Large scale brain simulations are not a technical problem

Marc de Kamps
Robotics and Embedded System
Institüt für Informatik
Technische Universität München
Boltzmannstrasse 3
D-85748 Garching bei München
Germany

Abstract— **It is obvious that we still understand little of the engineering principles of the brain. This is perhaps most obvious in the field of robotics, where artefacts still have to be programmed carefully for a specific task, instead of being able to learn by instruction, example and experience. The knowledge of cognition is distributed over a large number of fields that are not aware of each other's recent achievements. Modern software engineering techniques can help to integrate this knowledge, but I will argue that without an attempt to create a community of 'brain science', every technical solution is doomed to fail.**

I. Problem Statement

Given the fact that the brain is very heterogeneous and massively parallel, and until recently essentially a black box, it is not surprising that we have not yet fully understood the engineering principles of the brain. Any sense of disappointment about our inability to build artefacts with the same cognitive powers as biological creatures results from underestimating the complexity and the massive parallelism of the brain. This is not the real problem.

The brain is extremely heterogenous and there are a dozen of traditional disciplines that are involved in 'brain research'. These disciplines, psychology, biology, neuroscience, biophysics, chemistry, medicine, to name but a few, do not share a common methodology and terminology and are unable to keep track of progress in other fields. The problem is not that it is not possible to perform large scale simulations of the brain, on the contrary, as I will argue in **Key Avenues** there are plenty of options. The problem is to agree on what are useful simulations, how to finance them, and how to maintain the soft- and hardware infrastructure that is needed to perform them.

II. Current Research

In neuroscience there is a considerable body of theory and some advanced neural simulators [1], [2] are available that are applicable to single, or small groups of, neurons. There are quite a few publications on the behaviour of large homogeneous groups of neurons, often derived with statistical physics techniques, but surprisingly little is cast into publically available software.

In cognitive neuroscience, Connectionism still seems to be the predominant modeling technique. There are a number of simulators available, to mention a few: SNNS [3], PDP++ [4] and MATLAB. Of these PDP++ offers parallelization with an MPI interface. Undoubtedly there are many others, which offer a similar functionality.

Most of these tools are available as executable or as library. Frameworks, which offer the flexibility to integrate home-grown software with an existing suite, let alone middleware seem unexplored avenues at present.

III. Key Avenues

My own modeling has concerned attention in visual cortex [5], [6], combinatorial representations in vision and natural language [7] and statistical techniques to describe large groups of neurons [8]. I am working to integrate these models into a single framework that allows easy creation of networks, serialization of networks, and, importantly, aims to decouple neural algorithm from network structure. The advantage is that one can model experimentally determined structures with progressively more sophisticated neural algorithms. There are many other groups around the world with similar goals and indeed there I see a huge potential in numerous works on population dynamics, i.e. the statistical description of large groups of neurons, e.g. [9], [10], [11], *none* of which are currently available as software implementation. There are databases available which contain every known trace experiment done on macaque monkey [12] and which provide an impressive anatomical connection scheme, which can complement models that now only focus on a functional issues.

It is astounding to see what is available, and which, when combined in a well designed framework, would allow sophisticated models of complete cortical functions. Why is this not done already ?

Because of the communication problems, mentioned above. To construct a complex model of cognitive behaviour entails the crossing of disciplines. The first sobering experience is the combat with referees that do not share your background. The second is writing down your mathematically sophisticated model and complex code in a form that is accesible to readers.

Sometimes this is not really possible. It would be so much better to publish your model, complete with software. This, however, does not generate citation scores, but it does burden you with maintaining tutorials and reference documents. Software engineering tends to be dismissed by funding agencies as not innovative enough, so this is something you really have to do yourself. Experience shows that this is a major problem: often very promising projects get frozen within a couple of years. This is the real problem: *without an established modeling base that allows more complex models to be built on top of simpler ones, no real progress is possible in the understanding of a system as complex as the brain*. The lifetime of most models in cognition do not surpass the lifetime of a postdoc/PhD student.

High energy physics is faced with similar problems: it has to combine theoretical physical concepts with heavy engineering, computer science, material science, software engineering (some succesful libraries are thirty years old and still in use !) and people management. It has done that by creating a few centres around the world with its own funding channels. Given the complexity of the brain, a few specialized centres that bundle the fractured information of a dozen disciplines seem long overdue.

Many of these issues are discussed in greater detail in the chapter 'Constructed Brain' of the Roadmap of nEUro-IT.net [13], an EU funded network in the area of NeuroIT. A workshop on this chapter is foreseen in early 2006.

REFERENCES

[1] M. Hines, J. W. Moore, and T. Carnevale, "NEURON," 2004, http://www.neuron.yale.edu/neuron.

[2] J. M. Bower and D. Beeman, *The Book of Genesis: Exploring Realistic Neural Models with the GEneral NEural SImulator System*. New York: Springer Verlag, 1998.

[3] A. Zell and I. Fischer, "SNNS: The Stuttgart Neural Network Simulator," 2001, http://www-ra.informatik.uni-tuebingen.de.

[4] R. C. O'Reilly and Y. Munakata, *Computational explorations in Cognitive Neuroscience*. The MIT Press, 2000.

[5] F. van der Velde and M. de Kamps, "From knowing what to knowing where: Modelling object-based attention with feedback disinhibition of activation," *Journal of Cognitive Neuroscience*, vol. 13(4), pp. 479–491, 2001.

[6] M. de Kamps and F. van der Velde, "From artificial neural networks to spiking populations of neurons and back again," *Neural Networks*, vol. 14, pp. 941–953, 2001.

[7] F. van der Velde and M. de Kamps, "Neural blackboard architectures for combinatorial structures in cognition," *to appear in Behavior and Brain Sciences*, 2005.

[8] M. de Kamps, "A simple and stable numercial solution for the population density equation," *Neural Computation*, vol. 15, pp. 2129–2146, 2003.

[9] J. Eggert and J. L. van Hemmen, "Modeling neuronal assemblies: theory and implementation," *Neural Computation*, vol. 13, pp. 1923–1974, 2001.

[10] B. W. Knight, D. Manin, and L. Sirovich, "Dynamical models of interacting neuron populations in visual cortex," vol. Symposium on Robotics and Cybernetics: Computational Engineering in Systems Applications, E. C. Gerf, France: Cite Scientifique, 1996.

[11] A. Omurtag, B. W. Knight, and L. Sirovich, "On the simulation of large populations of neurons," *Journal of Computational Neuroscience*, vol. 8, pp. 51–63, 2000.

[12] K. E. Stephan, L. Kamper, A. Bozkurt, G. A. P. C. Burns, M. P. Young, and R. Koetter, "Advanced methodology for the collation of connectivity data on the macaque brain (CoCoMac)," *Philosophic Transactions of the Royal Society B 356*, vol. 1412, pp. 1209–1228, 2001.

[13] A. Knoll and M. de Kamps, "Roadmap of neuroit development," 2003, http://www.neuro-it.net/NeuroIT/Roadmap.