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A4_9 Computing isn't cool?

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Abstract

In this paper we discuss the thermal output of the supercomputer *ALICE* at the University of Leicester. From this value, we determine the rate of temperature increase that the Physics building at the University of Leicester would experience if heated entirely by this. We found that the rate of temperature increase was 5.33 K hr^{-1}. This value would vary in reality due to variables such as the lack of knowledge of all *ALICE*'s components and the radiation of heat from the building.

Introduction

The University of Leicester (UoL) has two supercomputers that are used throughout the school for staff and students. One of these supercomputers is named *ALICE* [1] which lies within the Physics building. Supercomputers are incredibly useful when it comes to world-leading research, but they radiate a huge amount of thermal energy; some institutions already use this energy output of their supercomputers to heat their buildings [2]. UoL does not use this thermal output of their supercomputers, however in this paper we explore this notion. We determine how much thermal energy UoL's supercomputer (*ALICE*) produces and how much would it heat up its residing building.

Theory

As the heat output of *ALICE* is not known to us, we decided to sum the thermal design power (TDP) of the central processing units (CPU) and the graphical processing units (GPU) components of the supercomputer, which can be found at [3]. According to Intel, "(TDP) represents the average power the processor dissipates when operating at Base Frequency, (this is when) all cores are active under an Intel-defined, high-complexity workload" [4]. Table 1 shows the TDP of all the components that are in *ALICE*. Source [3] does not state the specific model of the memory nodes and GPU nodes, so we have looked at the frequencies stated in the source, and assumed the model as best as we can.

Component	Total quantity (as found from [3])	TDP per component (W)
Intel Xeon Gold 6132 Processor (2 per node)	340	140 [4]
Ivy Bridge CPUs (assumed I3-3120M)	8	35 [5]
Nvidia Tesla k40m	8	245 [6]
Intel Xeon Gold 6132 Processor (for memory nodes)	8	140 [4]

Table 1: TDP values for components in *ALICE*

Once the total TDP of the components were found, we discovered the temperature change by using the specific heat equation (1).

$$Q = mc_p \Delta T \tag{1}$$

Where: Q is the thermal energy, m is the total mass of air, c_p is the specific heat capacity of air at constant pressure (1.006 kJ kg^{-1} K^{-1} [7]), and ΔT is the change in temperature. We then used the density of air ($\rho_a = 1.225$ kgm^{-3} [8]) and the volume of the physics building at UoL (V) to determine the rate of temperature change, as shown in equation (2).

$$\frac{d\Delta T}{dt} = \frac{P}{\rho_a V c} \tag{2}$$

Where t refers to time, P is the total thermal power output and V is the volume of the building. As the original floor plans were not available to us, we estimated the area of the physics building to be 3100 m^2 (2 s.f.). This was determined using Google Maps [9]. There will be an error attached to this area, so the value was rounded to 2 significant figures to minimise this. We measured the three floors of the building to be 3 m, 3 m and 2.5 m (to the nearest half of a metre). We shall add 0.5 m, due to the floors themselves having some dimension, which is incalculable. This means the total volume of the building is 27900 m^3.

Assumptions

In this paper we assume that the processors are working at maximum power and therefore produce the thermal output as stated by their manufacturers. We also neglect any storage/random access memory (RAM) that is in the computer, as we assume that the heat output of this will be negligible compared to that of the CPU or GPU.

A significant amount of energy would dissipate out of the building. However the information to calculate this could not be found accurately. We have used the assumption that the building is entirely hollow as to ignore the effects of convection currents and the heating of the bricks that the floor itself is made from; this as an issue with the current model that could be addressed in future research. The power supply of *ALICE* would also provide a significant amount of heat. However, this is not mentioned in source [3] and thus we are unable to account for this.

Results and Discussion

Using equation (2) we achieve a value of 5.33 K hr^{-1}. This is a significant amount of heat output, which would easily be able to heat the physics building. There would be losses due to the: heat radiating from the building, items storing heat, heat transfer etc. However, even with this in mind, this is a significant amount of energy that could be utilized.

Conclusion

We have calculated that the *ALICE* supercomputer would be able to heat the physics building by 5.33 K hr^{-1}. However, this value may be an overestimation due to many factors including the assumptions of the components being constantly in use and the lack of heat energy escaping the building.

References

[1] `https://bit.ly/32VE3r1` [Accessed 25/10/19]

[2] `https://bit.ly/31MdnrF` [Accessed 25/10/19]

[3] `https://bit.ly/2C1njmJ` [Accessed 25/10/19]

[4] `https://intel.ly/2Nc1PZl` [Accessed 25/10/19]

[5] `https://intel.ly/2qKq9Km` [Accessed 25/10/19]

[6] `https://bit.ly/368Qsdv` [Accessed 25/10/19]

[7] `https://bit.ly/2PoDiD6` [Accessed 25/10/19]

[8] `https://bit.ly/2WhwI2K` [Accessed 25/10/19]

[9] `https://bit.ly/2MViwJq` [Accessed 25/10/19]