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Termpaper

The Human Brain Project

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1 Introduction

According to a recent study, nearly a third of European citizens are affected by some kind of brain disease [1] and at the same time are modern computers exploiting ever-higher numbers of parallel computing elements while facing a wall as power consumption rises with the number of processors, potentially to unsustainable levels. These two problems might have no direct connection to each other but can be solved with one and another and that is exactly where the Human Brain Project comes into play. Understanding the brain is one or maybe even the greatest challenge of the 21st century. Being able to understand how the human brain works also means to know what makes us human, being given the ability to cure and treat brain diseases but also comes with ideas for new computing technologies.

2 The Platforms

Therefore HBP's first goal is to split the system in 6 ICT-based[1] research platforms, providing neuroscientists, medical researchers and technology developers access to innovative tools and services to accelerate their pace of research by quite a notch.

2.1 Neuroinformatics Platform

This platform uses state-of-the-art ICT (semantic technologies, distributed query technologies, etc.) to give researches, especially neuroscientists, the ability to structure massive amounts of data and organize it easily. These new tools also allow them to analyze and interprete exactly that functional data and construct brain atlases, which will give the possibility to construct and develop 3D multilevel atlases of the mouse, rat and human brains. The mining of all that data and analysis of activity data will give a step further in researching as predicting parameters where experimental data is not yet available will be possible.

2.2 Brain Simulation Platform

The Brain Simulation Platform will provide a collection of software tools, giving researches the opportunity to build and simulate models of the brain but also to perform in silico[2] experiments that would be difficult or impossible in the lab. The goal of all this is to simulate multiscale, multilevel models of the whole human brain. These capabilities will play a big part in identifying specific functions of the brain, contributing to studies of neurological and psychiatric diseases and to new simulation-based techniques of drug discovery. Simplifications of those models will form the basis for neuromorphic computing systems.

[1]Information and Communication Technologies
[2]is an expression used to mean performed on computer or via computer simulation

2.3 High Performance Computing Platform

Current supercomputing technology lacks the power and software to simulate models of complete human brains and all the massive volumes of data that come with it. This is exactly the problem which this platform is working on. For this the HBPs Supercomputer will be used, for it will gradually evolve toward the exascale over the duration of the project. Satellite facilities dedicated to software development, molecular simulations and massive data analytics will take on the given task to develop a capability for in situ[3] analysis and visualization of exascale data sets.

2.4 Medical Informatics Platform

The Medical Informatics Platform will federate all kind of clinical data currently locked in archives of hospitals and research facilities and make it available to relevant research communities in order to identify biological signatures of diseases. This could originate a new category of biologically based diagnostics of disease causation. Hypotheses developed this way could then be tested through in silico experiments provided from the Brain Simulation Platform in order to identify new strategies for treatment without having to invest in expensive programs of animal experimentation or human trials.

2.5 Neuromorphic Computing Platform

This Platform will allow non-expert neuroscientists and engineers to perform experiments with NCS[4]. These are hardware devices incorporating simplified versions of the brain models. The Platform will provide access to three classes of NCS:

1. systems based on physical emulations of brain models, running much faster than real time
2. numerical models running in real time on digital multicore architectures
3. hybrid systems

The platform will be tightly integrated with the High Performance Computing Platform, which will provide essential services for mapping and routing circuits to neuromorphic substrates.

2.6 Neurorobotics Platform

The Neurorobotics Platform will offer a software and hardware infrastructure for connecting brain models to detailed simulations of robot bodies or to physical robots. This will allow neuroscientists to dissect the neuronal mechanisms responsible for cognitive capabilities and behaviors to support the development of neurorobotic systems.

[3] translates literally to in position
[4] Neuromorphic Computing Systems

Second Goal

The second goal of the project is to trigger and drive a global, collaborative effort that uses the platforms to address fundamental issues in future neuroscience, future medicine and future computing. A growing proportion of the budget will fund research by groups outside the original HBP Consortium, working on themes of their own choosing. At this point of time this initiative already involves 130 universities around the world [5].
The end result will be not just a new understanding of the brain but will also provide an answer for the second problem as understanding how the human brain is able to manage its massive amount of processing units while computing reliably with unreliable elements and the way different parts of the brain communicate within each other can bring up the key not only to a completely new category of hardware (Neuromorphic Computing Systems) but to a paradigm shift for computing as a whole.

3 Future Computing

The brain differs from modern computing systems in many ways. First the components of the brain are always highly diverse which confers robustness as recently shown [3]. Second the components behave stochastically, it is impossible to predict precise output for a given input. Third they can switch between communicating synchronously and asynchronously. Fourth the way of transmitting data diverse from a computing system as every neuron appears to interpret information differently. For all those reasons, understanding the brains computing paradigm has the potential to produce a shift in current models of computing.

3.1 High Performance Computing

The common approach supercomputers followed until now of retrieving a job and processing it without interruption does not meet the requirements of neuroscientists, who need to interact with simulations in real time. Researchers in other areas of the life sciences have similar needs. But this will produce petabytes of data in seconds which is nearly impossible to transmit to other computers, which analyze it, with good performance. The HBP will address this problem through developing software making it possible to run simulations and visualizations on exascale systems, with tens to hundreds of millions of cores.

3.2 Low-power neuromorphic computing

Nowadays the only way to increase performance beyond Moores[5] Law is to increase the number of processors, power consumption will inevitably rise. Brain-inspired ICT technologies pioneered by the HBP will alleviate this problem. Using physical models of the brain and many-core neuromorphic technologies will operate in an asynchronous and clock-less manner, enormously reducing energy consumption. As the project proceeds

[5] the complexity of integrated circuits doubles each, depending on the reference, 12 or 24 months

ever-larger neuromorphic computing devices will be developed, with numbers of artificial neurons and synapses close to the human brain, making it possible to improve the performance and reducing the power consumption of supercomputers.

3.3 Neuromorphic computing systems

In recent years, ICT has made great progress in addressing once intractable problems (driving automatically, . . .), however it requires an enormous programming effort and powerful computing resources, consuming large amounts of energy. The best strategy to alleviate these problems lies in exploiting neuromorphic technology [4]. A key goal of the HBP is to build such systems with the ability to learn new tasks without explicit programming. One such task would be the extraction of high-level information from noisy sensor data like computer vision. Simple devices could be integrated into compact, low-power systems with the ability to control complex physical systems (e.g. vehicles). Like the brain, such systems will be able to create models of their environment, including their own actions and those of others, to predict consequences of their decisions, and to choose the action most fit to lead to a given goal. Examples would include technical assistance to humans, autonomous navigation, self-repair and more.

4 Conclusion

Thinking back some centuries, reflecting just how much neuroscience, medicine and computing changed in this short period of time, it is the more exciting to cogitate what might change in the upcoming years, what could be possible and how it would affect our daily lives. The more we contemplate this topic the more saddening the thought is that some of it could just as well be in vain as a major part of these matters is close to coming to an end of its great process, taking modern computing models into account for example. At this point of time there might not be a great lack of performance nor is it of need to keep an eye on energy usage and consumption, but what if there was? What if we encounter a problem that is absolutely not possible to calculate due to a lack of performance? It might not take too long until exactly this problem is down-to-earth, which is why it is just the more important to think of strategies and ways to keep this process running without elapsing. The Human Brain Project is just one of the many steps in the right direction of achieving that goal, "*to build a completely new ICT infrastructure for future neuroscience, future medicine and future computing which will catalyze a global collaborative effort to understand the human brain and its diseases and ultimately to emulate its computational capabilities* [. . .]", cf. [2]

References

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