ASPECTS OF AN AUTOMATA-BASED WORLD MODEL

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Preface

This paper presents some of aspects of an automata-based model of physical phenomena. The first section lays a general foundation on which to build the model-theoretic approach that is developed later. The actual process of constructing theories which serve to "co-ordinate our experiences and bring them into a logical system"[1] is discussed. The second section deals briefly with the attempt at deriving an adequate basic conceptual model. The model was originally presented in a paper rather optimistically entitled "Unification of Physics". This leads directly to the third section on the tesselation automata model. A number of points are discussed concerning the characteristics of the model and how they relate to ideas in contemporary physics.

Before I begin, I would like to make some comments concerning the general approach used in this work. The projects, of which this paper is a culmination, have all been done within the academic framework of Colloquium Studies at the University of Lethbridge, a program which allows a great deal of freedom for the student in developing projects independently, drawing on the resources of the university as required. The overall goal of the projects was to provide an introduction to current and past work in the area of theoretical physics. There have been many spin-offs from the projects, however, which together with the core projects themselves, have provided the basis of my undergraduate degree. Critics of this educational route at an undergraduate level often suggest that the end result may be a student whose background is sketchy and whose work will be insubstantial and redundant. I interpret this criticism as, at root, the suggestion that the final product of the educational process, sometimes called a student, may not be in a position to contribute directly to the raising of the techniological status quo. Personally, I resent this characterization of learning. It seems, in some respects at least, that those who hold this opinion fail to recognize the value of the spirit of free inquiry which is so evident in the work of seventeenth and eighteenth century precursors of the modern age. It may well be the case that few will agree that physics today has

really prostituted itself in this way, but I hope that a majority will share my respect for the ideals at stake.

Foundations

Our understanding of the world in modern times has come to be expressed in terms of relatively abstract theories in physics. It is how these theories are produced with which we are concerned here. Linguists and grammarians use the term "parsing" to refer to the decomposition of sentences of a language into their basic elements and descriptions of how these elements are related. If we think of the world as presented to us as collections of experiences, similarities can be seen between the parsing of a collection of sentences by the grammarian and the reduction of our experiences or scientific experimental obsevations to a systematic theoretical explanation. Defining the relationships between the elements and deciding on what the elements themselves will be is often referred to as deriving the deep structure of the sentence.[2] Analogously, physicists produce abstract theories which relate to the underlying conceptual models.

There are two well known methods of parsing a sentence. The top-down approach consists of starting with the hypothesis that the complete collection of symbols is a sentence and then proceeds to extract smaller and smaller components and sub-components until the elements (or words) themselves have all been extracted. The alternate method starts from the bottom that is at the level of the elements, and proceeds to build larger and larger sub-components until the sentence itself is produced. The contemporary approach to systematizing our observations may for the most part be characterized as paralleling the top-down parsing technique. The tessellation automata model which is discussed later, however, should be classified as being a bottom-up approach. The reader should be warned not to carry the analogy too far. It is hoped that as this presentation continues, the distinction I am attempting to make will become clearer.

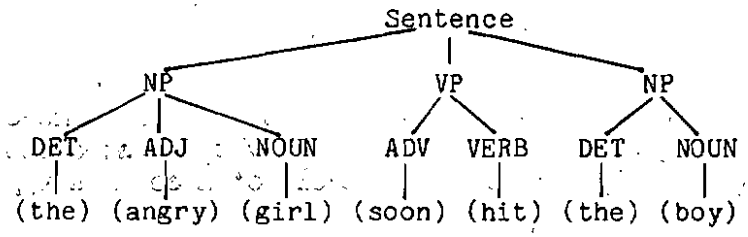

Figure 1. The deep structure of a sentence

In the bottom-up approach we begin by defining the basic and fundamental characteristics of the conceptual model and then generate or derive the consequences of these characteristics. We want to obtain, of course, a "parsing" which represents as accurately as possible the nature of the world. Therefore the consequences of our model must be tested against reality. If we do not find a sufficient number of correspondences with reality, we may be forced to abandon or modify our original fundamental characteristics until we find a set which leads to a large number of interesting correspondences. The process of fitting our model to the world is an interactive one where at each stage in the derivations we are faced with the option of continuing with the next higher level consequences or to

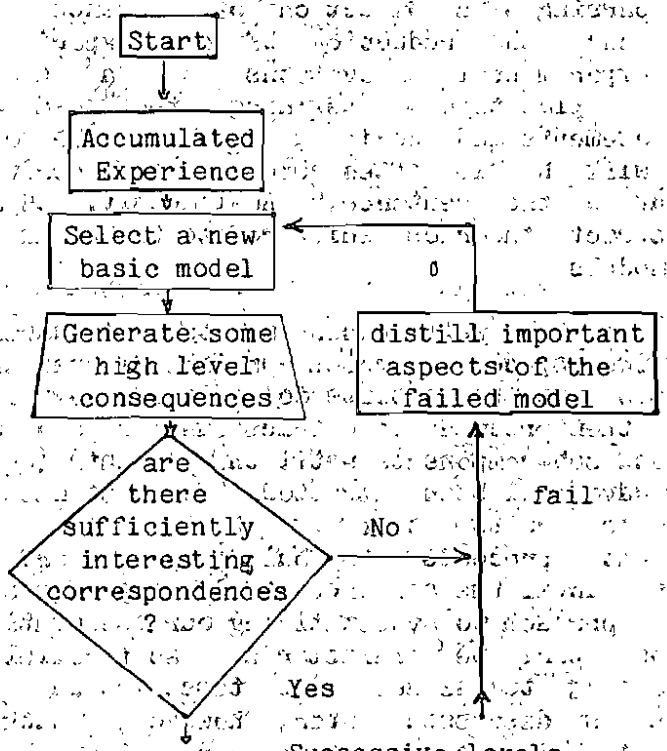

Figure 2. Flowchart of the Bottom-up "parsing" approach (Also called upside-down physics)

Presumably, after each regress we achieve more and closer correspondences or alternatively we might succeed in all phenomena or even that all models of a certain type are adequate.

One feature which seems to be characteristic of all theories of physics is that the conceptual models behind them all contain a "passive" and an "active" component. The passive component of a model represents its structural aspects. For example, the mathematical abstraction of a three dimensional Cartesian space is such a passive structure. The active component is, in rough terms, what makes the model "work". Practically speaking, the active component is often expressed in the form of the force laws of classical mechanics or the world-lines of general relativity. In most theories it takes the form of the fundamental dynamic equation.[3]

An important part of the process of producing models of physical phenomena is the "interface" between human beings and other physical systems of the universe and how this interface determines the nature of the models which can be produced. It is the structure of the brain and the nature of the sense organs which determines the kind of processing of sensory input that will take place. An equivalent re-statement might be that it is the kind of thought processes that go on in our brains when we think about things, which limit the kinds of models that we will see as having acceptable correspondences with reality. There is, therefore, an inherent weakness in the theory production process. How do we successfully integrate the concept of human being making theories about the world into the model of the world? We would hope that a "complete" theory is possible in that it might be able to deal in some way adequately with what we might term an intelligent entity and how such entities construct models of their environment. To anticipate the results of the tessellation theory discussed later, we are concerned how an "observer" embedded in the tessellation space and the kind of information processes in which it can engage, can produce its own model of its environment.

If we can deal adequately with the concept of an intelligent entity, that is, if we find a sufficient number of correspondences with reality in the model, then we might find ourselves with some intuitions about what it might mean for an intelligent entity to have a different kind of thought process than our own. What we could hope to do is to break through the seemingly impenetrable barrier to a purely objective view point. The danger lies, though, in the possibility that our models may be in their primary assumptions quite arbitrary and so that our presumed ultimate objectivity would lose all relationship to reality.

The VLT Hypothesis

In the paper "Unification of Physics" some of the conceptually basic aspects of contemporary physics are re-considered in an attempt to formulate an alternate conceptual framework or model with which to systematize experience. The physical quantities of classical mechanics are examined as representative of the measurements which can be made of physical phenomena. That the quantities are all interrelated is clear from the laws of physics and is demonstrated in the expression of the dimensions of the quantities in units of three or four fundamental quantities, generally length, time, and mass. The assumption is made that simplifying the expression of the physical quantities in terms of a minimal set of fundamental quantities or dimensions will reflect more accurately the "deep structure" of the conceptual models behind them.

After a little juggling and rewriting of the quantities, eliminating square and cube roots[4] and introducing additional fundamentals only if unavoidable, we end up with something like that shown below.

Quantity	MLT	VLT
acceleration	LT^{-1}	LT^{-1}
area	L^2	L^2
displacement	L	L
energy	ML^2T^{-2}	V^2L
force	MLT^{-2}	V^2
mass	M	$V^2L^{-1}T^2$
time	T	T
work	ML^2T^{-2}	V^2L
charge	Q	VL
electric field strength	$MLT^{-2}Q^{-1}$	VL^{-1}
electric potential	$ML^2T^{-2}Q^{-1}$	V
magnetic field strength	$L^{-1}T^{-1}Q$	VT^{-1}
momentum	MLT^{-1}	V^2T

Figure 3. A partial table of the dimensions of physical quantities.

The result is a system of three dimensions, length (L), time (T), and what we have arbitrarily called environ (V). The dimension V, is the sole constituent of the electric potential quantity so we would naturally have the tendency to call V electric potential. But because it is difficult to interpret, for example, force as the square of electric potential or mass in units of volts square,

seconds squared, per meter. We have no conceptual models which we can relate to. What we are doing, though, is creating a new model, using the re-dimensioned quantities as a guide.

Much of the "Unification of Physics" paper is devoted to finding an adequate interpretation or model of V. The ascription to V of "length-like" dimensional qualities, following the success of the theory of relativity in giving time length-like qualities, proved to be an important generalization. The claim is made that V is "hidden" in the formulation of contemporary physics in much the same manner as the relative nature of time was hidden in classical mechanics. The paper ends with the general suggestion that V be associated with information about the environment of the physical sub-system under study.

Tessellation Spaces, Introduction

After two years and some exposure to the abstract theories of computing science,[5] the problem of interpreting V was attacked again. The paper which resulted, "An Application of Tessellation Spaces to Theoretical Physics", clearly presented a "bottom-up" approach and related V to the abstract concept of state.

A tessellation space is best visualized as a vast (perhaps infinte) array of very simple computers. The inputs to each computer are connected in a regular manner to the outputs of a number of other computers in the array. Each computer, with its relative location in the network, is referred to as a "cell" of the tessellation and at any given time is in one of a set of internal states. Each computer in the array has the very simple job of converting the inputs to it and its own internal state at time t, to the output and its next internal state at time t + a, where a is positive and usually 1. This job is referred to as the local transition function. The pattern of states of the cells in the tessellation at any time t is called its configuration. It can be shown that successive simultaneous invocation of the local transition function, given the interconnections of the cells, will result in a well defined next configuration. A temporal sequence of configurations is called a propagation. The function which defines the interconnections of the cells is called the neighbourhood function. The neighbourhood function and the internal state set of the tessellation make up what we earlier called the passive component of the model, while the transition function describes the active component.

The first use of a tessellation was by von Neumann as a model of biological reproduction.[6] Many different tessellations have been defined since then and a relatively large number of theorems about their general properties have been proved.

Our interest in tessellation models derives mainly from its relation to the earlier VLT hypothesis; each cell in the tessellation has a location (L) and is in a particular state (V) at any given time (T). The tessellation model which we have studied most, largely because it is simply defined and supports amazingly complex propagations, and upon which most of that which follows is based is known as John Conway's game-of-life.[7]

The initial reaction to the suggestion of a tessellation as a model of physical phenomena is often that it is obviously inadequate. Most of the processes which we observe in the universe do not, after all, seem to be discrete in nature either physically or temporally. We must remember, however, that the correspondences with reality have to take place at a high level in the model. The question with which we are really concerned is whether or not the results of an observational process within the tessellation itself correspond well with the results that we obtain in our experiments in the world. It is important to maintain a distinction of levels of the model as seen from the "god's eye view" of the producer of the model and the attributes of higher levels of organization within the model as detected by a process also within the model are likely to be vastly different.

Tessellation Space, as a conceptual model

After implementing the game-of-life tessellation on a digital computer, an attempt was made at developing what might be termed an abstract "physics" of tessellation space. The "physics" took what was essentially a pre-Galilean qualitative form with prospects of becoming more quantitative as more data was collected. Basically, all that was done was to observe several times a sequence of several thousand consecutive configurations, choosing the initial configuration at random. The result was a "high level" concept of "action". In the game-of-life there exist small (composed of few cells) sub-configurations which have relatively stable properties. One such sub-configuration or object appears to move with respect to other objects. John Conway called them

"gliders". Viewing the tessellation as a model universe, gliders seem to play the role of distributing "activity" or local disruptions of the objects. Because of the way in which gliders move, and the symmetry of the neighbourhood function, gliders distribute their "quantum" of action, statistically on a $1/r^2$ basis throughout the configuration. There seems to be some correllation between this process and the nature of electro-magnetic fields.

We are not, however, making any claims as to the overall adequacy of the game-of-life tessellation model as statistically or otherwise an accurate quantitative model. We wish only to find qualitative properties which show significant correspondences with "reality", or equivalently, our current theories of physical phenomena.

Other objects besides gliders are known to have the property of moving, but all of them are more complex (composed of more cells) and statistically therefore we would expect to observe them in random configurations less often. In fact, in our observations none of these objects were observed. These objects, when produced, would also serve to distribute activity. We might relate them to weaker $1/r^2$ fields such as gravity.

It was generally observed that "older" configurations tended to contain collections of relatively inactive sub-configurations. We dubbed these ensembles. Smaller sub-configurations within ensembles generally interact by the "random" production of pseudo-objects which seem to "explode" into activity. Because this interaction is intense and short ranged, we might draw some parallels with the strong interactions of particle physics.

Action then is that abstract quantity of activity which can be transferred from one ensemble to another over relatively long distances only in discrete quanta, but which may propagate within the ensemble in a "continuous" manner. The quantum of action in the tessellation model is easily related to the equivalent concept in quantum mechanics. It might prove interesting to consider the effect of this "break down" of the quanta in the vicinity of relatively dense regions of space to contemporary quantum theory.

If we stop for an instant and look back over the last page and a half, it is interesting to note how quickly it is possible to jump from one level, where we are talking

about computers and cells and states to the much higher level where we are talking about gliders, ensembles, and action. This concept of levels may be formalized as an ontological hierarchy of terms. It is perhaps characteristic of the bottom-up approach that the ontological status of our terms is so prominent. The top-down approach allows our ontological perspective to "float" so to speak, since we are not immediately tied to any base-level model. This factor could be at the base of many confusions in contemporary physics.

Foot-notes

1. Albert Einstein, "The Meaning of Relativity", page 1.
2. N. Chomsky, "Syntactic Structures", S-Gravenhage: Mouton and Co., 1957.
3. C. A. Hooker, "Metaphysics and Modern Physics, Contemporary Research in the Foundations and Philosophy of Quantum Mechanics", Reidel Publishing Co., 1973.
4. Square roots and cube roots of fundamental quantities seem to imply a deeper dimensionality. For example, the square root of area is length.
5. Arbib, "Theories of Abstract Automata", Prentice-Hall.
6. J. von Neumann, "Theory of Self-Reproducing Automata", (A. W. Burks, ed.), University of Illinois Press.
7. M. Garner, "Cellular Automata", in Scientific American, February 1971. See also Scientific American, October and November 1970.