Edge of Chaos Project

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Project Goal:

Mutation rate is considered the primary contributor to the phenomena called the edge of chaos. The phenomena presents itself in a system like Avida by driving a population to extinction, see figure 1. The question that arises, and the goal of this experiment, is to determine whether or not this phenomena occurs at some fixed minimum mutation rate, given the other system parameters are the same. If the edge of chaos is not fixed, what other system parameters would play a part in determining the edge of chaos for a given run?

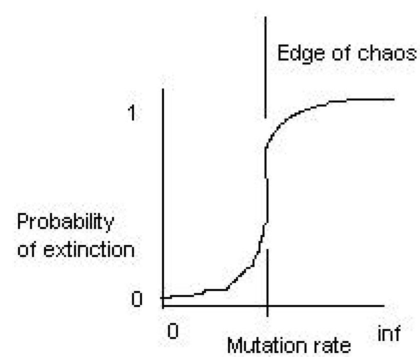

Figure 1: Probability of extinction vs. Mutation rate

Impact:

The answers to the above questions will determine whether there is a tight upper bound on mutation rate, where any higher mutation rate will guarantee extinction. By mapping the interplay of system parameters to the edge of chaos, it may be possible to determine a quantifiable value for where the edge will be given a set of parameters. This issue is important to any evolutionary process for the appropriate choice of mutation rate.

Expected Results:

The extensive experiments of the DEVO lab have shown that even with mutation rates below the edge of chaos mutation rate, an entire population has a chance of extinction. This leads us to hypothesis that the edge of chaos is simply: as mutation rate increases, a conditional probability of extinction based on mutation rate given population size and/or genome length approaches one. Thus the edge of chaos is not so much a sharp edge but more a crumbly edge which allows for variation in the mutation rate marking the edge of chaos. We expect to see the occurrence of extinction increase as the mutation rate approaches the edge of chaos, at which point the probability of avoiding the extinction approaches zero.

The primary system parameters that will be evaluated in this experiment are different types of mutation rate(point, cosmic, insertion, deletion, etc), population size, and genome length. We expect that different types of mutations will give rise to a different mutation rate that forms an edge of chaos, though some may not have an edge of chaos by itself, such as insertion.

The larger genome sizes will give the organisms added protection from lethal mutation and much higher mutation rates will be needed to produce an edge of chaos. More specifically, large genomes make mutation of vital instructions less likely, and allow build up of large neutral, or junk, instructions.

The larger population sizes will also give some protection for lethal mutation, but not to the extent of genome length. We expect that due to the fact that some of the population may get fewer mutations, those will have the relatively higher relative fitness and produce a larger number of offspring. While this may only stave off the inevitable, an equilibrium may be reached at a higher population size over that of a much smaller population size.

Methods:

The null hypothesis for this experiment is that the edge of chaos is fixed and independent of genome length and population size. To test the hypothesis, a series of experiments will be performed and data collected. The primary experiment involves finding an edge of chaos. To do this, we first need to setup the Avida parameters. The two key parameters from the default setup to change for this experiment is death will be on and mass action will be the replacement method. The reason for choosing mass action is simply that local replacement will keep approximately equally fit organisms near each other, and the reason for choosing death is to enuse a sterile population will die off. With the higher mutation rates, more fit organisms could gather lethal mutations quicker, depending on mutation type, and thus would generate a kill zone around themselves. Thus, mass action should provide a more fair ground for organisms to attempt to delay or offset the extinction.

Before we begin the experiments, an initial population that will seed all the experiments must be generated. This population will be generated by allowing the initial filled population, due to the inject all command, to evolve with task bonuses off for ten seconds. The population after this procedure should be randomized. The quantity ten seconds was determined by a visiting student to the DEVO lab who was studying randomization of genomes. His results are currently in the publication process.

Beginning with the randomized, full population with a fixed mutation rate. Let this population run for a fixed number of updates or until extinction. Repeat this process with different random number seeds until a mutation rate is found that causes extinction in at least ten different runs. Each of these runs will have a constant population size of 70x70 and starting and fixing the genome length at 100. The type of mutation rate for this experiment will be point mutation rate.

Once a mutation rate has been found, and an extensive number of runs have shown extinction with a probability of at least 95%, this will become the baseline mutation rate for the other experiments. The first experiment will be to determine the effect of population size on the edge of chaos. This will be accomplished by performing five runs at 40x40, 50x50, 60x60, 80x80, 90x90, ..., 100 and may sample a few higher population sizes of 130x130 and 160x160.

The next experiment will be to determine the effect of genome length on the edge of chaos. Beginning with the determined mutation rate and a population size of 70x70, fixed length genomes of sizes greater and smaller than 100 will be run.

The final set of experiments will be to test the various types of mutation rates and their effect. A reproduction of the experiment to find a mutation rate at the edge of chaos will be performed where all the mutation rates will be held at their default value. Each mutation type will be varied individually to find where and if this type has an edge of chaos. Some of the mutation rates will be done together, and singly, such as insertion and deletion due to their complementary behaviors.

Timeline:

10/8 Preparation of a population for a starting population

10/10 Completed tracking the edge of chaos mutation rate for this population

10/17 Begin experiments varying other parameters

11/3 Begin Analyzing data

11/12 Begin writing final report, and preparing presentation

11/24 Presentations begin