

Introduction to Evolutionary Computation



Questions to consider during this lesson:

- How is digital evolution similar to biological evolution?
How is it different?
- How can the principles of natural selection be applied
to solve engineering design problems?

Evolution

Evolution is a process that results in heritable changes in the traits of a population of organisms over multiple generations

Evolution occurs whenever and wherever three conditions are met:

- **replication** (reproduction)
- **variation** (differences among individuals)
- **competition** (different reproduction rates)

This process is called natural selection. There are other mechanisms that contribute to the process of evolution, but natural selection is the main force that leads to adaptive traits

Introduction to Digital Evolution

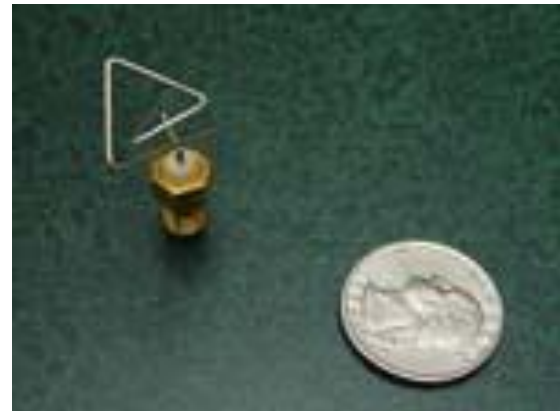
- * Avida software was created to study the process of evolution (“a” = artificial “vida” = life)
- * Digital organisms are small, self-replicating computer programs
- * Digital organisms live and reproduce in a virtual environment determined by the user
- * Random replication errors cause mutations to occur in the programs as they reproduce, which leads to variation within a population



- * Instance of evolution in a model environment
- * Digital organisms and the environment in Avida differ from the biological world, but the mechanisms that cause evolution are the same
- * The application enables researchers to address questions about evolution that are difficult or impossible to answer using biological organisms
 - * Faster replication
 - * Larger population sizes
 - * Complete control over environment
 - * Observe and record events without interfering

Evolutionary Computation & Engineering

- * The principles of natural selection can be applied to engineering problems
 - * A random set of potential solutions to a problem are competed in a modeled environment
 - * The best solutions outcompete less efficient solutions
- * Evolutionary computation has been applied to solve many engineering problems, such as:
 - * robotic controllers and morphology
 - * self-managing computer systems
 - * a NASA satellite antenna →

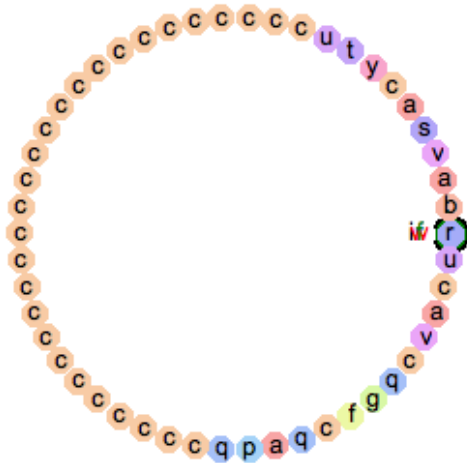




AVIDA-ED

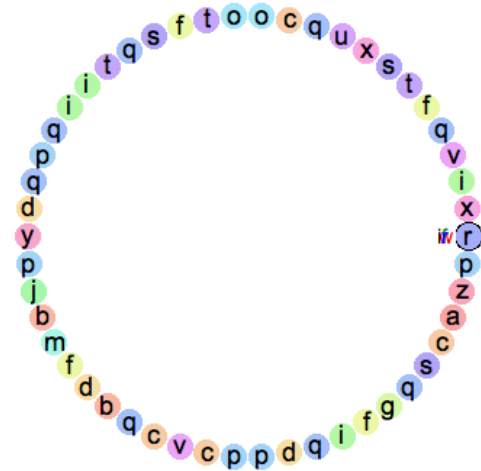
- * Avida-ED is an educational version of Avida that was developed to teach evolution and the nature of scientific inquiry
 - * user-friendly interface
 - * you can ask your own questions and collect data to answer them
 - * outcomes are not preprogrammed – every run is unique
 - * you can observe mutations, replication and the effects of evolution on a population

Digital Organisms in Avida-ED process numbers from their environments



Original ancestor:

- Capable of replication only
- Half of its code is (c), which is a no-operation command



Descendant:

- Differs from ancestor due to random replication errors
- May have a series of commands that code for a specific function (for example, adding two numbers together)

The ancestor organism reproduces in the virtual petri dish and results in a population of unique individuals

The screenshot displays the Avida-ED software interface. On the left, a sidebar contains 'Viewers' (Population, Organism, Analysis) and a 'Freezer' section with 'Configured Dishes' (e.g., @example no_mutations) and 'Populated Dishes' (e.g., @example Update200). The main window shows a virtual petri dish with a small square representing the ancestor organism. A yellow circle highlights a 'Flip to Settings' button in the top right of the petri dish area. Below the petri dish is a 'Fitness (rescaling)' color scale and a 'Time (Updates): -1' indicator. A yellow circle highlights a play/pause button at the bottom center. On the right, a data panel shows various metrics and two tables. A yellow callout box points to the 'Flip to Settings' button with the text: 'Click here to change the environmental variables'. The bottom left corner features the 'Screencast-O-Matic.com' logo.

Click here to change the environmental variables

Metabolic Rate:	-	Avg. Metabolic Rate:	0
Gestation:	-	Avg. Gestation:	0
Age (updates):	-	Avg. Age (updates):	0
Ancestor	-		-

Functions	Times Performed	Functions	Orgs Performing
Not-	-	Not	0
Nan-	-	Nan	0
And-	-	And	0
Or-	-	Or	0
Oro-	-	Oro	0
Ant-	-	Ant	0
Nor-	-	Nor	0
Xor-	-	Xor	0
Equ-	-	Equ	0

Average Fitness

Time (updates) : Average Fitness

The user controls which logic functions are rewarded, as well as the mutation rate and world size

Click here to return to the virtual petri dish

Viewers

- Population
- Organism
- Analysis

Freezer

- Configured Dishes
 - @example no_mutations
- Populated Dishes
 - @example Update200
- Organisms
 - @ancestor

@default

Flip to Petri Dish

Environmental Settings

Per Site Mutation Rate

World Size

3.0 % 60 x 60 cells

Ancestral Organism(s)

Place offspring:

Near their parent Anywhere, randomly

What resources are available in the environment?
(strength of reward shown in parentheses)

Easy (x 2)	Moderate (x 4)	Hard (x 8)	Very Hard (x 16)	Brutal (x 32)
<input checked="" type="checkbox"/> notose	<input checked="" type="checkbox"/> andose	<input checked="" type="checkbox"/> orose	<input checked="" type="checkbox"/> norose	<input checked="" type="checkbox"/> equose
<input checked="" type="checkbox"/> nanose	<input checked="" type="checkbox"/> ornose	<input checked="" type="checkbox"/> antose	<input checked="" type="checkbox"/> xorose	

Repeatability Mode:

Experimental (natural variation) Demo (forces exact replay)

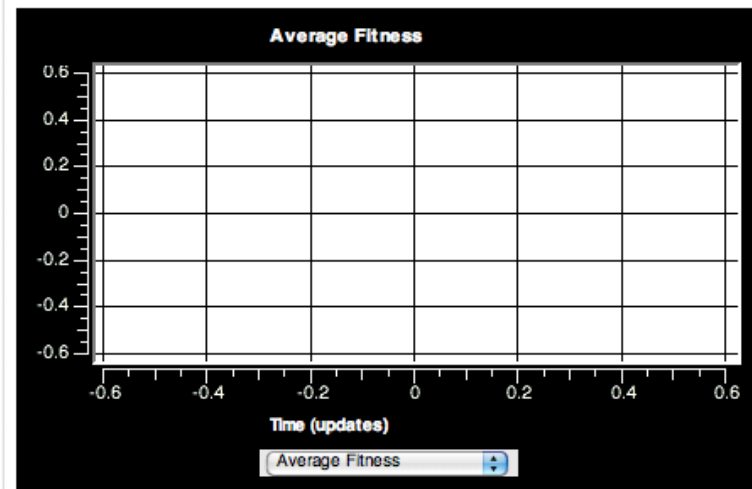
Pause Run:

Manually At 0 updates

Freeze Petri Dish

Fitness:	-	Avg. Fitness:	-
Metabolic Rate:	-	Avg. Metabolic Rate:	-
Gestation:	-	Avg. Gestation:	-
Age (updates):	-	Avg. Age (updates):	-
Ancestor	-		

Functions	Times Performed	Functions	Orgs Performing
Not-	-	Not	-
Nan-	-	Nan	-
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Orn-	-	Orn	-
Oro-	-	Oro	-
Ant-	-	Ant	-
Nor-	-	Nor	-
Xor-	-	Xor	-
Equ-	-	Equ	-



Summary

Avida-ED provides an instance of evolution because digital organisms:

- **replicate**
- **differ from each other** due to random replication errors
- **compete** for space on the virtual petri dish

Although the digital organisms are not identical to any biological organism, the processes that act on them and lead to evolution are the same

Software such as Avida can be used to solve engineering problems.

Each digital organism represents a possible solution and the digital environment is a model of the real-world conditions that the design would be subjected to.

Discuss your answers to the following questions:

1. How is digital evolution similar to biological evolution? How is it different?
2. How can the principles of natural selection be applied to solve engineering design problems?