

15. Genetic algorithms

Generative Music AI

THE **SOUND** OF AI



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Overview

1. Intuition
2. Formalisation
3. Music generation with genetic algorithms
4. Strengths and limitations

What are genetic algorithms (GA)?

Genetic algorithms are optimization techniques inspired by the process of natural selection

Natural selection

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Natural selection

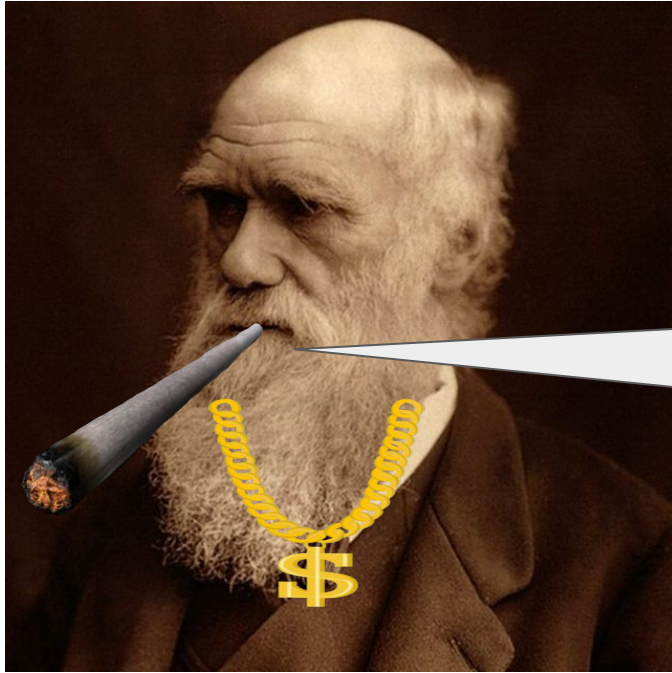
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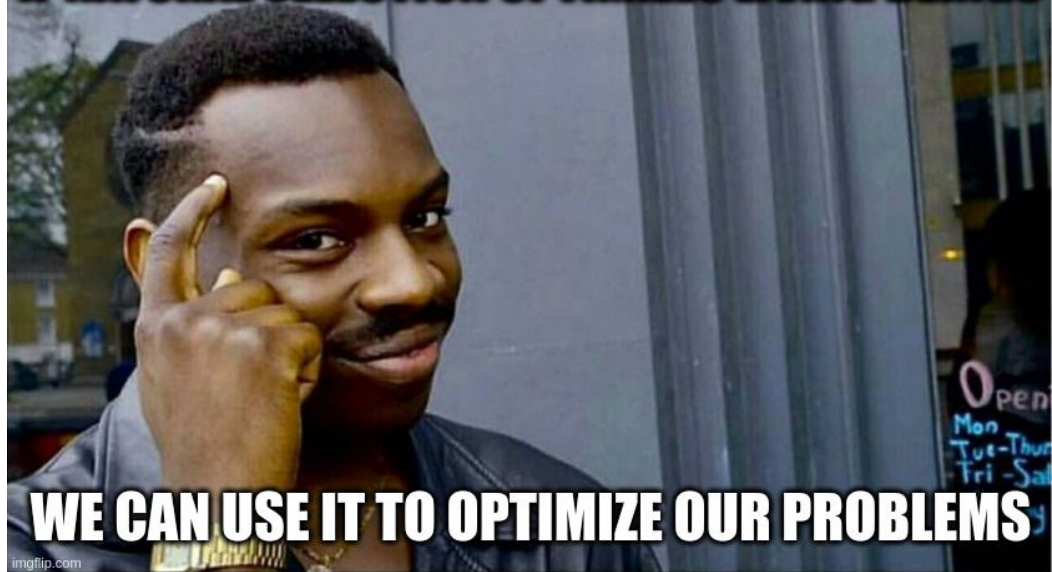
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- Over many generations, these processes can result in adaptations and the evolution of species



Survival of the
fittest bro!

IF NATURAL SELECTION OPTIMIZES LIVING BEINGS



WE CAN USE IT TO OPTIMIZE OUR PROBLEMS

Core idea

Solutions evolve over generations to
optimize a specific objective

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Individual animals

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Survival of the fittest

GA applications

- Aerospace design
- Routing problems
- Inventory management
- Parameter optimization for ML
- Financial portfolio optimization
- DNA sequence alignment
- Anomaly detection in signal processing
- Art / music generation
- ...

Formalising GA: Key elements

- *Population*: A set of candidate solutions (individuals)

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# of legs	height	width	color
5	80	90	red

Formalising GA: Key elements

- *Population*: A set of candidate solutions (individuals)
- *Chromosomes*: Encoded version of the candidate solution
- *Fitness function*: Measures how effective a solution is

Formalising GA: Genetic operators

- Selection
- Crossover (recombination)
- Mutation

Selection

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- Roulette wheel selection, tournament selection, and rank selection

Crossover

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- One-point crossover, two-point crossover, ...

One-point crossover

Parent 1

# of legs	height	width	color
5	80	90	red

Parent 2

# of legs	height	width	color
3	57	60	brown

One-point crossover

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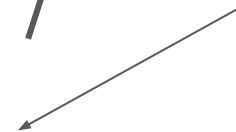
One-point crossover

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# of legs	height	width	color
5	80	90	red

Parent 2

# of legs	height	width	color
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# of legs	height	width	color
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Two-point crossover

Parent 1

# of legs	height	width	color
5	80	90	red

Parent 2

# of legs	height	width	color
3	57	60	brown

Two-point crossover

Parent 1

# of legs	height	width	color
5	80	90	red

Parent 2

# of legs	height	width	color
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# of legs	height	width	color
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Crossover

- Combine the genetic information of two parents to produce new offspring
- Parts of the chromosomes are exchanged between two parents
- One-point crossover, two-point crossover, ...
- **Creates genetic diversity and can lead to new solutions**

Mutation

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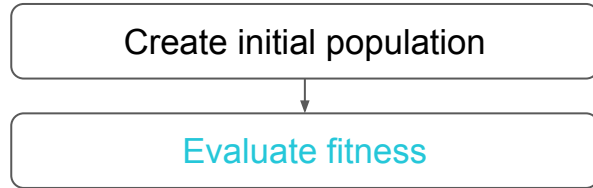
Mutation

- Introduce variation into the offspring's genetic makeup
- Random changes are made to parts of the genetic code of the offspring
- Prevents the algorithm from becoming too homogeneous and helps exploring solution space
- Mutation rate is low to prevent random search

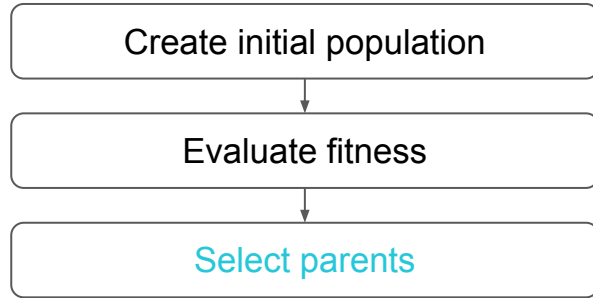
GA step by step

Create initial population

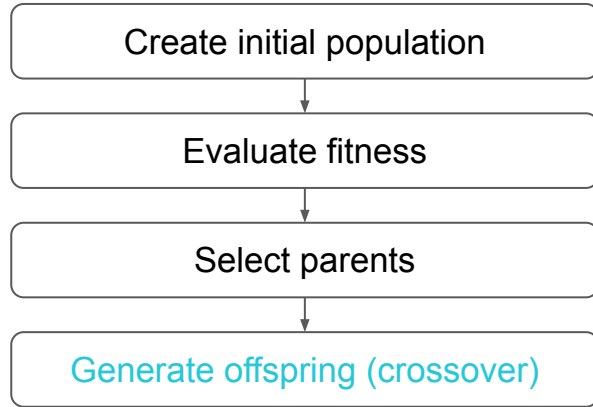
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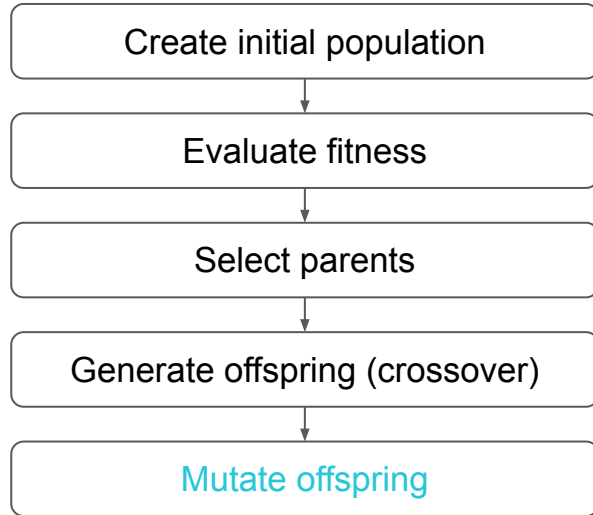
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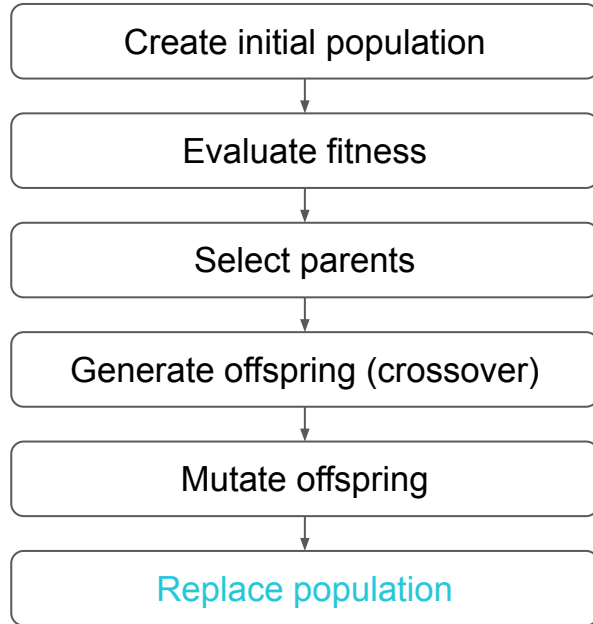
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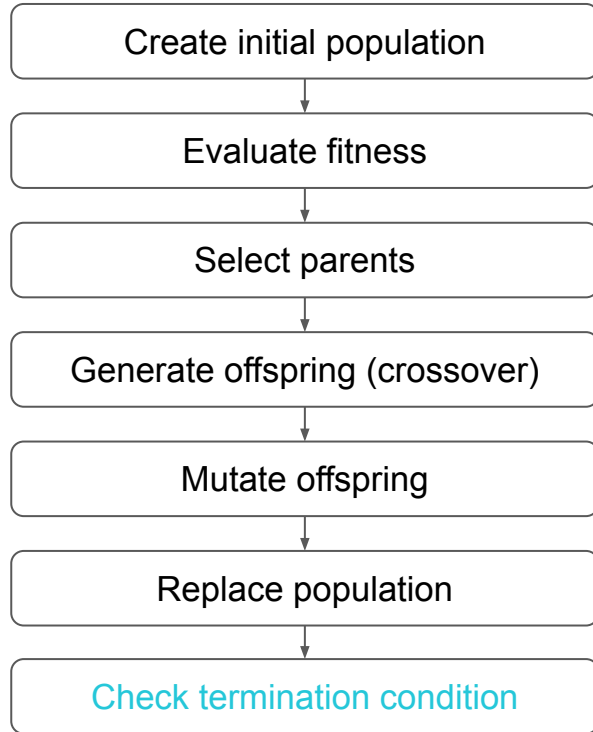
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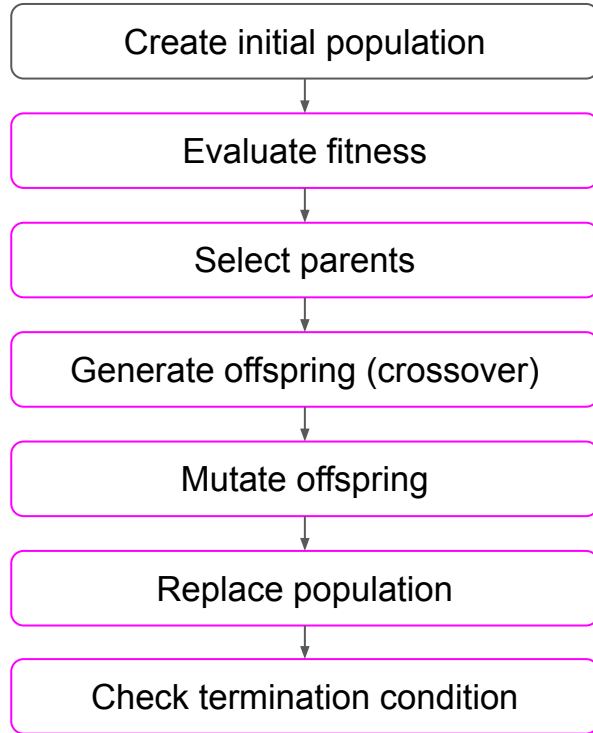
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iteration / generation

What are GAs good for?

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- Problems where traditional optimization techniques fail
- Large, complex, multimodal search spaces
- Diversity and adaptation

GA for music generation

1. Encode music elements as chromosomes

GA for music generation

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2. Craft the fitness function

GA for music generation

1. Encode music elements as chromosomes
2. Craft the fitness function
3. Run the algorithm

Use cases for music generation

- Melodic development
- Chord progressions
- Rhythmic patterns
- Entire compositions
- Sound synthesis
- ...

Encoding music as chromosomes

- Melody
- 1 note per gene
- Pitch + duration

C4-0.5	D4-1.0	C4-1.0	E4-2.0	C4-4.0
--------	--------	--------	--------	--------

Encoding music as chromosomes

- Chords
- 1 chord per gene

Cm	Dm	D	Gm	C
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Encoding music as chromosomes

- Sound synthesis
- 1 synth parameter per gene

cut-off frequency	reverb	freq osc 1	freq osc 2	delay
0.34	0.46	0.22	0.56	0.22

Fitness function

- Evaluates the aesthetic value of a composition

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- Infer from music theory

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- Evaluates the aesthetic value of a composition
- Infer from music theory
- Learn from data
- Subjective - what is a good melody?

Fitness function for melody

- Linear combination of multiple criteria:
 - Scale conformity
 - Melodic contour
 - Rhythmic variation
 - Dissonance resolution

$$F = w_1 \times \text{SC} + w_2 \times \text{MC} + w_3 \times \text{RV} + w_4 \times \text{DR}$$

Interactive GA

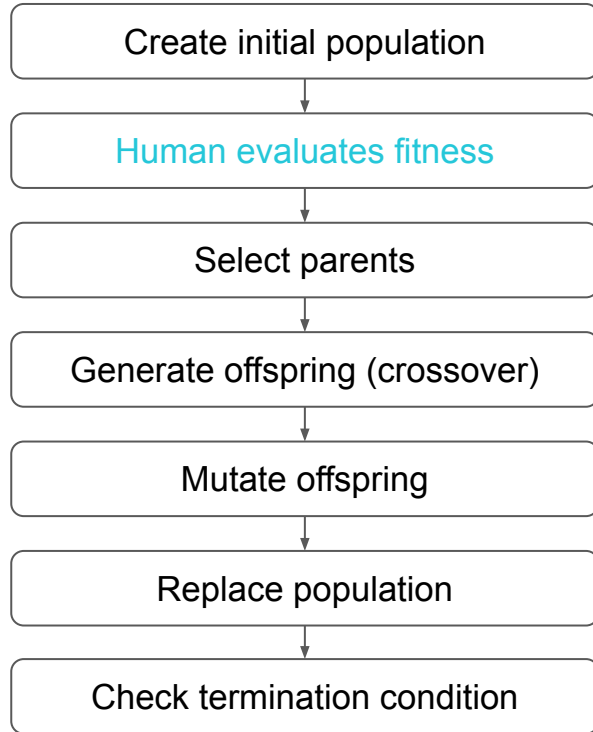


crafting
a fitness function



you being
the
fitness function

Interactive GA



Pros and cons of GA



- Flexible
- Explore unconventional ideas
- Good results

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- Crafting fitness function is complex
- Subjectivity

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- GA for music generation:
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- Music fitness function is complex to develop
- Unconventional musical ideas

What's up next?

Chord accompaniment generation for a
melody with genetic algorithms