Genetic Algorithms

Basics

Our job here is a modelling task.
How to model a problem as Genetic Search

• Basic Hypothesis: Evolution has been a great learning device.
  Let’s model it.

• Inputs
  – Population of Individuals
  – Old style: individuals are strings.
  – New style: individuals are trees (LISP programs).
  – Selection scheme for mating
  – Huge number of variations
  – Definition of mating
  – Many possibilities, depending on representation.
  – Definition of Fitness function
  – This defines what is to be optimized.

Usually, there are mutation operations too.

• output: individual which defines a high value for a fitness function (objective function).
Properties

- GAs have more parameters, structural and numeric, than Neural nets.
- GAs are used for function/control optimization.
- GAs follow a non-systematic search procedure.
- Diversity of population is an important concern.
- Neither general-to-specific or specific to general search
- Stochastic search methods have few guarantees

Basic Algorithm

Let Population size be Size
For some number of generations do
  Let Pop be the initial population (200 is considered small)
  Stochastic selected pairs for mating
  Mate the pairs
    stochastically combine the genes of pairs
  Maybe mutate some members of Population
  Stochastically select Size members for next Generations
Example: Function Optimization

Given: real-value function $f$ on $[0,1]$ to maximize.

**individual:** real number in range 0 to 1.

**mating:** take two real numbers and produce offspring, usually by crossing over the bits. Other ways?

**mutation operator** flip a bit, with some small probability.

**fitness function:** given function $f$

With right parameter setting, successful finding maximum when function has many local maximums.

Example: Function Creation

Goal: create a program which generates random numbers.

**individual:** Expression trees, i.e. parse trees where internal nodes are operations like plus and times and leaves are constants or input value. We also allow tests at internal nodes.

**mating:** Take two trees, pick random internal nodes, (of same type: operation or test), and interchange subtrees.

**mutation:** change a test, operation or leaf.

**fitness function:** some statistical test that function is random. This only will achieve a pseudorandom number as the resulting function is clearly deterministic.

Lisp functions are essentially expression trees so this could be a way to generate Lisp code.
Refinements

• Termination
  – Average Fitness of total Population is a standard parameter.
  – When Average Fitness ceases to increase, terminate algorithm.
  – Other measures are: best fit and fitness variance.
  – As a general rule, GAs try to maintain high variance, as this is a measure of diversity.

• Pair Selection
  – may allow self-mating
  – may allow mating with parents
  – probability of selection depends on fitness.
  – may be selected more than once (or not).

• Mating
  – Simplest: Fixed size strings.
    Model crossover, i.e. first k from one string, rest from other.
  – Variable string. Similarly.
  – May have genes, i.e. substrings that you don’t allow to intermingle.
  – If use trees, then cross-over builds new tree from each.
  – Many more.

• Mutation
  – stochastically choose members
  – stochastically vary them

• Next Generation
  – May include members of previous generations
  – May force inclusion of some members of previous generations
  – May allow hill-climbing of members (lamarckian)
  – Selection is stochastic
Performance

- Very expensive/slow
- Unclear value of huge number of parameter selection
- Has been used for control of chemical plants, robotics
- A theorem says it should do well, if there is local structure that determines the general successfulness of the individual.

Successes

- Steam Plant (Smith)
- Robot control (Koza)
- Evasion planning for planes

Questions

- How would you model the 8-queens problem using a genetic algorithm approach? (More than one method might be possible).
- How would you model the task for using genetic algorithm to find a lisp program to reverse a list?
- What algorithms are natural competitors of Genetic Algorithms?
- How would you evaluate the performance capability of Genetic Algorithms?