The Marchitecture: A Cognitive Architecture for a Robot Baby

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Abstract
The Marchitecture is a cognitive architecture for autonomous development of representations. The goals of The Marchitecture are domain independence, operating in the absence of knowledge engineering, learning an ontology of parameterized relational concepts, and elegance of design. To this end, The Marchitecture integrates classification, parsing, reasoning, and explanation. The Marchitecture assumes an ample amount of raw data to develop its representations, and it is therefore appropriate for long lived agents.

Introduction
Traditional approaches to Artificial Intelligence focus on selecting an application and then constructing representations for that domain. These approaches are problematic in that they require much labor intensive knowledge engineering. Furthermore, these systems tend to be brittle, often failing when they encounter unanticipated situations. An alternate approach is to have the computer develop its representations autonomously. In this alternate approach, the robot is viewed as a “robot baby” (Cohen et al. 2002). The robot is provided a minimal amount of knowledge (implicit or otherwise) about the world and is expected to learn and develop a conceptual structure from large amounts of raw sensor data over a long period of time. This approach is attractive because it requires little knowledge engineering and is robust because the agent learns to adapt to unanticipated situations.

If such an agent is to acquire human level intelligence, it will need to be able to represent and learn relational concepts (e.g., “cousin”, “above”, or “enemy”). Development of a cognitive architecture is necessary for the solution to the problem of Artificial Intelligence. Many cognitive architectures have been proposed (Sun 2004), but, to our knowledge, none focus on domain independent autonomous development of representations from raw relational data.

Related Work
Several cognitive architectures have been proposed in the past. Earlier examples include SOAR (Rosenbloom, Laird, & Newell 1993), and ACT-R (Anderson 1983). For overviews of these and other architectures see (Sun 2004).

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new data using concepts that it has already formed. Failing that, the Main Loop uses the Concept Formation module to find analogies in the data and use them to form new concepts with which to recharacterize the data. This process is akin to the assimilation/accommodation process described by developmental psychologists (Piaget 1954). The Marchitecture forms concepts by finding large and/or frequent subgraphs. We refer to this process as analogy discovery. Although the subgraph isomorphism problem is intractable in the worst case, the most useful concepts are the most common and therefore the most likely to be discovered. The Marchitecture employs a number of tricks to find frequent subgraphs, such as an approximate canonical form. In practice, finding subgraph isomorphisms is usually feasible (McKay 1981). These tricks are encapsulated in the Graph Abduction and Set Abduction modules, which find supergraphs of a given subgraph. We use Minimum Description Length as a measure for which subgraphs should be turned into concepts. That is, we keep the concepts that allow us to most concisely characterize the data. It has been argued that this may be one of the core purposes of concepts (Wolff 2003).

The Parsing/Explanation module uses a top-down/bottom-up algorithm similar to that described by (Hawkins & Blakeslee 2004). This module uses the Abduction module to find concepts that are supergraphs of a given set of data. Once a set of concepts are proposed, the Parsing/Explanation module uses the Hypothetical Introduction module to search different “parses” or segmentations of the data, choosing the parsing that results in the shortest description length. Hypothetical Introduction also methodically posits unbound parameters for concepts proposed by Abduction. Concepts can be “unpacked” to perform reasoning. That is, a concept can be expanded and the resulting statements are entailments of that concept. The Parsing/Explanation can thus explain data either by classification or by explaining the data using a series of concept unpacking (which amounts to forward chaining).

Combinations of graph abduction, concept unpacking, and hypothetical introduction can be used for prediction, planning, reasoning, and explanation.

There are some open issues with the current design: Minimum Description Length might not be the best metric for a model. For example, a short model of Euclidean Geometry would simply be the 5 postulates and a set of derivation rules. This model would be complete, but it might be better if some useful lemmas were cached. Thus, sometimes a faster model is preferable to a smaller model.

## Conclusion

The Marchitecture tightly integrates several aspects of cognition. The strength of The Marchitecture lies in its simplicity and in its focus on development of representations. So far, we have implemented the Concept Formation module of The Marchitecture (described in detail in the URL below the authors’ address), Set Abduction, and Graph Abduction, and tested these on a variety of domains (also described in that paper). To guard against domain dependence, we have a set of disparate domains on which to test The Marchitecture. Our goal is to apply our algorithm to RISK, Conway’s Life, robot sonar data, and a traffic simulation domain.

## References


