Of Optimalism and the Genetic Meme to Engineering

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Richard Lewontin is a respected author and geneticist. In his review of "Unto Others: The Evolution and Psychology of Unselfish Behavior" by Sober and Wilson, he attacks three universal themes found in the ideology of evolution as a source of a universal history. "Survival of the Nicest?" breaks down the statements of Sober and Wilson pointing out their flaws. However, engineering problems are not held in the same constraints as biological evolution and Lewontin attempts to puff unfair criticism on using genetic memes in engineering.

Of Optimalism

The first universal theme that Lewontin addresses is that of optimization. Within evolutionary biology, organisms that evolve over time are driven by natural selection in response to "problems posed by nature." From the mantra of survival of the fittest, one could interpret the surviving offspring of the evolutionary process to be the best suited to solve those problems from nature. Therefore, since all organisms have evolved, it could be concluded that all organisms have been developed to best survive or reproduce or whatever the criteria of best should happen to be.

Such a worldview is known as *optimalism*. This interprets all evolved structures to be the optimal or best solution. But Lewontin quickly destroys this notion of optimalism in genetic evolution. The first thing it overlooks is that there may be multiple branches along a possible tree of evolution with some branches extending longer than others. If evolution occurs somewhat linearly, there is no way to jump to another branch if one's branch ends far below the apex of the tree.

To take the argument the other way, we know that a great deal of the information contained within human DNA is junk with no *current* useful purpose. Many properties of organisms are not the direct properties of natural selection, as explained by Lewontin, but rather are tagging along with other genetic traits that were affected by selection. So we have all this junk that seems to be part of life, yet unused by it. Wasting all those nucleotides doesn't seem to be the most efficient use of an organisms resources, as in suboptimal.

Of the Genetic Meme

The cultural understanding of genetic evolution is that of Darwinism. The basic operation and properties of an organism are defined within its genetic code. Over time and generations, the genetic code is modified by a number of processes including mutation, crossing and breeding. Some genetic changes cause no outward change to the organism while others are of direct influence, this relating to the junk and redundancy of most organisms. In a collection of organisms, natural selection will allow some individuals to thrive and multiply and others to die out or at least dilute into the population depending on reproduction. This would be a direct consequence of the same survival of the fittest manta used when explaining optimalism. The best organisms in the given environment win.

Once this view was thoroughly integrated into our understanding of nature as a culture, despite its possible flaws and mistakes, it was able to reach other aspects of society. One major, non-biological application of this genetic meme is the use of specialized computer algorithms known as genetic algorithms. The basic idea behind a genetic algorithm is to take the process of genetic manipulation and natural selection and ramp it up. They were developed first in the 60s by a University of Michigan professor, John Holland.

A genetic algorithm starts with a population of postulates, these are usually just random noise. Electronic DNA in this sense is just a sequence of numbers in a computer instead of in a molecule. Then each postulate is tested for *fitness*. The fitness test is designed to select postulates that are desirable. For complex problems, the fitness tests usually start out with quite simple things and work up slowly to more complex systems. Postulates with the highest fitness are saved while those with the lowest fitness are discarded. The best ones are then mutated or bred together depending on the algorithm and retested for fitness. The cycle the repeats until the maximum level of fitness levels out.

As one can see a genetic algorithm is fundamentally based on optimalism. If the technique does not produce a more optimized solution than the original postulate, especially when most starting points are random to begin with, then nothing has been gained and the algorithm is a failure. Here is were I believe Lewontin is making his claim that engineers are flawed in their use of this evolutionary ideal to optimize solutions.

Yet, I cannot help but question why Lewontin is unhappy with our use of this method. He gives the example of the Traveling Salesman's Problem where a genetic algorithm isn't able to find a significantly better answer than a human could with traditional means, in fact it could even be a worse solution. To give a similar example, look at the keyboard experiment by Peter Klausler. He attempted to use a genetic algorithm to develop a more efficient layout of letters on a computer keyboard. In the end, his algorithm produced a result that was functionally similar to layout by Dvorak in 1930. But the issue was not with optimalism here, it was that the problem had already been well defined and had a statistically optimal solution.

Engineering Applications

Of course there are millions of engineering applications that could definitely benefit from the application of genetic algorithms and evolutionary design techniques. These techniques shine in situations of extremely high complexity. Although these may not please Lewontin because they might perpetuate optimalism, they are extremely important.

One simple and fun example is provided by Steven Johnson writing about a researcher at Oxford successfully using genetic techniques to teach simple stick figures to walk. For games and movies with computer generated characters, modeling the simple act of walking takes an enormous amount of time and is very unnatural. By using an genetic algorithms, the stick figure with bones, joints and muscles was taught to walk entirely on its own in as little as 20 generations, maybe a few minutes of computer time. The simulation looks completely human, which is remarkable given the fact that the program started with random data. Of course the fitness function was tweaked specifically to get an actual walking function because when the program was first run, it generated other forms of transportation, such as rolling and crawling. Yes, traditional methods could produce this same result, but the time consumed would be immense.

While on the subject of transport, another group has used genetic algorithms to create a self-healing robot that could be used in battle. NewScientist reports that if part of the mechanical motive system of this robot is damaged, a genetic algorithm quickly determines the most efficient way to move within the remaining constraints.

NASA's Advanced Supercomputing Division has been using genetic algorithms to design new therapeutic drugs using genetic algorithms. Unlike old methods were a drug was isolated from some other biological source, such as morphine or penicillin, these techniques can actually be used to sort through millions of possibilities of molecules directly and design from the ground up drugs that will save lives. Even if the solution is not the absolute optimal, as long as it meets the constraints of the fitness function, it still has save tens if not hundreds or thousands of man-years of trial and error work.

Optimalism in Engineering

Which brings the discussion back to the point on optimalism. Researchers at Michigan State University and California Institute of Technology point out to John Roach that, "biologists have assumed that each step along the path to a complex new function is a step up—an improvement—in terms of producing an organism that is better adapted to its environment." This is the exact argument of optimalism that Lewontin is trying to dissuade. But Roach points out that some of the mutations were deleterious at first but were crucial in later development of complex functions. Said another way, evolution doesn't always go forward, it is somewhat more random.

So then how can this be interpreted? Obviously since the 1960s we have significantly advanced the field of genetic algorithms and genetic programing for engineering drugs, computer programs, chips, and robots. Although we say the solutions are optimal, researchers and engineers recognize that there can be disparate plateaus of optimal evolution and we can intervene when necessary. So is it a problem then that the cultural meme of genetic natural selection has been incorporated into engineering design even if it is misses the mark with its biological source?

No. Genetic algorithms and techniques are here to stay, until they have been superseded by the next great engineering techniques. We only need be wary of runaway complexity as GA designed computers design even more powerful computers and we as humans are left in the dust in understanding. Yet that is a topic for another paper entirely.

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