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A Comparative Review of Traditional AI, Generative AI, and Organoid Intelligence

Dr. K.R. Martin¹, Jegan G²

¹Assistant Professor, Department of Information Technology, St. Joseph's College (Autonomous), Tiruchirappalli, Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu, India, E-mail: martin_it2@mail.sjctni.edu

²PG Student, Department of Information Technology, M.Sc. Computer Science Programme, St. Joseph's College (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli, Tamil Nadu, India. Email: jegan171104@gmail.com

ABSTRACT

Computers are transforming dramatically. For years, AI has been extremely good at completing difficult computational tasks as well as pattern recognition, but only using a rule-based approach. A breakthrough happened a year ago in the form of Generative AI, which enables computers to produce new text and images and gives machines the appearance of being creative. The challenge of artificial intelligence tools, though, is that neither type runs on regular silicon computer chips, which means they consume prodigious amounts of electricity and are rapidly approaching the physical limits of conventional hardware.

This is where Organoid Intelligence (OI) emerges as a wholly new approach: Instead of a computer chip, it uses a network of tiny, lab-grown human brain cells connected to machines to compute. With living cells, OI can learn as it goes and consume a fraction of the power of a conventional computer. In this review paper, we compare the structure, learning model, and power consumption of standard AI, Generative AI, and OI and examine how the use of biological cells could fix AI's issues and revolutionize technology.

Keywords: Traditional Artificial Intelligence, Generative AI, Organoid Intelligence, Machine Learning, Deep Learning, Foundation Models, Large Language Models, Brain Organoids, Biocomputing, Neuroplasticity, Energy Efficiency, Silicon Computing.

1. Introduction

Artificial Intelligence (AI) is growing very fast and is highly flexible. Traditional AI is used to solve more problems, study data, and find patterns. Generative AI (Gen AI) is a new model or type of AI. It can allow the creation of text, images, code, and other content. In 2026, AI systems need a lot of computer power and electricity. They also produce a lot of heat, so large cooling systems are needed. As AI becomes more powerful, its energy use also increases. This is becoming a major problem for the future. Organoid Intelligence (OI) is a new idea that uses small groups of lab-grown brain cells called brain organoids. Scientists are studying whether these living cells can help computers process information and learn. The human brain can do many complex tasks while using very little energy. Because of this, researchers are exploring OI as a possible way to build more energy-efficient computers.

The main objective of this review paper is to compare Traditional AI, Generative AI, and Organoid Intelligence. It aims to understand how these systems work, how they learn, and how much energy they use. The paper also explores how Organoid Intelligence may help reduce the high energy needs of modern AI. Finally, it looks at the possibility of combining computer chips with biological cells in future computing systems. This paper mainly focuses on hardware, learning methods, and energy use. It also discusses the future use of biological computing and some of the ethical issues related to using human brain cells.

2. REVIEW OF EXISTING STUDIES

2.1 Previous Research

These limitations were originally addressed by researchers with larger, faster silicon chips - but these would require enormous amounts of power. When it was demonstrated that silicon chips could not emulate the human brain's full capabilities or its efficiency, researchers began focusing on the biology and the harnessing of Organoid Intelligence (OI).

2.2 Existing Approaches

Two approaches are being studied as to how this can be achieved: Organoid Intelligence Roadmap Smirnova et al. Also imagined a future in which the organoids would communicate via micro-sensors, to and from an electronic fluid system-water-based channels inside the organoid that could sustain cells and translate electrical signals. Brainoware System: Researchers led by Cai created a human brain-like organoid on a chip with small electrodes that could send, receive and process information.

2.3 Important Findings

Research shows a progression from:

Traditional AI: Task-specific prediction

Generative AI: Flexible content generation and generalization; Organoid Intelligence: Biologically inspired, energy-efficient, self-learning computing

OI remains experimental, and Traditional and Generative AI are more developed. OI could provide an entirely new avenue in biocomputing.

3. Comparative analysis

Evaluation Parameter	Traditional AI	Generative AI	Organoid Intelligence (OI)
Foundational Substrate	Silicon semiconductors	Advanced silicon wafer clusters	Living biological neural tissue (stem-cell organoids)
Core Architecture	Von Neumann computing (CPUs)	Distributed tensor/parallel arrays (GPUs, TPUs)	3D biological neural networks mounted on Micro-Electrode Arrays (MEAs)
Operational Mechanism	Supervised learning & statistical regression	Deep transformer networks & probabilistic token prediction	Synaptic plasticity, biological self-assembly & neuroplasticity
Primary Tooling / Interface	Python, R, C++, scikit-learn	Python, PyTorch, CUDA, custom LLM frameworks	Electrophysiological stimulation, microfluidic control, patch-clamp interfaces
Power Consumption	Kilowatts to tens of kilowatts per cluster	Megawatts (10 to 30+ GWh per training run)	~20 Watts (roughly equivalent to a single human brain)
Cooling & Environmental Footprint	Moderate HVAC cooling requirements	Millions of gallons of evaporated cooling water per facility	Zero thermal water cooling; requires liquid nutrient perfusion
Adaptation Speed	Rigid; requires total retraining on new parameters	Slow fine-tuning; susceptible to catastrophic forgetting	Rapid; adjusts to stimuli within minutes to hours
Main Advantage	Deterministic, highly auditable, reliable precision	Human-like fluency, multi-modal synthesis, broad reasoning	Unmatched energy efficiency, innate parallel processing
Critical Limitation	Zero spontaneous adaptability	Severe energy bottleneck, hallucination, silicon scaling wall	Biological perishability, non-standard outputs, ethical implications

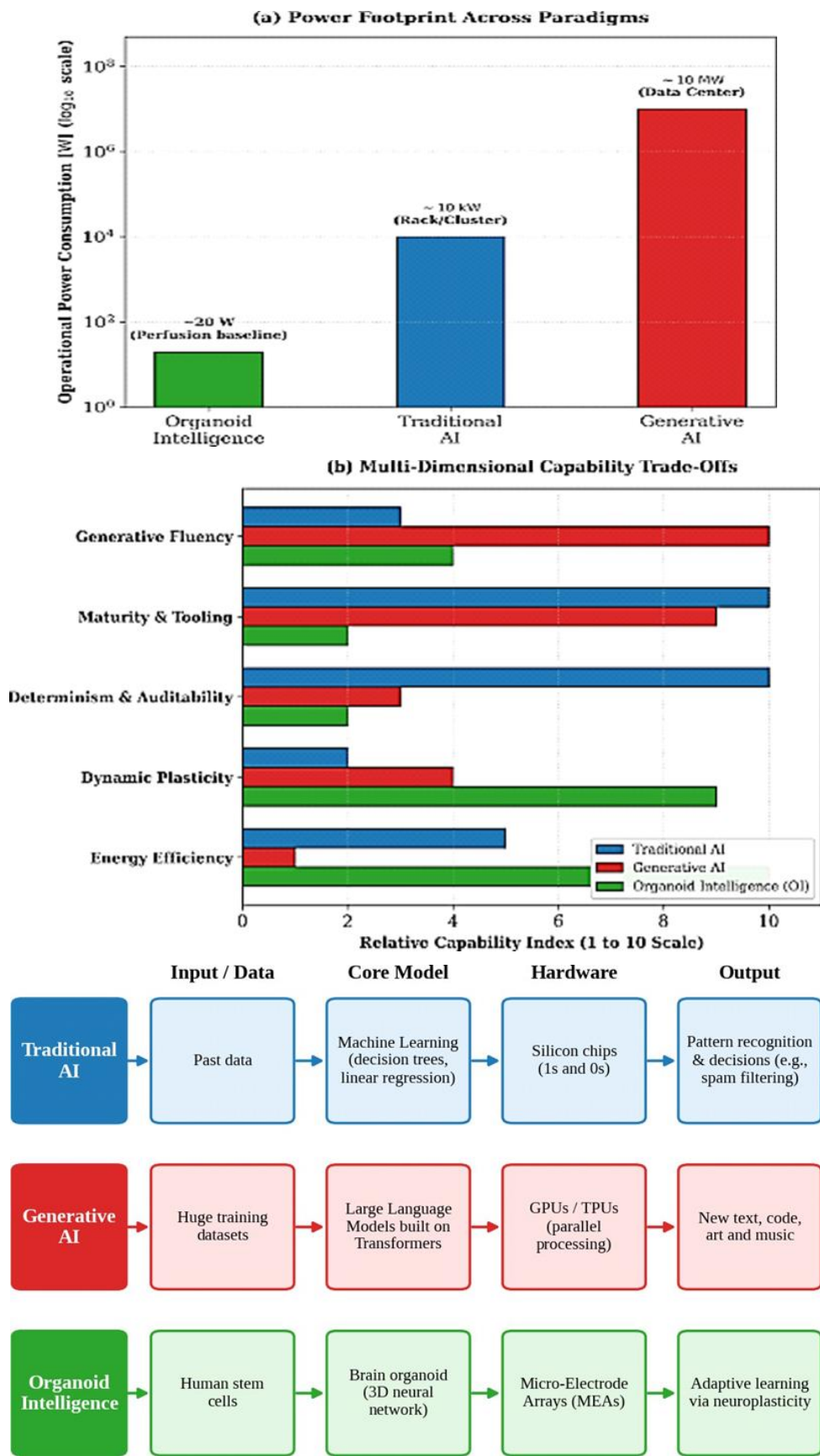


Figure 1: Processing pipelines of Traditional AI, Generative AI and Organoid Intelligence

3.1 Traditional Artificial Intelligence: The Foundation Background and Purpose:

Traditional AI (Narrow AI): Allows computers to go through past data to recognize data patterns and make informed decisions. Narrow AI was built to save time, decrease human labor, and address straightforward logical problems like the automatic identification of spam emails.

How It Works:

OLD STYLE AI programming languages like python, java, c++.. The basic technology used for developing traditional AI is called Machine Learning (ML) and it learns data patterns using various algorithms like decision trees, linear regression..

Hardware:

Conventional AI Silicon chips are composed of billions of transistors in modern day computers. The silicon chips do the math by using 1s and 0s.

Resource and Power Consumption:

Needs for Water & Energy To train AI models, you need a lot of electricity-and they also need a lot of water. Intense ML training uses a lot of power, and coolers rely on a lot of water.

Advantages:

High Accuracy: Accurate with good training data.

Speed: Processes millions of data points quickly.

Reliability: Uses logical and understandable mathematical processes.

Disadvantages:

No Creativity: Cannot create beyond its training.

Difficult to Use in Different Tasks: Not generalizable to other tasks easily.

High Energy Demands: The complex AI necessitates additional data, electricity, and water.

3.2 Generative Artificial Intelligence: The Creative Engine Background, Origins, and Public Release:

Open-AI Blog Generative AI Intro: Gen AI was built to address the deficiencies of Traditional AI and its inability to be creative in these phases: ELIZA in 1966 coined the earliest use of conversational AI, GANs in 2014 made generating realistic images possible, transformers in 2017 improved comprehension of text, and in 2022 Chat-GPT put Gen AI in the hands of the masses.

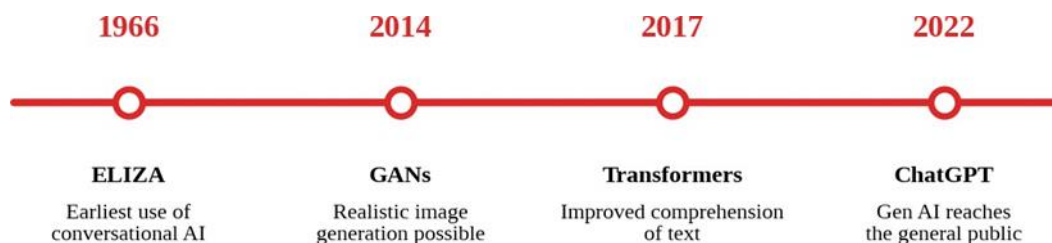


Figure 2: Key milestones in the development of Generative AI.

How It Works:

Gen AI relies on Python programming and LLMs - large language models that are built upon the Transformer architecture. The LLM models are trained on huge chunks of data and complete the sentence using context.

Hardware:

Gen AI requires high processing power with cutting edge Graphical Processing Units (GPUs) and Tensor processing Units (TPUs) that work on several processors in parallel, completing numerous calculations in a single moment.

Resource and Power Consumption:

Gen AI consumes a lot of resources. Large models can take up to 10-30 GWh of electricity to train, and data centres need large amounts of water for cooling.

Advantages:

Highly Creative: CreateText, Art,Music, and Code. Human-Like

Interaction: Understands natural language.

Time-Saving: Quickly summarizes, writes, and generates ideas.

Disadvantages:

High Energy Consumption: Demands very high power and water use. Hallucinations: Can generate incorrect information confidently.

Hardware Constraints: Future scalability may be constrained by silicon chip constraints.

3.3. Organoid Intelligence:

The Living Brain Background, Origins, and Purpose:

Commercial silicon chips use astronomical amounts of power, and scientists are now investigating biological brain cells for computer chips. This research is called "Organoid Intelligence" (OI), and it aims to bring the power requirements of AI down by using living biological wetware.

Gaming Brain (2022): Researchers, including Brett Kagan, trained brain cells to

Play the video game Pong using Dish Brain. From the scientific roadmap (2023): 3D human brain cell cultures could be used for computing (by Lena Smirnova and her team). Brainoware (2023): Hongwei Cai and team performed speech recognition and mathematics problem-solving through a brain organoid.

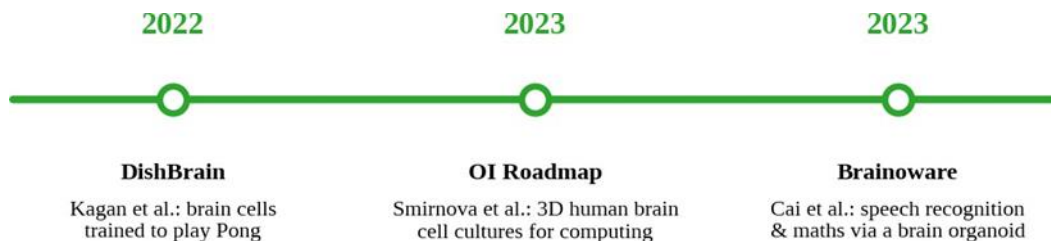


Figure 3: Key milestones in the development of Organoid Intelligence.

Working:

OI's Approach Brain organoids: 3D clusters of human cells grown from stem cells Brain organoids form networks of neurons, like a brain, and change their connections in order to learn.

Hardware:

How OI works OI employs MEAs with small electrical sensors. The organoid receives electrical signals, interprets, and transmits the information to the computer.

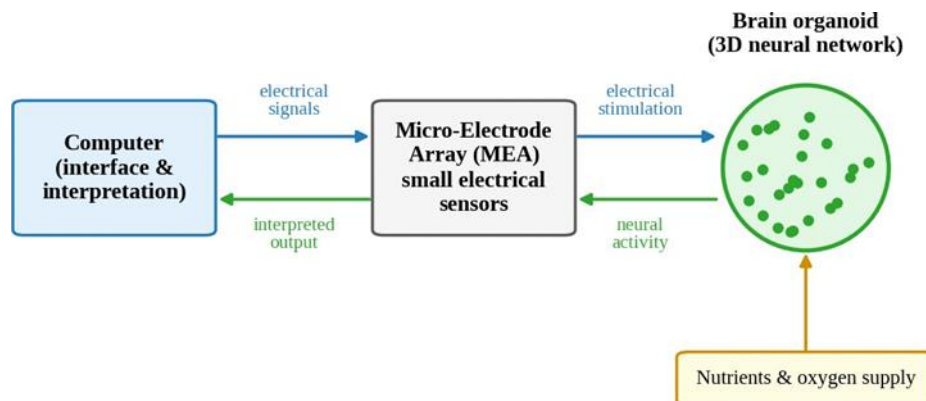


Figure 4: Signal flow between the computer, the MEA and the brain organoid.

Resource and Power Consumption:

OI is designed to lower the resource intensiveness of AI: Whereas state-of-the-art supercomputers can consume as much as 21 megawatts to perform the same kinds of calculations that the human brain does on roughly 20 watts, OI consumes

significantly less cooling water than AI but requires a constant supply of nutrients and oxygen.

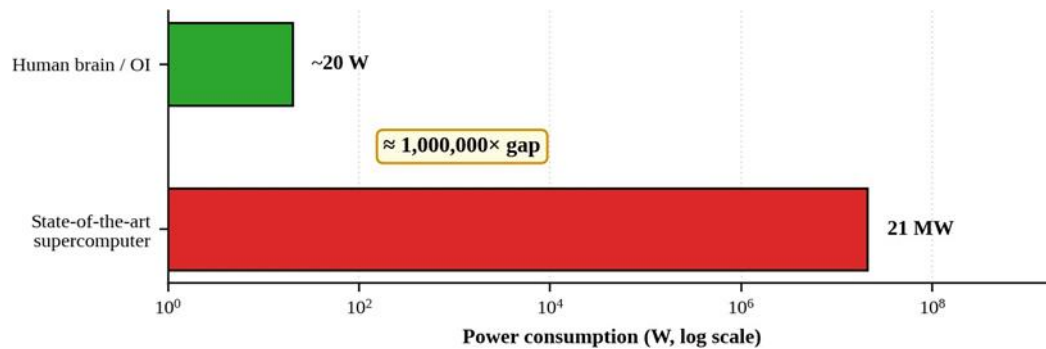


Figure 5: Power consumption of a state-of-the-art supercomputer versus the human brain / OI.

Advantages:

Zero Energy Metering: Consumes less electricity and water.

Consistent, Fast Learning: Learning new knowledge and skills is possible with neuroplasticity.

Small Data Needs: Small Data can be derived from Less data without loss of information.

Disadvantages and Challenges:

Maintains Life: Air, Food.

Ceiling Effect: Cannot capture the full range of X and Y.

Ethical Issues: Concerns over pain and consciousness.

Early Science: Experimental and less easy to control than silicon AI.

4. Conclusion

Traditional AI is effective for specific tasks, while Generative AI enables flexible content creation but requires significant computational resources. Organoid Intelligence offers a promising biological approach with potential energy efficiency and adaptive learning. However, OI is still experimental and faces challenges such as biological maintenance, scalability, control, and ethics. Overall, future research could combine AI and biological computing to create more efficient, adaptive, and sustainable intelligent systems.

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