CS 786G *Cognitive Modeling*
Week 11 Discussion Paper
Port and vanGelder : *Computational* vs *Dynamical* modeling of cognition

Steve Woods
89800462

May 26, 1995

Introduction

In this brief paper, I discuss the work of Port and van Gelder in Port & van Gelder (1995) in which they attempt to justify the appropriateness of a *dynamical* approach to, or model of, cognition and artificial intelligence, as opposed to the more *computational* approach that is typically referenced in other related research. I will first outline what I believe is meant by the term "model" in this context, and then identify the features of the computational model that the authors see as faulty and which the dynamical model consequently is thought to achieve. Finally, I will attempt to comment to the primary of these features from the computational perspective where possible.

Models

Modeling a process is not a reproduction of that process, but rather an attempt to represent the important aspects of some not-fully-understood process within the scope of some language or structure that is more familiar. For instance, it has been useful for financial purposes to model the way in which business systems perform through the construction of simulations which connect many separate sub-tasks or processes through well-defined interactions identified through system analysis techniques. As another example, engineers frequently subject design models to testing through the use of "virtual" circumstances in which extremes of variables such as weather, usage or various other forms of stress act in combination on the model. In each of these circumstances, the actual or source system (from a shop-floor to some hypothesized bridge) is modeled or approximated through purely arbitrary representations which contain no *necessary* physical or functional identity with the modeled object/system. Integral to the adequacy of these models, however, is the correspondence between predicted or expected behaviour in the model and in the source. This should come as no surprise since this correspondence is precisely the intent of the model construction. Similarly, interpretations of some source process in terms of degree-of-fit to some created (mathematical, simulational, or whatever) model can never be taken to mean identity. For instance, the "laws of physics" as constructed as an approximation of reality in toto, have no direct affect of constraint on the behaviour of the universe, but rather serve as (partially) reliable predictors or interpretors of the behaviour, always subject to revision. One suspects in contrast that the way in which the universe behaves is not subject to such revision.

Attack

Port & van Gelder (1995) conducts a rather long attack on the use of computational methods as a toolset for the modeling of cognition. There are several prongs to this attack re-iterated with some frequency throughout this work. I will first present an interpretation of each these prongs in turn, and address them immediately afterwards. These criticisms may be (badly and briefly)[1] summarized as follows:

1. Cognition is a continuous process. Computational models[2] are by definition discrete. Dynamical models are by definition continuous. Therefore, dynamical models are "better" than computational models for modeling cognition. Further still, since computational models are discrete and time is continuous, no adequate representation of time can be presented in a computational model.

2. In fact, "natural" cognition contains both continuous state change *and* discrete state change. Dynamics provides for the modeling of both these changes. Therefore, dynamical modeling is "better" since computational models have only discrete state representation with no conception of state "between" machine states.

3. Neurophysiology suggests that the brain[3] is a "... dynamic, constantly active ... composite of many interacting systems"[4]. Consequently, any model of cognition must be capable of handling multiple, simultaneous interactive activity. Dynamical systems are precisely the simultaneous, mutually influencing activity of multiple parts or aspects[5].

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[1] For a more complete, repetitive account, please refer directly to the source, Port & van Gelder (1995).

[2] As represented in the form of a Turing machine and its states and transitions.

[3] While the brain may not account for all of cognition, it certainly is an important component of whatever "natural" cognition might be.

[4] This description seems to correspond to Minsky's Society of Mind conception of human cognition.

[5] In the form of connected simultaneous equations describing all of human cognition as variable and parameters.

Computational systems[6] try to force this behaviour out of sequential structures, and several other attempts at parallel computation are inadequate to attain this dynamism. In addition, other potential parallel computational attempts to model cognitive systems are doomed to fail since parallel algorithm construction is "devilishly tricky", and besides, computational methods can't model situations in which mutiple components are constantly influencing and being influenced by other components. Since computational systems can't do the job, and dynamical systems can, dynamical systems are better.

4. Cognitive processes take place at varying time scales, as evidenced through various cognitive tasks such as *visual recognition* on the ms scale, *movement* on the order of seconds, or *understanding* which may range from minutes to hours. That these processes affect one anther across time scales is certain. Dynamical methods can handle this variety of scales through adaptation of parameters from fixed to variable, but variable over longer time scales than the state variables of the dynamical process/system equation. Computational methods (**in contrast!**) have no "natural" way of accounting for differing time scales. Therefore, dynamical methods are better.

5. Cognitive systems are highly structured in behaviour and organization, and additionally, these systems emerged somehow from systems that were non-cognitive. Dynamical methods have been shown in simple cases to ential regular spatio-temporal structures from unstructured (chaotic ?) systems. Computation has fallen (or sometimes has) into pre-existing innate structuralism with Chomsky and Fodor, and consequently is unable to account for emergent cognition, now and forever. Therefore, dynamic methods are better.

6. Cognitive systems are embedded in two senses: physically in a body, and within the environment in which the cognitor exists. In the first sense, any model of cognition must represent this physical embeddedness. "The behaviour of the nervous systems, of bodies (limbs, muscles, bone, blood), and of the immediate physical environment **are**[7] all best described in dynamical terms, and consequently the responsibility of connecting this level which is "fundamentally dynamic" to a computational other cognitive level is extremely difficult, and their is "little reason to believe that a ... cross-level, cross-kind explanation will be feasible in the case of natural cognitive systems". In the second sense, how could an essentially "atemporal" computational system interact with the essentially temporal real-world in which thought and action both emerge over time asynchronously.

[6]Port & van Gelder (1995)[p.20] actually say "most" such systems.
[7]Emphasis mine.

Response

Of course, the description of the points of attack described in the previous section are highly simplified, however I have attempted to extract the main points of the arguments or statements so as to be able to briefly discuss them here. In short, I claim that these arguments are individually unconvincing. Lets look at each.

1. *Continuous universe...* It would appear that in this statement is implied a strong claim, namely that the nature of cognition is inherently about continuous reasoning rather than an approximation of some level of continuity. While our (human) cognition functions within the continuous medium of the universe, the claim that any such cognitive agent is capable of describing how processes evolve in real time seems strange .... for example, which of the words of the last paragraph were written/read 2.34 seconds ago ? Perhaps a model which is fundamentally incapable of answering this type of question is more reliable as a cognitive model than one which can. Further, a great body of work has been done in expressing temporal modes of reasoning in AI (temporal logics, temporal constraint reasoning, etc.) all of which at some level may be seen as a way of dealing with a continuous universe within a discrete framework. I believe that a better argument of the insufficiency of such approaches is required before discounting computation as a model of cognition on this basis.

2. *Continuous and Discrete universe ...* I see this critique as a variation of the first that is answered with the similar response that more argument is required to discount computation as adequate for handling both discrete and continuous change, at least at some sufficient level of abstraction.

3. *Multiple part integration...* The argument first tries to typify all AI systems by several examples, contradicts itself with the existence of parallel models, and then attacks this type of construction with a vague, unsubstantiated claim that such use is somehow too "tricky" to suffice. Once more the outright claim is made that computational systems are in some way incapable of handling mutiple-near-simultaneous inputs and outputs. This would be a highly interesting result if quantified with respect to input and output requirements, or perhaps bandwidth transmission, in such a way that cognition would be necessarily excluded from all possibly solvable problems based on some hardware, software or other complexity results, however, this is not done.

4. *Varying time scales...* This argument seems still another variation of the first two in which computation's failures are poorly described if described at all. Any criticism hinging on the use of the term "natural" of two models over the other is highly subjective.

5. *Cognitive structure...* Once more computational approaches are poorly generalized by a few previous examples. In addition, the unsubstantiated attack on the structuralist

work of linguists such as Chomsky really begs the question of the nature of mind. Surely there is room for both emergence and structuralist aspects of cognition, or if this been disproved satisfactorily elsewhere, a citation or explanation is required.

6. *Embeddedness...* Surely there can be no argument about the fundamental embeddedness of cognition from the view of computation. Most research and discussion in AI today is from the viewpoint of attempting to understand intelligent agents better, and invariably such talk focuses on the fundamental issues of embeddedness in both the bodily and environmental senses.

In conclusion, it appears as if Port & van Gelder (1995) strives to discard computational approaches to modeling cognition on the basis of some *fundamental* difference from actual cognitive process, and similarly embrace dynamism on the basis of a *fundamental* similarity. Unfortunately (?) this "fundamentalness" has not been formalized well from ad-hoc criticisms from a computational perspective. Underlying this paper somewhere is an argument that cognition and mind are fundamentally part of a continuous universe in which discrete changes sometimes manifest themselves from one point of view, further, any attempt to abstract this continuity as discretization within a model fundamentally removes that model from a possible successful modeling of mind. However, nothing stated arouses confidence in the necessarily continuous nature of mind or disqualifies a discrete representation of such a nature. The claim of a formula-basd explanation of cognition as somehow being more "natural" than a computation-based model or explanation is curious, at least without more elaboration as to how, exactly, some cognitive system is capable of manipulating such expressions. This manipulation, should it exist, of continuous expressions is not likely (in my opinion) to be continuous, but rather discrete approximations which suggests a discrete view of cognition, perhaps using a continuous representation. At any rate, this paper has left me rather unconvinced about the strength of the argument against computation.

References

Port, R. & van Gelder, T. (1995), It's About Time: An Overview of the Dynamical Approach to Cognition, *in* 'Mind as Motion: Exploration in the Dynamics of Cognition', Bradford/MIT Press.