Genetic Algorithm for Cognitive Radio

CWT Cognitive Radio
weekly meeting presentation

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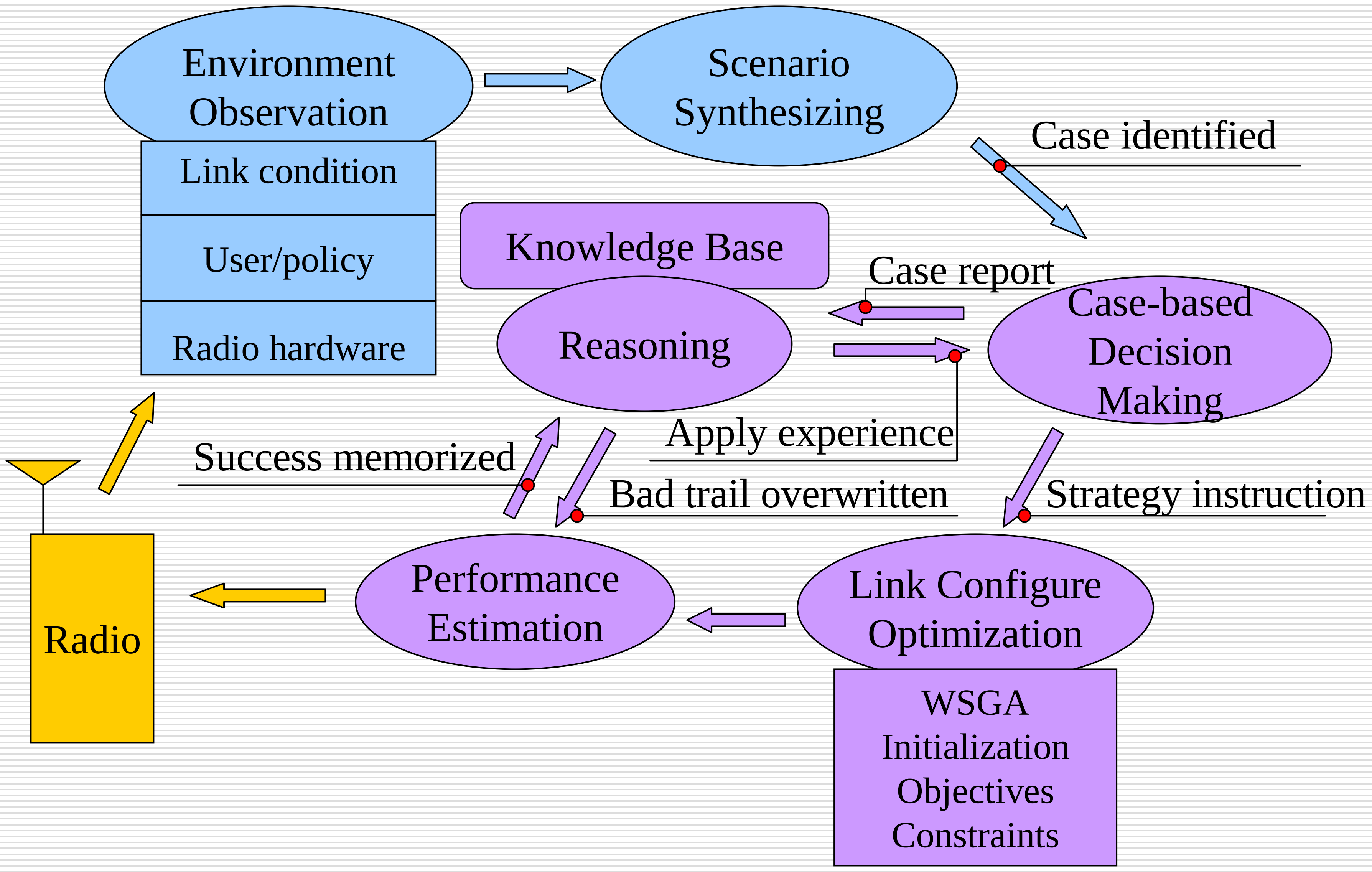
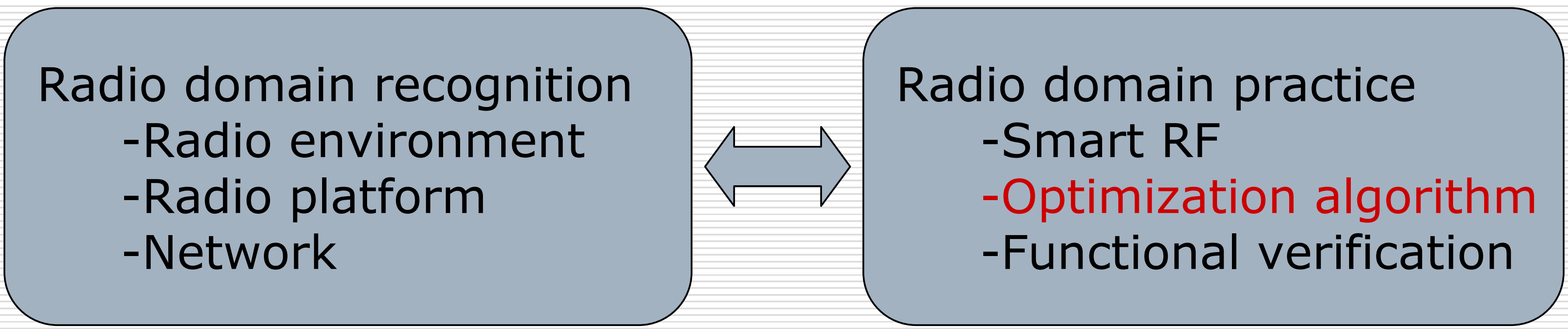
09/23/05

Cognition Loop Diagram



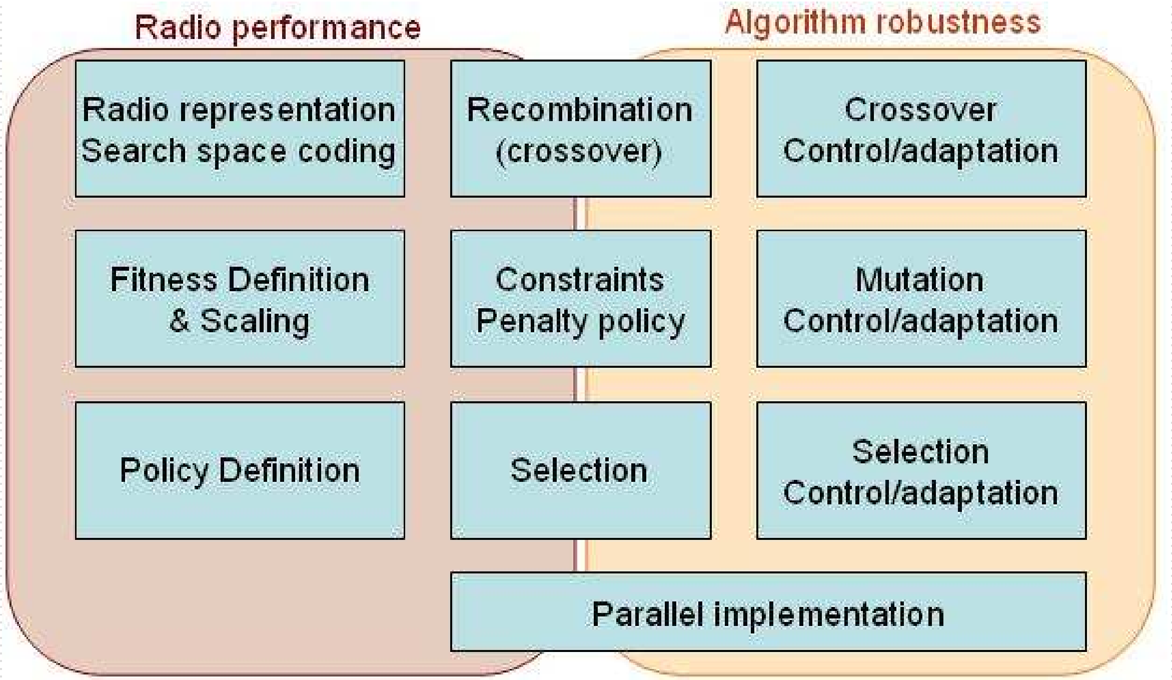
Radio-domain Cognition

- Learning cycle
  - Modeling: Markov Model, Neural Network
  - Decision: Fuzzy logic, case-based reasoning
  - Practice: Genetic algorithm (GA), Fuzzy decision
  - Verification: ?



Why Use GA for Cognitive Radio?

- Wireless system multi-objective performance
- Non-mathematical, non-close-form constraints
- Global, multi-objective, constrained optimization



Genetic Algorithm (GA)

- Genetic algorithm background
- An optimization view of GA
- Solution space and fitness space
- Adaptive GA (AGA)
- Parallel implementation of GA

Evolution

- The tautology of "survival of the fittest"
- The ultimate coupled imperatives:
  self-replication and *natural selection*

Diversity is achieved through innovation in engineering of the organism and its associated fitness is embodied through the natural selection.

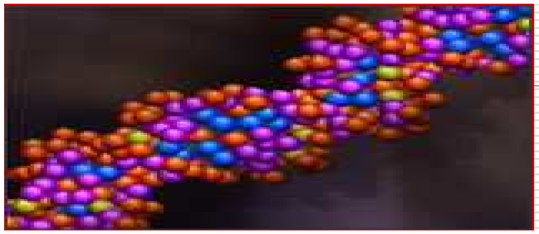
Evolution in Algorithm

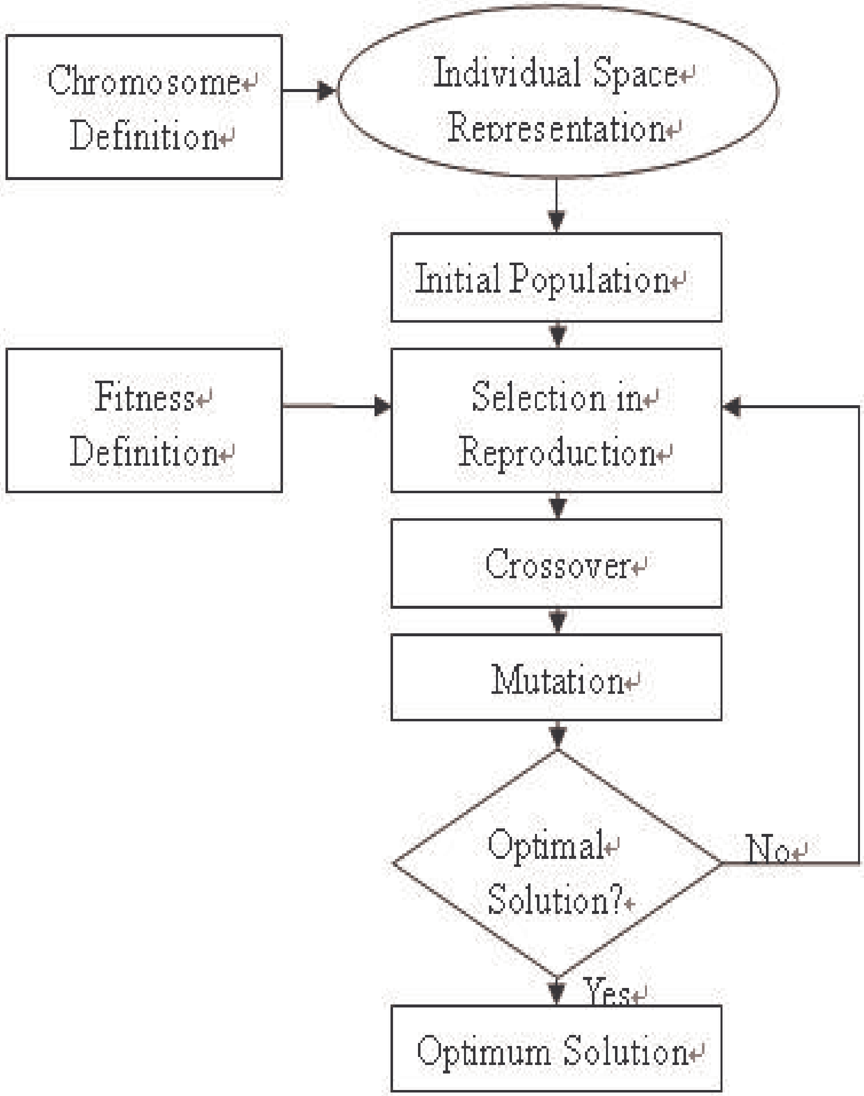
- Evolutionary Algorithm (EA)
  - Genotype space – individual space
  - Fitness space – natural selection
- Evolutionary programming (EP)
- Evolutionary strategy (ES)
- Genetic Algorithm (GA)
  - Emphasis on genes
  - Recombination and mutation
  - Genotype of chromosome

Are we from Gene Lottery?

GA or AG – Algorithm of Genes

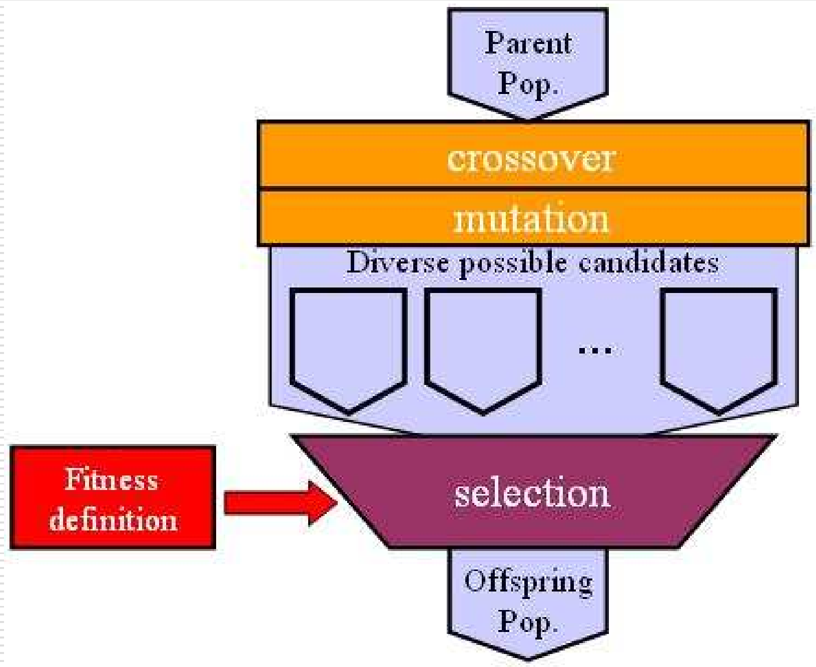
- Chromosome of genes
- Population for parallelism
- Gene operations
  - Recombination
  - Mutation
- Gene competition
  - Fitness of genotypes
  - Selection scheme
- Gene survivors
  - Pareto-front
  - Solution extraction





An Optimization View of GA

- Genetic operation vs. evolving process
- Genetic operations
  - Recombination
  - Mutation
- Evolving Process
  - Selection
- Termination criterion
- Solution extraction



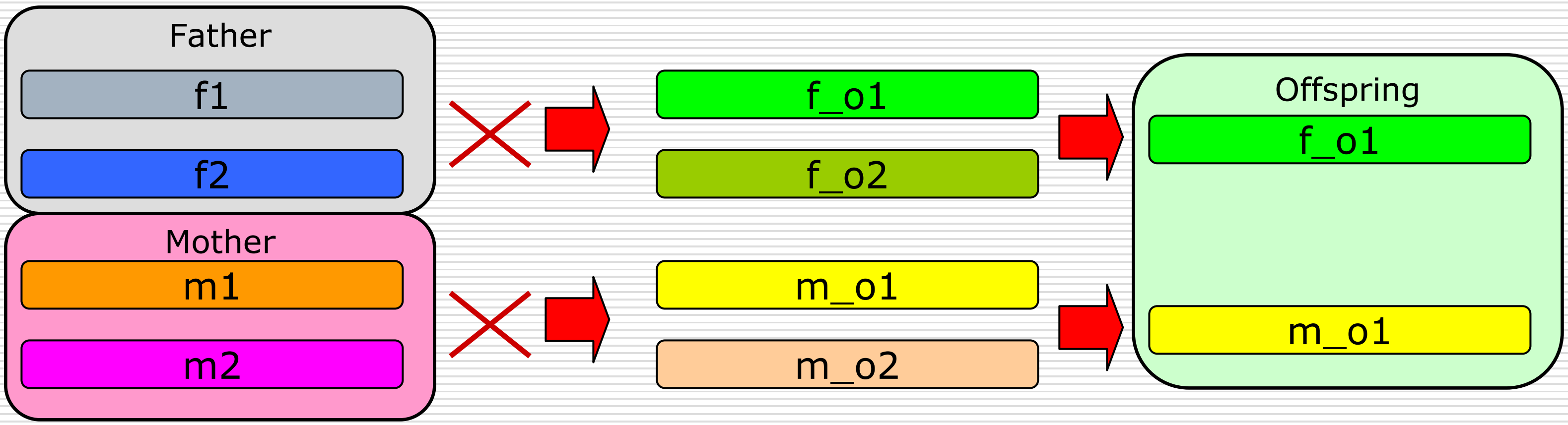
Genetic Operation vs. Evolving Process

	Genetic operation	Evolving process
Domain	internal gene behavior	external selection force
Regime	in chromosome	over population
Goal	for diversity	for trend
Behavior	gene reshuffle	individual competition
Result	new genotypes	the fittest survives
Rules	self-determined	environment defined
They are Coupled in each algorithm iteration. Fitness (on genotype) binds them together.		

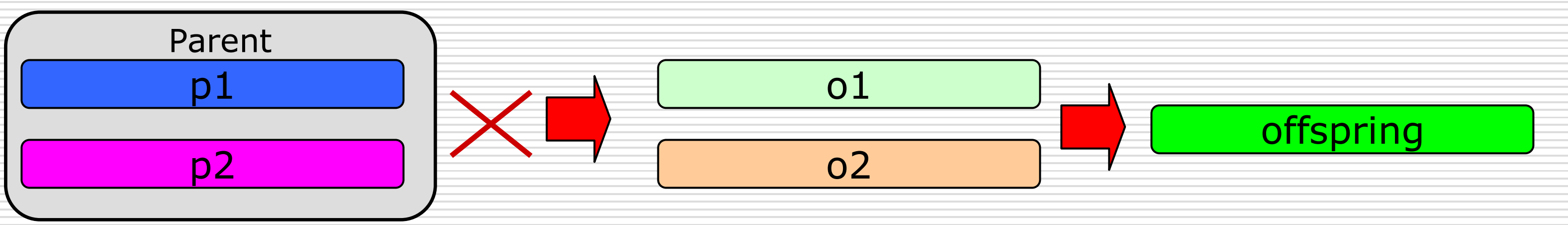
Note: Genetic Operation **itself** is NOT related to optimization!

Natural Binary Recombination

- Binary: crossover as shown in nature
- Ideal for computer implementation



Simplified as there's no difference between father and mother:



Crossover and Mutation

Parent 1

A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{33}	B_{11}	B_{12}	B_{21}	B_{22}	B_{31}	B_{32}	π_1	π_2	π_3

Parent 2

A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{33}	B_{11}	B_{12}	B_{21}	B_{22}	B_{31}	B_{32}	π_1	π_2	π_3

Crossover – 2 parents cross genes to build 2 offspring

Offspring 1

A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{33}	B_{11}	B_{12}	B_{21}	B_{22}	B_{31}	B_{32}	π_1	π_2	π_3

Offspring 2

A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{33}	B_{11}	B_{12}	B_{21}	B_{22}	B_{31}	B_{32}	π_1	π_2	π_3

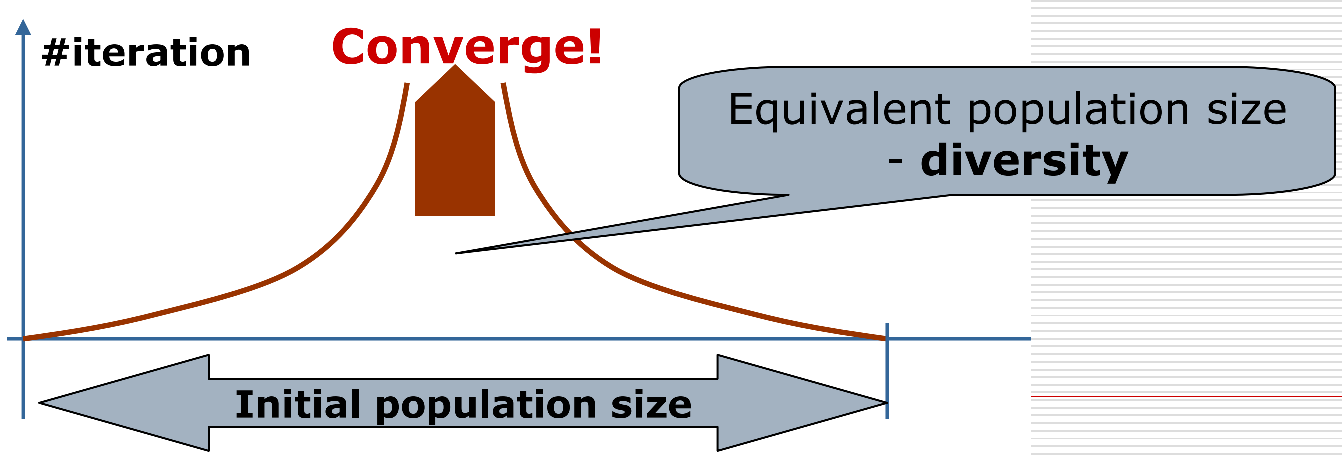
Mutation – offspring 2 has 3 genes randomly mutated

Offspring 2

A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{33}	B_{11}	B_{12}	B_{21}	B_{22}	B_{31}	B_{32}	π_1	π_2	π_3

Population Initialization and Mutation

- Diversity bias and control
  - Population size and distribution
  - Mutation schemes
- Projection in fitness space
- Radio domain knowledge dependency



Fitness Landscape

- Solution space ➔ fitness space
- Human vs. target problem
  - Human: allele independently determines genotypes
  - Target problem: equation mixes parameters
- Parameter dependency complicates the prediction
- Genetic operations scatter the population onto the fitness landscape in an amorphous manner
- GA searches optimum directly on fitness landscape
  - projection prediction based on fitness calculation
  - pdf shaping prediction

Target Problem is Random and Time-variant

- Communication signals are random
- Wireless channels are time-variant
- Both solution space and fitness space are non-static
- Objective function and optimal criteria are adaptive

- Classic GA is a statistical search by nature
- Classic GA is static by nature
- Classic GA is memory-less by nature

Advanced GA Design

- Highly adaptive
- Learning and self-evolution
  - Artificial neural network
- Distributed implementation
  - Migration approach
- Hybrid GA design
  - With local annealing methods
  - With case-based decision maker

Highly-adaptive GA Design

- Adaptive to environment and target problem
  - Efficiency-driven or accuracy driven – searching tactics
  - Calculation based or prediction based – memory effects
- Adaptive to itself
  - Iteration-based adaptation
  - Population-based adaptation
    - Exploit the information of the current population
    - Genotype (solutions) distribution
    - Phenotype (fitness) distribution
  - Adapt GA operation according to the status of current iteration as well as previous iterations

What to Adapt

- Solution space encoding
- Fitness space scaling
- Genetic operation and parameters
- Selection scheme and parameters

Generational Adaptation Design

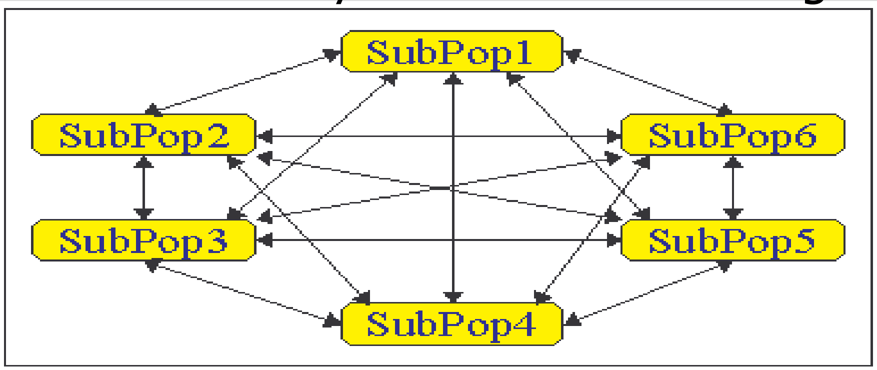
- Explorative pressure adaptation
  - Crossover depth
  - Mutation probability and deviation
  - Tournament selection
- Exploitative pressure adaptation
  - Crossover interpolation scaling
  - Statistical control of mutation
  - Proportional selection
- Convergence vs. accuracy
  - Population size “breathing”
  - Loop termination criterion control

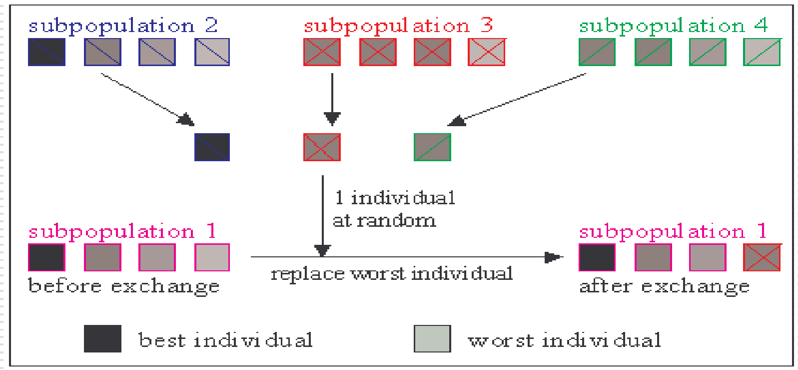
Individual Adaptation Design

- Protection on the superiors
  - Less crossover and elite-coupling
  - Dithering mutation for local annealing
  - Moderate selection pressure on sub-group
- Punishment on the inferiors
  - More crossover and unbalanced-coupling
  - Wild mutation for outreach
  - Strict selection pressure on sub-group
- Sub-group processing favors distributed processing

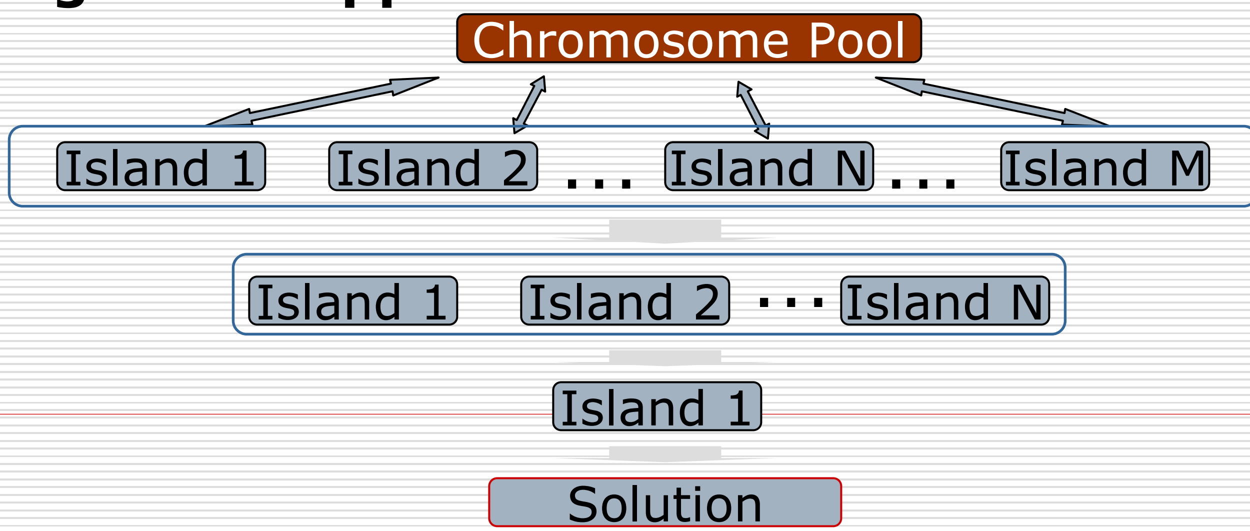
Parallel Implementation of GA

- Computation distribution
- Island theory - chromosome migration





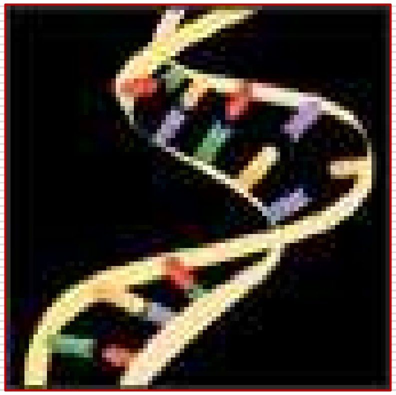
Annealing island approach



Thank you!

Nature, to be commanded, must be obeyed.

- Francis Bacon (in Novum Roganum, 1620)



Any questions? Well, wait for our paper!