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Beyond Shannon is beyond AI

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1. Introduction

Systems of artificial intelligence (AI) are powerful search tools and are useful as chat bots. However, they are characterized by some kind of “limitation”.
On the one hand, nobody can express in scientific terms the nature of this “limitation” at the time being. On the other hand, the relevance as well as the extend of this limitation can be measured by the hundreds of billions of dollars which are spent to overcome it, with the goal of creating a so called “artificial general intelligence”, which is supposed to be free from said limitation.
Spending this money makes sense only, if said limitation is only due to the limited amount of available computing power. Then spending money in order to increase computing power would make sense.
If said limitation instead is of a more fundamental nature, then it might not be overcome by increased computing power.

Many people believe, that they are doing mathematics, when they for instance do a division. Investigating the historical record one finds instead, that the algorithm for division learned at school as well as the algorithm used by the most advanced computing systems is nothing but an accounting tool from late medieval times [1],[2]. Knowing this helps to obtain a better understanding of our present situation.
In a similar way one should begin a study of the foundations of AI with a study of the historical record: if AI is limited by a fundamental flaw, this flaw might have been introduced *m*any decades ago, so that it had time to become a standard, due to the normative force of the facts.

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2. Shannon theory

Until today, information theory is based on the work of Shannon. In the second world war Shannon studied for the war effort the transmission of messages through analog radio devices. The main subject of his study was the effect of noise on the signal transmission: for instance, if the receiver of a message understood orders sent by headquarters wrongly due to noise in the transmission line, friendly fire might have been the result. To avoid this was Shannon's subject of study.
And since noise is a statistical phenomenon, Shannon based his work on the mathematical field of statistics.

This leads to a first observation, relevant for a better understanding of artificial general intelligence: a few decades after Shannon, analog message transmission was substituted by digital transmission. In practice, this eliminated the problem of noise. Nowadays one can send an email to thousands of people, and each of them will receive precisely the same email, without any noise whatsoever. Therefore there is no reason anymore for basing information theory on statistics.
AI has therefore no base in mathematics, it is not a "science" in the traditional sense, but merely a "technology".

After the war Shannon summarized his research in a book, which is until today the foundation of information theory [3]. On the first page of his book he writes:
"The fundamental problem of communication is that of re-producing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning; .... These semantic aspects of communication are irrelevant to the engineering problem. "

Already the statement "frequently the messages have meaning" is difficult to understand: in reality, a message is characterized by having a meaning, a message without meaning can hardly be considered a message. A more correct statement would be "always the messages have meaning".
By excluding the meaning of the message from the engineering problem, as a consequence all instances of information processing based on Shannon's theory will not have access to the meaning of a message. Said differently, they cannot possibly understand the meaning of the message, they cannot understand the message.
This is a fundamental problem, which hardly can be overcome by means of computing power.

If now Shannon's thoughts were scientifically correct, and the resulting information theory were unambiguously correct scientifically, then machines, which can understand messages (texts or images) would be forever impossible.
But so would brains. But brains do exist and function well, understanding what they are seeing.

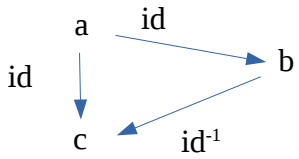
It is therefore worthwhile to analyze Shannon's argument in more detail:
He requires, that ideally the message sent and the message received should be materially identical. For instance, digital messages should be identical bit by bit.
The reason for this requirement is unambiguously clear: the receiver of the message must understand the message correctly, or said more precisely: the meaning of the message sent and the message received must be the same.

So in reality Shannon does the contrary of what he says: instead of excluding the meaning of the messages from science, he introduces it to science, by defining a fundamental measurement for messages: according to Shannon, two materially identical messages have the same meaning. Against his intention, Shannon has introduced the “meaning” of messages to the realm of natural science.

3. A physics measurement procedure

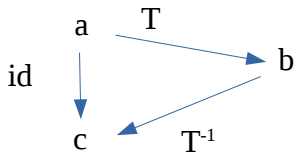
The Shannon concept for identical messages is not yet a physics measurement procedure. For example, when one sends a message from Berlin to New York, one cannot compare the two messages, because they are at different places in space. (This is similar to the problem which led Einstein to the theory of relativity: how can one synchronize clocks which are distant from each other in space?).
There is only one possible solution to this problem: one needs to send the received message back to Berlin, so that this returned message can be compared to the original message at Berlin. If they are identical, one can (at least from a mathematical point of view) assume, that they are also identical to the message at New York.
The transmission of a message can be understood as an identity operation, so for sending the message “a” from Berlin to New York, and referring to the received message as message “b” one would write $b=id(a)$. And sending back the message to Berlin would result in $c=id^{-1}(b)$.
The measurement procedure can then be expressed by a fundamental graph of category theory [4]:

Figure 1: measurement procedure for transmission of messages.



This measurement procedure can be generalized by applying any kind of message processing, T, instead of the most simple case of message processing, which is id.

Figure 2: general measurement procedure. If this graph is true, a and b have the same meaning.



T can for instance be a translation from English to Chinese: when the text a is translated from English to Chinese, resulting in the Chinese text b, $b=T(a)$, and if the translation of text b back from Chinese to English $T^{-1}(b)$ is identical to the original, a, then the Chinese text and the English text must have the same meaning (this is only to introduce the basic principle. For its application, further steps need to be considered, for instance several slightly different texts might all have the same meaning, as discussed later.)

From this discussion it becomes clear, that understanding the meaning of a message is an issue of mathematical structure: figure 2 suggests, that the set of input messages and the set of output messages need to be isomorph, if one wants to get access to the meaning of the messages.

A rational discussion of Shannon's work therefore leads to the necessity to discuss and to understand the mathematical structure of the information processing system. This is in contrast to the situation of state of the art computing: in Turing's theory mathematical structure is no issue, because Turing machines explicitly are imagined as general purpose machines. While Shannon theory, as explained above, is based on an obsolete mathematical framework.

In a next step we will show, that a physics of information has the potential to overcome the shortcomings of AI technology. First, we briefly summarize what is known about the mathematical structure of information processing:

4. Algorithmic and mathematical structures

Since the work of Schoenfinkel it is known, that a certain task can be performed (meaning "a precise mapping of input to output can be performed") by different programs with different mathematical properties [1],[5]. Can one then identify among these possible algorithms a "most suited" or "most natural" one, or are the mathematical properties of programs irrelevant?
It was then shown that even algorithms, which perform the basic operations of multiplication or division, do not have a defined axiomatic mathematical structure, so that their properties are different from the properties of their respective mathematical functions [1] .
It was next shown, that it is possible to write an algorithm with the same properties as the mathematical functions of multiplication and division. The same argument was also discussed for the functions of addition and subtraction in [6].
This fact – that even when performing a well defined mathematical operation as division or multiplication - different algorithm with different mathematical properties may be used for doing the correct mapping from input to output, will be referred to as "algorithmic ambiguity".
(For the case of multiplication and division a historical search shows, that nowadays used algorithms without any axiomatized mathematical structure date back to late medieval times, they were accounting tools, created by an accountant (A.Riese), not a mathematician [2]. They were published in a book whose title clearly says, that these tools were inspired by the mode of operation of the abacus [3].)

In a next step, one finds, that for instance addition can be expressed in terms of axiomatized mathematical structure in the frame work of category in two different ways:
either as a coproduct. Then, in a+b=c a, b and c are objects of a category (alternative 1).
Or instead one can consider "+b" to be a morphism, which maps object a to object c (alternative 2).
This ambiguity cannot be resolved within the field of mathematics or information theory. It can be resolved by means of physics. For this purpose, a counting experiment is suggested in [1], based on thought experiment proposed by Wittgenstein [7]. One finds, that (alternative 1) is in contradiction with reality, while (alternative 2) is in agreement.

This shows, that there are mathematical structures which are equivalent to the structure of nature or of reality, and there are other mathematical structures, which are not. One may refer to this situation as “mathematical ambiguity”.

5. General computation

Any mathematical function on a finite number of input values can be expressed by means of a lookup table, which associates to each possible input value the corresponding result. For instance, addition or multiplication of two numbers can be done by a lookup table.
The size of such a general lookup table – listing all possible results – may be very large. For instance, for multiplying two 16 bit long numbers, one needs a lookup table with 2^{32} elements.
For the case of mathematical functions, which always have a well defined mathematical structure, one can substitute this large general lookup table by an ordered system of small lookup tables. Such a system is referred to as “algorithm”. An example is figure 1 of [1].
Also a general image recognition system can be created from a lookup table. For instance, an image with 1.000.000 pixels can show $2^{1.000.000}$ different pictures. A lookup table with $2^{1.000.000}$ elements would then contain a description of each of these pictures. Again, the creation of such a general lookup table is not practical for several reasons.
The question is then, whether one can reduce the size of this table, because of its mathematical structure, conserving this structure, or the relevant part of it.

6. Image recognition

As a simple introductory example we choose a very limited world, or a limited part of the world: a tool board with 30 different tools. We want to supervise this tool board by an optical control system, which shall inform us of whether some tools are missing. Each of the 30 different tools can be or can not be at its precise location. So the tool board can be in one of 2^{30} states. “Supervision” here means, that the system is to give a correct description of the actual state of the system by means of providing a list of tools present.
Correspondingly, there are 2^{30} images, so our image recognition system would need to consist only of 2^{30} elements, independent of the number of pixels in the image. The problem has a clear axiomatized mathematical structure:
The 30 different tools form a Boolean algebra with 30 elements,
also the 30 images of these tools form the same Boolean algebra,
and so do the 30 descriptions of these tools.

This structure allows to create a surveillance system, which verifies for each of the 30 possible positions the presence or absence of the corresponding tool at this position, creating a list of tools present: for each set of tools, the corresponding set (or list) of descriptions is produced.
Making in this way use of the mathematical structure of the problem permits, to substitute the general lookup table with 2^{30} elements with 30 lookup tables with 1 element each.
In spite of this large reduction, input and output are still isomorph.

Using Shannon's term "meaning", the surveillance system has access to the meaning of the images, it "understands" what it is seeing.

This system can then be further improved and extended, always making use of well defined mathematical structures.
For instance, in our example it was implicitly assumed, that the presence of a certain tool at its position will always result in the same pixel pattern at this position, so a one-to-one comparison pixel by pixel is possible. In reality, noise in the pixels and geometric uncertainties may produce slightly different pictures of the same tool. This problem can be resolved still within Boolean algebra by making use of Boolean ideals.

7. Outloook

When instead objects can be at any position in space, Boolean algebra is not sufficient anymore. One needs to add Euclidean vector algebra. In pre-categoric mathematics, this situation would not be easy to handle, since conventional mathematics is subdivided in many fields, like Boolean algebra, vector algebra etc. The task is made easier by category theory, because a category may contain morphisms from different fields of mathematics, in the same way as the "outer world" contains different fields of mathematics.

In this discussion no specific technical requirements on the kind of information processing systems were made. What was said can be applied to computer systems as well as human brains. There, the arguments proposed in our discussion, find their correspondence in the mirror neurons discovered by G. Rizzolatti in monkey brains, and the Hale Berry neurons in the human brain. A "Hale Berry neuron" is a neuron, which is associated to the set of all possible images of a certain person, for instance. Likewise a contract with a certain meaning would be defined by the association to a set of contracts.

In difference to AI scenarios, a physics of information scenario does not lead to dystopic previsions of the future, and it does not marginalize the human being in any way, quite in contrary. This should be subject to a separate future discussion.

8. Data centers

AI is in need of data centers of a dystopic size, and the construction of these data centers has already begun. This leads to an absurd situation: on the one hand, AI has the goal to become more similar to the human brain, on the other hand the human brain has a power of about 20 W, compared to the Gigawatts consumed by those data centers – obviously what AI is doing, is not at all similar to what the brain is doing.
As is generally known, the data centers are needed in order to create statistical distributions, not to create axiomatized mathematical structure. Effectively, the data centers constitute an effort to substitute mathematics by huge amounts of money and electrical energy and water.

Instead of spending billions of dollars for these data centers, one could invest a few millions for developing the physics of information. Programs written according to the physics of information do not need any training and therefore do not need data centers, since they simply reflect the given mathematical structures of reality.

9. Conclusion

We have shown for the first time, that present AI technology is not able to create artificial general intelligence from an increase of computing power. Likewise, traditional AI cannot create autonomous drones, or loitering drones without glass fiber cables, from increased computing power.
In the normal use of human language (Wittgenstein), somebody or something which has no access to the meaning of a message and does therefore not understand the message, would never be called “intelligent”. In so far the term “artificial intelligence” is misleading. A more precise term might be “fake intelligence” (FI).
The physics and mathematics arguments, which lead to these negative conclusions, at the same time lead to a positive conclusion, too: based on science, information processing systems can be build, which are by far superior to traditional FI technology, continuing a scientific development interrupted in 1933 [1].

The impact of these technologies on the position of the human being in the world needs to be discussed in future separate studies. For the time being it might be sufficient to mention, that from a scientific point of view there is absolutely no reason for expecting dystopic scenarios (which instead result from FI).

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