A working list: Definitions of Artificial Intelligence and Human Intelligence

The AGI Sentinel Initiative (AGISI.org), research survey to understand the definitions and goals of Machine Intelligence (MI).

The definitions listed below are provided to help respondents consider what constitutes machine intelligence and thus the goal of AI. They were curated from published papers, articles, books, and research studies, among other sources.

Respondents have the opportunity to confirm their level of agreement with the cited definitions and to propose their own or an alternative definition and, if appropriate, citation or reference.

Whilst we have not included it as a definition or goal, it is worth reminding respondents of the survey that in the initial Dartmouth paper outlining the purpose of the study meeting, which heralded the science of Artificial Intelligence (AI) (*in name at least*), the authors stated: *"The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it"* (McCarthy et al., 1955).

Since the Dartmouth study meeting, and the wildly cited earlier work by Turing (1950), as Russell and Norvig (2010) point out, the history of artificial intelligence has not produced a clear definition of AI. Thus - Artificial Intelligence is a field of study whose major goals include its own definition. The robust work by Legg and Hutter (2007), leading to a definition of Machine Intelligence, is one of the most frequently cited recent definitions, yet has shown to be problematic to measure (Schaull, Togelius, & Schmidhuber, 2011; Hernández-Orallo & Dowe, 2010). Furthermore, one of the authors, Shane Legg, declared in a later co-authored paper with Joel Veness (Legg & Veness, 2011/2013): *"We believe that until we have a more precise definition of intelligence, the quest for generally intelligent machines will lack reliable techniques for measuring progress."*

We hope the results of our study, which will also include a rigorous review of the literature, will help inform academics, researchers, and practitioners with respect to an agreed upon definition of the goals of AI from the widest number of practitioners and researchers, and in so doing help towards the creation of building something like an artificial scientist to benefit humanity.

We have deliberately omitted the references and citations in the survey form for two reasons 1) brevity and 2) endeavor to eliminate some potential bias in choices.

The definitions are provided in historical (published date) order first and then alphabetical order starting with the surname of the first cited author. Respondents should not infer any priority based on the order in which the material is presented.

References:

Hernández-Orallo, J. and Dowe, D. L. (2010). Measuring universal intelligence: Towards an anytime intelligence test. Artificial Intelligence.
Legg, S. and Hutter, M. (2007). Universal Intelligence: A Definition of Machine Intelligence. Minds and Machines, 17(4):391–444, Springer.

Legg, S. and Veness, J. (2011/2013). An Approximation of the Universal Intelligence Measure. Available also on Arxiv 2011.

McCarthy, J., Minsky, M. L., Rochester, N., Shannon, C.E. (August 31, 1955). A Proposal For The Dartmouth Summer Research Project On Artificial Intelligence. (Portions of the proposal have been reprinted in John McCarthy, Marvin L. Minsky, Nathaniel Rochester, and Claude E. Shannon (Winter 2006). A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence. AI Magazine, Vol. 27, No. 4, p. 12.)

Russell, S. J. and Norvig, P. (2010). Artificial Intelligence: A Modern Approach. Third Edition, Prentice Hall.

Schaull, T., Togelius, J., and Schmidhuber, J. (2011). Measuring Intelligence through Games (Note - the theory presented by Schaul et al. may have subsequently been overcome in Volodymyr Mnih, et al. (2015). Human-level control through deep reinforcement learning. Nature, 518:529–541, Macmillan Publishers Limited.)

Turing, A. M. (1950). Computing Machinery and Intelligence. Mind 49:433–460.

Table 1: Definitions of Artificial Intelligence or Machine Intelligence.

No.	Author(s)	Definition of Artificial Intelligence or Machine Intelligence	Title and other publication details
1	Winston, P. H.	"Artificial Intelligence is […] the study of the computations that make it possible to perceive, reason, and act."	Artificial Intelligence. Third Edition, Addison-Wesley Publishing Company, 1992.
2	Fogel, D. B.	"[Intelligence is] the capability of a system to adapt its behavior to meet its goals in a range of environments."	Defining Artificial Intelligence. In Evolutionary Computation: Toward a New Philosophy of Machine Intelligence. Third Edition. The Institute of Electrical and Electronics Engineers, Inc., IEEE Press, 2006.
3	Legg, S. and Hutter, M.	"Intelligence measures an agent's ability to achieve goals in a wide range of environments." "A very general and flexible capacity to succeed when faced with a wide range of problems and situations."	Universal Intelligence: A Definition of Machine Intelligence. Minds and Machines, 17(4):391–444, Springer, 2007.
4	McCarthy, J.	"Intelligence is the computational part of the ability to achieve goals in the world."	What Is Artificial Intelligence	Basic Questions, Formal Reasoning Group, 2007 Available at https://goo.gl/GM5wwX (Last accessed: October 8, 2018).
5	Wang, P.	"The essence of intelligence is the principle of adapting to the environment while working with insufficient knowledge and resources. Accordingly, an intelligent system should rely on finite processing capacity, work in real time, open to unexpected tasks, and learn from experience. This working definition interprets "intelligence" as a form of "relative rationality."" "Intelligence is the capacity of a system to adapt to its environment while operating with insufficient knowledge and resources."	What Do You Mean by "AI"? In P. Wang, B. Goertzel, and S. Franklin (eds.), Artificial General Intelligence 2008, Proceedings of the First AGI Conference, Frontiers in Artificial Intelligence and Applications, 171:362–373. IOS Press Amsterdam, The Netherlands, 2008.
6	Laird, J. E., Wray, R. E., Marinier, R. P., and Langley, P.	"The goal is to build computer systems that exhibit the full range of the cognitive capabilities we find in humans. […] The ability to pursue tasks across a broad range of domains, in complex physical and social	Claims and Challenges in Evaluating Human-Level Intelligent Systems. In B. Goertzel, P. Hitzler, & M. Hutter (eds.), Proceedings of the Second

		environments. [A human-level intelligence] system needs broad competence. It needs to successfully work on a wide variety of problems, using different types of knowledge and learning in different situations, but it does not need to generate optimal behavior."	Conference on Artificial General Intelligence. Atlantis Press, 2009.
7	Goertzel, B.	"Pragmatic general intelligence measures the capability of an agent to achieve goals in environments, relative to prior distributions over goal and environment space. Efficient pragmatic general intelligences measures this same capability, but normalized by the amount of computational resources utilized in the course of the goal-achievement."	Toward a Formal Characterization of Real-World General Intelligence. In E. B. Baum, M. Hutter, and E. Kitzelmann (eds.), Artificial General Intelligence, Proceedings of the Third Conference on Artificial General Intelligence, AGI 2010, Lugano, Switzerland, March 5–8, 2010, pp. 19-24. Advances in Intelligent Systems Research 10. Amsterdam: Atlantis, 2010.
8	Nilsson, N. J.	"Artificial intelligence is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment."	The Quest for Artificial Intelligence. A History of Ideas and Achievements. Cambridge University Press, 2010.
9	Russell, S. J. and Norvig, P.	"Intelligence is concerned mainly with rational action. Ideally, an intelligent agent takes the best possible action in a situation." "The designing and building of intelligent agents that receive percepts from the environment and take actions that affect that environment." Four possible goals: "systems that think like humans, systems that act like humans, Systems that think rationally, Systems that act rationally."	Artificial Intelligence: A Modern Approach, Third Edition. Prentice Hall, 2010.
10	Muehlhauser, L. and Salamon, A.	"Intelligence measures an agent's capacity for efficient cross-domain optimization of the world according to the agent's preferences."	Intelligence Explosion: Evidence and Import. In A. H. Eden, J. H. Moor, J. H. Soraker, and E. Steinhart (eds.), A Scientific and Philosophical Assessment (pp. 15–42), Springer, 2012.
11	Bostrom, N.	"Machines matching humans in general intelligence — that is, possessing common sense and an effective ability to learn, reason, and plan to meet complex information-processing challenges across a wide range of natural and abstract domains."	Superintelligence. Paths, Dangers, Strategy. Oxford University Press, 2014.
12	Gershman, S. J., Horvitz, E. J., and Tenenbaum, J. B.	"We chart the view of intelligence as computational rationality: computing with representations, algorithms, and architectures designed to approximate decisions with the highest expected utility, while taking into account the costs of computation."	Computational rationality: A converging paradigm for intelligence in brains, minds, and machines. Science 349(6245):273–278, 2015.
13	Mnih, V. and other 18 authors	"A central goal of general artificial intelligence [is to] create a single algorithm that would be able to develop a wide range of competencies on a varied range of challenging tasks."	Human-level control through deep reinforcement learning. Nature, 518:529–541, Macmillan Publishers Limited, 2015.
14	Ema, A. and other 11 authors	AI is defined as "intellectual machines and systems [...] that could automatically sense people's situations or expectations, and offer necessary information before it is required."	Future Relations between Humans and Artificial Intelligence: A Stakeholder Opinion Survey in Japan. IEEE Technology and Society Magazine, 35(4):68–75, December 2016.

15	United States Defense Science Board (DSB)	"Artificial intelligence, the capability of computer systems to perform tasks that normally require human intelligence (e.g., perception, conversation, decision-making)." "AI systems will provide the most added value (the competitive edge), not only by equating human intelligence, but precisely by surpassing it – even if only within a narrow domain, such as information analysis or reaction time."	Defense Science Board Summer Study on Autonomy. Publisher: United States. Defense Science Board, 2016. Available at https://goo.gl/mm6N6y (Last accessed: October 8, 2018).
16	De Spiegeleire, S., Maas, M., and Sweijs, T.	"One strategically (and therefore analytically) relevant definition for our purposes is that of AI as a rational optimization agent that can (enable humans to) act competently in the world (that is, subtype Behavior and Rational)."	Artificial Intelligence and the Future of Defense: Strategic Implications for Small and Medium Sized Force Providers.The Hague Centre for Strategic Studies, 2017.
17	Lewis, C. W. P. and Monett, D.	"Machine Intelligence is the ability of a 'bounded optimal' agent to provide rational, unbiased guidance and service to humans so as to help them achieve optimal outcomes in a range of circumstances." "Machine Intelligence (MI) is the continuation of intelligence by an artificial agent in support of humanity."	A Theory on Understanding Human Intelligence and a Persuasive Definition of Machine Intelligence for the Benefits of Humanity. (Working paper, unpublished)

Table 2: Definitions of Human Intelligence.

No.	Author(s)	Definition of Human Intelligence	Title and other publication details
1	Ebbinghaus, H.	"Intelligence means organization of ideas, manifold interconnection of all those ideas which ought to enter into a unitary group because of the natural relations of the objective facts represented by them. The discovery of a physical law in a multitude of phenomena apparently unrelated, the interpretation of an historical event of which only a few details are directly known, are examples of intelligence thought which takes into consideration innumerable experiences neglected by the less intelligent mind. Neither memory alone nor attention alone is the foundation of intelligence, but a union of memory and attention."	Psychology: An Elementary Text-book. M. F. Meyer (Ed.). Boston: Heath, 1908.
2	Binet, A. and Simon, T.	"Intelligence serves in the discovery of truth. But the conception is still too narrow; and we return to our favorite theory; the intelligence marks itself by the best possible adaptation of the individual to his environment."	The development of intelligence in children (the Binet-Simon scale). In H. H. Goodard (Ed.), The development of intelligence in children. Baltimore: Williams & Wilkins (original work published 1909, republished 1916).
3	Wechsler, D.	"Intelligence is the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment. It is global because it characterizes the individual's behavior as a whole; it is an aggregate because it is composed of elements or abilities which, though not entirely independent, are qualitatively differentiable."	The measurement of adult intelligence. Baltimore: Williams & Wilkins, 1939.

4	Bigge, M. L.	"Intelligence is an individual's ability to respond to a given situation by anticipating the possible consequences of his actions."	Learning Theories for Teachers. Third Edition, London: Harper & Row Publishing, 1976.
5	Humphreys, L. G.	Intelligence is an individual's "entire repertoire of acquired skills, knowledge, learning sets, and generalization tendencies considered intellectual in nature (problem solving skills) that [is] available at any one period of time."	General Intelligence. In C. R. Reynolds and R. T. Brown (eds.), Perspectives on bias in mental testing, Springer, 1984.
6	Anastasi, A.	"Intelligence is […] a quality of behavior. Intelligent behavior is essentially adaptive, insofar as it represents effective ways of meeting the demands of a changing environment."	Intelligence as a quality of behavior. In R. J. Sternberg and D. K. Detterman (eds.), What is intelligence?: Contemporary viewpoints on its nature and definition (pp. 19–21). Norwood, NJ: Ablex, 1986.
7	Das, J. P.	"Intelligence, as the sum total of all cognitive processes, entails planning, coding of information and attention arousal. Of these, the cognitive processes required for planning have a relatively higher status in intelligence. Planning is a broad term which includes among other things, the generation of plans and strategies, selection from among available plans, and the execution of those plans. […] Coding refers to two modes of processing information, simultaneous and successive. […] The remaining process (attention arousal) is a function basic to all other higher cognitive activities."	On definition of intelligence. In R. J. Sternberg and D. K. Detterman (eds.), What is intelligence?: Contemporary viewpoints on its nature and definition (pp. 55–56). Norwood, NJ: Ablex, 1986.
8	Sternberg, R. J.	"Intelligence is mental self-government. […] The essence of intelligence is that it provides a means to govern ourselves so that our thoughts and actions are organized, coherent, and responsive to both our internally driven needs and to the needs of the environment."	Intelligence is mental self-government. In R. J. Sternberg and D. K. Detterman (eds.), What is intelligence? Contemporary viewpoints on its nature and definition (pp. 141–148). Norwood, N.J: Ablex, 1986.
9	Fontana, D.	"[Intelligence is] the ability to see relationships and to use this ability to solve problems."	Psychology for Teachers. Second Edition, London: Macmillan, 1988.
10	Gottfredson, L. S.	"Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather it reflects a broader and deeper capability for comprehending our surroundings — "catching on," "making sense" of things, or "figuring out" what to do."	Mainstream science on intelligence: An editorial with 52 signatories, history, and bibliography. Intelligence, 24:13–23, 1997.
11	Ramos-Ford, V. and Gardner, H.	"[Intelligence is] an ability or set of abilities that permit an individual to solve problems or fashion products that are of consequence in a particular cultural setting."	Giftedness from a multiple intelligences perspective. In N. Colangelo and G. A. Davis (eds.), Handbook of gifted education. Second edition (pp. 439–459). Boston: Allyn & Bacon, 1997.
12	Simonton, D. K.	"My view of intelligence is basically a Darwinian one. It's based on sort of the old Functionalist notion that goes way back to Francis Galton, that says that there are a certain set of cognitive capacities that enable an individual to adapt and thrive in any given environment they find themselves in, and those cognitive capacities include things like	Definition of Intelligence. Human Intelligence. Streaming Video, 2003. Available at https://www.intelltheory.com/simonton_interview.shtml (Last accessed: October 8, 2018).

		memory and retrieval, and problem solving and so forth. There's a cluster of cognitive abilities that lead to successful adaptation to a wide range of environments."	
13	Sternberg, R. J.	"Intelligence is: 1) the ability to achieve one's goals in life, given one's sociocultural context; 2) by capitalizing on strengths and correcting or compensating for weaknesses; 3) in order to adapt to, shape, and select environments; and, 4) through a combination of analytical, creative, and practical abilities."	The Theory of Successful Intelligence. Journal of Psychology, 39(2):189–202, 2005.
14	Deary, I. J., Penke, L., and Johnson, W.	"Intelligence is clearly a combination of the ability to 'figure things out on the spot' and the ability to retain and repeat things that have been figured out in the past."	The neuroscience of human intelligence differences. Nature Reviews, Neuroscience, 11:201–211, March 2010.
15	Hampshire, A., Highfield, R. R. , Parkin, B. L. , Owen, A. M.	"Human intelligence is most parsimoniously conceived of as an emergent property of multiple specialized brain systems, each of which has its own capacity […] that contribute to an individual's ability to perform across a broad range of cognitive tasks."	Fractionating Human Intelligence. Neuron 76:1225–1237. Cell Press, Elsevier Inc., December 2012.
16	Stanovich, K. E.	To think and behave "rationally means taking the appropriate action given one's goals and beliefs and holding beliefs that are commensurate with available evidence." Intelligence is thus: "optimal behavior in the domain of practical affairs. The optimization of the individual's goal fulfillment."	Assessing Cognitive Abilities: Intelligence and More. Journal of Intelligence. 2(1):8–11, February 2014.
17	Sniekers, S. and other 29 authors	"Intelligence is associated with important economic and health-related life outcomes."	Genome-wide association meta-analysis of 78,308 individuals identifies new loci and genes influencing human intelligence. Nature Genetics (pp. 1–8), 2017.

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