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- Assignment 4 -

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Abstract

Recently, there is a significant progress in many domains such as natural language processing, speech recognition and computer vision. However, despite the impressive capabilities of modern GPUs they are not comparable with the human brain as they still far less powerful and efficient than it.so we are mentioning some similarities and differences between the human brain and the most advanced GPU, NVIDIA's A100 aiming to understand the fundamental principles of neural computation and compare the performance of modern GPUs and the human brain considering some few terms.

1. Computational power

the human brain has approximately **86 billion neurons**, that is based on the latest estimates, and assuming that one biological neuron is equivalent to one hardware CUDA core, hence we would need **86 billion CUDA cores** to match the number of neurons in the brain. If we used the most powerful GPU available for scientific computation nowadays - the NVIDIA A100 Tensor Core GPU - which has 6,912 CUDA cores per unit. then we need to divide 86 billion over 6912 which gives **12.44 million**, which represents the number of NVIDIA A100 Tensor Core GPUs to match the computational power of the human brain in terms of the number of CUDA cores.

If we assumed that each HGX A100 unit contains 8 of these NVIDIA A100 GPUs, we would need approximately **1.555 million HGX A100 units to match the computational power of the human brain** in terms of the number of CUDA cores. It's important to mention that there are many aspects that contribute to the overall performance of a system and the number of CUDA cores is one measure of computational power but not the only factor that determines the capabilities of the system.

2. Energy needed in both cases and power consumption

To estimate the energy required for a system with the same number of CUDA cores as the number of neurons in the human brain,
we need to consider the power consumption by units of HGX A100, Air-conditioning for the whole building that housing a system with 1.555 million HGX A100 units and finally lighting and other electricity uses. Calculating the energy and power consumption for a hypothetical system that uses 1.555 million HGX A100 units to match the computational power of the human brain is a complex task that depends on several factors, including the efficiency of the hardware, the cooling system, and the building's electricity infrastructure. However, we can make some rough estimates based on the specifications of the HGX A100 units and some assumptions about the system's power and cooling requirements.

Firstly, Each HGX A100 unit has an average power consumption of about **400 watts per GPU**, or **3200 watts per unit** (assuming eight GPUs per unit) **[1]** . Therefore, 1.555 million HGX A100 units would consume a total of **4.976 GW** of power at average performance. However, it's important to note that the actual power consumption of the system would depend on the workload and how many of the HGX A100 units are active at a given time

Secondly, considering Air-conditioning for the whole building that housing the system, to cool a system of this size, we would need a substantial air-conditioning system capable of removing the heat generated by the HGX A100 units. The power consumption of the air-conditioning system would depend on several factors, including the size of the building, the cooling capacity of the system, and the ambient temperature. Assuming a conservative estimate of 500 watts per ton of cooling capacity, we would need a cooling system with a capacity of at least 18,000 tons to cool a building that houses 1.555 million HGX A100 units. This would require a power consumption of approximately **9 MW** (assuming a coefficient of performance of 4).

Finally lighting and other electricity uses, assuming a conservative estimate of 50 watts per square meter for lighting and other electrical systems, a building that houses 1.555 million HGX A100 units would require a power consumption of approximately **80 MW** for these systems (assuming a building size of approximately 160,000 square meters).

So the total power of the system is around **80Mw+9Mw+4.976Gw= 5.65 GW.**
While the total power consumption of the brain would be approximately **20 watts**.
Therefore, we can see that the energy requirements of a computational system with the same number of CUDA cores as the number of neurons in the human brain would be significantly higher than the energy requirements of the brain itself it is not even comparable
This is due to the fact that current computer systems are far less efficient than biological systems in terms of energy consumption. Overall, the energy and power consumption of a system that uses 1.555 million HGX A100 units to match the computational power of the human brain would be substantial, likely requiring several hundred megawatts of power and a sophisticated cooling and electrical infrastructure. These estimates are rough and should be taken as an illustration of the scale of the power and cooling requirements, as the actual energy consumption would depend on several factors that are difficult to predict accurately.

3. The weight of the human brain w.r.t. the manufactured brain

1. The average adult **male weighs about 1370 grams**, whereas the average **brain weight of females is 1200** grams, Males' brain weight falls by 2.7 grams and that of females' falls by 2.2 grams annually as they age and Independent of sex, brain weight rises by an average of 3.7 gm for each centimeter of body height. so on average we can say its **1.3 kg.** **[2]**

2. And for the manufactured brain, HGX A100 System Weight Full configuration: NW 62kg, GW 95kg (Gross weight including host + packaging box + rails + accessory box) [**3]**.

for 1.555 million of HGX A100 units packaged weight is around 97 million kgs. For cooling 2,000-2,500 square feet we need Air Conditioner of 4 tons **[4]**

then for 160,000 square meters (**1722225.6 square feet**) , we need around **861.12** tons for air conditioner.
assuming that building and racks weight is equal to 4 times weight of the units.

then the total weight of the system = 97 million +97*4 million + 861.12 tons = **780 million kg**

4. What will be the total cost of hardware equivalent to a human brain?

If hardware represents only 17% of any useful and complete IT system
and our hardware cost is equal to the cost of one HGX A100 is 150k$ on average **[5]**

(150k$ on average) * NUMBER OF HGX A100 USED (Which is **233.25** billion$)

then the total cost of hardware equivalent to a human brain = **1372 billion$**

5. Add any other issue of comparison you think is important.

The human brain is a highly specialized and flexible system that can adapt and learn in response to new information and experiences. The current state-of-the-art deep learning models are still limited in their ability to generalize and learn from small amounts of data.

- The human brain is a massively parallel system, with many neurons working together to process information. While modern GPUs are highly parallel as well, they still operate on a different scale than the brain.

- The human brain is a highly energy-efficient system. While deep learning models have made significant progress in reducing energy consumption, they are still far less efficient than the brain.

- The human brain is capable of complex cognitive tasks such as creativity, imagination, and emotion, which are currently beyond the reach of deep learning models.

Problem 2

Based on our assumption that the human brain is connected on average to about 10,000 other cells and has 8 billion neurons, then the total number of synapses in the human brain can be estimated as follows:
86 billion neurons x 10,000 synapses per neuron = 860 trillion synapses

While the base hardware of ChatGPT (GPT-3: 175 billion parameters) has a total of 175 billion trainable parameters
so it is obviously that the human brain has a significantly larger number of synapses than the base hardware of ChatGPT
as human brain: 860 trillion synapses
ChatGPT base hardware: 175 billion parameters

The human brain has approximately is 4.9 million times more synapses than the base hardware of ChatGPT. This highlights the vast difference in complexity and processing power between the human brain and even the most advanced artificial neural networks currently available. It's important to note that while artificial neural networks like ChatGPT have made significant progress in recent years, they are still far from matching the complexity and sophistication of the human brain.

Table of Comparisons

Point of comparison	The human brain	HGX A100 system
the required number of units to simulate a human brain	1 human brain	1.555 million unit of HGX A100
Energy	highly energy-efficient system	still very far efficient than the brain
Power consumption	20 Watts	5.65 GW
capability of complex cognitive tasks	capable of complex cognitive tasks such as creativity, imagination, and emotion	currently beyond the reach of deep learning models.
Weight	1.37 kg for male and 1.2 kg for female	780 million kg
Parallelism	massively parallel system, with many neurons working together to process information	modern GPUs are highly parallel as well, but they still operate on a different scale than the brain.
ability to generalize and learn from small amounts of data.	highly specialized and flexible system that can adapt and learn in response to new information and able to learn from small amount of data	The current models are still limited in their ability to generalize and learn from small amounts of data.
Total cost	Gift from Allah	1372 billion USD
portability	portable	Nearly impossible

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