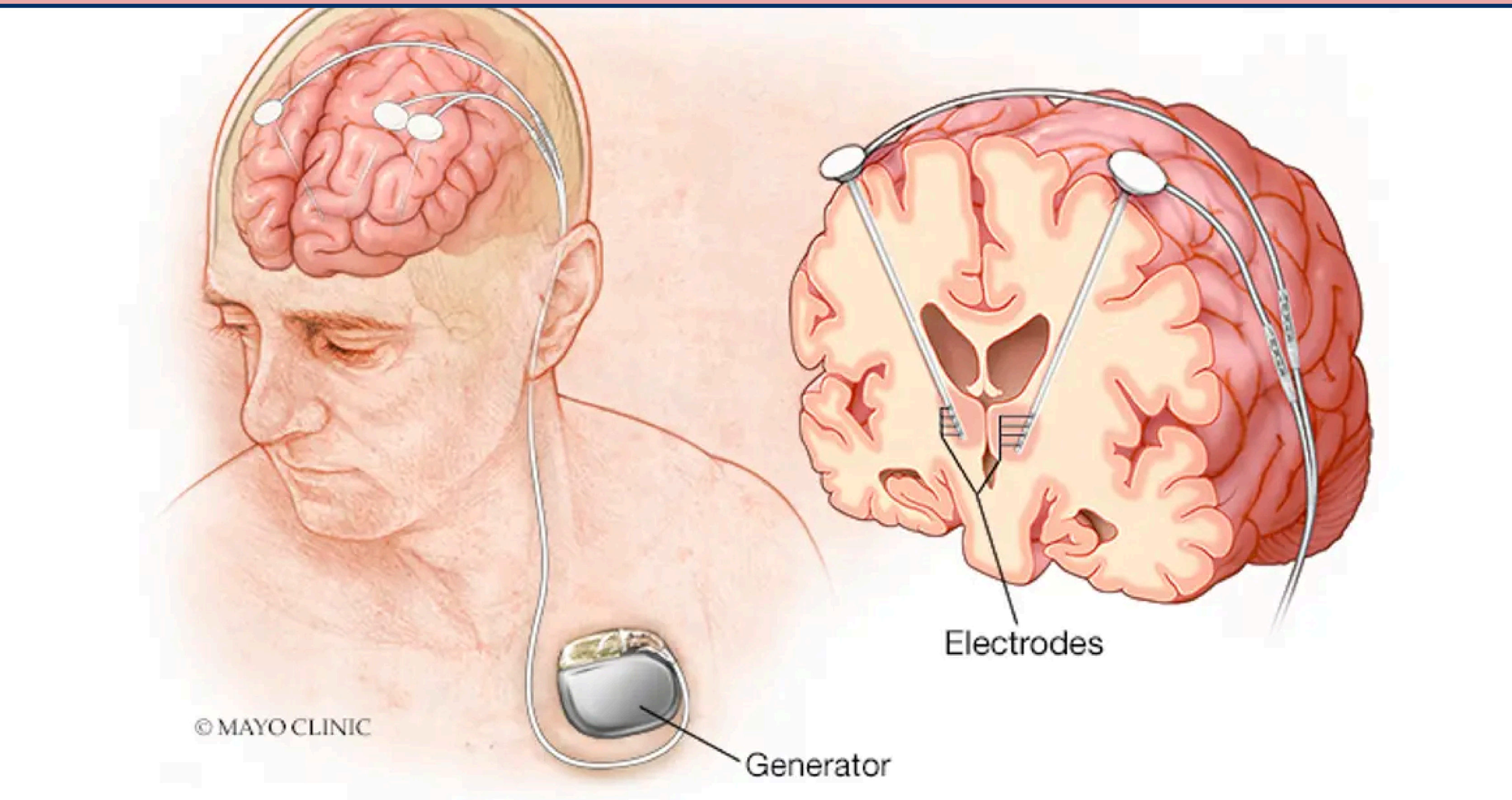


Source: Streed, J. Advances in Deep Brain Stimulation Transform Lives. Mayo Clinic

Abstract

Parkinson's disease (PD) is a progressive hypokinetic movement disorder characterized by motor dysfunction, including tremors, rigidity, and bradykinesia — a primary symptom of PD that refers to slowness of movement (Bologna et al., 2020). The prevalence of PD is increasing, particularly among older adults, with a growing number of diagnoses in younger populations. As a result, research into effective treatment interventions has been a pivotal area of research. Two of the most effective treatments are levodopa therapy and Deep Brain Stimulation (DBS), which are often used in combination to improve motor symptoms. Managing levodopa levels alongside DBS presents a significant challenge: fluctuations in levodopa concentration leads to frequent "on-off" periods and dyskinesias, while manual DBS adjustments are ambiguous in terms of what the optimal level of stimulation is required. This research proposal presents a machine learning model that predicts real-time levodopa levels based on neural firings and patient symptoms. The model also dynamically adjusts DBS stimulation parameters to optimize motor function while minimizing side effects. This model has the potential to enhance the precision and efficacy of Parkinson's disease treatment, providing a more personalized and responsive therapeutic approach alongside already existing therapeutic methods.

Methods

Subjects

Testing and Training:

To test and train the machine learning model, we require a sample of:

- Healthy participants
- Participants with Parkinson's Disease who:
  - Currently on levodopa
  - Have undergone Deep Brain Stimulation (DBS)

Potential Electrode Insertion Sites:

- Substantia Nigra pars reticulata (SNr)
- Subthalamic Nucleus (STN)
- Globus Pallidus interna (GPi)

Patient Data

To further test, train, and refine the model, we require existing datasets on neuronal firing patterns associated with levodopa administration. These datasets should include:

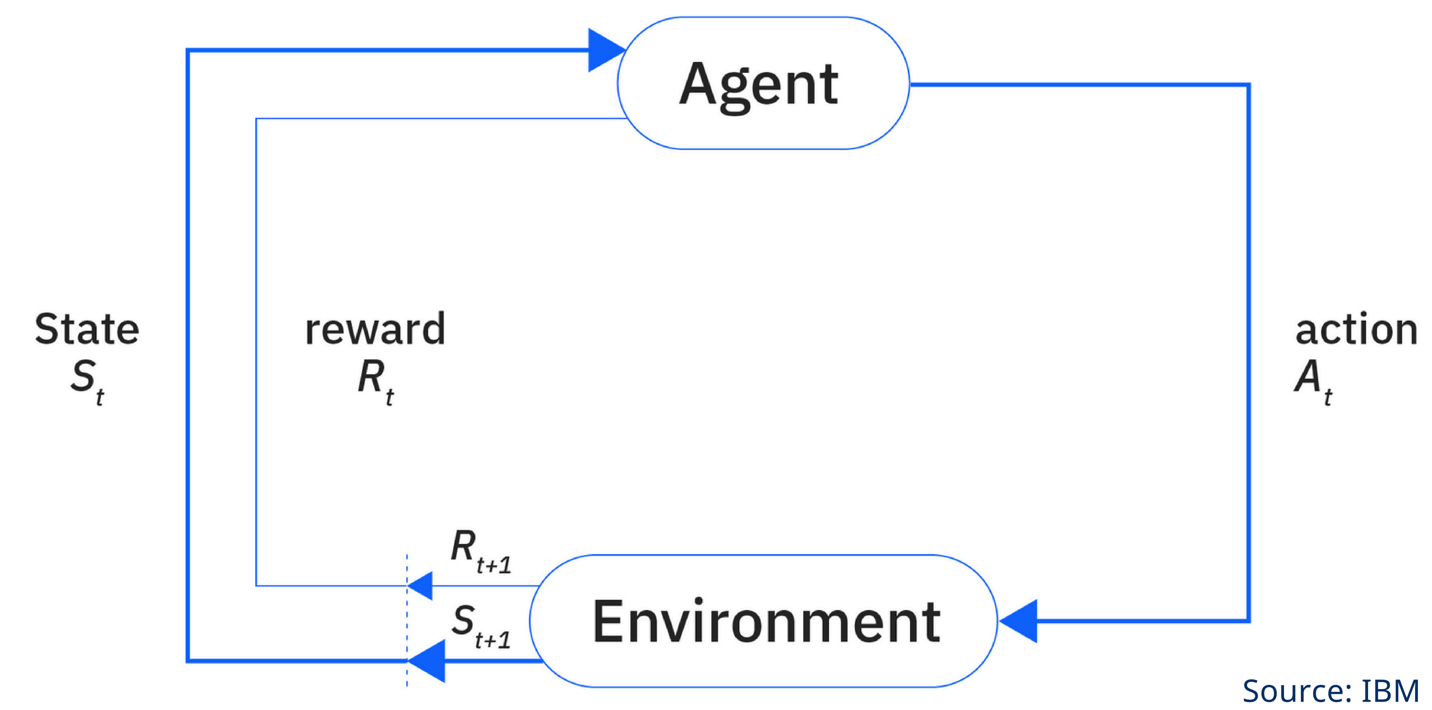
- Pre- and post-levodopa firing rates: *to analyze effectiveness of levadopa in certain areas of the brain*
- Motor symptom severity before and after treatment
- Electrophysiological data from DBS-targeted regions (e.g., SNr, STN, GPi)

Required Libraries and Packages

Python will be the primary language used for the model, developed in a Jupyter notebook. Reinforcement Learning (RL) will optimize dosing and stimulation adjustments.

Libraries & Packages:

- Pandas: Data analysis and cleaning
- NumPy: Handling numerical data and arrays
- Matplotlib: Visualization of brain regions and neural patterns
- MNE: Analyzing neurophysiological data (MEG, EEG, sEEG, ECoG)
- Neo + Spyke Viewer: Electrophysiology data handling and visualization
- PyTorch: Developing and training the RL model
- TensorFlow: Alternative framework for large-scale model deployment

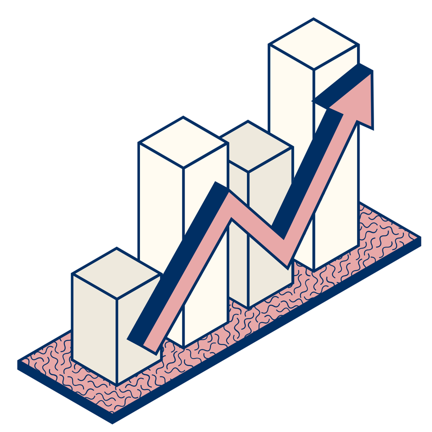


Source: IBM

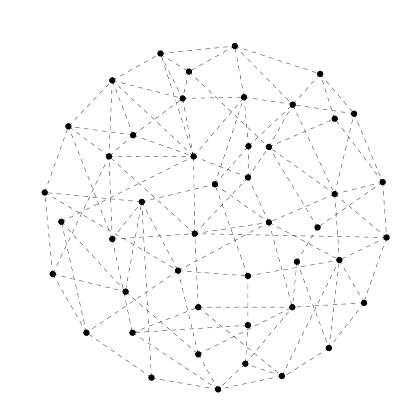
Generally how reinforced learning in machine learning works. Output from the environment is either favourable or not. If favourable, model is rewarded, and that behaviour is encouraged. If the outcome from the environment is unfavourable, the model decreases likelihood of that action occurring again.

Discussion

The model takes input from patient symptoms recorded after exposure to different DBS stimulation levels and employs a reinforcement learning technique to refine its predictions over time. By continuously learning from patient responses, the model adapts to individual needs, ultimately determining the optimal levodopa dosage and DBS adjustments for each patient.



Based on existing neurophysiological data on levadopa or deep brain stimulation frequencies, build the model



Teach and train the model, ultimately attaining a high accuracy percentage

Testing and training results in personalized levels of levodopa administered to participants

Levodopa tends to come in the form of pills, however recent advances allow for levodopa to be injected in the patient's gastrointesinal system.

Source: Tonus-les

References

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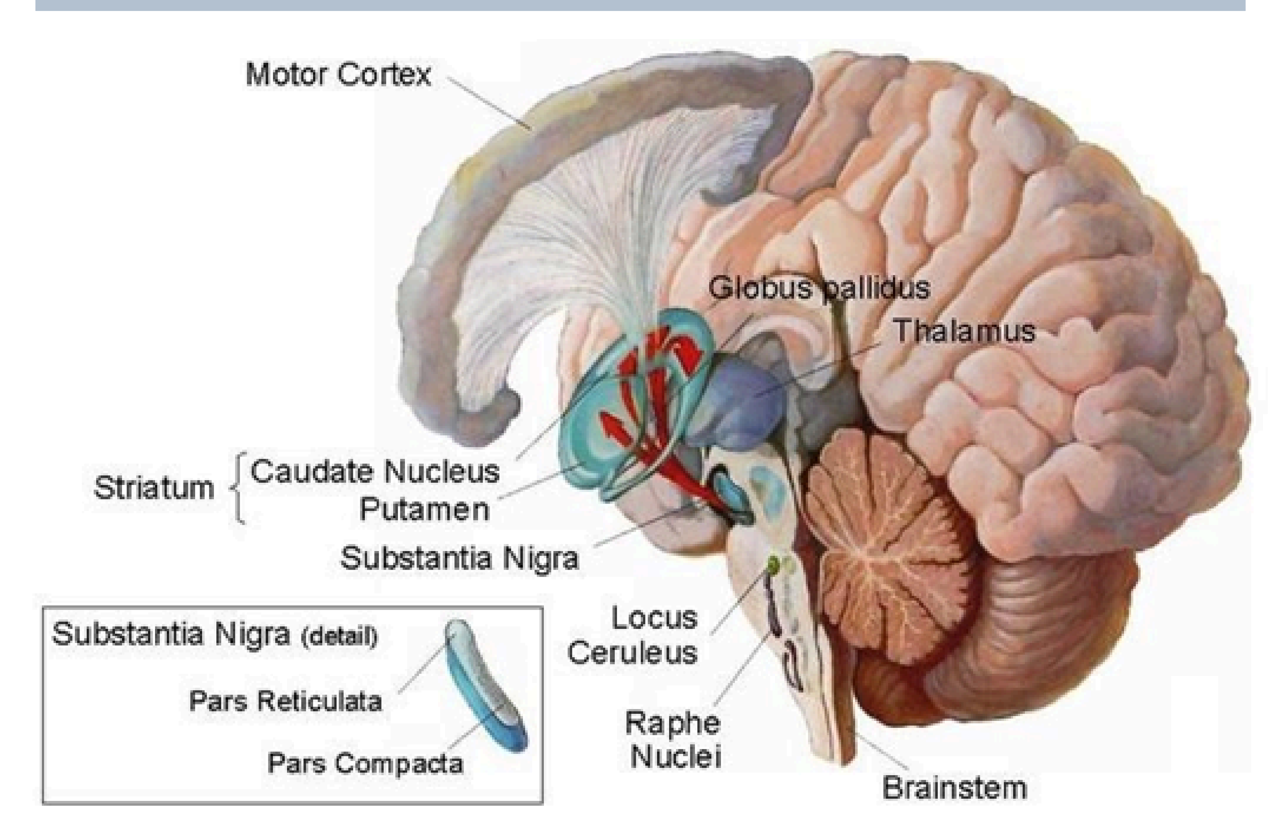

Source: Fymat, A. L. Neuroradiology and Its Role in Neurodegenerative Diseases. International Institute of Medicine & Science, California, U.S.A.