Deceptiveness and Neutrality

The ND Family of Fitness Landscape

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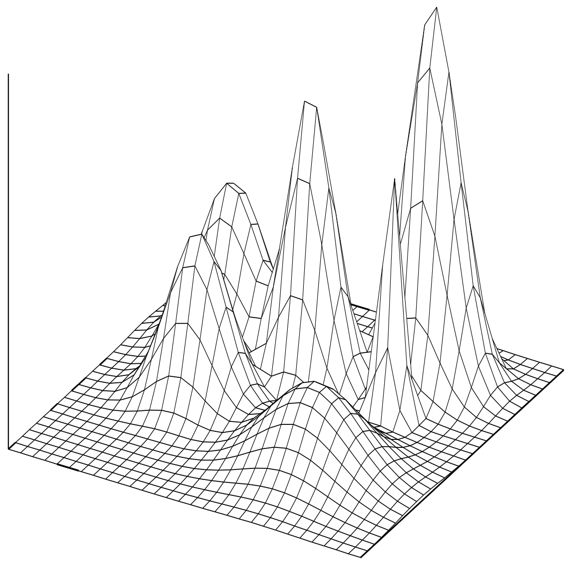
Seattle, July 11^{th} 2006

Outline

- Introduction
- ND-Landscapes
- Tuning Deceptiveness of ND-Landscapes
- Additive extended ND-Landscapes

Introduction : Fitness Landscapes



Fitness landscape $(\mathcal{S}, \mathcal{V}, f)$:

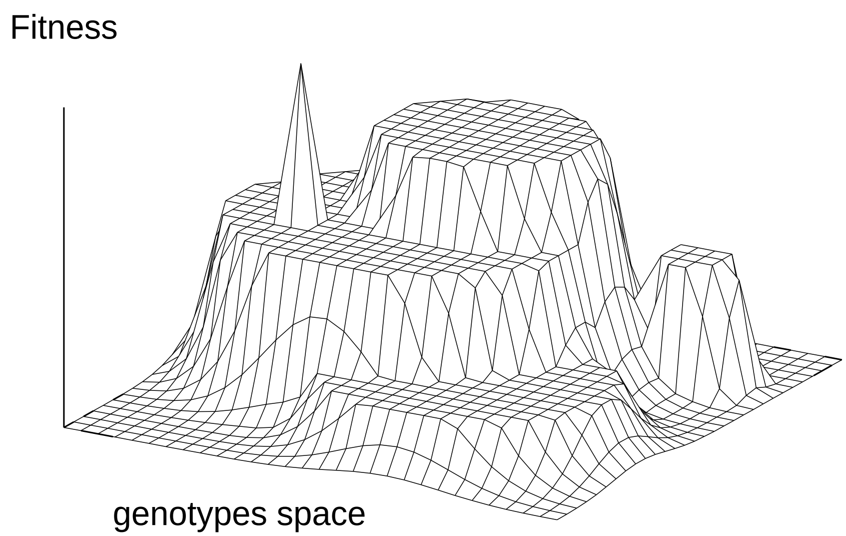
- $\mathcal{S}$: set of potential solutions,
- $\mathcal{V} : \mathcal{S} \to 2^{\mathcal{S}}$: neighborhood function,
- $f : \mathcal{S} \to \mathbb{R}$: fitness function.

Neutral Fitness Landscapes

Neutral theory (Kimura $\approx$ 1960)

Theory of mutation and random drift

Considerable number of mutations have no effects on fitness values



- plateaus
- neutral degree
- neutral networks [Schuster 1994, RNA folding]

Neutral Fitness Landscapes: Definitions

- The *neutral neighborhood* of s is the set of neighbour which have the same fitness $f(s)$
  $\mathcal{V}_{neut}(s) = \{s^{'} \in \mathcal{V}(s) \mid f(s) = f(s^{'})\}$
- The *neutral degree* of a solution is the number of its neutral neighbors
  $nDeg(s) = \sharp(\mathcal{V}_{neut}(s) - \{s\})$.
- A *neutral network* is a connected graph where vertices are solutions with the same fitness value and two vertices are connected if they are neutral neighbours.

A fitness landscape is neutral

if there are many solutions with high neutral degree.

Evolution Dynamic on Neutral Networks

Convergence of a population on neutral networks

[Bornberg 99, Nimwegen 99, 01, Wilke 01]:

infinite population under mutation and selection,

population converges to the solutions in the neutral network with high neutral degree.

Neutral Degree Distribution:

- The NDD (Neutral Degree Distribution) is an important feature of neutral landscapes.
- Thus, we need specific landscapes with tunable NDD to study the influence of neutrality.

Tunables Neutral Landscapes

NK

$$f(s) = \frac{1}{N} \quad (\quad 0.02 \quad + \quad 0.31 \quad + \quad 0.91 \quad + \ldots + \quad 0.20 \quad)$$

NK_q [Newmann *et al* 1998]

$$f(s) = \frac{1}{N(q-1)} \quad (\quad 1 \quad + \quad 3 \quad + \quad 3 \quad + \ldots + \quad 0 \quad)$$

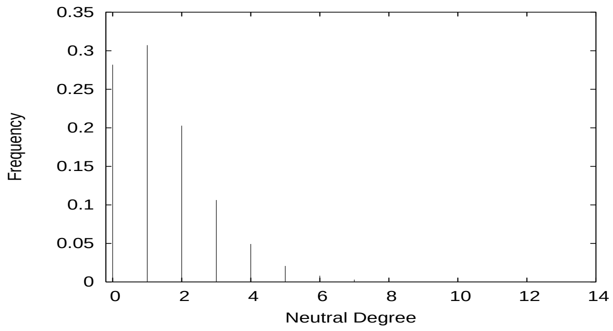
NK_M [Lobo 2004]

$$f(s) = \frac{1}{N.M} E[M. \quad (\quad 0.02 \quad + \quad 0.31 \quad + \quad 0.91 \quad + \ldots + \quad 0.20 \quad)]$$

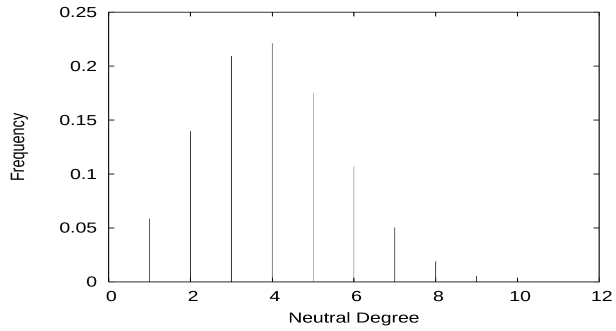
NK_p [Barnett 1998]

$$f(s) = \frac{1}{N} \quad (\quad 0.02 \quad + \quad 0.31 \quad + \quad 0 \quad + \ldots + \quad 0.20 \quad)$$

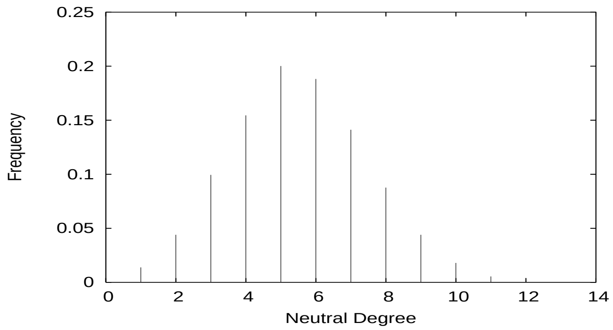
NDD for tunable Neutral Landscapes



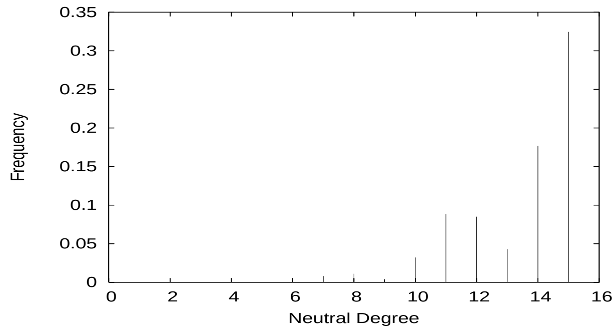
NKp with $N = 16$, $K = 5$, $p = 0.8$



NKq with $N = 16$, $K = 4$, $q = 2$



Technological with $N = 16$, $K = 4$, $M = 20$



Royal Road with $N = 16$, $n = 4$, $k = 4$

Introduction : Neutral Landscapes

In these neutral landscapes,

- Neutrality is more an add-on feature or an incidental property than a parameter.
- Neutrality is obtained by reducing the number of different fitness values.
- We can hardly highlight the influence of neutrality

That is why we proposed the ND-Landscapes

ND-Landscapes : Description

- N refers to the number of bits of a solution ($s \in \{0, 1\}^N$)
- D refers to the expected Neutral Degree Distribution

Goal : Creation of a fitness landscape with a NDD similar to D

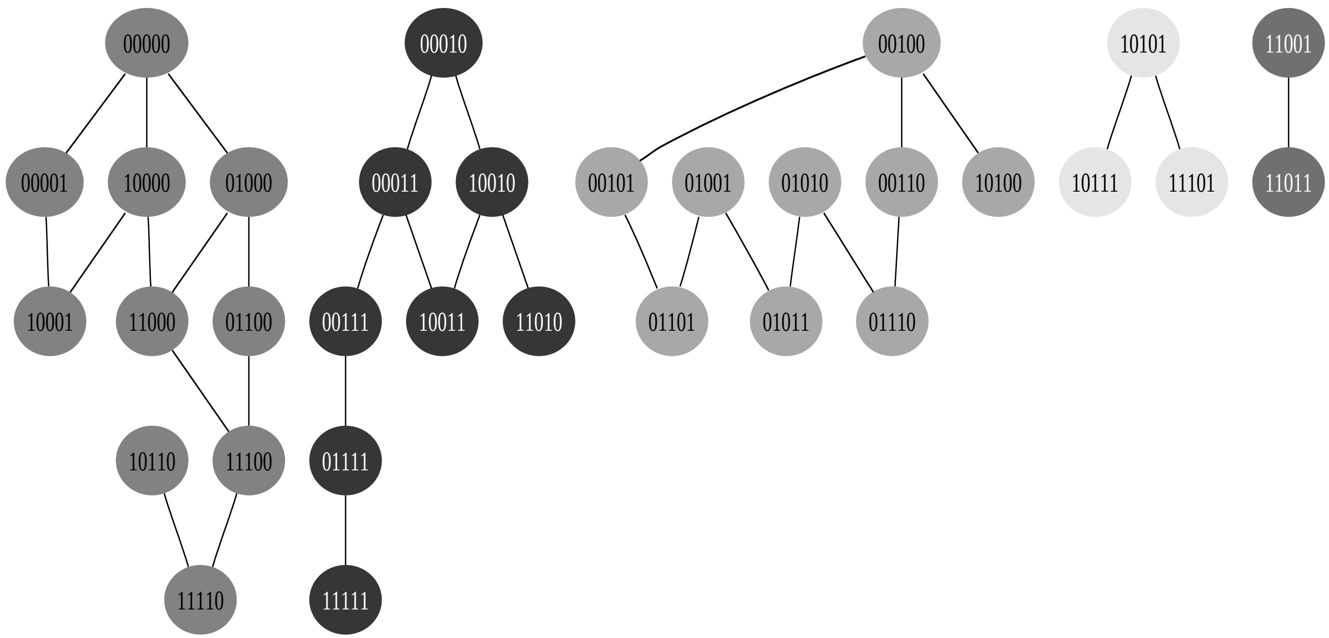
Method:

- Exhaustive definition of the landscape to build the neutral networks
- Simulated annealing to alter the landscape so that its NDD is closer to D
- Give a fitness value to every neutral networks.

ND-Landscapes : Example of a tiny ND-Landscape

for $N = 4$ and the Neutral Degree Distribution D

D[0]=0 D[1]=0.25 D[2]=0.5 D[3]=0.25



ND-Landscapes : Algorithm

CandidatesList $\longleftarrow \mathcal{S}$ sorted by distance from s_0.

while not empty(*CandidatesList*) **do**

s $\longleftarrow$ head(*CandidatesList*)

for d = 0 to N **do**

if s can't have *d* neutral neighbours

then D'[d] $\longleftarrow$ 0

else D'[d] $\longleftarrow$ D[d]

end for

n $\longleftarrow$ RouletteWheel(D'[d])

Give a value to some unaffected neighbours so that *s* has exactly n neutral neighbours

and so that the neutral degrees of solutions $\notin$ *CandidatesList* are unchanged.

D[n] $\longleftarrow$ D[n] - $\frac{1}{2^N}$

CandidatesList $\longleftarrow$ next(*CandidatesList*)

end while

ND-Landscapes : Adjustment by SA

To improve the resulting NND after algorithm, we use Simulated Annealing:

Adjust the landscape by modifying the fitness of some solutions such as neutral distribution of a ND-Landscape be closer to the input distribution.

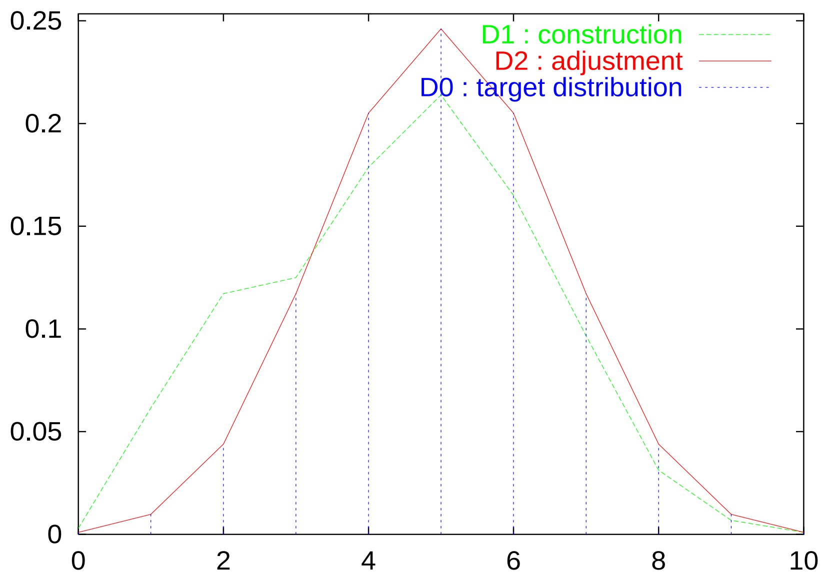
Description of SA:

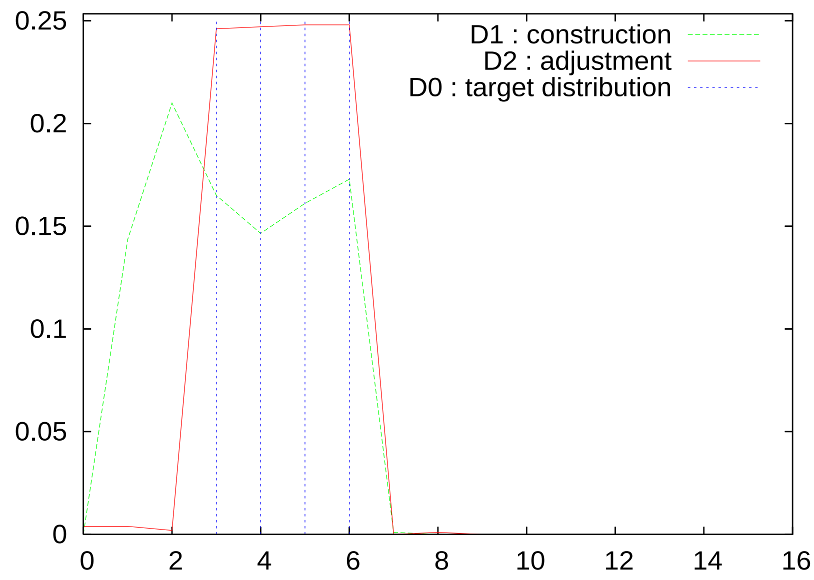
- Local operator : change the fitness value of one solution.
- The acceptance of a transition is determined by the difference between the distance to the input distribution before and after this transition.

$$dist(D, D') = \sqrt{\sum_{i=0}^{N} (D[i] - D'[i])^2}$$

ND-Landscapes : Resulting NDD

NDD obtained after exhaustive construction and after simulated annealing.





$$RMS(D_1, D_0) = 0.110$$

$$RMS(D_2, D_0) = 0.00338$$

$$RMS(D_1, D_0) = 0.0937$$

$$RMS(D_2, D_0) = 0.00246$$

Fitness value of Neutral Networks

The fitness of each neutral network has no influence on the NDD.

Hence we can modify the landscape without altering its NDD.

Give fitness values of neutral networks:

- at Random
- or....

What optimizer do with neutral fitness landscapes ?

Three possibilities :

1. Decreases the neutrality
2. Uses a specific algorithm
3. Increase the neutrality with the choice of redundant coding

1. Decreases the neutrality

Neutrality affect the performances, lack of information

minimum Linear Arrangement problem [E. Rodriguez, PPSN05] :

labeling a graph

$$LA(G, \varphi) = \sum_{(u,v) \in E} |\varphi(u) - \varphi(v)| \in \mathbb{N}$$

with $G = (V, E)$ and $\varphi : V \rightarrow \{1, n\}$ arrangement

“LA represents a potential drawback because different linear arrangments can result in the same total edge length. This incomplete information can prevents the search process from fi nding better solution.”

Change fitness function :

$$\phi(G, \varphi) = LA(G, \varphi) + I_{norm}(G, \varphi)$$

2. Uses a specific algorithm

Neutrality of the problem can not be change

- Netcrawler [L. Barnett 98] : some kind of stochastic hill climber
- Extrema selection [Stewart 01] : selection according to the distance of population centroid

  “It is suffi cient to recognise that the neutrality of a fi tness function may be a signifi cant issue when evolving solutions. With this in mind, the remainder a novel modifi cation to the standard GA which is specifi cally designed to take in advantage of Neutral Network”

3. Increase the neutrality with the choice of redundant coding

Escape from local optima

- Cartesian GP [Vassilev 00] :

  "(...) the role of landscape neutrality for adaptive evolution is to provide a path for crossing landscape regions with poor fitness."

- Dual GA [Collard 00] : add one bit and a specific operator
  $f(x0) = f(x)$, $f(x1) = f(\bar{x})$
  and $op(x1) = \bar{x}0$

Open question

Neutrality in fitness landscapes : drawback or not ?

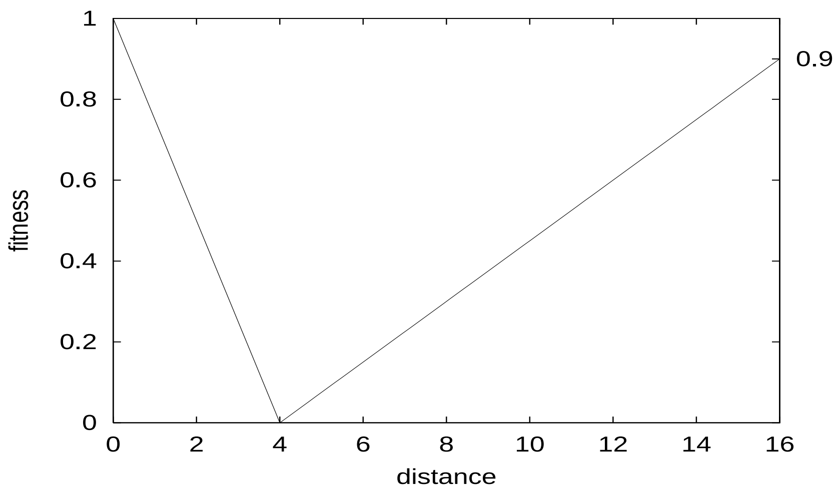
We propose 2 families of ND-landscapes :

- Same Neutral Degree Distribution and with different difficulties
- Increases the average neutrality changes the difficulty of landscapes

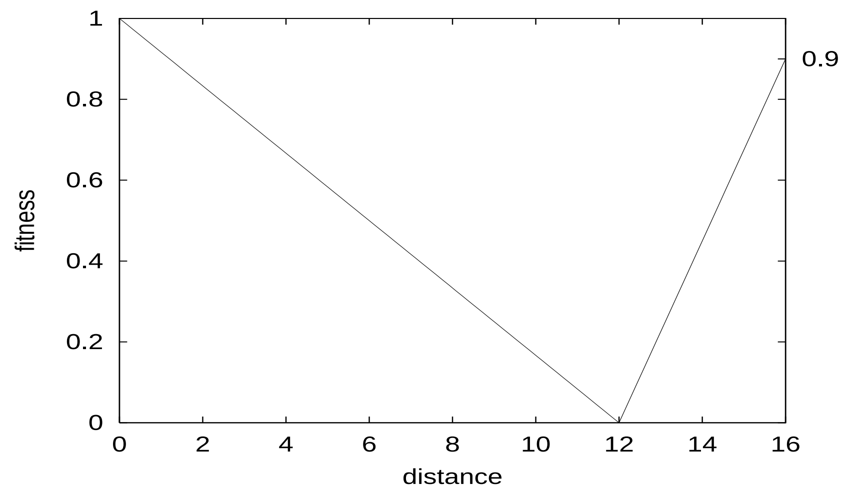
Tuning Deceptiveness of ND-Landscapes

Trap Functions

We will use the following trap functions to set the difficulty.



deceptive trap



easy trap

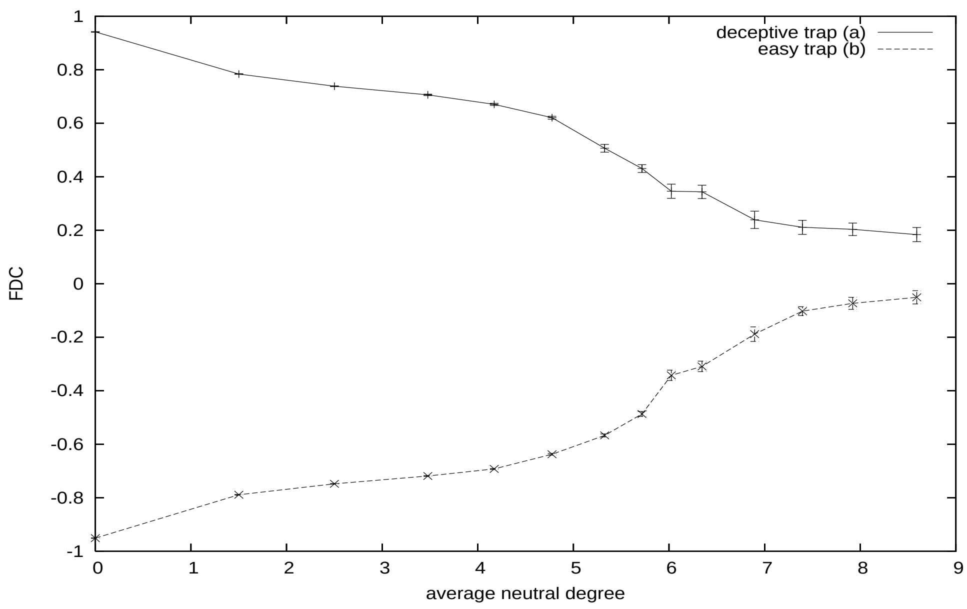
Tuning Deceptiveness of ND-Landscapes

Trap Functions

- Choose the optimum neutral network, denoted NN_{opt}, (for example the one containing the solution 0^N) and set its fitness to the maximal value 1.0
- For each neutral network, we compute the distance d between its centroid and the centroid of NN_{opt}
- Fitness value of the NN is set according to a trap function

Tuning Deceptiveness of ND-Landscapes

Fitness Distance Correlation

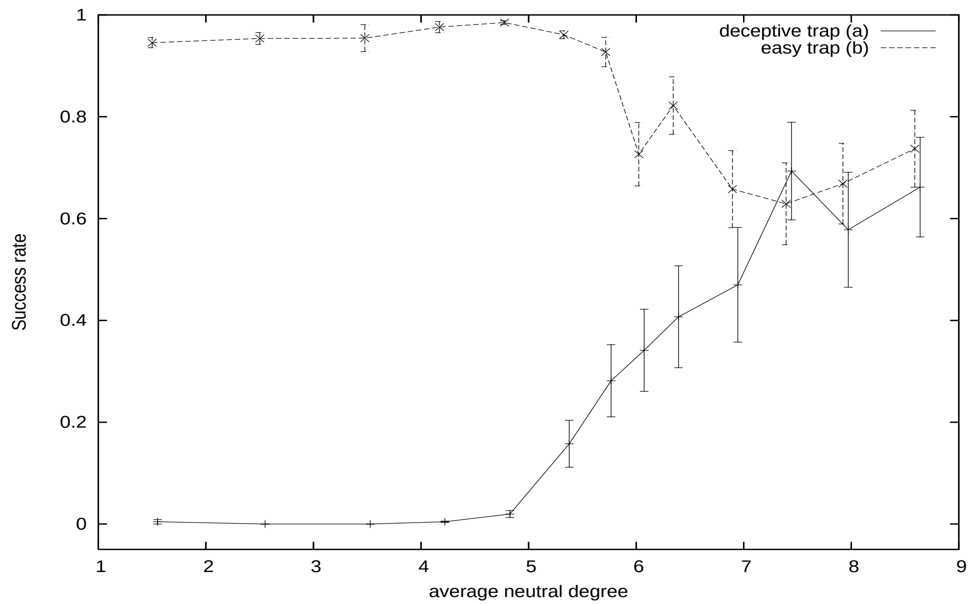


Average neutral degree

Tuning Deceptiveness of ND-Landscapes

Performances of simple GA

succes rate



Average neutral degree

Neutrality in ND-Landscapes

- Landscapes with same NDD but different difficulties
- Adding neutrality to a deceptive landscape makes it easier
  but adding neutrality to a easy landscape makes it harder.

Neutrality in fitness landscapes :

sometime drawback,

sometime not !....

$\longrightarrow$ more precise decription of neutral fitness landscapes is needed

Additive Extended ND-Landscapes

- Exhaustive generation $\Longrightarrow$ size limit
- Solution : Concatenation of small ND-Landscapes to create a bigger one.
- The NDD of the resulting landscape is the convolution product of the NDDs of the small ND-landscapes.
- The convolution product of two normal (resp. χ^2, Poisson) distributions is a normal (resp. χ^2, Poisson) distribution

Conclusion:

- Proposition of a new landscape with tunable neutrality
- Study of the interplay between deceptiveness and neutrality
- An idea to avoid exhaustive generation : additive ND-landscapes

Futures works:

- Uses ND-landscapes to study the population dynamics of EA
- Uses ND-landscapes to study the difficulty in neutral fitness landscapes