Neuromorphic Computing

Source:TH

Recently, the researchers at the **Indian Institute of Science (IISc)** have developed a **neuromorphic or brain-inspired analog computing.**

- This system is capable of storing and processing data in **16,500 states** using **molecular film**.

What is Neuromorphic Computing?

- **About:**
  - Neuromorphic computing is a process designed to **mimic the structure and function of the human brain** using **artificial neurons and synapses**.
  - It represents a significant shift from **traditional binary computing** to **neuromorphic computing,** allowing systems to **learn from the environment**.
- **Working Mechanism:**
  - It involves the use of **Artificial Neural Networks (ANN)** made up of millions of **artificial neurons**, similar to those in the human brain.
  - These neurons **pass signals to each other in layers**, converting input into output through **electric spikes or signals,** based on the architecture of **Spiking Neural Networks (SNN)**.
    - This allows the **machine to mimic the neuro-biological networks** in the human brain and perform tasks efficiently and effectively, such as visual recognition and data interpretation.
- **Key Features:**
  - **Brain-Inspired Design:** Neuromorphic systems replicate the brain's architecture, particularly the **neocortex,** which is responsible for higher cognitive functions such as **sensory perception and motor commands**.
  - **Spiking Neural Networks:** These systems use spiking neurons that communicate through electrical signals, closely resembling biological neuronal behavior. This design allows for parallel processing and real-time learning.
  - **Integration of Memory and Processing:** Unlike traditional von Neumann architecture, which separates memory from processing, neuromorphic systems integrate these functions, enhancing computational efficiency.
- **Advantages:**
  - It **allows computers to process information more efficiently,** enabling **faster problem-solving**, **pattern recognition, and decision-making** compared to traditional computing systems.
  - It has the ability to **revolutionise AI hardware**, **enabling complex tasks** like training **Large Language Models (LLMs)** on personal devices, addressing hardware limitations and energy inefficiencies.
    - Current **AI tools** are restricted to **resource-heavy data centers** due to a **lack of energy-efficient hardware**.
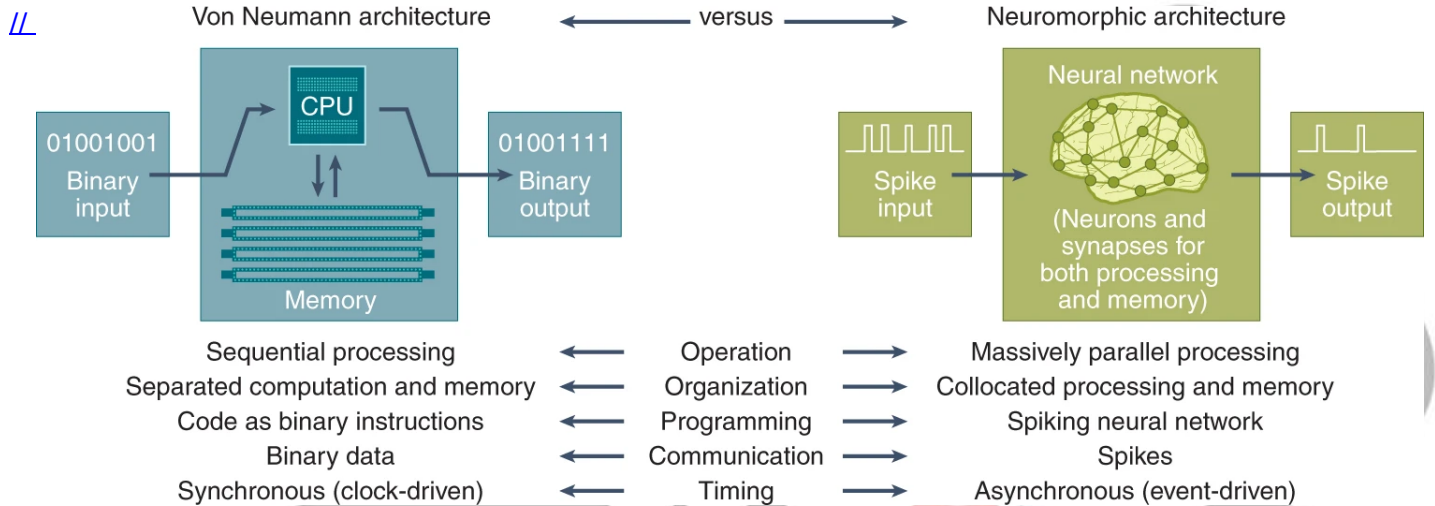- **Integration with Molecular Film:**
  - **Molecular films** are ultrathin layers of molecules that can be engineered to **exhibit specific electrical and optical properties**, enabling the creation of brain-inspired data storage and processing devices.

- This film acts as a neuromorphic accelerator, simulating brain-like parallel processing to quickly handle complex tasks like matrix multiplication and improve computer performance when combined with silicon chips.
- The recent advancement involves a molecular film offering 1**6,500 possible states**, surpassing traditional binary systems.
  - This film utilizes **molecular and ionic movements** to represent memory states, mapped via precise electrical pulses, creating a **"molecular diary"** of states.
- **Differences from Traditional Computing:**
  - **Parallel Processing:** Neuromorphic computers can **process multiple streams of information simultaneously**, unlike traditional computers that operate sequentially.
  - **Energy Efficiency:** They **consume less power** by computing only when relevant events occur, making them ideal for applications requiring real-time data processing.
  - **Traditional binary computing** operates with **bits in two states: 0 or 1**, similar to a light switch being on or off. In contrast, **analog computing uses continuous values,** similar to a dimmer switch with a range of brightness levels.

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Von Neumann architecture	versus	Neuromorphic architecture
01001001 Binary input → CPU ↕ Memory → 01001111 Binary output		Spike input → Neural network (Neurons and synapses for both processing and memory) → Spike output

	Operation	
Sequential processing	← Operation →	Massively parallel processing
Separated computation and memory	← Organization →	Collocated processing and memory
Code as binary instructions	← Programming →	Spiking neural network
Binary data	← Communication →	Spikes
Synchronous (clock-driven)	← Timing →	Asynchronous (event-driven)

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Q. With the present state of development, Artificial Intelligence can effectively do which of the following? (2020)

1. Bring down electricity consumption in industrial units
2. Create meaningful short stories and songs
3. Disease diagnosis
4. Text-to-Speech Conversion
5. Wireless transmission of electrical energy

Select the correct answer using the code given below:

(a) 1, 2, 3 and 5 only
(b) 1, 3 and 4 only
(c) 2, 4 and 5 only
(d) 1, 2, 3, 4 and 5

Ans: (b)