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Implications on the Consciousness of Various Animals given Mathematical Models

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While many lifeforms on earth have beautifully complex interactions with the environment around them as well as other members of their species that humans are still baffled by, the field of biological modelling is unraveling many of the mysteries behind these animals and their actions. The goal of this paper is to show that as we develop more mathematical models of animals, the less credit we can give to claims that the animals are conscious in a capacity beyond what machines and computers are capable of. Using parts of Rene Descartes', automation theorists of the 1800's, John Searle, and David Chalmer's philosophies and arguments, this paper isolates how each algorithm detracts from the potential for consciousness from the animals. Lastly, the paper poses an alternative conclusion for the outcome on the consciousness of the animals explored as it pertains to AI.

Rene Descartes was a famous French philosopher who tackled the issue of consciousness in NHAs in the 1600's, when we wrote his both "Discourse on the Method of Rightly Conducting one's Reason and Seeking Truth in the Sciences"[1] and his "Principles of Philosophy" [2]. In his writing, he discusses the differences between man and all other animals. While he wasn't quite right in some of his beliefs - such as his idea that animal spirits are what give our bodies then energy to move - he did make an argument placing humans above other animals by way of a 'soul'. This 'soul' was religiously based, as he believed man was the sole possessor of the soul, and this soul could remain when our bodies die and thus could be shown to move to an afterlife, but essentially served as an explanation for our free will. The soul provided man with his free will, rationality, and subjective experiences, such as "emotions or passions of the mind that don't

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[1] Descartes, René, *Discourse on the Method*
[2] Descartes, René, *Principles of Philosophy*, SIAXXXVIII

consist of thought alone, such as the emotions of anger, joy, sadness and love"[3]. However, it also provided us with the ability to feel sensations such as pain and pleasure[4] which has widespread implications for NHAs. Because the soul is a uniquely human phenomena, it was Descartes' belief that NHAs must be incapable of pain, pleasure, emotions, or passions.

Knowing that NHAs are incapable of all of these phenomena, Descartes wrote in his 1637 discourse that animals were simply machines. To defend his classification, Descartes brought up an example similar to thought experiment we will discuss later. In it, he asks the reader to imagine a machine constructed in such a way that it responds to stimuli in a manner that we would expect a living being to, or even respond to jabs to its body by responding with an exclamation of "Ouch, that hurts!". Descartes argues that this machine will never have the ability to respond to every possible interaction, or formulate new sentences on its own, something that even "the dullest of men can do"[5]. Another example is given by a machine that performs better than we ever could in some action, but again argues that it is impossible a machine could ever be built that excels in every action that a human can perform. Yet, he still explains both away by saying that their entire ability (or perceived ability) comes from the specific arrangement of the organs that they were built with - something that they themselves are incapable of changing and thus limited in what they can accomplish. Descartes explains this phenomena by pointing out that even the least intelligent of men can cobble together sentence or comprehensible utterances yet no NHAs are able to talk like we do. According to him, this shows that all NHA's lack any reason whatsoever, affirming their status as biological automata - as the brightest and most gifted

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[3] Descartes, René, *Principles of Philosophy*, SIAXXXVIII
[4] Ibid
[5] Descartes, René, *Discourse on the Method*

members of some species - assuming they have any reason whatsoever - should be able to create their own language to communicate, at least to the extent of a disabled child. Since we lack any evidence of this, it is clear that animals lack all reason.

Descartes used NHA's lack of reasons (and therefore anything more than the physical body) to justify the use of vivisection - live dissections of animals to learn more about the systems within them. The root of his argument was that the soul was responsible for feeling pain and pleasure[6], and since animals lack the soul, they don't feel pain. Any cries uttered are simply reactions to the outside stimuli to certain organs, just as described with the biological machines described in his Discourse. While we now know that many animals feel pain, what I argue is that it has no impact on the possibility of NHA consciousness since they still don't suffer. It is clear that it would be biologically advantageous for an organism to feel pain in dangerous situations, as it lets the organism know it needs to escape the source of the painful stimulus. However, even if they feel pain, biological automata have no ability to suffer. There is no emotional state with which their pain coincides with to let them suffer. It is simply pain signals being shot to the brain from the nociceptors on the animal.

The Chinese Room[7] is a thought experiment proposed by John Searle in 1980 in response to the increase of artificial intelligence of the time, primarily around what is known as 'Strong AI'. In his paper, Searle brings up the idea of a room containing an operator who is unfamiliar with the Chinese language. From outside the room, the operator is given examples of Chinese characters and a set of instructions on constructing an answer from the characters on the given writings. The operator scribbles down the marks in the instructions that match the key of the

[6] Descartes, René, *Principles of Philosophy*, SIAXXXVIII
[7] Searle, John

input writing, then slots the paper full of their own scribbles through the slot in the wall. This pattern continues and the operator continues their process of scribbling marks that match the corresponding marks in the instruction set. It is clear to see that the operator doesn't understand the relationship in a meaningful way. However, to an outside observer, it looks to them like for every sensible input they give the room, they get a corresponding, sensible output, so they could conclude that the room (and operator inside) understand the Chinese language since that is the only observation to make.

This is a useful thought to keep in mind throughout this paper. We may see animals creating beautiful, complex, geometric shapes like flocking birds or schooling fish, or cooperating to forages or explore the surrounding area like bees or ants, and we might conclude that all of these actions are obvious examples of higher level thinking and some level of consciousness to be cooperating in such efficient ways. However, if we boil their actions down to the mathematical algorithms that we have discovered, we can understand the root cause of the actions they take.

Throughout the 18th and 19th centuries, a well discussed theory was conscious automatism. This field was roughly dedicated to the discussion of whether or not there was merit to ascribing the description of biological automata in the manner Descartes ascribed to the 'brutes'. The field saw such names the British Empiricist David Hume or T.W. Huxley, as both wrote their thoughts on the possibility of consciousness in animals. Hume argues in his work "A Treatise on Human Nature"[8] that many of the actions made by brutes are simply habitual actions. The dog can infer from the master's tone that punishment is coming, but this comes from their

[8] Hume, David P III, S XVI

memories of previous instances where the tone associated some punishment. However, this is not a sign of reason (on any level recognized as human) but rather that "habit is nothing but one of the principles of nature, and derives all its force from that origin."[9]. While reason plays a similar role for these philosophies, the philosophers themselves around this time were much less inclined to attribute causes to religion, as Descartes did. This gives us both a human-based view as to why animals are essentially living machines as well as a divinely-grounded approach concerning Descartes' soul.

Many of these biologically inspired algorithms center around the interactions between conspecifics, such as flocking, foraging, and exploring. The reason behind this is simple - many animals utilize basic rules to reduce the amount of coordination an individual has and spread the work over all individuals in the crowd. This is what is known as an emergent behavior. Emergent behaviors are useful in biology as they don't require much higher-order thinking yet still yield beneficial results for the species, such as increasing survival rates with predators around. While at first, these algorithms may seem like 'pet-projects' which are the results of bored mathematicians and computer scientists, but actually hold many real-world benefits.

Mimicking evolution is the intuition behind a field of artificial intelligence known as genetic algorithms. The idea behind this field is that the process of evolution has had hundreds of millions of years to fine tune the processes behind many animals behaviors, such as foraging behavior from animals or maximizing group survival during travel. Real world problems have been solved using biologically inspired ideas - such as maximizing the efficiency of vertically aligned wind turbines by copying the process behind schooling fish minimizing their drag in the

[9] Hume, David P III, S XVI

water[10], synchronizing a network using a linear time algorithm modeled after fireflies 'blinking' together[11], or even reducing energy consumption in a 31,000 square foot mall in Zimbabwe by 90% by capturing the efficiency of termite mound cooling methods[12].

The first algorithm and set of animals we will investigate is the BOIDs algorithm and flocking bids/schooling fish. The BOIDs algorithm was developed by Craig Reynolds in the 1980's to model the behavior of birds in as simple of an algorithm as he could. Using only three parameters to layout the rules for each 'boid' object to follow, he developed an algorithm that resembles both the flocking behavior of birds and the swarming of schooling fish. These parameters are are separation (the amount of space each boid leaves its flock mates to avoid crowding), alignment (aligning each boid to be steering in the direction of the average alignment of the flock mates), and cohesion (steering towards the average position of the flock). While these three rules seem basic, the intuition behind them explain much of the reason they work so well. Separation leaves birds in a flock space to move and see, improving their chances of surviving in case of a predatory attack as well as their ability to move together. Alignment keeps the flock from running into each other all the time by maintaining an overall sense of direction. Cohesion improves the individual's chance of survival by essentially padding the directions that a predator could come from with other birds in the flock.

An important piece of the BOIDs algorithm is that the rules can be expanded on to allow more complex models. While not originally part of the BOIDs algorithm, Heppner & Grenander [13] created a similar algorithm in which they add a 'random impact' to account for the seemingly

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[10] Whittlesey et al.
[11] Dolev, Welch
[12] Atkinson, Jon
[13] Heppner, F. H. & Grenander

random movements flocks tend to make. Even after adding these additional rules, it is still clear that any primary school student could still follow these rules, given enough time and knowledge of multiplication. What I propose now is that the animals whose behavior is similar to the behavior predicted by this algorithm are not only less conscious than the children stepping through the algorithm, but lack any sort of consciousness at all. Instead, they are simply biological machines, whose brains are wired in such a way that these operations are expressed as pure instinct.

When we see these animals, be them birds or fish, they look as if they are communicating instantaneously and following a higher order social 'dance' with each other member in the group, since they all avoid colliding with one another and have the ability to change direction with ease. Originally, this was credited by some as proof of telepathy amongst these animals[14], as in Edmund Selous' 1931 book, "Thought-transference (or what?) in birds"[15]. However, what Selous attributed to 'collective consciousness' may have been an example of a system of living machines. The easiest way to understand this would be to look back at the Chinese Room example. The actions that we can observe are simply the outputs of unknown internal decisions, but these decisions may be as simple as the rule look-up that the individual in the Searle's thought experiment was left to do. Imagine a circuit, similar to the wires and gates inside your computer or phone's central processing units, where copper and gold wires are replaced by neural pathways, binary inputs are replaced by the result of the optical observations and generation of the 3 dimensional environment and the actors within it, and the output replaces bytes with a direction vector to fly in.

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[14] Heppner, Lebar Bajec pp 4
[15] Selous, Edmund

Having such a specialized brain would benefit the animal following it greatly, as this kind of modularization for such a significant activity in the organism's life would provide significant improvements in speed, where this kind of operation could be repeated for each instant and thus provide a continuously updating function which output the best direction to travel. If this idea sounds far fetched, I would like to bring up an electronic device with which we are all aware of - the extraordinarily advanced and complex advancement so helpful to humanity's achievements in the past century - the calculator. From my knowledge of Assembly Language and Computer Architecture from the class of the same name at this university, a simple calculator is nothing more than electrical charges being passed around inside an ALU, where simple binary operations are combined to solve calculations from addition to exponentiation to calculus equations in more advanced calculators. This serves as an external ‘brain’ for us humans, which has been modularized to speed up advanced calculations which would take us longer than we would want. The brains of these flocking animals may be the equivalent of a calculator, but within their skulls. Hopefully this example makes concrete how such a circuit would benefit the organism which developed it. Pile on the millions of year which evolution has had to refine the abilities of the animals and you reach an efficient solution to the problem of moving from point A to point B without being eaten. Another fact that would point towards this type of neural module being a possible outcome for these animals would be that not only birds, but also fish have developed similar behavior. This could be an example of convergent evolution, where totally separate species evolve similar traits over time. Having not only one, but multiple instances of this occurring may mean that this is the most effective approach to solving this problem and thus lends credit to my proposal.

Having shown that such a structure for the brains and subsequently system of processing is quite possible for birds, it is clear that these animals should lack any sort of consciousness as defined by Chalmers[16]. Given that Chalmers roughly defines consciousness as the ability to form subjective experiences, it is clear that these machines of animals should be unable to form such experiences, as machines are not able to form subjective instances. Whatever a machine commits to its memory has an innately objective background, since there must have been some set of rules that governed which part of the experience to save. Therefore, it must be impossible for flocking bird and schooling fish to be conscious.

The second algorithm to dissect is the class of algorithms surrounding modeling bee foraging. These are a group of algorithms that deal with modeling the behavior shown by colonies of bees in foraging for food sources around the nest. While not as simple as simply abiding by a few rules like in the BOIDs algorithm, this algorithm provides a simple model that accurately captures the exploration for food sources, the recruiting of other bees when a promising source is found, and even scouting for profitable food sources outside of the local area by certain scout bees[17]. These types of algorithms have found significant use in optimizing combinatorial problems - a class of problems which typically take significant time to solve (on the order of n! iterations to solve a problem with only n variables). This is largely in part to the efficiency with which bees have evolved - as the scouts are responsible for finding the food for the colony and thus them succeeding in as little time as possible is beneficial for the whole colony. In this algorithm[18], bees are ‘initialized’ in random locations that are set to be the ‘flower

[16] Chalmers, David
[17] Pham D.T. et al.
[18] Pham D.T. et al.

patches' surrounding the hive representing the initial search of a colony for novel food sources. Each scout evaluates the fitness - how good their current flower patch is - and returns to the hive. Here, the algorithm utilized the famous 'waggle-dance' of bees to recruit other bees to forage from the highest fitness patches. Then, either the bees find a higher fitness flower patch in the search around the colony and thus recruit the foraging bees to a new source or the foraging bees use up the resources from the flower patch and the resulting fitness of the flower patch decreases. This process continues over and over for some number of iterations and returns the solution it discovered. This algorithm is then repeated again and again and the final return value is the best solution the algorithm could find from the random initializations and subsequent behaviors.

While this algorithm is more complex than the BOIDs algorithm, this still shows a level of automation of the animal that should be enough to consider the organism a biological automata. Similar to the BOIDs arguments, these behaviors are instinctual for the bees, as bees know and understand such interesting concepts as the waggle dance. This would suggest a biological origin for the behavior given the universality of the actions and their meanings. By Morgan's Canon, since we can explain bee behavior with a process of random initializations and subsequent fitness-based exploration, it is reasonable to conclude that they are simply following such an allocation algorithm, programmed into their brains via evolution over the millions of years that they have existed.

Lastly, we explore the complex behavior shown by ant colonies in their exploration and foraging of their surroundings. Ants engage in one of the most efficient models of foraging for food, as they will find the shortest path from their colony to the food source. As a method of solving optimization problems (Shortest Path, Traveling Salesman), researchers looked to harness this exploration method to capitalize on the efficiency. This is exactly what Deneubourg did in his investigation and subsequent model on the exploration/foraging actions of ants[19]. The basic idea is that initially, given a choice of paths, ants will pick a path to travel at random. If the path was short or easy, then on the return trip, they leave pheromones for retracing their steps and signaling to the other ants that their path is the better one. As traffic over the paths increases, the colony finds the shortest/most efficient path from their origin to their destination[20]. The resulting model is less of an algorithm in the sense of the previous two algorithms, but actually says more about the minds of the species. The model is a simple two equations describing the probabilities of the i^{th} ant choosing a path after the previous i-1 ants.

Like the BOIDs algorithm, any child could follow this model, yet the payoff for such a simple model is vast. With such efficiency, a colony of foraging or exploring ants could accomplish the task of finding the shortest path to a food source or traveling the colony as a whole to a new location in close the minimum amount of time, allowing them to gather more resources for the colony. While their actions originally may have appeared to be the result of communication and teamwork amongst individuals, it is simply individual ants optimizing their own path which happens to have the beneficial side effect to other ants of letting them know which path is the optimal path. This would show a level of instinctual decisions similar to the bees or the birds and fish - where evolution has pre-programmed them to engage in the actions that they do. This preprogramming would indicate that the ways the brains of the ants function in are hard-wired and are simply the same manner of output from given inputs as discussed in the section on the BOIDs animals.

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[19] Deneubourg et al.
[20] Ibid

If we look at these animals not as conscious beings but as living machines following simple algorithms, we can begin to reject hypothesis on the consciousness of other animals as we model more and more animals. Given the recent uptake in popularity of biological modelling in the field of mathematics, many more of these types of algorithms are currently being developed. From these, way may be able to reach similar conclusion on the animals they originate from and their potential for consciousness.

If, however, you reject that these animals are unconscious as I have described above, then you must be willing to accept that even machines are capable of being conscious to some extent. This goes against many of the currently held notions of consciousness and what can be conscious, including the very inclusive view of panpsychism and integrate information theory. Even these say that a machine could never be conscious, as it is simply ‘simulating’ or ‘emulating’ the signs of consciousness. As Christian Koch wrote “Just like a computer simulation of a giant star will not bend space–time around the machine, a simulation of our conscious brain will not have consciousness"[21]. Yet, it is not inconceivable that the biological machines discussed in this paper may have some form of consciousness, and thus, future AIs may also possess some form of consciousness. Over the course of time, as our understanding and techniques for creating artificial intelligence improve, and potentially as more transhumanist ventures are undertaken, the algorithms we need to allow a machine to form subjective experiences may begin to surface. However, there would/will be many ethical implications around testing such AI/programs as it would inevitably include powering off the program. This would radically change the current views and upend many of the previously held philosophies as

[21] Tononi & Koch

mentioned earlier. However, this is a question that could take up an entire book (and indeed has) and doesn't yet have an answer, and will likely not have an answer for many more years to come.

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