The Work Turing Test

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Embodiment: A Prerequisite for Intelligence

Understanding intelligence and replicating it in a technological artifact may be the least well-understood scientific challenge we face today. Psychologists and cognitive scientists cannot even agree on a definition of intelligence. Instead, they resort to operational definitions in the form of intelligence tests. The Turing Test (TT) proposed by Alan Turing in 1950 (Turing 1950) is a highly influential operational definition for intelligence in computers (French 2000). In spite of its influence, using the TT as a guide and benchmark for progress in articificial intelligence (AI) research has not yet led to a principled understanding of what constitutes intelligence.

The original Turing Test puts linguistics and reasoning in the center of attention. This reflects the assumption of early AI research that intelligence is primarily (or even exclusively) the result of symbol manipulation.

Since then, the dominance of symbol manipulation has come into question. Complementing symbol manipulation, the notion of embodiment has received significant attention in the cognitive sciences (Varela, Thomspon, and Rosch 1991). Embodiment has triggered progress and novel perspectives in a variety of areas including philosophy (Lakoff and Johnson 1999), perception (Noë 2006), or robotics (Brooks 1990), to name just a few. Even mathematics, assumed by some to be the language of nature (Wigner 1960), arguably can be traced back to origins in embodiment (Lakoff and Núñez 2000).[1] Rather than attributing cognitive capabilities to the brain, these capabilities are now rooted in the brain, the body, and also the environment (Clark 1997; Clark 2008). Also, there can be little doubt that embodiment plays a vital role for language and thought (Pecher and Zwaan 2005; de Vega, Glenberg, and Graesser 2008), the former representing a core aspect of the operational definition of intelligence in the TT. Daniel Wolpert even argued, convincingly, that the brain only evolved to support embodiment.[2]

[1]This view provides a reasonable explanation for the "unreasonable effectiveness of mathematics in the natural sciences": mathematics was invented by humans to describe their experiences in a world governed by the very laws of nature mathematics captures so aptly (cf. (Wigner 1960)).

[2]Daniel Wolpert's TED talk from July 2011

Testing Intelligence of Embodiment

Given the importance of embodiment for biological intelligence and cognition, it would be surprising if embodiment did not play a fundamental role in artificial intelligence as well. If embodiment is inseparably intertwined with intelligence, then embodiment must also be part of an operational definition of intelligence.

In 1991, Harnad provided such an embodied operational definition by adding a robotic component to the TT, leading to the Total Turing Test (TTT) (Harnad 1991). To pass the TTT, "The candidate [robotic agent] must be able to do, in the real world of objects and people, *everything* that real people can do, in a way indistinguishable (to a person) from the way real people do it" (Harnad 1991). Furthermore, he stated: "I suggest instead that the constraints of the TTT [Total Turing Test] itself provide the most likely route to a discovery of any functional modules (if they exist) that may underlie our behavior capacity" (Harnad 1991), and in particular the capacity to behave intelligently. Harnad therefore recognized the possibility that embodiment might provide the required scaffolding (one might call it bias, prior, or restriction to a lower-dimensional solution space) to successfully address the challenge posted by the TT.

The key proposition here is that intelligence must be understood in the context of embodiment. By embodiment we simply refer to the agent possessing a body that can perceive the world and interact with it. We do not include the touchy issue of emergent behavior. Rather than adding an embodied component to the TT, we proposed to make embodied intelligence the only component of an operational definition of *physical* intelligence, i.e. intelligence that exclusively pertains to performing physical work in the world, ignoring for now other intellectual capabilities of humans, such as language, chess, theorem proving, etc. If embodiment is the prerequisite for intelligence in the human sense then the field of AI should attempt to solve this prerequisite problem *prior to* addressing full-fledged intelligence (Brooks 1991). We therefore propose a new Turing Test that only pertains to *physical intelligence*.

The **Work Turing Test (WTT) for Physical Intelligence** can be state as follows:

> A robot passes the Work Turing Test if it can carry out any set of instructions by autonomously performing physical work such that the resulting state of the

world is indistinguishable from one that would result from a cooperative, capable, non-expert human carrying out the same instructions.[3]

In contrast to the TTT, the WTT does not consider robotic capabilities *in addition* to the TT, instead it focuses on them *exclusively*. Also in contrast to the TTT, the WTT judges intelligence by the outcome of the robot's actions, not by the way the outcome was achieved. Robots therefore may perform their tasks in ways very different from people, as long as the outcome is indistinguishable.

The WTT requires the robot to exhibit the capabilities of a "cooperative, capable, non-expert human"on *any* set of instructions. The removal of an appendix, for example, clearly would not be an appropriate task, as a non-expert human would also not be able to perform it. The assembly of a shelf, however, probably would be.

The Parameters of The Work Turing Test

The set of instructions provided to the robot in the WTT represents the test's main parameter. Defining this parameter is a great challenge in itself but also a great opportunity. It is a challenge because it involves many yet unsolved research issues, and it is an opportunity because it enables the definition of a gradient of progress, something neither the TT and TTT are able to provide. Such a gradient can serve as a continuous guide for AI research, providing interpretable feedback to the research community and a shared benchmark.

The set of instructions in the WTT can provide a gradient along three important dimensions:

1. the complexity of the individual tasks contained in a set of instructions,
2. the variability of the tasks considered within a single set, and
3. the representation and level of detail of the instructions for each task in a set.

The *representation and level of detail* of the instructions captures the challenge of finding appropriate representations for robust action in the real world. In other words, we can define a new, simpler kind of language to capture a narrower range of situations, compared to natural language. After fifty years of AI, robotics, and the Turing Test, it is becoming increasingly apparent that neither natural language itself nor a complete and truthful model of the world are a viable answer. But what is the right representation or language? Does it depend on the robot's embodiment? On the task? On the environment?

The *complexity of individual tasks* can only be assessed once a particular embodiment of the robot and the corresponding representation for action and perception have been fixed. How should the ease or complexity of a task be judged? By the degree to which it is tailored to the embodiment (or vice versa)? By some inherent measure of the changes required to the world by the task? Based on information theory, physical work/energy, geometry, complexity of motion?

[3]This definition of the Work Turing Test was first publicized in 2003 on the author's homepage.

The *variability of the task* within a single set can probably only be assessed once the two criteria above are understood a little bit better. But certainly a set of highly similar tasks (assembling a chair and a table) will be simpler to perform than a set of highly diverse task (assembling a chair and making a chicken burrito).

Conclusion

The Work Turing Test (presumably) reduces the complexity of the challenge posed by the Turing Test by focusing on what we have called physical intelligence: performing physical work in the world to accomplish tasks. The Work Turing Test does not consider cognitive capabilities required for non-physical tasks. The ability to vary the complexity of tasks considered renders the Work Turing Test a useful challenge for AI, providing a way of incrementally advancing the state of the art toward human capabilities.

References

[Brooks 1990] Brooks, R. A. 1990. Elephants don't play chess. *Robotics and Autonomous Systems* 6(1–2):3–15.

[Brooks 1991] Brooks, R. A. 1991. Intelligence without representation. *Artificial Intelligence* 47(1–3):139—159.

[Clark 1997] Clark, A. 1997. *Being There—Putting Brain, Body, and World Together Again*. The MIT Press.

[Clark 2008] Clark, A. 2008. *Supersizing the Mind*. Oxford University Press.

[de Vega, Glenberg, and Graesser 2008] de Vega, M.; Glenberg, A.; and Graesser, A. 2008. *Symbols and Embodiment—Debates on Meaning and Cognition*. Oxford University Press.

[French 2000] French, R. M. 2000. The Turing Test: The first 50 years. *Trends in Cognitive Sciences* 4(3):115–122.

[Harnad 1991] Harnad, S. 1991. Other bodies, other minds: A machine incarnation of an old philosophical problem. *Minds and Machines* 1(1):43–54.

[Lakoff and Johnson 1999] Lakoff, G., and Johnson, M. 1999. *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought*. Basic Books.

[Lakoff and Núñez 2000] Lakoff, G., and Núñez, R. E. 2000. *Where Mathematics Comes From*. Basic Books.

[Noë 2006] Noë, A. 2006. *Action in Perception*. The MIT Press.

[Pecher and Zwaan 2005] Pecher, D., and Zwaan, R. A., eds. 2005. *Grounding Cognition—The Role of Perception and Action in Memory, Language, and Thinking*. Cambridge University Press.

[Turing 1950] Turing, A. M. 1950. Computing machinery and intelligence. *Mind* 59(236):433–460.

[Varela, Thomspon, and Rosch 1991] Varela, F. J.; Thomspon, E.; and Rosch, E. 1991. *The Embodied Mind*. The MIT Press.

[Wigner 1960] Wigner, E. P. 1960. The unreasonable effectiveness of mathematics in the natural sciences. *Communications on Pure and Applied Mathematics* 13(1):1–14.