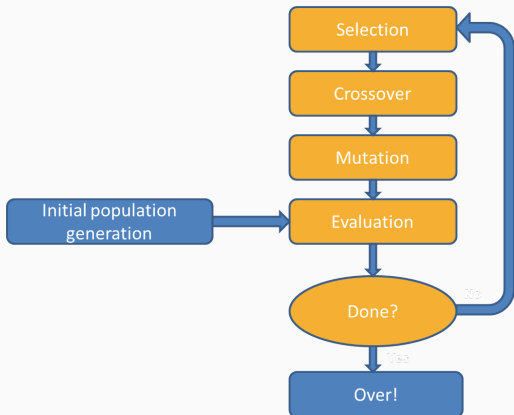
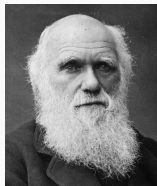


A Brief Introduction To Evolutionary Computation

András M. Joó

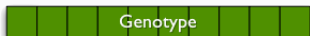
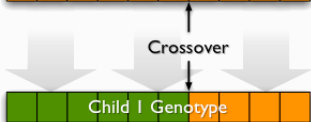
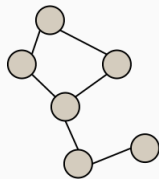
Evolutionary computation

- ▶ a subfield of artificial intelligence,
- ▶ simulates the Darwinian evolution **in silico**

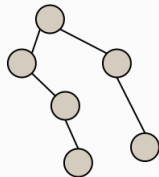


Terms

- ▶ genotype, phenotype, encoding, fitness function
- ▶ search operators: selection, crossover, mutation

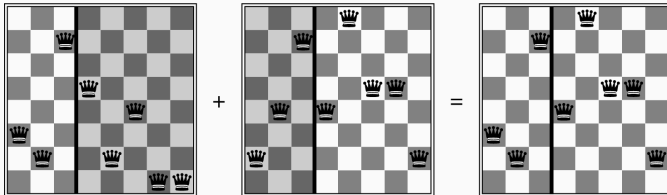
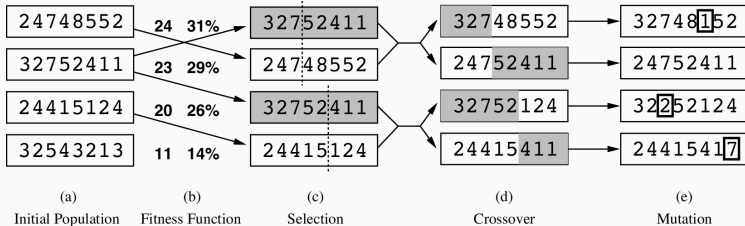


Mutation



Genetic algorithms

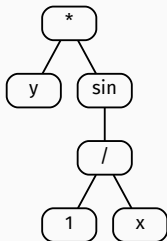
- ▶ linear representation (binary, integer, real, etc)



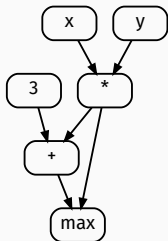
- ▶ why GAs work? John Holland (70s), building block hypothesis, schema theory

Genetic programming

- ▶ automatic generation of expressions / trees
- ▶ major representation types:



(a) tree - Koza



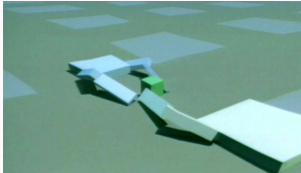
(b) graph - Poli

```
1 void gp(double r[8]) {  
2   r[0] = r[5] + 71;  
3   r[7] = r[0] - 59;  
4   if (r[5] > 2)  
5     r[4] = r[2] * r[1];  
6   //...  
7   r[0] = sin(r[4]);  
8 }
```

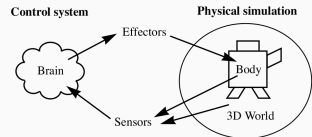
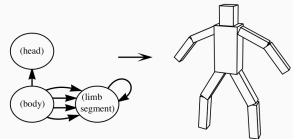
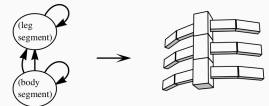
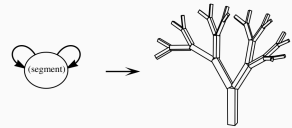
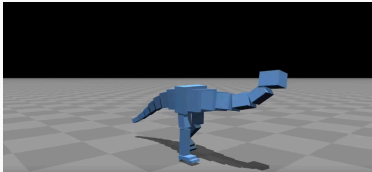
(c) linear - Banzhaf

Toy examples

- ▶ virtual creatures, Karl Sims, 1993



- ▶ bipedal creatures, T. Geijtenbeek, 2013



Evolving game playing algorithms

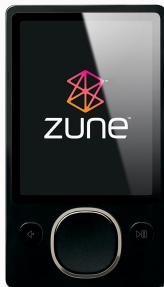
- ▶ games are important in computer science as they are abstract models of our world
- ▶ Omid E. et al: Genetic Algorithms for Evolving Computer Chess Programs (2013)
- ▶ outperformed a two-time world computer chess champion (3000+ Élő points)



Finding and fixing bugs

- ▶ the cost of software bugs world-wide is \$300B+/year (Cambridge University, 2013)
- ▶ Stephanie Forrest, et al: A Genetic Programming Approach to Automated Software Repair, GECCO, 2009

```
void zunebug_repair(int days) {
    int year = 1980;
    while (days > 365) {
        if (isLeapYear(year)){
            if (days > 366) {
                // days -= 366; // repair deletes
                year += 1;
            }
            else {
                days -= 366;      // repair inserts
            }
        } else {
            days -= 365;
            year += 1;
        }
    }
    printf("current year is %d\n", year);
}
▶ }
```



Speeding up programs

- ▶ Bowtie, a highly optimized DNA sequencing software package (maintained by John Hopkins Univ.)
- ▶ it consists of 50,000+ lines of hand written C++ code
- ▶ evolutionary computation achieved 70x speedup on certain sections
- ▶ William B. Langdon, Mark Harman: Optimising Existing Software with Genetic Programming IEEE Transactions on Evolutionary Computation, 2015.



Malware

- ▶ if you think that WannaCry is the worst thing that could have happened, think again
- ▶ undetectable malware can be evolved: Sadia Noreen et al, Evolvable malware GECCO, ACM, 2009

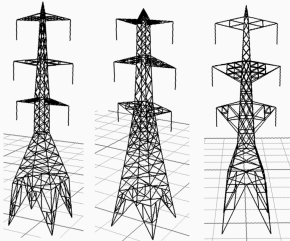


Construction

- ▶ roof structure with complex curvatures, Ottawa Railway Station, Kociecki, 2014

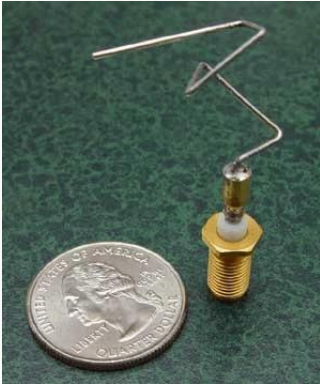


- ▶ pylons evolved to withstand icing and wind, British Architects pylon design competition, Byrne, 2014



Electrical engineering

- ▶ 2006 NASA ST5 spacecraft antenna, the world's first artificially-evolved object to fly in space
- ▶ wide beamwidth for a circularly polarized wave & wide impedance bandwidth



Aesthetic artefacts



(a) Sims, 94



(b) NeuroSystems



(c) McCormack, 94



(d) Collomosse, 2008

There is more to EC

- ▶ flavors: differential evolution, evolution strategy, grammatical evolution, neuroevolution, etc.
- ▶ zillions of ways to tweak: population model, selection/ recombination/ mutation zoos, parallel implementations, co-evolution, multi-objective variants, etc.
- ▶ (infamous) issues: premature convergence, loss of phenotypic/ genotypic diversity, code bloat, etc.
- ▶ lots of implementations: Java (ecj), Matlab (ga-builtin), C++ (beagle, galib), etc.

Takeaway thoughts

Evolutionary computation (EC) can

- ▶ come up with good engineering solutions
- ▶ generate aesthetic artefacts
- ▶ invent programs/ find and fix bugs based on positive & negative examples
- ▶ optimize programs better than the brightest software developers
- ▶ generate undetectable malware

Caution

- ▶ EC, although powerful, is no silver bullet
- ▶ there is no free lunch

