If intelligence is the ability to solve unanticipated problems, then AI needs universal representations

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Abstract

If Artificial Intelligence (AI) is defined as the ability to deal with unanticipated problems without human intervention, then knowledge representations used for AI must be universal. Representations cease to be universal when designers install algorithms that require or generate their own ad-hoc data structures and cause interoperability problems to arise. By contrast, algorithms based on a universal representation will always take their input from, and generate their results in that same representation. The algorithms themselves are also expressed in the same representation, resulting in full interoperability between all fields of knowledge.

The recently discovered Matrix Model of Computation (MMC) can *perfectly represent any finitely realizable physical system* while still operating by finite means. The MMC primarily serves as a model for a formal mathematical theory of cognition. The imperative form of the MMC (iMMC) is defined as a pair of sparse matrices, one describing services and the other sequential links for flow of control between the services. The columns are domains, and the elements are roles played by each domain in the services or sequences. Many important properties follow from the simple definition. The model is a Turing-equivalent virtual machine, it is connectionist, it is a computer program ready for execution but not a programming language, it is a relational database, it has a data channel where data flows, it is machine-interpretable, and naturally supports ontologies of objects. It is also structured as a fractal and exhibits self-similarity because submatrices are MMC models with the same properties as the main matrices. A seemingly endless variety of possible applications have emerged, and a few have been lightly explored: neural networks, theories of Physics, business modelling, neuroscience, software engineering, UML models, object-oriented analysis. The MMC is a unifying notion in Systemics.

However, the iMMC contains a number of man-made structures. Man-made structures are solutions to problems obtained by humans and by the application of human intelligence, of which the AI system has no knowledge and can not understand or deal with. They serve important purposes, but also constrain the system's ability to learn or to infer ontologies. Culprits include code and variable reuse, imperative control of the sequences of execution, elaborate domain representations, multifunction services, separation between control domains and regular domains, and several others. The subject of this work is the elimination of all man-made structures from the iMMC and their conversion to matrix representations, in an attempt to give the MMC an opportunity to develop its own structures and intelligence. The results are fascinating. As traces of human intelligence are systematically sought out and progressively eliminated, the mathematical formulation begins to exhibit many brain-like features, in spite of the fact that the MMC is not and was not intended to be a model of the brain. The final result is the *canonical form* of the MMC (cMMC), defined as a single sparse matrix in canonical form (somewhat similar to single-assignment code), where the rows are services, the columns are domains, and the matrix elements are the roles played by the domains in the services. The *energy function* is the profile of the matrix, and the *attractors* are the objects in the natural ontology of the system. This energy function is universal, unlike the domain-specific energy functions found in Lyapunov's theory. The brain-like features include massive parallelism, robustness, service autonomy, domain-independence, the ability to learn without bounds in either extension or degree of detail, a dynamic

mode with the ability to infer ontologies autonomously by profile minimization, and many others. *Bootstrap learning* in the cMMC is any process that loads the information into the matrix, such as direct programming, conversion from an existing program, learning, sensory input, followed by or combined with profile minimization in order to reveal the ontology.

A sizable effort will be needed to develop the MMC for a practical application. But it has to be done only once. It is possible to develop depth-first (highly specific for a purpose) or breadth-first (like a child learning in school). I suspect that considerable breadth will be needed in either case, and I am convinced that the full potential of the MMC is at the level of human intelligence and beyond.

Keywords: artificial general intelligence, matrix model of computation, universal interoperability, bootstrap learning, ontology, attractor, inference, system dynamics, energy function, theory of cognition.