ALIFE26

Hands-on Tutorial on Brain-Computer Interfaces (BCI)

August 19th, 2026

TIMETABLE

Time	Session	Duration
10:00 – 10:10	FUNDAMENTALS OF BCI AND SIGNAL PROCESSING TECHNIQUES EEG Signal processing, applications	10 MIN
10:10 – 10:25	AI INTEGRATIONS FOR BCI ENHANCEMENTS Autoencoder & multimodal analysis	15 MIN
10:25 – 11:10	GAMING AND INTERACTION Signal conversion and classification, interactive session	45 MIN
11:10 – 11:15	SHORT BREAK	5 MIN
11:15 – 11:30	PRESENTATION ON INTERESTING AL CONCEPTS FOR INTERACTION ENABLEMENT Embodiment, hybrid biological-digital systems, interactive evolutionary environments	15 MIN
11:30 – 11:50	FINAL GAME INTERACTIVE EVOLUTIONARY PLATFORM Highlights from current AL interactive systems	20 MIN
11:50 – 12:00	Q&A SESSION	10 MIN

Tutorial Organizers

Bruno Senzio-Savino B
Yamagata University
Invited Researcher

Mahdi Khosravy
Cross-Compass Ltd.
Senior Research Scientist

Alyssa Adams
Cross-Compass Ltd.
Senior Research Scientist

Olaf Witkowski
Cognisee
Chief Scientist

Explore limitless possibilities!

https://bsenzio.github.io/bmitutorialALIFE26/

BRAIN–COMPUTER INTERFACE (BCI)

Principles • Discovery • How It Works • How It's Used

A BCI is a direct communication pathway enabling the brain to interact with external devices, bypassing the body's muscles.

1 FUNDAMENTAL PRINCIPLES

Neural Signal Acquisition
Detect electrical or hemodynamic activity from the brain.

Signal Processing
Filter noise, extract relevant features, and transform the signals.

Pattern Recognition
Identify patterns and map them to user intentions.

Translation & Output
Convert intentions into commands for external devices or feedback.

Closed-Loop Adaptation
The system learns and adapts with continuous use.

2 HOW IT WAS DISCOVERED

1924 Hans Berger
First recorded the human electroencephalogram (EEG).

1960s–70s
Neuroscience & engineering advanced how we measure and interpret brain signals.

1990s First BCIs
Early systems demonstrated brain signals controlling a cursor or device.

2000s–Now
Improved sensors, machine learning, and real-time systems enable practical, non-invasive BCIs.

3 HOW IT WORKS

1 Acquisition
Sensors rapture brain activity (EEG, ECoG, fNIRS, etc.).

2 Preprocessing
Remove noise, segment, normalize, and filter.

3 Feature Extraction
Extract meaningful representations.

4 Classification / Decoding
Map patterns to intentions (or mental states).

5 Command / Output
Execute actions, provide feedback, or control devices.

4 HOW IT IS USED

Neurorehabilitation
Restore movement and communication after injury or disease.

Assistive Communication
Enable communication for people with paralysis (e.g., ALS, locked-in syndrome).

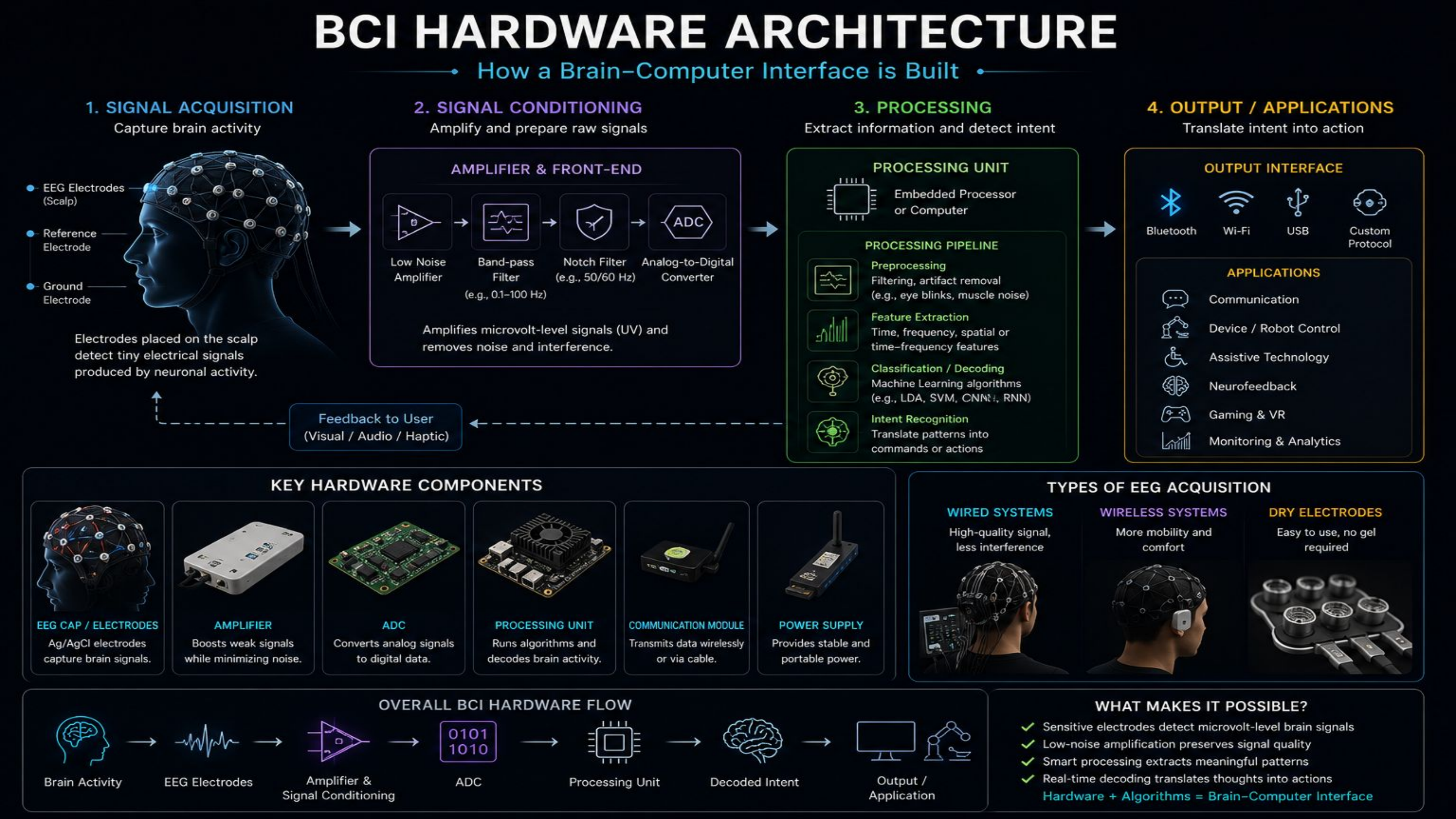
Device Control
Control computers, prosthetics, drones, wheelchairs, and more.

Cognitive Enhancement
Improve attention, learning, and mental training.

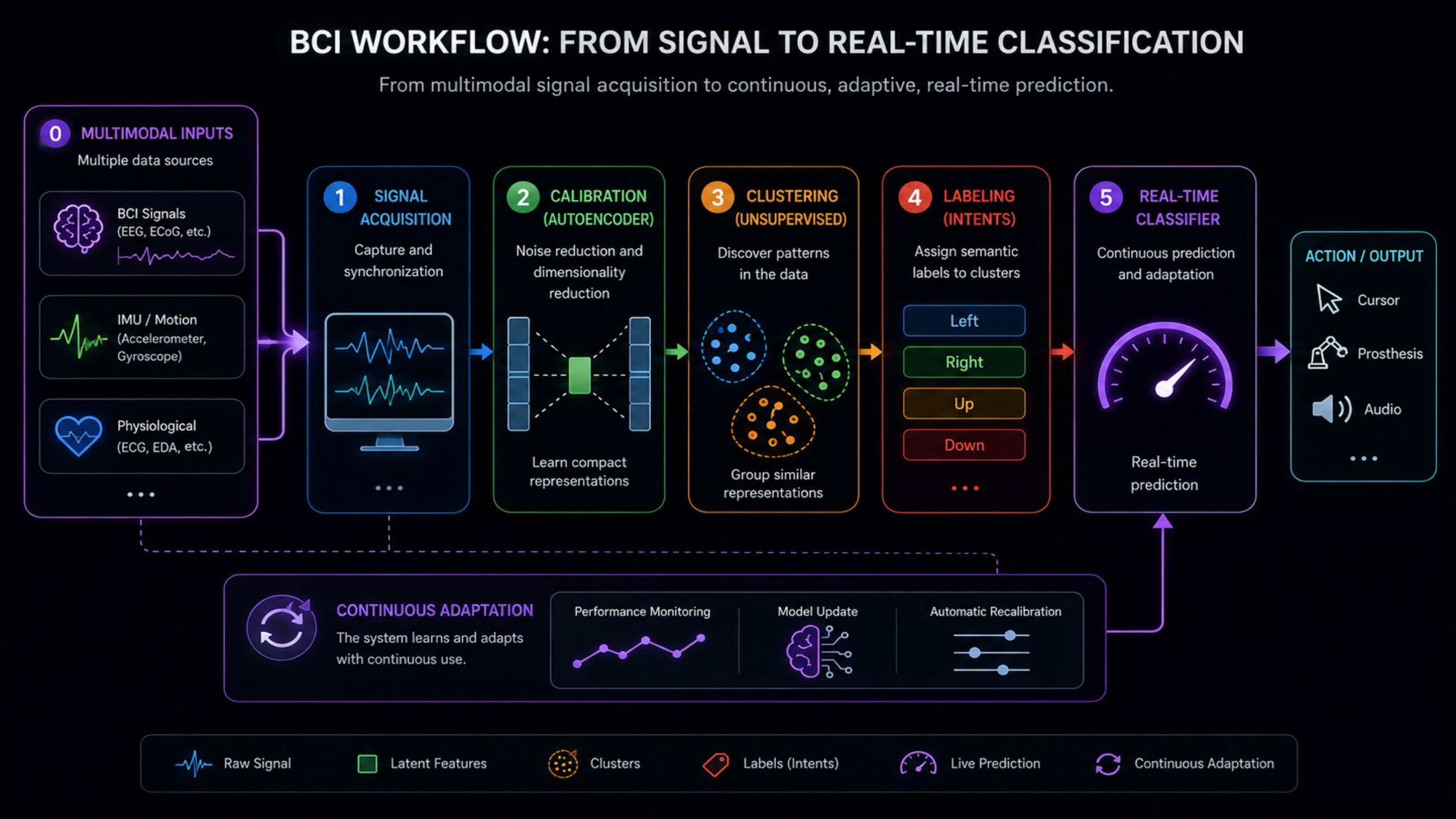
Neurotechnology & Research
Study the brain and develop new human–computer interactions.

BCIs bridge the gap between mind and machine, opening new possibilities to enhance human potential and improve quality of life.

Brain Signals »» Processing »» Decoding »» Action »» Impact


BCI HARDWARE ARCHITECTURE
How a Brain–Computer Interface is Built
1. SIGNAL ACQUISITION
Capture brain activity
EEG Electrodes (Scalp)
Reference Electrode
Ground Electrode
Electrodes placed on the scalp detect tiny electrical signals produced by neuronal activity.
2. SIGNAL CONDITIONING
Amplify and prepare raw signals
AMPLIFIER & FRONT-END
Low Noise Amplifier
Band-pass Filter (e.g., 0.1–100 Hz)
Notch Filter (e.g., 50/60 Hz)
ADC
Analog-to-Digital Converter
Amplifies microvolt-level signals (UV) and removes noise and interference.
3. PROCESSING
Extract information and detect intent
PROCESSING UNIT
Embedded Processor or Computer
PROCESSING PIPELINE
Preprocessing
Filtering, artifact removal (e.g., eye blinks, muscle noise)
Feature Extraction
Time, frequency, spatial or time–frequency features
Classification / Decoding
Machine Learning algorithms (e.g., LDA, SVM, CNN, RNN)
Intent Recognition
Translate patterns into commands or actions
4. OUTPUT / APPLICATIONS
Translate intent into action
OUTPUT INTERFACE
Bluetooth
Wi-Fi
USB
Custom Protocol
APPLICATIONS
Communication
Device / Robot Control
Assistive Technology
Neurofeedback
Gaming & VR
Monitoring & Analytics
Feedback to User (Visual / Audio / Haptic)
KEY HARDWARE COMPONENTS
EEG CAP / ELECTRODES
Ag/AgCl electrodes capture brain signals.
AMPLIFIER
Boosts weak signals while minimizing noise.
ADC
Converts analog signals to digital data.
PROCESSING UNIT
Runs algorithms and decodes brain activity.
COMMUNICATION MODULE
Transmits data wirelessly or via cable.
POWER SUPPLY
Provides stable and portable power.
TYPES OF EEG ACQUISITION
WIRED SYSTEMS
High-quality signal, less interference
WIRELESS SYSTEMS
More mobility and comfort
DRY ELECTRODES
Easy to use, no gel required
OVERALL BCI HARDWARE FLOW
Brain Activity
EEG Electrodes
Amplifier & Signal Conditioning
0101 1010
ADC
Processing Unit
Decoded Intent
Output / Application
WHAT MAKES IT POSSIBLE?
Sensitive electrodes detect microvolt-level brain signals
Low-noise amplification preserves signal quality
Smart processing extracts meaningful patterns
Real-time decoding translates thoughts into actions
Hardware + Algorithms = Brain–Computer Interface

Hardware EEG



BCI WORKFLOW: FROM SIGNAL TO REAL-TIME CLASSIFICATION
From multimodal signal acquisition to continuous, adaptive, real-time prediction.
0 MULTIMODAL INPUTS
Multiple data sources
BCI Signals (EEG, ECoG, etc.)
IMU / Motion (Accelerometer, Gyroscope)
Physiological (ECG, EDA, etc.)
...
1 SIGNAL ACQUISITION
Capture and synchronization
...
2 CALIBRATION (AUTOENCODER)
Noise reduction and dimensionality reduction
Learn compact representations
3 CLUSTERING (UNSUPERVISED)
Discover patterns in the data
Group similar representations
4 LABELING (INTENTS)
Assign semantic labels to clusters
Left
Right
Up
Down
...
5 REAL-TIME CLASSIFIER
Continuous prediction and adaptation
Real-time prediction
ACTION / OUTPUT
Cursor
Prosthesis
Audio
...
CONTINUOUS ADAPTATION
The system learns and adapts with continuous use.
Performance Monitoring
Model Update
Automatic Recalibration
Raw Signal
Latent Features
Clusters
Labels (Intents)
Live Prediction
Continuous Adaptation

APPLICATIONS OF BCI

BCIs can be used in two main ways depending on the user's role: actively generating commands or passively being monitored.

ACTIVE BCIs

The user actively generates brain signals to control or interact with a system.

1. Attention-based control systems

(Soft control of interfaces)

Using attention to select, navigate or modulate interface elements.

2. Brain-driven game interactions

(Hard interface control, P300)

Using brain responses (e.g. P300) to trigger actions in games or virtual environments.

3. User-intent detection

(Motor imagery)

User imagines a movement to control a device or software (e.g., move left or right).

PASSIVE BCIs

The system passively monitors brain activity to infer the user's mental or emotional state.

1. Cognitive workload monitoring

(Meditation, TDAH, Sleep ...)

Continuously assesses mental load, focus or relaxation levels.

2. Neuroadaptive interfaces

(Neurofeedback, audio, emotion...)

Systems adapt in real-time to the user's brain state.

3. Implicit human-state assessment

(Emotion Recognition...)

Detects emotions or affective states without requiring explicit input.

KEY TAKEAWAY Active BCIs empower users to control systems with their minds. | Passive BCIs provide valuable insights about the user's internal state.

EXAMPLES OF ACTIVE AND PASSIVE BCIs

BCIs can either actively gontrol external systems or passively monitor brain activity to provide insights and feedback.

ACTIVE BCIs

The user actively generates brain signals to control devices or systems.

1. Video game intention recognition

(Soft control, light commands)

Detect intentions (e.g., move, select, jump) to control actions in a game.

2. Brain wave authentication

Use unique brain patterns to authenticate users securely.

3. Robot / Limb Control

Control robotic arms or assistive devices using motor imagery or neural commands.

PASSIVE BCIs

The system passively monitors brain activity to assess mental or emotional states.

1. TDAH detectors in classroom

Monitor attention levels in real time to help teachers support students with ADHD.

2. Meditation apps for Yoga, etc.

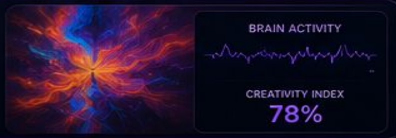
Track brain activity (e.g., calmness, focus) to guide and improve meditation practice.

3. Audio feedback applications

Provide real-time auditory feedback based on brain states (e.g., concentration, relaxation).

4. Art BCI

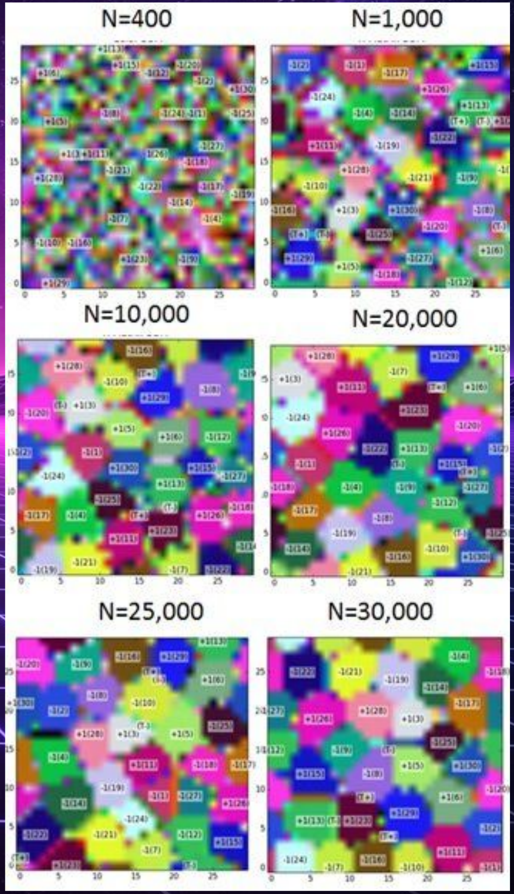
Translate brain activity into visual art, music or interactive creative experiences.

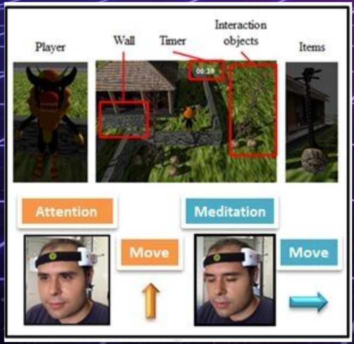


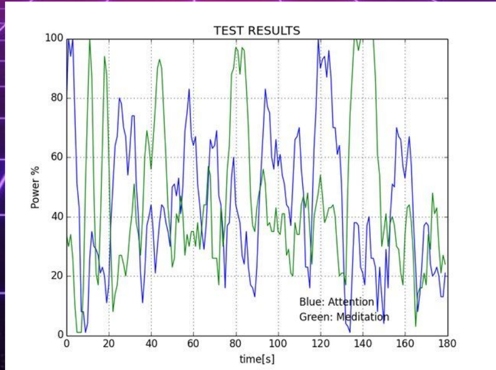
ACTIVE BCIs = Control
You use your brain to do something.

PASSIVE BCIs = Insight
The system observes and understands your state.

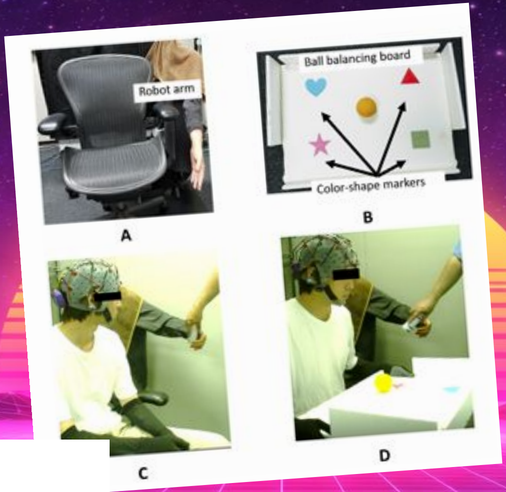
A little BCI here, a little BCI there…







Supernumerary Limb Control



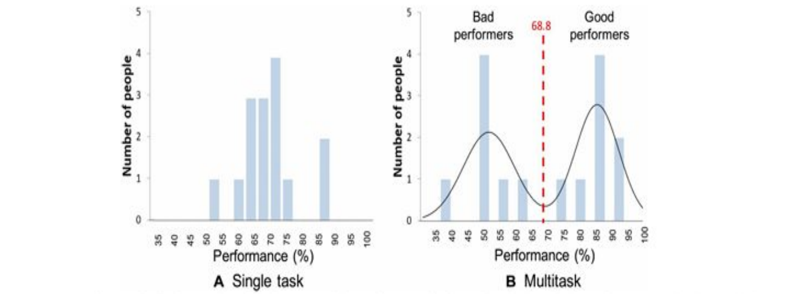


Fig. 2. Histograms showing the distribution of people with respect to their performances for the single task and multitask conditions. (A) Single task. (B) Multitask. Panel (B) also shows a visual representation of the probability function resulting from the GMM-EM algorithm. The performance score (68.8) corresponding to the boundary between the two modalities was used to separate the two groups: good performers (above the boundary) and bad performers (below the boundary).

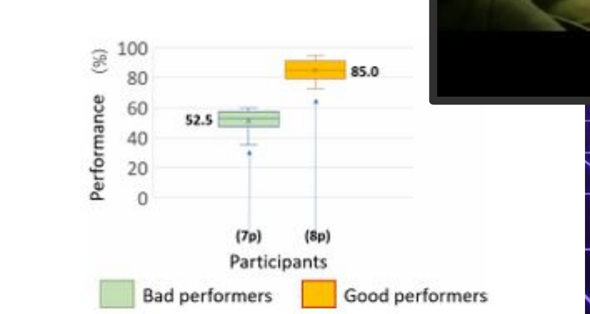


Fig. 3. The two modalities for the multitask condition. Performance median score and the number of good performers (eight people, median = 85) and bad performers (seven people, median = 52.5) for multitask condition. Error bars indicate min/max values.

BCI COMBINED WITH OTHER SIGNALS

Multimodal interfaces for more robust, accurate and intuitive human–machine interaction.

More Accurate
Combining signals reduces false positives and errors.

More Robust
Works better in real-world conditions and variability.

More Intuitive
Leverages complementary information from the user.

COMPLEMENTARY SIGNALS

BCI
Brain Signals

Measures brain activity (EEG) to infer mental states, intentions or cognitive workload.

Examples: Motor imagery, attention, workload, emotion

EMG
Muscle Activity

Measures electrical activity produced by muscles to detect movement or muscle activation.

Examples: Hand grasp, arm movement, facial expressions

EYE TRACKING
Gaze & Pupils

Tracks eye movement, gaze direction, blink rate and pupil size to infer intent and engagement.

Examples: Gaze direction, blink detection, pupil dilation

MULTIMODAL FUSION
Data Integration

Sensor fusion and machine learning combine signals to improve performance and reliability.

APPLICATIONS

Assistive Communication & Control
Enable users with severe motor disabilities to communicate and control devices more reliably.

Gaming & Entertainment
Enhanced immersion and control by combining brain signals with muscle activity and gaze.

Robotics & Prosthetics
More natural and precise control of robotic arms or prosthetic devices using multimodal inputs.

Driving & Mobility
Monitor driver attention and intent, detect drowsiness and enhance adaptive assistance.

Wellness & Mental Health
Monitor stress, focus and emotions through combined neurophysiological signals.

WHY COMBINE SIGNALS?

Higher Accuracy
Complementary signals reduce ambiguity and improve detection.

Greater Robustness
Performance is maintained even when one signal is noisy or weak.

Faster & More Reliable Responses
Faster intent detection and more stable control.

Richer Context Understanding
More complete picture of the user's state and environment.

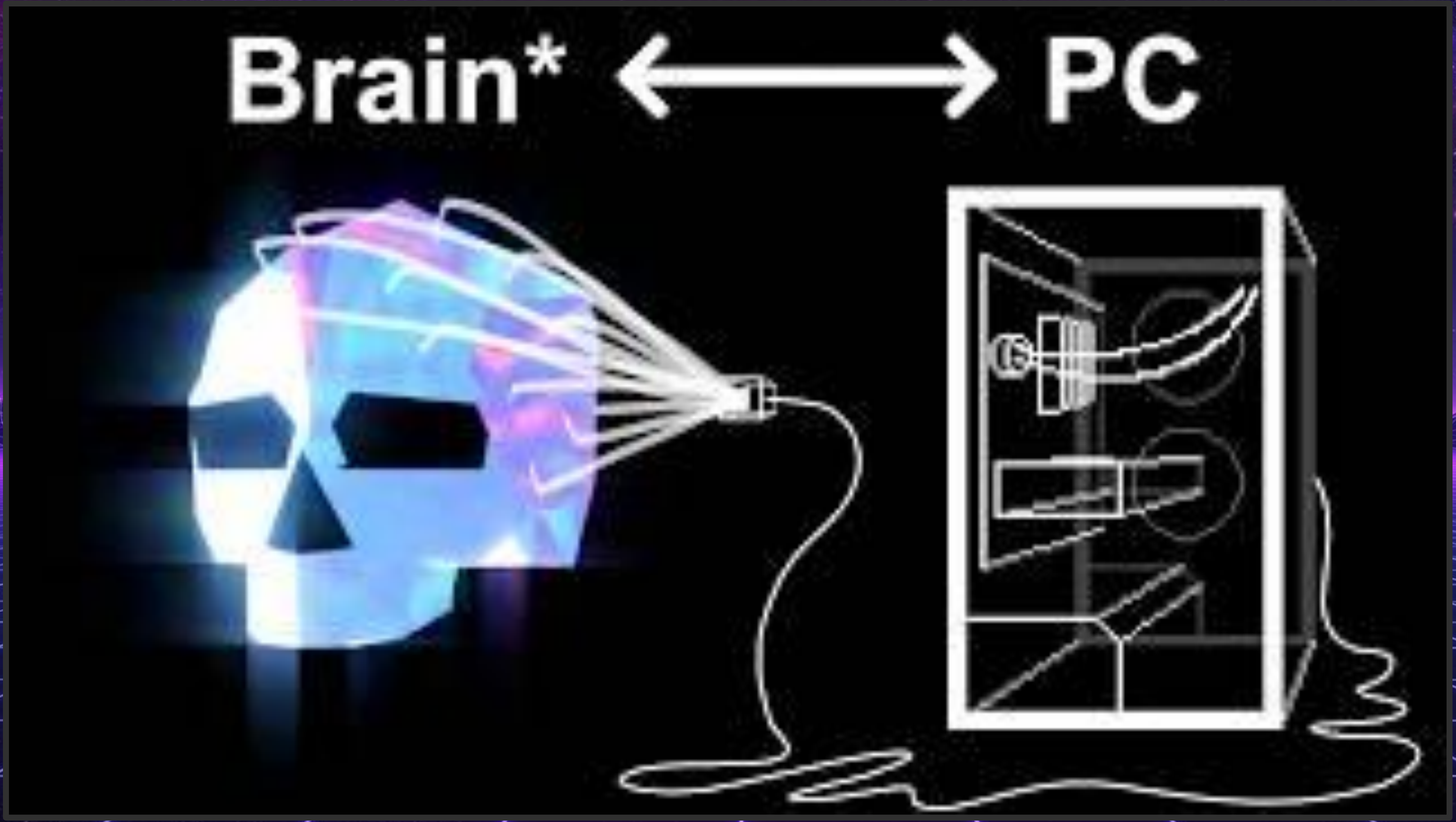
TYPICAL MULTIMODAL BCI PIPELINE

1. **Signal Acquisition** — EEG + EMG + Eye Tracking
2. **Preprocessing** — Filtering, artifact removal, normalization
3. **Feature Extraction** — Time, frequency, spatial and statistical features
4. **Fusion & ML Model** — Feature fusion and machine learning / deep learning
5. **Decision & Output** — Intent recognition and command generation
6. **Action / Application** — Control device, feedback or display output

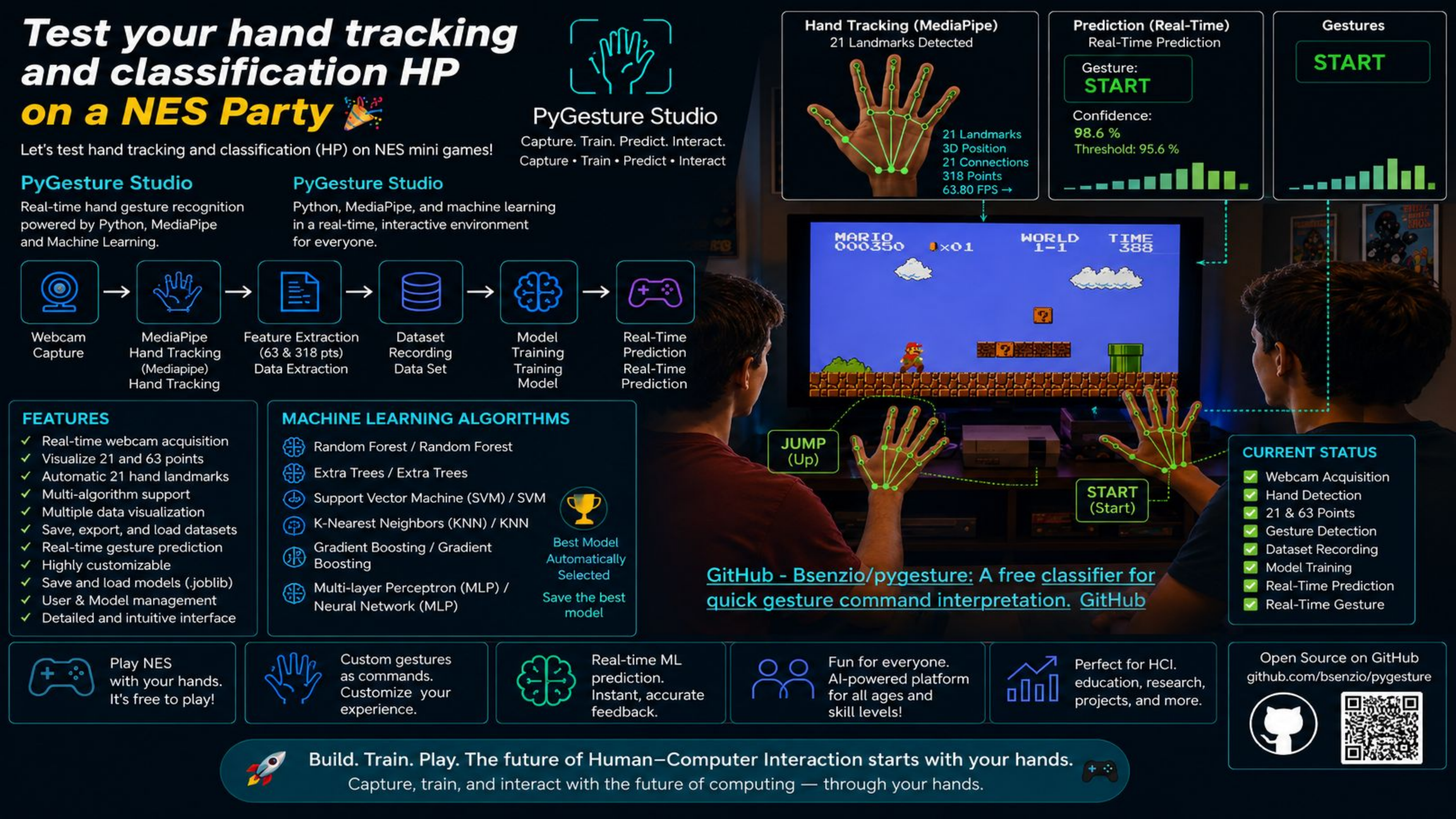
KEY TAKEAWAY

Combining BCI with EMG and Eye Tracking unlocks the full potential of human intent decoding and enables smarter, more natural and reliable interfaces.

BMI without BCI? How come?



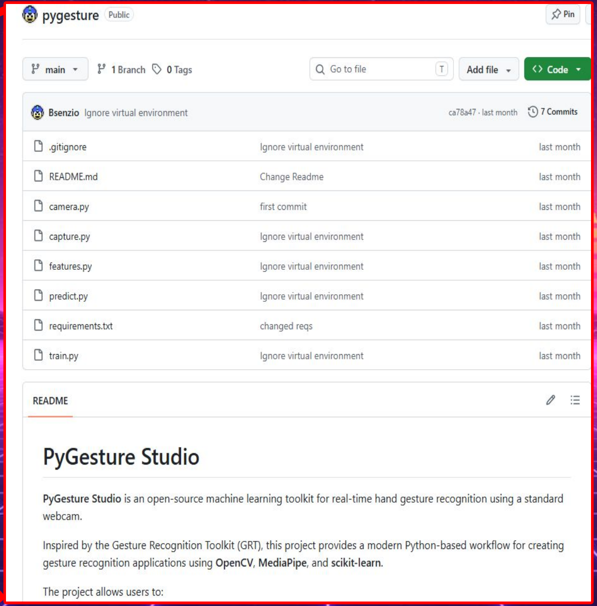
Source: https://youtu.be/g45Xa6QVKng?si=A2qZGWDvW0363uNJ


Test your hand tracking and classification HP
on a NES Party
Let's test hand tracking and classification (HP) on NES mini games!
PyGesture Studio
Capture. Train. Predict. Interact.
Capture • Train • Predict • Interact
PyGesture Studio
Real-time hand gesture recognition powered by Python, MediaPipe and Machine Learning.
PyGesture Studio
Python, MediaPipe, and machine learning in a real-time, interactive environment for everyone.
Webcam Capture
MediaPipe Hand Tracking (Mediapipe) Hand Tracking
Feature Extraction (63 & 318 pts) Data Extraction
Dataset Recording Data Set
Model Training Training Model
Real-Time Prediction Real-Time Prediction
Hand Tracking (MediaPipe)
21 Landmarks Detected
21 Landmarks
3D Position
21 Connections
318 Points
63.80 FPS →
Prediction (Real-Time)
Real-Time Prediction
Gesture:
START
Confidence:
98.6 %
Threshold: 95.6 %
Gestures
START
MARIO 000350
×01
WORLD 1-1
TIME 388
JUMP (Up)
START (Start)
FEATURES
✓ Real-time webcam acquisition
✓ Visualize 21 and 63 points
✓ Automatic 21 hand landmarks
✓ Multi-algorithm support
✓ Multiple data visualization
✓ Save, export, and load datasets
✓ Real-time gesture prediction
✓ Highly customizable
✓ Save and load models (.joblib)
✓ User & Model management
✓ Detailed and intuitive interface
MACHINE LEARNING ALGORITHMS
Random Forest / Random Forest
Extra Trees / Extra Trees
Support Vector Machine (SVM) / SVM
K-Nearest Neighbors (KNN) / KNN
Gradient Boosting / Gradient Boosting
Multi-layer Perceptron (MLP) / Neural Network (MLP)
Best Model Automatically Selected
Save the best model
GitHub - Bsenzio/pygesture: A free classifier for quick gesture command interpretation. GitHub
CURRENT STATUS
Webcam Acquisition
Hand Detection
21 & 63 Points
Gesture Detection
Dataset Recording
Model Training
Real-Time Prediction
Real-Time Gesture
Play NES with your hands. It's free to play!
Custom gestures as commands. Customize your experience.
Real-time ML prediction. Instant, accurate feedback.
Fun for everyone. AI-powered platform for all ages and skill levels!
Perfect for HCI. education, research, projects, and more.
Open Source on GitHub
github.com/bsenzio/pygesture
Build. Train. Play. The future of Human–Computer Interaction starts with your hands.
Capture, train, and interact with the future of computing — through your hands.


Can you convert one signal into another?
Exploring the bridge between brainwaves and hand movements
EEG BRAIN SIGNALS
Brain Signals (EEG)
Brain Activity
Neural Signals
EEG Waves
Intention
IS IT POSSIBLE?
From brainwaves...
...to hand movements?
BRIDGING MIND AND MOVEMENT
Connecting brain and body
Applications: BCI, Assistive Technology, VR/AR, Robotics, Neurofeedback and more
HAND TRACKING
Hand Tracking
21 Landmarks
63 Features
21 Hand Landmarks
63 Features
Hand Landmarks
21 Landmarks
Feature Extraction
63 Features
Movement / Gesture
Recognition
Understanding. Translating. Connecting.
Understand. Translate. Connect.
The future is in our hands and minds.
The future is in our hands and minds.

Can you BMI without BMI too?

https://github.com/Bsenzio/pygesture



pygesture Public

Pin

main | 1 Branch | 0 Tags | Go to file | Add file | Code

Bsenzio Ignore virtual environment — ca78a47 · last month — 7 Commits

.gitignore	Ignore virtual environment	last month
README.md	Change Readme	last month
camera.py	first commit	last month
capture.py	Ignore virtual environment	last month
features.py	Ignore virtual environment	last month
predict.py	Ignore virtual environment	last month
requirements.txt	changed reqs	last month
train.py	Ignore virtual environment	last month

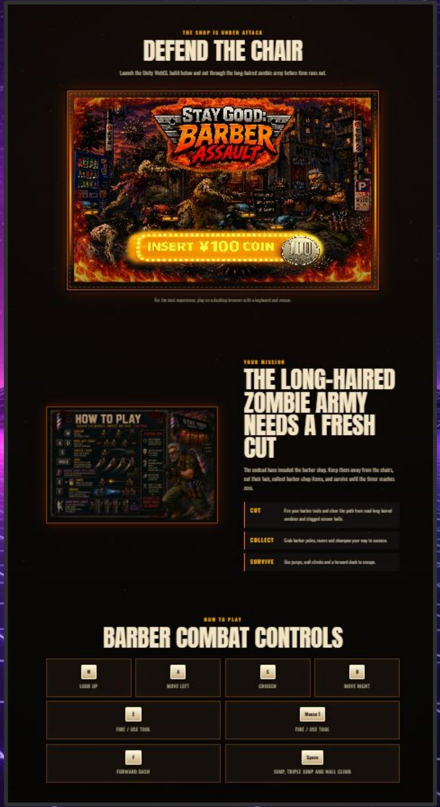
README

PyGesture Studio

PyGesture Studio is an open-source machine learning toolkit for real-time hand gesture recognition using a standard webcam.

Inspired by the Gesture Recognition Toolkit (GRT), this project provides a modern Python-based workflow for creating gesture recognition applications using **OpenCV**, **MediaPipe**, and **scikit-learn**.

The project allows users to:



FFA:
https://app.kosmi.io/room/120fkz

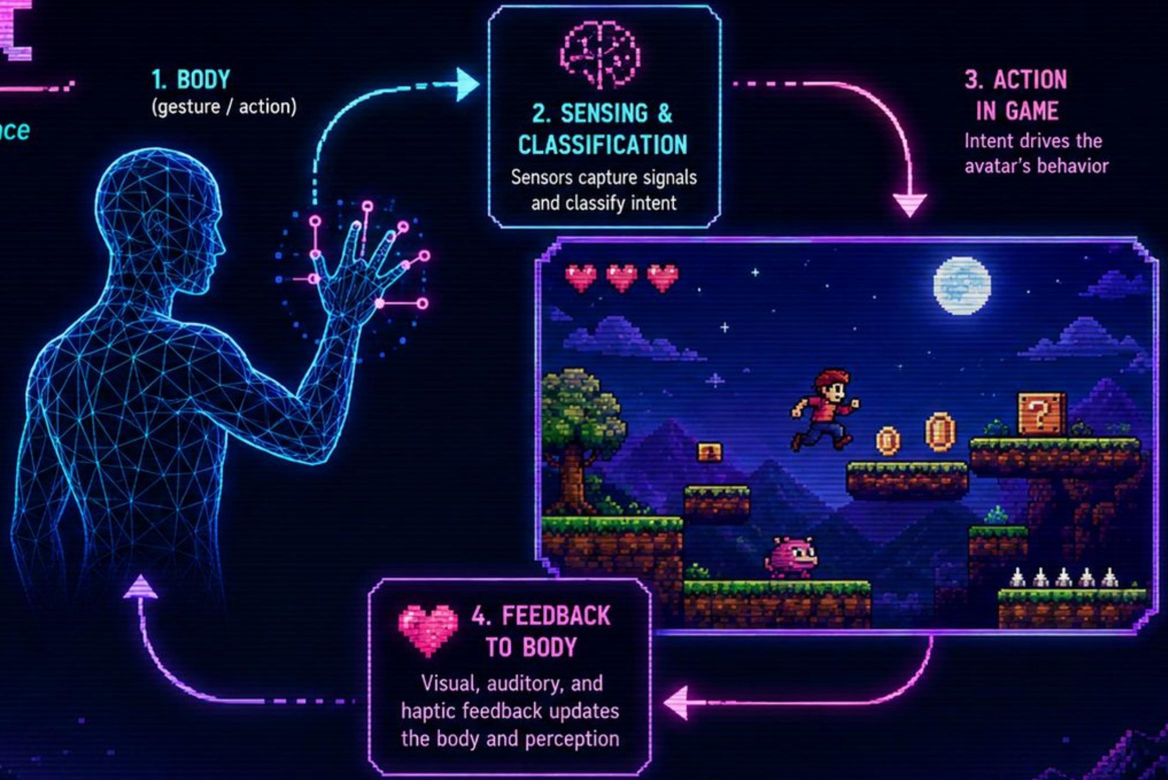
Solo:
https://bsenzio.github.io/TestStayGood/

Session Break

Embodiment

How a body shapes perception, action, and intelligence

- Cognition is grounded in bodily action
- Perception and movement co-create behavior
- In interaction, the human body becomes part of the system



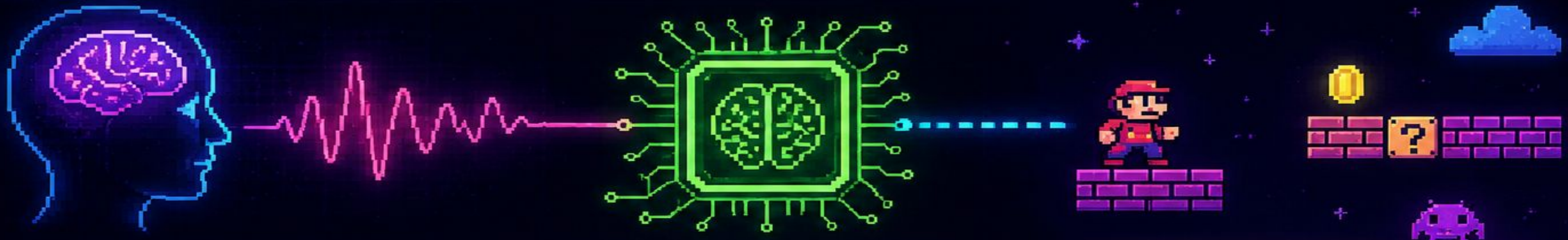
Embodiment = intelligence emerging through a body acting in an environment

1UP
1985

HYBRID BIOLOGICAL-DIGITAL SYSTEMS

When biological signals and digital systems combine to create new forms of interaction.

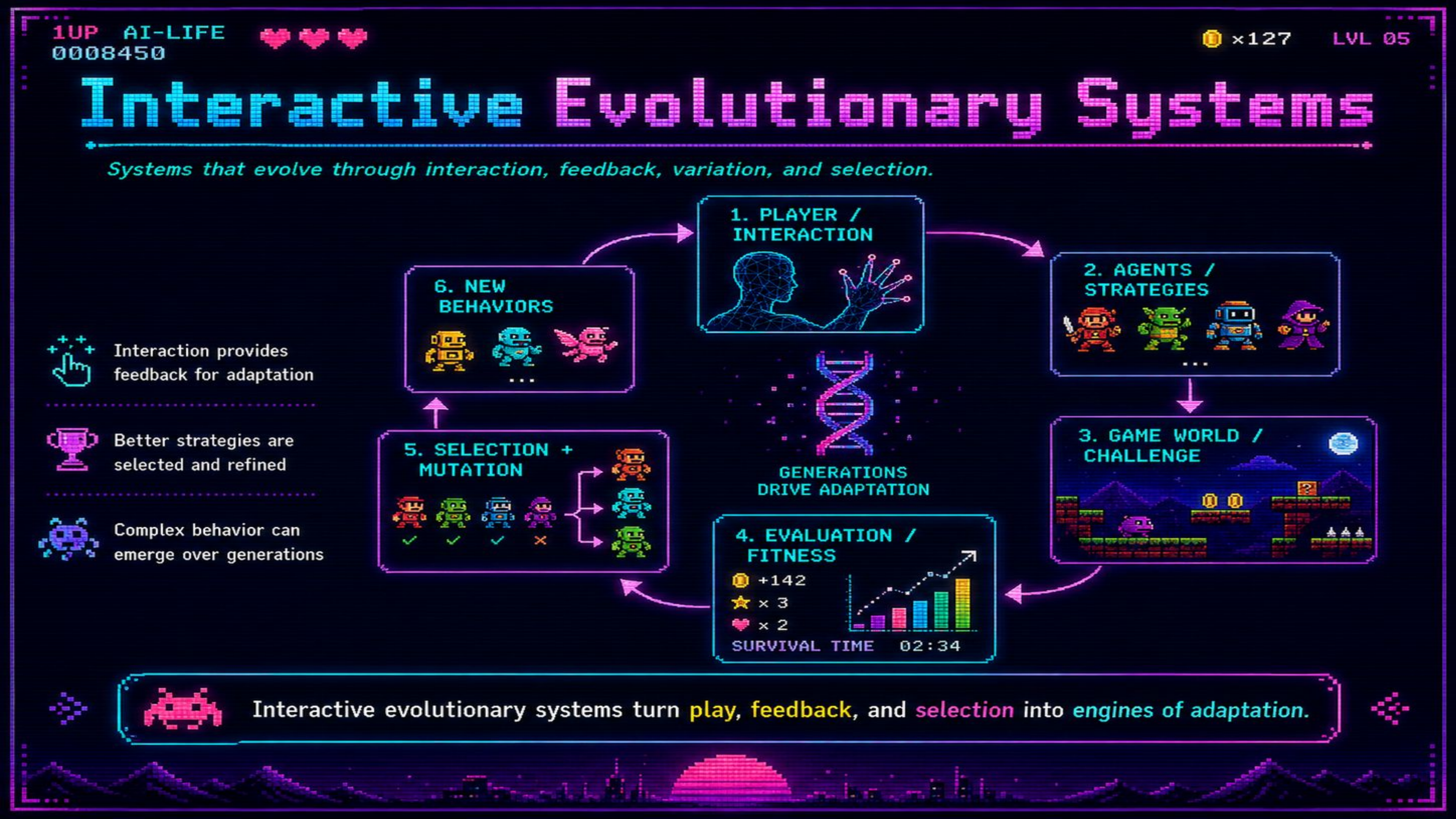
BIOLOGICAL YOU	DIGITAL INTERFACE TRANSLATION LAYER	DIGITAL WORLD THE SYSTEM

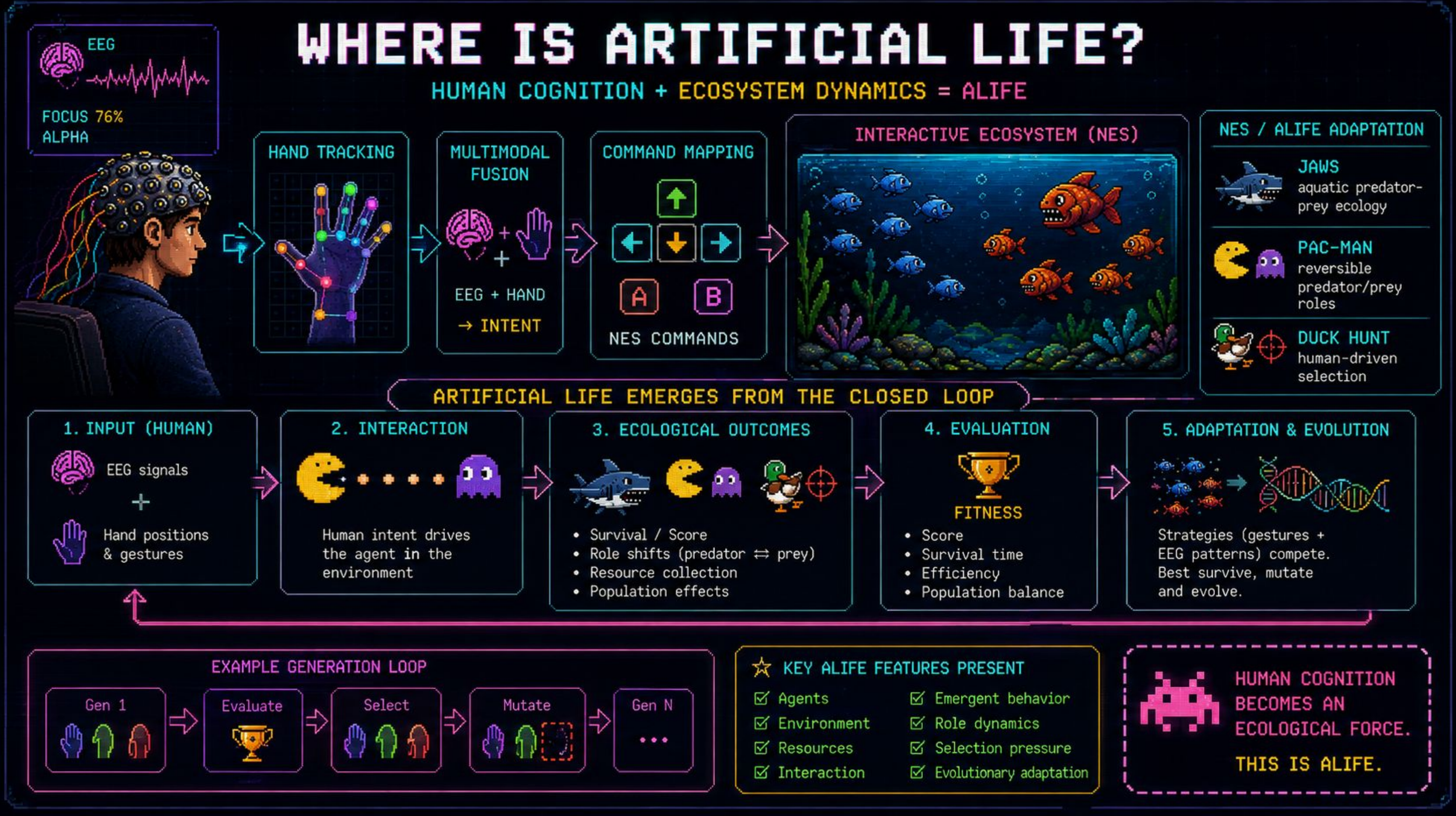


BIOLOGICAL	DIGITAL INTERFACE	DIGITAL WORLD
Brain activity (EEG)	Signal Processing	Game control
Eye movements	Feature Extraction	Virtual agents
Hand gestures	Machine Learning	Generative worlds
Heart rate	Decision / Mapping	Adaptive systems

Hybrid systems blur the boundary between the biological and the digital, enabling new possibilities for interaction, adaptation and co-evolution.

START


1UP AI-LIFE
0008450
×127
LVL 05
Interactive Evolutionary Systems
Systems that evolve through interaction, feedback, variation, and selection.
1. PLAYER / INTERACTION
2. AGENTS / STRATEGIES
...
3. GAME WORLD / CHALLENGE
4. EVALUATION / FITNESS
+142
× 3
× 2
SURVIVAL TIME 02:34
5. SELECTION + MUTATION
6. NEW BEHAVIORS
...
GENERATIONS DRIVE ADAPTATION
Interaction provides feedback for adaptation
Better strategies are selected and refined
Complex behavior can emerge over generations
Interactive evolutionary systems turn play, feedback, and selection into engines of adaptation.


WHERE IS ARTIFICIAL LIFE?
HUMAN COGNITION + ECOSYSTEM DYNAMICS = ALIFE
EEG
FOCUS 76%
ALPHA
HAND TRACKING
MULTIMODAL FUSION
EEG + HAND
→ INTENT
COMMAND MAPPING
A
B
NES COMMANDS
INTERACTIVE ECOSYSTEM (NES)
NES / ALIFE ADAPTATION
JAWS
aquatic predator-prey ecology
PAC-MAN
reversible predator/prey roles
DUCK HUNT
human-driven selection
ARTIFICIAL LIFE EMERGES FROM THE CLOSED LOOP
1. INPUT (HUMAN)
EEG signals
+
Hand positions & gestures
2. INTERACTION
Human intent drives the agent in the environment
3. ECOLOGICAL OUTCOMES
• Survival / Score
• Role shifts (predator ⇄ prey)
• Resource collection
• Population effects
4. EVALUATION
FITNESS
• Score
• Survival time
• Efficiency
• Population balance
5. ADAPTATION & EVOLUTION
Strategies (gestures + EEG patterns) compete. Best survive, mutate and evolve.
EXAMPLE GENERATION LOOP
Gen 1
Evaluate
Select
Mutate
Gen N
...
KEY ALIFE FEATURES PRESENT
Agents
Environment
Resources
Interaction
Emergent behavior
Role dynamics
Selection pressure
Evolutionary adaptation
HUMAN COGNITION BECOMES AN ECOLOGICAL FORCE.
THIS IS ALIFE.

NEUROADAPTIVE EVOLUTION IN NES-STYLE GAME WORLDS

BCI transforms classic games into evolutionary environments.

BCI → GAME WORLD → EVOLUTION

Gaze / Focus	Growth	1
P300 / Intention	Mutation	2
Energy / Resources	Reproduction	3
Population Diversity	Evolutionary Outcomes	4

The original game does not need built-in evolution; the BCI layer adds selection pressure, mutation events, and resource control.

BEST NES FITS

E.V.O.: Search for Eden

Direct match for evolution, adaptive traits, and survival.

SimAnt

Colony dynamics, reproduction, and emergent population behavior.

Kirby's Adventure

Ability adaptation and embodiment changes in response to the environment.

KEY IDEA

NES games become Artificial Life environments when neural signals shape selection, mutation, and reproduction.

PREDATOR-PREY ATTENTION ECOLOGY IN NES-STYLE GAME WORLDS

BCI turns attention into ecological selection pressure.

BCI → SELECTION → ECOLOGICAL BALANCE

Gaze / Focus	→	Select Prey	1
P300 / Intention	→	Confirm Bias	2
Energy / Survival	→	Predator Efficiency	3
Population Shift	→	Ecological Outcomes	4

BCI STATUS

The original game does not need a full ecosystem model; the BCI layer adds attention bias, survival pressure, and population control.

BEST NES FITS

E.V.O.: Search for Eden

Strong fit for food chains, adaptation, and ecological competition.

Jaws

Clear predator-prey tension, marine survival, and asymmetric ecological pressure.

Pac-Man

Abstract but useful for chase dynamics, pursuit, avoidance, and oscillating predator-prey behavior.

KEY IDEA

NES games become Artificial Life laboratories when neural signals bias selection, survival, and ecological balance.

▶ PRESS START TO CONTINUE

SWARM GUIDANCE SYSTEM IN NES-STYLE GAME WORLDS

Neural intention shapes collective behavior, attraction fields, and emergence.

BCI → FIELD CONTROL → SWARM EMERGENCE

Gaze / Focus	→ Attract Agents	1
P300 / Intention	→ Switch Field Mode	2
Energy / Strength	→ Control Radius	3
Agent Movement	→ Emergent Pattern	4

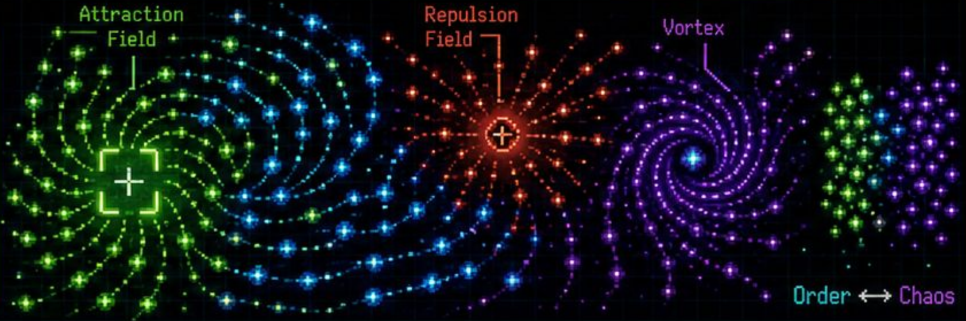
BCI STATUS

FOCUS

INTENTION

ENERGY

SWARM LINK



The game does not need explicit intelligence; the BCI layer adds field forces, local rules, and collective reorganization.

BEST NES FITS

1. Galaga

Ideal for coordinated enemy formations, attraction patterns, and swarm-like movement.

2. Xevious

Good match for layered aerial swarms, spatial fields, and adaptive attack waves.

3. Life Force

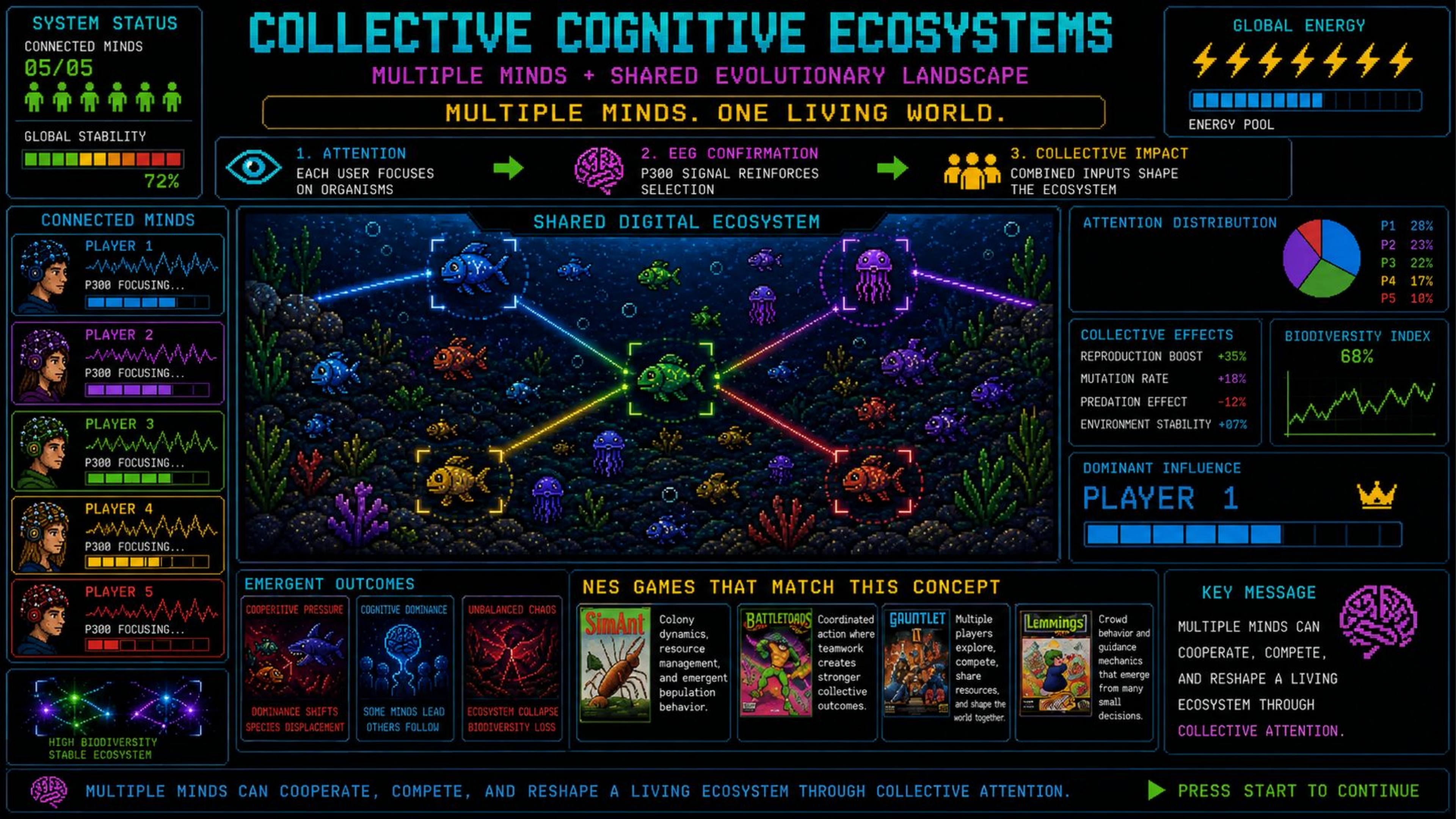
Strong fit for biological swarms, organism-like environments, and emergent hazards.

Also useful: Gradius, 1943, The Guardian Legend.

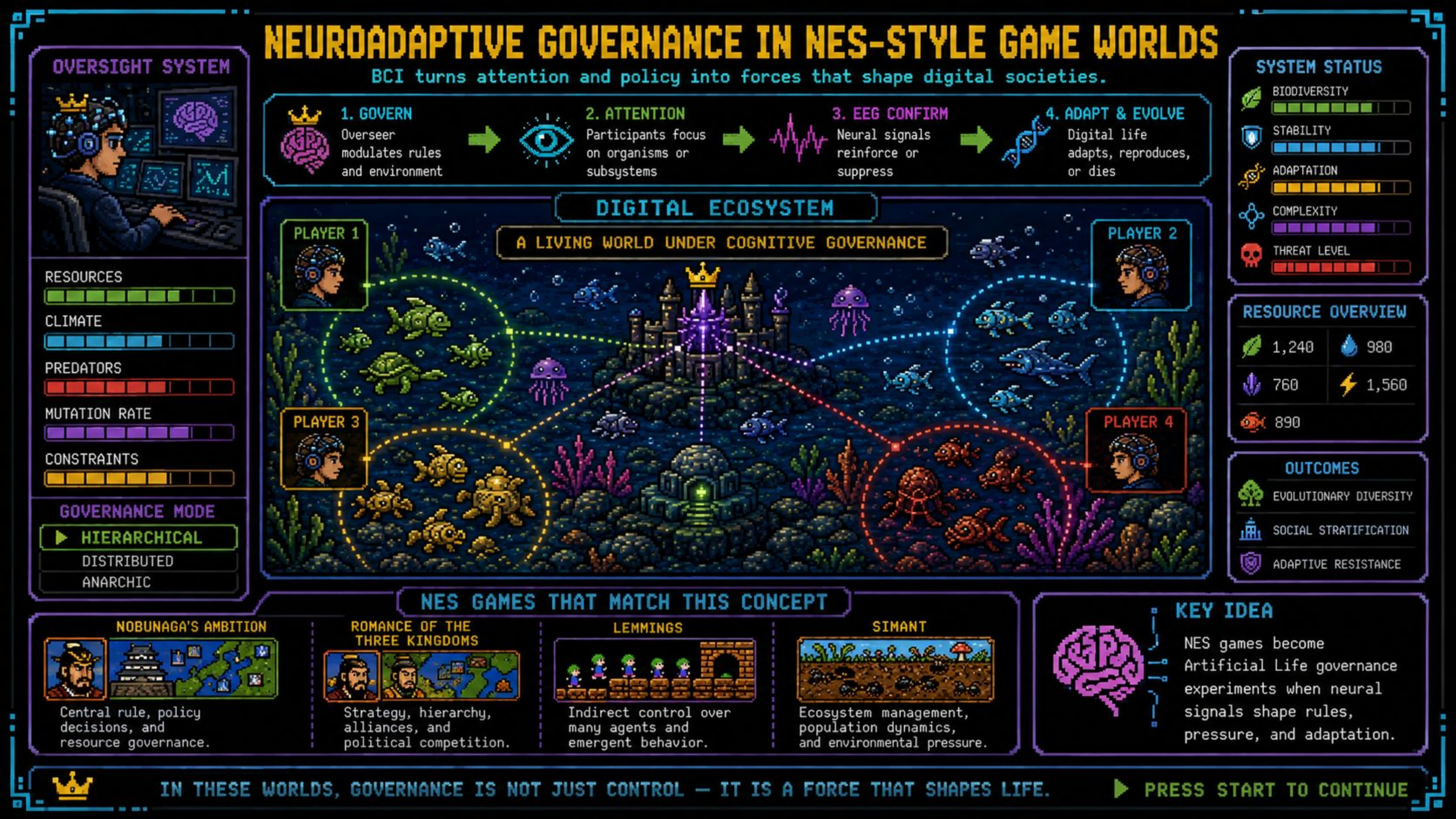
KEY IDEA

NES shooters become Artificial Life laboratories when neural signals guide attraction, repulsion, and emergent swarm behavior.

▶ PRESS START TO CONTINUE



COLLECTIVE COGNITIVE ECOSYSTEMS
MULTIPLE MINDS + SHARED EVOLUTIONARY LANDSCAPE
MULTIPLE MINDS. ONE LIVING WORLD.
SYSTEM STATUS
CONNECTED MINDS
05/05
GLOBAL STABILITY
72%
GLOBAL ENERGY
ENERGY POOL
1. ATTENTION
EACH USER FOCUSES ON ORGANISMS
2. EEG CONFIRMATION
P300 SIGNAL REINFORCES SELECTION
3. COLLECTIVE IMPACT
COMBINED INPUTS SHAPE THE ECOSYSTEM
CONNECTED MINDS
PLAYER 1
P300 FOCUSING...
PLAYER 2
P300 FOCUSING...
PLAYER 3
P300 FOCUSING...
PLAYER 4
P300 FOCUSING...
PLAYER 5
P300 FOCUSING...
HIGH BIODIVERSITY
STABLE ECOSYSTEM
SHARED DIGITAL ECOSYSTEM
ATTENTION DISTRIBUTION
P1 28%
P2 23%
P3 22%
P4 17%
P5 10%
COLLECTIVE EFFECTS
REPRODUCTION BOOST +35%
MUTATION RATE +18%
PREDATION EFFECT -12%
ENVIRONMENT STABILITY +07%
BIODIVERSITY INDEX
68%
DOMINANT INFLUENCE
PLAYER 1
EMERGENT OUTCOMES
COOPERITIVE PRESSURE
DOMINANCE SHIFTS
SPECIES DISPLACEMENT
COGNITIVE DOMINANCE
SOME MINDS LEAD
OTHERS FOLLOW
UNBALANCED CHAOS
ECOSYSTEM COLLAPSE
BIODIVERSITY LOSS
NES GAMES THAT MATCH THIS CONCEPT
SimAnt
Colony dynamics, resource management, and emergent population behavior.
BATTLETOADS
Coordinated action where teamwork creates stronger collective outcomes.
GAUNTLET II
Multiple players explore, compete, share resources, and shape the world together.
Lemmings
Crowd behavior and guidance mechanics that emerge from many small decisions.
KEY MESSAGE
MULTIPLE MINDS CAN COOPERATE, COMPETE, AND RESHAPE A LIVING ECOSYSTEM THROUGH
COLLECTIVE ATTENTION.
MULTIPLE MINDS CAN COOPERATE, COMPETE, AND RESHAPE A LIVING ECOSYSTEM THROUGH COLLECTIVE ATTENTION.
PRESS START TO CONTINUE


NEUROADAPTIVE GOVERNANCE IN NES-STYLE GAME WORLDS
BCI turns attention and policy into forces that shape digital societies.
OVERSIGHT SYSTEM
RESOURCES
CLIMATE
PREDATORS
MUTATION RATE
CONSTRAINTS
GOVERNANCE MODE
HIERARCHICAL
DISTRIBUTED
ANARCHIC
1. GOVERN
Overseer modulates rules and environment
2. ATTENTION
Participants focus on organisms or subsystems
3. EEG CONFIRM
Neural signals reinforce or suppress
4. ADAPT & EVOLVE
Digital life adapts, reproduces, or dies
DIGITAL ECOSYSTEM
A LIVING WORLD UNDER COGNITIVE GOVERNANCE
PLAYER 1
PLAYER 2
PLAYER 3
PLAYER 4
SYSTEM STATUS
BIODIVERSITY
STABILITY
ADAPTATION
COMPLEXITY
THREAT LEVEL
RESOURCE OVERVIEW
1,240
980
760
1,560
890
OUTCOMES
EVOLUTIONARY DIVERSITY
SOCIAL STRATIFICATION
ADAPTIVE RESISTANCE
NES GAMES THAT MATCH THIS CONCEPT
NOBUNAGA'S AMBITION
Central rule, policy decisions, and resource governance.
ROMANCE OF THE THREE KINGDOMS
Strategy, hierarchy, alliances, and political competition.
LEMMINGS
Indirect control over many agents and emergent behavior.
SIMANT
Ecosystem management, population dynamics, and environmental pressure.
KEY IDEA
NES games become Artificial Life governance experiments when neural signals shape rules, pressure, and adaptation.
IN THESE WORLDS, GOVERNANCE IS NOT JUST CONTROL — IT IS A FORCE THAT SHAPES LIFE.
PRESS START TO CONTINUE

FROM HAND TRACKING TO NEUROADAPTIVE ARTIFICIAL LIFE

Commands can control games — or become forces inside living digital worlds.

1. INPUT LAYER

HAND TRACKING

Hand Pose → Classifier → Command

EEG / BCI

EEG Signal → Decoder → Command / Cognitive State

Same interaction architecture, different signal source.

2. COMMAND LAYER

GESTURE COMMANDS

LEFT / RIGHT / A / B / SELECT

A B

EEG-DERIVED OUTPUTS

Attention / Workload / Engagement / Intention

BCI can emulate game commands or modulate system parameters.

3. WHAT THE SYSTEM CAN CONTROL

EVOLUTION	ECOLOGY	SWARMS	COLLECTIVE ECOSYSTEMS	GOVERNANCE
Growth, mutation, reproduction.	Predator / prey balance.	Attraction, repulsion, emergent motion.	Multiple players influencing one world.	Rules, resources, policy pressure.

4. RESEARCH OUTCOME

Human Signal → Command / Cognitive State → ALife Parameter → Emergent Behavior

- ★ Measure adaptation, diversity, and stability
- ★ Study cooperation, conflict, and dominance
- ★ Turn attention into ecological or evolutionary pressure
- ★ Move from game control to world shaping

KEY IDEA

The brain is not only a controller.
It can become part of the dynamics
of an artificial world.

★ From controlling a game to becoming part of the game's dynamics.

▶ PRESS START TO CONTINUE

HUMAN-IN-THE-LOOP ARTIFICIAL LIFE

From command classification to emergent digital worlds

HUMAN + CAMERA + EEG

COMMAND CLASSIFIER

- EVOLUTION
- PREDATOR-PREY ECOLOGY
- SWARMS
- COLLECTIVE ECOSYSTEMS
- GOVERNANCE

Let's use different **NES-style games** to explore Artificial Life concepts under the same **command-classification pipeline.**

1. **HUMAN SIGNALS** — hand pose / attention / intention
2. **CLASSIFIER** — features → commands
3. **GAME WORLD** — commands become rules, pressures, or actions
4. **OBSERVE** — adaptation, cooperation, competition, feedback, emergence

KEY IDEA

Artificial Life is not only about simulating creatures. It is about observing **lifelike patterns**, **adaptation**, **organization**, and **evolution** emerging from simple rules, agents, and environments.

DISCUSSION

- What patterns emerged?
- What was directly controlled?
- What changed through feedback?
- How could EEG replace or extend hand tracking?

BUILD → PLAY → OBSERVE → REINTERPRET → DISCUSS

PRESS START TO REFLECT

Q&A

Thank you so much!

See you on the next level!