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THE LEVELS OF HUMAN INTELLIGENCE

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The February, 2000 issue of Wired magazine contains a feature article by Kevin Warwick, a professor of cybernetics at the University of Reading in the U.K. Warwick describes the computer implants he has already inserted in his body and he rhapsodizes unabashedly about all the devices he can't wait to install so that he can realize his goal of becoming a true cyborg, the first of a new "race" of part-human, part-computer "creatures". I quote:

> *"... Humans are crazy enough not only to build machines with an overall intelligence greater than our own, but to defer to them and give them power that matters. So how will humans cope, later this century, with machines more intelligent than us?... Linking people via chip implants directly to those machines seems a natural progression, a potential way of harnessing machine intelligence by, essentially, creating super humans. Otherwise, we are doomed to a future in which intelligent machines rule and humans become second-class citizens..."*

To say the least, the quote is "highly disturbing". Like so many technologists, Warwick is calling for us to "save ourselves" by getting hooked up to the so-called "super intelligence" of computers. Once again, it is the all-too-familiar refrain that our salvation lies in, through and with technology.

At best, Warwick is confusing calculative speed with intelligence. At worse, he is saying that the essence of humans is their brains, which do not require a body or a "human housing" either to function or to exist. As we shall see, he is wrong on both accounts.

Warwick's may be an extreme position, but it is neither rare nor unique [Hayles, 1999]. He is merely much more open and positive about than many. His views are shared by a much wider following than one would like to believe exists. However, his confusion over the nature of intelligence is disturbing in someone so influential in the social construction and uses of technology.

One thing is clear. Whether one welcomes the prospect of human cyborgs, or one is horrified by it, the situation calls for the most demanding analysis we can bring to bear on one of the most important issues of all times. The key to any such analysis is our understanding of intelligence.

Given that my PhD on this very topic was over 30 years ago, it seems timely to repeat what is known about intelligence to the next generation of artificial intelligence (AI) enthusiasts. The issue of artificial intelligence is one of the most important and perplexing issues of the computer cum communications revolution, namely, can human thought be simulated?

This paper re-visits the findings and the conclusions from my PhD dissertation. It says that if you are going to build a machine that solves problems like humans do, then you need to incorporate the thinking of nearly all of the "other minds" with whom the initial mind interacts, and hence, are a "fundamental part" of that mind.

In short, human intelligence is fundamentally social. We not only learn from

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those to whom we talk and interact, but we are them.

TURING'S TEST?

In 1950, the renowned British computer scientist Alan Turing proposed a test to differentiate between humans and computers, and by implication, between humans and machine intelligence. It is known appropriately enough as Turing's Test.

Take any characteristic of human beings such as intelligence, emotions, creativity, etc., that you would like a computer to mimic. Then, put a "real, live" human being, or person one, in one room, and a computer in another. Next, put a second human being known as the judge in a third room. Now, give person one and the computer the same series of questions or tasks to complete. Then, feed person one's responses and the computer's to the judge.

Naturally, the judge does not know beforehand in which room the person or the computer is located. If the judge cannot differentiate between the responses of the human and the computer, then according to Turing's Test, the computer has successfully mimicked human behavior. In fact, the computer and the human should be regarded as identical.

Turing's Test is extremely important. This is not because it works or is necessarily a valid test, which it is not. It is important because prominent computer scientists believe it is a valid way to establish when computers have either become the equal of humans, or have surpassed them. For instance, consider what Kurzweil has to say:

> [By the year 2029,] computers appear to be passing forms of the Turing's Test deemed valid by both human and non-human authorities, although controversy on this point persists. It is difficult to cite human capabilities of which machines are incapable. Unlike human competence, which varies greatly from person to person, computers consistently perform at optimal levels and are able to readily share their skills and knowledge with one another.

A sharp division no longer exists between the human world and the machine world. Human cognition is being ported to machines, and many machines have personalities, skills, and knowledge bases derived from the reverse engineering of human intelligence. Conversely, neural implants based on machine intelligence are providing enhanced perceptual and cognitive functioning to humans.

Turing's Test assumes that a single person by his or herself is competing against a computer. Furthermore, it also assumes that humans judge the differences between the person and the computer. Could the person being simulated act as the judge? Could it decide whether its own responses are human-like or not? If you are uncomfortable with this idea, then you are getting a feel for the problem.

MY BIASES

Let me state my position and my biases as clearly as I can. I am not hostile towards technology in the slightest. I am in fact a techie-junkie of the first order. As my wife says, "If it plugs in, Ian has it." She refers to my study as "The Gadgetorium."

I cannot stress enough that I have a Ph.D. in Engineering Science with a major emphasis in Industrial Engineering from one of the world's leading schools of science and technology, the University of California at Berkeley. My undergraduate major in Engineering Physics was also from Berkeley. It was and still is one of the most difficult undergraduate majors that Berkeley has to offer.

To earn my B.S. in Engineering Physics, I took most of the classes that a regular Physics major takes plus all of the undergraduate courses in Civil Engineering. I also have an M.S. in Structural Engineering from Berkeley as well. I practiced structural engineering for a brief while as a research engineer in the aerospace industry in Sunnyvale, California, just before it became "Silicon Valley. "

The thing that changed my life forever is the fact that when I was completing my

Ph.D. in Engineering, I took a 3-year minor in the Philosophy of Social Science. I was part of a four-person seminar that met every week for three years. It was so intensive that in effect my minor became my major. One definition of Philosophy is that it is about "thinking about thinking". Even better, it is "knowing about knowing." Above all, philosophy is the field par excellence for qualitative thinking and the construction and the analysis of complex arguments.

MODELING BILL'S THINKING

I first became involved with Turing's Test in 1964 when I was working on my Ph.D. in Industrial Engineering at the University of California at Berkeley, in the fledgling field of the computer modeling or simulation of complex human behavior. The experience taught me how deeply flawed Turing's Test is, and hence, why, as it currently stands, it cannot be used to establish whether humans and computers are the same.

My dissertation [Mitroff, 1967] was concerned with writing a computer program that would match as closely as possible the actual design behavior of a single engineer [Bill]. Bill's clients were Ph.D. students in nuclear physics as well as professors of physics. They were attempting to study the nuclear properties of liquid hydrogen. To accomplish this, they shot intense beams of nuclear particles at high energies into a hydrogen flask. The atomic properties of hydrogen were determined by the particles that resulted from the collisions between the incoming particles and the hydrogen in the flask.

Bill's job was to assist their research by designing pressure vessels that would fit snugly around the plastic flasks that contained their liquid hydrogen. Since hydrogen is highly explosive if it interacts with oxygen, one of the pressure vessel's main purposes was to keep air from getting into the flask and mixing with the hydrogen. The pressure vessel not only had to keep air out, but it had to be strong enough to contain a potentially dangerous explosion.

The best way to think of a pressure vessel is to imagine the walls of a balloon. Although they are extremely thin, nonetheless, the walls of a balloon have to be thick and strong enough to contain the increase in internal air pressure that results when we blow it up. Since the outside surface of a balloon is extremely malleable, it stretches in order to contain the increase in internal air pressure. In other words, the walls of the balloon develop a counter-balancing force, or more accurately, stress, in order to contain the increase in air pressure. We literally see this in the form of the balloon's "stretch" or expansion.

The same thing happens in a metal pressure vessel. However, since the walls are much thicker and stronger, the metal vessel does not stretch as much, at least not perceptibly to the naked eye. Nonetheless, if one uses precise instruments to measure the increase in the vessel's dimensions, then one finds that the metal has indeed "stretched," albeit by a very small amount. As a result, the walls of a pressure vessel develop a counter-balancing stress to contain the internal pressure. If the internal pressure becomes too great, then like a balloon, the vessel expands until it cannot do so anymore. When this happens, it finally pops or explodes.

The pressure vessel also had another critical function to perform. Since extremely low temperatures are required to keep hydrogen in a liquid state, the air inside of the vessel had to be pumped out creating an internal vacuum. But this meant that the outside air pressure was acting on the vessel to crush it. The walls of the pressure vessel therefore had to be thick enough to withstand a potential internal explosion, as well as the external force produced by the outside atmospheric pressure. At the same time, Bill was doing his best to make the walls of the vessel as thin as possible so he could satisfy the needs of the students.

The difficulty of Bill's task was as follows: If he made the walls of the pressure vessel too thick, but safe, then a physicist ended up studying the nuclear properties of the vessel instead of hydrogen! On the other hand, if he made the walls too thin, then he risked crushing the vessel and causing a dangerous explosion. There is no best solution to this situation. Every design that Bill came up with was a compromise.

In addition to balancing these two conflicting demands, Bill was also juggling other equally important considerations. If he made the walls of the vessel out of an exotic material such as beryllium, then he could make the walls even thinner and hence allow a physicist to perform his or her job even better. However, the cost of manufacturing the vessel would then go up dramatically. Since everyone works within the cost constraints of a budget, even physicists were limited in how much money they could spend in unlocking Mother Nature's secrets.

It took over a year for Bill and I working together as a close-knit team to flesh out all of his design rules. Many of them were implicit. As a result, Bill was not fully conscious of them. On the "surface," no pun intended, Bill's job was inordinately simple. Since the vast majority of hydrogen flasks were spheres or cylinders, the surrounding pressure vessels could be either spheres or cylinders as well.

If anything is simple from an engineering standpoint, it is the design of spherical and cylindrical vessels. The formulas for calculating the necessary thickness of the walls in spherical and cylindrical pressure vessels are among the simplest to be found in all of science and engineering. If things were so simple, then the task of building a computer program of Bill's behavior should have been completed in weeks, not months. One difficulty was that not all of the flasks were simple spheres or cylinders. This alone complicated the formulas for calculating the necessary required thickness of the walls. Still, this wasn't the real source of the difficulties.

The real difficulties were the social ones. While all of Bill's clients had their Ph.D.'s in physics, not all Ph.D.'s were equal. It made a tremendous difference whether one was a relatively new Ph.D. , or whether one was an older, more mature physicist. In general, the older, the more experienced, and the more prestigious the physicist, the better the engineering designs he or she received.

On the whole, younger physicists were insecure. As a result, they generally approached Bill with their own designs. Because they knew much more physics than Bill did, they also assumed that they knew much more engineering. How wrong they were! Therein lay their downfall.

Bill looked at the designs that the younger physicists insisted upon and would become cynical. If he said it once, then he said it scores of times, "I always give my clients what they ask for even if it's not what they need!"

Bill knew that by building exactly what an inexperienced physicist requested, and in many cases demanded of him, he would thereby be ruining their experiments. Because they treated him with disdain, Bill was deliberately getting back at them by playing a game of spite. Depending on the way the client treated him, he either facilitated or ruined their experiment.

The designs of younger physicists almost always ended up with much thicker walls than would have been the case if they had let Bill design them. A physicist would then have to run his or her experiment much longer to get the results they desired, if they ever could.

On the other hand, older, more experienced, more mature, and generally much more prestigious physicists-- a number were Nobel prize winners-- assumed the exact opposite. They assumed that Bill knew much more engineering than they did. They basically trusted him to come up with the designs they needed.

No wonder it took over a year to get all of Bill's "design rules" into a computer. The "rules" were a highly complex mixture of engineering formulas tempered by the informal and implicit "social rules of the game."

Since all of the designs had to be justified, they had to be accompanied by an engineering analysis of some kind. This was true even of those designs that were thrust upon him. The joker in all of this was that Bill could almost pick whatever formula he wanted to justify whatever design he produced!

One of the reasons why lay people generally assume that engineering is an exact science is that they believe, erroneously, that every physical phenomenon is governed by a single, well-defined equation or formula. Nothing could be further from the truth.

All of the formulas and the equations in science and engineering are approximations. They are based on ideal models which greatly simplify a situation so that a mathematical theory can be constructed of it [Mitroff, 1967]. The "real world" is generally so complicated that it is literally impossible to completely model it as it presents itself to us. But since different models often make radically different assumptions about the nature of the world, different formulas are possible.

In the real world, one is never dealing with perfect spheres or perfect materials. Real pressure vessels do not always behave as ideal, theoretical ones. For this reason, one has to test the ideal equations against the ones that result from laboratory tests. Often times there is a good agreement between experiment and theory. And in fact, in most cases, theory is modeled after the results of experiments. But often, there is a significant gap between theory and experiment. When this happens, one gets a different formula based on fitting a smooth curve to experimental results.

Bill was thus consciously and unconsciously making a choice as to which formula a particular physicist got for the design of his or her pressure vessel! Even though practicing engineers and savvy engineering professors knew that this happened all the time, the situation I was trying to capture was outrageously complex. I had to build a model that apart from the complex physical calculations had to anticipate Bills massive shifts in design criteria depending on the relationship he had with a particular client. Put another way, the model had to be able to operate at two levels of analysis: first at the engineering level, and second, at the strategic level which determined how the engineering rules were to be applied and which ones were to choose to apply in the first place!

TURING TESTING: BILL AND MY COMPUTER PROGRAM

After about a year of working together, I had put enough of Bill's design rules into a computer so that we were ready to test his behavior against the computer. The day finally came when we fed both the computer and Bill the same series of typical design situations. Working separately, the computer and Bill responded. Bill and I then compared the computer's responses with his. What transpired next, neither of us had anticipated.

Since the computer was able to perform many and much more complex calculations in a much shorter time than a human could ever possibly accomplish, the computer was thereby able to generate many more design alternatives that could potentially satisfy a physicist's needs. When Bill looked at the computer's responses, he saw immediately that the computer was producing many more different types of designs than he had ever considered before. And, many of them were better. As a result, he decided on the spot to use the computer on a regular basis as a new and improved design tool.

However, remember that the program was initially written to simulate Bill's knowledge. But once the program was available, he could now choose to use his "new" knowledge to extend his initial knowledge. Although he never construed of it as such, and hence put into these words, he had developed "meta-knowledge."

Once again, the computer model was initially developed to mimic Bill. But, a number of the designs that the computer was producing were so superior to Bill's that he ended up learning from the computer! The roles had become completely reversed! It was no longer clear who was the "knowledge source" and whom was the "beneficiary!" Bill decided to use the computer as a new and valuable design tool precisely because it added to his knowledge.

Consider the matter in another way. Bill was acting as the "third person or judge" in Turing's Test. Bill was judging whether the output that was produced by the computer was sufficiently different, better, etc., than the output he produced acting as the "first person" or "the actual human" that was being compared to the computer! He was playing two roles, at two inter-connected levels of analysis, and each was informing the other.

Deciding who is the "machine" and who is the "human" in Turing's Test is highly dependent on the skills, levels of intelligence, training, background, etc., of the person serving as the judge as well as those who are interacting with the judge. It is highly dependent upon those being simulated being able to appraise how "good" the simulation of themselves is.

THE FUTURE?

In the intervening years since I first built a computer simulation of Bill's behavior, I have often ruminated on the many lessons I learned. The first and the most important is that engineering only operates at one level of cognition. It sees a problem and tries to solve it as if it were an object that was separate from us. It does not stand above the situation and see that the object and the engineer as an "inseparable whole." In other words, it does not see and appreciate that only the "interactions" are "real," not the parts.

Ignoring such complications allows the so-called "hard sciences" to market themselves as clear, hard-nosed, practical thinkers. (This shows why the distinction between "hard" and "soft" is itself "soft." In the end, every so-called "hard science" rests on a bed of largely unexamined "soft" distinctions.)

This may be understandable when one is seeking funding, but it should not lead to our misrepresenting and thereby misunderstanding the nature of human and computer "intelligence. " (Even here I disagree strongly, since this funding strategy is responsible for perpetuating basic misunderstandings.) This is especially dangerous when it leads to our becoming cyborgs.

I am not objecting to people making grand, sweeping, and "soft" statements about the whole of reality and what is intelligence or acting as philosophers, for that is precisely what humans are required to do all of the time in order to make sense of their world. I am merely pointing out that such statements are not and can never be purely "scientific." These "perceptions" require them to "stand outside" themselves and comment on their own behavior. This points to the inherent limitations of scientific knowledge.

The reason I have kept pointing out that humans need to see and to judge their own thinking is that this has profound implications for whether computers or machines can simulate or replace humans. For instance, Turing's Test generally assumes that we can model or simulate the behavior of a single individual in isolation from all other social influences. And yet, my study of Bill demonstrated unequivocally that his behavior or rules could not be captured apart from the behavior or rules of his clients.

The fact that there is a social context to all things "human," is of fundamental importance. When Bill got "our" program (to secure his full cooperation in the project, we wrote it together; thus, from the very beginning we formed an interactive research "team"), he used it as if his own thinking was "outside" of himself. It was useful "precisely" because (pun intended) it could also calculate faster than he could. This ability to be both the subject and the object of thoughts is how "intelligence" works. It is drastically different from calculative speed alone.

The business of "knowing-that-I-know that I know" is the nature of intelligence. We become generally aware of our thinking through the process of reflecting on our creations.

Through the process of conducting my Ph.D. dissertation, I was studying both myself and Bill. The ability to switch from thinking to thinking-about-thinking, ie. meta-thinking, is precisely one of the basic things that makes us human.

Meta-thoughts are thus prior to scientific knowledge because without them, science cannot exist. We may be able to build machines that have scientific knowledge but it will be the biggest step to build machines that know they are thinking. Without meta-thoughts, we only have a very pedestrian kind of "knowledge" of the sort some AI writers confuse with human intelligence. For the time being, I cannot see machines knowing about. Knowing that they know.

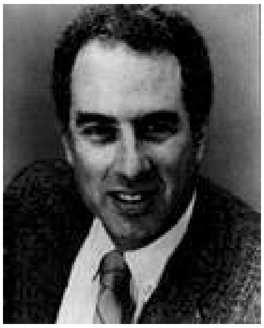
Finally, my dissertation also showed that there is no such thing as a simulation of a single mind without a simulation of all the other minds to which it is connected and thereby inseparable. The brain may be in the head, but the mind is "distributed" in society. Indeed, "mind" is a social construct.

But this means that in order for a simulation of a single mind to be said to exist there had to be a simulation of me as well! That is, in simulating Bill, I was following certain "implicit rules." Surely these "rules" are just as important to capture and to understand as the so-called "primary rules." Indeed, what is "primary?"

No wonder Turing's Test is so weak and full of wholes.

Computer scientists, who are supposed to hard-nosed and rigorous before they accept anything, are actually quite sloppy in their thinking. They literally need to go "back to school" and to get a broader education before they can accomplish their aims. They need to understand what it is to "think about thinking with and through others."

THE AUTHOR



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