The unique spatial firing patterns of the hippocampal place cells

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Bayesian integration is thought to be used by the brain for optimal decision-making based on information from different sources. Recent evidence indicates that the hippocampal place cells use this mechanism to integrate information at the level of a single cell as opposed to that at the network level as postulated earlier.

Dr Anu Aggarwal, of the University of Maryland, talks about the work behind the paper 'Neuromorphic VLSI Bayesian integration synapse.'

Tell us a little bit about your field of research

I am interested in Neuromorphic VLSI design and computational neuroscience. I had a medical degree when I first started learning computer programming. While learning programming, I became interested in the idea of computers performing as fast and as efficiently as brains. With that in mind, along with my interest in maths, physics and building devices, I joined Electrical Engineering at the University of Manchester. There, I got an opportunity to work in this field under Prof Bruce Hamilton. When I moved to the University of Maryland, USA to pursue my PhD, I got an opportunity to work in this field under Prof Robert W. Newcomb.

What particular applications are you focussing on?

I am currently working on implementing hippocampal formation in silicon and devising a theoretical computational neuroscience model explaining the unique spatial firing patterns of the hippocampal place cells. This is because the hippocampus is involved in spatial navigation and encoding space and time information on new episodic memories, which, if implemented in hardware, can be very useful in autonomous spatial navigation, e.g., in robotics. Moreover, the manner in which the sensory and motor information is processed in the hippocampal formation of the brain can provide unique insights into the higher order functions of the brain.

What are you reporting in your current Letter?

In this Letter, I report the silicon implementation of the hippocampal place cells based on Bayesian integration of inputs at the single cell level. I have designed and reported chip measurement results from silicon implementation of a Bayesian integration synapse and conductance neuron, which together, can perform such information processing at the single cell level.

What does this allow?

Our Letter presents the first ever silicon implementation of a Bayesian integration synapse. Moreover, this demonstrates its suitability for integration at the place cells, which has never been demonstrated before. This is significant because, even though Bayesian integration has been proposed as a mechanism of information processing by ensembles of neurons in the human brain, its role in information processing at the single cell level in the hippocampal place cells has only recently been highlighted. The silicon implementation of place cells is important as it has applications in autonomous spatial navigation and memory.

How do you think the field will develop over the next

decade?

I feel there is a basic challenge in this field – the neuromorphic engineers are trying to realise the function of a system that has fundamentally different smallest units from the ones they are using. The neurons and synapses of the brain individually consume much less power and are much smaller than the silicon transistors that are used by neuromorphic engineers to implement its function. The brain with units that are small and highly power efficient can afford to use several of them to perform computations efficiently, however the hardware implementations of the brain are grossly inefficient in terms of space and power consumption because each unit (silicon transistors) consumes a lot. One way devised to circumvent this problem has been to implement the neural networks in software, but that suffers from the problem of speed. Therefore, any implementation trying to achieve performance comparable to that of brain is only suboptimal. To optimise, we need to come up with more efficient basic units – in terms of space and power consumption – so that we can develop large systems more efficiently.

Secondly, one of the unique advantages of the brain is the ability to learn from, be plastic and adapt to its environment. This feature needs to be used in building more adaptable machines than are being designed currently. Imagine a robot goes to the Mars and, like humans inhabited the earth, inhabits Mars by learning from its environment and adapting to it or better still moulding it to fulfil its needs. How cool would that be?

What are you working on now?

We are working on implementing different parts of the brain in silicon with a view to develop systems that can help in autonomous robotic spatial navigation. Earlier, we developed circuits that could perform the function of the lateral superior olive in the brain and now we are working on circuits that can implement the function of the hippocampal formation. In addition to circuits, we are also developing mathematical models that explain the spatial firing patterns of the hippocampal place cells in particular and information processing by brain to perform higher order functions in general.

More information: Neuromorphic VLSI Bayesian integration synapse, [DOI: 10.1049/el.2014.4187](http://dx.doi.org/10.1049/el.2014.4187)

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