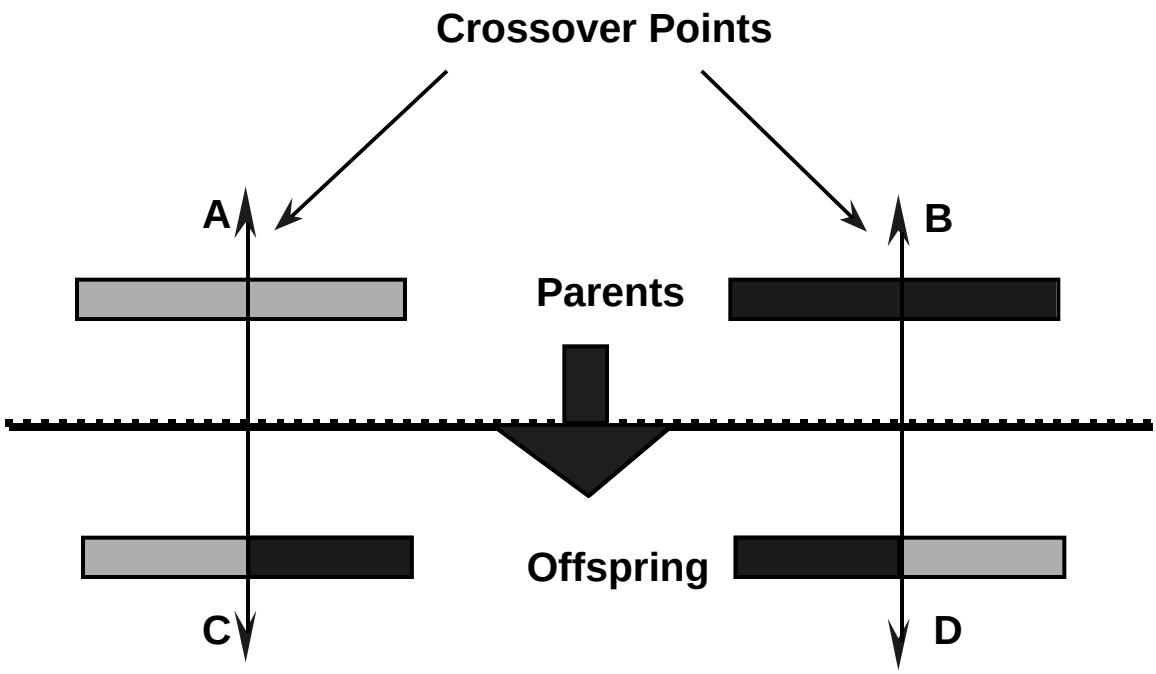
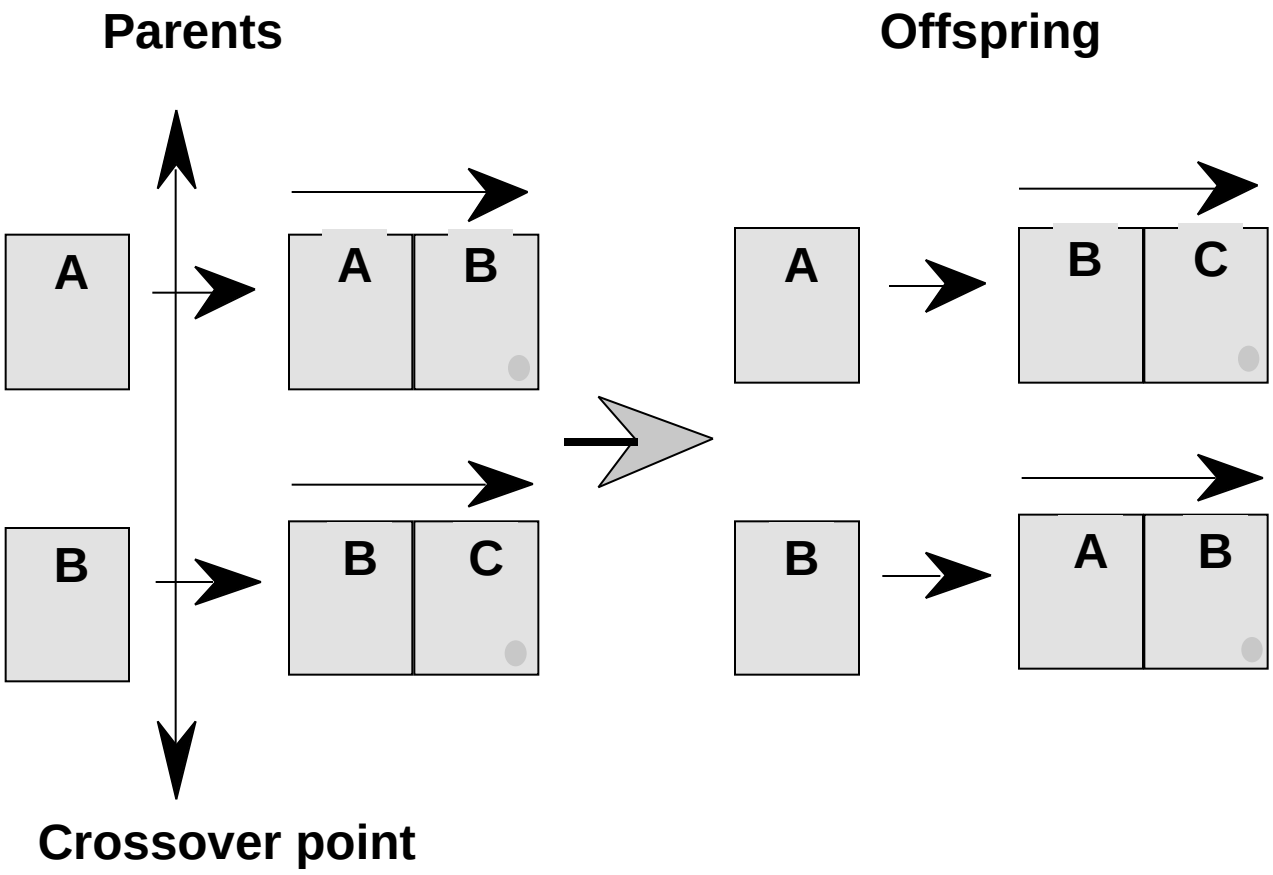
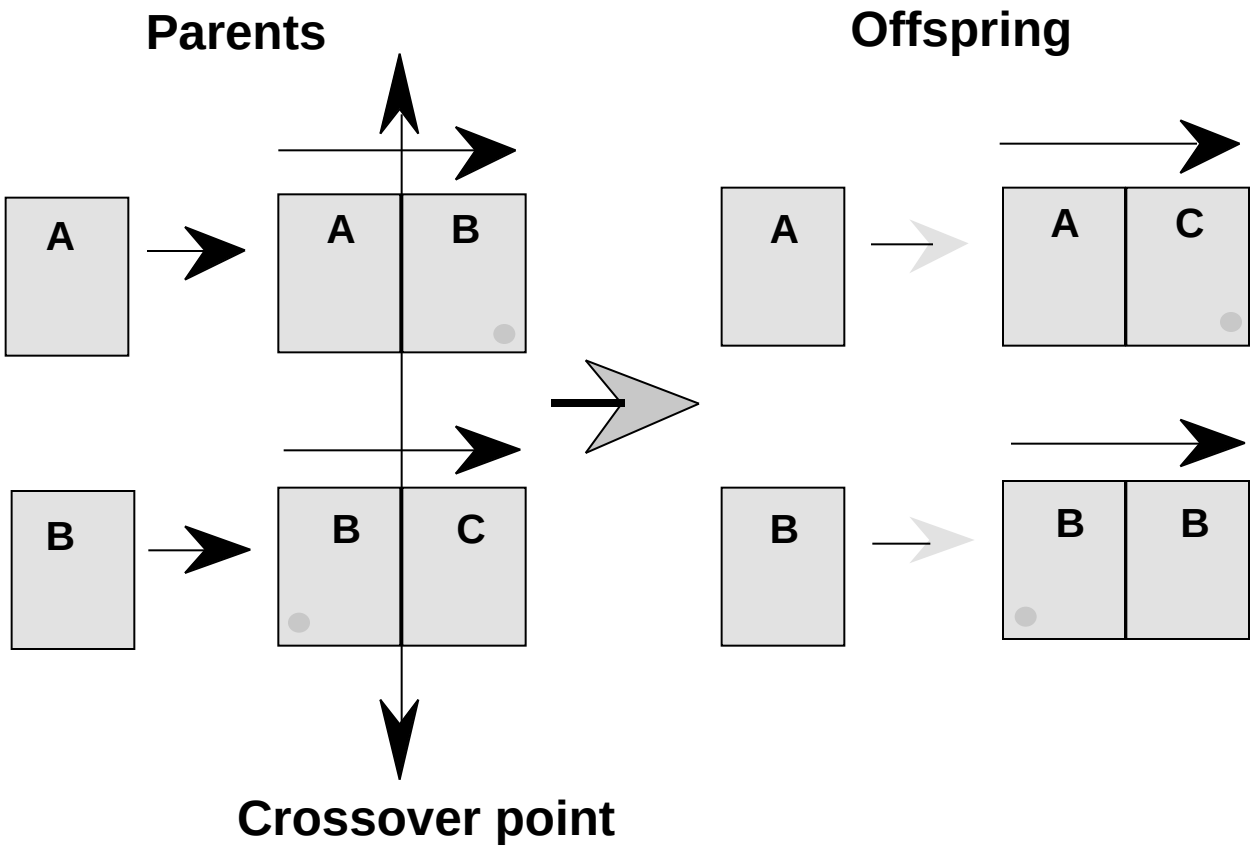
Genetic Engineering and Creative Design

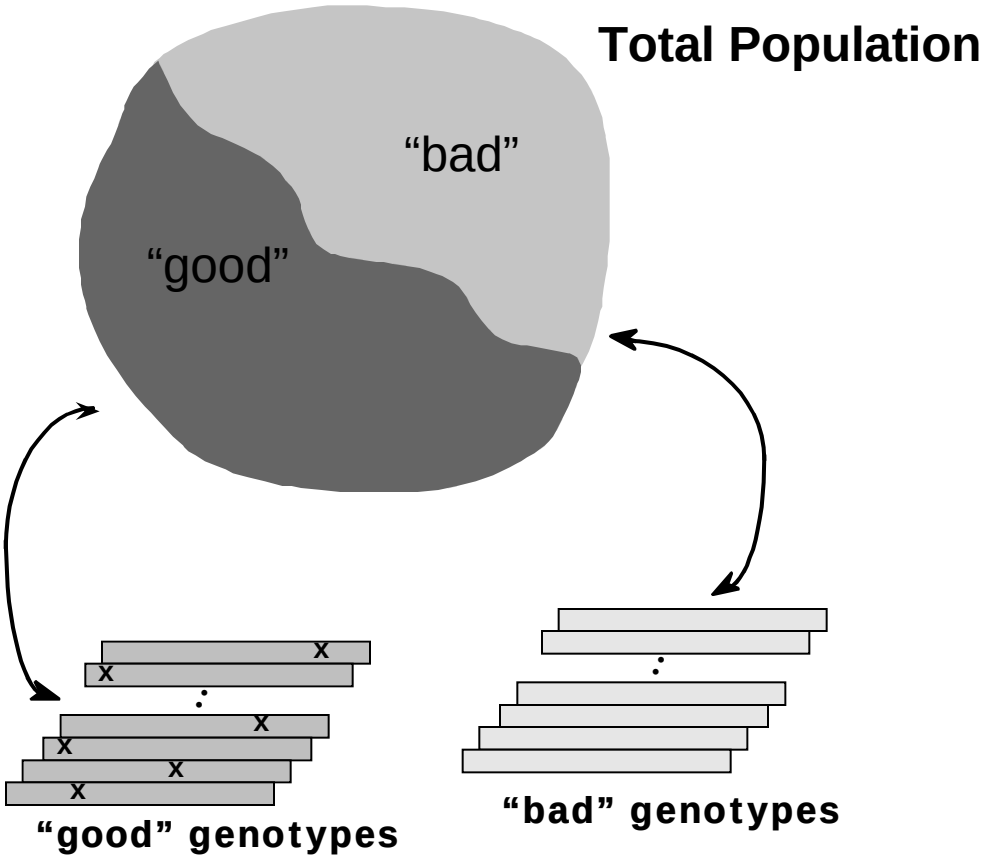
- Background
  - genes, genotype, phenotype, fitness
- Connecting genes to performance in fitness
- Emergent gene clusters ⇨ evolved genes

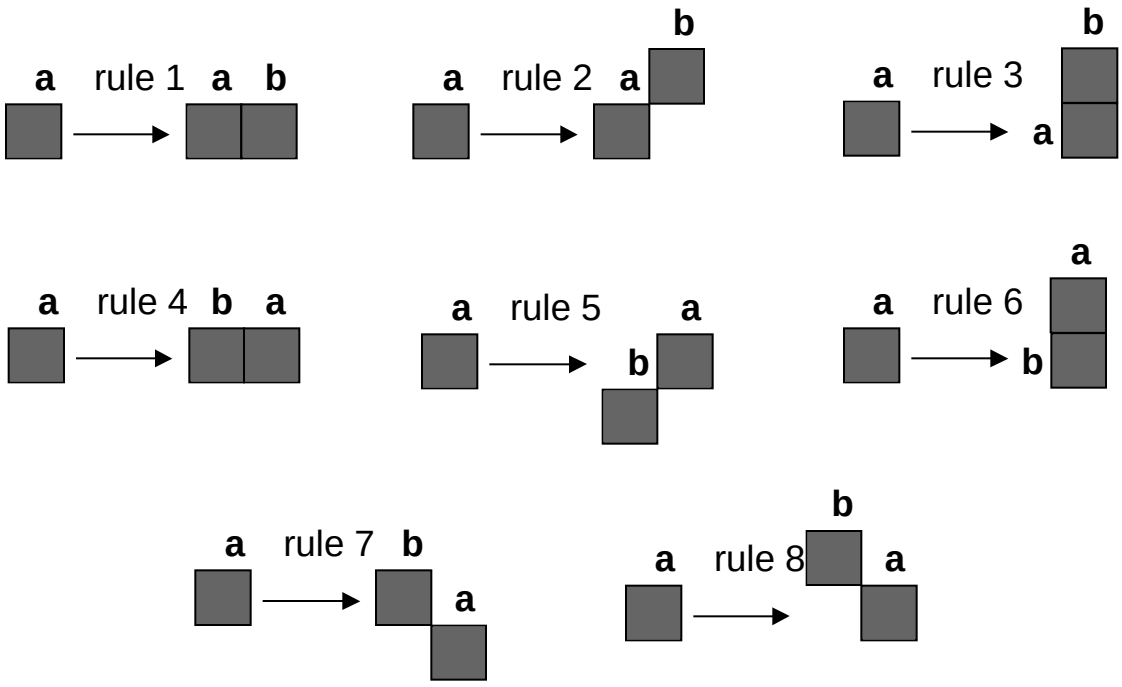
Evolution

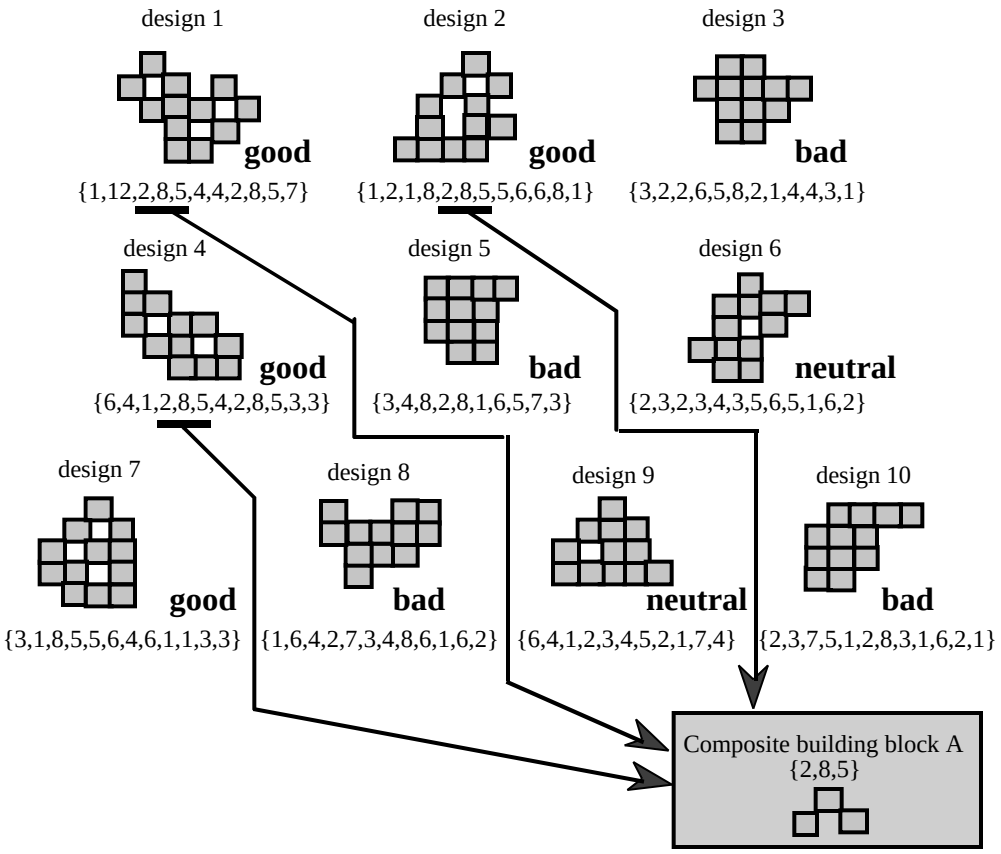



Parents
Offspring
A
B
A
B
B
C
A
B
B
C
A
B
Crossover point


Parents
Offspring
A
A
B
B
B
C
A
A
C
B
B
B
Crossover point

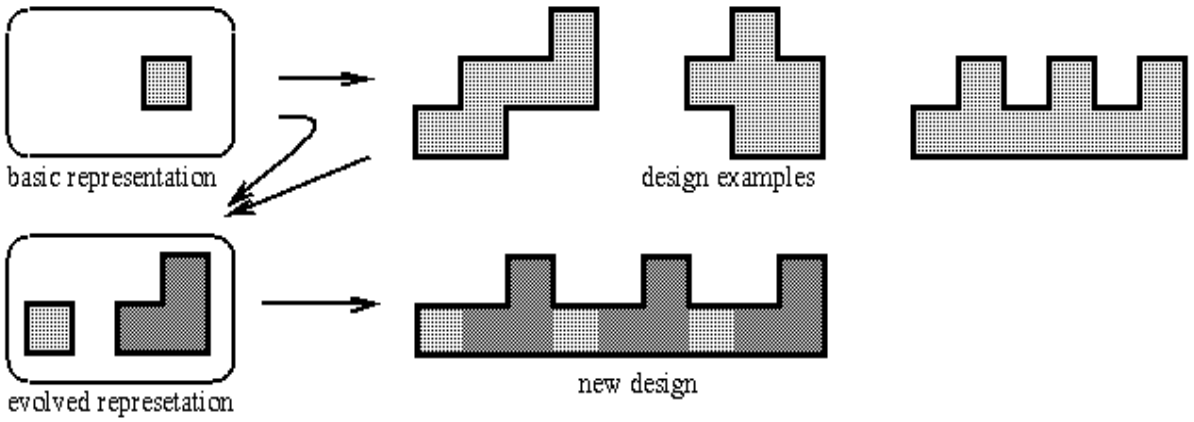

Total Population
“bad”
“good”
“good” genotypes
“bad” genotypes

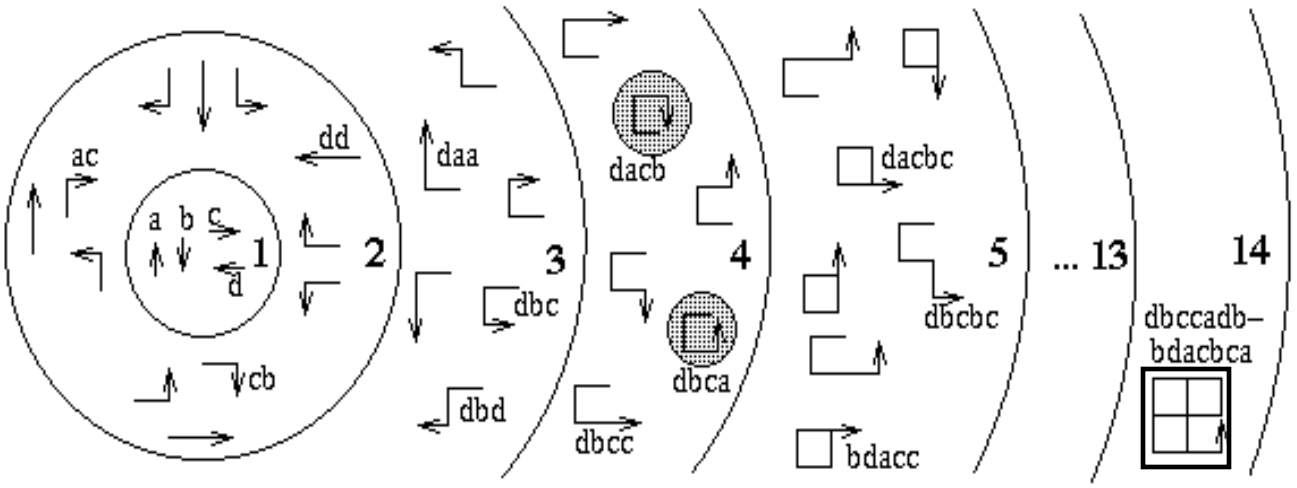

a
rule 1
a
b
a
rule 2
a
b
a
rule 3
b
a
a
rule 4
b
a
a
rule 5
a
b
a
rule 6
a
b
a
rule 7
b
a
a
rule 8
b
a

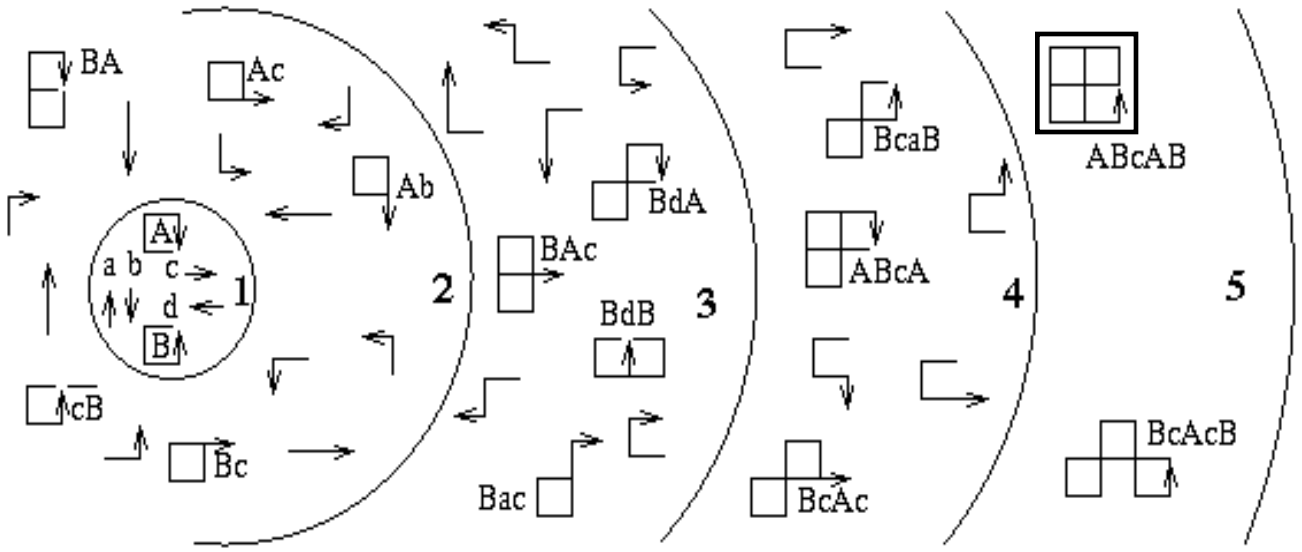

design 1
good
{1,12,2,8,5,4,4,2,8,5,7}
design 2
good
{1,2,1,8,2,8,5,5,6,6,8,1}
design 3
bad
{3,2,2,6,5,8,2,1,4,4,3,1}
design 4
good
{6,4,1,2,8,5,4,2,8,5,3,3}
design 5
bad
{3,4,8,2,8,1,6,5,7,3}
design 6
neutral
{2,3,2,3,4,3,5,6,5,1,6,2}
design 7
good
{3,1,8,5,5,6,4,6,1,1,3,3}
design 8
bad
{1,6,4,2,7,3,4,8,6,1,6,2}
design 9
neutral
{6,4,1,2,3,4,5,2,1,7,4}
design 10
bad
{2,3,7,5,1,2,8,3,1,6,2,1}
Composite building block A
{2,8,5}

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


basic representation
design examples
evolved represetation
new design


ac
dd
a b c
d
1
2
daa
dbc
dbd
3
dacb
dbca
dbcc
4
dacbc
dbcbc
bdacc
5
... 13
14
dbccadb–
bdacbca
cb


BA
Ac
Ab
A
a b c
d
B
1
2
cB
Bc
BAc
BdA
BdB
3
Bac
BcaB
ABcA
4
BcAc
ABcAB
5
BcAcB

Example task

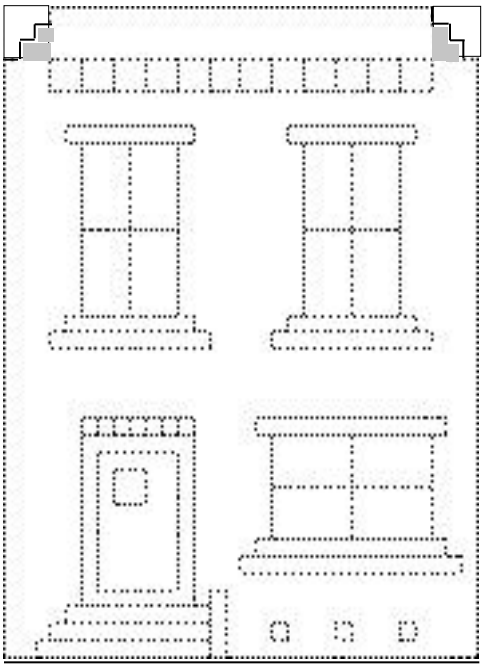
- Phenotypes are parts of drawing
- Higher fitness for better fit
- Turtle coding:

00 line

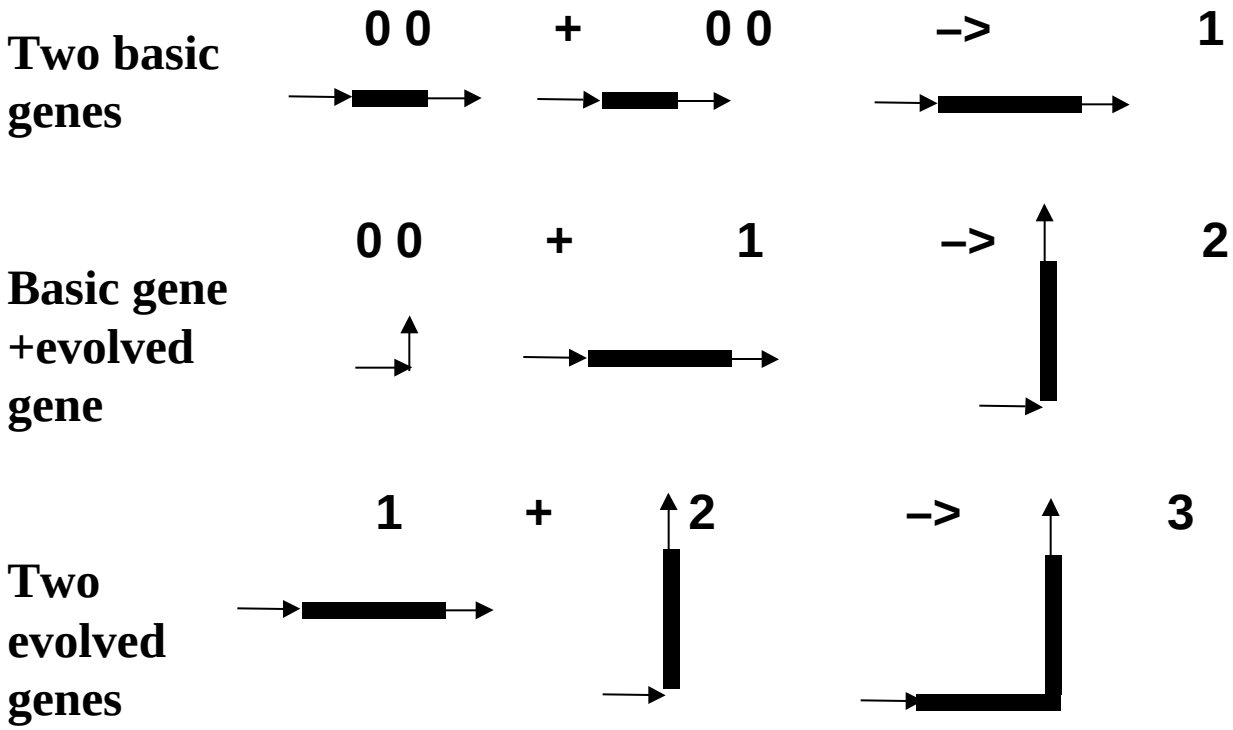
01 step

10 turn right

11 turn left



Coding of evolved genes



Modification to evolutionary system

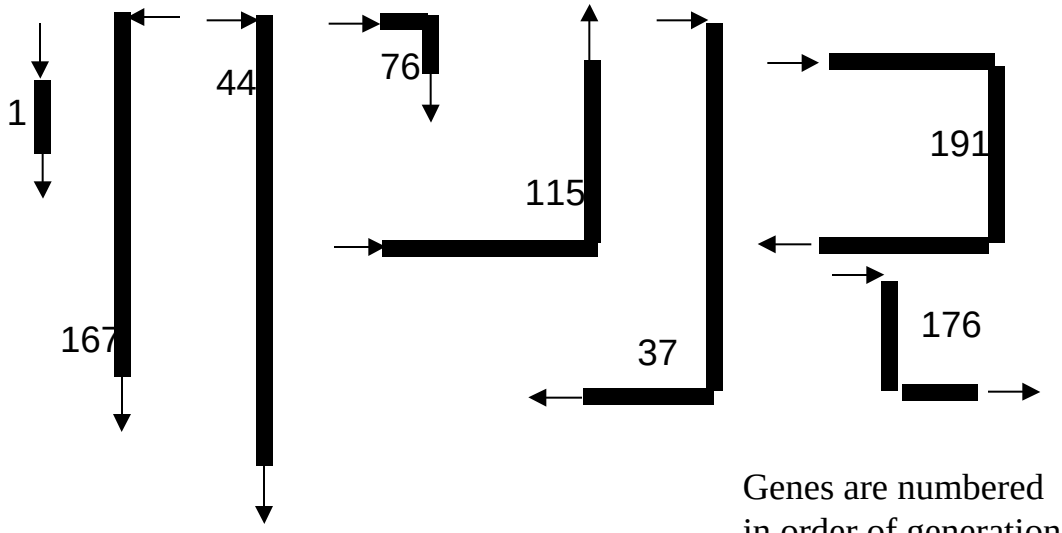
- Goal is high variety of fit individuals, not single optimal solution
- Convergence avoided:
  - Growing population:
    - Only duplicate and non-fitting individuals removed
  - Evolving fitness, proportional to number of individuals in same region:
    - Low fitness in densely populated regions
  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

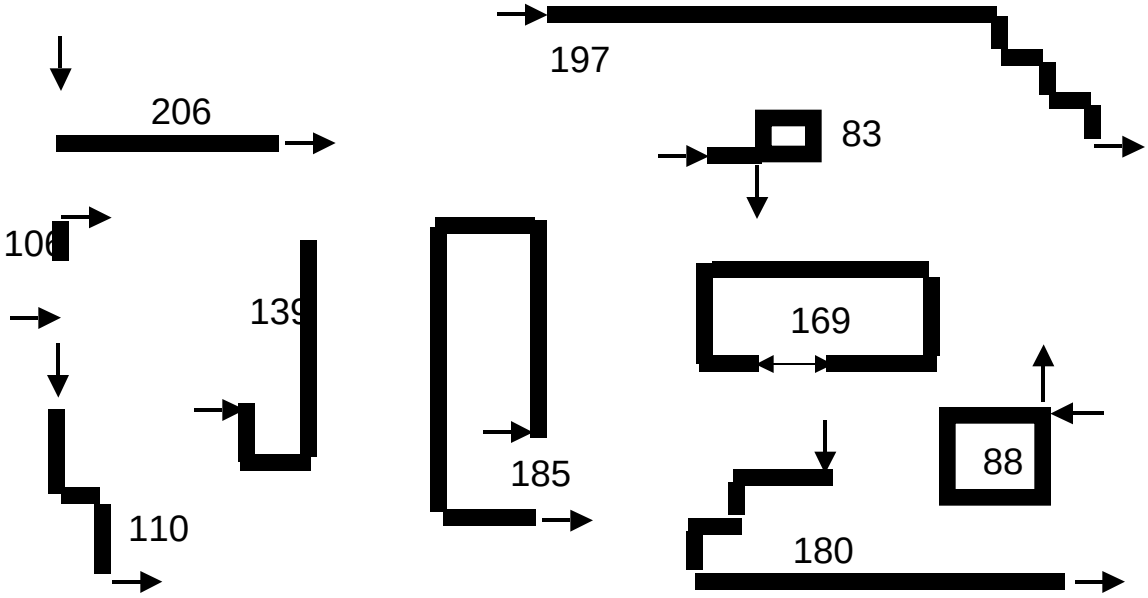
The set of evolved genes

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



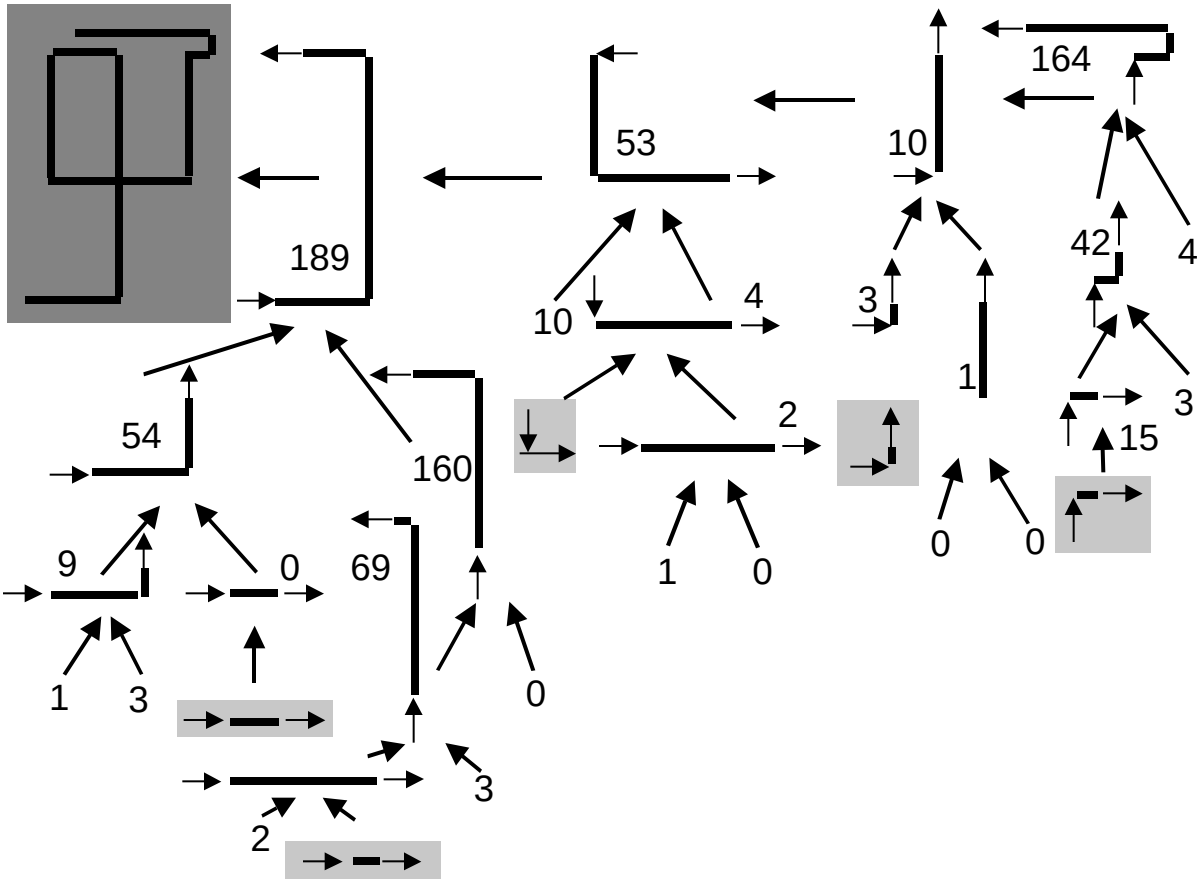
Genes are numbered in order of generation

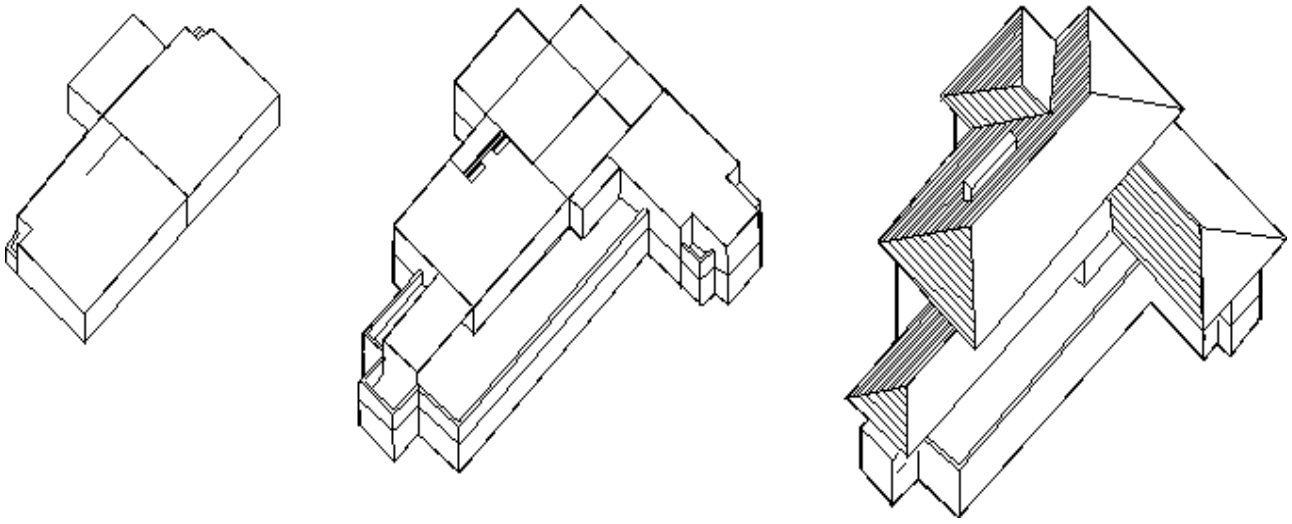
- Special genes
  - Every gene is special or occurs only in a small number of variations



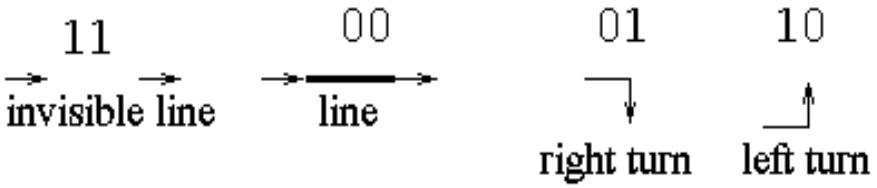
Genes are numbered in order of generation

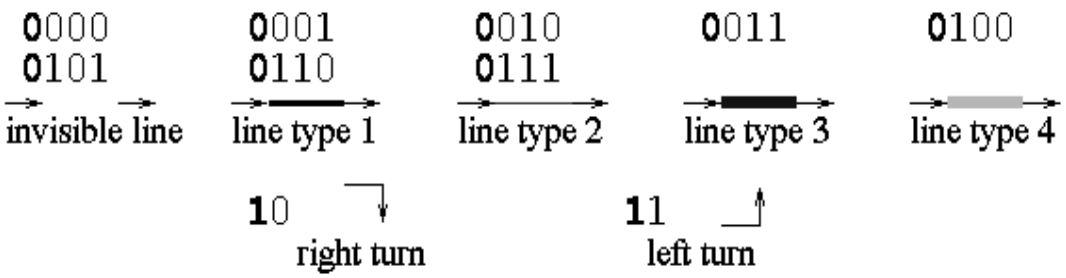
Example of Evolved Coding

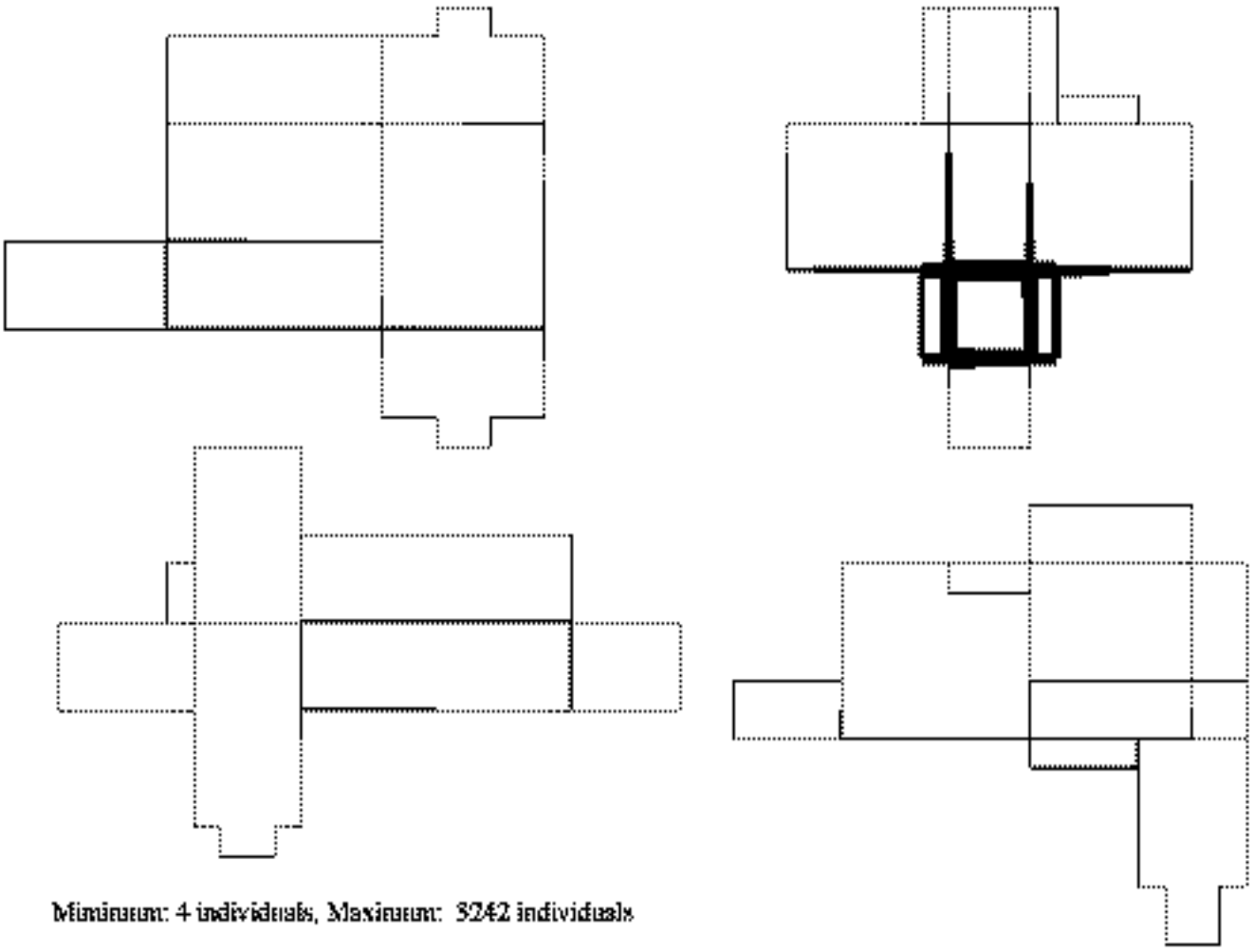




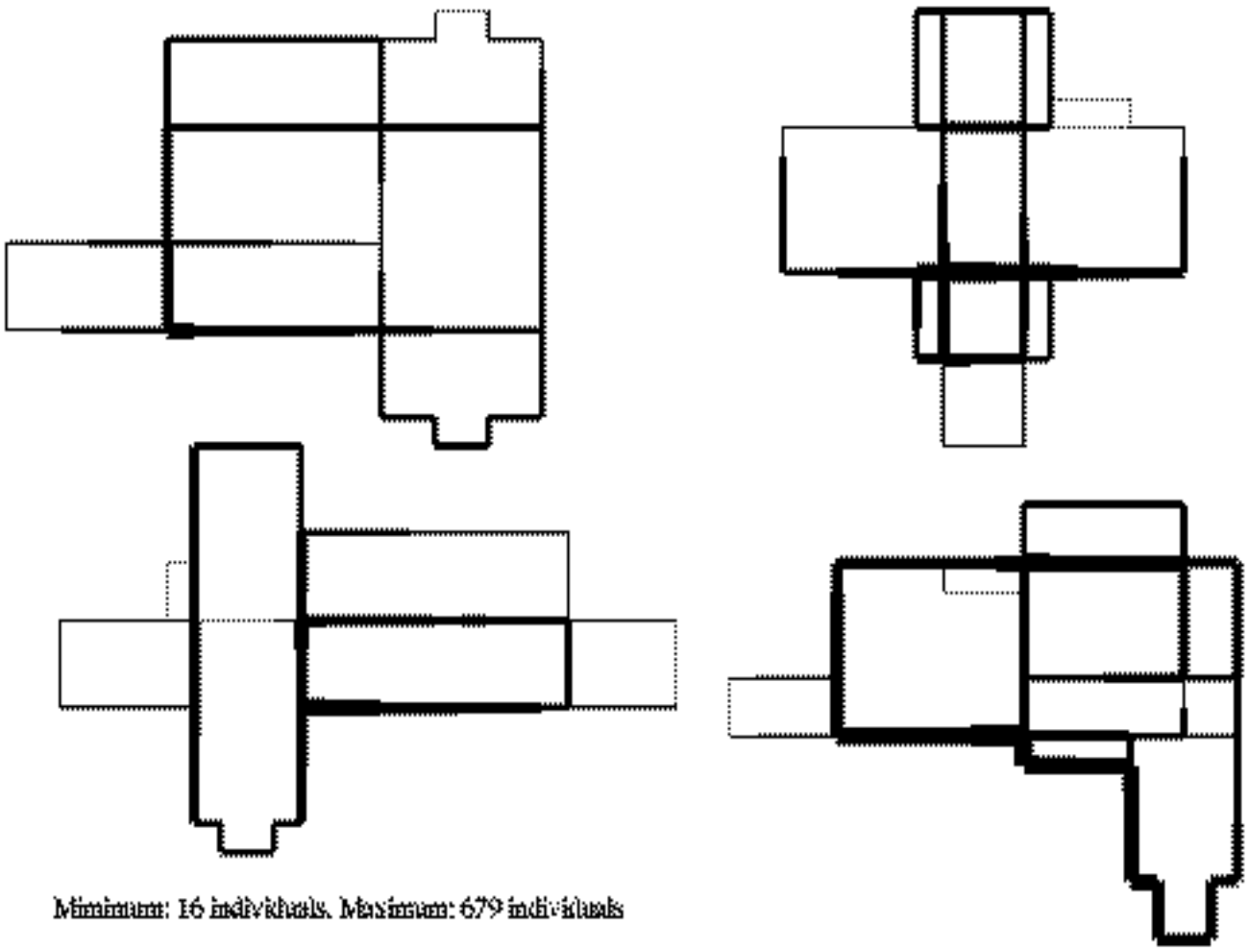

Porch
Service
Living
Fireplace


11
invisible line
00
line
01
right turn
10
left turn

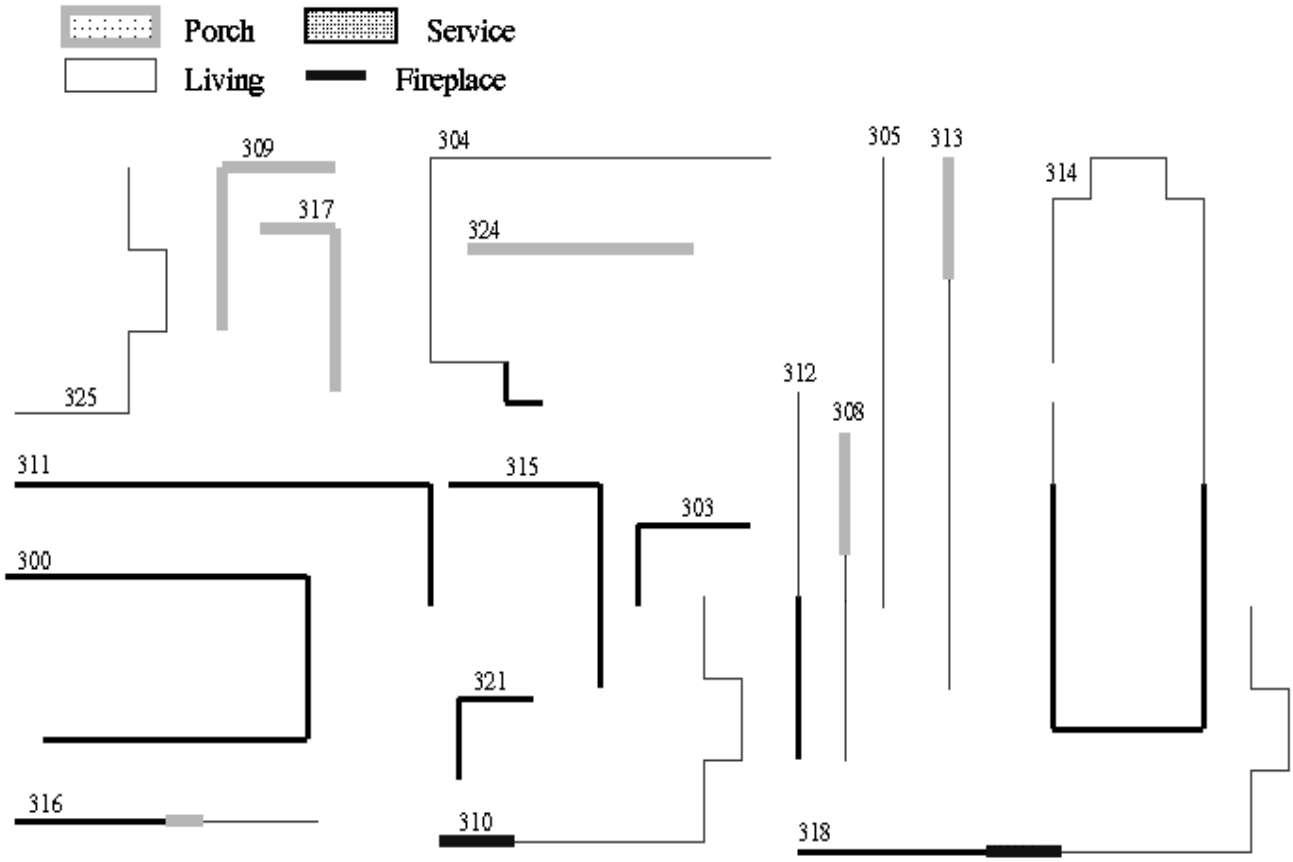

0000
0101
invisible line
0001
0110
line type 1
0010
0111
line type 2
0011
line type 3
0100
line type 4
10
right turn
11
left turn



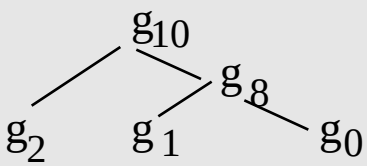
Minimum: 4 individuals, Maximum: 8242 individuals



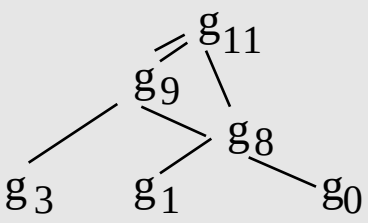
Minimum: 16 individuals. Maximum: 679 individuals


Porch
Service
Living
Fireplace
309
304
305
313
314
317
324
325
312
308
311
315
303
300
321
316
310
318

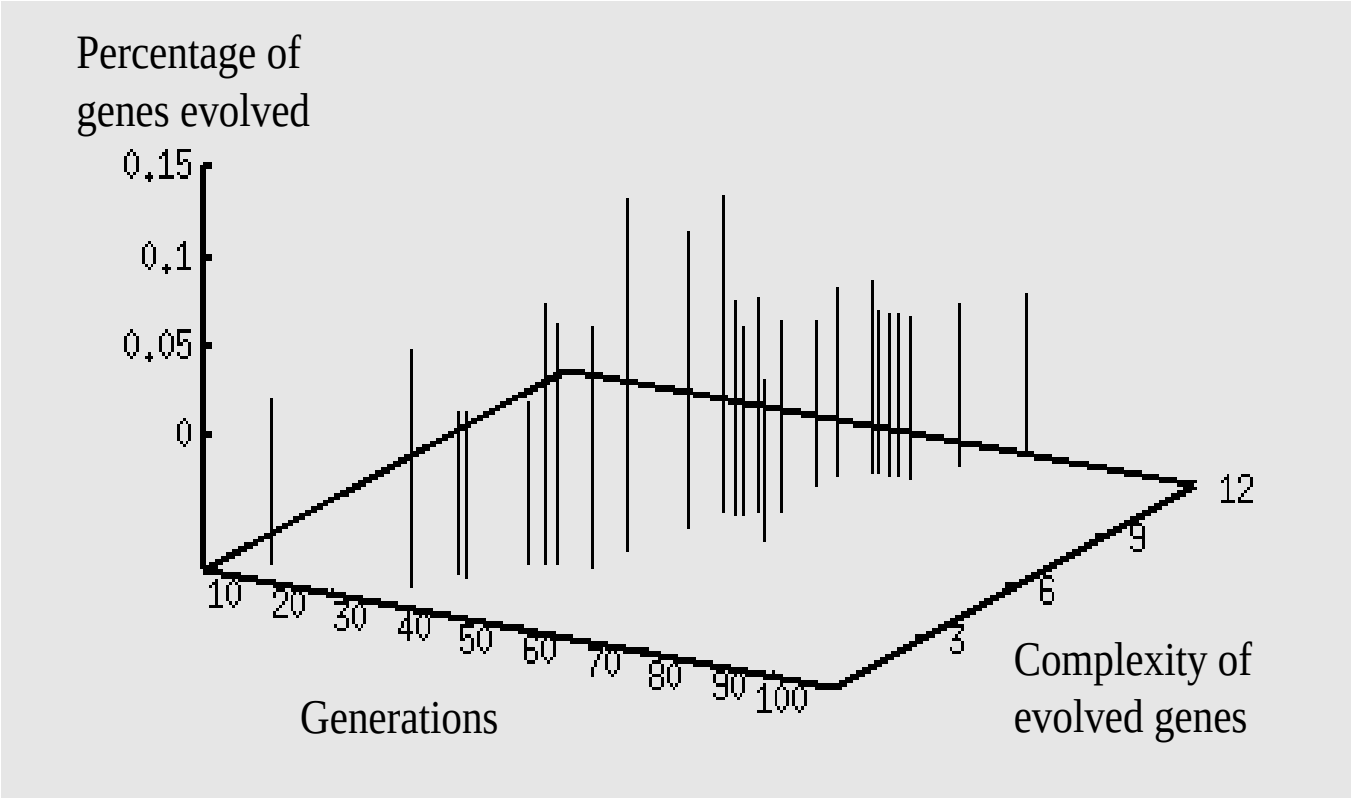
3-complexity
2-complexity
1-complexity
0-complexity

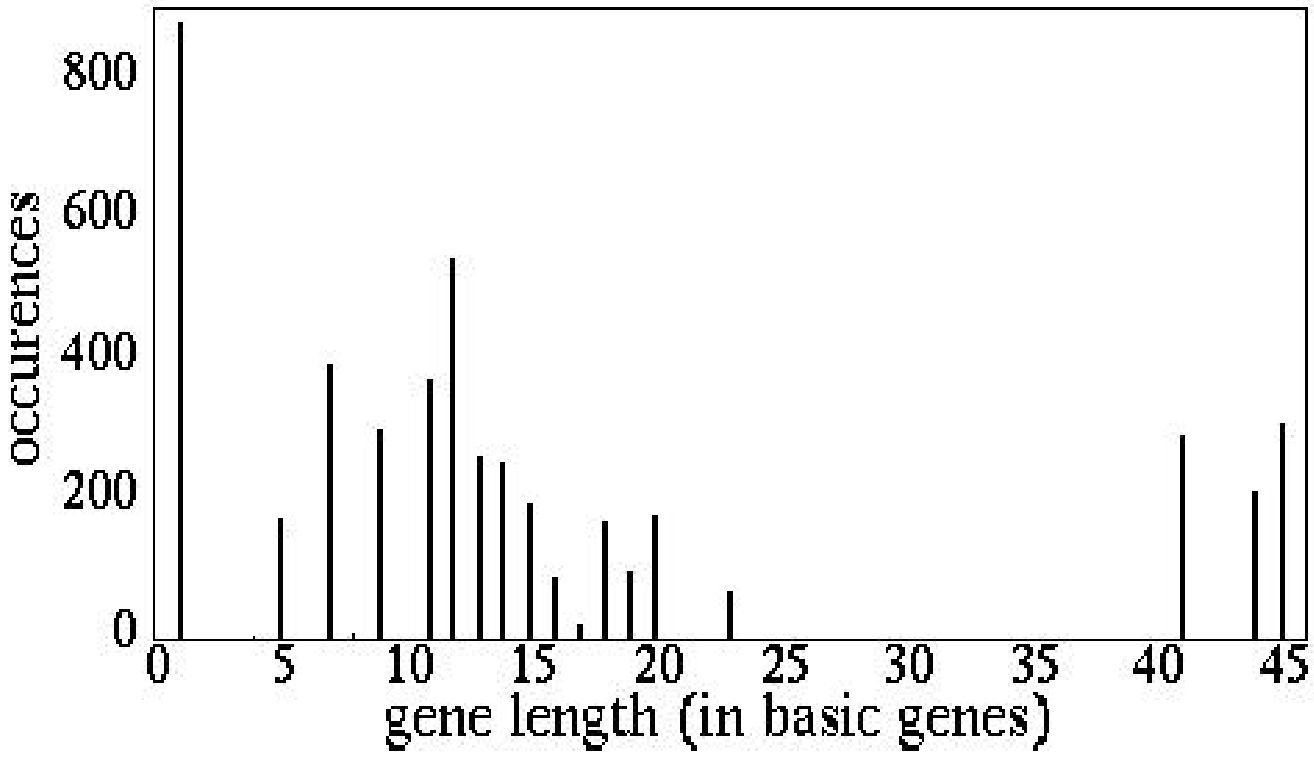


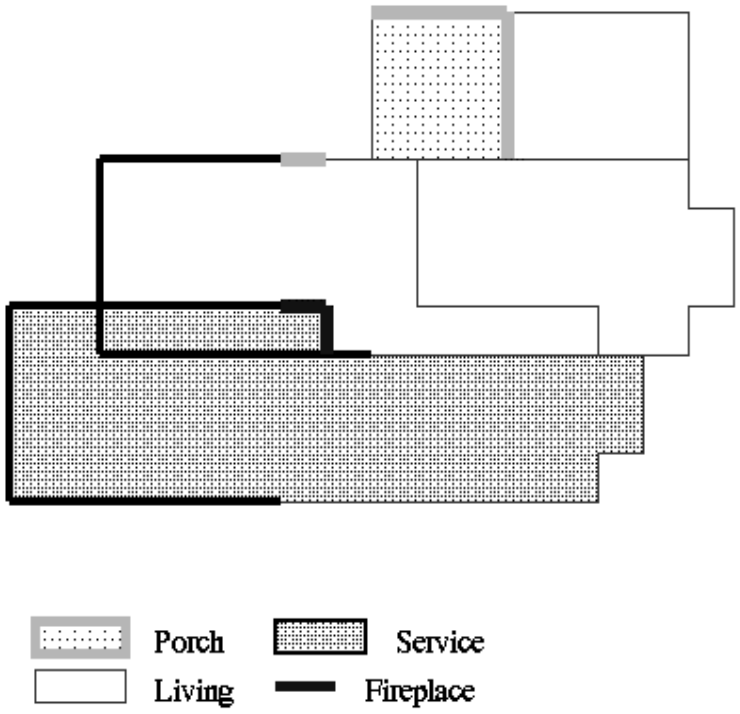
(a)

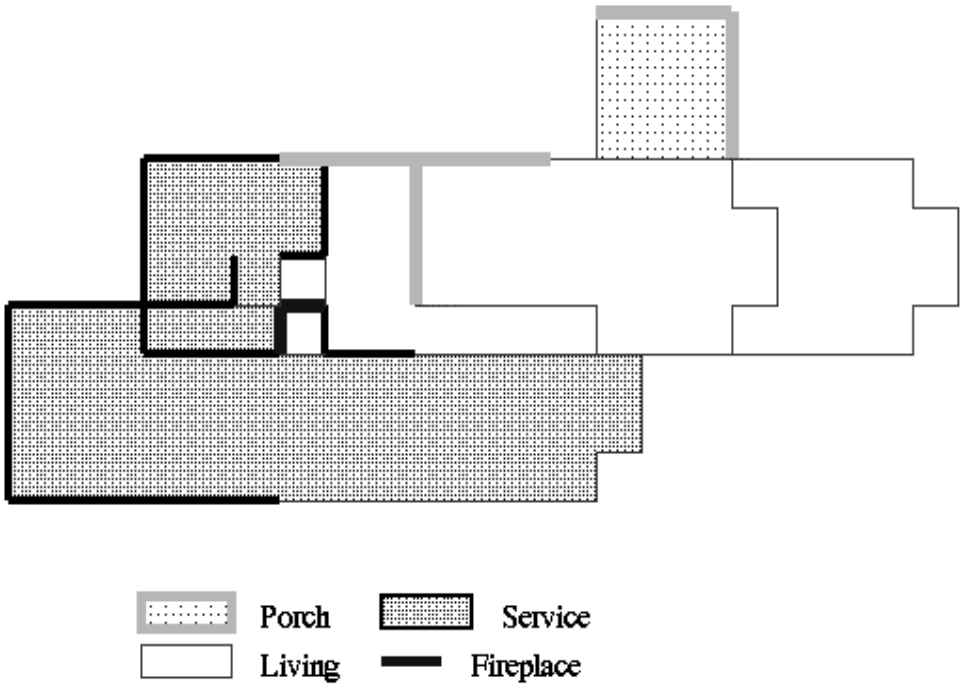


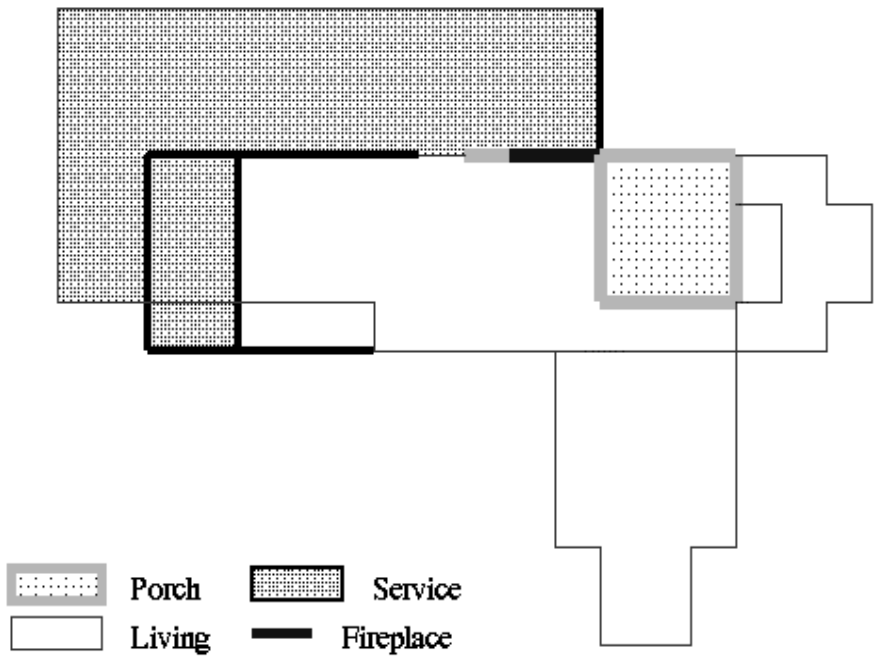
(b)

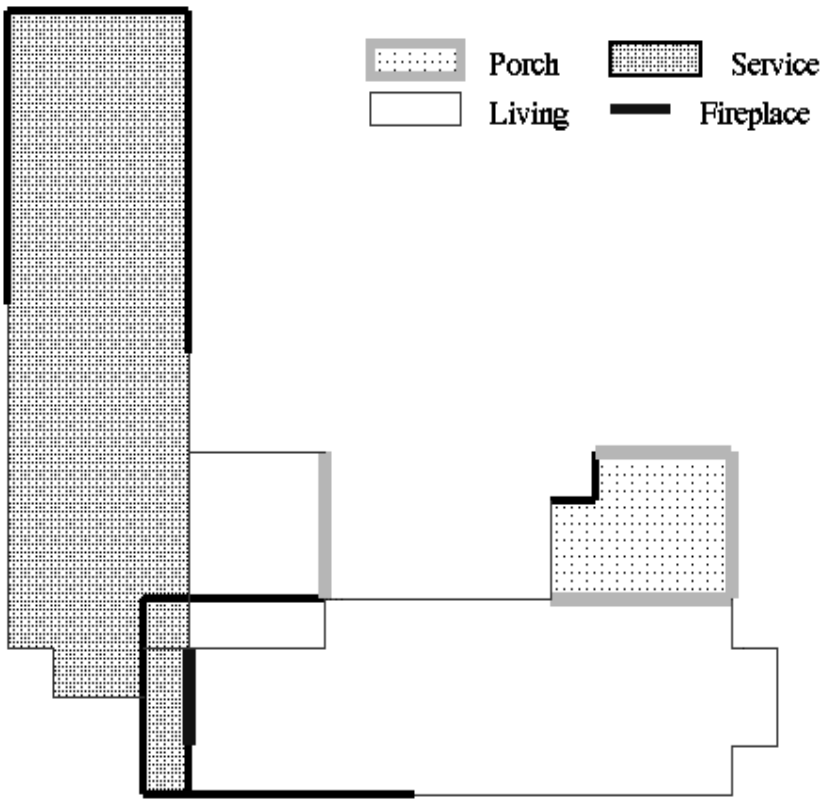

Percentage of
genes evolved
0.15
0.1
0.05
0
10
20
30
40
50
60
70
80
90
100
Generations
3
6
9
12
Complexity of
evolved genes

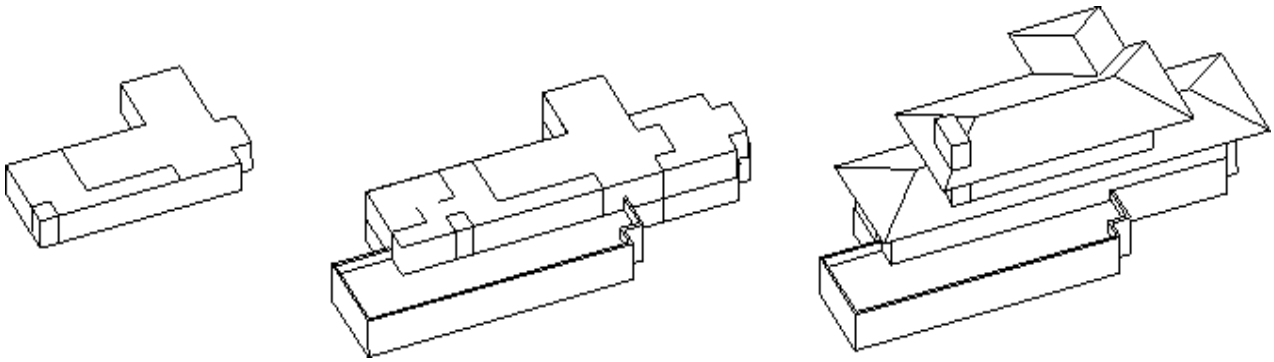

800
600
400
200
0
occurences
0
5
10
15
20
25
30
35
40
45
gene length (in basic genes)

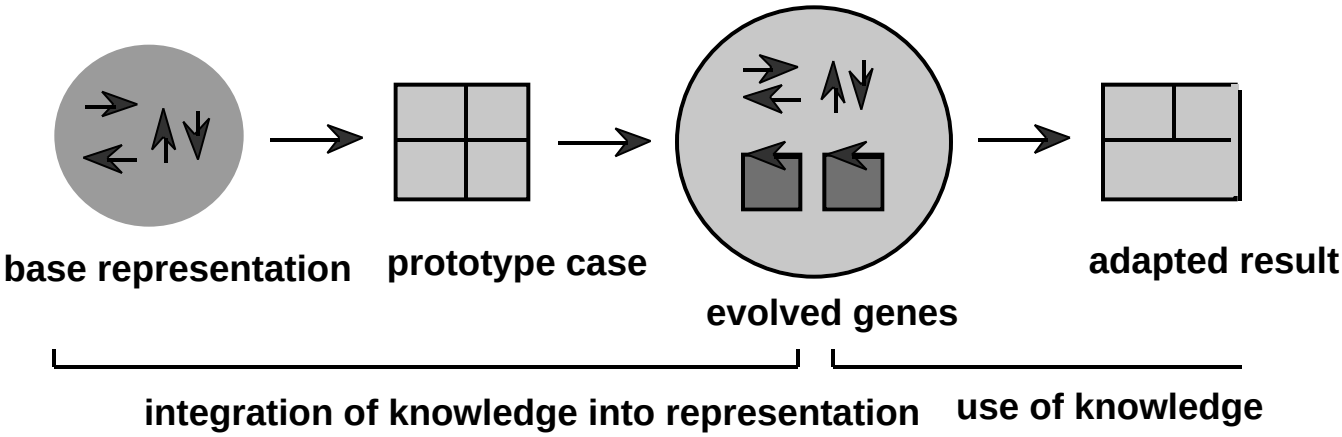

Porch
Service
Living
Fireplace

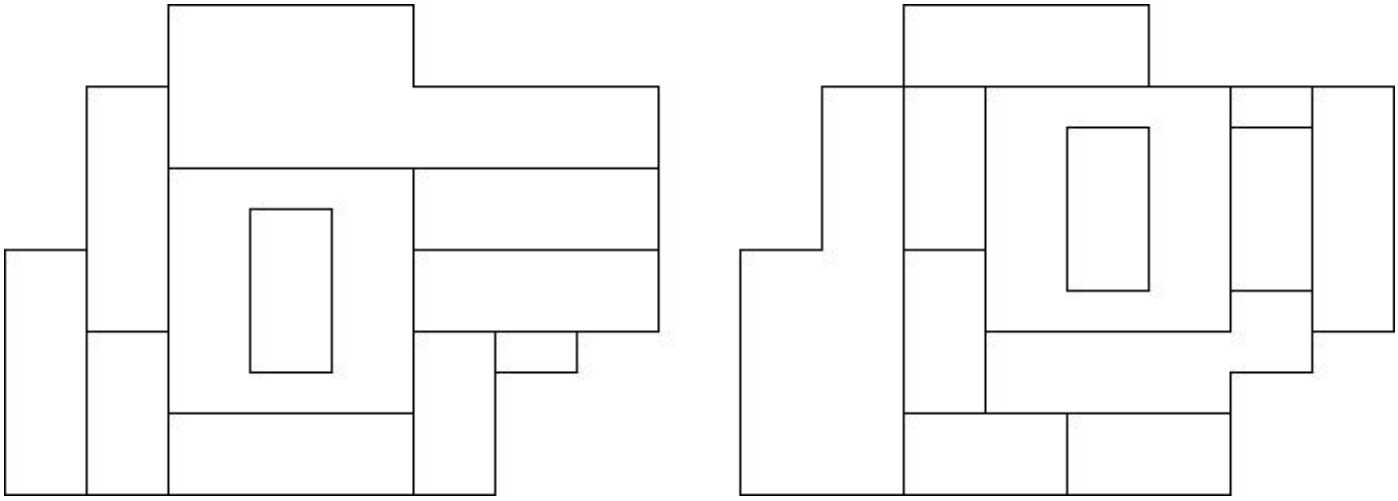

Porch
Service
Living
Fireplace

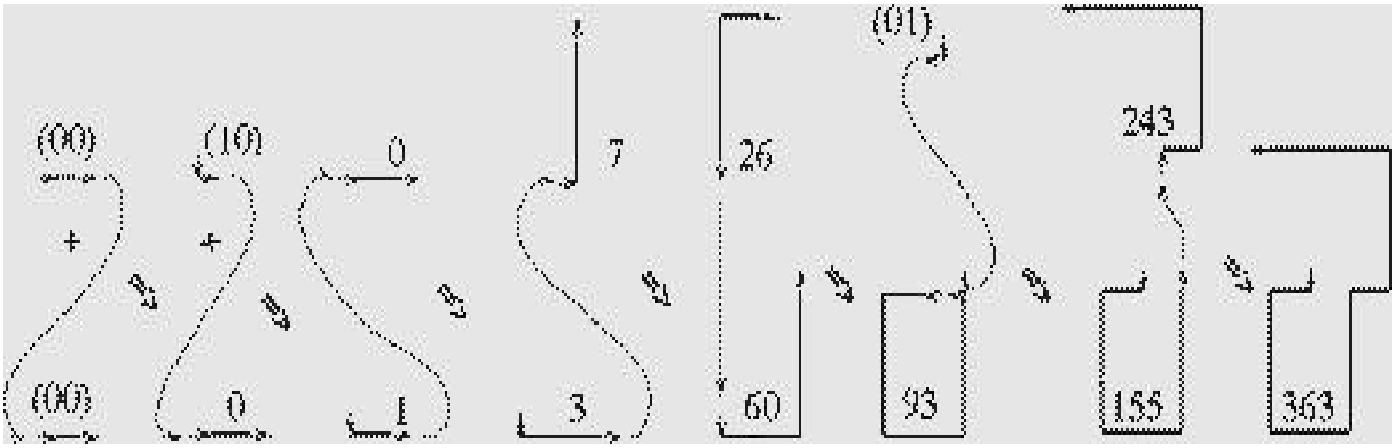

Porch
Service
Living
Fireplace

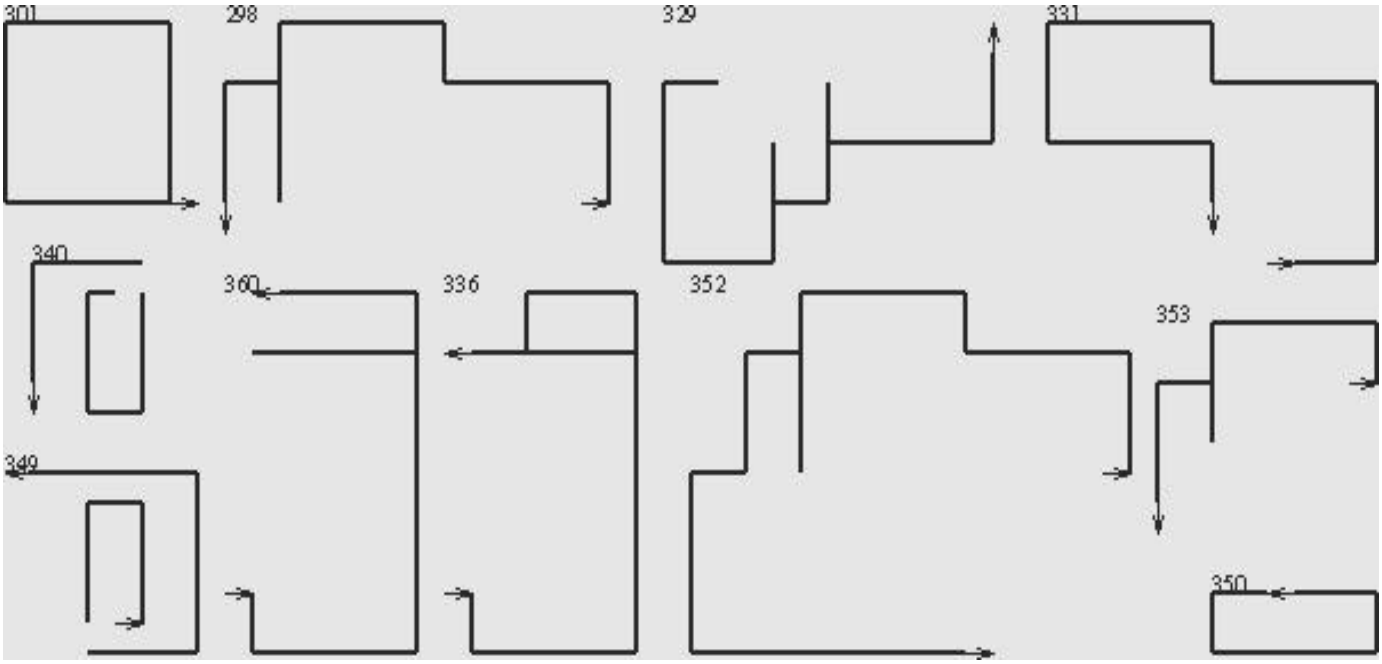

Porch
Service
Living
Fireplace

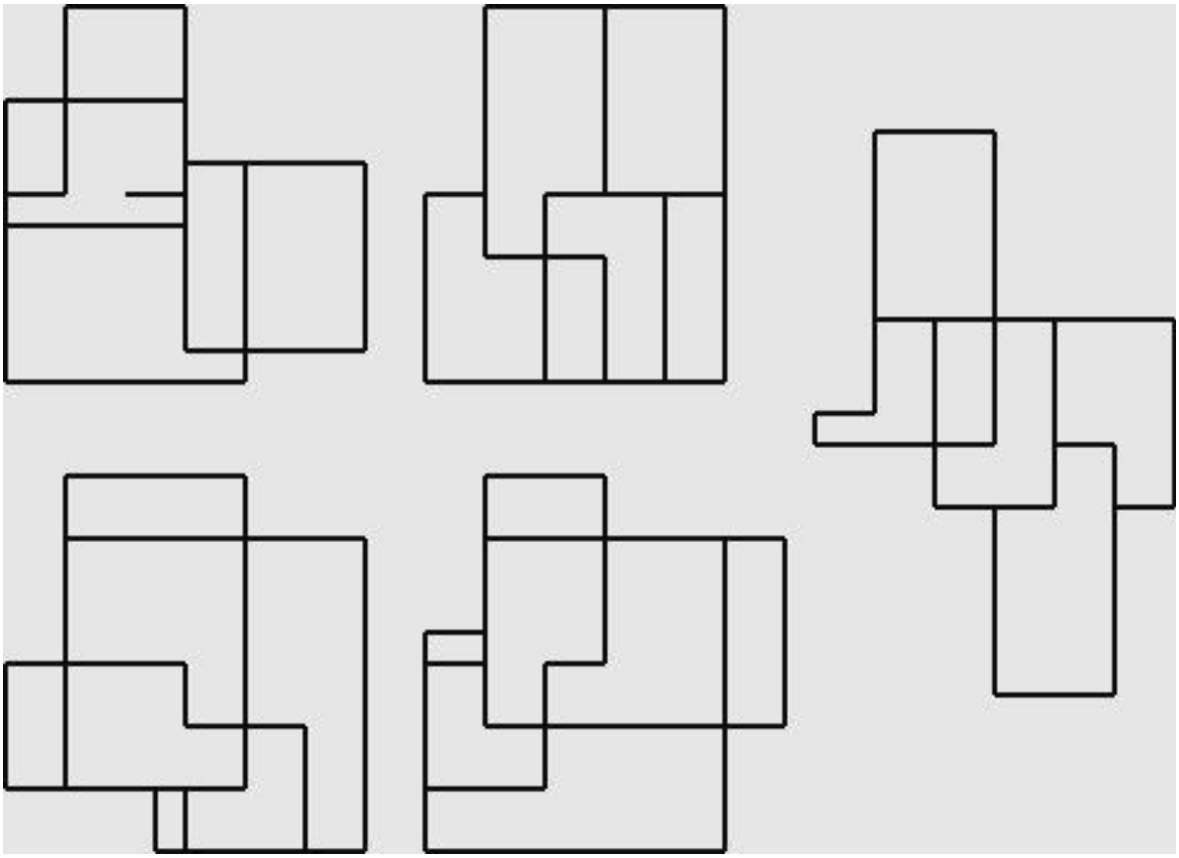



base representation
prototype case
evolved genes
adapted result
integration of knowledge into representation
use of knowledge




(00)
(10)
0
7
26
(01)
243
+
+
(00)
0
1
3
60
93
155
363


301
298
329
331
340
360
336
352
353
349
350



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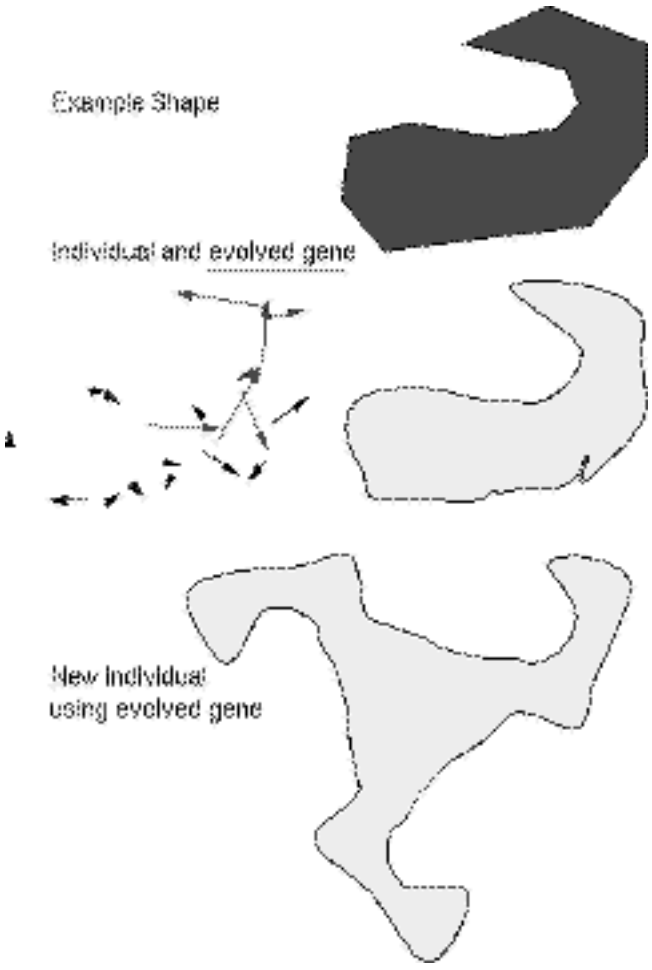
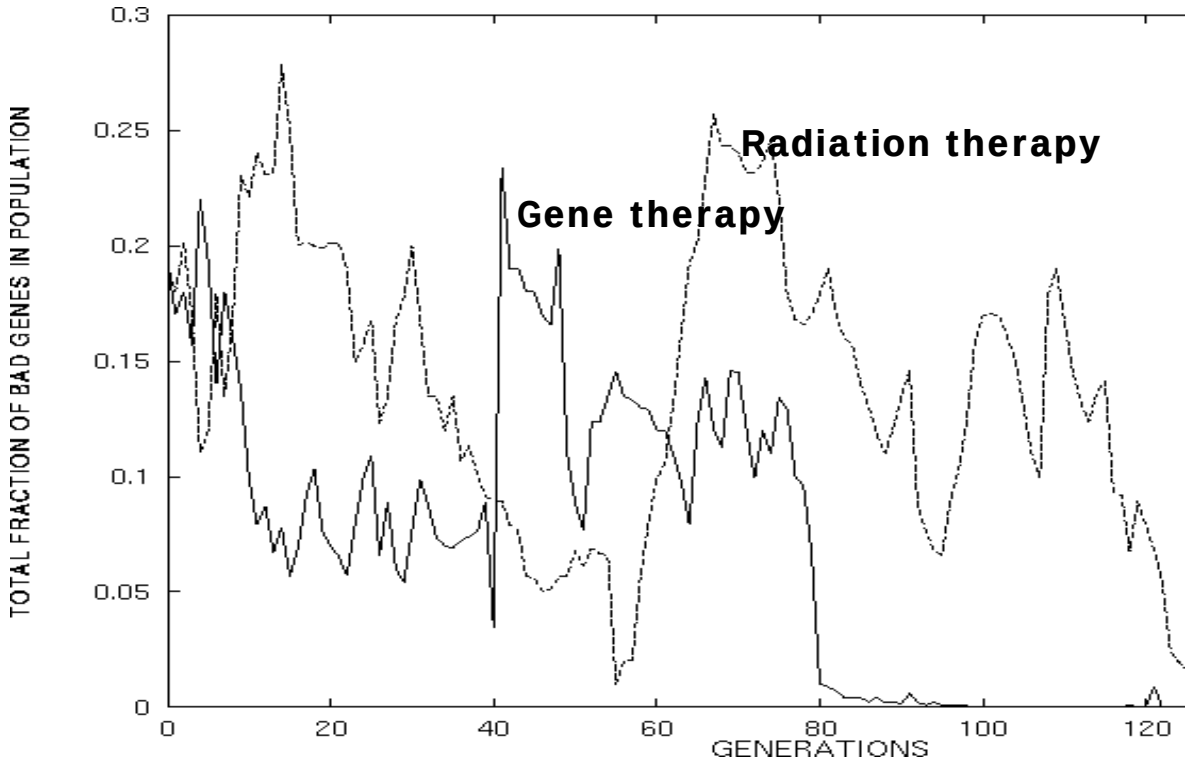

Example Shape
Individual and evolved gene
New individual
using evolved gene

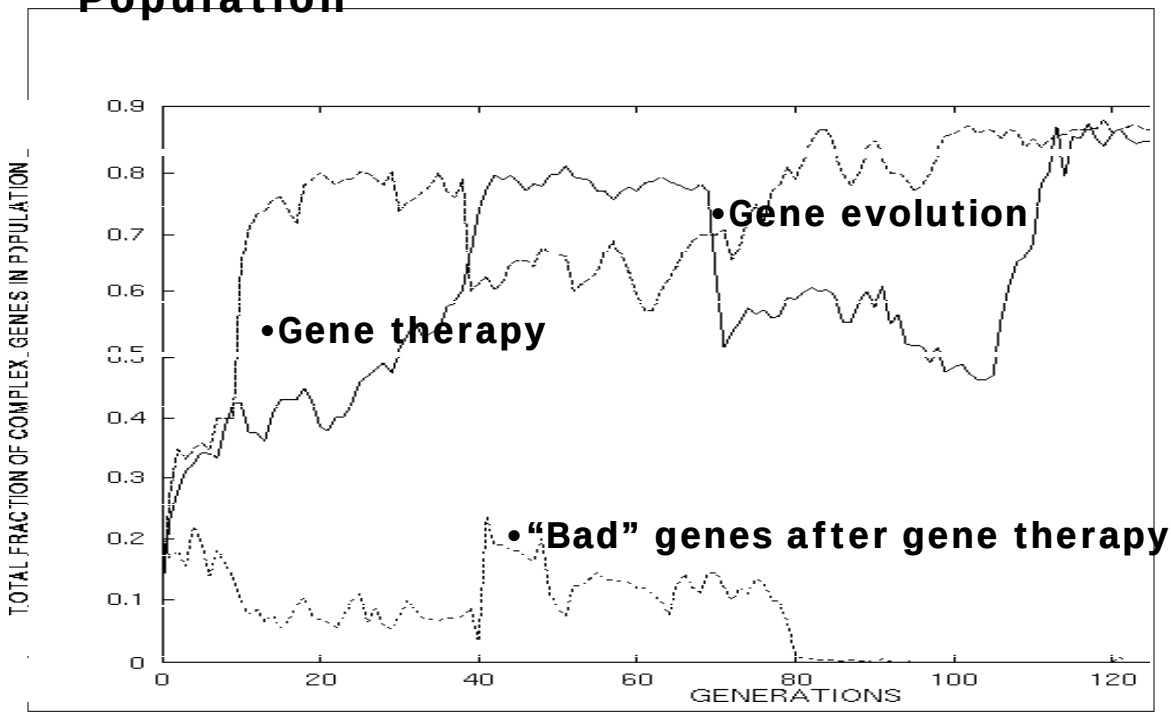
Genetic Engineering of “Bad” Genes

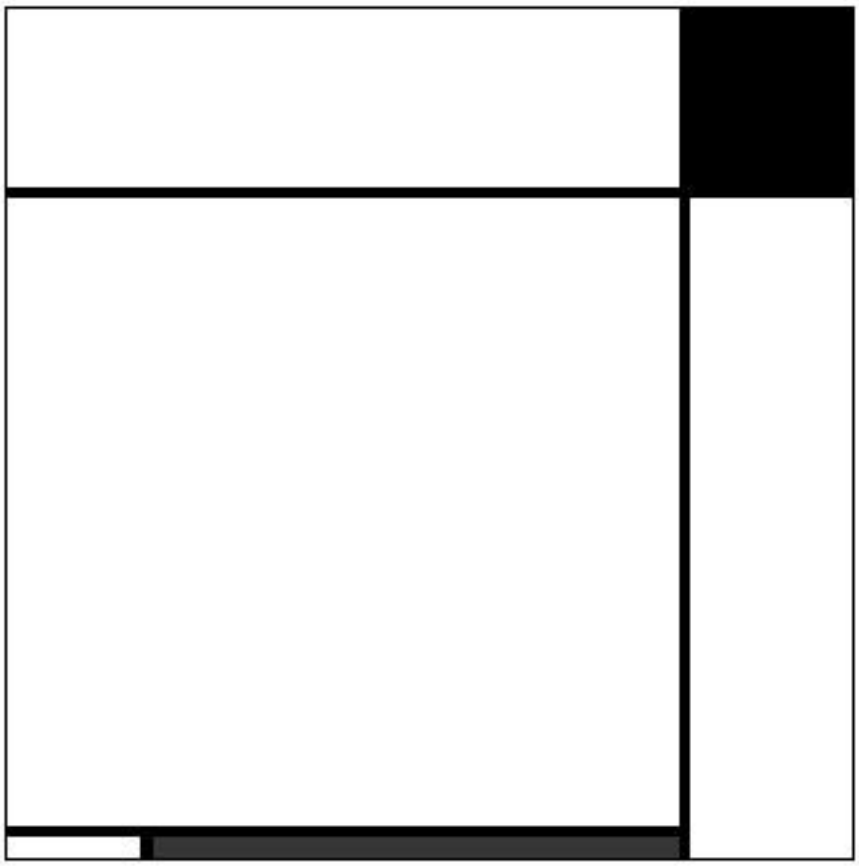
- locate “bad” gene groups
- remove “bad” gene groups
- ***radiation therapy*** for bad gene groups through high mutation rates
- ***gene therapy*** for bad gene groups through replacement with “good” genes
- ***cloning*** to increase percentage of “good” genes

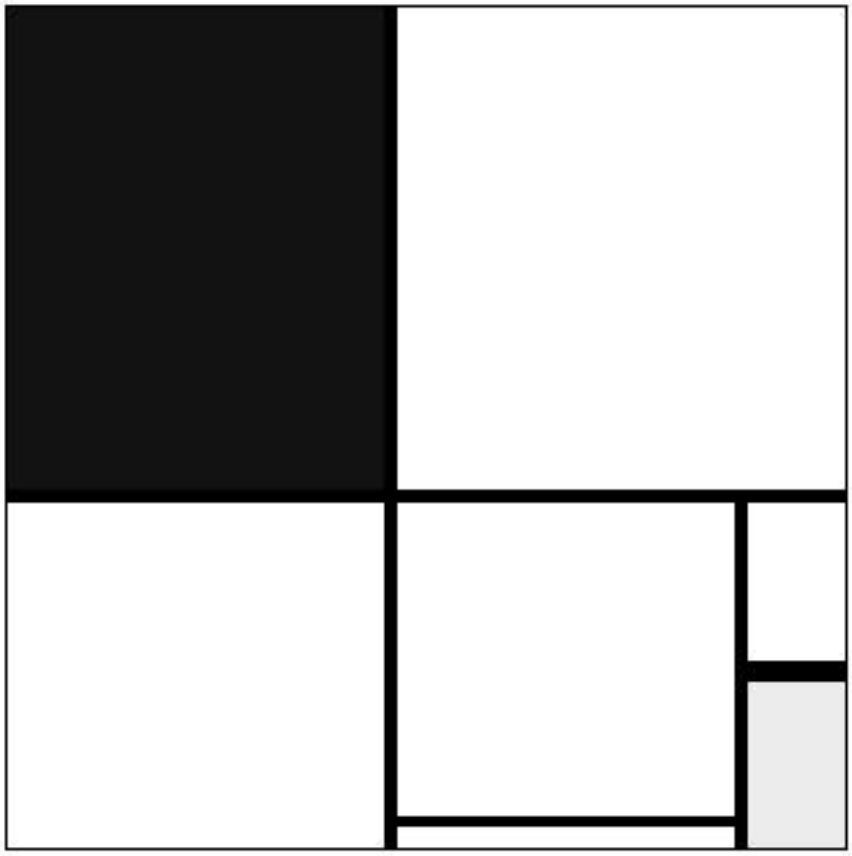
Total Fraction of “Bad” Genes in Population



Total Fraction of Evolved Genes in Population





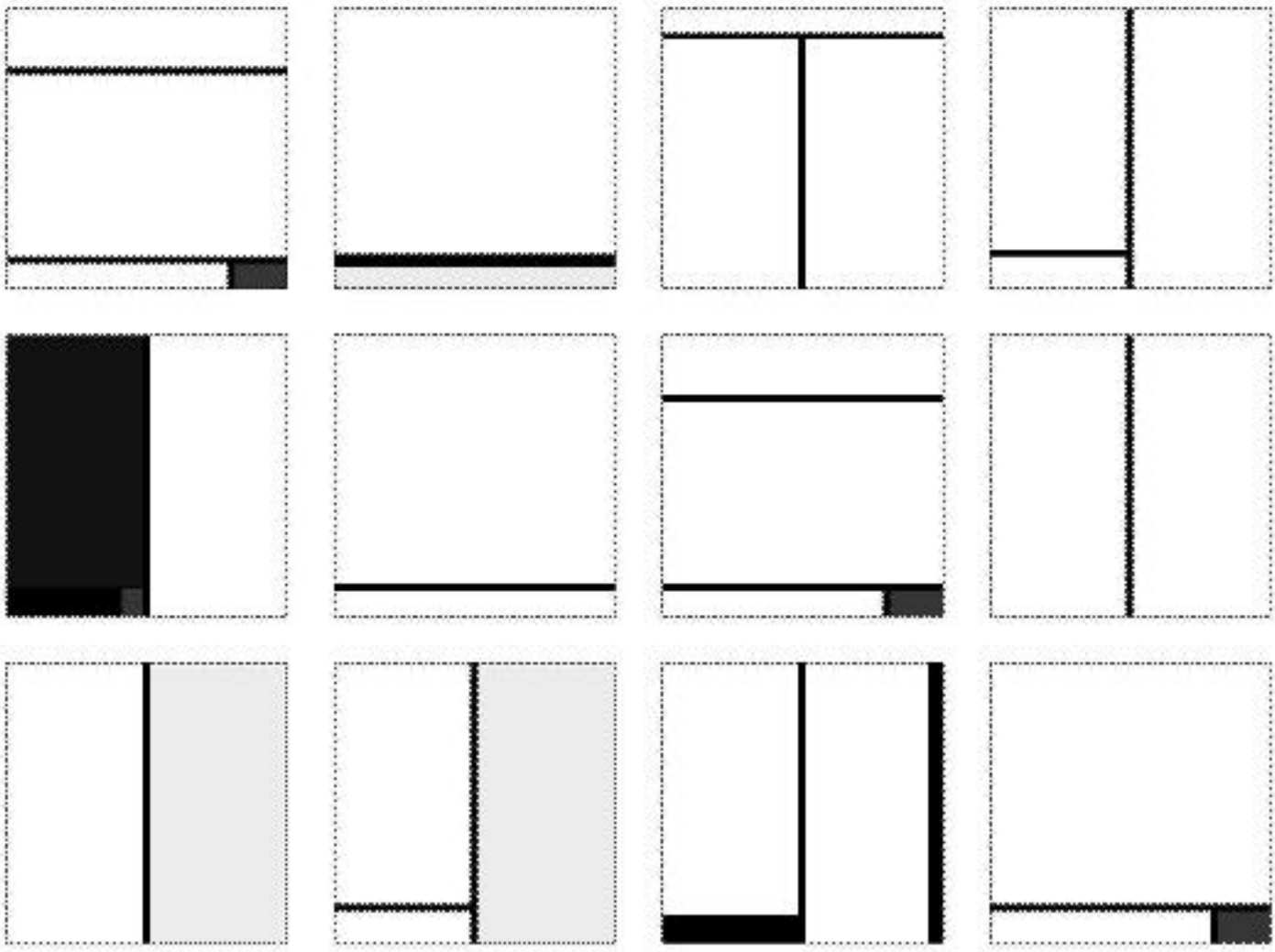


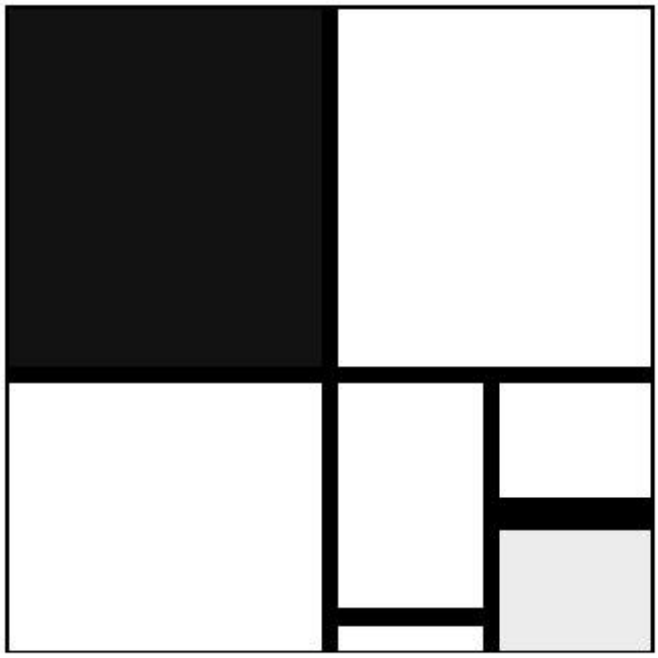
Genotype Form

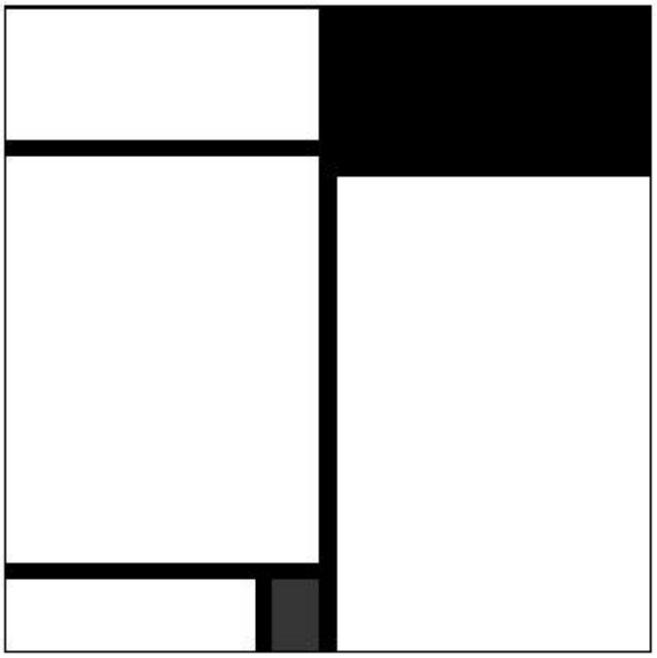
- In form of a tree
- Each node has four variables
  - direction of rectangular split (4 values)
  - fraction of the split (15 values)
  - colour of split area (10 values)
  - line width (3 values)

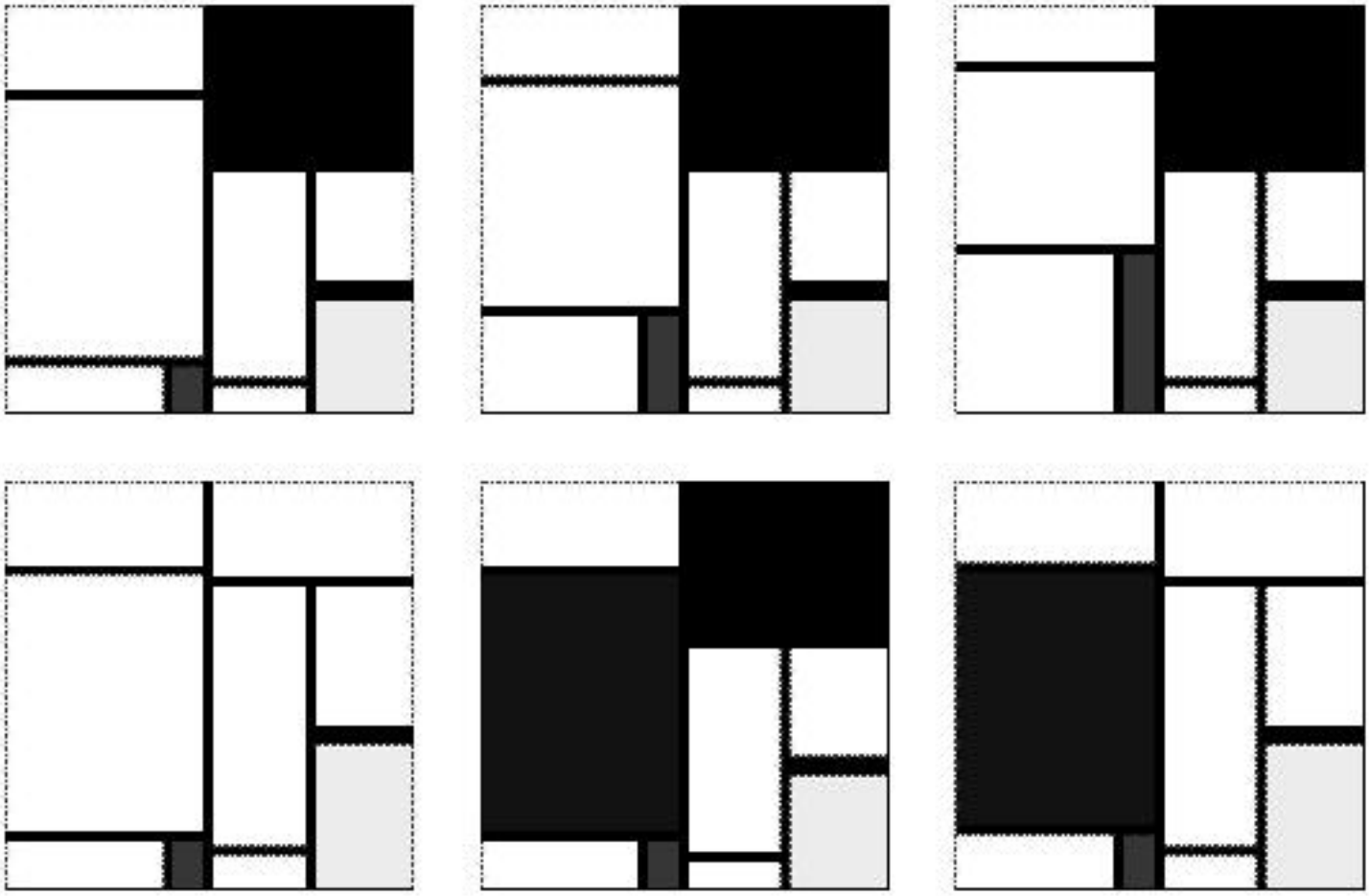
Fitnesses for Representation

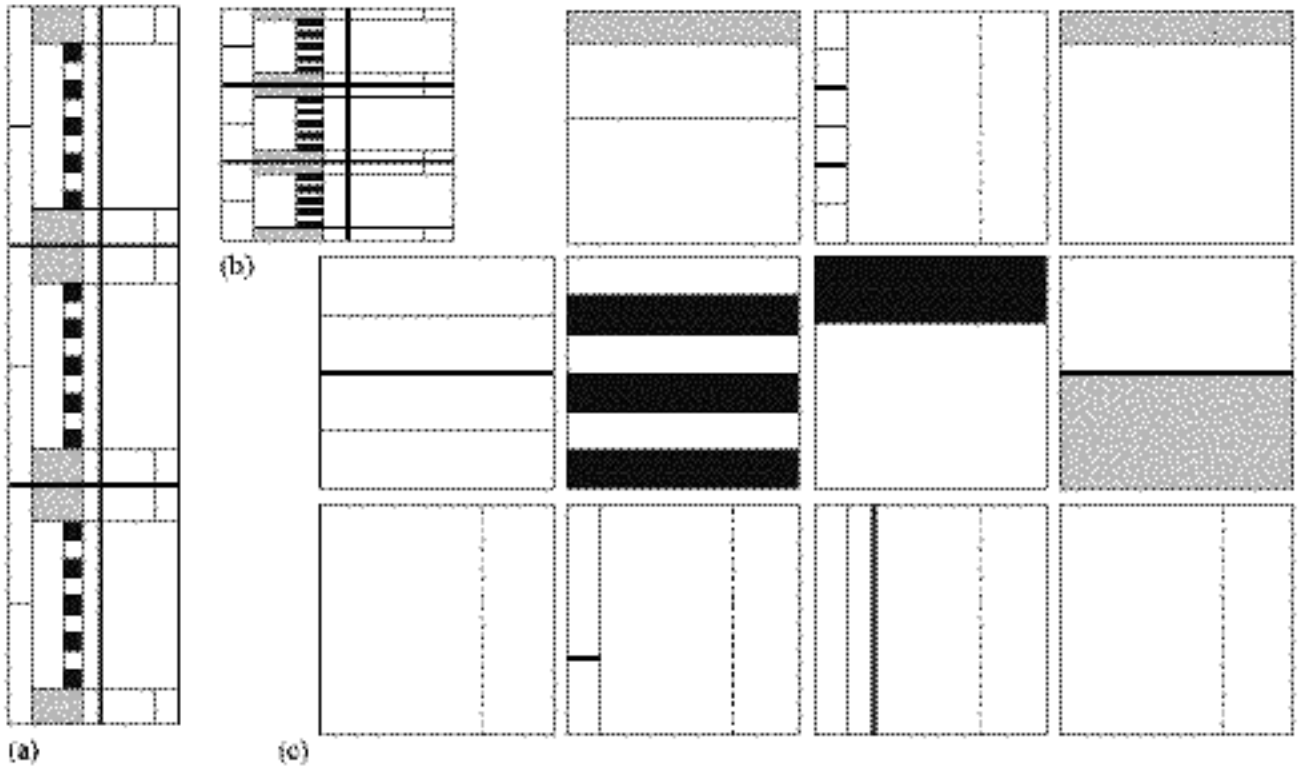
- offset between actual and required positions of dissection lines
- number of lines with correct line width, normalised
- number of correct colour panels, normalised
- number of lines assigned, normalised
- number of unassigned lines, normalised





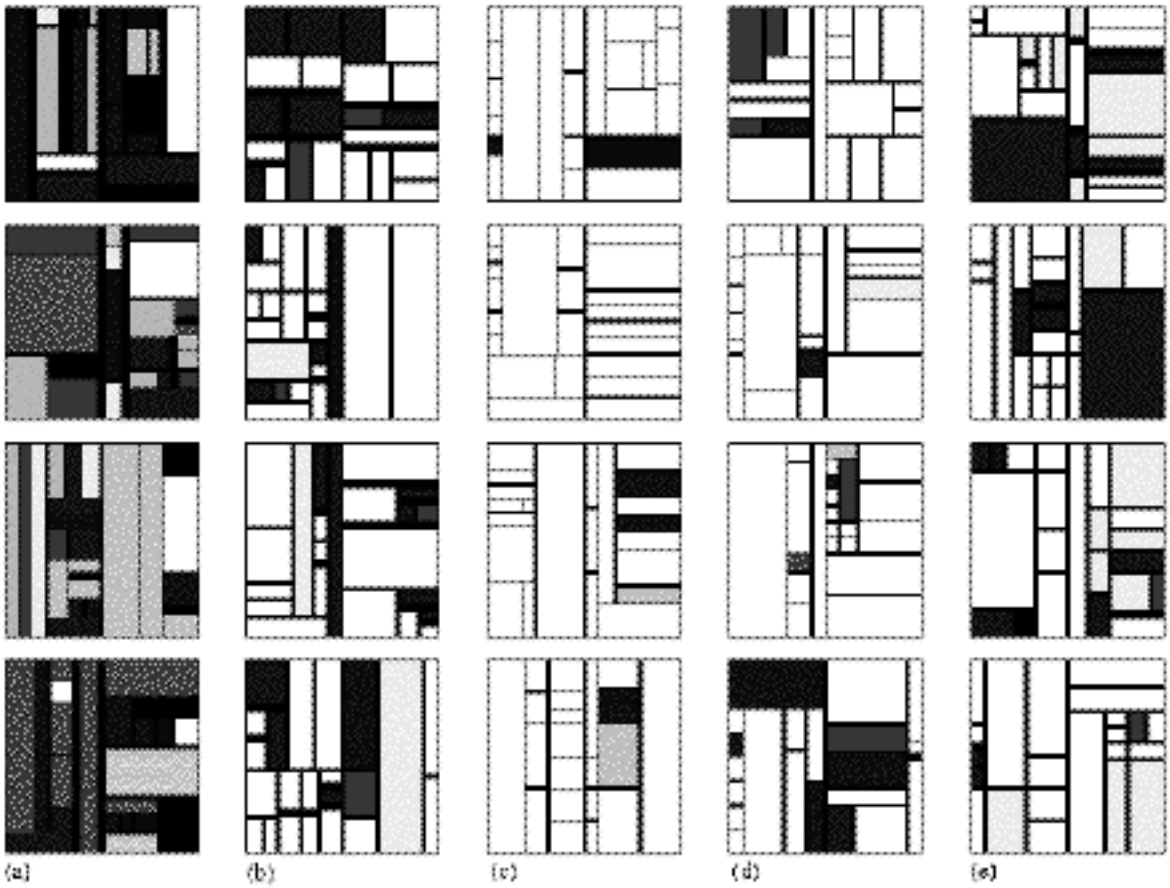


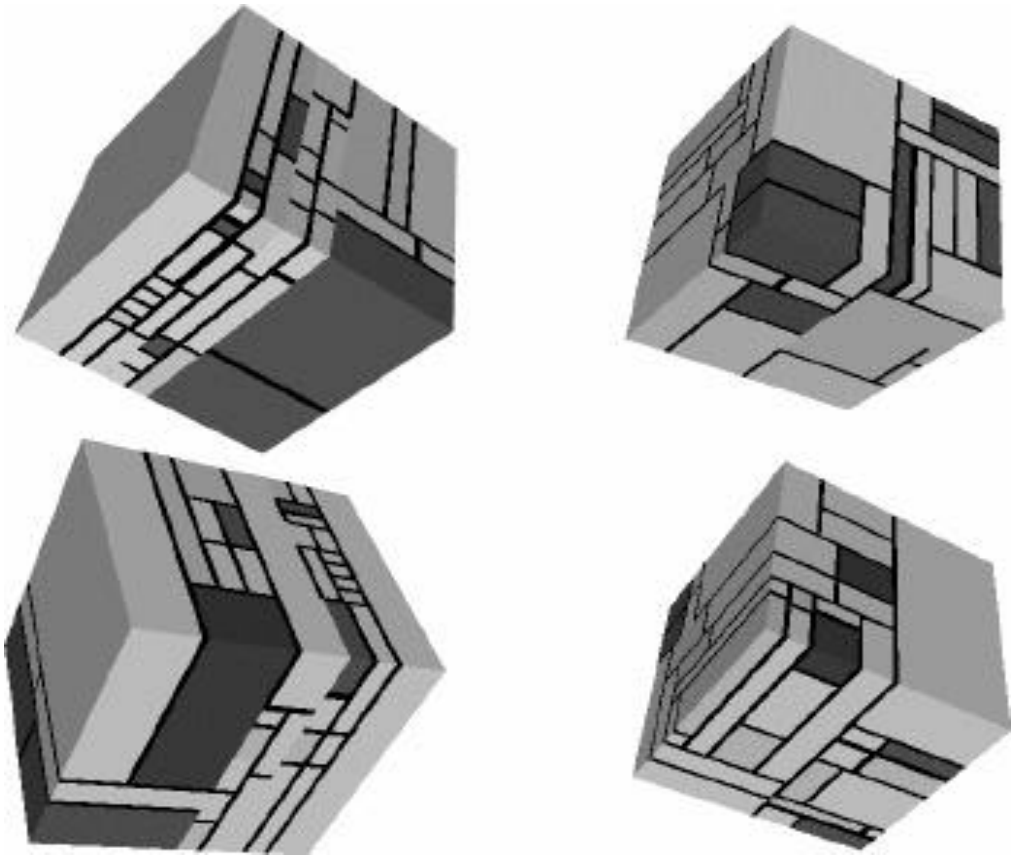



(a)
(b)
(c)

Flondrians

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


(a)
(b)
(c)
(d)
(e)



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