A Popperian Falsification of Artificial Intelligence - Lighthill Defended

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Abstract

The area of computation called artificial intelligence (AI) is falsified by describing a previous 1972 falsification of AI by British mathematical physicist James Lighthill. How Lighthill’s arguments continue to apply to current AI is explained. It is argued that AI should use the Popperian scientific method in which it is the duty of scientists to attempt to falsify theories and if theories are falsified to replace or modify them. The paper describes the Popperian method in detail and discusses Paul Nurse’s application of the method to cell biology that also involves questions of mechanism and behavior. Arguments used by Lighthill in his original 1972 report that falsified AI are discussed. The argument uses recent scholarship to explain Lighthill’s assumptions and to show how the arguments based on those assumptions continue to falsify modern AI. An important focus of the argument involves Hilbert’s philosophical programme that defined knowledge and truth as provable formal sentences. Current AI takes the Hilbert programme as dogma beyond criticism while Lighthill as a mid 20th century mathematical physicist had abandoned it. The paper explains John von Neumann’s criticism of AI that I claim was assumed by Lighthill. Next computer chess programs are discussed to show Lighthill’s combinatorial explosion still applies to AI computer programs but not humans. An argument showing that Turing Machines (TM) are not the correct description of computation is given. The paper concludes by advocating studying computation as Peter Naur’s Dataology.

1. Introduction

This paper applies the method of falsification discovered by Karl Popper to show that artificial intelligence (AI) programs are not intelligent and in fact are just normal computer programs in which programmers express their ideas by writing computer code. AI is meaningless metaphysics in the Popperian sense of metaphysics based on a number of incorrect assumptions and dogmas that was falsified by James Lighthill in his evaluation of AI for the British science funding agency (Lighthill[1972]). This paper defends Lighthill’s 20th century falsification of AI and explains how it applies to current AI.

Material is presented that the author developed from being encouraged to criticize AI as a 1960s Stanford University undergraduate and from a talk given to Paul Feyerabend’s philosophy of science seminar while the author was a computer science (CS in Literature and Science School) student at UC Berkeley. In order to understand why Lighthill’s criticism falsifies the AI research programme and why his arguments still apply to AI now in the second decade of the 21st century in spite of vast improvements in computer speed and capacity, it is necessary to understand the development of modern computers primarily by physicists after WWII. The paper uses recent historical scholarship to explain Lighthill’s background assumptions and shows how that background knowledge also falsifies current AI.

It was not just Lighthill who was skeptical of AI. Physicists in general are critics of AI.
See for example Roger Penrose’s two books that show the impossibility of artificial minds (Penrose[1994] and Penrose[2016]). There is a file in David Bohm’s archive at Birbeck College in London that appears to be Bohm planning to write a paper criticizing AI that I believe was never written.

The current lack of criticism of the AI research programme may be related to a historical accident of academic organization at Stanford University in the middle of the 20th century. The accident was that for some reason Stanford decided not to offer academic appointments to SLAC physicists who had academic appointments at the institution they came from. Assistant SLAC director Mathew Sands discusses this in his American Physical Society (APS) interview (Sands[1987], p. 192). Administrator Albert Bowker who was responsible for starting Stanford’s computer science as an academic discipline also discusses the problem with SLAC appointments (Bowker[1979], p. 6). Physicists encouraged the study computation. For example, Niklaus Wirth developed his various computer languages while working at and being funded by the Stanford Linear Accelerator (SLAC).

The effect of few physicists with academic appointments and I claim William Miller’s, who was responsible for the Stanford computer science after Bowker had departed from Stanford, incorrect understanding of the questionable intellectual standing of AI was that Stanford computer science became the Stanford AI Lab. For example, assistant CS professor Jeffrey Barth was fired in 1977 because he refused to work at the Stanford AI Lab. Miller explained the idea for Stanford computer science this way. "I think we tended to focus on fairly rigorous problems that could be recognized as rigorous problems. We followed the paradigms of more rigorous disciplines and established it as a science as opposed to an engineering or applied discipline" (Miller[1979], p. 11). Unfortunately, the result of the Stanford organization resulted in almost total suppression of criticism of AI.

2. What is Popperian falsification

Falsification is a method discovered by Karl Popper that argues general statements do not have scientific merit. Only singular statements Popper calls basic statements that have simple structure have meaning. Such statements can be disproven either by scientific experiments or by logic (Popper[1968], p. 74). Popper’s major contribution to the philosophy of science is to insist that it is the duty of every scientist to criticize one’s own theories to the fullest extent possible so that false theories can be modified or replaced. Popperians believe scientific method consists of numerous bold conjectures that are then tested and if falsified, eliminated or modified. Popper’s method calls for bold conjecture followed by stringent criticism.

Popper’s original falsification theory developed in the late 1920s and early 1930s is called naïve falsification (Lakatos[1999], pp. 64-85). The theory was improved and generalized by Popper and his colleagues during most of the 20th century. I am using the term Popperian philosophy in a sense that includes the modifications and improvement to Popper’s theory mostly carried out at the London School of Economics not just by Popper but also by: Imre Lakatos, Paul Feyerabend and Thomas Kuhn. The other aspects of Popperian methodology is most clearly expressed by Imre Lakatos as the Methodology of Scientific Research Programmes (MSRP) (Lakatos[1970]). There were disagreements among the Popperians about questions of emphasis but not about methodology or importance of rationality in science. James Lighthill, as holder of the Lucasian chair in applied mathematics at Cambridge University, was familiar with and part of the milieu that developed Popperian theory.

It is important to understand that falsification needs to be a necessary condition for scientific research. It is not sufficient because there are situations for which falsified theories need
3. Lighthill’s falsification of AI

Lighthill’s falsification of AI is quite simple (Lighthill[1972]) and I claim continues to apply to AI in spite of changes mostly in vastly faster computers that execute machine instructions in parallel and new names for algorithms such as “deep learning” that replaces alpha beta heuristics to improve logic resolution algorithms to implement intelligence. Lighthill argues AI is just CS described using the language of human intelligence and views computers and computation as tools for expressing people’s ideas.

Lighthill divides AI into three areas. Category A: Automation (feedback control engineering), Category C: computer based studies of the central nervous system, and Category B: the bridge area between A and B that is supposedly going to provide the magic synergy that allows creation of intelligent robots (p. 3). For example, current deep learning would fall into areas A and B. It falls into category B because it involves automatic logical deduction without any need for a person to program ideas into the algorithm, but also it is in category A because it "looks beyond conventional data processing to the problems involved in large-scale data banking and retrieval" (p. 5). I think Lighthill is arguing here that AI studies normal computer science but rephrases problems in terms of human attributes (p. 7 paragraph 2).

According to Lighthill for control engineering it should not matter how the engineering is accomplished. Lighthill writes in the section discussing category A: "Nevertheless it (AI) must be looked at as a natural extension of previous work of automation of human activities, and be judged by essentially the same criteria” (p. 4 paragraph 4). After more than 40 years of computer development, programmable digital computers are usually the best choice for control engineering. In modern terms current feedback control engineering is based on improvements in camera technology allowing more precise location measurements and more complex feedback. Advances and cost reductions in computer and storage technology allow large amounts of data to be processed faster and at lower cost.

In criticizing AI’s approach to area C since obviously it makes sense to study neurophysiology, Lighthill distinguishes syntactic automation as advocated currently by AI versus conceptual automation (p. 6). He asks if "a device that mimics some human function somehow assists in studying and making a theory of the function of the central nervous system" (p. 6 paragraph 4).

Lighthill criticizes the use of mathematical logic in AI by arguing practical use runs into a
combinatorial explosion (p. 10 paragraph 5) and argues there are difficulties in storing axioms favored by logicians versus heuristic knowledge favored by AI (p. 10, paragraph 6). In my view this is the crucial falsifier of AI. Namely, although Lighthill was attempting to provide a neutral assessment of AI, he did not believe in the Hilbert Programme that is the central tenet of AI.

Lighthill also discusses organization problems with AI methodology. He questions claims such as "robots better than humans by 2000" (p. 13) (now probably replace with 2030). Lighthill as a mathematical physicist also discusses the combinatorial explosion that allows humans to solve problems that can not be solved by formal algorithms.

3.1 Understanding Lighthill's falsification in modern terms

In 1972 Lighthill falsified AI by showing its individual claims were false and by arguing there was no unified subject but rather just normal problems in the area of computation involving computer applications and study of data. AI researchers were not convinced at the time, I think, because Lighthill did not make his Popperian view of science clear. The remainder of this paper discusses how 1970s scientific background knowledge especially in the physics and applied mathematics areas falsifies current AI methods. The discussion is possible because of recent scholarship especially in the areas of Hilbert’s philosophical programme and in the study of John von Neumann’s thinking during the development of digital computers.

4. Skepticism toward Hilbert’s programme of truth as formal proof

In the 1920s, mathematician David Hilbert conjectured that knowledge and truth consists solely of all sentences that can be proven from axioms. Hilbert’s original conjecture was a mathematical problem. However, it was interpreted as a philosophical theory in which truth became formal proof from axioms. A paradigmatic example is the Birkhoff and Von Neumann formalization of quantum mechanics as axiomatized logic (Birkhoff[1936], Popper[1968] attempted to falsify it). Hilbert’s programme as the basic assumption of AI is that knowledge about the world can be expresses as formal sentences. Knowledge is then expressed as formulas that can be derived using logic (usually predicate calculus) from other sentences about the world that are true.

In addition to the belief that knowledge is formal sentences, the foundation of AI is the belief that the Church”-Turing Thesis (Copeland[2015]) is true. Namely, that nothing can exist outside of formally proven sentences, proven from axioms. In the AI community this dogma is beyond criticism. However, the philosophical Hilbert programme was abandoned starting in the 1930s for various reasons. The reason most often given is that Godel’s incompleteness results showed the Hilbert programme could not succeed. The Hilbert programme is still believed in the logic area and AI seems to be grasping at straws by attempting to mitigate the Godel disproof by finding in practice areas where Godel’s results do not apply. Zach[2015] Stanford Encyclopedia of Philosophy article discusses some attempts to mitigate Godel’s results. See Detlefsen[2017]) for a more skeptical view of Hilbert’s programme.

There were a number of other reasons Hilbert’s philosophical programme was rejected. These other reasons explain why the AI argument that since people have intelligence, computer programs can also have intelligence. In the view of AI, the problem is just building faster computers and developing better algorithms so that computers can discover and learn the formal sentences in people’s heads. In fact the other reasons the Hilbert programme was abandoned show why Lighthill’s falsification is correct and why AI is meaningless metaphysics.
4.1 Von Neumann’s argument automata and neural networks useless at high levels of complexity

During the second half of the 20th century, John von Neumann’s work on computers and computations was widely accepted. Publication of Von Neumann’s work on computing did not occur until years after Lighthill’s falsification was written (in particular Aspray[1990], Neumann[2005] and Kohler[2001]). Lighthill was certainly familiar with Von Neumann’s work.

John Von Neumann studied automata and neural networks when he was developing his Von Neumann computer architecture. Von Neumann combined all his skepticism toward linguistics and automata as sources of AI algorithms in discussing problems with formal neural networks when he wrote:

"The insight that a formal neuron network can do anything which you can describe in words a very important insight and simplifies matters enormously at low complication levels. It is by no means certain that it is a simplification on high complication levels. It is perfectly possible that on high complication levels the value of the theorem is in the reverse direction, namely, that you can express logics in terms of these efforts and the converse may not be true" (Von Neumann[1966], quoted in Aspray[1990], note 94, p. 321).

Von Neumann also considered and rejected current AI methodology when he developed the Von Neumann computer architecture. In a 1946 paper with Herman Goldstine on the design of a digital computer Von Neumann wrote that some sort of intuition had to be built into programs instead of using brute force searching (Aspray[1990], p. 62). Edward Kohler (Kohler[2000]), p. 118) describes von Neumann’s discovery in developing modern computer architecture in an article "Why von Neumann Rejected Carnap’s Duality of Information Concepts" as:

"Most readers are tempted to regard the claim as trivial that automata can simulate arbitrarily complex behavior, assuming it is described exactly enough. But in fact, describing behavior exactly in the first place constitutes genuine scientific creativity. It is just such a prima facie superficial task which von Neumann achieved in his [1945] famous explication of the "von Neumann machine" regarded as the standard architecture for most post World-War-II computers.

The problem context in the area of operations research solution space searching that influenced both von Neumann and Lighthill was pre computer algorithmic operations research (see Budiansky[2013] for the detailed story). Understanding the limitations of combinatorial explosion arises naturally from that experience.

4.2 Skepticism toward linguistics and formal languages in computing

Starting with Ludwig Wittgenstein in the late 1930s, skepticism toward linguistics and especially formal languages become prevalent. Wittgenstein’s claim was that mathematical (and other) language was nothing more than pointing (Wittgenstein[1930]). The Popperians and English science in general were receptive to Wittgenstein and his "pointing" philosophy of mathematics. Popperians avoided linguistic philosophy because they viewed it as creating more problems than it solved. I read Lighthill’s falsification as assuming this attitude toward language. Modern AI still claims knowledge and truth is limited to provable formal sentences.

5. Physicist skepticism towards mathematics as axiomatized logic

In my view there was a more important reason for the rejection of Hilbert’s programme. Physicists were always skeptical toward axiomatized mathematics. Albert Einstein in his 1921 lecture on geometry expresses this skepticism. Einstein believed that formal mathematics was
incomplete and disconnected from physical reality. Einstein stated:

*This view of axioms, advocated by modern axiomatics, purges mathematics of all extraneous elements. ... such an expurgated exposition of mathematics makes it also evident that mathematics as such cannot predicate anything about objects of our intuition or real objects* (Einstein[1921]).

Niels Bohr argued that first comes the conceptual theory then the calculation. John von Neumann expressed the physicist attitude with a story relating a conversation with founder of quantum physics Wolfgang Pauli. "If a mathematical proof is what matters in physics, you would be a great physicist" (Thirring[2001], p. 5).

6. **Finsler’s rejection of axiomatics and general 1926 inconsistency result**

In addition to skepticism toward axiomatics, there was also skepticism toward set theory and its core claim that only sentences that are derivable from axioms (Zermelo Fraenkel probably) can exist. Swiss mathematician Paul Finsler believed that mathematics exists outside of language (formal sentences). Finsler claimed to have shown incompleteness in formal systems before Gödel in 1925 and that his proof was superior because it was not tied to Russell’s logic as Gödel’s was. See "A Restoration the failed: Paul Finsler’s theory of sets" in Breger[1996], p. 257 for discussion of Finsler’s result on undecidability and formal proofs and its history (also Finsler[1996] and Finsler[1969]).

7. **Chess - elite human players response to chess programs**

Superiority of chess programs over even the best human chess players is cited as evidence that in the future AI robots will be superior in all areas involving intelligence. In fact the situation is more complicated. The world’s best chess players are responding in interesting ways. This corroborates Lighthill’s claims that even in a formal sentence based toy world, combinatorial explosion limits problem solving ability of algorithms. Study of chess playing programs and evaluation of their efficacy show the problems with recent claims of AI successes in general.

In 1997, the Deep Blue chess program defeated then world champion Gary Kasperov. Since then the world’s best chess players have adjusted to computer chess programs. In the December 31 Financial Times newspaper chess column, Leonard Barton referring to US champion Fabiano Caruana writes: "The US champion and world No. 2 unleashed a brilliant opening novelty, which incidentally showed the limitations of the most powerful computers" (Barton[2016]).

In the October 14, 2017 Financial Times weekend edition, Barton discusses newer responses of the best chess players to computer chess programs. The best human chess players are changing to what are seemingly inferior opening such as Magnus Carlsen’s A3 (left rook pawn advances one square) because "Grandmasters are turning to the byways of opening theory as powerful programs analyze main lines to a depth unimaginable before the age of computers." Computer chess program "intelligence" is not way beyond human skill, but computers are a tool that allows large improvement in human ability to analyze chess moves. This is similar to microscopes as tools that allow understanding biological cells in previously impossible ways.

Also, US champion Fabio Caruana is still in the forefront of using computers as a tool to analyze positions. He found a variation on a well established opening "Caruana found a nuance at move 19 which was so strong that he had a won game while still in his prep." Barton sums up the reaction to computers as "Carlson’s message is clear. Offbeat openings can save a lot of wasted preparation."

It has taken two decades and Caruana was only five years old when Kasperov lost to Deep
Blue, but it appears computer algorithms will encounter combinatorial explosion problems so that more and more of the best players will be able to defeat computers.

In May 2017, Garry Kasperov published a book on his 1997 match against Deep Blue "Deep Thinking: Where Machine Intelligence Ends and Human Creativity Begins" (Kasperov[2017]). Kasperov blames the Deep Blue team psychological harassment for his loss. It was Kasperov versus a group of chess masters with access to a very good chess position analysis tool versus Kasperov alone in Kasperov’s view. This illustrates a common pattern in computer solving of problems. Injection of human knowledge by means of writing computer code is an integral part of the machine learning.

Possibly more interesting is how the claims show problems with AI scientific methodology and emphasize the lack of diligent attempts to falsify AI theory. First, the financial incentive structure of the challenge meant that Kasperov made more money by losing rather than by winning. From Kasperov’s viewpoint he could win and go back to collecting meager chess tournament prize money or lose and collect a large appearance fee plus receiving numerous other appearance fees as a marketing representative. Many AI claims of success involving human competition with computers follow this pattern. At a minimum, AI tests of this type need to use double blind protocols. A better method for determining if computers can defeat the best human players would be to use double blind tournaments where opponents may be humans or computers and participants and officials were not allowed to know who was who. Even better would be a system where chess player’s natural competitiveness was utilized so that losing to a lower rated human player would result in a large deduction of rating points.

Finally, progress in chess playing computer programs shows that chess programs are normal data processing applications in the Lighthill sense in which human knowledge of chess can be expressed and amplified by injecting it into computers by writing programs.

8. Turing Machine incorrect model for computation

The central argument for AI is based on the Church Turing thesis. Namely that Turing machines (TM) are universal and anything that involves intelligence can be calculated by TMs. Applying Lighthill’s combinatorial explosion arguments, it seems to me that TMs are the wrong model of computation. Instead a different computational model called MRAMS (random access machines with unit multiply and a bounded number of unbounded size memory cells) is a better model of computation (Meyer[2016]). Von Neumann understood the need for random access memory in his design of the von Neumann architecture (ibid. pp. 5-6). For MRAM machines deterministic and non deterministic computations are both solvable in polynomial bound time so at least for some problems in the class NP, the combinatorial explosion is mitigated. TM’s are universal in the sense that they can compute anything that a von Neumann MRAM machine can calculate. The problem is that Lighthill’s combinatorial explosion problem is much worse for TMs than MRAMs because for TMs, problems in NP are probably not computable in polynomial bounded time, but for MRAMs P=NP so there is no advantage to guessing or using heuristics. I claim von Neumann understood that random access and bit select capability that is missing from TMs leads to more problems that can avoid the combinatorial explosion problem.

A problem such as asking if two regular expressions are equivalent is outside the class NP so the calculation is inherently exponential implying that for algorithms there is no solution to the combinatorial explosion problem. This suggests that algorithms should be studied as normal data processing because AI’s assumption that heuristics and guessing will somehow improve algorithms is problematic.
9. Conclusion - suggestion to replace AI with Naur’s Dataology

A problem with this paper is that people trained to perform advanced computational research before the 1970s primarily by physicists can’t imagine AI as having any content, but people trained after CS became formalized as object oriented programming, computer programs verified by correctness proofs and axiomatized proofs of algorithm efficiency can’t imagine anything but computation as formalized logic. Computation researchers trained after the 1970s are unable to imagine alternatives to the AI dogmas. My suggestion is to adopt the ideas of Danish computer scientist, who was trained as an astronomer, Peter Naur. Naur argued that computation should be studied as dataology. dataology is a theory neutral term for studying data. Naur wrote "mental life during the twentieth century has become entirely misguided into an ideological position such that only discussions that adopt the computer inspired form" are accepted. (Naur[2007], 87).

In the 1990s, Peter Naur, one of the founders of computer science, realized that CS had become too much formal mathematics separated from reality. Naur advocated the importance of programmer specific program development that does not use preconceptions. I would put it as computation allows people to express their ideas by writing computer programs.

The clearest explanation for Naur’s method appears in the book Conversations - Pluralism in Software Engineering (Naur[2011]). This books amplifies the program development method Naur described in his 2005 Turing Award lecture (Naur[2007]). In Naur[2011] page 30, the interviewer asks "... you basically say that there are no foundations, there is no such thing as computer science, and we must not formalize for the sake of formalization alone." Naur answers, "I am not sure I see it this way. I see these techniques as tools which are applicable in some cases, but which definitely are not basic in any sense." Naur continues (p. 44) "The programmer has to realize what these alternatives are and then choose the one that suits his understanding best. This has nothing to do with formal proofs." dataology without preconceptions and predictions of imminent replacement of human intelligence by robots would improve the scientific study of computation. The next step for advocates of AI would be to try to falsify Naur’s dataology.

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