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EPISTEMOLOGICO-LOGICAL APPROACH TO THE VALIDITY OF MODELS IN VIEW OF THE FUZZY SYSTEM MODEL

By

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ABSTRACT

The validity of models is discussed with the aid of the recent results of semantics for the purpose of identifying what causes the fuzziness. First, the validity of models is logically defined and, second, the methodological views of the world are presented with their associated system models. Then the validity of models is more specifically redefined and the origin of the fuzziness is identified for each methodological view.

1. INTRODUCTION

As the validity of many empirical-scientific researches is essentially dependent on that of models, it is extremely important to define what the validity of models means. This is an important problem in the methodology of sciences but, unfortunately to us, the science methodologists have failed to formulate and discuss this problem. The logics which is a modern and formalistic version of the methodology of sciences has been no exception because it has been interested in no empirical science nor interdisciplinary science.

This paper first formally defines the meanings of models in empirical sciences and of their validities in an epistemologico-logical way with the aids of the paradigms of the probability and number theories and the semantics. In particular the semantics, or its recent version which happened to be called the model theory, will play the most important role in our discussion. The semantics which is a part of formal logic and deals with the meanings of words and statements will be applied to our problem as a problem of giving the meaning to the statement that a model is valid.

2. LOGICO-THEORETIC APPROACH TO THE VALIDITY OF MODELS

2.1 Logico-Theoretic Approach to Models versus Logical Theory of Models

For the purpose of analyzing and defining the meaning of a statement that a model is valid, the semantic technique which has confusingly been named the model theory may be useful. In the terminology of the empirical sciences the model denotes some copy of the real world suitable to the purpose of investigation and, therefore, is the seconday or derived world which might be said rather subjective. In the terminology of logic and metamathematics in which the truth depends fully on logic and never on the real world, the real application is secondary or derived and hence is called the model. In other words, according to the methodology of logic and metamathematics, the logical world is the true world and the real world is the model. Specifically in the terminology of metamathematics, logic is primary meanwhile mathematics which is less purely logical and is more reality-oriented than logic itself is an application of logic to a more realistic object and hence is called a model. Thus the logical theory of models is to relate a formal logic to a branch of mathematics as giving the former a mathematical meaning in a more realistic mathematical system.

The contrasting difference or the opposition is seen in the terminologies between logic and the experimental sciences as was discussed above. Despite this fact, the logical theory of models is still useful to the logical discussion of models in the empirical sciences as relating a model to the truth.

As a kind of preliminaries, let some general concept be sketched here about the logical theory of models. It could date back to the early days of formal logic itself (Löwenhein 1915, Skolem 1920, Gödel 1930, Tarski 1931, etc) as Chang & Keisler 1973 [2] claims. Or more moderately, it might be as old as semantics itself (Tarski 1935, Carnap 1942 and 1948, etc). These are not false in that the development of logic has always raised the problem of interpretation. Recognizing that the logical theory of models is one among many possible approaches to this problem, these claims seem too strong. One could contrarily say that it started only after every formalistic attempt resulted in failure in semantics, namely, after people began to accept a syntactical approach to semantics as the only possible way to remain for the formalization of semantics. In fact the logical theory of models is quite syntactical in form and is different from syntax mainly in its interpretation. Indeed, there is almost a one-to-one correspondence between the formalized logic and the logical theory of models. This close correspondence will be exploited in the later discussion below.

2.2 Definitions of Major Concepts

In both of logic and the empirical sciences, a model is secondary to the primary world and is a copy of the true world. If a model is a good copy of the true world, it is true or valid. Sometimes the truth denotes the empirical agreement with the real world and the validity denotes the logical correctness. In this paper the validity denotes the trueness of a model while the truth denotes the trueness of each statement in a model. Hence, when it is said in an empirical science that a model is valid, this means that the model is a good copy of the real world.

There may be two kinds of models in the empirical sciences; the descriptive and the normative models. The descriptive model is valid when it is a good copy of the present or existing world while the normative model is valid when it is a good copy of the expected or ideal world. Logic has no essential distinction between the present or existing world and the expected or ideal world because it is the matter of empirical recognition outside the scope of logical recognition. For this reason the subtle difference between the meanings of the descriptive and the normative models is inessential. In fact, the both can now be liguistically restated as follows; a model is a valid when its statement is a subset of the statements on the world; in other word, when the statement of a model is included in the statements on the world. This definition is liguistic in that it relates the statement of a model to a set or subset of the statements on the world instead of the world itself. Such a liguistic definition necessarily follows from the logicalness of our approach because logic is a part of the lingustic science.

This linguistic definition is formally restated as follows.

$$\models M \text{ iff } \quad S(M) \subset S(W)$$

where

$\models X$: X is valid or true

$S(Y)$: statements on or of Y

Actually, "Z $\models$ X : Z means (semantically leads to) X", and " $\models$ X : X is meant by anymeaningful premise", or "$\models$ X : (Z) (Z $\models$ X)".

The semantical symbol "$\models$" corresponds to the wellknown syntactical symbol "$\vdash$" with the distinction that $\models$ and $\vdash$ denote the semantical and syntactical proofs respectively. Such a notational correspondence to the syntax system is a typical character of the logical theory of models in contrast to other semantical theories.

This syntax-like definition also corresponds to the histrically wellknown definition of the truth [1] by which the semantical truth may be expressed in relation to the models as follows.

$$M \models X \quad \text{iff } S(X) \subset S(M)$$

where

$$M \models X \ : \ X \text{ is true or valid in a model } M.$$

Proposition 2.1 (Completeness of Logical Theory of Models)

$$M \models X \quad \text{iff} \quad S(M) \vdash S(X)$$

Verbally, there is a one-to-one correspondence between the logical theory of models and the syntax system of logic. In other words, the logical theory of models which is a version of semantics is quite syntactical in form and is different from the syntax system of logic only in its interpretation.

This property is named the completeness by [1].

3. THE MECHANISM VIEW OF THE WORLD

3.1 The Event-Schematic View of the World and its Resultant System Model

Pre-position 3.1 The world consists of the finite or countably infinite number of events.

This pre-position or presumption is basically the same as that of the probability theory. An event may be prime or atom or, alternatively, may be compounded from prime events. In the deterministic view, each event is either true or false; or equivalently, for the value of event v(e),

$$v(e) \varepsilon \{0, 1\}$$

For the simplicity, let the number of the prime events be finite and denoted by N. Each event taking on its value in {0, 1}, the total number of the possible states of the world is 2^N (the power set). Each state of the world is termed a monado. Hence there are 2^N-number of monados under the above assumption. The assumption of N-events is quite natural for the following reason; History of human knowledge is finite, and hence the total number of events recognized thus far is finite and is denoted by N_t for time t. Fixing the time, N_t may be written simply as N.

A compound event is compounded from events (prime or compound) by the logical connectives (conjunction, disjunction, implication and negation, or symbolically, $\wedge$, $\vee$, $\rightarrow$ and $\neg$). The human recognition may be defined as assigning an event a statement; or formally,

$$R : E \rightarrow F$$

where E is the event space and F is the statement or formula space. Linguistically, there is no need of strict distinction between a state of an event and its statement though the mapping R is not necessarily one-to-one (i.e., R or R^{-1} is ambiguous, that is, the recognition or the expression of an event is fuzzy).

A model is a (logically consistent) set of statements (or shortly, a compound statement) in which statements are compounded with each other by the aforementioned logical connectives. For example, a model experssed as a system of simultaneous equations is a compound statement (in this case, a system) in which statements (in this case, equations) are compounded with each other by the conjunction. Another example is a linear programming model which is a compound statement composed of the conjunction of linear inequalities. A simulation model is a compound statement which is usually called a program composed of the logical connections of statements (command etc) and is usually expressed by a block-diagram or flow-chart.

Now the validity of a model is defined as follows.

A model M is valid iff

$$S(M) \subset S(\underline{M})$$

where $\underline{M}$ denotes a monado.

Alternatively, a model M is valid iff

$$\underline{M} \models M$$

This definition is verbally explained as follows; if each statement in a model takes on the same truth value as the corresponding statement in a monado, then this model is valid under the monado; in other words, if a model is included in a monado, then this model is valid under the monado.

Proposition 3.1 (Consistency and Completeness of the Event-Schematic System)

The event-schematic system is consistent and complete in the terminology of logic.

Demonstration. This system corresponds to the propositional logic system. Hence the consistency and the completeness of the latter leads to those of the former.

This system is not necessarily deterministic. In fact it can easily turn probabilistic by re-reading each statement as "the probability of an event is p_1" and assigning the bi-valent truth value to this statement. This, however, makes the number of the states of the world or the number of the statements on an event uncountable, yielding that Proposition 3.1 holds no longer.

3.2 The Interpolationism View of the World and its Resultant System Model

Pre-position 3.2 The cardinal number of the prime events is countable and they are arranged on R^1.

The aim of the Pre-position 3.2 is to define the distance between events. Therefore new events are now derivable from event by the arithmetic operation. A prime event is an event. Also what is derivated from two events by the permissible rule is an event. The latter kind of events are called the derivative events.

The permissible rule may be as follows. Take a pair of prime events e_1 and e_2 which are adjacent each other on R^1. Let the truth values of their associated statements be $v(e_1)$ and $v(e_2)$ respectively. Then define an event e_3 with the truth value $v(e_3) = \alpha\ v(e_1) + (1 - \alpha)\ v(e_2)$ for $\alpha \varepsilon$ [0, 1]. It may be noted that e_3 is interpolated between e_1 and e_2 . The condition of the adjacency makes $v(e_3)$ "unique" for give $v(e_1)$ and $v(e_2)$. In fact, without this condition, the "same" event which is "located on the same position" of R^1 might take on different truth value, depending on which two events derivate this event. The adjacency is well defined under the condition of Pre-position 3.2

Theorem 3.2 The truth value of an interpolated event is unique.

It is easy to see that $v(e_3)\ \varepsilon [0, 1]$, namely, that the truth value of the statement on the derivated event is between the truth and false inclusively though the truth value of the prime event is either true or false. In other words, the operation causes the uncertainty.

When α is restricted to the rational number, the truth values of events are also restricted to the rational number. As is well known in the classic set theory, there is a one-to-one correspondence between the rational number and the natural number. Hence the resultant system model shares the basic structure with the number theory. This yields the following property due to the well-known Gödel's theorem.

Proposition 3.2 (Incompleteness of the Interpolationism System)

The interpolationism system is incomplete in the terminology of logics when α is rational.

When α is not restricted to the rational number, i.e., when α can be irrational, the truth values of events can be irrational. Then its logical property is more complicated and even its consistency can not be guaranteed.

4. THE ORGANISM VIEW OF THE WORLD

Pre-position 4. The world is the continuum

Now under Pre-position 4, an event itself does not exist but it is a fragment cut off from the world. Standing on the side of the empirical sciences, it can not be exactly measured where the world is cut off, i.e., where the event is located in the world. This causes the fuzziness of the resultant system.

The above pre-position of continum suggests that the resultant system corresponds to the algebra and that this system shares the basic structure as the algebraic system[3]. At the same time, as the title suggests, the resultant system shares the basic concept with the holism. In this sense it may be the closest to the underlying concept of the fuzzy set theory.

5. CONCLUDING REMARKS

This paper presented a couple of views of the world with their associated system models and showed what causes the fuzziness in each view of the world.

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