Global Intelligence

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Word Count: 1997
Group p207

November 29, 2011

In George B. Dyson's *Darwin Among the Machines: the Evolution of Global Intelligence*, he addresses the future of humanity and its relationship with machines. Throughout the book, he considers the properties of life and machinery, probing for similarities and differences between the two. In attempting to find differences between humanity and machinery, Dyson finds that the life and intelligence typically attributed only to humanity applies equally well to machinery. In particular, Dyson believes that evolutionary theory applies to machinery in the same way it applies to other living things. Because of this, Dyson believes that the appearance of machine intelligence is inevitable, and may have even happened already.

1 Emergence and Development of Machines

The title and main topics of Dyson's book are drawn from an article by Samuel Butler, entitled *Darwin Among the Machines*. In this article, Butler explored the current development of machines, noting the rapid and incessant growth of technology. His concern for the speed and direction of the growth was expressed in the article:

"We find ourselves almost awestruck at the vast development of the

mechanical world, at the gigantic strides with which it has advanced in comparison with the slow progress of the animal and vegetable kingdom. We shall find it impossible to refrain from asking ourselves what the end of this mighty movement is to be. In what direction is it tending? What will be its upshot?"

Butler is applying Darwin's principles of evolution to machines, stating that machines are evolving at a much faster pace than plants and humans. While it takes generations for even the most minute trait to change in plants and animals, machines operate under the constant selective pressures of mankind. It is this willful pressure that we place upon machinery that gives their development its astounding pace. In Butler's eyes, this characteristic of rapid evolution should be worrying to us, as we will quickly find ourselves unable to comprehend the pace of development. Without directive control of machine development, we pilot our species into a future of great risk.

How can it be that machines, lacking a reproductive system, can follow the same laws of evolution as all other lifeforms? Both Dyson and Butler believe that machines find a convenient surrogate womb in humanity. We are constantly driven to create, and machines are an area that humanity finds fascinating. Whether it be the convenience that machines lend to our everyday life, or our fascination with the power to create, we feel pressures to continue the development and creation of machinery. In this manner, both Butler and Dyson believe that our symbiotic relationship with machinery enables machinery to continue as a life-form and as a species, with the relationship enduring as long as the machines need us to reproduce. Butler, however, sees this relationship as short-lived:

"Each race is dependent upon the other for innumerable benefits, and, until the reproductive organs of the machines have been devel-

oped in a manner which we are hardly yet able to conceive, they are entirely dependent upon man for even the continuance of their species. It is true that these organs may be ultimately developed, inasmuch as man's interest lies in that direction; there is nothing which our infatuated race would desire more than to see a fertile union between two steam engines."

In effect, Butler sees a fearful future in which machines are no longer dependent on humanity to propagate their species, and sees the benefits of continued machine development to be a high-risk bet.

While Butler awaits the future in fear, Dyson inspects the origin of both species and finds striking similarity. In his book, he argues that the beginnings of life for both mankind and machinery must have occurred piecewise. The two requisite abilities for life—the ability to metabolize and the ability to reproduce—need not come into existence simultaneously. The metabolic processes of life (the "protein world", in Dyson's phrasing) are capable of existing without reproductive abilities (the "RNA world"). Dyson believes that a symbiosis between the two worlds is ultimately responsible for the genesis of life, with each part being too complicated and unlikely on its own. Instead of reproduction being immediately present, a stage of existence characterized by replication was necessary for both the protein and RNA worlds. By simpler chemical processes, each must have grown in number by exact replication until arriving at a symbiosis between the reproductive and metabolic parts.

Dyson takes the metabolic aspect of machinery to be self-evident. Machines are created, inputs are consumed, and some product appears as a result. But the reproductive structure remains elusive. The current method of reproduction, he claims, is very far from the reproductive processes that will appear. In particular, the selective forces on machines come entirely from humanity. We

pick and choose which machines should live and which should be discarded. An even larger roadblock in the process, Dyson claims, is that humanity is the agent by which change is introduced into the machine species. When we want a machine to perform a task, we carefully pick apart a design and make painstaking modifications. Dyson clearly states that two changes need to happen in the machine species in order for it to become independent of humanity. First, the property of self-modification must arise, and second, the machines need to respond to the selective pressures of nature, rather than those of mankind. Only when both of these conditions are met will machines truly become a species independent of human intervention.

2 Emergence of Intelligence

One of Dyson's greatest challenges encountered in writing his book is the problem of defining intelligence. He begins by defining intelligence as the possession of several characteristics: the ability to solve problems, think in the abstract, communicate, or reason. But in each of these he finds contradictions. Systems which we would not call intelligent appear to be capable of several of these properties. For example, a mechanical adding machine seems to be capable of solving problems, but nowhere in the machine can we pinpoint intelligence. Many of the properties that appear to confer intelligence upon a system are found elsewhere, related to objects that clearly do not appear truly intelligent. In addition, he finds it difficult to locate intelligence within any given person or system. Because people as objects can be decomposed into constituent parts, and all of the smallest parts seem to perform rather simple tasks, it would appear that intelligence is not a property of any given constituent. But he finds it difficult to rule out intelligence of the overall system in this manner.

"It would be rather unusual to claim that [a person] is unintelligent

on the grounds that no intelligence is required to do the job any single neuron or synapse in its brain is doing."

Instead, intelligence must arise as a property of a larger, more complicated system. In this manner he arrives at what he calls the central paradox of artificial intelligence:

> *"Systems simple enough to be understandable are not complicated enough to behave intelligently; and systems complicated enough to behave intelligently are not simple enough to understand."*

Reductionist design philosophies, in which the designer has complete control and understanding of operation of the design, can never be called intelligent. With this in mind, he finds that the only way to define intelligence is as a system with adequate complication.

How can it then be possible for intelligence to arise? If intelligence is defined by its impenetrability to understanding, how can we create it? It seems logical to assume that we can understand our own creations. Dyson believes that the solution to this problem is to create systems with behavior that we cannot understand or predict. By direct analogy to systems such as economies or brains, he believes that stochastic behavior on the part of interconnected and interacting systems can create emergent behavior. For example, in an economic system, agents act solely in the own interest, but complex properties emerge, leading to organization and functionality driven by no person in particular. In the eyes of both Butler and Dyson, these emergent properties are exactly the intelligence that we are seeking. Butler makes the claim that:

> *"The archetypal invisible hand of Adam Smith appears to be capable of building not only an economy, ... but a brainlike structure, perhaps a mind."*

Dyson believes that the most likely way for intelligence to emerge from structures we create is through interactions over these interconnected systems. The recipe for creating intelligence, it appears, is to

> *"(1) make things complicated enough, and (2) . . . wait for something to happen by accident."*

It seems reasonable to ask why something that happens by accident can be expected to happen. Dyson believes the the property of self-organization is crucial to making intelligence arise. If intelligence arises from a complicated structure, this structure needs to be created and maintained. But self-organization alone is not sufficient to cause the emergence of intelligence. If a system is isolated and expected to self-organize, what will guide its organization? The structure alone lacks meaning unless it is interpreted from within an environment and contextualized. If one were to undertake the task of creating machinery to interpret Morse code and output the decoded stream, a system which just happened to perform some other function would appear as non-functional. Even if the machine happened to learn how to play a perfect game of chess, only giving it the facilities to interpret Morse code would mask this ability.

> *"Meaning, however, has to be supplied from outside. Any individual system can only be self-organizing with with reference to some other system; this reference may be as complicated as the visible universe or as simple as a single channel of Morse code."*

Dyson appears to believe that self-organization, when taken together with an external influence such as natural or artificial selection, is an effective force in creating intelligence.

3 Global Intelligence and the Future

Having established the means by which intelligence can arise among machinery, Dyson questions if we are on the path to actually create such an intelligence. Examining the current state of affairs, he answers with a resounding yes.

Dyson anticipates the objection of critics that any emerging machine intelligence will be immediately obvious to the observer. He claims that systems of intelligence have emerged, even in nature, that are not obvious to the observer without particular inspection. Quoting the experience of physician Lewis Thomas in 1971, Dyson implies that a global intelligence in nature itself has emerged.

> *"I have been tying to think of the earth as a kind of organism, but it is no go, I cannot think of it this way. It is too big, too complex, with too many working parts lacking visible connections."*

But Dyson clearly believes that the earth itself possesses an innate intelligence, exhibiting the features of self-correction, regulation, and growth. If it is so difficult to see intelligence in the planet itself, then it makes perfect sense to him that the beginnings of machine intelligence are difficult to pinpoint.

Then where exactly is the main avenue on which machine intelligence will arise? Dyson claims that the interconnection of computers is providing this road. While the direct and physical connections between telegraph systems in the past set the stage for machine communication, the growth of virtual links in the form of switched networks provides computers the ability to self-direct and organize. With the ever-increasing ability of machines to communicate, this network becomes more and more similar to a brain as time passes. Like neurons, individual computing nodes which appear simple-minded on their own, are connecting to form an increasingly connected system, vastly too complicated for any individual to understand.

Seeing the properties of self-modification and organization in this complex system, together with the pressures of selection that it is facing, Dyson reaches a simple conclusion: the appearance of global machine intelligence is inevitable.