Spring 2020

Internal Badger Workshop

Session 3: On the Importance of Topologies

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- Badger architecture assumes a network of policy-sharing experts that are able to adapt to and solve a problem at hand.
- We can't reasonably expect the network of badger experts to be without structure (due to scaling reasons). I expect that a successful topology will be a number of densely connected clusters of experts, with sparse connectivity between them. A further assumption on my part is that this connectivity pattern is hierarchical and scale-free. Assuming this is indeed the case, there are two principal topics I would like to explore:
    1. Assume limited experts that alone cannot solve a problem, but after connecting to other experts, they can. What are the key factors that allow them to solve more? (This idea is scale-free - a single neuron can solve less than two neurons. And one computational cluster will solve less than two.)
    2. What is the right (scale-free) interface for communication between experts/clusters?

Pre-discussion Comments & Resources

Comments:

1. How does "intelligence" emerge out of cooperation of "dumb" agents? Is there some qualitative change? Are there some thresholds for a behavior to become intelligent?

   Inspiration by swarm intelligence.

   Relation to hierarchies of computation and epsilon machines.

   There may be a human bias to what we consider "intelligent" behavior - often we treat behavior as intelligent only before we can formalize it. We should avoid this caveat in the discussion.

2. An internal analysis was performed by Petr Hlubuček on how a fully connected network of experts learns to solve a toy task called "guessing game". Another related analysis was performed by Petr Šimánek. The analyses showed that initially the network of experts is in a highly connected and highly correlated regime, with high mutual information between experts. Progressively, as the network is converging to a solution, mutual information between experts is decreasing. Moreover, the network can be forced, through L1 regularization, to converge to a highly sparse regime, where only a few neurons are active and the algorithm expressed by their activity is rather

symbolic than distributed. This analysis supports the idea that a fully connected network structure may not be necessary for a functional Badger agent.

The assumption of scale-free connectivity laid out in the workshop title implies further questions. First, does the bandwidth of inter-cluster connections also scale, or is it kept constant? How should individual experts connect between clusters? Through a proxy, or directly? We expect the discussion during the workshop to shed more light on these questions.

Resources:

ToyArchitecture: a hierarchical approach to autonomous learning

On Epsilon Machines (OCCAM)

Discussion Notes

Paper/Resource links from the discussion:

[1] Leveraging Communication Topologies Between Learning Agents in Deep Reinforcement Learning
[2] Emergence, WWW and Internet
[3] Small-world Networks
[4] A Theory of Usable Information Under Computational Constraints

Discussion notes

1. What gives rise to intelligence:

- additional experts have additional information necessary to solve the problem (e.g. a XOR task on a vector - a missing input from any single expert degrades the performance of others to random).
- additional time to compute - with too little time for computation (or depth of the network), successful computation may not be possible and the network is forced to be “dumb” despite even theoretically optimal efforts.
- creativity / deliberation - considering counterfactuals and different possible futures may be the defining factor of consciousness (Araya) and also a marker of intelligence. It scales well - in parallel, many different futures and counterfactuals can be considered. No input data is necessary - deliberation can progress completely within one’s mind.

There may be some behavior state transition caused by number of experts, but it may not be similar to how for example law of large numbers erases fluctuations (e.g. in water).

2. Inspiration for connectivity between experts - The Internet:

- local broadcasts are possible and cheap, while at the same time any unit can, although with some effort, directly connect to any other unit
- requires dynamic routing. This will be challenging in the learning setting.
- inspiration for dynamic routing: mesh networks
- routing protocol has a built-in robustness

Suggested connectivity for the experts:

- Hard-coded topology -tree structure, hierarchical structure. At the same time it is not obvious if a learned topology will be better or not.
- An internal project called bipartite badger was a first step in this approach, but did not work too well

Other Misc. Notes

- There might be a natural trade-off between the number of inner loop steps and the number of experts
- Analogy of the internet, routing and networks in this setting
    - Establishing routing protocols should not be left to the unit, they should be guided. This is done by routers in existing networks (internet).
- One interesting approach might be the use of attention modules with relative addressing - due to invariance
- There are two forms of topologies discussed - a learned and a predefined/hard-coded one
- There is a continuum between a single expert and a collective
    - Where does intelligence emerge?
    - This might depend on how experts are connect
- Filters vs. units (composable)
    - *filter* - garbage in -> output - always same mapping
    - *unit* - can provide different outputs and can develop these in isolation (deliberation?)
        - e.g. Similar to writing down a proof
- Benefits of longer computation - i.e. inner loop steps
    - Generative processes might benefit from this more than others
- Theory of Usable Information
    - Some interesting ideas were thrown around in terms of counter-factual observations, generative (world model-like) alternative past and futures and what extra (usable) info we can extract from within