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THE POSSIBILITY OF MACHINE INTELLIGENCE AND THE IMPOSSIBILITY OF HUMAN-MACHINE COMMUNICATION

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ABSTRACT

One of the neglected topics in the few studies on the foundations of Artificial Intelligence is the nature of human-machine communication and the nature of machine intelligence. The major contribution of this paper is showing that human-machine communication is impossible and pinpointing the logical consistency of this conclusion with both that of the attainability of machine intelligence and that of the possibility of human-human communication.

To reach our conclusions we: (a) assume that the mind-brain identity theory, and the theory of evolution hold true; and (b) *appropriately* define the notions of "machine intelligence" and "communication". Our definition of machine intelligence is based upon the key requirement that, to be appropriate, such a definition must capture the *evolving* characteristics of machine intelligence. The cornerstone for an appropriate definition of communication is the notion of understanding. To this end we first define communication in terms of understanding and subsequently define and justify the notions of human-understanding, machine-understanding, and understanding.

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1. Introduction

> "I propose to consider the question, "Can machines think?" This should begin with definitions of the meaning of the terms "machine" and "think.""
>
> (Turing 1950)

A discipline may progress in two ways: (i) by posing and solving questions internal to itself; and (ii) by trying to critically assess its foundations. Work in Artificial Intelligence has largely been of the first kind. To a large extent this should be due to the fact that leaders of the field like Minsky (1968), Nilsson (1980*1982)[1], McCarthy (as cited by Kolata 1982), through their firm belief to the possibility of artificial intelligence and their unquestioning attitude to the philosophical foundations of the field, contributed to the complacency of the community at large.

Of course this is not to say that foundational work has not been done at all rather that such work (eg, Newell and Simon 1976, Newell 1981, Pylyshyn 1984), addressed the issue of extending and elaborating some of the fundamental assumptions of the field rather than investigating their validity.

Work on the closely related issue of the attainability of the engineering goal of AI has been considerable and varied. Some took a neutral view on the AI problem (eg George 1956). The majority argued against the possibility of realizing artificial intelligence (see, for instance, Ziff 1959; Dreyfus 1972; Searle 1980). Still others decided to attack Turing's test itself instead of the AI question (eg Gunderson 1964), whereas Turing (1950) was the only one who attempted to produce an argument to support the attainability of the engineering goal of AI. Turing's reasoning and a discussion of its inadequacy is presented in Gelepithis (1988).

Interestingly enough, in all cases of opposition the arguments produced were based on assumptions which were neither shared by, nor shown to be preferable to those of, the AI community. A comprehensive survey of such views, the neutral views concerning the AI problem and an indication of their incoclusiveness is given by Gelepithis (1984).

On the other hand Turing's reasoning for AI, although dispelled a number of irrelevant objections to machine intelligence and produced numerous hotted debates, it contributed very little in pinpointing closely related, fundamental questions. For instsance, his basic belief of an omnipotent programmability rather hindered fundamental discussion

[1] In the references below, in case of several editions or reprints the original edition is separated by an asterisk from the one I have used.

on the nature of human and machine languages. Another of the neglected topics in the studies on the foundations of Artificial Intelligence is the *nature* of human-machine communication and the *nature* of machine intelligence. This paper presents a summary of our investigations on these two closely related issues.

To investigate properly the nature of human-machine communication a clear, unambiguous conceptual basis is required. The elements of such a basis may be of two kinds. One, generally accepted principles, methodological assumptions, or theories. Two, appropriately defined meanings of terms. On the former our basic underlying assumptions are:

(i) The mind-brain identity theory[2]; and

(ii) The theory of evolution.

On the latter the key notions we have to define are 'machine intelligence' and 'communication'.

The key requirement for an appropriate definition of 'machine intelligence' is capturing its evolving characteristics. That requires us to define 'machine intelligence' in a way that is independent of both human constructability and of any human characteristics or features which might have been limiting its functions or development over time. An important consequence of these requirements is that they leave open the possibility of human-independent machine evolution. In other words in terms that would allow such a machine to develop itself in any way it may like. The following definition captures the essense of these requirements. By 'intelligent machine' we shall mean an entity which:

a) posseses sensors.

b) understands language.

c) is able to act on its environment.

d) is able to connect sensory, linguistic, and motor information.

In what follows I will use machine as an abbreviation for intelligent machine.

In accordance with the above requirements, words like understanding, language etc, have to be understood as stripped off their human connotations except if preceded by the adjective human. Finally, the notion of functional equivalence between machine and human may be invoked whenever a reader wishes to have a concrete, comparable realization of such a machine. One may, for instance, think of 'machine brain' as those structures (electromagnetic, molecular or whatever) responsible for the overall control of a machine.

[2] On this basis, in what follows, we use the terms mind and brain as synonymous and we consider the expressions mental states/processes as denoting the same things as the expressions brain states/processes. It should also be noted that although these identifications are highly contentious they do not affect the logic of our paper. For an exposition of, and a debate on, the mind-brain identity theory the reader is referred to Borst (1970).

For 'communication' we do not need to provide such framework requirements. It is generally accepted that (human) communication has to do with making something common (see for instance Cherry 1957*1980; Ogden and Richards 1923*1956):

"communication is always an act of sharing" (Cherry ibid p 306; his emphasis).

"Thus a language transaction or a communication may be defined as a use of symbols in such a way [t]hat acts of reference occur in a hearer which are similar in all relevant respects to those which are symbolised by them in the speaker." (Ogden and Richards ibid pp 205-206).

More specifically, human communication has been described in terms of mutual understanding. Everett Rogers, professor of International Communication at Stanford University writes:

"*Communication* is the process by which participants create and share information with one another in order to reach a mutual understanding." (Rogers 1986 p 188; his emphasis).

Our problem therefore, becomes one of defining understanding. Section two does exactly this: we define and justify the notions of human-understanding, machine-understanding, and understanding. In section three, our argument for the impossibility of human-machine communication is developed and the logical consistency of the attainability of artificial intelligence with the former conclusion is pinpointed.

2. The nature of Human Understanding

> "A number of laboratories around the world are investigating how to program computers to be a little more 'intelligent' than they are. Such studies soon came up against a fundamental problem concerned with 'understanding'. We have to discover, in rather precise terms, what is meant by 'understanding' a topic or a problem. Otherwise, attempts to get computers to do things normally requiring human intelligence, are likely to remain superficial and, in the long-run, unproductive."
>
> (Donald Michie 1974).

> "What is Understanding? What is consiousness? What is meaning? What does it mean to think? These of course, are philosophers questions. They are the bread and butter of philosophy. But what of the role of such questions in AI? Shouldn't AI researchers be equally concerned with such questions. I believe the answer to be yes and no."
>
> (Schank 1980).

Despite the centrality of the notion of understanding in AI and more generally in Cognitive Science the question of its *nature* has not been settled. Nonetheless, among the various attributes ascribed to understanding there are two which are virtually universally accepted. These will constitute the basis of our analysis. The first, is that human understanding always involves the grasp of meaning -whatever the latter may mean or hypothesized to be- (see, for instance, Anderson 1980; Franks 1972*1974). The second, is that human understanding (whatever it is) is a process (see, for instance, Dilthey 1900*1976; Greeno 1977; Ziff 1972) taking place in human brains (or/and minds). To our knowledge there is only one contemporary scholar (Moravcsik 1979) who has considered understanding as a state of the human mind. A critical review of the literature on the nature of understanding and reasons pinpointing the inadequacy of Moravcsik's view are presented in Gelepithis (1986); table 1 provides a summary we shall refer to again later on in this section. Our subsequent analysis is a logical extension of these two features of understanding, namely, its dependance on meaning; and its process nature. We start with the latter feature.

Viewed as a process, human understanding is required to be terminated. But although it may be accepted as obvious that the process of understanding should be terminated, it seems to be not obvious at all *where* it should be terminated.

Understanding is a special case of thinking. One may, for instance, be interrupted while trying to understand something and subsequently fail to catch again the thread of that particular reasoning. To be sure, there may be future recall of the interrupted process but our point here is only that at the time of interruption no understanding may be said to have occured. So, we conclude that not all terminated thinking processes are processes of understanding.

But let us assume that we witness a case of an undisturbed thinking process. When shall we say that one has achieved understanding? We have seen that just termination of the process is not adequate. What, then, additional conditions should be fulfilled in order to say that one has understood something?

Conceptions of Human Understanding

	Nature (Schools and Individuals)	Main advantage	Main disadvantage
PROPOSITIONAL	*Semasiosyntactic:* To understand a sentence in a language it is adequate to understand the meanings of the words comprising the sentence and know the grammatical rules of that language	Formalistic nature (applicability).	Inadequate requirements. Silent on the nature of understanding.
	Contextual: Semasiosyntactic requirements plus the context in which a sentence occurs.	Showed inadequacy of the semasiosyntactic approach.	As above
	Motivational: Contextual requirements plus knowledge of the motivation behind the utterance of of a sentence.	Showed inadequacy of the contextual approach.	As above (eg intention is lacking).
	Pask's work/view.	Powerful conceptual analysis.	Set of conditions given for understanding incomplete.
	Ziff's work/view.	Cleared several misconceptions in the study of understanding.	Too general to be useful.
HERMENEUTIC	*Majority of cases:* Understanding is seen as a primitive notion or, possibly, as a methodological tool (see, Ricoeur, Dilthey).	Ascribes to understanding its much needed significance.	Unnecessarily imprecise.
	Moravcsik: Understanding is seen as that state of mind which yields the insight that unites one's knowledge required to arrive at the solution to a problem.	Understanding describable in terms of knowledge. Partly successful criticism of the analytic school.	Against established linguistic conventions. Introduction of terms less clear than understanding itself eg, insight.

Table 1. The analytic (or propositional), and the hermeneutic (or non-propositional) views on the nature of understanding.

There is a particular thinking process which is closely related to, or comprises part of, human understanding which will help us to specify *where* human understanding is terminated. It may be called 'alleged understanding' or misunderstanding (Ryle 1949*1983 pp 58-59). Alleged understanding may be said to be the case whenever people think they have understood something only later to discover that what they had concluded was not the case. The key point in the event of misunderstanding is the fact that one's own predictions or explanations, according to his or her model of a situation, phenomenon, etc., turn out to be not the case. Assuming there was no fault in the inference process we conclude that there must have been mistaken premises. I use the word premises here in its most general sense to include things like beliefs, expectations, aspirations, and knowledge of any sort.

We see, therefore, that whenever misunderstanding is reached and no fault in the inference process is involved, there must have been some mistaken premises involved. We take this fact to be a strong suggestion that to reach understanding one's own premises, (concerning the phenomenon, topic, situation, etc. to be understood), must hold true. It is tempting, therefore, to postulate human understanding to be that thinking process at the end of which a description in terms of a set of premises, of whatever is attempted to be understood, is reached. In other words, the essence of human understanding is reducibility to a certain set of premises (equivalently reference beliefs or reference frame). Put in yet another way human understanding is a thinking process characherized by descriptive reductionism.

This leads us to the following definitional characteristics of human understanding.

1. Human understanding always involves the grasp of human meaning.
2. Human understanding is a process that takes place in human brains.
3. Human understanding is required to be terminated.
4. At the end of the process a description in terms of a human's own premises must be possible.

It follows that a human H is said to have understood S if and only if H can describe S in terms of a set of premises of his own.

The justification of our definition may be summarized as follows.

(i) It meets pinpointed inadequacies (Table 1); for it:

- provides necessary conditions for understanding.
- says what human understanding is.
- is in accordance with established linguistic conventions.

(ii) It satisfies the positive contributions of the propositional aproach (Table 1); for:

- Context, motivation, and principles can be seen as particular cases of a set of premises.

- The essence of the semasiosyntactic approach (ie, its formalistic nature) is accounted for as our definition implies the existence of a sequence of steps.

(iii) It satisfies our feeling for human understanding as a fundamental and central process (since we cannot resort to another cognitive process for describing understanding and we repeatedly try to understand something).

(iv) It does not violate the common sense of understanding as described by most dictionaries and encyclopaediae (eg Oxford, Longman, Brittanica).

(v) It is implicitly supported, in varying degrees, by the work of Nagel (1961), and Russell (1948).

Would a similar definition for 'machine understanding' stand? Let us see how the definitional characteristics of human understanding would read if we replace 'human' with 'machine'.

1*. Machine understanding always involves the grasp of machine meaning.

2*. Machine understanding is a process that takes place in machine brains.

3*. Machine understanding is required to be terminated.

4*. At the end of the process a description in terms of a machine's own premises must be possible.

We see that the above definitional characteristics of machine understanding do not violate the definition of machine we developed in section one. In fact they are congruent with the latter and we are therefore entitled to say that a machine M has understood something, S, iff M can describe S in terms of a set of premises of its own.

In accordance with the above definitions of human and machine understanding we shall say that an entity E has understood something, S, iff E can describe S in terms of a set of premises of its own.

3. Artificial Intelligence and the Impossibility of Human-Machine Communication

We saw, sections one and two, that human communication is best defined in terms of mutual understanding, and understanding, in turn, is defined as reducibility to one's own premises. We shall therefore say that a human H_1 communicates with another human H_2 on a topic S, if and only if, (iff), H_1 and H_2 understand each other on S. In other words H_1 communicates with H_2 iff H_1 understands S, H_2 understands S, and the two understandings are shareable.

To make subsequent presentation more compact we shall use the symbol U(H, S) to stand for the understanding a human H has on a topic S. We shall, therefore, say that H_1 communicates with H_2 on S iff $U(H_1, S)$ and $U(H_2, S)$ are shareable. In other words $U(H_1, S)$ is describable to and understood by H_2 ; and $U(H_2, S)$ is describable to and understood by H_1. The latter is equivalent with saying that the two understandings are describable and understood in terms of each other's premises. That is, $U(H_1,S)$ and $U(H_2, S)$ are shareable iff either $P_1 = P_2$ or P_1 and P_2 can be described in terms of each other; whereas P_1, P_2 are sets of premises for a topic S for H_1, H_2 respectively. It follows that a human H and a machine M can communicate iff either $P_H = P_M$, or P_H and P_M can be described in terms of each other. Is that possible?

Obviously, for such a description we need some human language, say L. Furthermore, for a machine to understand the 'described in L' human concepts it needs to understand L. It follows that H and M must be able to communicate on S = L. It is therefore required to describe L in terms of a set of premises. To analyse this requirement consider the following game.

Suppose we are given the words 'set', 'electron', 'water', 'pain' and we are asked to classify them in two mutually exclusive sets: either in the set of primitives P, or its complementary P'. It seems that 'set' falls in P 'electron' in P'. What about 'water' and 'pain'? It might seen obvious that H_2O being analyzable to its constituents parts and these in their turn to electrons should be placed in P'. Still I can think of no-one who would not place water in P. But even now we have problems, for 'set' and 'water' are two quite different primitives. Set can be a primitive for a mathematician whereas water is a primitive to anyone. What about 'pain' then? It might seems obvious to everybody that pain should be put in P, *but* Dennett (1978) has given a nice, although sketchy, model of pain; it follows we should put pain in P'. To summarise: Three out of our four words can be placed either in P or in P'. 'Electron' seems to be the only one of the four which can not be placed in P. Nevertheless, the class of concepts like electrons which can be placed in P' but not in P is not a singleton. Furthermore we notice that if we were able to distinguish electrons we could place electron in P but that requires sense experience which at present we do not possess.

What consequences can we draw from this game then? First, we may distinguish two stages in the development of human concepts: the first, let us call it the prelinguistic stage, which occured before the appearance of human language. The second, let us call it linguistic, after its appearance. Second, and more important, in correspondence to the linguistic and pre-linguistic stages in the development of human concepts, we distingusish two types of primitives: pre-linguistic (or sense) primitives and linguisic primitives. The former are the bottom-line building blocks on which human understanding may be built. As a consequence, of course, premises may be distinguished in prelinguistic (or sense) premises and linguistic premises.

So, to understand L requires someone to understand *both* human linguistic primitives *and* human sense primitives[3], since human linguistic primitives, (save purely linguistic ones), are related to human sense primitives. In other words, one finds himself in need of human sense primitives to understand human linguistic primitives *and*, at the same time, human linguistic primitives to describe the human sense primitives. One needs language to describe the senses *and*, at the same time, senses to understand language.

On this basis, let us now see why:

1. Human-machine communication is impossible. Whereas, both
2. Human-human communication; and
3. Machine intelligence are possible.

To help readers focus their potential criticisms we state at the outset that our argument for all three conclusions stated above is based on the second of our underlying assumptions, namely that, the theory of evolution holds true.

1. The human-machine communication case

We saw (page 8) that for an H, M to communicate with each other it is necessary either $P_H = P_M$, or P_H and P_M to be describable in terms of each other. Since P_H currently different from P_M, the second of the conditions must be realizable for either communication to be possible, or the first condition ever to become realizable.

We also saw that for P_H and P_M to be describable in terms of each other, H and M must be able to communicate on the same human language L. From our primitives game we saw that for a M to understand L it is required to understand both linguistic and sense premises (symbols P_{HL}, P_{HS} respectively). Such understanding requires M to possess both P_{HL} and P_{HS} , a requirement which can only be met if at least one representative from both P_{HL} and P_{HS} types were *given* to it by humans to start with.

Now P_{HS} may be *given* by only two possible procedures:

P_1: by description; and

P_2: by providing the carriers themselves of P_{HS} ie, the human sense organs themselves.

P_{HL}, of course, can only be described.

The case of P_{HS} being provided to a machine through the grafting of human sense organs, although extravagant and ethically questionable, to say the least, is nevertheless a possibility. Nonetheless, realization of that possibility would essentially mean that humans

3 To avoid possible misunderstandings let me introduce at this point two possible ways of looking at the relation between linguistic and sense primitives (more generally premises). From the neurophysiological point of view, and taking into accont the mind-brain identity theory, both linguistic and sense primitives must be identified with particular neural formations. The actual relation between (or among) such neural formations is, therefore, an empirical question outside the realm of current neurophysiology. From the logical point of view, linguistic and sense primitives are clearly distinct though closely related as our primitives game has shown.

have reconstructed themselves or more generally a symbiont which is, by construction, a superset of a human. P_2 therefore, leads to human reconstruction and subsequently does not affect the validity of our argument. We turn now to P_1 .

To describe (the meaning of) P_{HS} we need L. Furthermore, for a M to understand the 'described in L' P_{HS} it needs to understand L. But to understand L is equivalent to understanding both P_{HL} and P_{HS}. In other words we find ourselves in the vicious circle of needing P_{HS} to understand P_{HL} and P_{HL} to describe the P_{HS}. Put more concisely, to describe P_{HS} we need P_{HL} and these P_{HL} will not be understandable to our M except if related to P_{HS} and so on ad infinitum.

2. The human-human communication case

Since both human-human and human-machine communications are based on our generalized notion of individual understanding, what are the grounds for claiming impossibility for the latter case and possibility for the former? In a nutshell, human-human communication is achieved through the common background provided by the shared evolutionary past of all humans.

It is this shared evolutionary past which enables the sharing of P_{HS} among all members of the human kind. True, the headache of a particular individual is not the *same* headache that another human may develop. Nevertheless, both headaches have a common reference point: pain. Even if a human has never developed a headache or even any x-ache, pain remains a potential common reference point. One needs only to hit the so far ache-less individual! It is only in case of a human who has lost all sense of pain, as well as all memories of pain that ache-related communication between such an individual and a 'normal' human being may break down. Moreover, the richness of the shared evolutionary past of humans ensures that communication points can be found in even the most extreme cases of sense-deprived humans (eg, Helen Keller). Such a common evolutionary past simply does not exist between humans and machines.

3. The machine intelligence case

As we saw humans are fundamentally limited in *giving* machines the capability of understanding human language. Humans are only able to *give* formal, uninterpreted systems of information to machines. Naturally, such information systems provide machines with uninterpreted human premises. Such systems along with whatever additional information we, humans, have found useful to provide enable today's machines to carry out processing tasks on our behalf.

But of course, this limitation is only a human limitation. Machines may themselves *develop* their *own* premises through their *own* use of sensors and processing capabilities that we initially provided them with. This possibility may sound remote but we have no reasons to believe that it is impossible. Indeed, it is logically sound and in accordance with at least one of our theories for the emergence of human intelligence.

It follows that one should distinguish between 'machine understanding' in terms of uninterpreted human premises, what one should realy call 'machine-executed human understanding'; and machine understanding in terms of machine premises that humans may not necessarily know about. Similarly, one should distinguish between machine-exhibited human intelligence and machine intelligence proper. The former is already with us; the latter may well be too.

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