Genetic Engineering and Creative Design

- Background
  - genes, genotype, phenotype, fitness
- Connecting genes to performance in fitness
- Emergent gene clusters $\Rightarrow$ evolved genes
Evolution

Crossover Points

Parents

Offspring

A

B

C

D

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Parents

Crossover point

Offspring
Parents

A

B

Offspring

A

B

C

Crossover point
"good" genotypes

"bad" genotypes

Total Population
rule 1

rule 2

rule 3

rule 4

rule 5

rule 6

rule 7

rule 8
Evolving genes

- First step: evolve coding
  - One prototype case
  - Start with simple coding
  - Modified evolutionary system
- Second step: use coding
  - New design task
  - Use evolved coding
  - Reduced search-space
  - Usage of design knowledge from prototype
Example task

- Phenotypes are parts of drawing
- Higher fitness for better fit
- Turtle coding:
  - 00 line
  - 01 step
  - 10 turn right
  - 11 turn left
Coding of evolved genes

Two basic genes

\[0 0 + 0 0 \Rightarrow 1\]

Basic gene + evolved gene

\[0 0 + 1 \Rightarrow 2\]

Two evolved genes

\[1 + 2 \Rightarrow 3\]
Modification to evolutionary system

- Goal is high variety of fit individuals, not single optimal solution
- Convergence avoided:
  - Growing population:
    - Only duplicate and non-fitting individuals removed
  - Evolving fitness, proportional to number of individuals in same region:
    - Low fitness in densely populated regions
    - High fitness in unpopulated regions
    - Niching
Gene extraction

- Evolved genes composed of two (basic or evolved) sub-genes
- Most common pair of sub-genes identified and extracted
- Pairs have to occur in at least $N$ different individuals
- Genes replaced throughout population
- Number of evolved genes kept at 5% of number of individuals in population
The set of evolved genes

- Gene families
  - Every gene represents a larger group of similar genes (8–28 genes)

Genes are numbered in order of generation
- Special genes
  - Every gene is special or occurs only in a small number of variations

Genes are numbered in order of generation
Example of Evolved Coding
invisible line

10  right turn

11  left turn
Minimum: 4 individuals, Maximum: 3242 individuals
3-complexity
2-complexity
1-complexity
0-complexity

(a) | (b)
---|---
\(g_2\) | \(g_3\)
\(g_1\) | \(g_1\)
\(g_8\) | \(g_8\)
\(g_0\) | \(g_0\)
Genetic Engineering of “Bad” Genes

- locate “bad” gene groups
- remove “bad” gene groups
- radiation therapy for bad gene groups through high mutation rates
- gene therapy for bad gene groups through replacement with “good” genes
- cloning to increase percentage of “good” genes
Total Fraction of “Bad” Genes in Population

- Radiation therapy
- Gene therapy

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Total Fraction of Evolved Genes in Population

- Gene evolution
- Gene therapy
- "Bad" genes after gene therapy

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Genotype Form

- In form of a tree
- Each node has four variables
  - direction of rectangular split (4 values)
  - fraction of the split (15 values)
  - colour of split area (10 values)
  - line width (3 values)
Fitnesses for Representation

- offset between actual and required positions of dissection lines
- number of lines with correct line width, normalised
- number of correct colour panels, normalised
- number of lines assigned, normalised
- number of unassigned lines, normalised
Flondrians

- Mondrian painting $\Rightarrow$ genetically engineered genes: M-genes
- Frank Lloyd Wright windows $\Rightarrow$ genetically engineered genes in same representation: F-genes
- “Flondrians” are the genetic product of mating M-genes with F-genes