Laws of Form and the Force of Function. Variations on the Turing Test

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Abstract. This paper commences from the critical observation that the Turing Test (TT) might not be best read as providing a definition or a genuine test of intelligence by proxy of a simulation of conversational behaviour. Firstly, the idea of a machine producing likenesses of this kind served a different purpose in Turing, namely providing a demonstrative simulation to elucidate the force and scope of his computational method, whose primary theoretical import lies within the realm of mathematics rather than cognitive modelling. Secondly, it is argued that a certain bias in Turing's computational reasoning towards formalism and methodological individualism contributed to systematically unwarranted interpretations of the role of the TT as a simulation of cognitive processes. On the basis of the conceptual distinction in biology between structural homology vs. functional analogy, a view towards alternate versions of the TT is presented that could function as investigative simulations into the emergence of communicative patterns oriented towards shared goals. Unlike the original TT, the purpose of these alternate versions would be co-ordinative rather than deceptive. On this level, genuine functional analogies between human and machine behaviour could arise in quasi-evolutionary fashion.

1 A Turing Test of What?

While the basic character of the Turing Test (henceforth TT) as a simulation of human conversational behaviour remains largely unquestioned in the sprawling debates it has triggered, there are a number of diverging interpretations as to whether and to what extent it provides a definition, or part of a definition, of intelligence in general, or whether it amounts to the design of an experimental arrangement for assessing the possibility of machine intelligence in particular. It thus remains undecided what role, if any, there is for the TT to play in cognitive inquiries.

I will follow James H. Moor [13] and other authors [21, 2] in their analysis that, contrary to seemingly popular perception, the TT does neither provide a definition nor an empirical criterion of the named kind. Nor was it intended to do so. At least at one point in Alan M. Turing's, mostly rather informal, musings on machine intelligence, he explicitly dismisses the idea of a definition, and he attenuates the idea of an empirical criterion of machine intelligence:

> I don't really see that we need to agree on a definition [of thinking] at all. The important thing is to try to draw a line between the properties of a brain, or of a man, that we want to discuss, and those that we don't. To take an extreme case, we are not interested in the fact that the brain has the consistency of cold porridge. We don't want to say 'This machine's quite hard, so it isn't a brain, and so it can't think.' I would like to suggest a particular kind of test that one might apply to a machine. You might call it a test to see whether the machine thinks, but it would be better to avoid begging the question, and say that the machines that pass are (let's say) 'Grade A' machines. [. . .] (Turing in a BBC radio broadcast of January 10th, 1952, quoted after [3, p. 494 f])

Turing then goes on to introducing a version of what has come to be known, perhaps a bit unfortunately, as the Turing Test, but was originally introduced as the "imitation game". In place of the articulation of definitions of intelligence or the establishment of robust empirical criteria for intelligence, we find much less ambitious, and arguably more playful, claims. One purpose of the test was to develop a thought-experimental, inductive approach to identifying those properties shared between the human brain and a machine which would actually matter to asking the question of whether men or machines alike can think: *What is the common ground human beings and machines would have to share in order to also share a set of cognitive traits?* It was not a matter of course in Turing's day that there could possibly be any such common ground, as cognition was mostly considered essentially tied to (biological or other) human nature.[2] In many respects, the TT was one very instructive and imaginative means of raising the question whether the physical constitution of different systems, whether cold-porrige-like or electric-circuitry-like, makes a principled difference between a system with and a system without cognitive abilities. Turing resorted to machine simulations of behaviours that would normally be considered expressions of human intelligence in order to demonstrate that the lines of demarcation between the human and the mechanical realm are less than stable.

The TT is however not sufficient as a means for *answering* the questions it first helped to raise, nor was it so intended. Turing's primary aim for the TT was one demonstration, among others, of the force and scope of what he introduced as the "computational method" (which will be briefly explained in section 2). Notably, the computational method has a systematically rooted bias towards, firstly, considering a system's logical form over its possible functions and towards, secondly, methodological individualism. I will use Turing's mathematical theory of morphogenesis and, respectively, the distinction between the concepts of structural homology and functional analogy in biology as the background for discussing the implications of this twofold bias (in section 3). On the basis of this discussion, a tentative reassessment of the potentials and limits of the

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[2] In [1, p. 168 f], Margaret Boden notices that the thought that machines could possibly think was not even a "heresy" up to the early 20th century, as that claim would have been all but incomprehensible.

TT as a simulation will be undertaken (in section 4): If there is a systematic investigative role to play in cognitive inquiries for modified variants of the TT, these would have to focus on possible functions to be shared between humans and machines, and they would have to focus on shared environments of interaction rather than individual behaviours.

2 The Paradigm of Computation

Whether intentionally or not, Turing's reasoning contributed to breaking the ground for the functionalist arguments that prevail in much of the contemporary philosophies of biology and mind: An analysis is possible of the operations present within a machine or an organism that systematically abstracts from their respective physical nature. An set of operations identical on a specified level of description can be accomplished in a variety of physical arrangements. Any inference from the observable behavioural traits of a machine simulating human communicative behaviour, as in the TT, to an identity of underlying structural features would appear unwarranted.

Turing's work was concerned with the possibilities of devising a common logical form of abstractly describing the operations in question. His various endeavours, from morphogenesis via (proto-) neuronal networks to the simulation of human conversational behaviour, can be subsumed under the objective of exploring what his "computational method" could achieve across a variety of empirical fields and under a variety of modalities. Simulations of conversational behaviours that had hitherto been considered an exclusively human domain constituted but one of these fields, investigated under one modality.

Turing's computational method is derived from his answer to a logico-mathematical problem, David Hilbert's "Entscheidungsproblem" (the decision problem) in predicate logic, as presented in [8]. This problem amounts to the question whether, within the confines of a logical calculus, there is an unequivocal, well-defined and finite, hence at least in principle executable, procedure for deciding on the truth of a proposition stated in that calculus. After Kurt Gödel's demonstration that neither the completeness nor the consistency of arithmetic could be proven or disproven within the confines of arithmetic proper [7], the question of deciding on the *truth* of arithmetical propositions from within that same axiomatic system had to be recast as a question of deciding on the internal *provability* of such propositions. The – negative – answer to this reformulated problem was given by Turing [18] (and, a little earlier, by a slightly different method, Alonzo Church). Turing's path towards that answer was based on Gödel's elegant solution to the former two problems, namely a translation into arithmetical forms of the logical operations required for deciding on the provability of that proposition within the system of arithmetical axioms. Accordingly, the method of further investigation was to examine the calculability of the arithmetical forms so generated.

To decide on the calculability of the problem in turn, Turing introduced the notion of computability. A mathematical problem is considered computable if the process of its solution can be broken down into a set of exact elementary instructions by which one will arrive at a determinate solution in a finite number of steps, and which could be accomplished, at least in principle, by human "computers".[3] Even complex problems should thus become reducible to a set of basic operations. The fulfilment of the required routines demands an ability to apply a set of rules and, arguably, some mental discipline, but these routines are not normally considered part of the most typical or complex properties of human thought – and can be mechanised, in a more direct, material sense, by an appropriately constructed and programmed machine. Hence, Turing's notion of "mechanical" was of a fairly abstract kind. It referred to a highly standardised and routinised method of solving mathematical problems, namely the computational method proper. This method could be equally applied by human, mechanical or digital "computers", or by any other system capable of following the required routines.

Given this description of computability, the primary aim of Turing's models of phenomena such as morphogenesis, the organisation of the nervous system or the simulation of human conversation lies in finding out whether, how and to what extent their specific structural or behavioural patterns can be formally described in computational terms – and thus within the realm of mathematics. A successful application of the computational method to the widest variety of phenomena would have implications on higher epistemological or arguably even metaphysical levels, but, being possible implications, these are not contained within the mathematical theory.

3 The Relevance of Form and Function

The design of Turing's computational method intuitively suggests, but does not entail, that the phenomena in question are chiefly considered in their, computationally modellable, *form*. Turing focuses on the formal patterns of organic growth, on the formal patterns of neuronal organisation and re-organisation in learning, and on the logical forms of human conversation. The possible or actual functions of these formally described patterns, in terms of the purposes they do or may serve, are not systematically considered. A second informal implication of Turing's computational approach lies in his focus on the behaviour of isolated, *individual* systems – hence not on the organism in its environment, but on the human brain as a device with input and output functions.[4] Such focus on self-contained, individual entities was arguably guided by a methodological presupposition informed by the systematic goals of Turing's research: The original topics of his inquiry were the properties of elementary recursive operations within a calculus. Hence, any empirical test for the force and scope of the computational method, that is, any test for what can be accomplished by means of such elementary recursive operations, would naturally but not necessarily commence in the same fashion.

In order to get a clearer view of this twofold bias, it might be worthwhile to take a closer look at the paradigm of Turing's computational method. That paradigm, in terms of elaboration, rigour and systematicity, is not to be found in his playful and informal imitation game approach to computer simulations of conversational behaviour. Instead, it is to be found in his mathematical theory of morphogenesis [20]. This inquiry was guided by Sir D'Arcy Thompson's, at its time, influential work *On Growth and Form* [17], and it was directed at identifying the basic chemical reactions involved in generating organic patterns, from an animal's growth to the grown animal's anatomy, from the dappledness or stripedness of furs to the arrangement of a sunflower's florets and the phyllotactic ordering of leaves on a plant's twigs. The generation of such patterns was modelled in rigorously formal-mathematical fashion. The resulting model was impartial to the actual biochemical realisation of pattern formation. It would only provide some cues as to what concrete reactants, termed "morphogens" by Turing, one should look out for.

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[3] I am following B. Jack Copeland [4] here on his definition of computability, as he makes a considerable effort at spelling out what notion of computability Turing was using in [18]. He thus hopes to stem the often-lamented flood of loose and misguiding uses of that term in many areas of science.

[4] For this observation, see, for example, [9, p. 85].

Less obviously but similarly important, Turing chose *not* to inquire into any adaptive function, in Darwinian terms, of the patterns so produced. These patterns may or may not serve an adaptive function, and what that function amounts to is of secondary concern at best. Explaining the generation of their form does not contribute to explaining that form's function, nor does it depend on that function. In this respect, too, Turing's thoughts appear to be in line with, if not explicitly endorsing, D'Arcy Thompson's skeptical view of the relevance of adaptation by natural selection in evolution. The formative processes in organisms are considered at least partly autonomous from Darwinian mechanisms. Whether the florets of a sunflower are patterned on a Fibonacci series, as they in fact are, or whether they are laid out in grid-like fashion, as they possibly *cannot* be according to the mathematical laws of form expounded by Turing, is unlikely to make a difference in terms of selective advantage. In turn however, natural selection may not offer a path to a grid-like pattern in the first place, while enabling, but arguably not determining, the Fibonacci pattern. In likewise fashion, the cognitive abilities of human beings or other animals would not in the first place be considered as adaptive abilities, defined in relation to challenges posed by their environments, but in their, mathematically modellable, form.

Turing's bias towards form over function, in conjunction with his methodological individualism, created a difficulty in systematically grasping a relation that might look straightforward or even obvious to the contemporary reader, who is likely to be familiar with the role of populations and environments in evolution, and who might also be familiar with philosophical concepts of functions: *analogy of functions* across different, phylogenetically distant species. In Turing's notion of decoupling logical form from physical structure, the seeds of the concept of functional analogy appear to be sown, however without growing to a degree of maturity that would prevent the premature conclusions often drawn from Turing's presentation of the TT.

It is the condition of observable similarity in behaviour that has been prone to misguide both proponents and critics of the TT. One cannot straightforwardly deduce a similarity of kind – in this case, being in command of a shared form of intelligence – from a similarity in appearance. A relation of proximity in kind could only be firmly established on the grounds of a relation of common descent, that is, from being part of the same biological population or from being assembled according to a common design or *Bauplan*. This is the ultimate skeptical resource for the AI critic who will never accept some computer's or robot's trait as the same or equivalent to a human one. However convincing it may look to the unprejudiced observer, any similarity will be dismissed as a feat of semi-scientific gimmickry. Even a 1:1 replica of a human being, down to artificial neurones and artificial muscles made of high-tech carbon-based fibres, is unlikely to convince him or her. What the skeptic is asking for is a *structural homology* to lie at the foundation of observable similarities.

In the biological discipline of morphology, the distinction between analogies and homologies has first been systematically applied by Richard Owen, who defined it as follows:

> "ANALOGUE." – A part or organ in one animal which has the same function as another part or organ in a different animal.
> "HOMOLOGUE." – The same organ in different animals under every variety of form and function. [15, p. 7, capitalisation in original]

This distinction was put on an evolutionary footing by Charles Darwin, who gave a paradigmatic example of homology himself, when he asked: "What can be more curious than that the hand of a man, formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should all be constructed on the same pattern, and should include the same bones, in the same relative positions?" [5, p. 434] – where the reference of "the same" for patterns, bones and relative positions is fixed by their common ancestral derivation rather than, for Owen and other Natural Philosophers of his time, by abstract archetypes.

In contrast, an analogy of function of traits or behaviours amounts to a similarity or sameness of purpose which a certain trait or behaviour serves, but which, firstly, may be realised in phenotypically variant form and which, secondly, will not have to be derived from a relation of common descent. For example, consider the function of vision in different species, which is realised in a variety of eye designs made from different tissues, and which is established along a variety of lines of descent. The most basic common purpose of vision for organisms is navigation within their respective environments. This purpose is shared by camera-based vision in robots, who arguably have an aetiology very different from any natural organism. Conversely, the same navigational purpose is served by echolocation in bats, which functions in an entirely different physical medium and under entirely different environmental circumstances, namely the absence of light.

There are no principled limitations as to how a kind of function is realised and by what means it is transmitted. The way in which either variable is fixed depends on the properties of the (biological or technological) population and of the environment in question. In terms of determining its *content*, a function is fixed by the relation between an organism's constitution and the properties of the environment in which it finds itself, and thus by what it has to accomplish in relation to organic and environmental variables in order to prevail. This very relation may be identical despite the constitution of organisms and the properties of the environment being at variance between different species. Perceiving spatial arrangements in order to locomote under different lighting conditions would be a case in point. In terms of the *method* by which a function is fixed, a history of differential reproduction of variant traits that are exposed to the variables of the environment in which some population finds itself will determine the functional structure of those traits. If an organism is endowed with a reproducible trait whose effects keep in balance those environmental variables which are essential to the organism's further existence and reproduction, and if this happens in a population of reproducing organisms with sufficient frequency (which does not even have to be extremely high), the effects of that trait will be their functions.[5]

Along the lines of this argument, an analogy of function is possible between different lines of descent, provided that the environmental challenges for various phylogenetically remote populations are similar. There are no a-priori criteria by which to rule out the possibility that properties of systems with a common descent from engineering processes may be functionally analogous to the traits and behaviours of organisms. In turn, similarity in appearance is at most a secondary consequence of functional analogy. Although such similarity is fairly probable to occur, as in the phenomenon of convergent evolution, it is never a necessary consequence of functional analogy. The similarity that is required to hold between different kinds of systems lies in the tasks for whose fulfilment their respective traits are selected. Structural homology on the other hand does neither require a similarity of tasks nor a similarity of appearance, but a common line of descent from which some trait hails, whatever function it may have acquired later along that line, and whatever observable similarity it may bear

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[5] This is the case for aetiological theories of function, as pioneered by [23] and elaborated by [11].

to its predecessor. In terms of providing criteria of similarity that go beyond what can be observed on the phenotypical level, functional analogy trumps structural homology.

4 The Turing Test as Demonstrative vs. Investigative Simulation

On the grounds of the above argument, the apparent under-definition of the epistemical role of the TT owes to an insufficient understanding of the possibilities and limitations of functional analogy in the AI debates: It is either confounded with homological relations, which, as there are no common lines of descent between human beings and computers, results in the TT being rejected out of hand as a test for any possible cognitive ability of the latter. Or analogous functions are considered coextensive with a set of phenotypical traits similar, qua simulation, to those of human beings. Either way, it shows that inferences to possible cognitive functions of the traits in question are not warranted by phenotypical similarity. Unless an analogy of function can be achieved, the charge of gimmickry against the TT cannot be safely defused. If however such an analogy can be achieved, the test itself would not deliver the evidence necessary for properly assessing that analogy, nor would it provide much in the way of a suggestion how that analogy could be traced.

One might be tempted to put the blame for this insufficient understanding of functional analogy on Turing himself – but that might be an act of historical injustice. Firstly, he did not claim functional analogies to be achieved by his simulations. Secondly, some of the linkages between the formal-mathematical models which he developed and more recent concepts of evolution that comprise the role of populations and environments in shaping organic functions were not in reach of his well-circumscribed theory of computation. They were not even firmly in place at the time of his writing. Much of contemporary evolutionary reasoning owes to the Modern Synthesis in evolutionary biology, which was only in the process of becoming the majority view among biologists towards the end of Turing's life.[6]

With the benefit of hindsight however, and with the clarification of matters that it allows, is there any role left for the TT to be played in inquiries into human cognition – which have to concern, first and foremost, the *functions* of human cognition? Could it still function as a simulation of serious scientific value? Or, trying to capture Turing's ultimate, trans-mathematical objective more precisely and restating the opening question of this paper: Could the TT still help to identify the common ground human beings and machines would have to share in order to also share a set of cognitive traits? For modified forms of that test at least, the answer might be positive.

First of all, one should be clear about what kind of simulation the TT is supposed to be. If my reconstruction of Turing's proximate aims is valid, the imitation game was intended as a *demonstrative* simulation of the force and scope of the computational method, with no systematic cognitive intent. By many of its interpreters and critics however, it was repurposed as an *investigative* simulation that, at a minimum, tests for some of the behavioural cues by which people normally discern signals of human intelligence in communication, or that, on a maximal account, test for the cognitive capacities of machines proper.

The notions of demonstrative and investigative simulations are distinguished in an intuitive, prima facie fashion in [16, p. 7 f], but may not always be as clearly discernible as one might hope. Demonstrative simulations mostly serve a didactic purpose, in reproducing some well-known behaviours of their subject matter or "target" in a different medium, so as to allow manipulations of those behaviours' variables that are analogous to operations on the target proper. The purpose of flight simulators for example lies in giving pilots a realistic impression of experience of flying an airplane. Events within the flight simulation call for operations on the simulation's controls that are, in their effects on that simulation, analogous to the effects of the same operations in the flight that is being simulated. The physical or functional structure of an airplane will not have to be reproduced for this purpose, nor, of course, the physical effects of handling or mishandling an in-flight routine. Only an instructive simile thereof is required. I hope to have shown that this situation is similar to what we encounter in the TT, as originally conceived. No functional analogy between simulation and target is required at all, while the choice and systematic role of observable similarities is contingent on the didactic purpose of the simulation.

An investigative simulation, on the other hand, aims at reproducing a selection of the behaviours of the target system in a fashion that allows for, or contributes to, an explanation of that behaviours' effects. In a subset of cases, the explanation of the target's functions is included, too. Here, a faithful mapping of the variables of the simulation's behaviours, and their transformations, upon the variables and transformations on the target's side is of paramount importance. No phenomenal similarity is required, and a mere analogy of effects is not sufficient, as that analogy might be coincidental. Instead, some aspects of the internal, causal or functional, structure of the target system will need to be systematically grasped. To this purpose, an investigative simulation is guided by a theory concerning the target system, while the range of its behaviours is not exhausted by that theory: Novel empirical insights are supposed to grow from such simulations, in a manner partly analogous to experimental practice.[7] I hope to have shown that this is what the TT might seem to aim at, but does not achieve, as there is no underlying theory of the cognitive traits that appear to be simulated by proxy of imitating human conversational behaviour.

An alternative proposal for an investigative role of the TT along the lines suggested above would lie in creating analogues of some of the cognitive functions of communicative behaviour. Doing so would not necessarily require a detailed reproduction of all or even most underlying cognitive traits of human beings. Although such a reproduction would be a legitimate endeavour taken by itself, although probably a daunting one, it would remain confined to the same individualistic bias that marked Turing's own approach. A less individualistic, and perhaps more practicable approach might take supra-individual patterns of communicative interaction and their functions rather than individual minds as its target.

One function of human communication, it may be assumed, lies in the co-ordination of actions directed at shared tasks. If this is so, a modified TT-style simulation would aim at producing, in evolutionary fashion, 'generations' of communicative patterns to be tried and tested in interaction with human counterparts. The general method would be similar to evolutionary robotics,[8] but, firstly, placed on a higher level of behavioural complexity and, secondly, directly incorporating the behaviour of human communicators. In order to allow for some such quasi-evolutionary process to occur, there should not be a reward for the machine passing the TT, nor for the human counterpart revealing the machine's nature. Instead, failures of the machine to effectively communicate with its human counterpart, in re-

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[6] For historical accounts of the Modern Synthesis, see, for example, [10, 6].

[7] For this argument on the epistemic role of computer simulations, see [22].

[8] For a paradigmatic description of the research programme of evolutionary robotics, see [14].

lation to a given task, would be punished by non-reproduction, in the next 'generation', of the mechanism responsible for the communicative pattern, replacing it with a slightly (and perhaps randomly) variant form of that mechanism. In this fashion, an adaptive function could be established for the mechanism in question over the course of time. Turing indeed hints at such a possibility when briefly discussing the "child machine" towards the end of [19, pp. 455–460] – a discussion that, in his essay, appears somewhat detached form the imitation game proper.

For such patterns to evolve, the setup of the TT as a game of imitation and deception might have to be left behind – if only because imitation and deception, although certainly part of human communication, are not likely to constitute its foundation. Even on a fairly pessimistic view of human nature, they are parasitic on the adaptive functions of communication, which are more likely to be co-operative.[9] Under this provision, humans and machines would be endowed with the task of trying to solve a cognitive or practical problem in co-ordinated, perhaps collaborative, fashion. In such a situation, the machine intriguingly would neither be conceived of as an instrument of human problem-solving nor as an autonomous agent that acts beyond human control. It would rather be embedded in a shared environment of interaction and communication that poses one and the same set of challenges to human and machine actors, with at least partly similar conditions of success. If that success is best achieved in an arrangement of symmetrical collaboration, the mechanisms of selection of behavioural patterns, the behavioural tasks and the price of failure would be comparable between human beings and machines. By means of this modified and repurposed TT, some of the functions of human communication could be systematically elucidated by means of an investigative simulation. That simulation would establish functional analogies between human and machine behaviour in quasi-evolutionary fashion.

5 Conclusion

It might look like an irony that, where, on the analysis presented in this paper, the common ground that would have to be shared between human beings and machines in order to indicate what cognitive traits they may share, ultimately and in theory at least, is functionally identified, and where the author of that thought experiment contributed to developing the notion of decoupling the function of a system from its physical structure, the very notion of functional analogy did not enter that same author's focus. As indicated in section 4 above, putting the blame on Turing himself would be an act of historical injustice. At the same instance however, my observations about the formalistic and individualistic biases built into Turing's computational method do nothing to belittle the merits of that method as such, as its practical implementations first allowed for devising computational models and simulations of a variety of functional patterns in a different medium, and as its theoretical implications invited systematical investigations into the physical underdetermination of functions in general. In some respects, it might have taken those biases to enter this realm in the first place.

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