Dynamically adapting parasite virulence to combat coevolutionary disengagement

John Cartlidge

University of Central Lancashire
jpcartlidge@uclan.ac.uk

Participating in an evolutionary arms-race, natural coevolutionary predator-prey and host-parasite systems often exhibit accelerated evolution. Competitive Coevolutionary Genetic Algorithms (CCGAs) attempt to harness this evolutionary acceleration by engaging (multiple) evolving populations in competitive self-play.

By evaluating individuals competitively, CCGAs afford the possibility of tackling problems that are ill-defined, open-ended and lacking in formalism. This offers CCGAs a potential advantage over more traditional Genetic Algorithms (GAs) when fitness evaluation is difficult to operationally define. Analogously, one imagines that it is much easier to formally define the rules of the game of tennis than it is to define tennis playing ability. In practice, however, defining an *appropriate* game is often non-trivial.

Competitive evaluation leaves CCGAs susceptible to some adverse evolutionary dynamics. One such hindrance is "disengagement". This occurs when one coevolving population gets the upper hand and begins to easily outperform the other. Since it becomes impossible to discriminate between individuals according to ability, the selection gradient disappears and the coevolving populations begin to stagnate. The result is a stymied system that is left to flounder aimlessly.

To prevent disengagement, the author has previously introduced the "Reduced Virulence" technique (Cartlidge & Bullock, 2004, Evol. Comp., 12, p.193). This technique helps avoid disengagement by reigning in a population that inherits an advantageous bias. Rather than reward individuals that maximally damage a competitor, Reduced Virulence favors individuals that give opponents a chance. Perhaps counter-intuitively, Reduced Virulence enables accelerated evolutionary progress by disadvantaging a population's most successful individuals.

In this work, Reduced Virulence undergoes a rigorous sensitivity analysis in the Counting Ones domain (introduced by Watson & Pollack, 2001, GECCO, p.702, Morgan Kaufmann); an analytically tractable substrate designed to highlight the dynamics of coevolution. Following intuition, it is shown that for optimal performance, virulence should be increasingly reduced as the asymmetrical bias (and thus likelihood of disengagement) between coevolving populations increases. Interestingly, even when coevolution is unbiased, "Maximum Virulence" — equivalent to the canonical fitness evaluation of "reward all victories" — is shown not to be ideal. Thus, results suggest that (in the Counting Ones domain) when population sizes are small, it is never the case that the canonical coevolutionary setup should be favored. The generality of this result, however, is an open question.

Utilizing this information, a novel "Dynamic Virulence" algorithm is introduced. This algorithm adapts population virulence over time as populations evolve. It is shown that Dynamic Virulence is able to cope with varying bias better than fixed virulence and allows the discovery of optimal solutions under a much wider range of conditions than any individual fixed virulence setting.

Finally, it is discussed how analyzing the role of virulence in artificial systems may allow us to better understand virulence in nature. For instance, perhaps there is potential for a "Reduced Virulence" approach to tackling infectious diseases. Rather than killing mosquitoes to eradicate malaria, one could alternatively encourage malaria-resistant strains that are better able to survive.