2. Genetic Algorithms

Computational Music Creativity

Universitat Pompeu Fabra Barcelona
MTG Music Technology Group

to recap the theory

What are genetic algorithms (GAs)?

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Genetic algorithms are optimization techniques inspired by natural selection

Core idea

Solutions evolve over generations to optimize a specific objective

Formalising GA: Key elements

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

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# of legs	height	width	color
5	80	90	red

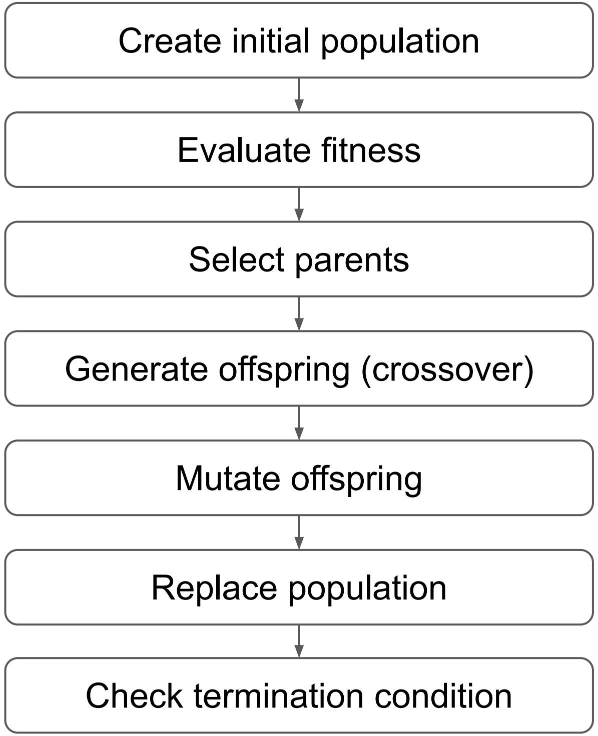
Formalising GA: Key elements

- *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

GA step by step



GA for music generation

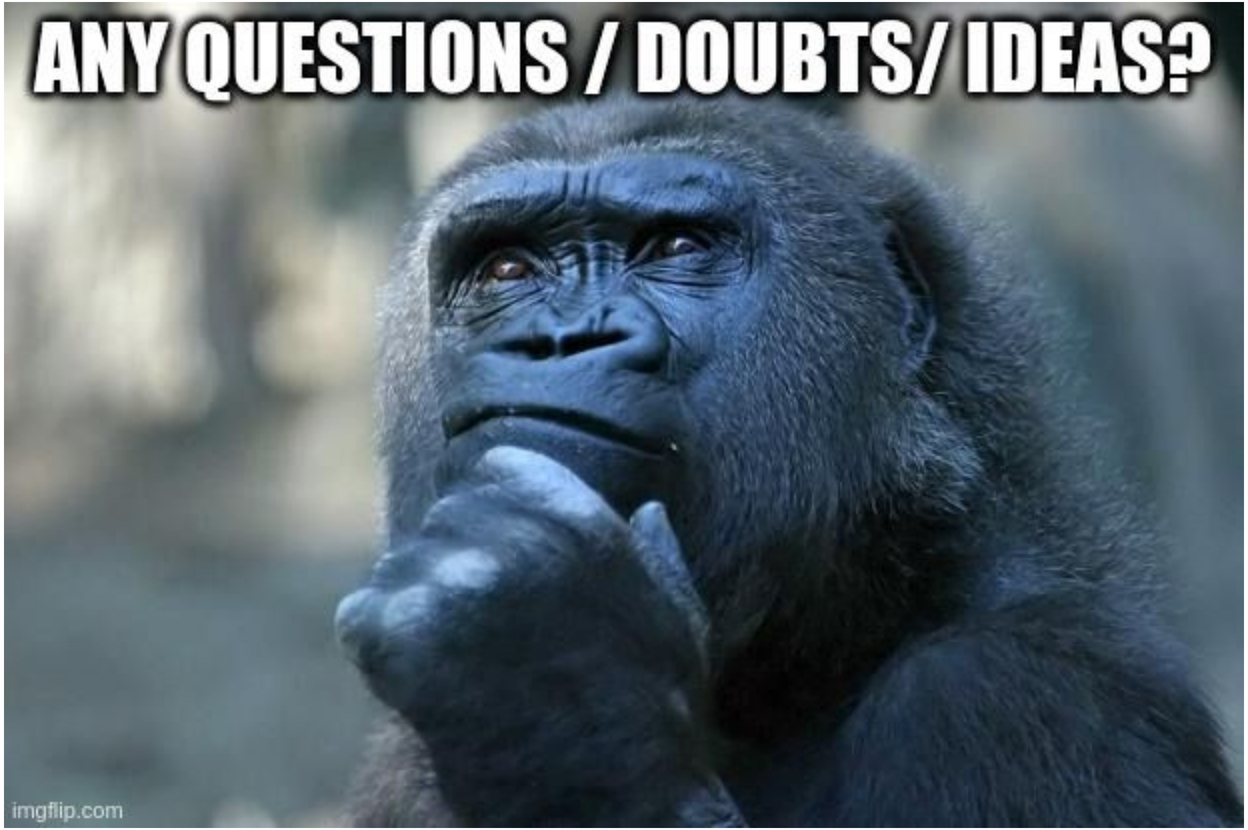
1. Encode music elements as chromosomes
2. Craft the fitness function
3. Run the algorithm

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


CONGRATULATIONS,
YOU'VE DONE EXACLTY WHAT IS
EXPECTED OF YOU


ANY QUESTIONS / DOUBTS/ IDEAS?
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genetic
algorithms

genetic
algorithms

Why I hate GAs

- Slow

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- Difficult to predict

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- Conflict across metrics

Why I hate GAs

- Slow
- Difficult to predict
- Conflict across metrics
- Premature convergence

Why I love GAs

Why I love GAs

Crazy as s**t

Iamus (2010)

Why I love GAs

- Good results, if used correctly
- Edge of chaos
- Route to *transformational* creativity?

Transformational or exploratory?

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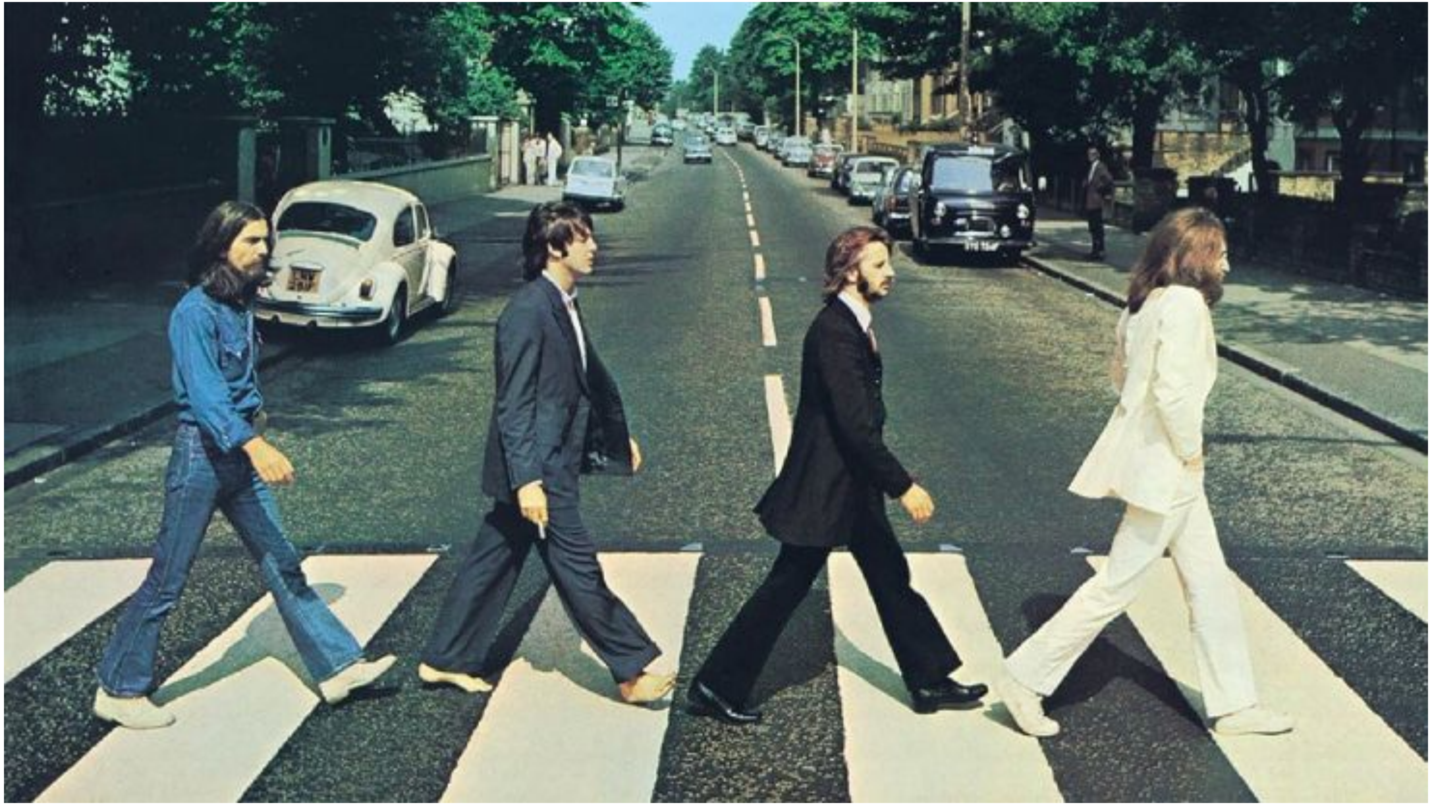
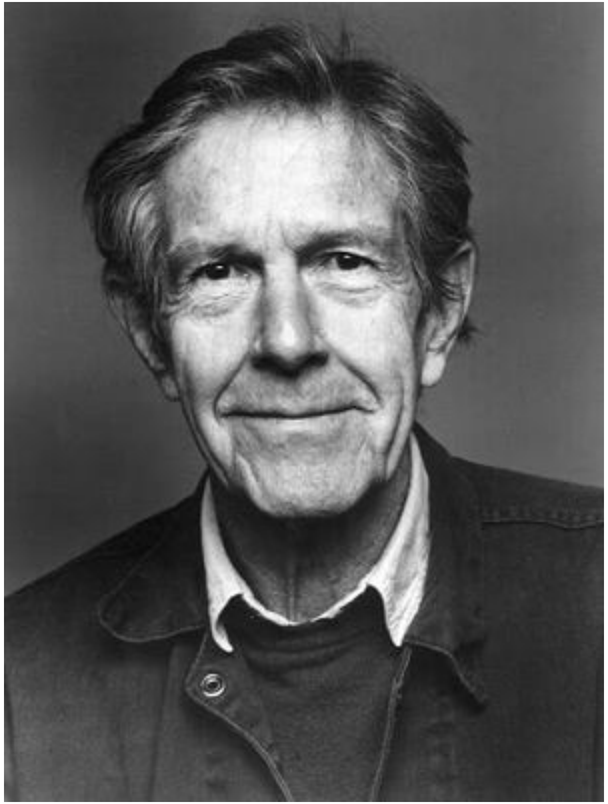
Transformational or exploratory?



Transformational or exploratory?



John Cage

Table 1. A typology of musical universals. Four types of universals are recognized, as described in the text. Below each class of universal is listed a few examples of that type. This listing is not meant to be comprehensive. See text for full listing.

Type 1: CONSERVED UNIVERSALS = all musical *utterances*

- use of discrete pitches
- octave equivalence
- transposability of music
- music organized into phrases
- arousal factors in emotive expression: tempo, amplitude, register

Type 2: PREDOMINANT PATTERNS = all musical *systems* or *styles*

- scales have seven of fewer pitches per octave
- predominance of precise (isometric) rhythms in music
- divisional organization of durational/rhythmic structure
- use of motivic patterns in melody generation
- use of idiophones and drums
- religious/ritual context for music-making
- use of verbal texts in vocal music
- communication-promoting or social-positive attitude towards music

Type 3: COMMON PATTERNS = *many* musical systems or styles

- small tempo range for any given musical form/style
- predominance of syllabic singing
- use of aerophones
- 'voice/instrument cross imitation'
- use of acoustic depiction in music
- association of dance with music

Type 4: RANGE UNIVERSALS = *a discrete set of possible states for all musical systems/styles*

- measured vs. unmeasured rhythmic types
- monophonic vs. heterophonic vs. homophonic vs. polyphonic texture types
- solo vs. group performance arrangements
- ostinato vs. stophic vs. through-composed sectional arrangements

My idea to get to Nirvana

1. Use music universals as fitness function
2. Run GA
3. See the (transformational?) folly that unfolds

Tips to use GAs

- Study music theory
- Start with one metric, then add more
- Change one metric at a time
- Avoid *roulette wheel* for selection

Activity 1: Fitness function design

Goal: Create a multi-objective fitness function for generating a pop-rock drum beat:

- What (3-4) metrics would you use? Why?
- How do you think they'll interact?

Instructions:

- Work in groups (5 people)
- 10' to come up with solution
- 5' to discuss together

GenJam (Al Biles, 1994)

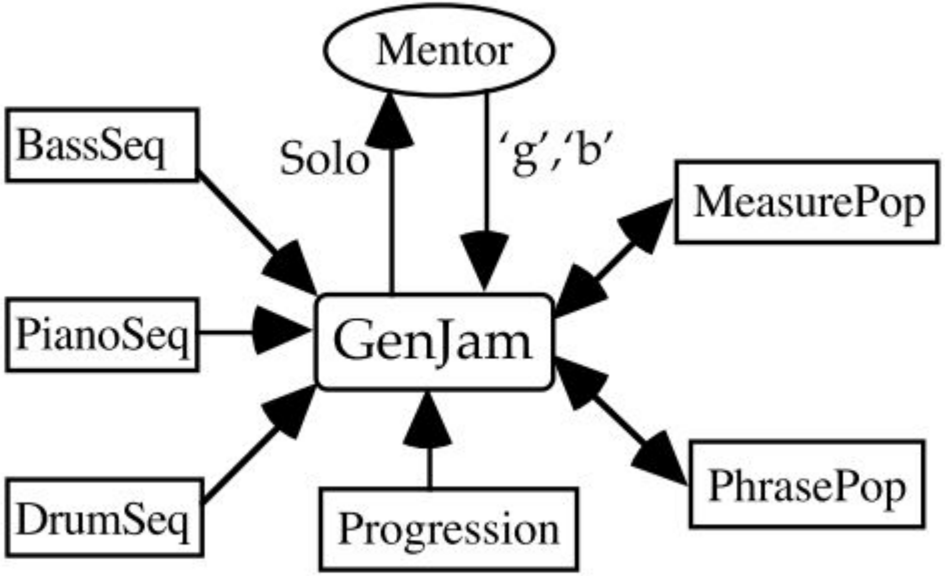
GA for jazz impros, using a human as the fitness function

GenJam (Al Biles, 1994)

GenJam: 3 modes

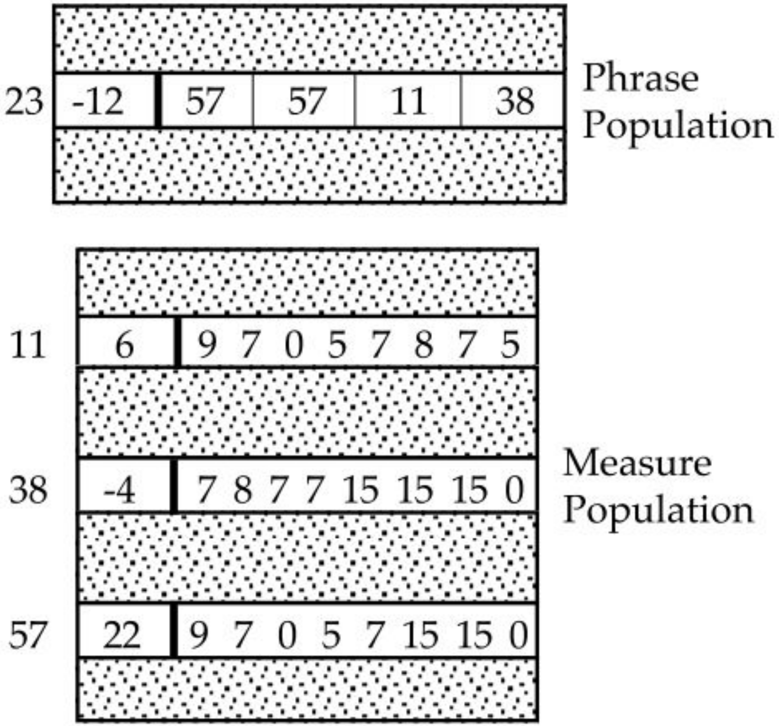
- Learning:
  - Build up fitness value
  - No genetic operators
- Breeding
  - Apply genetic operators
  - Half of the population replaced
- Demo
  - Performance

GenJam: Architecture



GenJam: Chromosomes

- Phrases
  - Gene = 1 measure
  - 4x measures per phrase
  - Population: 48 phrases
- Measures
  - Gene = musical event
  - 8 eight notes -> one 4/4 bar
  - Population: 64 measures



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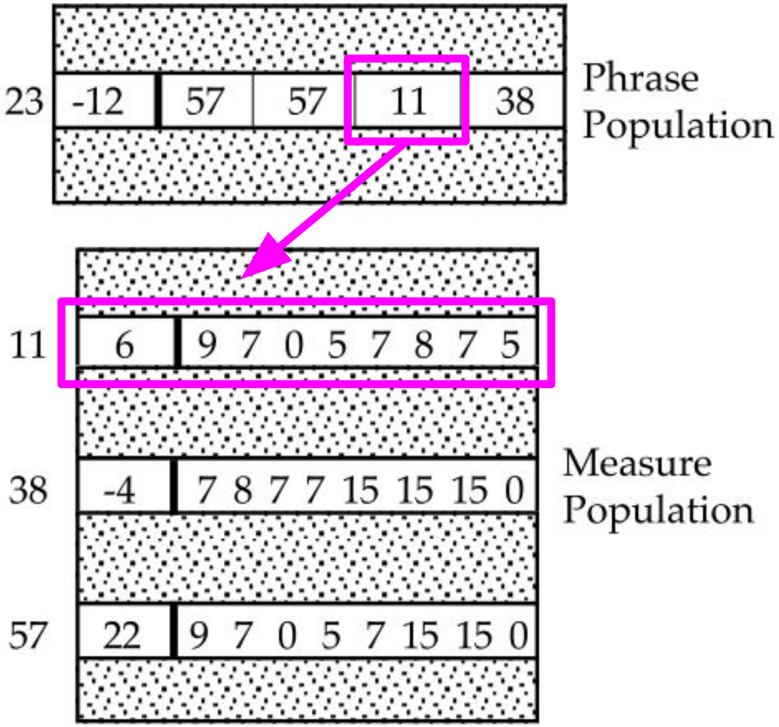
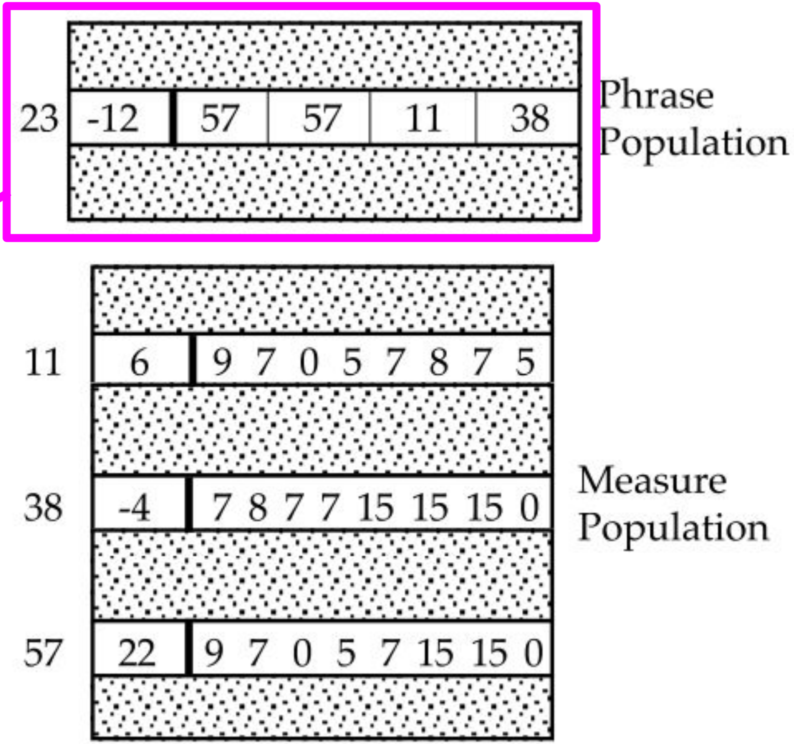


GenJam: Chromosomes



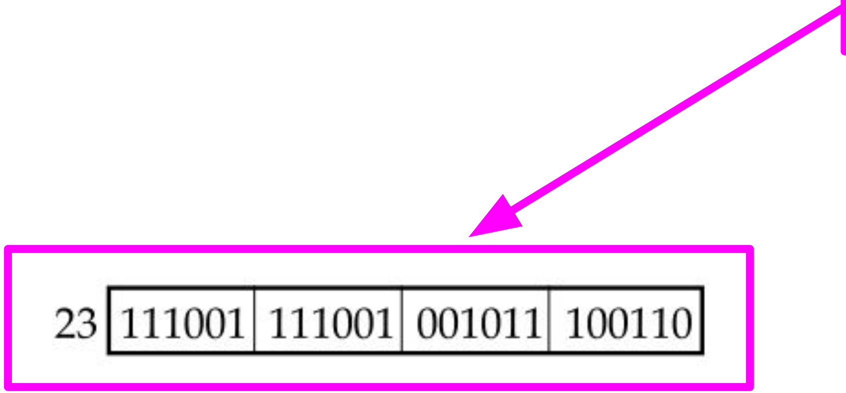


Figure 3. Phrase 23 Chromosome at the Bit Level

GenJam: Chromosomes

What do these values represent?

Measure genes

- 0 = rest
- 1 - 14 note
- 15 = hold

Chord	Scale	Notes
Cmaj7	Major (avoid 4th)	C D E G A B
C7	Mixolydian (~ 4th)	C D E G A Bb
Cm7	Minor (avoid 6th)	C D Eb F G Bb
Cm7b5	Locrian (~ 2nd)	C Eb F Gb Ab Bb
Cdim	W/H Diminished	C D Eb F F# G# A B
C+	Lydian Augmented	C D E F# G# A B
C7+	Whole Tone	C D E F# G# A#
C7#11	Lydian Dominant	C D E F# G A Bb
C7#9	Altered Scale	C Db Eb E F# G# Bb
C7b9	H/W Diminished	C Db Eb E F# G A Bb
Cm7b9	Phrygian	C Db Eb F G A Bb
Cmaj7 #11	Lydian	C D E F# G A B

Fitness: Interactive GA

- During *learning* mode human mentor:
  - Is presented with many phrases
  - Gives feedback
- Mentor gives “g” or “b”:
  - “g” -> +1 to phrase / measure
  - “b” -> -1 to phrase / measure

Genetic operators

- Active in *breeding* mode
- At each generation half of the measure population replaced
- Operators
  - Tournament selection
  - One-point crossover
  - 6 musically meaningful mutations per population

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Mutation Operator	Mutated Measure
None (Original Measure)	9 7 0 5 7 15 15 0
Reverse	0 15 15 7 5 0 7 9
Rotate Right (e.g., 3)	15 15 0 9 7 0 5 7
Invert (15 - value)	6 8 15 10 8 0 0 15
Sort Notes Ascending	5 7 0 7 9 15 15 0
Sort Notes Descending	9 7 0 7 5 15 15 0
Transpose Notes (eg. +3)	12 10 0 8 10 15 15 0

Mutation Operator	Mutated Phrase
None (Original Phrase)	57 57 11 38
Reverse	38 11 57 57
Rotate Right (e.g., 3)	57 11 38 57
Genetic Repair	57 57 11 29
Super Phrase	41 16 57 62
Lick Thinner	31 57 11 38
Orphan Phrase	17 59 43 22

Training

- Process:
  - Alternating between *learning* and *breeding* phases
  - Mentor listens to 24 new phrases per generation
- Outcome:
  - Over generations, solos evolve from dissonant to coherent and melodic
  - Pitch and interval distributions shift to align with musical norms

Performance

- *Demo* mode
- Phrases are selected with tournament selection
- Selected phrases are played back in real-time

GenJam limitations

- …

[GenJam: A Genetic Algorithm for Generating Jazz Solos]

Activity 2: Genetic encoding

Goal: Propose a chromosome representation for a 4-bar drum beat in 4/4 time (kick, snare, hi-hat, crash cymbal).

- Work in groups (5 people)
- 10’ to come up with solution
- 7’ to discuss together

Assignment 1: Genetic Harmonizer Upgrade

Re-adapt the genetic algorithm you've seen in the tutorial to harmonize a melody in a jazz style.

Deadline: 25 January at midnight