An introduction to Evolutionary Algorithms

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Background

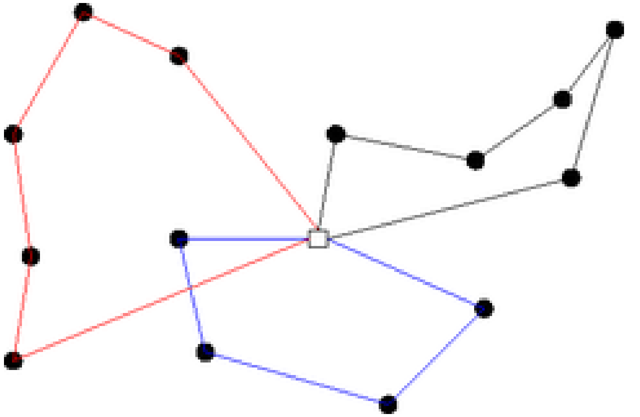
- In this lecture:
  - Why solving some problems is difficult
  - Evolution as search and adaptation
  - A quick guide to genetics
  - Using a simple EA
- (Next week, how to build an evolutionary algorithm in detail)

Background

- Prior to this lecture we have examined *deterministic* AI
- Evolutionary Algorithms are *non0-deterministic*
- Evolutionary Algorithms (and techniques such as neural nets) are *nature inspired*

Problem solving

- Multi-vehicle routing
  - A company has to deliver goods to customers
  - The goods are located in a central depot
  - Each vehicle can only carry a limited capacity
  - A variation introduces time-windows for each customer



Vehicle routing

- The *objective* of the problem is to minimise the cost
  - In this case the cost could be directly related to the distance travelled
  - More complex variants may have multiple objectives
    - Cost
    - Distance
    - Emissions
    - Qty of vehicles

Vehicle routing

- There exists many possible solutions to our problem
  - Some solutions are not *feasible*
    - *a vehicle in 2 places at once*
    - *visiting a customer outside of a time window*
    - *too many visits for the capacity of a vehicle*
  - Feasible solutions are those that can be utilised

Optimisation & Search

- This is essentially a search problem
- The **problem** is to find a feasible solution
- The **search-space** is the set of all possible solutions
- The **optimum solution** is the solution that gives us the **best** result based on the objectives

Search and Optimisation

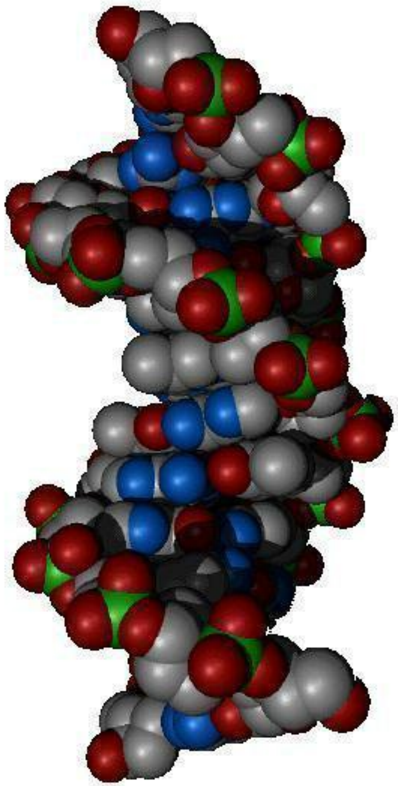
- This type of problem is common in many areas of real-life:
  - Scheduling timetabling in a university
  - Cutting shapes from sheets of metal
  - Finding the optimal design of an aeroplane wing
- They are all characterised by:
  - A search space that is too large to look at every solution by hand
  - A desire to find the "best" solution to the problem concerned

Evolution

- In a population of individuals, the environmental pressure causes natural selection (survival of the fittest)
  - This causes a rise in fitness of the population
  - Over time, the population adapts to best fit its environment
  - This can also be thought of as “optimising” some “survival function”

Natural Genetics
Really Simplified Version

- The information required to build a living organism is coded in the DNA found in the cells of that organism
- Within a species, the vast majority of the genetic material is the same
- Small changes in the genetic material give rise to small changes in the organism
  - E.g size of petals, height, hair colour



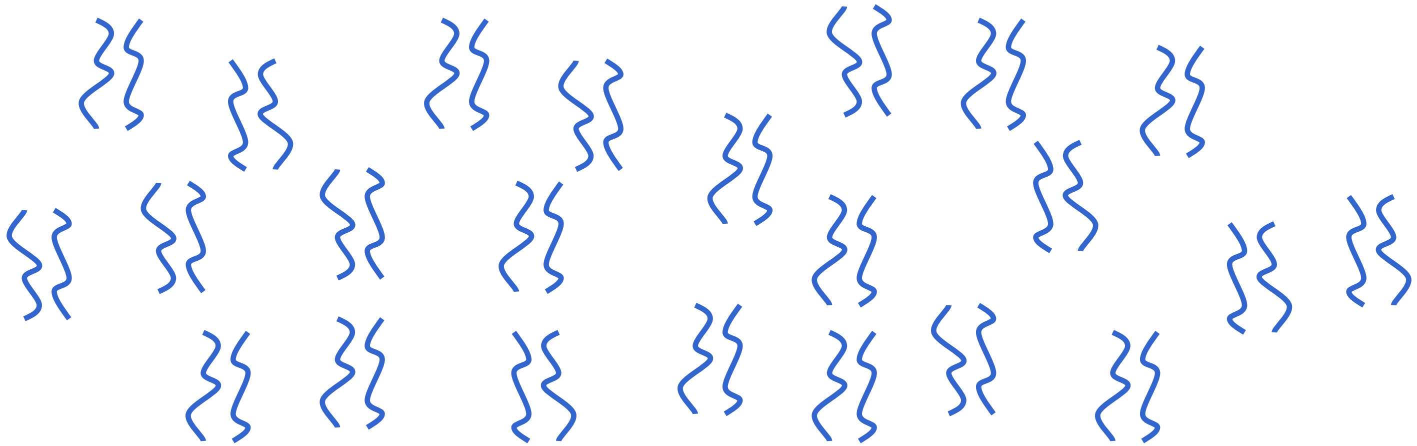
DNA and Genes

- DNA is a large molecule made up of fragments. There are four fragment types, each one acting like a letter in a long coded message:

- Certain groups of fragment types are meaningful together
- These groups are called genes

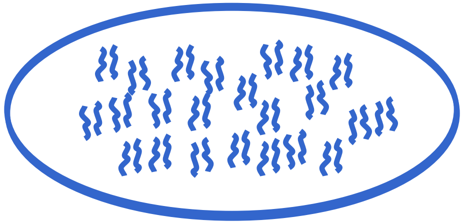
Reproduction
Example: Humans

- Human DNA is organised into chromosomes
- Most human cells contains 23 pairs of chromosomes which together define the physical attributes of the individual:



Reproductive Cells

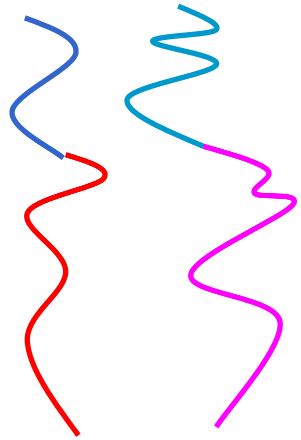
- Reproductive cells are formed by one cell splitting into two – each pair of chromosomes splits



- Before the split the pairs of chromosome undergo an process called *crossover*

Crossover

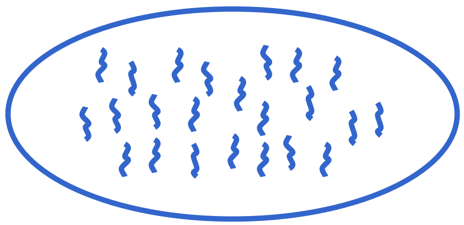
During crossover the chromosome pairs link up and swap parts of themselves:



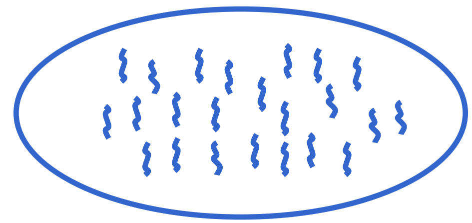
Your reproductive cells have a combination of your parents’ genes

Fertilisation

Sperm cell from Father



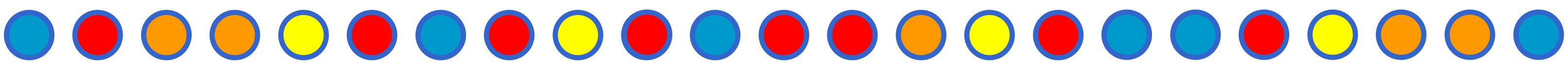
Egg cell from Mother



Join to make new person cell

Mutation

- Occasionally some of the genetic material changes very slightly during this process



- This means that the child might have genetic material information not inherited from either parent
- This is most likely to be catastrophic - the new cell doesn’t develop into an embryo

Theory of Evolution (simplified)

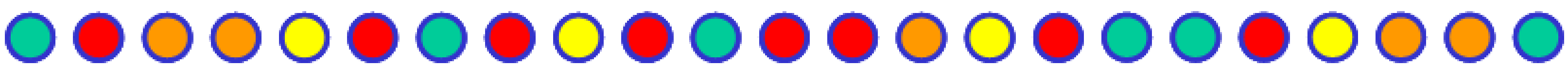
- Mutation, Crossover =>New genetic material or new combinations
- Offspring often less able to survive and so reproduce
- Occasionally more able to survive and so reproduce
- More reproduction leads to more of the “new improved” genetic material

Theory of Evolution (simplified)

- “Good” sets of genes get reproduced more
- “Bad” sets of genes get reproduce less
- *Emergent property:*
  - Organisms as a whole get better and better at surviving in their environment

Evolution as Search

- Evolution - search through the enormous space of all possible genetic combinations for a good solution to the problem of survival in a particular environment



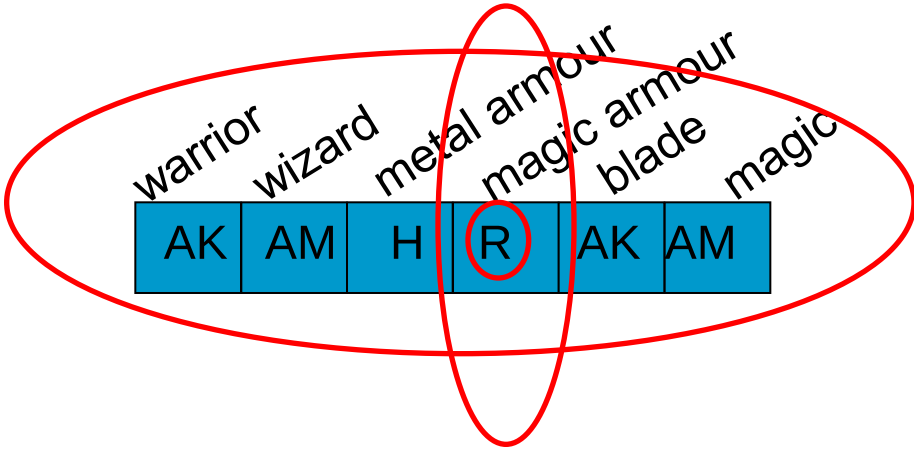
- We can borrow these ideas to:
  - Find solutions in vast search spaces
  - Find solutions which adapt over time

Role-playing example

- Use evolution to evolve NPCs responses to possible player attacks
- NPCs which perform badly in one generation shouldn’t pass on traits to next (and vice versa)
- Consider simple example with:
  - 6 attack scenarios
  - 6 possible responses
  - (real game would have many more ….)

An Evolutionary Algorithm

- We can use a **chromosome** to *represent* the set of possible player behaviours
- Each **gene** in the chromosome represents one of the scenarios
  - One gene for each scenario
- The **value** of the gene indicates the response to that scenario
  - Value drawn from a set of possible NPC responses



AK: AttackKnife

AM:AttackMagic

H: Hide

R: Retreat

MA: Magic Armour

LA: MetalArmour

The Initial Population

- Start off with population of **completely random** chromosomes
  - – It is likely to be very poor
  - – (random chance some things might be OK)

AM	H	R	R	LA	H

AK	H	LA	R	AM	LA

R	H	R	R	AK	MA

AK	AM	R	AM	AK	MA

MA	MA	H	AK	LA	R

R	LA	R	AK	H	AM

H	H	MA	LA	AK	AM

LA	MA	AM	R	H	H

Evaluating the Chromosomes

- We need to assign a “fitness” to each member of the population
- The fitness measures how good the chromosome is at providing an opponent that is a challenge to a player
- Ideally it has a numeric value that we can easily quantify
  - i.e. the higher the better

Fitness

- Typical role-playing games assign hit-points to each character
- They are reduced as a player is injured and can be gained by attacking other players:
  - Fitness = total damage received
  - Fitness = total damage inflicted
  - Fitness = number of players killed
- We can evaluate any chromosome by playing a game against an NPC with behaviours defined by the chromosome

Selection

- We need to pick parents from the population to make new offspring
- Fitter parents should have more chance of being selected
- (but we still need to give some chance to weaker individuals as they may contain some good genes)

AM	H	R	R	LA	H	101
R	H	R	R	AK	MA	86
MA	MA	H	AK	LA	R	45
H	H	MA	LA	AK	AM	234
AK	H	LA	R	AM	LA	18
AK	AM	R	AM	AK	MA	57
R	LA	R	AK	H	AM	99
LA	MA	AM	R	H	H	156

Selection

- Choose a size of tournament, call it n
  - Randomly pick n individuals from the population
  - Evaluate fitness of each chosen member
  - Highest fitness one is chosen as the parent

MA	MA	H	AK	LA	R

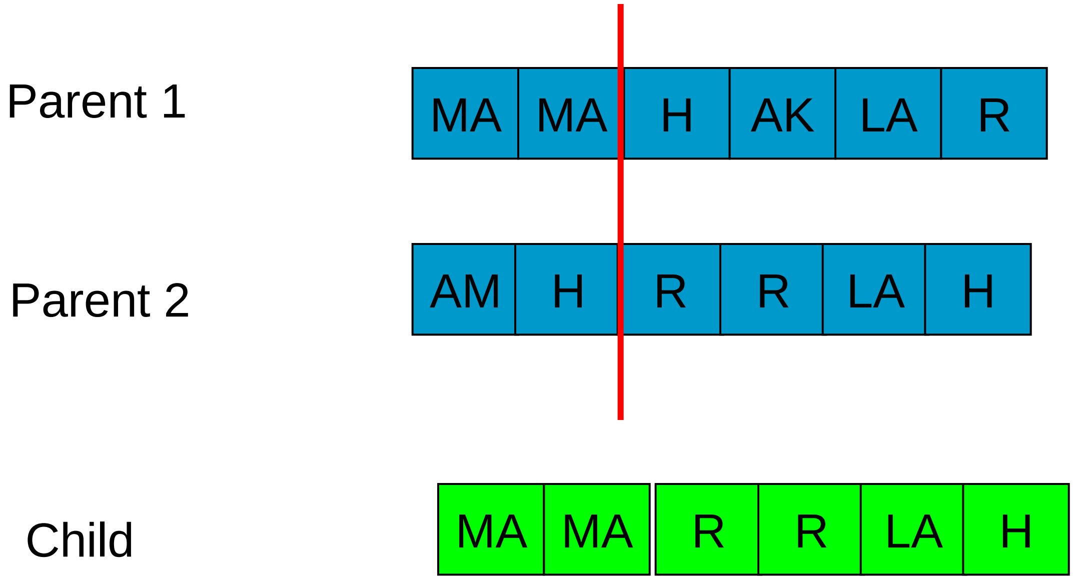
- Repeat to choose 2nd parent

AM	H	R	R	LA	H

AM	H	R	R	LA	H	101
R	H	R	R	AK	MA	45
MA	MA	H	AK	LA	R	87
H	H	MA	LA	AK	AM	234
AK	H	LA	R	AM	LA	18
AK	AM	R	AM	AK	MA	57
R	LA	R	AK	H	AM	99
LA	MA	AM	R	H	H	156

Crossover

- The function of crossover is to produce new offspring that inherit genetic traits from their parents
- Pick a random point and swap information:



Mutation

- Mutation serves to introduce (a small) amount of genetic variation into a population
- Pick a random gene and change the value to a new random value

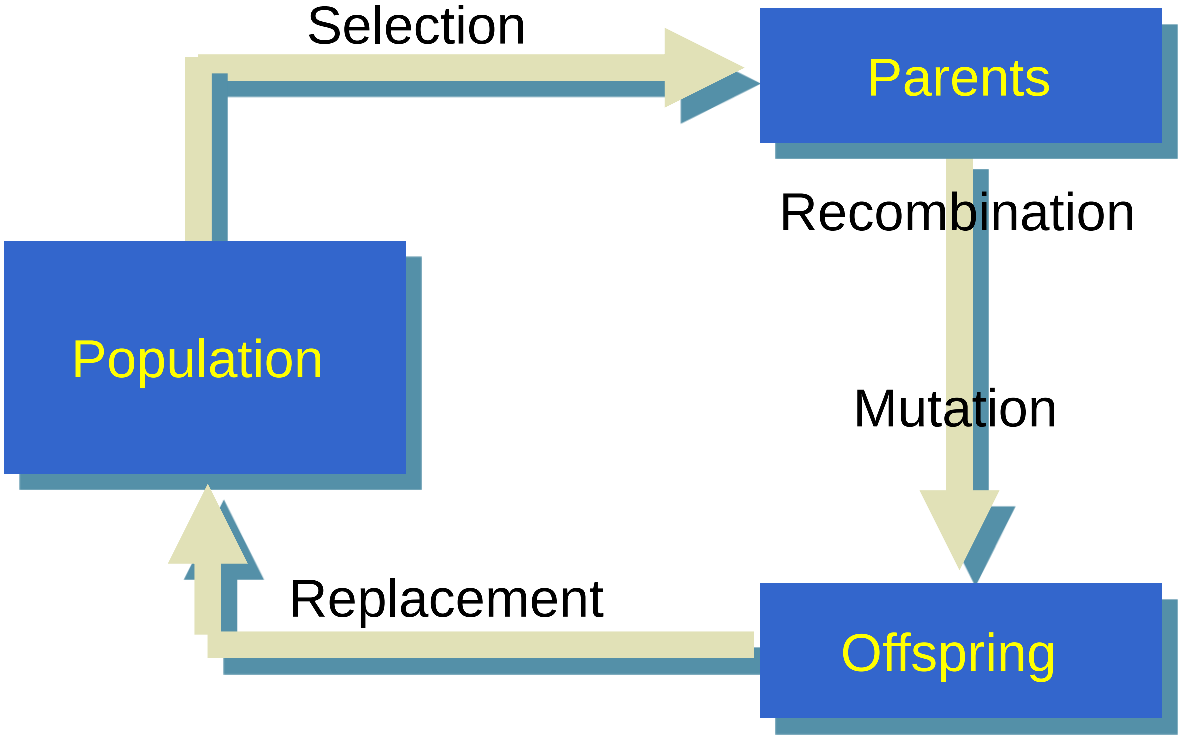
MA	MA	R	R	LA	H

- The population (might) now contain some new genetic material

Replacement

- Having created new offspring, they need to go back into the population
  - The population shouldn't grow in size
  - We need to replace some of the old population with the new offspring
- Which ones should we replace ?
  - The worst ones
  - Or …have a tournament, the winner is the chromosome with lowest fitness

The Evolutionary Cycle



A Typical Evolutionary Algorithm

BEGIN

INITILIASE population with random candidate solutions

EVALUATE each candidate

REPEAT UNTIL (some termination conditions)

1. SELECT parents
2. RECOMBINE to form child
3. MUTATE child
4. EVALUATE child
5. UPDATE population to form next generation

END

Evolution: Summary

- There are two fundamental forces which form the basis of evolutionary systems:
  - Variation operators (mutation/crossover) create novelty
  - Selection acts a force to increase quality
- Many elements are stochastic:
  - Fitter elements have more chance to be selected but some weak ones will be…
  - Recombination relies on random choices of “pieces” to combine
  - Mutation randomly changes genes to other genes