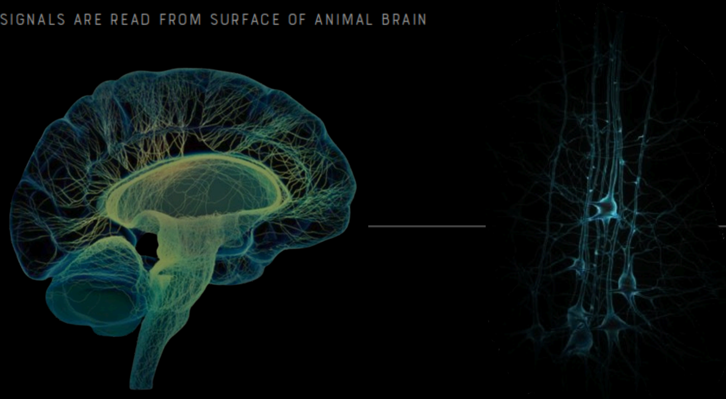
SYNTHETIC INTELLIGENCE LABS

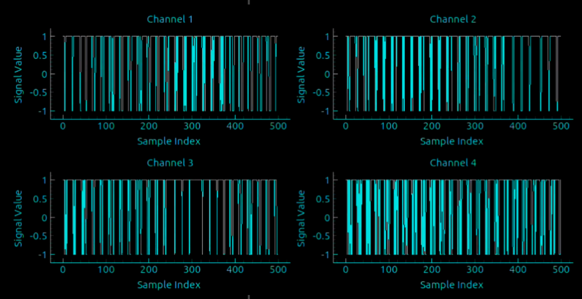
DEVICE NAME: BIO SILICON INTELLIGENCE SYSTEM
MODEL NUMBER: MODEL 01

OUTPUT FREQ RANGE: UP TO 20 KHZ

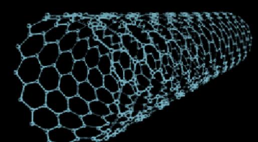
We present the Bio-Silicon Intelligence System (BSIS), an innovative hybrid platform integrating biological neural networks with silicon-based computing. BSIS combines computational systems with rat brains through carbon nanotube-coated electrodes, enabling high-fidelity neural interfacing and bidirectional communication. Neural signals are read from a custom multi-electrode array (MEA), processed via a FreeEEG32 board and BrainFlow[1,2], and analyzed using proprietary software. The system employs a dual signaling approach for training the rat brain, incorporating a reward solution and human-inaudible distress sounds.

BRAIN SIGNALS ARE READ FROM SURFACE OF ANIMAL BRAIN

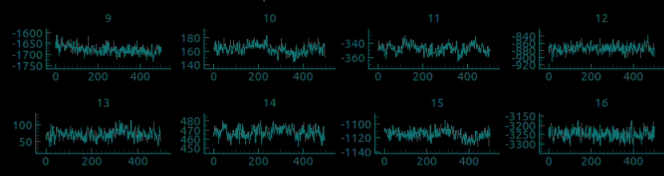


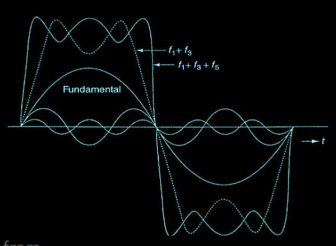


CARBON NANOTUBES SELF-ORGANIZE TO REACH SYSTEM EQUILIBRIUM BY IMPROVING CONNECTIONS FROM NEURONS TO ELECTRODES



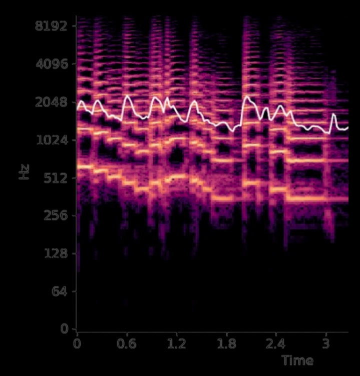
Our custom microelectrode arrays are coated with Multiwalled Carbon Nanotubes, which have demonstrated the ability to spontaneously form networks that mimic natural neural pathways, promoting targeted and robust synaptic connections [3][4][5]. This self-organizing behavior helps to align the electrodes precisely with the neurons, ensuring that the neural signals are captured with high specificity and fidelity. The branching out of these connections to the right neurons is facilitated by the inherent properties of MWCNTs, which support the growth and guidance of neurites. Consequently, the system's overall performance is improved, with enhanced signal clarity and reduced noise, thereby augmenting the efficiency of neuron-electrode interfaces and contributing to more accurate and reliable neuro-computational interactions.

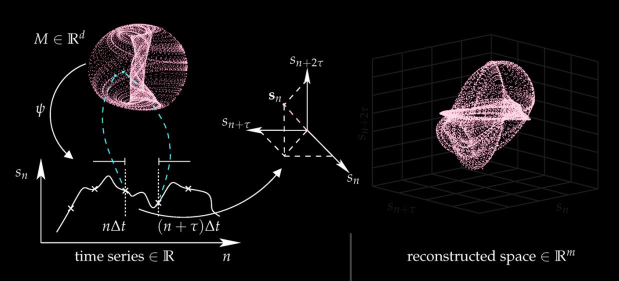




In our software we extract features from the neural signals such as spectral centroids, derived from the fast fourier transform[6][7][8][9][10][11], spectral edge density[12][13][14][15][16], Higuchi fractal dimension [17], evolution rate [18] by using the Hilbert transfrom [19][20], variance, root mean square, and peak count.

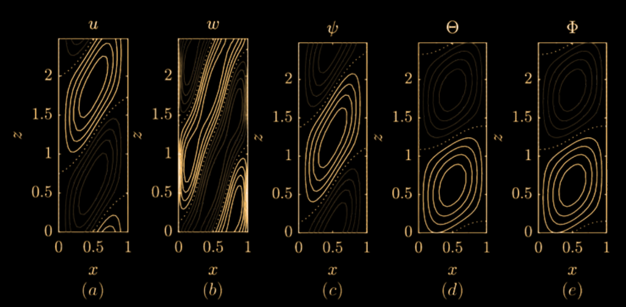
FEATURES SUCH AS SPECTRAL CENTROIDS, HIGUCHI FRACTAL DIMENSION, SPECTRAL EDGE DENSITY AND OTHERS ARE EXTRACTED FROM NEURAL SIGNALS

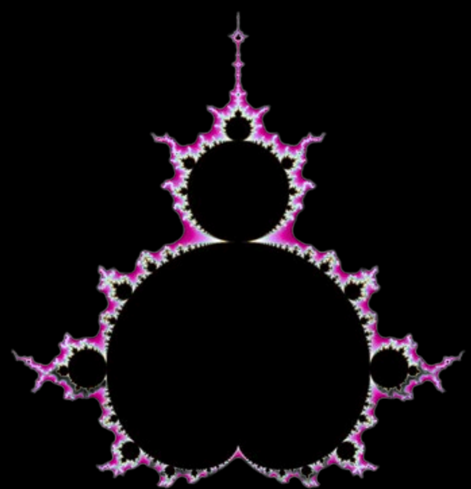


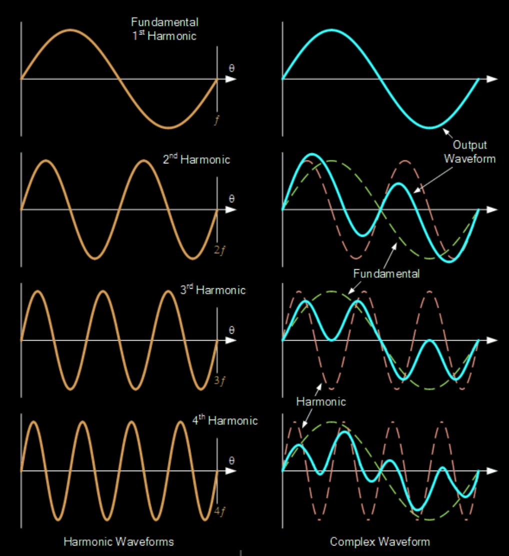


DATA ENCODED ANALOGUE AND DIGITAL NEURAL STIMULATION

The Bio-Silicon Intelligence System (BSIS) uses digital stimulation by encoding neural feedback into binary signals, translating features like score and distance to target into ON (150 microvolts) or OFF (0 microvolts) signals. This method generates distinct waveforms based on neural activity outcomes, with reward producing clean sine waves and distress creating chaotic waves, which are then combined to control external devices in real-time.The digital stimulation signal outputter transmits these encoded signals to stimulation hardware for smooth playback, managed through ring buffers and audio streams. It ensures precise and continuous neural feedback transmission by translating binary values to amplitude values and managing seamless signal transmission through continuous buffering and audio playback. The Bio-Silicon Intelligence System (BSIS) supports analog stimulation by encoding neural feedback into analog signals, translating game state features into parameters for signal generation. The analog signal generator produces complex, realistic neural activity patterns through various transformations, including quantum-inspired transformations using parameterized Hermitian matrices. The system ensures precise signal transmission by running audio outputs through voltage dividers and using ring buffers to maintain continuous playback. Grounded shielding minimizes electromagnetic interference, ensuring high-fidelity signal acquisition and processing for effective neural interfacing and advanced neurotechnology research.

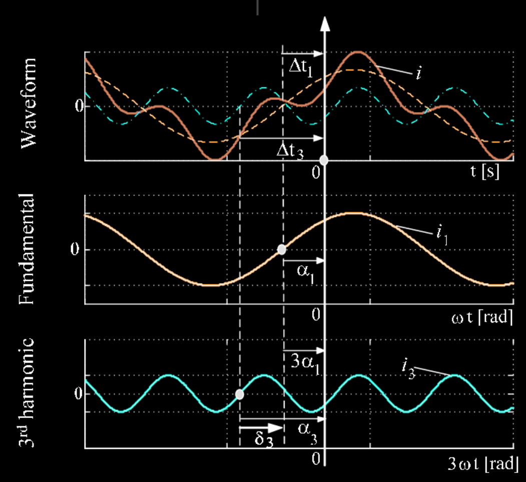


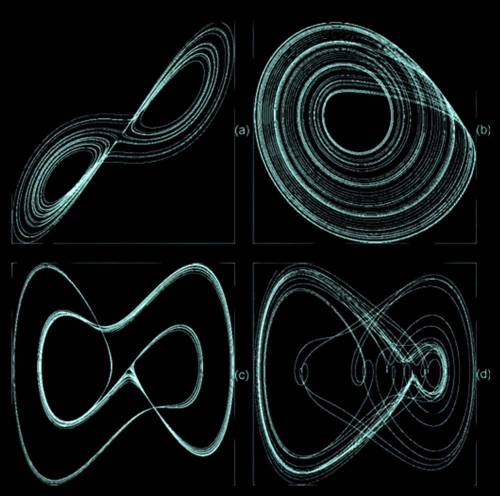




FUSION OF ANALOGUE AND DIGITAL A.I. IN BOTH BIOLOGICAL AND SILICON FORM

Our system's functionality mirrors analogue AI in its continuous signal processing and adaptive response mechanisms. In analogue AI, information is processed as continuous waveforms, capturing the natural, uninterrupted flow of data. Similarly, our system processes neural signals in their continuous form, which allows for the detection of intricate variations in neural activity that would be lost in a discrete, digital approach. This continuous processing is crucial for accurately reflecting the dynamic and complex nature of neural signals, which are inherently variable and rich in detail. By maintaining the continuity of the data, our system can provide a more detailed and precise analysis, akin to how biological neural networks operate, capturing the subtle nuances of neural activity in real-time.





The software includes a component for translating neural signal features into actionable commands for applications such as interactive games. This is achieved through the FeaturesToGameAction class, which maps extracted neural features to specific game actions. The system dynamically adjusts the game actions based on real-time changes in neural signal features, providing a responsive and adaptive control mechanism. The FeaturesToGameAction class listens to the "EXTRACTED FEATURES" topic for incoming neural signal features and publishes game actions to the "GAME ACTIONS" topic using MQTT [21]for communication. A graphical user interface (GUI) built with PyQt5 [22] displays the neural signal features, their values, and the corresponding actions taken, updating dynamically based on incoming data. The core features processed include Higuchi fractal dimension, evolution rate, spectral centroids, spectral edge density, variance, standard deviation, root mean square (RMS), and peak count. Instead of using predefined mappings for actions, the script compares the current feature values to previously recorded ones.

The dynamic adjustment of force based on changes in neural signal features can be deeply understood through the lens of continuous signal processing and control theory. These systems process information in a manner that mimics biological neural networks, allowing for a more natural and fluid integration of neural data into interactive applications. Continuous signal processing enables the capture of subtle variations in neural activity, providing a richer and more nuanced understanding of the underlying dynamics. The theoretical foundation for this approach lies in the study of continuous dynamical systems, capturing the inherent complexity and adaptability of neural processes. By leveraging these principles, systems can dynamically adjust interactive forces in response to real-time neural signals, creating a seamless and responsive user experience.

References
[1] FreeEEG32. Available: https://github.com/neuroidss/FreeEEG32-beta.[2] BrainFlow. Available: https://brainflow.readthedocs.io/en/stable/.[3] J. Xia et al, "Magnetically Compatible Brain Electrode Arrays Based on Single-Walled Carbon Nanotubes for Long-Term Implantation," vol. 14, (3), pp. 240, 2024.[4] T. Saliev, "The advances in biomedical applications of carbon nanotubes," vol. 5, (2), pp. 29, 2019.[5] S. M. Abd El-atty et al, "Engineering molecular communications integrated with carbon nanotubes in neural sensor nanonetworks," vol. 12, (2), pp. 201-210, 2018.[6] J. M. Grey and J. W. Gordon, "Perceptual effects of spectral modifications on musical timbres," J.Acoust.Soc.Am., vol. 63, (5), pp. 1493-1500, 1978.[7] J. W. Cooley and J. W. Tukey, "An algorithm for the machine calculation of complex Fourier series," vol. 19, (90), pp. 297-301, 1965.[8] Z. Yang et al, "A Chua's Chaotic Chirp Spread-Spectrum Power Spectral Homogenization Strategy Based on Distribution Transformation," vol. 13, (12), pp. 2296, 2024.[9] G. A. Beyene et al, "Dynamical Analysis of a 3D Fractional-Order Chaotic System for High-Security Communication and its Electronic Circuit Implementation," vol. 30, (4), pp. 1375-1391, 2023.[10] M. Varanis et al, "Signal Analysis in Chaotic Systems: A Comprehensive Assessment through Time-Frequency Analysis," 2024.[11] J. Basdevant, "Energy, quantization and quantum tunneling," in Lectures on Quantum Mechanics: With Problems, Exercises and SolutionsAnonymous 2023, [12] M. M. Todd, "EEGs, EEG processing, and the bispectral index," vol. 89, (4), pp. 815-817, 1998.[13] B. Levin, "A representation for multinomial cumulative distribution functions," pp. 1123-1126, 1981.[14] R. Koenker and G. Bassett Jr, "Regression quantiles," pp. 33-50, 1978.[15] S. Lawrence, "Marple Jr.(Eds.), Digital Spectral Analysis with Applications," 1987.[16] S. Kay, "Spectral estimation," pp. 58-122, 1988.[17] T. Higuchi, "Approach to an irregular time series on the basis of the fractal theory," Physica D, vol. 31, (2), pp. 277-283, 1988.[18] D. K. Bandy, J. R. Hall and M. E. Denker, "Predicting the evolutionary dynamic behavior of a laser with injected signal using Lyapunov exponents," vol. 92, (1), pp. 013841, 2015.[19] D. Hilbert, "Grundzüge einer allgemeinen theorie der linearen integralrechnungen. (zweite mitteilung)," vol. 1904, pp. 213-260, 1904.[20] B. Boashash, "Estimating and interpreting the instantaneous frequency of a signal. I. Fundamentals," Proc IEEE, vol. 80, (4), pp. 520-538, 1992.[21] (). MQTT. Available: https://mqtt.org/.[22] (). PyQT. Available: https://www.riverbankcomputing.com/software/pyqt/.