Brute force computation and intelligence

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Abstract: Energy use and the necessary data are a good metric for comparing natural and artificial performance. How much energy and how much data processed for achieving a well-defined goal are quantifiable. Artificial entities could justifiably be defined as intelligent if, in executing a task, energy and data usage would be as much or less than those of a living entity (not only human) performing the same task. The qualifier *intelligent*, pertaining to performance, stands in contrast to brute force methods achieving equal performance, but at higher cost.

Key-words: data, energy, matter, living matter, anticipation, adaptivity, brute force

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1 Preliminaries

It is assumed that the physics of energy is known well enough so that it not be rehashed here. In order to perform work, energy is needed. The physics of particles changing position in space is appropriate for describing phenomena ranging from those dealt with in Galileo's mechanics, as well as those that Newton tried to explain. In Einstein's famous equation, $E=mc^2$, a more encompassing view is expressed: energy and matter are, if not the same, at least tightly intertwined. For everything in the universe that is embodied in matter, this knowledge informs a view successfully applied in constructs usually described as machines. They are embodied instantiations of deterministic causality: a force is applied, and work is performed in a manner reflecting the characteristics of the forces involved.

Things are a bit more complicated in respect to living matter. By its nature, the living depends on energy metabolized from the environment. Obviously, the energy processes involved in the work of a lever and the processes characteristic of machines that process data are different. But it takes intelligence to apply force in order to move a boulder, as it takes intelligence to answer questions on ChatGPT. In our days, intelligence is of special interest given the impressive performance of machines intended to achieve intelligence. These preliminaries are unavoidable for everyone trying to characterize the performance of the artificial—i.e.,
human-made—in contradistinction to the natural.

2 Performance Evaluation

In the absence of adequate evaluation means and methods, the current state and the future of artificial intelligence (AI) cannot be meaningfully assessed. The premise for adequacy is the understanding of what the subject of evaluation is. It is expressed in the specific metric, i.e., the benchmark, to be applied when evaluation of performance is undertaken. The evaluation must be agnostic of how the goal of conceiving, designing, and building machines labeled *intelligent* is reached. In other words, whether computer-based, or of any other nature (various machine types preceded the Turing machine, and there is future even after the Turing machine), the machine's purpose cannot be confounded with the means by which the purpose might be achieved, or even with the machine's output. The moving of goalposts (the "AI effect," i.e., what was once labeled AI and became routine data processing [1] will not help in defining how AI is different, or not, from the broad understanding of algorithmic computation. Neural computation seems intelligent only if the performance (LLM and its expression through GPT or any other similar kind) is disconnected from the brute force at the expense of which it is achieved. Yann Le Cun, of distinguished accomplishments in convolutional neural networks, remarked (Twitter of 3/27/23, 7.05 pm): "Humans don't need to learn from a trillion words to reach...intelligence." While trained on trillions of words, ChatGPT is still questioned. Is it a better hammer or a nail gun? Therefore, evaluation is not optional, but necessary if humans want to remain in control of their destiny.

Awareness of the difficulty of defining intelligence is ([2], [3], [4], [5], provide some examples) is indicative of the acknowledged need to go beyond the “inaugural banner” (the Dartmouth Conference of 1956). “An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves” was defined as a goal in the *Proposal for a Summer Research Project*. Among the aspects discussed in the paper, How Can a Computer be Programmed to Use a Language: “It may be speculated that a large part of human thought consists of manipulating words according to rules of reason and rules of conjecture (August 31, 1955). It sounds almost like today, but we are still not clear in respect to evaluating what has been achieved

All known attempts at a metric of progress in A—i.e., was this goal achieved—have so far failed. Following in the footsteps of Diderot (1746: “s’il se trouvait un perroquet qui répondit à tout, je prononcerais sans balancer que c’est un être pensant”, translated as “…if there was a parrot which could answer every question, I should say at once that it was a thinking being”) [6], Turing suggested an imitation test.7Chollet ([2, p.3] described it as a way to “outsource the task” of distinguishing machine intelligence from human intelligence to “unreliable human judges.” They themselves don’t know better—as we discover in our days of excitement over text-to-image performance of LLM production. Together with its “relatives”—e.g., the Total Turing Test, the Loebner Prize—the Turing test is but the better-known example of such failures. The reason for this unavoidable outcome—i.e., its inadequacy—is obvious: the curse of circularity. Minsky’s definition—“AI is the science of making machines capable of performing tasks that would require intelligence if performed by humans” [7])—points to the “center” of the circle in which AI, as a particular form of computer science, keeps moving. It takes intelligence to perform tasks related to survival. Agriculture is a living example. Or you can do it by brute force, turning it into an industrial task that consumes more energy than it makes available through its products. Extending the radius (from expert systems to deep learning to whatever else) does not break the circularity of the enterprise: what goes in (data in standardized form) comes out (processed data in standardized form). The specification of the data—the standards for representation—proliferates in the processed data. But there is no knowledge to account for. The immense amount of data used in training neural networks is but the most recent example. Moreover, there is no way to meaningfully quantify the cost of the performance.

This paper (part one of a series of elaborations on the subject, [8], [9], [10], [11] starts by placing the subject in its proper context: How does the living achieve its intelligent performance? Evidently, not by brute force! The living is proof: It experiences self-healing, but it can also be subjected to the mechanics of “fixing” [12]. Based on this observation, a first attempt at defining artificial intelligence, and what it takes to achieve it, is expressed in the form of an axiom. It pertains to data and energy—parameters which can be measured. Therefore, the consequences of the axiom are testable. The outcome of tests—take the same task and have it resolved by various individuals (young, adult, elderly, male, female, healthy, ill, etc.) and by machines—could guide in a possible more stringent formulation of the criteria suggested.

3 Learning from the Biology of Survival

important it is to understand the Diderot and Turing focused on imitation as an identifier of intelligence. No doubt, machines embodied in lifeless matter succeed more and more in emulating activities associated with living matter organisms. Emulation is the domain of the artificial—of AI, in particular, and more recently of Machine Learning (ML), as a particular form of AI. But is it intelligent to consume more resources for achieving the same result if less would do? Not surprisingly, the discussion of the Singularity ([13], [14]), the presumed state in which the artificial outperforms the living, was reignited by recent accomplishments. At any cost—never mind, immediate price and long-term consequences. Indeed, the artificial knee or hip are mechanically better than the natural. But replacement means high energy cost invasive procedures, with consequences impossible to fully assess in advance. Is the situation of the “artificial brain” any different? The salamander regeneration process [15] is one example of how dynamics of the living.

Large Language Model (LLM) developments integrate the attempt to use language in trigger performance, such as text-to-image generation, and furthermore to create language models which mimic understanding language and generate similes of human language. ChatGPT stole the show, but it is by far not unique (Bard, Bing AI Chat, etc. are alternatives), neither in performance nor in the basic principle applied and represented by Transformers.

> GPT-4 is a large multimodal model (accepting image and text inputs, emitting text outputs) that, while less capable than humans in many real-world scenarios, exhibits human-level performance on various professional and academic benchmarks [16].

The context is clear: computation in non-living matter (artificial neural networks, ANN) and language performance characteristic of the human (embodied in living matter) are compared to each other. It is therefore justified to see how the distinction between matter and living matter can help in understanding what this all means. Since intelligence-driven evolution of humanity reached the level at which resource consumption became an issue of its survival, to ignore the consequences of this situation means to ignore the perspective of sustainability.

In living matter across scales—from cells to organisms to species—activities for the preservation of life cannot consume more energy than what metabolism affords. This is the *Minimum Energy Principle* (MEP). The MEP does not hold for the human being. From the entire realm of the living, only the species *homo sapiens*—*thinking* being the ultimate identifier—consumes more energy in its self-preservation than what metabolism alone contributes. What became known as *culture*—i.e., the tamed nature within which human activity takes place—is the outcome of progressively increasing energy use, and thus the continuous remaking of oneself. No other form of life on Earth has this behavioral pattern. The human being redefined itself in respect to physical abilities—augmented by tools and machines—and to thinking—cognitive abilities, associated with a larger brain. The augmented capabilities are energy and data dependent.

Designing and building non-living matter with capabilities that can be associated with natural intelligence—the cutting edge of science today—is an energy-hungry endeavor. Outsourcing natural functions to artifacts starts with the use of tools. They are in anticipation of their use, i.e., a way to multiply future possibilities. Tools date back to the first identifiable human forms of activity. Their development is in full swing in our days when intelligence itself—in the form of processes emulating intelligent behavior—is expected from machines. From their hard condition—matter made into artifacts—to their soft condition—programs to activate various machines—they represent knowledge put into action. The immediate result of this pattern—from hardware to software—is the disconnect between means of existence—ecological sources of energy—and progressively reduced natural expression, i.e., declining anticipatory action.

Understanding how change takes place—including their own changes over time—humans produced science. Based on it, technology effectively substituted the innate anticipatory abilities of individuals. Artificially constructed models of the future inspired by the past became the goal. The minimum energy threshold characteristic of survival was effectively overwritten by the optimistic principle of *Everything Is Possible* (EIS)—at the expense of the ecological system. The human species lives at the expense of the rest of the environment of its existence. And it is the only species *devolving* into overpopulation. No other living being could afford activities in which the outcome is lower than the effort to achieve it. The flipping of the Upside/Downside Ratio, i.e., the negative yield of human activities, is characteristic of a new stage in the life of societies. It documents the assertion that human beings live more and more at the expense of the future.

It is justified to define intelligence in the perspective of the MEP, in conjunction with its particular expression as the Data Minimum Principle (DMP). Taking in reality through the senses consumes energy. Given the behavior conditioned by the MEP, it follows that the living, through perception, measures reality to the minimum possible. This means that data pertinent to life interactions cannot be less than the minimum it takes for the preservation of life. Various artifacts (wearables are an example) provide sensors for acquiring even more data than what the organism needs for its functioning in the environment. This no longer reflects survival needs but rather expectations of all kinds; for example: living longer, or enjoying life above and beyond what the environment affords, often at the expense of the ecology.

4 The Axiom of Intelligence

Given the obsession with higher performance in imitating life, it is justified to evaluate the performance of artificial means, in order to assess their viability. Based on this understanding, an evaluation principle (could be articulated as an axiom) can be formulated:

> Artificial entities could justifiably claim intelligence if, in executing a task, they would use as much energy or less, and as much data or less, than a living entity performing the same task. [17]

Energy use and the necessary data are a good metric for comparing natural and artificial performance: how much energy and how much data is used in a well-defined activity. Some machine learning applications (chess, or *Go* playing can use as much electricity as a small town over the duration of the performance [18], [19]. Training GPT (and any other similar applications) has a large footprint (GPT-3 took 1.287 gigawatt hours, the equivalent of what 120 US households would consume during a whole year). ChatGPT may have consumed as much electricity as 175,000 individuals in January of 2023 [20]**.**

The energy consumed by the miniscule bar-tailed godwit during migration is acquired through metabolism. The data processed are acquired through "measuring," i.e., sensing the environment. (Data acquisition also involves energy expenditure.) The take-off, ascent, gliding, bonding, soaring, and continuous forward flight by the action of flapping wings are energetically different. Some actions are more "expensive" than others. Altitude is yet another factor: less oxygen, for example, addressed by a different motoric for consuming less of it [21]. For the sake of the discussion, it suffices to mention that a power of 4.3 watts is actually used for the flight [22]. This is by some orders of magnitude less than what would be needed to guide an artificial bird of similar size and weight. Winning, or losing for that matter, a game of chess or of *Go* does not require a power plant if performed by a human being. Getting a robot to dance or to collect samples from Mars, or getting a submersible to collect samples from the ocean depths requires lots of data and lots of power. The data processed by humans in playing the games is in the order of kilobytes. This is way smaller than the huge data amounts (order of 10^{120}) guiding the artificial playing machine. The human brain operates on 20-30 watts—less than an LED source. Even the plankton inhabiting the oceans is much more intelligent than what the most sophisticated machinery, based on the deterministic science dominating civilization, can achieve. This pertains to the energy used and the data collected and is expressed in its adaptive performance. Indeed, the dynamics of the plankton is non-deterministic. The plankton navigates the oceans under terrible conditions, finding survival niches for which we do not have names. In anticipation of adverse conditions, swarms of migrating birds or of fish change, respectively, flight altitude or swimming depth. Even under the most generous assumptions of scientific and technological progress, performance comparable to that of living entities in a continuous *state of anticipation* is not even on the agenda of current science and technology. Such a performance is as impossible as doubling a cube using a compass and ruler, or as squaring the circle.

What makes the difference is the anticipatory component of the activity. Migratory behavior exhibits adaptive characteristics associated with anticipatory processes driven by the possible future. The timeline (migration start) and the trajectory are fine-tuned to possible storms, as though the migrating birds, or migrating fish or animals, are prescient of what might affect—possible future—their respective journeys (on the predictive performance of Veeries, see [23], one reference from among many). Artificial entities embodied in non-living matter are "fired up" with energy from the outside and with data from measurements of similar activities. To be precise: the living senses the environment. Sensing involves energy use: to measure is an activity engaging the entire living being. When the available energy acquired through metabolism or stored is too low, the living ceases to take in "reality." The interlocking of energy and matter in the living is different from that expressed in Einstein's equation.

5 Intelligence and Sustainability

The living is in a state of anticipation from the start of life until its end. It is a continuous state, with various forms of expression and variable intensity. It engages the entirety of the organism, at all its levels. In this sense it depends on metabolism and on perceptual activity. Avoiding danger, as opposed to reacting to it, is, from the perspective of the data involved and the energy consumed, quite different. Outperforming others in the context of the competitive nature of life and in securing evolutionary advantage takes place also on account of energy use and data processing appropriate to the circumstances.

Inventions qualify as examples of activities driven by anticipation. Anticipatory processes effectively extend awareness of cause-and-effect into the richer sense of causality that integrates past, present, and possible future. “Sensing” the future, i.e., virtually living it before it becomes real, means awareness of consequences. From an energy and data perspective, this is different from the practice of predicting it on account of measuring reality and inferring from a current state to a future state. It succeeds (or fails) if the energy expense undermines life. That is, if the data goes beyond what a specific living entity can afford to acquire, there is no future state to account for. The minimum energy for the human being is not predicated by the threshold of life, i.e., what is needed to maintain life, but rather by gaining independence from environmental limitations. Human beings extract from the environment more and more energy than is needed to survive and multiply. They adopted brute force not only for wars, but also for taming the environment. Moreover, because they can, humans also acquire more data than what would be needed to maintain life. Data surveillance is not intelligent, but rather integrates brute force control mechanisms into patterns of social life (mediated, for example, by social media).

A metric for artificial intelligence is, however, not only a means for comparing natural and artificial performance. It also provides a view of skewed social relations and the consequences of surrendering intelligence to brute force machines. Understanding this dynamic could help in the broader evaluation of what it takes to achieve sustainability. On their current course, AI and ML achievements qualify as brute force performance to the detriment of meaning. In the absence of intelligence, sustainability cannot be achieved.

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