SYSTEMS ANALYSIS OF KNOWLEDGE

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Summary

The article focuses on deductive, hypothetico-deductive and hypothetico-inductive knowledge, knowledge on the basis of soft formalization, knowledge as a process of decision-making and tacit knowledge. Deductive knowledge is characterized by rigid formalization whereas there is no formalization in tacit knowledge. Other types of knowledge have secondary (non-rigid) formalization. In order to characterize non-rigid formalization the author suggests modification of hypothetico-deductive and hypothetico-inductive methods of creating and defining knowledge. It is argued that the basic tendency of knowledge evolution consists in emphasizing the importance of non-rigid formalization and in establishing closer relations among different types of knowledge.

1. Introduction

The subject of systems analysis of knowledge is the study of mutual connection of factors, which determine trends of its change. The dynamics of cognitive process is, in turn, determined by two factors: 1) logically consistent and sufficiently complete model description of a certain "fragment of reality " in a purposely chosen language for the achievement of this aim; 2) periodic revision taking growing volume of practical and empirical data into account, theories (models) for better explanation, prediction (foreseeing), realization, and practical usage (achievement of set goals).

The expressive capacity of a language, within which theories or models are built, is essential, as it determines the range of possible model creations. Languages themselves as well as models and theories built in them are gradually changed. In knowledge itself new notions, problems, and questions requiring answers periodically occur. It is an open system and a person forms part of it.

According to the famous thesis of Galileo, to make science progress, everything measurable should be measured and everything unmeasurable should be turned to be so. On the one hand, it results in the complication of the number notion. Besides natural and rational numbers there gradually appeared real and complex ones, quaternions, matrices as "numberlike" objects, differential operators, p-adic numbers and the like. On the other hand, there unexpectedly emerged the essential examples of "non-calculable" knowledge.

Still another aspect of this process is the growing volume and precision of observations and calculations, improvement of acquisition and analysis methods, including computer usage. The latter represents a complex experimental apparatus, manages the experiment, collects and analyses the data. Information science (informatics), which deals not only with computers, but also with systems like "computer + measuring device" comes into functioning as a component of knowledge.

The drivers of change of knowledge are also cultural, social, political and conceptual methods. To express these and other factors, which influence knowledge development let us represent, as is common to do, as a 3-levelled hierarchic system. The lower level will make empirical and practical knowledge, the middle one will represent theoretical or model knowledge and the upper one - methodological or metatheoretical knowledge. The first two levels represent knowledge of "reality", and the last - knowledge of knowledge.

The middle level is a set of interconnected notions and laws, expressed, when possible, by means of a system of equations. There are also formal rules, which make it possible to draw logical conclusions from the complex of laws, non-contradictory assumptions and empirical data, pass on from theoretical level to empirical one and (in some way) vice versa. It enables us to speak about explanatory, predictive and transforming functions of knowledge.

The problem, however, is that accumulation of new data will sooner or later destroy knowledge as a whole and will require its restoration on a new level (for a vaster complex of data). That is why the development of knowledge is always a compromise between aspiration for maximum possible simplicity of laws, theories and models and growth of their complexity, resulting from the necessity to match knowledge and new data, predict new and yet unknown facts, and find new applications of knowledge and new effective ways of actions. As a result, various types of knowledge emerge.

According to the means of functioning and inner structure we distinguish deductive, hypothetico-deductive and hypothetico-inductive knowledge, knowledge on the basis of soft formalization, and knowledge as a process of decision-making and tacit knowledge.

Deductive knowledge is characterized by strict formalization, tacit knowledge has no formalization. The rest of the types of knowledge have some flexible formalization.

Strict formalization is realized by means of deductive logic. To reveal the inner structure of knowledge the axiomatic method is preferable, whereas for the practical construction of proofs or, usually, for realizations of logical inferences another logical technique becomes preferable.

Since deductive formalization is completely characterized by means of deductive logic, examination of this formalization is outside the scope of systems analysis of knowledge. In the scope of the latter, however, all the other kinds are included. It is essential, as the basisc tendency of knowledge evolution is a relatively quicker growth of non-strict formalization and establishing closer relations among various types of knowledge.

2. Hypothetico-deductive method (h.d.m.)

Hypothetico-deductive method is a means of creating concrete scientific knowledge and is simultaneously a means of its substantiation. It is based on drawing logical conclusions from the concrete laws and assumptions available. Besides, some conclusions must bear direct comparison with the results of observations and experiments in order to allow us to find out whether they are true or false. The method itself admits double usage: top-down (from theoretical level to empirical one) and bottom-up (from empirical to theoretical level). Each of them has different properties and represents different functions in scientific knowledge.

While applying h.d.m. from top to bottom, we draw conclusions by means of logical deduction. As a result, we obtain more or less unknown propositions from known grounds. This process is stable (it may lead to the growing number of true conclusions) and relatively simple. As a result it reveals the latent content of hypotheses and theories and creates conditions for their objective checking. Hypotheses and theories possessing this property are called checkable. Checkability is the necessary condition for creation and acceptance any new hypothesis. The notion of checkability of all assumptions is included in the scientific honesty code. While using h.d.m. from bottom to top a scientist is aware of experimentally proven phenomena and would like to find out, from what assumptions they follow. Solution of this problem is not simple (a great number of alternatives are possible), indefinite (no algorithm of choosing alternative exists) and unstable (the growing number and precision of experimental data may sooner or later lead to the revision of our decision).

Real application of h.d.m. in science itself should be clearly distinguished from its logical reconstruction in systems analysis of knowledge. The former does not have any alternative: there is no other means of comparing abstract knowledge with observations, but drawing simple conclusions from it, which due to their relative simplicity make it possible to find out whether they are true or false. Logical reconstruction of h.d.m., on the contrary, assumes different, more or less successful, alternatives. An important peculiarity of h.d.m. is the fact that it includes rules of rejecting assumptions, with one exception; there are no rules of their acceptance. The main h.d.m. rejecting rule is a deductive rule *modus tollens*:

$$(H \Rightarrow e, \neg e) \Rightarrow \neg H \,, \qquad (1)$$

(⇒ signifies logical inference, and ¬ represents negation). It makes the researcher face the choice: either to reject the hypothesis in case of existence of a counterexample (establishing falseness of the conclusion being checked), or modify it in such a way that this counterexample will cease to be its conclusion.

If $H \Leftrightarrow H_1 \wedge ... \wedge H_n$, (⇔ denotes logical equivalence), the application of rule (1) in the case of existence of a counterexample leads to the disjunction $\neg H_1 \vee ... \vee \neg H_n$, and one cannot say, which of its components is responsible for the false conclusion.

Correspondently there emerge two different cases. If we apply rule (1) and obtain disjunction $\neg H_1 \vee ... \vee \neg H_n$, then we face the problem of farther collecting evidences, which allow us to exclude certain disjuncts by means of disjunctive syllogism:

$$\neg p \vee \neg q, p \Rightarrow \neg q \quad (2)$$

This method of exclusion may lead to the creation of a more perfect hypothesis. The validity of applying this deductive rule is based on the assumption, that at least one disjunct in $\neg H_1 \vee ... \vee \neg H_n$ is true.

If we do not apply rule (1) and try to modify *H* differently, our knowledge becomes inconsistent: both *e* (as a conclusion of *H*) and ¬*e* (as an empirical evidence) are included in it. This contradiction exists till *H* is not substituted by its modification, from which *e* does not follow. As one can never say beforehand, when the suitable modification will be suggested, the system reconstruction of h.d.m. must use both classical and para-consistent logics, which makes it possible to handle contradictions without having arbitrary conclusions. Such a decision, however, leads to other problems, as it creates the threat of rejecting disjunctive syllogism, which is absolutely necessary in h.d.m. Combining disjunctive syllogism with para-consistence requires the usage of nonmonotonic logic.

The usage of the latter in the h.d.m. system reconstruction leads to a new concept of scientific explanation, which makes it possible to distinguish syntactically between explanation and prediction. Prediction is always a deductive inference from a hypothesis, and it forms a logical basis for their checkability. Explanation, on the contrary, may be both deductive and non-deductive (nonmonotonic). In the latter case explanation is being built as a free assumption, compatible with the rest of knowledge. The principle of "the absence of opposite evidence" is the basis of such explanations.

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Biographical Sketch

Vladimir N. Kostiuk is the leading research officer in the Institute of Systems analysis (Russian Academy of Science), Doctor of philosophy, Doctor of economy, Professor, and a specialist in the field of methodology of system research and macroeconomics. He has published more than 100 scientific articles, including 6 monographs. At present he is engaged in researching complex system evolution (economy, socium, complex natural systems).