

- 4 Sergey Gavrilets, *Fitness Landscapes and the Origin of Species* (Princeton University Press, 2004).
- 5 John Langrish et al., *Wealth from Knowledge: Studies of Industrial Innovation*, Part Two (London: Macmillan, 1972).
- 6 George Basalla, *The Evolution of Technology* (Cambridge University Press, 1988).
- 7 John Z. Langrish, "Darwinian Design: The Memetic Evolution of Design Ideas," *Design Issues* 20, no. 4 (Autumn 2004). See also J. Z. Langrish, "Different Types of Memes: Recipemes, Selectemes and Explanemes," *Journal of Memetics* 3, (1999). [http://cfpm.org/jom-emit/1999/vol3/langrish\\_jz.html](http://cfpm.org/jom-emit/1999/vol3/langrish_jz.html) (accessed February 2, 2014).

**Donald A. Norman and Roberto Verganti**

### Hill Climbing and Darwinian Evolution: A Response to John Langrish

We find John Langrish's argument to be puzzling. We wrote a paper on product evolution and he chides us for failure to cite the literature in evolutionary biology.

The issue is our discussion of optimization through small, local iterations—each iteration moving in the direction that yields an improvement, stopping when all further changes lead to a decrement. This is a well-known technique, widely understood and discussed in a wide variety of disciplines. The mathematics are well studied. There are numerous variants of this method, such as gradient descent and ascent, hill climbing, and simulated annealing. For the purpose of this response, let us call them all "hill climbing." All these methods lead to local optimization but are incapable of finding a global optimization. This is an indisputable fact of mathematics, very widely-known, and in our opinion so well known that they are not necessary to cite nor are they open to discussion.

As Langrish properly points out, Darwin considered evolution to be a kind of local optimization process. Moreover, he was aware of the difficulty of reaching a global optimum. So how does evolution work? Langrish seems to think that Darwin assumed that this method had to work, else his theory "would absolutely break down." Langrish cites this as evidence that we are wrong in our assessment of the

imitation of hill-climbing optimization. Langrish's quotation of Darwin's statement was a hope not a proof.

The problem of reaching global optimization has been well-studied, once again, in many disciplines. A simple solution is to use different starting points, and if the space of possible starting points is well-covered, then one is likely to lead to a global optimization. This is precisely what we said in our paper. We stated that by starting at a different point in space, driven either through new technological possibilities or meaning change, the new starting point can lead to a superior solution. Indeed, this is what Langrish himself partially suggests in his list of possible candidates for solving the dilemma. Multiple entities climbing at the same time but taking different routes (his suggestion 3) are examples of different starting points. His suggestion of changes in the landscape (his suggestion 4), is what we mean by new technological innovations or changes in meaning.

But many of his suggestions are rather bizarre, perhaps because he is not aware of the underlying mathematics. Suggestions 1 and 2, that a ridge might connect local peaks, do not solve the problem of having to descend (de-optimize) in order to traverse the ridge, unless there is a path across the ridge that does not require a descent. Hill climbing methods fail if the ridge requires any decrease in value, but they will succeed if the ridge never entails a decrease. Note that it is possible to traverse ridges that require some de-optimization through any one of a number of stochastic optimization methods. These are also well-studied in the literature on optimization, but these are not the methods we discuss in our paper because we did not believe they would apply to the normal process of invention and improvement.

Langrish's suggestion 5 is correct but irrelevant. We assume the full space of possibilities, namely the space existing in the world. That is, we do not assume a simple-minded geological metaphor. Actually, adding dimensions also increases the likelihood of multiple local maxima: more places to get stuck.

We stated that all radical innovations do come from pre-existing ideas and innovations. So how do they combine if not by local incremental

optimization? By novel combinations, that's how. We proposed that these novel combinations are done through tinkering, through systematic trial and error, through accidents, through a deliberate design act, or through whatever events transpire. New technologies and new meanings provide new starting points as well as novel combinations. The formation of these combinations does not arise through hill climbing nor optimization mechanisms. Once the combination is assembled, then a hill-climbing process begins to determine if the new combination will survive or not, and then whether it can climb the hill to an optimization point. (This is precisely how genetic algorithms work: they randomly combine features of winning organisms, creating new novel transformation.) Some proposals for the mechanisms of biological evolution are similar. In addition, biological mechanisms probably are stochastic because of the existence of "noise" and probably follow optimization processes, whether through noise (stochastic processes), the mixing of genes (as in genetic algorithms), multiple starting points (as Langrish points out), or any one of the multitude of well-known ways of modifying simple hill climbing techniques.

Unfortunately, Langrish does not clarify his perspective for optimization: who is surviving, who is succeeding? Optimization from the perspective of the species may not lead to optimization for the world. Optimization from the perspective of the world probably leads to species that get stuck in local maxima and therefore die, or in Langrish's words, are "overtaken by a 'cousin' climbing a different and higher peak." We look from the perspective of the individual entity, for example, an organization or a firm. Of course the socio-economic system evolves and survives, but individual firms and organizations that get stuck in an old pattern of local maxima disappear (consider Olivetti, Polaroid, Digital Equipment Corporation, etc.), overtaken by organizations that abandon the path-climbing process of their industry and find new combinations. Although, in this Schumpeterian mechanism of creative destruction, new organizations may come from the ashes of previous ones, the old entity is definitely not happy to disappear.

In the published literature on the economics and business of innovation and technological change, the concepts of local maxima and path dependence are well studied and the importance of disruption as a strategy for success is a well-known mechanism. We refer to this body of literature in our citations of studies of radical innovation (see our notes 15 and 16—in particular, the work of Clayton Christensen), and then when we acknowledge Giovanni Dosi, a well-known evolutionary economist (note 26). We connect these theories to our discussion of design research in relation to drivers of change such as technology and meaning.

We thank Langrish for his interest in our paper, but similar issues have been faced in many disciplines. As we have demonstrated, his attempts to map biological mechanisms to our approach are either already accounted for (his suggestions 3 and 4) or are inappropriate (his suggestions 1, 2, and 5). We see no reason why we should have cited every field that has thought about problems of local versus global optimization; and, we see no reason to modify our suggestions based upon his analyses.

We are accused of being creationists. We plead guilty. That's what the field of design is all about: all-seeing, overarching designers who look over their creations and go in and change them. Designers have that luxury. Release a product and call it back for revision. Or completely change the next release, keeping the stuff that worked and deleting the stuff that didn't. Or completely repurpose it for some other usage that had not been considered at first. None of this incremental creep that evolution must suffer through: designers get rid of the appendix when it is no longer needed. Designers are creators.

Radical innovation in the field of design does not come from hill climbing. It comes from putting together things that never before were thought to belong together. It comes from the heart and mind of the designer. Yes, as designers we are creationists. We teach it, practice it, and take delight in it.