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Mind, Symbolism, Formalism: Is Leibniz a Precursor of Artificial Intelligence?

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The assumption that Gottfried Wilhelm Leibniz is a precursor of the idea of Artificial Intelligence is misleading. The argument is to distinguish between episteme and mind, recognition and cognition. Leibniz interpreted formal symbolic operations as a mere epistemological instrument, but not as a description of what actually happens within the mind: Leibniz denied that a machine can be used as an explanative model of cognition.
(Author)

1. The Relation between Artificial Intelligence and Leibniz: a Common Misunderstanding

There is a broadly shared opinion within contemporary theories of mind: Rationalism in 17th century and especially Gottfried Wilhelm Leibniz' version, is a precursor of the fundamental ideas of Artificial Intelligence and Computational Theory of Mind (1, 2, 3). René Descartes' „mathesis universalis" interpreted as the project of a universal artificial language for producing and representing quantifiable knowledge (4); Gottfried Wilhelm Leibniz' „characteristica universalis" interpreted as an instrument to derive and to demonstrate all true sentences automatically (5): Are these ideas not the early versions of a research program which the pioneers of Artificial Intelligence, Allen Newell and Herbert Simon claimed with their dictum (6): That a mechanized physical symbol system is the necessary and sufficient condition for intelligent behavior? And which the Computational Theory of Mind (7, 8) condensed to the thesis that cognition is nothing but the computational manipulation of mental representations (9, p.11)?

But to claim Artificial Intelligence as a successor of the rationalistic philosophy in the 17th century is much to sweeping a statement (10). It is - in a certain sense - misleading and wrong.

To get this sense, we have to introduce a distinction. What Artificial Intelligence is about can be interpreted in a double way: we can sketch a quite excessive or a more prosaic picture.

Here is the excessive version: Artificial Intelligence is a kind of operative research on the human mind. Insofar as human cognition can be described as an algorithmic formal operation, and insofar the computer is a machine to execute formal procedures, the functioning of the computer is transferable to the human mind. What happens within our mind is the unconscious working of a computer-like mechanism. Thus the computer is an explanative model of the human mind: the mind is a kind of computer.

But the idea of a functional analogy between the machine and the human mind, is not a rationalistic one. More over: This assumption is inconsistent with the rationalistic concept of the mind: Leibniz (11) - as before him Descartes (12) - explicitly excluded that a machine is of use as a model of the mind. If the association of Leibniz with Artificial Intelligence is based on the assumption that a machine gives us an explanative model of the human mind, then this assumption is wrong.

But we have a more modest version of what Artificial Intelligence is about: Artificial Intelligence creates real machines which are capable of executing virtual symbolic machines.

The history of the human mind comprises the evolution of the exterior instruments of human reasoning, particularly artificially created symbolic systems. If such a symbolic system is organized in form of an interpreted calculus, it can be characterized as a „symbolic machine" (13). Symbolic machines are culturally created epistemic technologies. They rationalize the process of problem-solving by means of external algorithmic processes of symbol manipulation. Interpreted in the context of this non-connectionistic symbolic technologies, Artificial Intelligence creates automatized symbolic machines.

Leibniz was an upholder of the epistemological usefulness of symbolic machines. He developed the idea of a formal system as a general instrument of knowledge procedures and he discovered the possibility of transforming a virtual formal system into a real machine. Thus there is a relationship between the Leibnitian theory of knowledge and the Artificial Intelligence program exteriorizing and mechanizing human intellectual activity.

But to interprete Leibniz as the pioneer of Artificial-Intelligence-as-a-model-of-the-mind constructs a continuity where we actually find a significant gap. It is the gap between a certain external epistemical technique and its internalization into internal mental processes (14). In this view, mechanized symbolic operations function for Leibniz as a methodological prescription and not as an explanative model: A formal system establishes a norm how we should think if we want to get true knowledge, but it is by

no means a description of what we actually do if we are thinking.

To be aware of this difference, may be a way to make us more subtle and sensitive for the question what is a promising aim and what is a dead end in Artificial Intelligence research.

2. Reducing Truth to Correctness by Symbolic Machines

Let me first demonstrate that calculization is for Leibniz an exterior technique of reasoning.

Besides the experiment in natural science, the invention of the calculus is the most momentous scientific innovation of the early modern era. „Calculus" is understood not only in the restricted sense of the infinitesimal calculus but as a general technique of reasoning and demonstrating. Leibniz is - as far as I can see it - the first to get the idea of the general epistemic benefits of calculized operations. A benefit which is connected with the rationalistic project of reducing truth to correctness. But before we reconstruct this idea, we have to sketch an epochal change, the threshold of which is marked by the work of Leibniz. This change may be described as the transition from an „ontological symbolism" to an „operative symbolism" (15).

2.1 From „Ontological" to „Operative Symbolism"

„Ontological symbolism" means that a symbol refers to an object which exists independent of its symbolic representation. If our intellect operates symbolically, it really operates with the „things" the symbols stand for. Under this condition the idea of rules to manipulate symbolic expressions which are independent of its interpretation cannot arise. Within ontological symbolism formalism is excluded.

This changes, however, with „operative symbolism". Here the interpretation of symbolic systems is detached from its construction; the rules of forming and transforming the symbols are not depending on their meaning any longer. Within operative symbolism the process of symbolic activity gets a certain self-sufficiency. The characteristic feature of the operative symbolism is the calculus, a formal system which can be interpreted in different ways.

Although „ontological" and „operative" symbolism are idealized categories, we may recognize that during Greek antiquity - the era of the formation of classical tragedy, science and philosophy - „ontological symbolism" was the dominant model - even in mathematics. But in the premodern era of the 15th, 16th and 17th century the idea of operative symbolism got more and more influential.

The basic idea of operative symbolism is that we have not to take care of the meaning of the symbols when we manipulate symbols corresponding to pregiven rules. This independence of the signs from the signified objects, was only possible in the context of a media-invention: The invention of a non-linguistic art of writing.

Normally we interpret alphabetic writing as the spatial image of the temporal sequence of spoken discourse. But with the rise of written reckoning in the 15th century and with the invention of the symbolic algebra in the 16th century, a kind of writing emerges, which was not a transition from spoken into written language any longer. This writing - it is well known under the label „formal language" - functions as a pure graphical construction, a genuine writing system: We may spell out a formalistic expression, but we cannot communicate within a formalistic system.

The rise of operative symbolism in the premodern era was possible only in the context of the discovery of formal writing systems as a medium for knowledge acquisition and demonstration.

2.2 Leibniz' Contributions to Operative Symbolism

Refering to the shift from ontological symbolism to operative symbolism Leibniz is a - perhaps the - dominant figure. And it is just his insight into the functioning of a formal system, that gives him the idea that reasoning and consciousness may be separated if thinking can be calculized.

Descartes in his „*Regulae ad directionem ingenii*" still supported, that to operate with intellectual symbols presupposes a permanent awareness of the symbolized objects (4). But Leibniz discharged this awareness with the following arguments:

(a) All our reasoning is based on sign processes: „*ratiocinatio omnis in usu characterum constitit*" (16). The reason for the indispensible semiotic nature of the human intellect is, that the finite human mind is insufficient for grasping the infinitely many attributes which things possess. Thus instead of having an unmediated experience with the objects of knowledge, we build symbolic structures to represent these objects (17). But this can be done in multiple ways.

(b) Our natural language is the most influential representational medium. With its vagueness, its metaphoricity and its grammatical variability, every day language serves very well for our communicative behavior, but it is inadequate for our cognitive activities (16). Thus we have to look for a language which can be used as a technique. Such a symbolic instrument for reasoning cannot be found, it must be produced - artificially.

In contrast to the fleeting nature of human speech, such a „language" should be a system with an ongoing fixed materiality, which speaks not to the ears but to the eyes. Leibniz called such graphical signs which are independant of speech, „*characteres*". Characters are of permanent material stability, with the consequence that they can be manipulated. Within mathematics, systems of characters have already been established which successfully function as cognitive instruments (17). These are the socalled *calculi*.

(c) The prominent example for the operative use of a calculus is the decimal numeral system. Like every calculus it has a double function: It is a *medium* for representing infinitely many numbers with a finite alphabet of numerals and at the same time it is an *instrument* to operate with numbers by the manipulation of the numerals according to algorithmic rules. With the decimal numeral system, written reckoning becomes a cultural technique. For Leibniz a reckoning-rule has the status of a rule to transform signs (18): The concept of the algorithm is born.

With the dissemination of the decimal system the use of a formal language became a model even for higher mathematics. The invention of *Letter Algebra* by Francois Vietc, *Analytical Geometry* by René Descartes, and - last not least - *Infinitesimal Calculus* created by Leibniz himself: these mathematical achievements were all based on the construction of calculi.

(d) The dodge of a calculus is, that the rules of forming and transforming the characters do not refer to the meaning but only to the syntactical features of the characters. The construction and the interpretation of calculi diverged. Leibniz was aware of this detachment:

He characterizes the profits of his infinitesimal calculus as the possibility that the mathematical operation with the differentials becomes independent of beliefs concerning the „ontological nature" of infinite mathematical objects (19). Unlike the proponents and the opponents of his calculus, who both interpret his calculus in a denotational manner, Leibniz emphasized that the inner coherence of his calculus does not depend on the metaphysical dispute how to interpret the differential symbolism (20). To calculate correctly does not presuppose an answer to the question, if an infinitesimal magnitude exists as an actual or as a potential infinity (21).

Even concerning his logical calculi Leibniz stressed the autarky of his systems in relation to special interpretations: His logical calculi developed about 1686 can be interpreted in a multiple perspective, as extensional, intensional or modal systems (22, 23). As Detlef Thiels argued: They do not only allow different interpretations, but seem to be constructed for different interpretations (24).

When Leibniz sketched his *ars combinatoria*, the variations, permutations and combinations of the strings of signs do not refer to a special referent: A diversity of referential domains is possible. Leibniz stresses: If we interpret the signs as multitudes, we get Algebra; if we interpret them as spatial points, we get Geometry, and if we interpret them as terms, logic is the result (17, p.531).

(e) But Leibniz was not only a practician of calculization, he also got the concept of a calculus and of calculizing reasoning. A concept which is exemplary realized in, but not limited to Mathematics and Logic (16).

To use a calculus as an intellectual instrument, two conditions have to be taken into account: (a) There must be given a symbolic system consisting of a finite repertoire of characters and rules to form and transform strings of characters. (b) An interpretation for the calculus must be discovered, which stated a connection between the objects and the calculus in such a way, that the legal formulae of the calculus correspond to true sentences about the objects represented. Insofar as (a) and (b) is fulfilled, problems of the domain in question can be solved by the aid of mechanized symbolic operations. A complex and complicated intellectual action can be reduced to the rule governed manipulation of signs. The calculus serves as a „*filium Ariadne*" which directs recognition under the condition, that we have no immediate access to the world. Leibniz calls this kind of calculized, non-intuitive recognition „blind or symbolic reasoning" (25).

(f) Leibniz tries to generalize the operative function of formalizing. He had the vision of a „*scientia generalis*" organised as an „*ars characteristica*" (16). Within this „*calculus ratiocinator*" all true sentences would be mechanically derived and refering to each sentence it would be decidable, if it is well formed or not, that means, if the sentence is true or wrong. With such a „*calculus ratiocinator*" all knowledge acquisition and all knowledge proving would be an effective procedure. Errors of reasoning would be pure mistakes of calculization.

The research of Gödel, Church and Kleene in the 20th century has demonstrated, that such a universal calculus is logically impossible. But what is not impossible, is the invention of „local" calculi; that are formal systems which represent a limited region of objects (26).

2.3 Followers of the Leibnizian Program

Concerning the connection between Leibniz and Artificial Intelligence, it is of importance only, that the Leibnizian program of calculized reasoning as a „scientific practice" and as a „prophetic concern" has established a certain tradition. The precursor of this tradition is the Katalanian philosopher and theologician Raimundus Lullus (1235-1315), its followers are George Boole (1815-1864), Gottlob Frege (1848-1925), the young Wittgenstein and Rudolf Carnap. This tradition is marked by four assumptions:

(a) Rational thinking can be made explicit by algorithmic procedures within a formal symbolic system.
(b) These formal procedures can be interpreted in a numerical and in a logical perspective.
(c) The semantics of the formal expressions is a compositional semantics, that is: semantical differences are definable as syntactical differences.
(d) All knowledge is propositional or can in principle be transformed into a propositional format.

But what is missing is the idea, that calculized operations on symbolic representations is something which happens inside the human mind. Neither for Leibniz nor for Boole, Frege, Wittgenstein, or for Carnap formal procedures are explanations of mental processes which actually take place, if we are thinking. Mechanized

reasoning establishes a methodological norm how to acquire reliable knowledge and is not a description how the mind really works. An epistemological technique is intended, but not a theory of the mind.

As far as I can see Alan Turing is the first author, who claimed, that effective procedures which can be executed by a machine, are suitable descriptions of human cognition (27, 14). With Alan Turing there is a shift from „operative symbolism" to „mental symbolism". But this process of the internalization and transformation of formal procedures into mental representations and mental events is another subject.

We should know more about Leibniz' refusal of a machine as a possible model of the mind.

3. Why a Machine is not a Model of the Mind

In Leibniz' oeuvre we can find initial stages of the insight, that formalization and mechanization are equivalent procedures: They are concepts with the same extension. The consequence is, that if an intellectual activity is formalizable, it can - in principle - be executed with a real machine.

Leibniz tried technically to realize the symbolic machines, he had created. He designed the first four-species adding machine (28). He invented the binary numeral system and algorithms to operate on binary representations; and he tried to outline a machine working on the digital numerals (29). Furthermore we have some blueprints of logical artefacts and machines.

3.1 Consciousness Cannot be Explained in Mechanized Terms

But the machine did not serve as a model for the human mind. Leibniz - as Descartes - refused the idea of an analogy between the machine and the mind. The most famous reference is his thought-experiment in the „Monadologie" (30). Leibniz argued: Imagine that we could design a machine capable of perception, thinking, and consciousness. Imagine further that we could enlarge the machine to the dimensions of a mill so that we could enter it. What we will find inside is the mechanical movement of the parts of the machine, but we look in vain for something which can explain consciousness. Thus consciousness or perception „is inexplicable by means of mechanical reasons, that is by means of shape and movement" (30, § 17).

We seem to be confronted with a paradoxical configuration. With regard to calculized reasoning, thinking can be externalized as a formal operation, that is: it can in principle be mechanized. But concerning mental activity, that means: the concrete working of the human mind, thinking cannot be explained in technical terms. The split off between mind and consciousness is possible for the epistemic operations, but impossible for our cognitive behaviour. The question is: why?

3.2 The Distinction between Episteme and Mind, Recognition and Cognition

Here a Leibnitian distinction is relevant. It is the difference between „*essentia*" and „*existentia*" (31). „Essence" is the intelligible nature of things, the homogeneous result of abstract thinking, the status of which is possibility and virtuality. But a possibility which is realized, is „existence". For Leibniz whatever exists, exists as an individual being, that is: as a monade. Existence is concrete, it is individualized essence.

What really exists represents the world from an indispensible individual point of view. For some monads this representation is a kind of unconscious perception, for some it is a conscious perception and for some - Leibniz calls them „souls", „minds" or „spirits" - it is apperception or self-consciousness (30). Having self-consciousness does not only mean to be able to use the intellect, but to show reflective activity, to speak of the „I" and the „Me" and to have a will (30, § 30). With regard to minds Leibniz speaks of „being free".

We have not to investigate here the complicate relation of reasoning, speaking and willing. What is of relevance here is the fact, that „episteme" in the sense of intersubjective reasoning procedures and „mind" in the sense of the individual cognitive activity represent the difference between „*essentia*" and „*existentia*": Cognition is the concrete performance of an existing, an individual being, whereas calculized recognitions are epistemic strategies belonging to the region of „*essentia*". To think of a calculus as a predicate not of the episteme but of the concrete working of the human mind, would be a category mistake: Abstract essence would be confused with concrete existence.

Because mechanized recognition is an epistemological ideal, the inference from epistemic procedures to the functioning of the human mind is inadmissible. Thus Leibniz excluded that the machine can serve as an explanative model of the human mind.

3.3 The Compnter not a Tool, but a Medium of the Human Mind

It is not by chance that the Leibnitian program of calculized reasoning is located within the area of Enlightenment. Striving to enlighten the people, was based on the assumption that the natural light of human reason was distributed to everybody and it was of relevance only to get people to use their mind in a correct way. Calculized thinking was the project of transforming truth into correctness, an epistemological knowledge-technique, necessary just because the normal activity of our mind is not wworking in this way.

If we interpret symbol-oriented Artificial Intelligence in the horizon of the long lasting history of calculizing and nowadays even automatizing the exterior symbolic operations, this perspective gives us a fruitful explanation of what is happening within AI. But to pretend that

the formal procedures of the computers are an example for the inner functioning of the mind, transforms a culturally created medium into the natural equipment of the mind. For Leibniz the situation is the other way round: The impossibility to explain the phenomenon of consciousness in technical terms, is a hint that our mind in its mental life does not work like a mechanism, because it realizes an indispensible subjective point of view. But intersubjectivity as an epistemological ascription cannot substitute subjectivity as a cognitive description.

What do we learn from this story? Whatever a machine is doing, should not be expressed in terms of substituting human beings. Incredible overestimation and groundless fear, both are founded on such an anthropomorphic conception of technical artefacts. Symbolic Artificial Intelligence physically realizes symbolic machines. It creates a kind of entities the use of which is notto do better what humans already do quite well, but to facilitate experiences, we do not have without the computational apparatus. The computer should be interpreted not as a tool - or a model - of the human mind, but as a medium of human knowledge.

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