# CSE/ECE 848 Introduction to Evolutionary Computation

## Module 3 - Lecture 10 - Part 4

# Evolutionary Programming

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# Evolutionary Programming

- First EP was proposed at around the same time as ES(Rechenberg/Schwefel), and shared many of the same characteristics
- First conceived by L. Fogel, there are some differences, especially in the early work
- Fogel was interested in what an evolutionary approach combined with an AI “program” could do
- Was taken up by his son David Fogel

# Common Elements

- ES and EP and to some extent GAs share common ideas
- Differ on some of the fundamental issues
- Has caused some controversy over the years, but the camps have really “merged” today

# Goals of EP

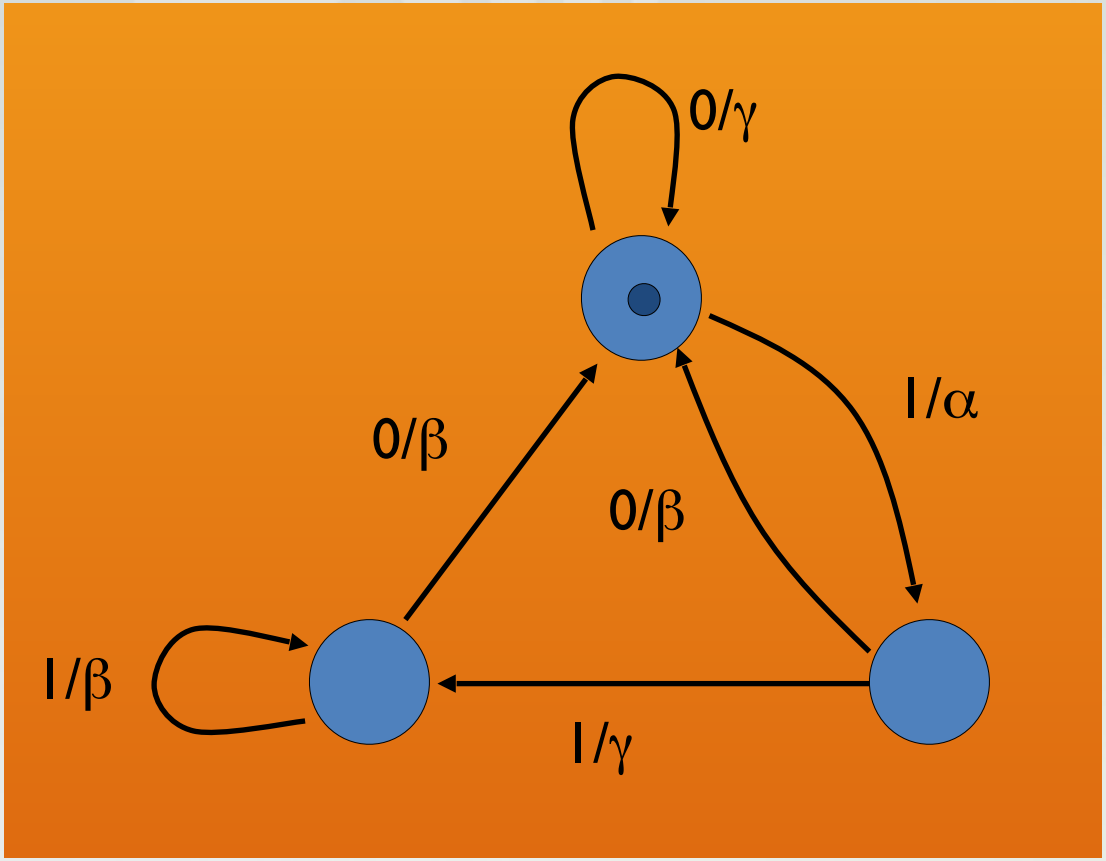
- One of the original goals, unlike the engineering optimization of ES, was to develop “AI” machines, using some of the principles of evolution
- More like GP or classifier systems, wanted to create systems which could take in input and derive suitable responses

# Population of FSMs

- The choice of elements for the population, were not full "solutions", as in ES, but automata, finite state machines, which could be adapted and therefore perform some task.

# Recall FSMs

Finite number of states, transitions between states with output ({0,1} inputs, {α,β,γ} outputs)



# Basic Operation

- Construct random parents (random FSMs)
- Input stream is provided, and typically the output symbol is compared to the next input symbol.
- Measure of difference is then provided (mean-square error, absolute error) as is appropriate for the particular problem. Fitness is the payoff over the stream according to payoff function.

# New Machines

- Offspring machines are created based on mutation:
  - change an output symbol
  - change an input symbol
  - add a state
  - delete a state (must have more than one state at the time)
  - change the initial state (same restriction)

# Basic Operation II

- The number of mutations is chosen
- Mutations are chosen with respect to some probability distribution (typically uniform, but others possible)
- Offspring are then evaluated
- In a fixed population, child and parent [see (1+1)-ES] are compared and the best is kept
- Repeat

# Typical Application

- These were originally tested as predictors of time-varying sequences, such as simple signal prediction, or even some tests like prisoners dilemma.

# Modern EP

- Modern EP is much closer to ES than to anything else
- EP has less of a focus on FSM and more on the evolution of solutions
- There are some important, but a little more subtle differences between ES and EP (modern)

# Basic Differences of ES-EP

- EP does not use a recombination operator of any kind
- The objective function value is normally scaled (as opposed to ES, but like a GA and GP): The scaling of the function value allows to emphasize differences at various points in the run
- Selection is probabilistic, often uses a kind of tournament selection to maintain diversity (ES requires a deterministic selection operator)
- Originally, EP had no self-adaptation, but Fogel has proposed models, called meta-EP, which self-adapt based on the variances found in the population

# ES vs. EP, empirically

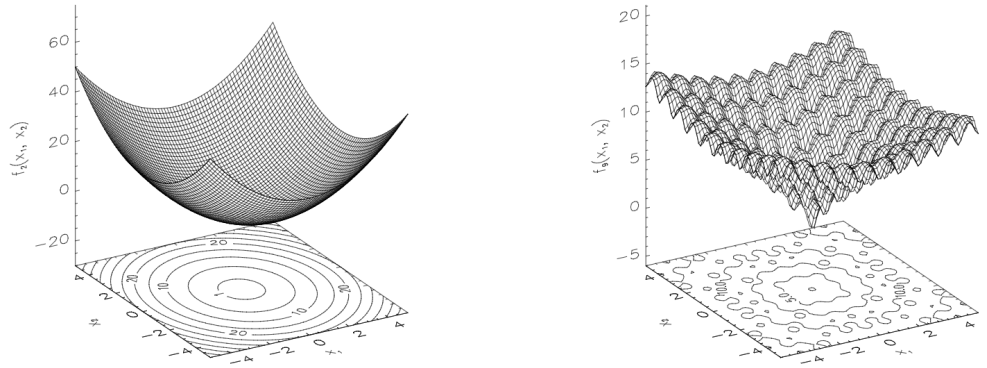


Figure 2: Three-dimensional plots of the sphere model (left) and Ackley's function (right).

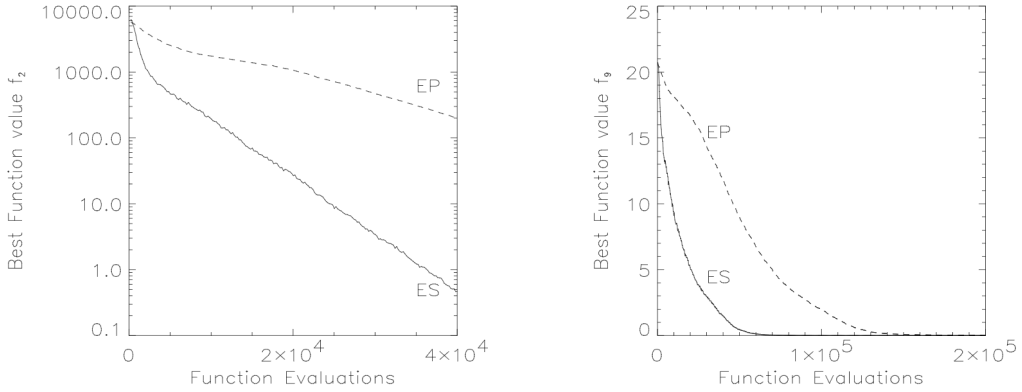



Figure 3: Experimental runs of an Evolution Strategy and Evolutionary Programming on $f_2$ (left) and $f_9$ (right).

Evolutionary Programming
and
Evolution Strategies:
Similarities and Differences

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# Disadvantages of EP

- EP has never been very popular
- Slow
- AI researchers at the time did not find the approach appealing because of its randomness
- Overall, the goal of EP now is to see what it can do that another approach (such as a tree search) cannot do