Journal of Physics Special Topics
An undergraduate physics journal

P2_12 A No Brainer

C. Kinsman, C. Murgatroyd, D. Mott, J. Stinton

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

December 12, 2021

Abstract

The aim of this paper is to discuss the feasibility behind the idea of a brain in a vat. This will be achieved by finding the size and cost of a structure that could be used to replace the Corpus Callosum. This is found to be $1.722m^3$ with a cost ≈£14.6bn. Finally, other physical limitations to this idea are discussed.

Introduction

The idea of a "brain in a vat" comes from an argument presented by Rene Descartes about a demon who systematically deceives us[1], however this was more notably represented in the film "The Matrix". This idea is that what we perceive as reality is merely the projections of a complex computer program on to our disembodied brains. This paper focuses on the feasibility of such a machine with modern technology.

Assumptions

The first thing that must be discussed is how a simplified picture of the brain can be built up. This model assumes the brain is made up of just white and grey matter, and the other parts are neglected. White matter is used for the propagation of signals from the grey matter to other areas of grey matter (or to the rest of the body and vice-versa). The task is to deceive the brain into believing it isn't disembodied. The first logical step therefore must be to assume that the computer has control over the white matter and therefore control over the signals sent to the brain and react to those received from it.

As literature on the size of structures in the brain is poorly covered, a particular area must be chosen to focus in on. The Corpus Callosum that sits between the two hemispheres and is a commissural tract[2], meaning it transmits signals between the two hemispheres. We focus on this area because it is highly documented and can therefore be used as an analagous area.

Corpus Callosum has approximately 200 million nerve fibers and a computer attempting to deceive said brain would need to be connected to all of these. If we want to manipulate the signal, we would need to pass the signal through a microchip. A CPU, whilst efficient, small and with a high number of electrical connections, is not appropriate because it works sequentially meaning each signal is processed one by one. The chip that must be chosen is a Field-Programmable Gate Array (FPGA) as it satisfies the important condition of parallel processing. To achieve the goal an array of FPGA's must be set up to replace the Corpus Callosum.

Method

The main consideration when designing this array of FPGAs is to reduce the size of this structure so that the two hemispheres are not separated by a great distance as this could lead to signal loss between the two hemispheres.

The first step is looking at the number of electrical connections required this being 200 million[2] for the Corpus Callosum. We must have 1 pin on our FPGA dedicated to receiving a signal and 1 pin dedicated to transmitting the signal. The volume of FPGAs required to make these connections is then determined, alongside the cost of such a set up.

Results

Equation 1 describes the volume of the replacement structure (N_C) as a function of the number of number of nerve fibres (N_{NF}) and number of pins per FPGA (N_{PF}). Where D, L and w describe the depth, length and width of the structure respectively.

$$V = \frac{2 \times N_{NF} \times D \times L \times w}{N_{PF}} \quad (1)$$

From equation we can find the volume of the structure, and can thus modify the height by deciding how wide our structure. This is based on the number of FPGA's in both the length and width. Figure 1 shows this exact relation. From this figure and the equation described above, the number of FPGA's required, if using those with the maximum number of pins (1976)[3], is found to be 202430. The volume this occupies is $1.722m^3$ and the cost found is ≈£14.6bn based on the price of an individual FPGA of this specification[3].

Conclusion

Whilst the model shown here not only is reduced by the fact that it focuses on a very specific part of the brain, it also is a very reduced way of looking at the supporting electronics. What is interesting however, is the two dots in figure 1. The blue dot represents the actual size of the Corpus Callosum. The red dot represents the length, width and depth of this area being multiplied by a factor of 12.5 respectively (or the volume by a factor of 12.5^3). If we were to shrink our structure down to the size of the Corpus Callosum using the scale factor described above, we

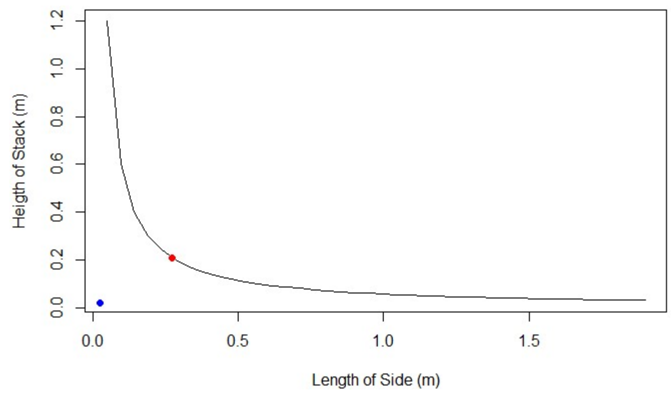

Figure 1: Plot of the height of the structure as a function of the length as the width changes. The blue dot represents the size of the Corpus Callosum and the red dot represents the Corpus Callosum if it has been scaled up to fit the curve.

exceed well past the quantum limit as the size of the gates on an FPGA are ≈15nm[4] and issues with quantum effects start to arise at ≈7.5nm[5]. To complete this task ourselves we would need to overcome this issue alongside finding the correct mapping of the other white matter tracts. Who's to say that hasn't happened already, and all of this is just a very powerful supercomputer telling us that we are blocked by things like the quantum limit.

References

[1] `https://bit.ly/3rrQrhD` [Accessed 28 November 2021]

[2] `https://bit.ly/3ph4T9y` [Accessed 28 November 2021]

[3] `https://bit.ly/3G6FqXi` [Accessed 28 November 2021]

[4] `https://bit.ly/3ph7sZ9` [Accessed 28 November 2021]

[5] `https://bit.ly/3I5lDcB` [Accessed 28 November 2021]