Joe Z. Tsien - A Postulate on the Brain's Basic Wiring Logic (2015)

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0.1 Context

0.2 Learned in this study

0.3 Things to explore

- I am not convinced about the "power of two" argument

1 Overview

2 Notes

- Ask what the basic function of the structure or product is, then try to come up with the corresponding design blueprint to achieve it
- What is the central function of the brain? To discover relational patterns and knowledge about a complex, evolving world in the service of generating adaptive behavior
- The brain - as an information processing device - could potentially employ numerous connectomic strategies to carry out cognitive computing
  - One-to-one direct mapping
  - Completely random wiring as a form of sparse code
    - Evidence demonstrates that this is not the case in real brain
- Binary coding scheme would be dynamically unstable in biological systems
- It also lacks the intrinsic ability to discover conceptual knowledge
- The brain at its microscale is made of preconfigured, conserved 'functional connectivity motifs' (FCMs) across its central circuits
- Each FCM consists of principal projection neuron cliques receiving specific inputs, as well as other principal project neuron cliques receiving progressively more convergent inputs that are comprehensively and combinatorially arranged
- The total number of neuron cliques with distinct input convergences follows the formula $n = 2^i - 1$, where i is the number of distinct information inputs and n is the number of neural cliques with all possible combinatorial connectivity patterns
- This wiring logic has six basic properties or requirements
  1. The wiring logic should be implemented in many brain regions regardless of macroscale or mesoscale anatomical patterns. This logic should also hold true for various animal species and for different cognitive computing
  2. The specific neural cliques should represent unique features about perspective stimuli, whereas the subgeneral and general neural cliques extract categorical or combinational relationships among features and knowledge
  3. Executing wiring logic should be via a nonrandom mechanism

4. The specific-to-general feature extraction computation can explain the functional purposes of cortical layers
   - The classic three- or six-layered cortex is an ideal microarchitecture to execute this power-of-two-based wiring logic
     * Input cortical layers should host most of the specific neural cliques, whereas deep layers accomodate more subgeneral and general neural cliques
5. The power-of-two mathematical logic confines the total number of distinct inputs coming into a given microcircuit in order to best utilize the available cell resources
   - For instance, at a mere i = 40, the total number of neurons n required to cover all possible connectivity patterns within a microcircuit would be more than 10^12, already exceeding the total number of neurons in the human brain
   - By employing a submodular approach, a given circuit can greatly increase the input types it can process with the same number of neurons
6. As an evolutionary conserved principle, this wiring logic should be already present as preconfigured, genetically programmed patterns prior to learning
   - There are two major theories on how networks generate representations
     1. Selectionism Theory of Learning, or Neural Darwinism, which is based on synapse overproduction during development and followed by regressive selection via learning
     2. Constructivism Theory of Learning, which postulates that learning interacts with the growth of neural connections over the developmental period to gradually construct representational networks

3 See also

4 References

Tsien, Joe Z. "A Postulate on the Brain's Basic Wiring Logic." Trends in neurosciences 38.11 (2015): 669-671.