Chapter 2

A Practical Definition of Intelligence

1. WHAT IS INTELLIGENCE?

Studying mathematics, one learns that before one can use any term, one has to precisely define it. When I first started seriously thinking about how the mind works, I applied this approach rigorously, perhaps a bit too much so. Since then I've gotten used to non-mathematical ways and loosened up a bit, but I still find definition of terms a pretty good way to approach difficult problems. In this chapter, I'll pursue this strategy, but with a psychological rather than mathematical flavor. The theme is intelligence. I'm claiming the Internet is going to become a self-organizing, distributed, intelligent system. But what does this mean? What is "intelligence" anyway?

In the next chapter I'll take this one step further and ask: What is mind? And in Chapter 5 and Appendix 3 I'll take a more rigorous approach to both topics, giving a hierarchy of definitions starting with foundational concepts like pattern and simplicity and ending up with intelligence and mind. But first, here, I'll ask: What is intelligence? The ideas given in this chapter are very similar to those I presented in the chapter on intelligence in *The Structure of Intelligence* in 1993, but they've been simplified and fine-tuned over the years, and I think they're in fairly good shape now.

Without further ado, then: What does it mean to say the Internet may become intelligent? What does it mean to say that Webmind, a computer program, is intelligent?

Let me first say what it doesn't mean. Intelligence doesn't mean precisely simulating human intelligence. Webmind doesn't do that, and it would be unreasonable to expect it to, given that it lacks a human body. The Turing Test, "write a computer program that can simulate a human in a text-based conversational interchange," always seemed to me a bit silly. It's fine as an existence proof, which is how it was intended – Turing was confronted with people who believed AI was impossible, and he wanted to prove the existence of an intelligence test for computer programs. He wanted to make the point that intelligence is defined by behavior rather than by mystical qualities, so that if a program could act like a human it should be considered as intelligent as a human. Fair enough, and a bold leap for the 1950's. But just because the Turing test is *an* intelligence test for computer programs, doesn't mean it's a good one.

But if we put aside the imitation of humans, and accept that an intelligent computer program is a nonhuman, alien being, then how do we measure or even conceptualize its intelligence?

I'm not going to propose a specific IQ test for computer systems. This might be an interesting task, but it can't even be approached until there are a lot of intelligent computer programs of the same type. IQ tests work fairly well within a single culture, and much worse across cultures – how much worse will they work across species, or across different types of computer programs, which may well be as different as different species of animals?

What is needed right now is something much more basic than an IQ test: a working, practical understanding of the nature of intelligence, which can be used as an intuitive guide for work on the development of intelligent machines. That's the goal of this chapter. The next chapter provides some formal definitions that quantify, among other things, the intuitions presented in this one.

2. A PSYCHOLOGY PERSPECTIVE

Though there is a vast psychological literature on intelligence, it contains surprisingly few insights into the foundational question which interests us here: what is intelligence, and how can it, practically or theoretically, be quantified? The problem is that, , theories of intelligence are not all theories of the same thing. Rather, they tend to be theories of different aspects of intelligence. To make matters worse, the theorists who propose these theories rarely make it clear just what aspects of intelligence their theories embrace

The confusion may be traced back to the turn of the century. First, Galton (1883) analyzed intelligence as a combination of various psychophysical abilities, everything from strength of grip to reaction time. And then, not too much later, Binet and Simon (1916) proposed that intelligence is a matter of problem solving, logical reasoning and spatial judgement. Binet's approach was of more immediate practical use – it led to the I.Q. test, which is fairly good at predicting certain aspects of behavior; e.g. at predicting which children are capable of benefiting from schooling. But aspects of Galton's theory have recently been revived. It is now clear that mental speed is closely connected with intelligence; and some modern psychologists have advocated studying intelligence in terms of quantities such as speed of lexical access. Now it is recognized that the ideas of Galton and Binet, though at first glance contradictory, are on most important points complementary: they refer to different aspects of intelligence.

My favorite psychological theory of intelligence is Sternberg's "triarchic theory", which proposes to synthesize several apparently contradictory currents in the contemporary psychology of intelligence. It seeks to understand the interconnections between: 1) the structures and processes underlying intelligent behavior, 2) the application of these structures to the problem of attaining goals in the external world, and 3) the role of experience in molding intelligence and its application. Let's consider these three aspects of intelligence in turn.

2.1 Structures and Processes of Intelligence

In the triarchic theory, the structures and processes underlying intelligence are divided into three different categories: metacomponents, performance components, and knowledge-acquisition components. From the point of view of internal structure, intelligence is understood as a problem-solving activity which is allocated specific problems from some external source.

Metacomponents have to do with the high-level management of problem-solving: deciding on the nature of the problem with which one is confronted, selecting a problem-solving strategy, selecting a mental representation of the problem, allocating mental resources to the solution of the problem, monitoring problem-solving progress, and so on. Studies show that all of these factors are essential to intelligent performance at practical tasks.

Metacomponents direct the search for solutions; but they do not actually provide answers to problems. The mental structures which do this are called performance components. These are of less philosophical interest than metacomponents, because the human mind probably contains thousands of different special-case problem-solving algorithms, and there is no reason to suppose that every intelligent entity must employ the same ones. Most likely, the essential thing is to have a very wide array of performance components with varying degrees of specialization.

For example, consider a standard analogy problem: "lawyer is to client as doctor is to a) patient b) medicine". Solving this problem is a routine exercise in induction. Given three entities W, X and Y:

1. the memory is searched for two entities W and X,
2. a relation R(W,X) between the two entities is inferred from the memory,
3. the memory is searched for some Z so that R(Y,Z) holds

This process is a performance component. It is not "low-level" in the physiological sense; it requires the coordination of three difficult tasks: locating entities in memory based on names, inference of relations between entities, and locating entities in memory based on abstract properties. But it is clearly on a lower level than the metacomponents mentioned above.

Some psychologists believe that the number of performance components is essentially unlimited, with new performance components being generated for every new context. In this point of view, it is futile to attempt to list the five or ten or one hundred most important problem solving algorithms; the important thing is to understand how the mind generates new algorithms. There is certainly some truth to this view. However, it may be argued that there are some relatively high-level performance components which are of universal significance – for instance, the three forms of analogy to be discussed in the following chapter. These general algorithms may be used on their own, or in connection with more specific procedures

This brings us to the knowledge acquisition components of intelligence: those structures and processes by which performance components and metacomponents are learned. For example, three essential knowledge acquisition components are: sifting out relevant from irrelevant information, detecting significant coincidences, and fusing various bits of information into a coherent model of a situation.

The importance of effective knowledge acquisition for intelligence is obvious. The ability to speed-read will help one perform "intelligently" on an I.Q. test; and the ability to immediately detect anomalous features of the physical environment will help one perform intelligently as a detective. One might argue that factors such as this do not really affect intelligence, but only the ability to put intelligence to practical use. However, intelligence which is not used at all cannot be measured; it is hard to see how it could even be studied theoretically.

2.2 Intelligence as Experience

The experiential approach to intelligence begins with the idea that most behavior is "scripted" (Schank and Abelson, 1977). Most actions are executed according to unconscious routine; and strict adherence to routine, though certainly the intelligent thing to do in many circumstances, can hardly be called the essence of intelligence. It would rather seem that the core of intelligence is to be found in the **learning** of new scripts or routines.

For instance, one might focus on the rate at which newly learned scripts are "automatized". The faster a behavior is made automatic, the faster the mind will be free to focus on learning other things. Or one could study the ability to deal with novel situations, for which no script yet exists. Insight, the ability to synthesize appropriate new metacomponents, performance components and even knowledge acquisition components, is essential to intelligence. It has been extensively studied under the label "fluid intelligence" (Snow and Lohman, 1984).

The relevance of insight to tests such as the I.Q. test is a controversial matter. It would seem that most I.Q. test problems involve a fixed set of high-level metacomponents, as well as a fixed set of performance components: analogical, spatial and logical reasoning procedures. In other words, in order to do well on an I.Q. test, one must know how to manage one's mind in such a way as to solve puzzles fast, and one must also have a mastery of a certain array of specialized problem-solving skills. However, in this example one sees that the dichotomy between metacomponents and performance components is rather coarse. It would seem that, to do well on an I.Q. test, one has to have a great deal of insight on an **intermediate** plane: on a level between that of specific problem-solving methods and that of overall management strategies. One must have a mastery of appropriate high-level and low-level scripts, and an ability to improvise intermediate-level behavior.

2.3 Intelligence and Context

One may look at intelligence as an array of structures and processes directed toward the solution of specific, externally given problems. One may understand intelligence as the **learning** of new structures and processes. Or – third in Sternberg's triarchy – one may hypothesize that

> intelligent thought is directed toward one or more of three behavioral goals: **adaptation to an environment, shaping of an environment,** or **selection of an environment**. These three goals may be viewed as the functions toward which intelligence is directed: Intelligence is not aimless or random mental activity that happens to involve certain components of information processing at certain levels of experience. Rather, it is purposefully directed toward the pursuit of these three global

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