

Advanced Search

Genetic algorithm

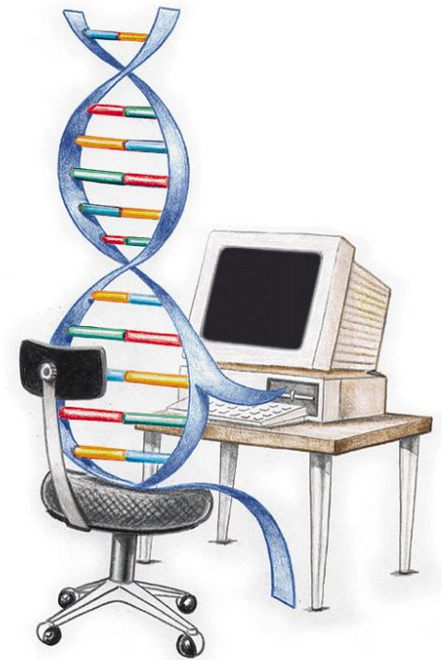
Yingyu Liang

`yliang@cs.wisc.edu`

**Computer Sciences Department
University of Wisconsin, Madison**

[Based on slides from Jerry Zhu, Andrew Moore <http://www.cs.cmu.edu/~awm/tutorials>]

GENETIC ALGORITHM



Evolution

- Survival of the fittest, a.k.a. natural selection
- Genes encoded as DNA (deoxyribonucleic acid), sequence of bases: A (Adenine), C (Cytosine), T (Thymine) and G (Guanine)

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- The chromosomes from the parents exchange randomly by a process called **crossover**. Therefore, the offspring exhibit some traits of the father and some traits of the mother.
 - Requires genetic diversity among the parents to ensure sufficiently varied offspring
- A rarer process called **mutation** also changes the genes (e.g. from cosmic ray).
 - Nonsensical/deadly mutated organisms die.
 - Beneficial mutations produce “stronger” organisms
 - Neither: organisms aren’t improved.

Natural selection

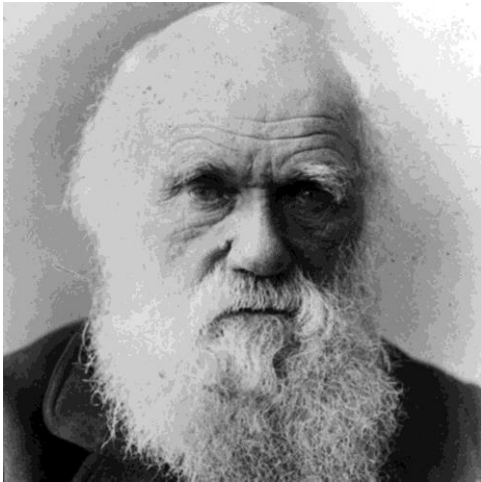
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Natural selection

- Individuals compete for resources
- Individuals with better genes have a larger **chance** to produce offspring, and vice versa
- After many generations, the population consists of lots of genes from the superior individuals, and less from the inferior individuals
- Superiority defined by fitness to the environment

Evolution and Natural Selection

- Popularized by Darwin
- Mistake of Lamarck: environment does not force an individual to change its genes

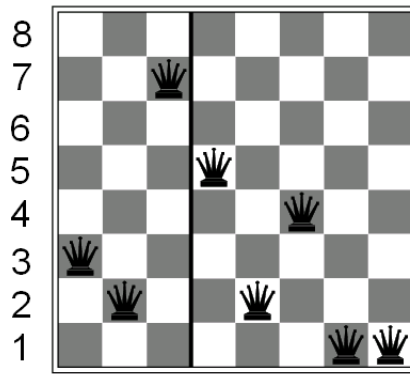


Genetic algorithm

- Yet another AI algorithm based on real-world analogy
- Yet another heuristic stochastic search algorithm

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- Each state s is called an **individual**. Often (carefully) coded up as a string.



(3 2 7 5 2 4 1 1)

- The score $f(s)$ is called the **fitness** of s . Our goal is to find the global optimum (fittest) state.
- At any time we keep a fixed number of states. They are called the **population**. Similar to beam search.

Individual encoding

- The “DNA”
- Satisfiability problem

What is the individual encoding scheme?

$$A \vee \neg B \vee C$$

$$\neg A \vee C \vee D$$

$$B \vee D \vee \neg E$$

$$\neg C \vee \neg D \vee \neg E$$

$$\neg A \vee \neg C \vee E$$

Individual encoding

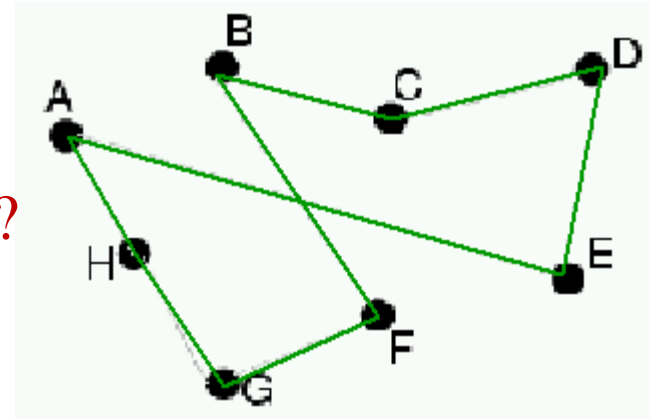
- The “DNA”
- Satisfiability problem
(A B C D E) = (T F T T T)

$$\begin{aligned} &A \vee \neg B \vee C \\ &\neg A \vee C \vee D \\ &B \vee D \vee \neg E \\ &\neg C \vee \neg D \vee \neg E \\ &\neg A \vee \neg C \vee E \end{aligned}$$

Individual encoding

- The “DNA”
- TSP

What is the individual encoding scheme?



Genetic algorithm

- **Genetic algorithm:** a special way to generate neighbors, using the analogy of **cross-over**, **mutation**, and **natural selection**.

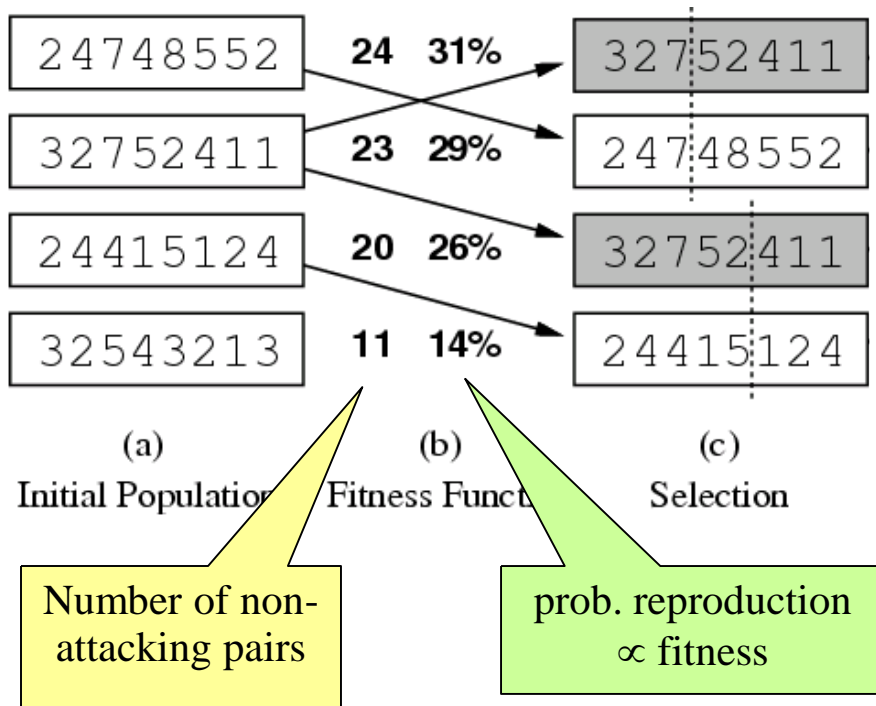
24748552
32752411
24415124
32543213

(a)

Initial Population

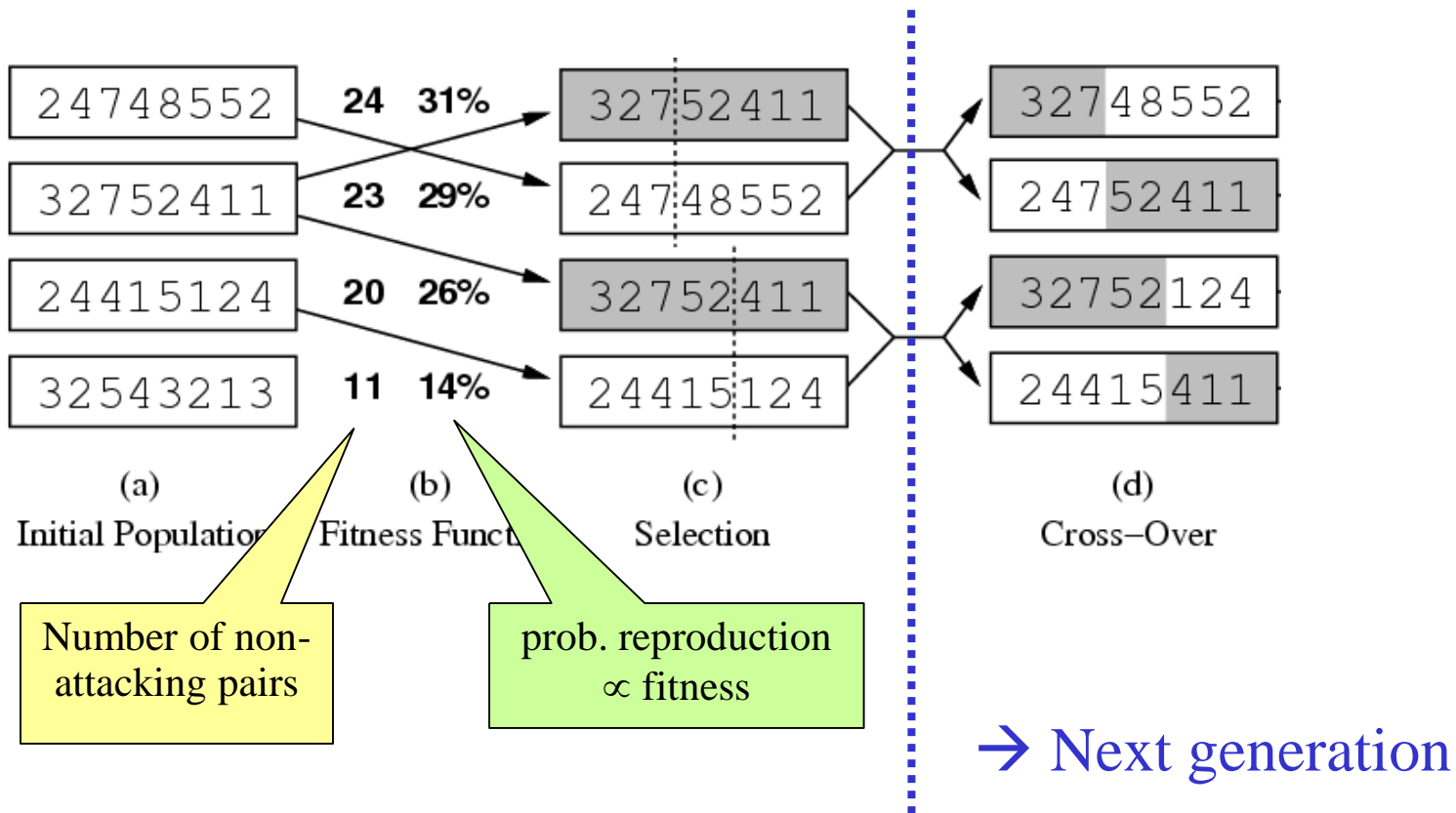
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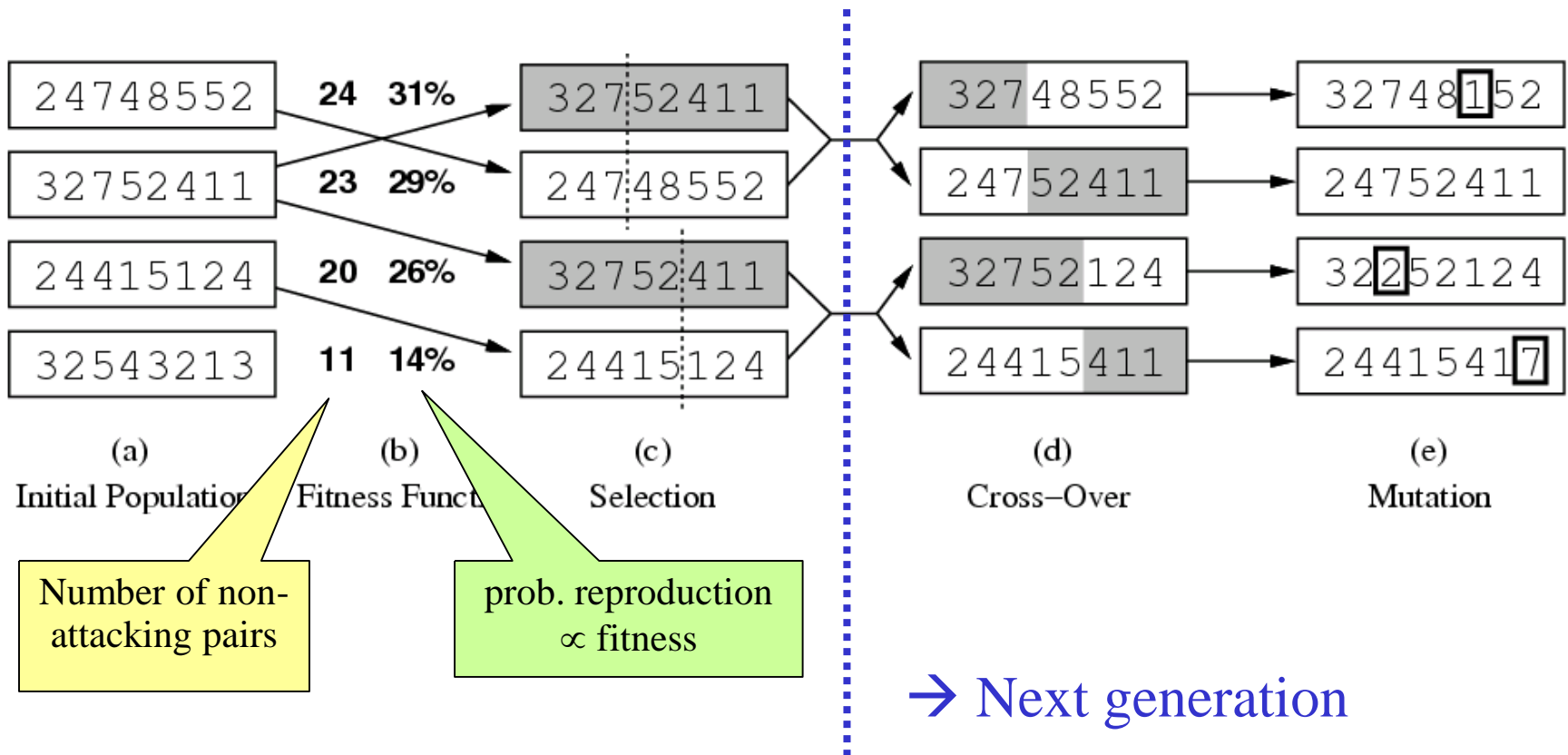
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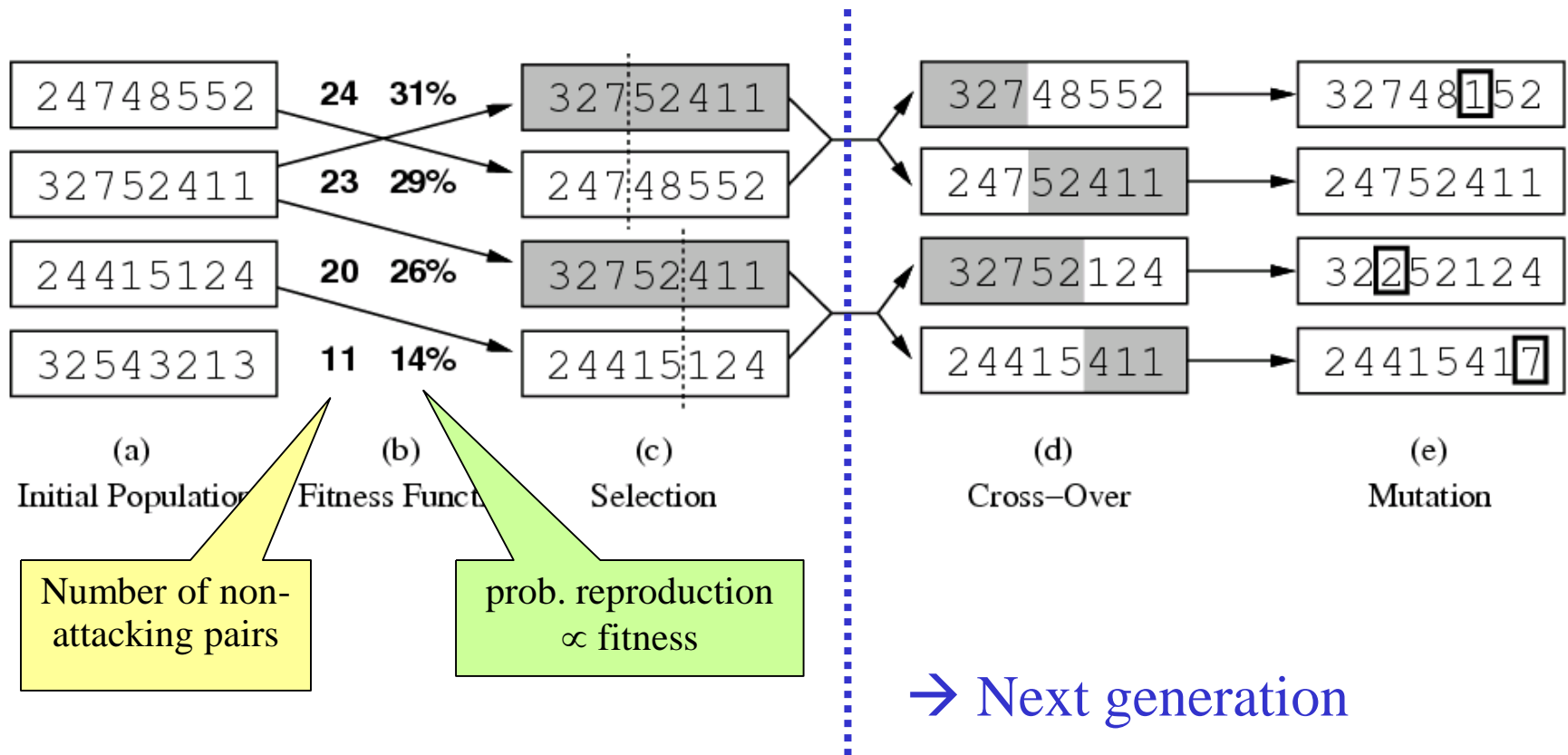
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How about for the SAT and TSP problems?

Genetic algorithm (one variety)

1. Let s_1, \dots, s_N be the current population
2. Let $p_i = f(s_i) / \sum_j f(s_j)$ be the reproduction probability
3. FOR $k = 1; k < N; k += 2$
 - parent1 = randomly pick according to p
 - parent2 = randomly pick another
 - randomly select a crossover point, swap strings of parents 1, 2 to generate children $t[k], t[k+1]$
4. FOR $k = 1; k \leq N; k++$
 - Randomly mutate each position in $t[k]$ with a small probability (mutation rate)
5. The new generation replaces the old: $\{s\} \leftarrow \{t\}$.
Repeat.

Proportional selection

- $p_i = f(s_i) / \sum_j f(s_j)$
- $\sum_j f(s_j) = 5+20+11+8+6=50$
- $p_1=5/50=10\%$

Individual	Fitness	Prob.
A	5	10%
B	20	40%
C	11	22%
D	8	16%
E	6	12%

Variations of genetic algorithm

- Parents may survive into the next generation
- Use ranking instead of $f(s)$ in computing the reproduction probabilities.
- Cross over random bits instead of chunks.
- Optimize over sentences from a programming language. Genetic programming.
- ...

Genetic algorithm issues

- State encoding is the real ingenuity, not the decision to use genetic algorithm.
- Lack of diversity can lead to premature convergence and non-optimal solution
- Not much to say theoretically
 - Cross over (sexual reproduction) much more efficient than mutation (asexual reproduction).
- Easy to implement.
- Try hill-climbing with random restarts first!