12.

Implementing Evolution in Video Games

Barrie Robison (University of Idaho), Terence Soule (University of Idaho), Christopher Mirabzadeh (University of Idaho), David Streett (University of Idaho), & Nicholas Wood (University of Idaho)

Abstract

Instruction of evolutionary biology at the state and national K-12 level is fraught with challenges. We need new methods to teach and engage students, teachers, and the public in evolutionary education. We are therefore developing video games that feature explicit models of biological evolution. Our premise is that adding biological evolution to video games makes the games better for the game player and facilitates player comprehension of complex concepts that are hard to teach. Traditional video games are usually scripted, featuring "*waves*" of enemies that have defined and predictable characteristics. A player's success in such games is based on learning the predictable, rote script necessary to advance to subsequent levels. By integrating principles of evolutionary biology, we argue that video games can be made more compelling. One of the reasons why evolution has not been correctly implemented in video games is the perception that evolution is an inherently slow and gradual process – to slow to add much value to a video game. In this paper, we describe two simple video games in which *generations* of enemies undergo adaptation through natural selection. The enemies with the traits that best counter the player's strategies survive to reproduce, and their offspring feature prominently in the next generation (analogous to a game level or wave). In both cases, we demonstrate significant phenotypic evolution of enemy populations over time scales that are amenable to game play.

Background

Instruction of evolutionary biology at the state and national K-12 level is fraught with challenges. Understanding of evolution relies on comprehension and integration of a dizzying array of other fields, from genetics to geology (Miller, Scott, & Okamoto, 2006). Fundamental misconceptions about science and evolutionary biology, and rampant anti-intellectualism and opposition from creationist groups further complicate essential scientific education in our public schools. Thus, we often face a battle as to whether we ***can*** teach evolution, let alone confronting the complexities of teaching it well.

We argue that evolutionary education could be enhanced by developing video games based on models of biological evolution. Not only do we argue that evolution can make better video games, but also that playing these games could demonstrate and teach difficult concepts.

Evolution in Commercial Games

There are numerous cases in which evolution is being used to market video games. Many of these titles simple use the word “evolution” in their title, such as “Halo – Combat Evolved”, or “FIFA Pro Soccer Evolution”. The choice to use evolution in these titles likely stems from the linkage between evolution and the perception of improvement, advancement, or optimality. This is, unfortunately, reinforcing a misconception that biological evolution is directed force leading to optimality.

While these examples of evolution in video games are unfortunate, there are other titles that profess (ether implicitly or explicitly) to demonstrate biological evolution. While it is nice that evolution is being used to make a more compelling game, the reality is that all of these titles are deeply flawed, and reinforce fundamental misconceptions about evolution. In the following section, we will consider three typical misconceptions regarding evolutionary biology (Alters & Nelson, 2002), and provide examples for each.

Misconception 1: Individuals evolve

A very common implementation of evolution in video games is one in which an individual character “evolves” by acquiring new traits or abilities. Examples abound, but the recent title “Evolve” by Turtle Rock Studios (2015) serves as a particularly compelling case. In Evolve, four players battle against a gigantic monster controlled by a fifth player. This creature can acquire energy by eating other (smaller) creatures or players. Once enough energy is acquired, the player is asked to press a button or key to “evolve”. Once this ability is activated, the creature appears to burrow into a cocoon like structure, and then the player can choose to evolve one of several new abilities. Evolve is admittedly a very fun game that has met with commercial success, but the process described above is not evolution. Rather, biologists would likely refer to this process as metamorphosis.

Unfortunately, the conflation of individual metamorphosis with evolution is very common in video games. Other examples include the Pokemon series, and any game in which “upgrades” are cast as evolution (a recent redeployment of space invaders – Space Invaders Infinity Gene is an example).

Were “Evolve” to actually feature evolution, it would require a population of giant monsters with variation in their traits. If this variation could be inherited, then the monsters best able to survive against the four player team or to kill and eat the other creatures would reproduce and those traits would increase in frequency in the next generation. Given the high quality art and design necessary to create the creatures, a game such as this would likely run into significant performance issues.

Misconception 2: Evolution involves agency

Another common game trope involving evolution is the conference of agency over evolution to the player. In this case, the player is allowed to choose the direction of evolution, usually by selecting options in a tech or upgrade tree. While Evolve also employs this mechanism, we will use a different game to demonstrate this misconception. Spore (released by Maxis in 2008) is a game that professes to be about evolution. Indeed, the supporting text on the Steam site for spore states “Single Cell to Galactic God, evolve your creature in a universe of your own creations. Play through **Spore’s** five evolutionary stages: Cell, Creature, Tribe, Civilization, and Space." The problem is that as the player progresses through the game, they are given choices about which traits to evolve (Bohannon, 2008). Another example is Plauge: Evolved. In this game, the player chooses the mutations to evolve so that their pathogen (a virus, bacterium, fungus, or other such things) can infect and kill the world population. In both cases, the games are tremendously fun but badly misrepresent biological evolution.

Misconception 3: Evolution implies progression, optimality, or perfection

This misconception is typically reinforced by games that use evolution in their title to imply quality or improvement. The aforementioned Halo Combat Evolved, and FIFA Pro Soccer Evolution can be placed alongside Ark, survival evolved, and a host of others. In reality, evolution is a process driven by probabilities and usually does not arrive at the "perfect" solution.

Collectively, we argue that to date video games have used the idea of evolution for marketing purposes, but implementation of evolution has been deeply flawed at best. Our premise is that evolution CAN be implemented in a video game, and that doing so will make the game better and enable the game to be used for educational purposes. In this paper, we test whether evolution can be implemented in a game and demonstrated on a time scale appropriate to casual game play.

Examples of two evolutionary video games

Here, we present two examples of evolutionary video games that demonstrate phenotypic evolution over time scales consistent with video game play. In each of our games, a population of enemies is pitted against the player. This population is comprised of reproducing individuals whose genome is encoded by an "infinite alleles" quantitative trait model. That is to say, each allele at a locus is a number drawn from a Gaussian distribution of mutational effects scaled to the phenotype produced by that locus. In the simulations presented here, we generate standing genetic variation in the initial population by drawing mutations at each locus.

Fitness of each individual in the population varies by game, but is typically determined by how long the individuals survive, how much damage they inflict on the player, and how many resource items they consume. At the end of each generation, each individual generates gametes at a rate proportional to its fitness. Gametes are then randomly selected from the gamete pool to generate a number of offspring equal to the desired population size.

Traits of each individual are calculated using a function particular to that trait. For example health may be calculated by summing the individual's genome values, applying a sigmoid function to map the variation to an appropriate range, and then adding an intercept representing the minimum health.

Example 1: Evolution of color in *The Ladybug Game*

The Ladybug game is a simple demonstration of evolution developed by Author using the Processing programming language. In this game, the player controls a ladybug and attempts to eat aphids. The aphids' color is controlled by a digital genome with three genes. These genes determine the value of red, blue, and green using an RGB color scale (see Figure 1 for a screenshot). The background of the game is a specific color, and the aphids that most closely match that color are more difficult to detect. The longer the aphids survive, the more likely they are to reproduce. Generations are continuous, and reproduction is asexual.

Population size is fixed at 10. When one aphid is caught one of the other nine is randomly selected to reproduce. When an aphid reproduces all three genes (red, green, and blue) are copied from the parent and then mutated. The mutation effects are drawn from a uniform distribution with a range of -30 to 30. Thus, the mutation rates in this game are artificially high. In this example, we set the ladybug to autonomous mode (not controlled by a player), in which the ladybug "sees" all aphids in a 180 degree arc in front of it. It chases the aphid whose color is most different from the background, where the difference is the sum of the absolute differences in the red, green, and blue channels. In the case of no selection the ladybug chases the closest aphid in front of it. If there are no aphids in front of the ladybug, it travels in a straight line until it hits a wall and then it turns around. The aphids can wrap around the screen, which gives them a way to escape the ladybug – although they aren't "smart enough" to do that intentionally.

In this example, we ran 5 replicate games in which selection was active, and 4 replicate games in which selection was turned off. Our hypothesis was that selection on color can be realized over a time frame typical of a "casual game" – in our case one minute. We tested whether the genetic value for color at each "gene" was under selection by using an ANOVA with replicate nested within treatment.

Figure 1: A screenshot of The Ladybug Game at the end of a replicate.

We analyzed the genetic values of each population at the end of the experiment using an ANOVA in which replicate was nested within treatment (Selection or No Selection). For all three color genes, we observed a significant difference ($p<0.001$) between the games played with selection and the games in which selection was deactivated (Figure 2. Thus, over the course of one minute, a player could witness the rapid evolution of color in response to player controlled or autonomous predation.

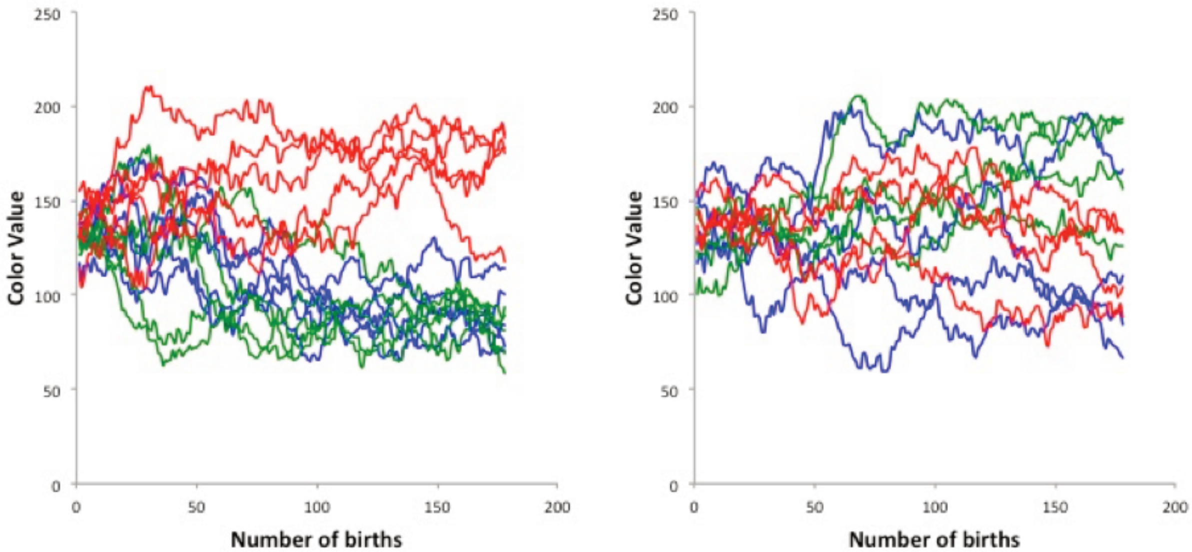

Figure 2: The evolution of color genes under selection for matching a red background (left) and with selection deactivated (right). Each line of a specific color represents the population mean genetic value for that locus in a particular replicate.

Example 2: Evolution of speed and armor in “Project Hydra”

In the second example, we present evidence that evolution can be demonstrated using a more advanced game engine and player experience. In this case, we use a prototype (codenamed Project Hydra) being developed by one of our graduate classes (CS 504 – Video Games and Evolution). In this game, the player controls a tank, and must navigate a map to rescue planetary colonists housed in mining pods (see Figure 3 for a screenshot). The player and the colonists are being preyed upon by alien creatures that are a sexually reproducing population (fixed at 100 individuals) with a diploid genome. The genome uses an infinite alleles model to generate genetic variation that controls their morphology, armor, health, speed, etc.

Figure 3: A screenshot of the Project Hydra prototype. The player controls the tank (center of the screen) and defends the pods from a population of alien enemies.

In this case, we again set the player element to autonomous mode, in which the tank was stationary and protecting resources nearby. A population of 100 creatures per generation was then allowed to attempt to damage the tank and collect resources. We replicated this condition three times, and then ran three replicates in which the tank did not fire. We observed significantly different evolutionary patterns between these two treatments. In the case of autonomous fire mode, we observed rapid evolution of armor, allowing the creatures to resist damage at the cost of reduced speed. In the control treatment (with no tank fire), we observed the evolution of high speed creatures with reduced armor (Figure 4). We used an ANOVA of the generation 5 data to test whether the outcomes for each trait were significantly different. The ANOVA indicates that after only 5 generations the two treatments differed significantly for both speed and armor value ($p<0.001$).

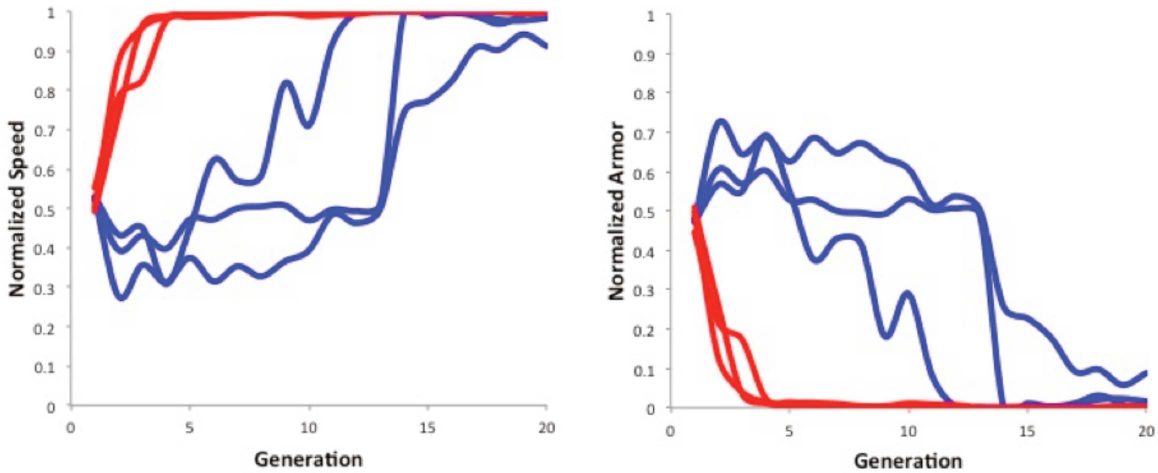

Figure 4: Rapid evolution of speed (left) and armor (right) phenotypes when the player tank can damage and kill the enemies (blue lines) and when damage is turned off (red lines).

Conclusion

We have demonstrated that accurate models of evolution need not undermine game play, and can be experienced over intervals commensurate with typical play times (less than two minutes of game play or over several "waves"). Our model does not reinforce the typical misconceptions regarding evolutionary biology that typify the current cohort of video games that profess to portray evolution. By having the enemy population evolve, we remove agency over evolution from the player. Our model also clearly demonstrates that individuals do not evolve, but populations do. Finally, the stochastic nature of our model, in which mutations are randomly drawn from a distribution and population sizes are small enough to allow genetic drift, allows demonstration that evolution does not result in a perfect solution in every case. One caveat is necessary to emphasize, however. These examples use artificially high mutation rates to generate the genetic variation upon which the player selects. Caveats such as this should be made explicit to the players of evolutionary games.

Future Work

While we have shown that evolution CAN be implemented in video games, we must now test whether these games can effectively teach evolutionary concepts (Corredor, Gaydos, & Squire, 2014). We are now collaborating with education professionals to test the educational value of our games, and refine them to make them more effective (Squire, DeVane, & Durga, 2008). In addition, we are keenly interested in whether evolution can actually IMPROVE game play.

Acknowledgements

The authors would like to acknowledge the work of T. Devault, M. Zeigler, A. Ambriz, and J. Aurajo on Project Hydra. Components of this work were supported by BEACON – an NSF Science and Technology Center.

References

Alters, B. J., & Nelson, C. E. (2002). PERSPECTIVE: TEACHING EVOLUTION IN HIGHER EDUCATION. *Evolution*, *56*(10), 1891-1901.

Bohannon, J. (2008). Flunking Spore. *Science*, *322*(5901), 531.

Corredor, J., Gaydos, M., & Squire, K. (2014). Seeing Change in Time: Video Games to Teach about Temporal Change in Scientific Phenomena. *Journal of Science Education and Technology*, *23*(3), 324-343. doi:10.1007/s10956-013-9466-4

Miller, J., Scott, E., & Okamoto, S. (2006). Public Acceptance of Evolution. *Science*, *313*, 765-766.

Squire, K. D., DeVane, B., & Durga, S. (2008). Designing centers of expertise for academic learning through video games. *Theory into Practice*, *47*(3), 240-+. doi:10.1080/00405840802153973