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KANT'S LOGIC AND SYNTHESIS OF ONTOLOGIES IN
INTELLECTUAL SYSTEMS¹

This article develops a procedure of the synthesis of actual experience according to Kant's "Critique of Pure Reason" and applies this procedure to the methods of ontology construction as an internal representation of the object domain in an autonomous intellectual system. The author draws analogies between Kantian notions and certain concepts introduced in the research on artificial intelligence.

Keywords: *Kant, logic, artificial intelligence, ontologies, intellectual system.*

Today, it is rather common to apply Kant's ideas in social, political and moral practice. However, it is less common to apply his ideas in the research on Intelligence modelling. I suppose, the reason is that both sides of such relation are very complicated. For AI researchers, it is very difficult to understand the complete power of Kant's ideas and, vice versa, for Kantian philosophers, it is difficult to grasp the key problems of the AI-research. Moreover, Kant's purpose was predominantly philosophical. For the procedural application of his ideas, we need to process them, for example, by finding analogies with intelligence studies in modern researches on intellectual systems.

Any intellectual system (IS) – a natural or an artificial one – constructs the inner world representation, which underlies the formation of the basis for admissible judgments on the environment by the IS that, alongside values (axiological unit), serve as the basis for decision-making. Such inner world representation is usually called the *ontology*. Any IS includes a ontology. The key question is how

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ontology is formed in a natural IS and whether these methods can set the pattern for a ontology construction in an artificial IS. Another question is how the knowledge acquired on the basis of ontology can be used for the arrangement of reasoning in an IS. The experience of handling these tasks in the research on artificial intelligence (AI) showed that a considerable progress could take place through addressing philosophical interpretations of cognition and their adaptation to the research on IS. Particularly, in the 1990s, there were attempts to apply Kant's transcendental philosophy to the problems of IS inner world construction [4, 5, 6, 7, 1, 2, 3].

An important component of an IS activity is the derivation of 'new' knowledge from that already acquired (in particular, knowledge generated on the basis of the ontology). For this purpose, one engages a basic logical system and the system of heuristics limiting the set of possible derivatives of the given formula or pointing at the most efficient ways of the formula derivation. There arises a question: what defines the choice of heuristics? Are they arbitrary recipes invented to reduce the number of variants? Do they rest on the considerations connected, for instance, with the peculiarities of the field of knowledge this system of deduction search is constructed for? Literature suggests both approaches.

The analysis of the correlation between formal and transcendental logic in Kant's philosophy offers an interesting example of heuristic motivation connected with the ontology structure. The problem, being solved in Kant's works by formal and transcendental logics, can be interpreted as the *problem of the construction of deductions of reason*. Kant reveals it in "The Critique of Pure Reason" A 304-305/B 361. Formal logic (syllogistic and some modi of the logic of propositions) is an apparatus of making a deduction from given hypotheses. According to Kant, it is a deduction of reason. But already at this (syntactic) level,

transcendental logic can be used as a negative heuristic in relation to the deductions of formal logic, i.e. to prohibit some deductions that otherwise could be possible. So, for example, the application of the category of substance prohibits a number of deductions made by conversion, opposition to the predicate, and some modi of the first and second figure of syllogism from hypotheses of a peculiar kind, since some terms of these hypotheses are given a special status. Then, the application of the second analogy of experience to the deduction from universal implications ($\forall x(P(x) \rightarrow Q(x))$ type) allows us to reduce the set of possible deductions from such hypotheses². The limitations of the set of deductions from the given hypotheses are connected with the application of categories defining the structure of possible experience in transcendental philosophy. These limitations can be interpreted as the limitation of the set of deductions from the hypothesis by the statements that can have interpretation in the field of possible experience and exclusion of those consequences that cannot have such interpretation but can claim it on the basis of their form.

Transcendental logic gives us an example of a negative heuristic motivated by the representations of the object field structure (in this case, the field of possible experience), the system of deduction search is constructed for. So, ontological considerations serve here as the source of heuristics. Therefore, the interaction of formal (FL) and transcendental logics (TL) gives us the model of the interaction of purely logical rules and ontology in the process of logical deduction. TL, based on the peculiarities of a priori knowledge representing the structure of the world (by means of categories), can be interpreted as ontology – in the literal Aristotle's sense as the *theory of types of being*,

² For more details on transcendental logic as a negative heuristic, see [8].
On role of syllogistics as method of deduction in TL, see [10].

defining general conditions for the ontology construction peculiar to this IS. In the model of FL and TL interaction, transcendental logic plays the role of the limiter of FL deductions, which rests on the basic information on the ontology structure.

The experience of AI research offers us the following procedure of the ontology construction in the framework of an IS: (a) a basic fragment of knowledge is built into the given IS (knowledge received from an expert or a complex of knowledge about the world necessary for a robot); (b) the inner representation of the world the system will reason about and/or in which it will operate, is constructed on the basis of this fragment.

In the previous publication [5], I analysed Kant's method of cognitive ability reconstruction as a pattern for IS architecture design and outlined the stages of the IS 'inner world' construction on the model of the reconstruction of the levels of cognitive ability. In particular, I argued that Kant's construction of the actual experience of cognition agent can serve as a paradigm for an IS ontology construction. Now I will turn to a detailed analysis of this thesis. Further investigation will be based on the following analogy: *what Kant understands by actual experience in the functioning of cognitive ability is a particular case of what is understood by the ontology in the AI research.*

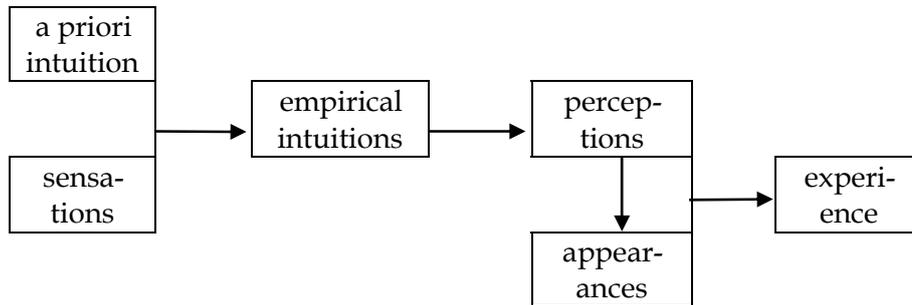
The construction of actual experience

I will investigate into Kant's method of actual experience construction by the following means: firstly, I will conduct the substrata analysis of experience, i.e. will try to answer the question: which components related to sensibility take part in the synthesis of agent's experience? Then, on the basis of the analysis results, I will try to answer the question: what is the sequence of syntheses, which unites these components into the whole of actual experience? Kant himself solves this problem in the chap-

ter “On the deduction of the pure concepts of the understanding” from the “Analytic of concepts”. What is experience according to Kant? I will answer this question analytically, considering the concept of experience as given and following Kant in the direction of its components. On the basis of numerous contexts where Kant uses this term, *actual experience* can be defined as *knowledge on the connection between appearances and corresponding perceptions*. Thus, our initial question resolves itself into the following one: what are perceptions and appearances?

Perceptions are usually defined by Kant as representations accompanied by sensations (the term 'representation' is indefinable). The term 'appearance' is mostly used there where Kant wants to emphasise the difference between the available knowledge (of objects) and the unavailable knowledge (of things-in-themselves). Nevertheless, one can determine a more 'objective' meaning of this term. Appearances can be defined as the 'objects of perceptions' (A 165/B207)³ or the 'objects of a possible experience' (A239/B298), constructed on the basis of the given perceptions according to the rules of reason. So, we have the following procedure: appearances are formed on the basis of given perceptions, and the mental connection between perceptions and appearances generates the experience of the agent. So, the following task is to analyse the concept of perception. Perceptions are the result of application of synthesis of apprehension to empirical intuition (B 161f). Intuitions are the way knowledge is related to its object (A19/B33). Empirical intuition is an intuition that is related to its object by means of sensation (A20/B34). Empirical intuition is the synthesis of pure intuitions (space and time) and sensations that are the initial components of sensibility. It leads to the 'substrata' scheme of the agent's experience.

3 All references to the “Critique of Pure Reason” will be to this edition [9].



One should take into account that a priori intuitions are the forms of perception that are reconstructed by means of the basic fragment of knowledge as the result of the initial analytic procedure [5].

Every component of this scheme is formed by more elementary ones in the process of a synthesis of a certain type. To perform these syntheses, Kant offers two types of agent's abilities: apperception and imagination. The transcendental deduction of categories shows us the method of synthesising experience from perceptions, the a priori forms of perceptions and categories.

There is no clear description of the sequence of such syntheses either in the first, or in the second edition of "The Critique of Pure Reason".

It is obviously determined by the fact that, in the "Analytic of concepts", Kant himself aspired, first of all, to show the role that categories play in the synthesis of experience, and considered the process of synthesis only to the degree that was necessary for the transcendental deduction of categories. In the context of my research mentioned above, it is required to extract the procedure of the actual experience construction from Kant's deduction. The analysis of texts, in my opinion, shows that the extraction of an unambiguous sequence of syntheses from a text is impossible. Thus, further research will include a considerable element of reconstruction, i.e. it will be one of the possible variants of such sequences that will not contradict Kant's

text. In my reconstruction, even the order of synthesis will differ from Kant's one.

The first type of synthesis that makes all others possible is the synthetic unity of apperception (SUA), which juxtaposes the representation "I think" to every representation, thus relating it to the unity of the agent. This initial synthesis turns arbitrary representations into the representations of the given agent forming the basis for further syntheses. Regarding sensations, SUA performs the function of subsuming them under a priori forms of space and time, since, otherwise, sensations could not be accompanied by the meta-representation "I think". SUA unites a priori intuitions and sensations into a more complex component of experience – empirical intuition. Nevertheless, the role of SUA is not limited by this. The "I think" representation once being attached to concrete representations accompanies them alongside the whole procedure of experience synthesis. For the further processing of empirical intuition, Kant suggests considering the synthesis of apprehension: "the composition of the manifold in an empirical intuition, through which perception ... becomes possible" (B 160). Kant makes an example about a house to explain what he means by this: "... I as it were draw its shape in agreement with the synthetic unity of manifold in space" (B 162). To continue Kant's example, one can say that an a priori space intuition immediately has a certain synthetic unity expressed in the ability of space to serve as an environment for the formation of different figures. Being applied to empirical intuition, synthesis of apprehension generates one of such figures corresponding to the sensations that take place in this empirical intuition; thus, there emerges the only, necessarily determined by 'here and now' circumstances, perception.

This synthesis of apprehension is subject to categories in that sense that a necessary condition of perception turns out to be what, in general, makes the synthesis of the

homogeneous possible, which is the category of quantity. The result of the synthesis of apprehension application to empirical intuition is perception. The synthesis of apprehension generates a certain sequence in empirical intuition, though this sequence is subjective and random (for instance, the perception of a house can start with the upper part and end with the basement or vice versa). There arises a question about the correlation between this subjective sequence of perception (synthesis of apprehension) and the connection of the manifold in an object.

Due to the subjectivity and random nature of the object perception sequence, numerous non-congruous perceptions of the same object are possible. And the fact that this set of perceptions relates to the same object is to be established. The first stage of the way towards the object of perception is the synthesis of imagination, which Kant calls figurative synthesis. This name is connected with the fact that synthesis, in essence, resolves into the construction of figures in space. The examples of figurative synthesis are mental drawing of a line, imaginary description of a circle, three dimensional representations by drawing three mutually perpendicular lines from one point, auxiliary construction for proving geometry theorems etc.

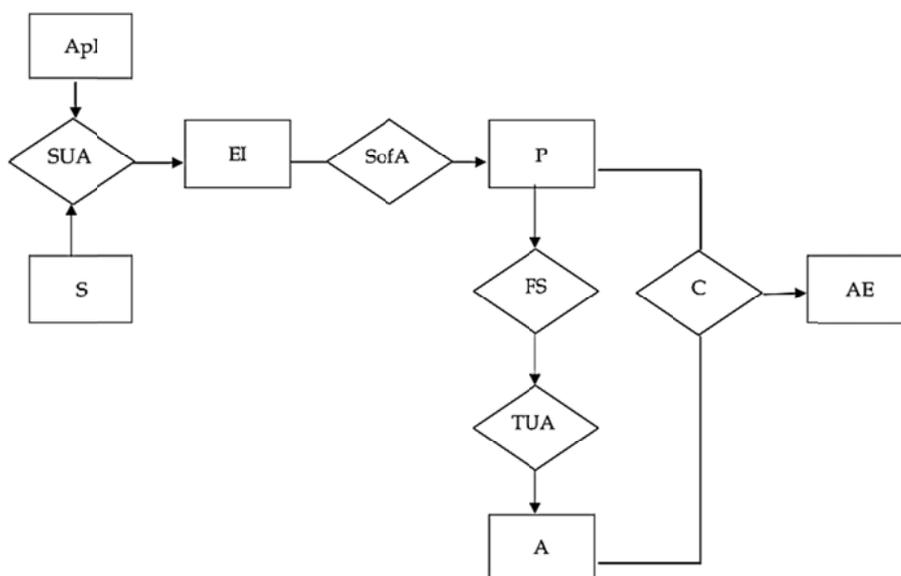
Figurative synthesis creates "objects of the intuition that is possible for us" (B 152). Kant does not provide a detailed explanation how this synthesis creates the objects of intuition that is possible for us. But the §§ 24-26 of "Analytic of concepts" bring to the conclusion that the figurative synthesis of empirical intuition consists in drawing all figures compatible with the sensation received by the agent, which forms the matter of perception. So, if the (still unknown) object of empirical intuition is a house, figurative synthesis should create in a priori space all possible forms compatible with the received sensations. Figurative synthesis, developing possible a priori forms, takes on the task of combining this form with empirical components of

perception. It is this combination that should generate the object of perception: "The transcendental unity of apperception is that unity through which all the manifold given in intuition is united in a concept of the object" (B 139). The form, the transcendental unity of apperception (TUA) realises in, consists in the statement: "That is the aim of the copula *is* in them: to distinguish the objective unity of given representations from the subjective" (B 142). These Kant's statements seem to have the following meaning: there are the given S_1, S_2, \dots, S_n perceptions that serve as subject in judgements, while the forms generated in the course of figurative synthesis play the role of predicates, and if the form is found, for which S_1 is P, S_2 is P, \dots, S_n is P is true, then P stands for the form of the object of this class of perceptions, which does not depend on the character of its apprehension. In other words, if we manage to prove that every perception from a certain set is a different apprehension of the form of the same house constructed in the course of figurative synthesis, then the house of the given form is the object of perception.

As mentioned above, Kant calls the objects of perception 'appearances'. TUA carries out, firstly the search of appearance form and only then constructs its object. How it occurs, Kant shows not in the "Analytic of concepts" but in the "Analytic of principles". Kant argues there that the final determination of the object of perception is connected with the consideration of the corresponding appearance in the framework of the rule expressed by a certain category (A 191/B 236). However, it means that the given appearance and, therefore, the perception that designates it, are related to other perceptions and appearances. But this is, indeed, the actual experience of the agent, since "...experience is cognition through connected perceptions..." (B 161). The peculiarity of Kant's procedure is that experience is given immediately with its object, since these

objects cannot be defined beyond the connection imposed on them by categories.

So, the transcendental deduction of categories allows us to determine the procedure of actual experience synthesis that consists in a set of perceptions and appearances arranged by categories as rules of reason. This resolves into the following scheme of generating actual experience:



Where Apl is an a priori intuition, S – sensations, EI – empirical intuitions, SofA – synthesis of apprehension, P – perceptions, FS – figurative synthesis, A – appearances, C – categories, AE – actual experience.

Analogies from the AI

In the beginning of the paper I mentioned that an autonomous IS that includes perceptions necessarily comprises the inner representation of the object field as an ontology. Though in contemporary literature on this field of AI, the ontology is usually interpreted as “knowledge on the object field organised by certain methods and means of knowledge representation” [11], for the approach adopted in this paper, this definition seems to be insufficient. The

reason is that the ontology of an autonomous IS should be coordinated with the type of information it receives from the environment through the perception block and serves as one of the bases for decision making. In this case, I think, the whole Kant's procedure of the ontology construction can be consecutively applied. Thus, now I will try to outline general ways of the application of actual experience construction procedure to the synthesis of an autonomous IS ontology. Since Kant's procedure has not been implemented in any AI system, I will refer to different attempts of constructing such systems involving certain steps of procedure analogous to Kant's ones.

For an autonomous IS, perceptions are the information received from sensors, while an a priori intuition is built in the perception block tools of preliminary sensor information processing. According to Kant's scheme, the IS knowledge base should contain a metaoperator that selects from chaotic input signals the signals that will form the material for further processing. i.e. belong to the field where further operators can be applied. Such analogue of Kant's SUA ("I think") can be, for instance, the operator of 'importance' that performs scanning for the object the 'attention of the system will be drawn to' [12]. So, Kant's "I think" creates the structure of the operator that fulfils two functions: 1) input of sensors' data relevant to the task to the field of the system's 'attention'; 2) connection of these data to the initial forms of perception that are peculiar to the system. According to Kant, this procedure results into empirical intuition, i.e. the signal of the presence of something undefined in the field of cognition, which is expected to become an object. If one draws an analogy from the field of scene analysis, it is, for instance, the combination of light spots that serves as the object of further analysis.

The next stage is the synthesis of apprehension, in the course of which, perception is derived from empirical intuition. Perception is the result of initial attempts to lo-

calise the object, which is inseparable from the method of localisation. For example, we choose a point (spot) as the beginning of apprehension and then outline the object under consideration. Moreover, there can be many perceptions (outlines) of one object. For instance, by modelling the limited world of toy blocks, Patrick Winston mentions that the computer programme should provide the solution to two problems: (1) the transformation of electronic eye signals into an outline, (2) the translation of the content of the outline into the language of statements about objects, their interrelations and properties [13]. The construction of perception lies in the realm of the first problem. In the world of toy blocks, perception is the outline from which objects are still to be determined.

The next stage, according to Kant, is figurative synthesis, where the a priori form of perception is being processed: space or time is constructed in an a priori intuition. If we continue with the world of toy blocks, figurative synthesis corresponds to the definition of the types of lines, junctions and figures in general that can exist in this world in connection with this outlines. So, the task of the procedure analogous to figurative synthesis is the definition of a set of forms corresponding to the perceptions received but already separable from the act of perception.

The next stage of experience synthesis, according to Kant, is the determination of perception objects, i.e. appearances. In modelling the toy brick world, the construction of a three dimensional body, which generates the outline, on the basis of the outline corresponds to this stage. How does this synthesis take place? Kant says: by means of transcendental (object) synthesis, i.e. formulating judgements, the subjects of which are single perceptions and predicates are forms determined by figurative synthesis. If we manage to compare the same form, this form will give us the object of the class of perceptions. In Winston's system, the stage of translation of the outline's content into

the language of statements about objects corresponds to transcendental synthesis.

This procedure results into the construction of objects. But, in order to build the corresponding ontology, we need their properties and relations. And here we are confronted with something completely new that Kant's procedure of actual experience composition contributes to the practice of the ontology construction. Since every act of synthesis (SUA, FS, TUA, SofA) takes place in accordance with categories; and categories are nothing else than general schemes of relations between appearances (objects), by constructing objects, we also obtain their relations.

In an autonomous IS database, this procedure creates a ontology, for which all statements of the basic fragment of knowledge are true and which is coordinated with the type of perception peculiar to this autonomous IS. Moreover, it determines the conceptual scheme of this ontology as a system of categories received at the stage of the analysis of the basic fragment of knowledge and forms the basis for the extension of this model.

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