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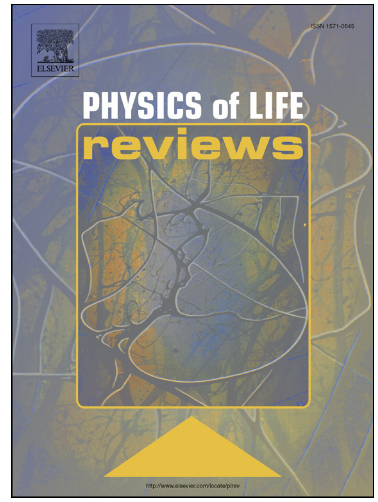

A computational discussion on brain topodynamics

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Comment

A Computational Discussion on Brain Topodynamics
Comment on “Topodynamics of Metastable Brains” by Arturo Tozzi et al.

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Tozzi *et al.* [1] present an exciting (algebraic) topological approach to formally underpin and realize the Operational Architectonics (OA) model [2][1] of brain-mind functioning. They call this approach *brain topodynamics* and it represents a novel intersection of OA and computational topology and proximity. Not only does this model advance our understanding of brain-mind functions, but it provides a solid theoretical framework to implement autonomous systems for mimicking human brain-mind activity. My interest in this work stems from a desire to create automated systems and applications that produce results similar to a human performing the same task. Along these lines, this paper comes at a time when society is dramatically benefiting from to two major developments – general purpose computing with graphics processing units (GPUs)s [3] and applications of deep artificial neural networks [4] – and it stems form the new areas of computational topology and proximity [5, 6] that ultimately may have equal effect, especially as the work reported in this paper is adopted and disseminated. Thus, the focus of this comment is to discuss the computational aspects of Tozzi *et al.*'s contribution in light of general purpose computing using GPUs, deep learning neural networks, and computational proximity; where the goal is the synthesis of human perception for autonomous systems that mimic human behaviour.

1. General Purpose Computing using GPUs

While Tozzi *et al.* identify that the presented approach could serve to inspire new computing systems with nodes built into high dimensions [p. 29], it is the case that the mappings, projections, and intersections inherent to the presented approach are ideally suited to current heterogeneous computing environments and hardware. Briefly, the traditional programming model of writing code to be executed exclusively on a central processing unit (CPU) has now given way to heterogeneous computing, where inherently serial portions of a problem run on the CPU and large data intensive, parallel portions are offloaded to the GPU, resulting in significant increases in performance [7]. In regards to the OA topodynamical framework, the heterogeneous computing model, and, specifically, GPUs have evolved many features that would allow aspects of the presented model to be realized in scientific computing applications. First and foremost, GPUs offer thousands of processors (within a single GPU) that can execute hundreds of thousands of active threads. Moreover, they offer simulated unified (*i.e.* shared) memory between the CPU and GPU; dynamic parallelism that allows the parallel threads to spawn new parallel processes (called kernels); and they provide task parallelism, which means multiple parallel tasks, again each consisting of very large numbers of threads, can be concurrently executing within a single application.

The result is that the following highlights from Tozzi *et al.*'s paper can be realized within a heterogeneous computing application. The paper begins [p. 1] with the notion that the brain displays a vast amount of interconnected topological mappings, which is a necessary condition for GPU applications as they require significant parallelism to offset the overhead in sending computations to the GPU and to mask long latency operations. Next, Tozzi *et al.* emphasize that neuronal assembly operations can be modelled by mappings and projections [pp. 7 & 19] that are both parallel and serial in nature. This approach to solving problems is also the same paradigm employed in heterogeneous computing systems. Further, the work of mapping trajectories from lower to higher dimensions and then looking for descriptive matches (*i.e.* intersections, likely tolerance based [8], between the higher dimensional antipodal points) is parallel in nature and will require significant resources if the number of neuronal assemblies is quite high. Again, this problem is a natural fit for heterogeneous computing systems and could be realized with existing (off-the-shelf) hardware. Additionally, dynamic parallelism is a mechanism that can be used to implement

[1] See their paper for full list of references for the OA model.