ALGORITHMIC MUSIC COMPOSITION

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HISTORY

Mozart's dice game

”Anleitung zum Componieren von Walzern so viele man will vermittelst zweier Würfel, ohne etwas von der Musik oder Composition zu verstehen”

=> 45,949,729,863,572,161 different yet similar waltzes

Source: https://www.youtube.com/watch?v=fK2MCXpDWB4

1955 Hiller, Isaacson: First computer-generated composition

1991 Gibson, Byrne: Musical Composition Using Genetic Algorithms And Neural Networks

2011 Donnelly, Sheppard: Evolving Four-Part Harmony Using Genetic Algorithms

MUSIC COMPOSITION AS SEARCH PROBLEM

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Goal:

- Compose music without or with minimal human guidance

Approach:

- Search the set of all possible compositions
- Return one which sounds good

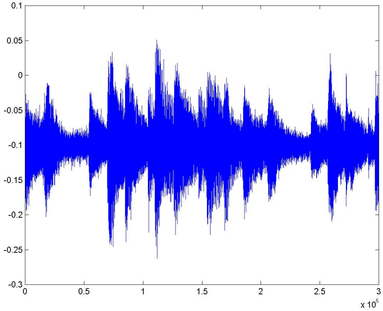
Problems:

- How to represent music?
- Search space is very big – how to search efficiently?
- How to evaluate if something sounds good?

How can we represent music?

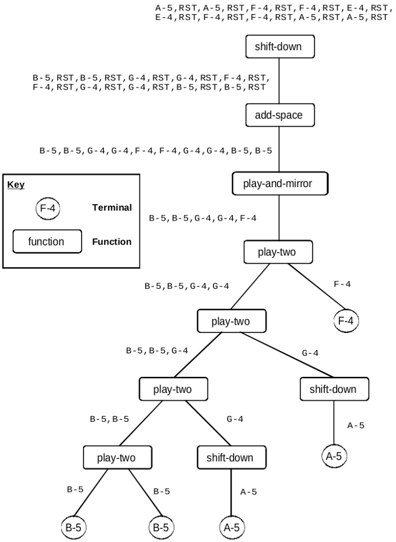
- Audio files
- Flat structure
- Hierarchical structure

MUSIC REPRESENTATION



Source: http://www.angelfire.com/art2/speech-audio-seperat/

Source: http://www.well.com/user/bryan/last.gif



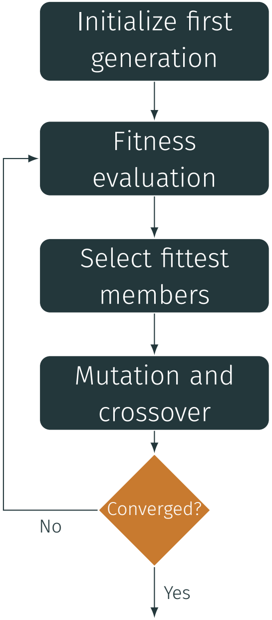
Source: http://graphics.stanford.edu/ bjohanso/papers/gp98/johanson98gpmusic.pdf

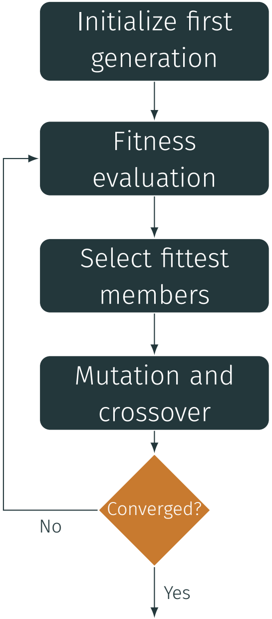
EFFICIENT SEARCHING

How can we search efficiently?

- Genetic algorithms

GENETIC ALGORITHMS





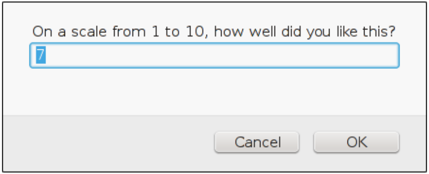
Example: Maximize function $f : \mathbb{R}^n \mapsto \mathbb{R}$

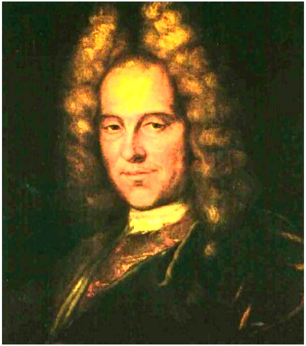
- **Initialization:** Select $x_1, \ldots x_k \in \mathbb{R}^n$ at random
- **Fitness** of x: $f(x)$
- **Mutation:** Shift by random $\varepsilon \in \mathbb{R}^n$
- **Crossover** of x and y: Choose value from line-segment between x and y

MUSIC EVALUATION

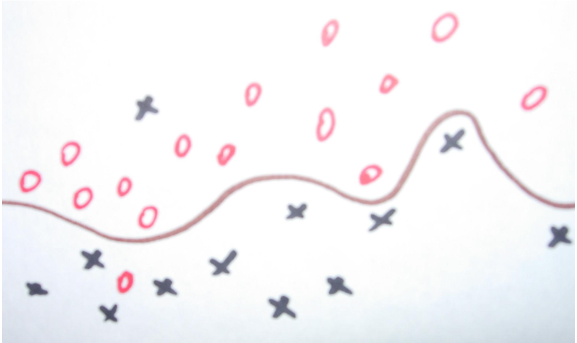
How can we evaluate music?

- Human based
- Rule based
- Machine learning based


On a scale from 1 to 10, how well did you like this?
7
Cancel
OK



Source: https://en.wikipedia.org/wiki/Johann_Joseph_Fux



Source: http://conferences.telecom-bretagne.eu/fps2012/program/slides/07.pdf

EVOLVING FOUR-PART HARMONY ...

Patrick Donnelly, John Sheppard
Evolving Four-Part Harmony Using Genetic Algorithms
Applications of Evolutionary Computation, 2011, pp 273-282

Used techniques:

- Flat music representation
- Genetic algorithms
- Rule based Fitness

Music representation:

- Four parallel parts
- Each part: List of (pitch, duration) tuples
- In C-major
- Total length not fixed

Example:

```
part 1: { (60, 1/4), (62, 1/4),
          (64, 1/4), (62, 1/4) }

part 2: { (48, 1/2), (52, 1/2) }

part 3: { (52, 1/2), (55, 1/2) }

part 4: { (55, 1/4), (57, 1/4),
          (59, 1/2) }
```

Genetic Algorithms

Initialize first generation with C-major chords

Mutation: Apply one of these operations to a random part

Repeat Note:

→

Shift Random Note:

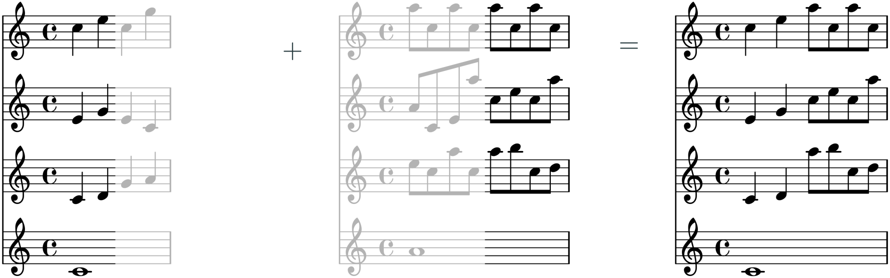
→

Alter Length:

→

Total: 11 operations

Crossover: Cut and glue two elements together



Rule Based Fitness

RULE BASED FITNESS

What does good music need?

- Melody (Should be catchy)
- Harmony (Melodies should interact nicely)
- Rhythm (Emphasize meter)
- Structure (Intro, outro, reoccurring themes, ...)
- Timbre/Intonation

$\Rightarrow$ Music theory provides tools to enforce these constraints

RULES

- **Leap Height:** Two consecutive notes should not have an interval larger than a 9th
- **Voice Crossing:** An upper part should always play higher than a lower part
- **Opening/Closing Chord:** The piece should start and end with a C-major chord
- **Intervals:** Pure and dissonant intervals should be avoided
- **Total:** 15 rules

$\text{fitness}(\text{rule}_i) = \frac{n_i - v_i}{n_i}$

total fitness = $\sum_i (\omega_i \cdot \text{fitness}(\text{rule}_i))$

- n_i = Number of places where rule i could be violated
- v_i = Number of places where rule i actually is violated

EXAMPLE

$\text{fitness}(\text{rule}_i) = \frac{n_i - v_i}{n_i}$

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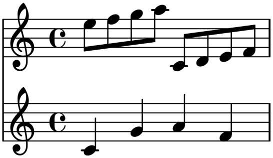

Leap Height:

- n_i = number of leaps = 10
- v_i = number of large leaps = 1
- fitness(Leap Hight) = $\frac{9}{10}$

Voice Crossing:

- n_i = num. of parallel notes = 4
- v_i = number of crossings = 2
- fitness(Voice Crossing) = $\frac{1}{2}$

Pro:

- Strong music-theoretical foundation
- Works well in practice

Contra:

- Humans need to define the rules for each genre (Cannot be automated)
- Some genres are hard to express by rules

SUMMARY

We discussed:

- Genetic algorithms
- Rule based fitness functions

Using these tools it is possible to generate interesting music without human interaction.

SOURCES

Papers:

- Patrick Donnelly, John Sheppard
  Evolving Four-Part Harmony Using Genetic Algorithms
  Applications of Evolutionary Computation, 2011, pp 273-282

Images:

- https://en.wikipedia.org/wiki/Johann_Joseph_Fux
- http://conferences.telecom-bretagne.eu/fps2012/program/slides/07.pdf
- http://www.angelfire.com/art2/speech-audio-seperat/
- http://www.well.com/user/bryan/last.gif
- http://graphics.stanford.edu/ bjohanso/papers/gp98/johanson98gpmusic.pdf
- https://www.youtube.com/watch?v=fK2MCXpDWB4

END