UCD CASL

Complex & Adaptive Systems Laboratory

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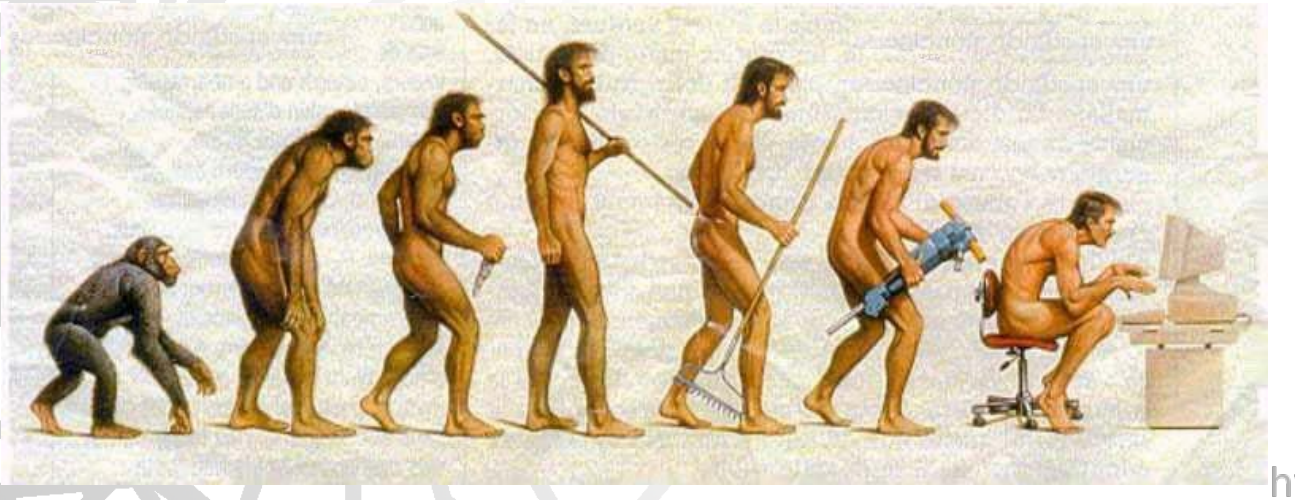
Introduction to Evolutionary Computation

COMP30290 Natural Computing
COMP41190 Natural Computing and Applications

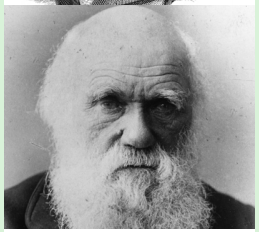
Origin of the Species

Million Years Ago	Event
?	Origin of Life
3500	Bacteria
1500	Eukaryotic Cells
600	Multicellular Organisms
1	Human Language



Origin of the Species

Milestones

$\sim$ 200y.a. **Jean-Baptiste Lamarck**:
Lamarckism or soft-inheritance:
- Passing of lifetime acquired characteristics.

$\sim$ 140y.a. **Charles Darwin**:
Theory of Natural Selection:
- Natural vs. Artificial Selection (a.k.a. breeding).

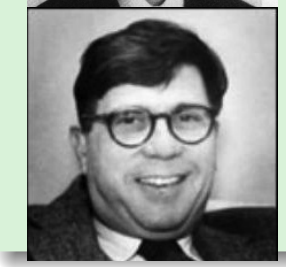
$\sim$ 140y.a. **Gregor Johann Mendel**:
Mendelian Inheritance:
- Basis of Modern Genetics.

$\sim$ 80y.a. **Fisher, Haldane & Wright**:
Population Genetics:
- Combined evolution, genetics, and statistical probabilities.

Origin of the Species

Milestones



$\sim$ 60y.a. **James D. Watson**:
Helix structure of DNA:
- Watson-Crick base paring of nucleotides.

$\sim$ 60y.a. **Francis Crick**:
Helix structure of DNA:
- Watson-Crick base paring of nucleotides.

$\sim$ 40y.a. **Motoo Kimura**:
Neutral Theory of Molecular Evolution:
- Variation at molecular level likely result of genetic drift.

$\sim$ 40y.a. **Richard Lewontin**:
Molecular Diversity:
- Evolution at molecular level.

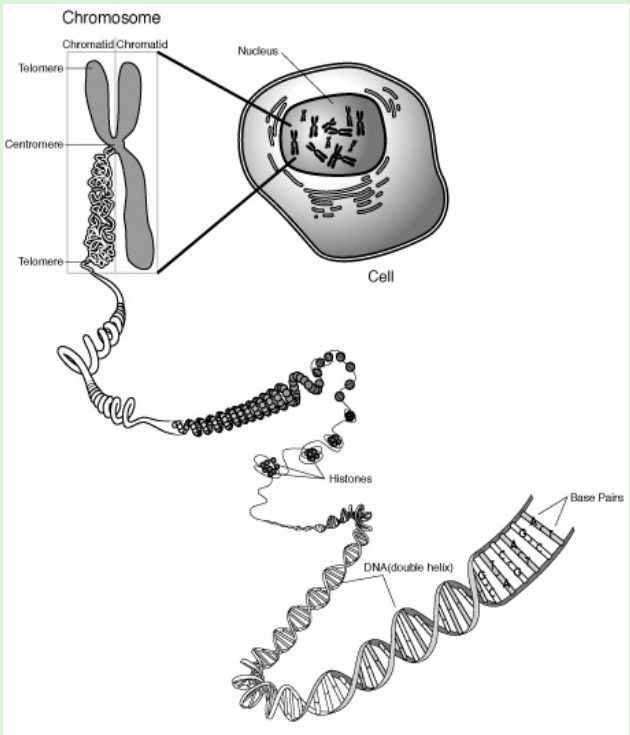
Origin of the Species

But...

Epigenetics: back to Lamarckism!

Origin of the Species

Genetics



Chromosomes:

- composed of Deoxyribonucleic acid: **Genetic fingerprint of individuals**;
- Located in nucleus (eukaryotes) or cytoplasm (prokaryotes);
- Double helix of base pairs: Adenine, Thymine, Guanine and Cytosine;
- Sequence of genes;
- Exons and Introns;
- Genome.

Sequence Space

- Individual
  - Chromosome
  - Gene
  - Exon
  - Intron
  - Genome

.....AGGCACCGTAGTTTAATAAGGGCTA....

.....AGGCACCGTAGTTTAATAAGGGCTA....

.....AGGCACCGTAGTTTAATAAGGGCTA....

.....AGGCACCGTAGTTTAATAAGGGCTA....

- Genome lives in Sequence Space

Organism	Length
Small Virus	10000
Bacterium	4 Million
Humans	3.5 Billion

Evolutionary Computation

Brief History

- Evolution with computers can be traced back to 1948 (Turing);
- First PhD in Computer Science (John Holland, 1959) popularised Genetic Algorithms;
- 1960s:

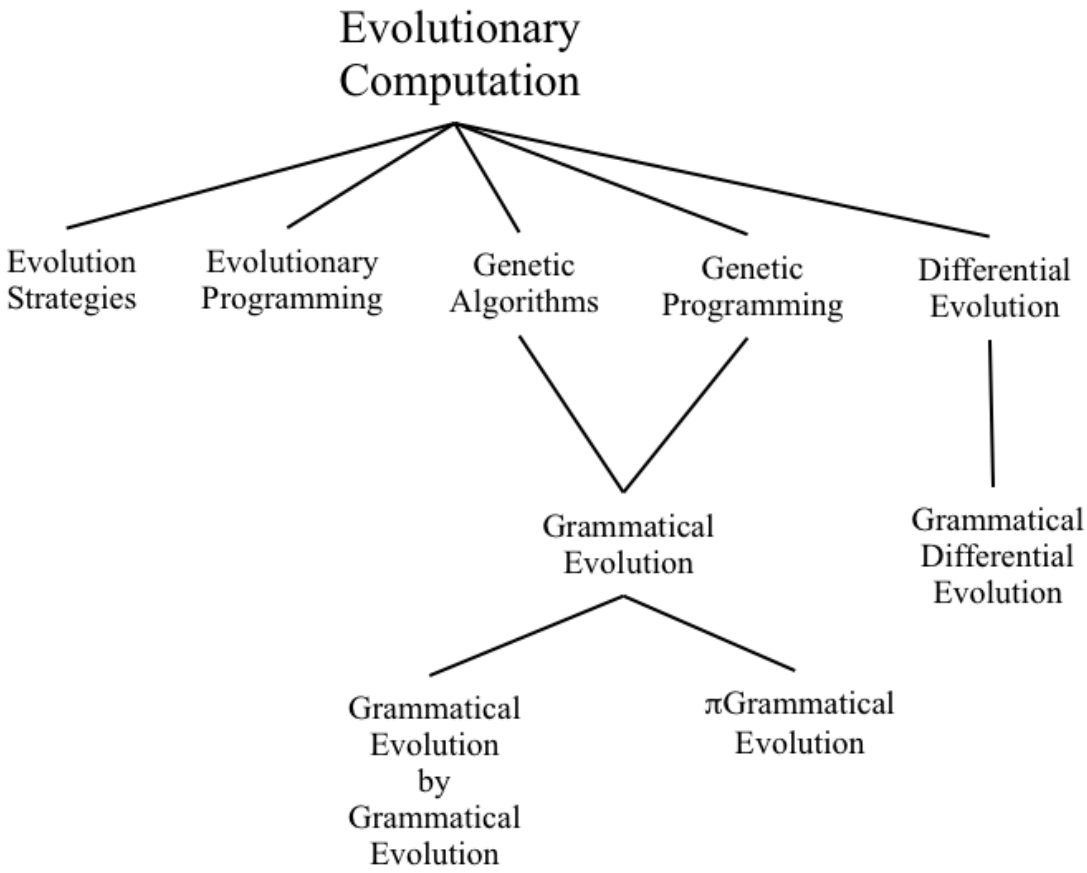
Genetic Algorithms
(Evolutionary Programming)

vs.

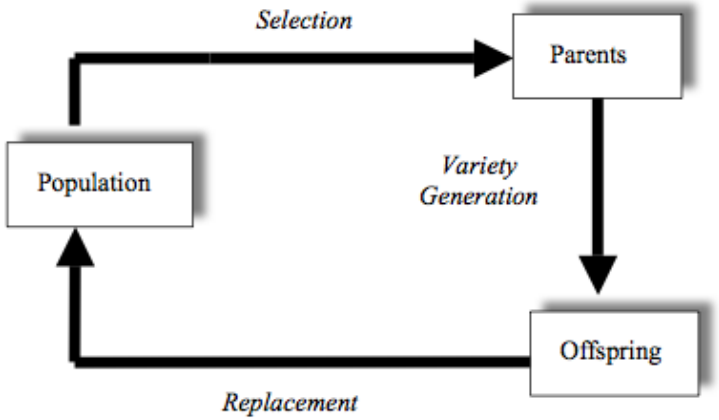
Evolution Strategies

- 1985: First Conference;
- 1992: Genetic Programming (1^{st} instance 1958!);
- 1990s: Unified under EC.

Evolutionary Computation



Evolutionary Computation



$$x[t+1] = r(v(s(x[t])))$$

Evolutionary Algorithm

```
Initialise Population;
While (termination condition FALSE):
    select Parents;
    create Offspring;
    Update Population;
EndWhile
```

Polar Bear Example

- World's largest carnivore;
- Descendent of Brown Bear;
- Separate evolution for last 4-5 million years;
- Clear/White Fur;
- 4 Legs;
- Furred Soles;
- Broad Forepaws;
- Large and Stocky:
  - 1.8-2.5m length (tip of nose to tail);
  - 150-800kg.

Colour	Legs	Soles	Forepaws	Length	Weight
White	4	Furred	30.4cm	2.2m	785.4kg
Category	Integer	Boolean	Float	Float	Float

Polar Bear Example

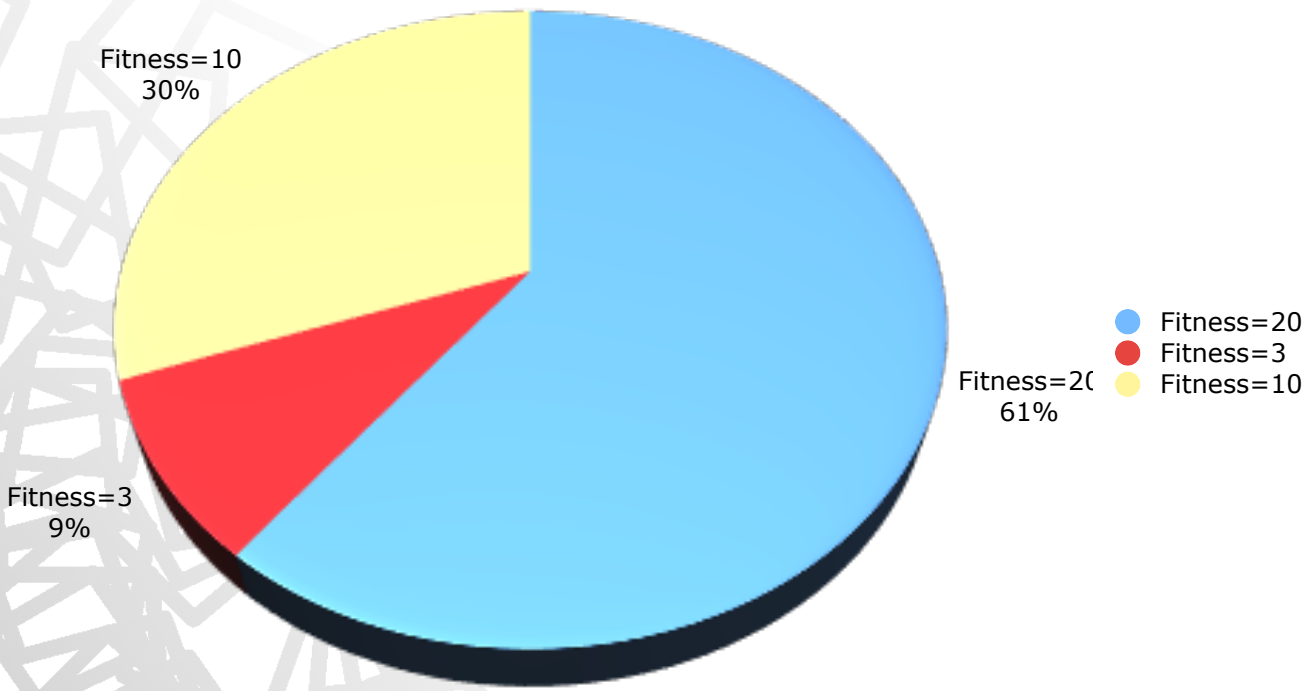
Colour	Legs	Soles	Forepaws	Length	Weight	**Fitness**
White	4	Furred	30.4cm	2.2m	785.4kg	**20 years**

Colour	Legs	Soles	Forepaws	Length	Weight	**Fitness**
Brown	4	Furred	29.9cm	1.1m	203.7kg	**3 years**

Colour	Legs	Soles	Forepaws	Length	Weight	**Fitness**
White	4	No Fur	15.4cm	1.8m	771.6kg	**10 years**

Average Fitness of Population= 11 years
Best Individual Fitness = 20 years

Polar Bear Example (Selection)



Polar Bear Example (Variation)

Parents:

Colour	Legs	Soles	Forepaws	Length	Weight	**Fitness**
White	4	Furred	30.4cm	2.2m	785.4kg	**20 years**
Brown	4	Furred	29.9cm	1.1m	203.7kg	**3 years**
White	4	No Fur	15.4cm	1.8m	771.6kg	**10 years**

Offspring:

Colour	Legs	Soles	Forepaws	Length	Weight	**Fitness**
White	4	Furred	31.2cm	2.2m	798.1kg	**23 years**
White	4	Furred	29.5cm	1.9m	778.1kg	**15 years**
White	4	No Fur	15.4cm	1.7m	741.6kg	**7 years**

Polar Bear Example (Replacement)

- Several approaches possible;
- Generational population (offspring replace parents).

New Population:

Colour	Legs	Soles	Forepaws	Length	Weight	**Fitness**
White	4	Furred	31.2cm	2.2m	798.1kg	**23 years**
White	4	Furred	29.5cm	1.9m	778.1kg	**15 years**
White	4	No Fur	15.4cm	1.7m	741.6kg	**7 years**

Average Fitness of Population= 15 years
Best Individual Fitness = 23 years

Evolutionary Computation

Black Art of EC

- Population-based search;
- Stochastic;
- **Design representation**;
- **Design fitness measure**;
- **Design algorithm (e.g., balanced variety generation operators and selection pressure)**.

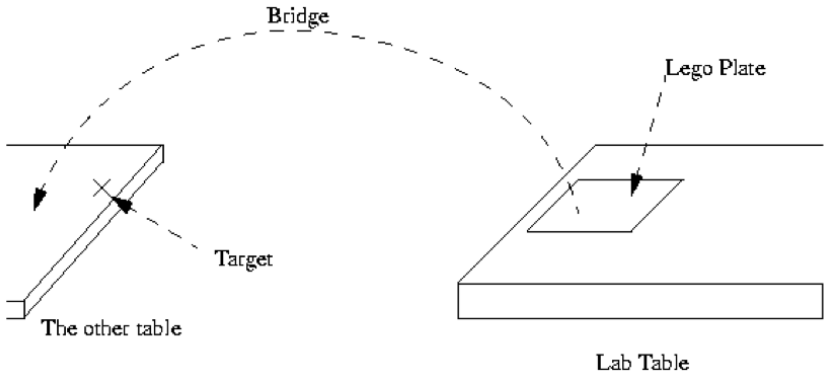
Evolutionary Computation

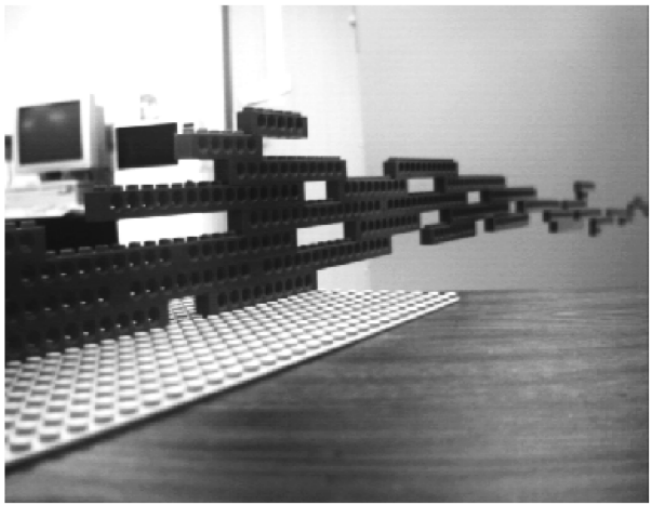
Applications

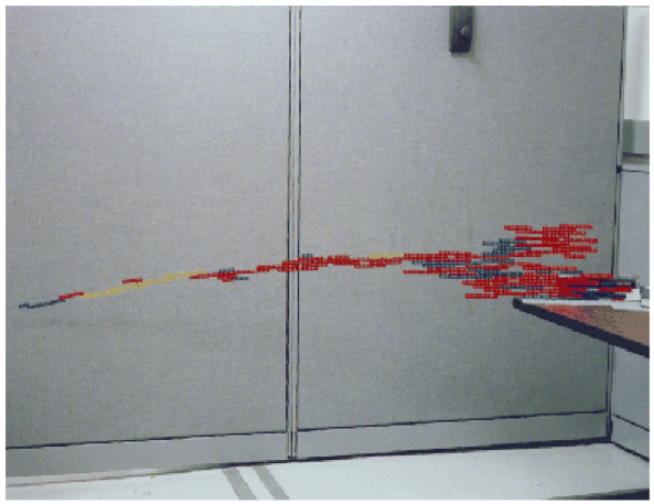
- Too many to list!;
- Engineering;
- Design;
- Sound Synthesis;
- Circuit Design;
- Games;
- Financial Modelling;
- Bioinformatics;
- Human-competitive results.

Evolutionary Computation

Funes & Pollack (1997)



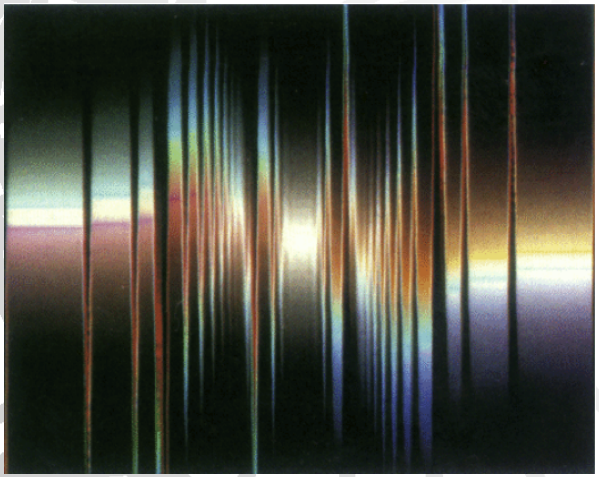




Evolutionary Computation

Karl Sims (1991)



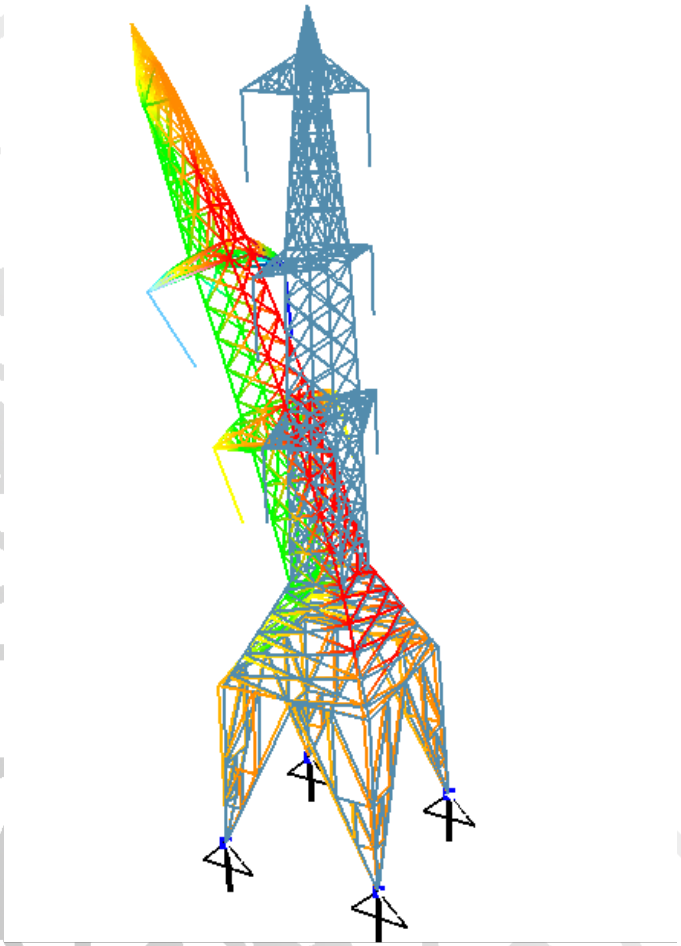


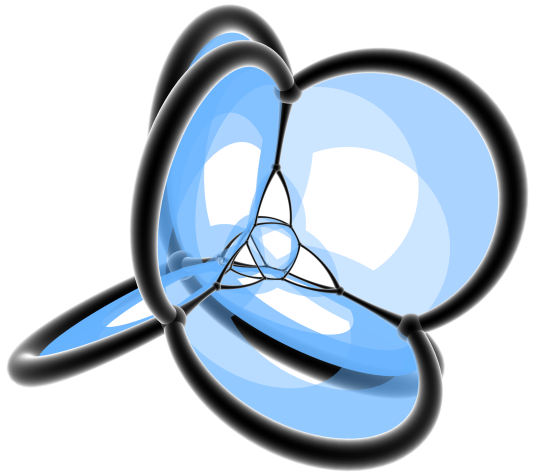

Evolutionary Computation

Al Biles (1993)
GenJam

Evolutionary Computation

Natural Computing Research and Applications (NCRA) Group





Evolutionary Computation

[video]

Next Classes

- Lecture Tuesday 17th September 15h - 16h (Genetic Algorithms - Mike);
- Lecture Thursday 19th September 15h - 16h (Genetic Programming #1 - Miguel);