Report #4 – Polyscheme

CMSC 828D – Human Level AI and Computational Cognitive Neuroscience

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We, as human beings, are facing tons of challenging and very different tasks every day. Sometimes these difficult tasks could seem to be out of our controls, but we are not afraid of them, because we have powerful brains that have obtained good knowledge, and are very good at **integrating** multiple knowledge representations, disparate reasoning, uses of many sensors/perceptions and other external information sources.

We can borrow this integration idea and use it in the robotic area to make further improvement. The question is, obviously, how.

A. COGNITIVE SUBSTRATE

Integration is not easy, though, especially when we are facing tons of problems and we have tons of algorithms, data structures, knowledge representations, reasoning forms and other logic tools to choose from. Unfortunately, if we are determined to pursue such integration idea and want to integrate all of these, the fact that there is an enormous amounts of knowledge available gives us a *profusion problem*,[2] as described by the author Nicholas Cassimatis. In every simple problem domains, we might need to collect and integrate huge amounts of information, which is daunting and unrealistic to do.

We might need to step back, and take a closer look at how human beings solving problems. In our class, it was mentioned that our neurons are similar in both structures and general functionalities. In addition, we human beings learn new things also by using very similar mechanisms that were developed in our earlier cognition, typically we use old things we have learned as basis and then adapt our knowledge to new domains. Also as suggested by other works [4, 5], *the superficial dissimilarity among those domains hides deeper similarities*. Such adaption and generality could bring us some good news when facing the *profusion problem.*

A *cognitive substrate hypothesis* is proposed by the author, that among the huge amount of problems we can use a much smaller but representative set of computational problems as basis, if we can solve this smaller set of problems effectively, we can then easily extend our knowledge to the rest problems and make the rest problem easier to be solved. [2] The set of computational mechanisms that is used to solve this smaller set of problems are called *cognitive substrate*. A preliminary list of items that can constitute a *cognitive substrate,* as generally guessed by the author, includes *reasoning about time, space, parthood, categories, causation, uncertainty, belief, and desire.* [1] Several components in the list will be mentioned later in later sections of this report.

B. IDEA - *Polyscheme*

Polyscheme, as proposed by Nicholas Cassimatis, is a cognitive architecture and a cognitive substrate for potentially solving integration problems in cognitive science, artificial intelligence and robotics. As the name suggests, it can consist of multiple components together, which, however, at first glance might not be very exciting because many traditional cognitive architectures also have such 'multi-agent' style. There is one important difference, a quite interesting idea, that is *Polyscheme* can enable ***every step*** *of every algorithm to be executed using multiple representations and be potentially* ***assisted by every other algorithms*** [1, 3]. In other words, in my understanding, *Polyscheme* is more like an organic fusion of several inter-dependent and possibly parallel-executed machine learning algorithms: algorithms are executed in an interleaved execution fashion so that each of them has influences over others and can even communicate with others during the run time. This is something traditional multi-agent architecture cannot do, traditional architectures are having merely inorganic combinations (or pipelines) of independent ML algorithms, which is not like human beings and does not have the real integration.

Polyscheme is a cognitive substrate so that it has multiple *specialists* (the word means basic computational mechanisms), such as difference specialist, tracking specialist, causal rule specialist, identity hypothesis specialists. Each specialist has different basic functionalities and use different machine learning/AI algorithms. One more unique feature in this *Polyscheme* architecture is that, those specialists can communicate via a ontology/logic based representation-neutral language, for example, each specialist can report its stand on a certain proposition (*StanceOn(prop)* function), and can also talk to other specialists via *ReportOpinion* function. When the environment or new sensory information is coming, each specialist can do re-simulation via back-tracking search and re-generate their opinions and broadcast its ideas for other specialists to reconsider their past decisions. In summary, the author designs these basic components (do the real work) together with communication feature/attention control strategies (change computational flow), in the hope of achieving real integration and solving tasks that are more complicated. [3]

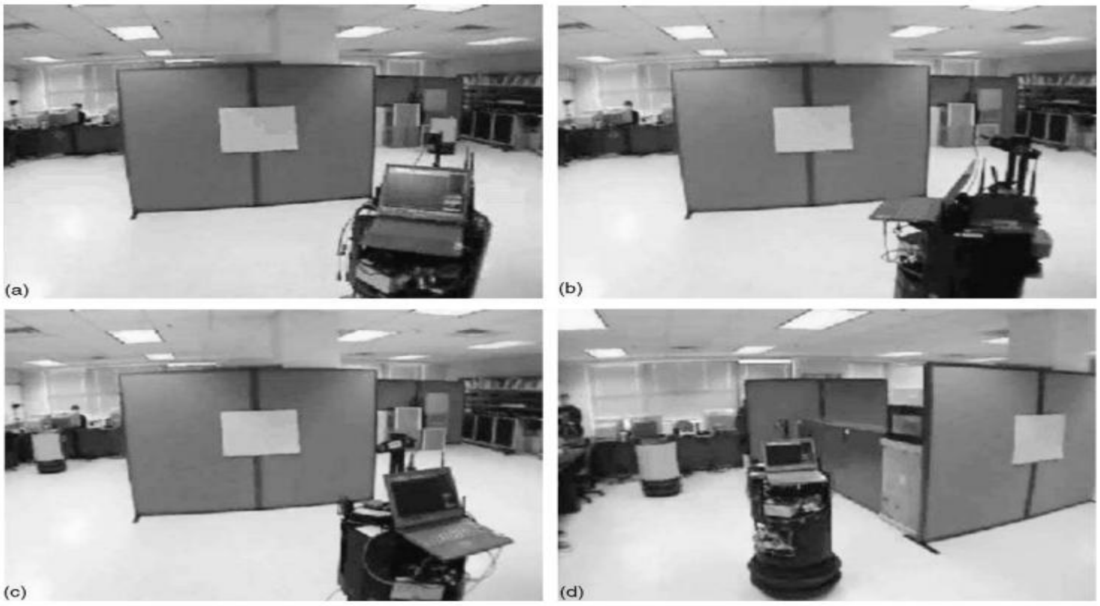
C. REAL EXAMPLE – ROBOT INFERENCE

The author has demonstrated *Polyscheme's* ability to integrate multiple reasoning and planning algorithms via diverse sources of sensory information in a real robotic framework. [1]

As a start, a robot A with *Polyscheme* architecture can see another robot 1 in the right corner (Figure 1a), then it finds that Robot B is moving left (by Robot A's tracking specialist) and cannot be observed because of a wall between A and B (Figure 1b). At a later time, Robot A finds another Robot C (which has same-looking as Robot B, recognized by object-recognition specialist of Robot A), but at a different position on the left side of the wall (Figure 1c). By using causal rule specialist, Robot A might infer that the Robot C and Robot B is the same robot (via Identity hypothesis specialist that incorporates other specialists' information due to the communication feature), because if Robot B is moving from right to left (observed via tracking specialist) and there is no other obstacle in between behind the wall (causal rule specialist), the Robot A should be able to see Robot B again because the wall is not long enough (as shown in the figure).

However, when Robot A moves close to Robot C, it finds that there is another wall (via its object-recognition specialist) behind the first wall (Figure 1d). This new observation directly contradicts what Robot A infers previously that "*there is no other obstacle in between*". Thus a difference specialist notice the difference, and perform the backtracking search, and then modify the truth values of previously opinions. Then the causal rule specialist reject the previous inference that Robot B and C are the same, and make a new inference given the new environment that, Robot B and C are the same. [1]

The figure is shown below,



Thank you for reading!

Bibliography

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