An evolutionary algorithm for harmonic music composition

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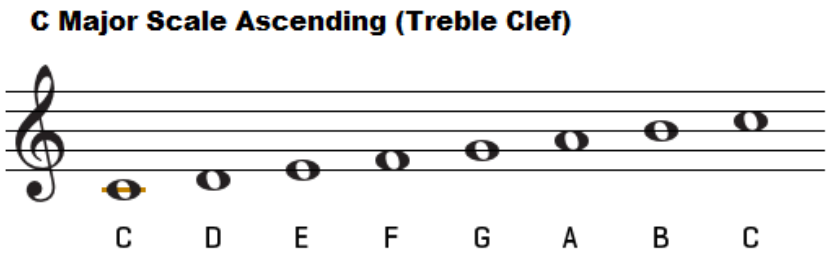
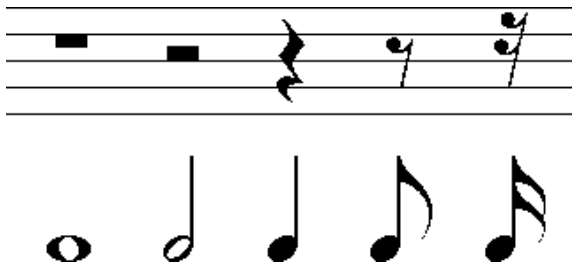
Outline

The harmonic music composition problem

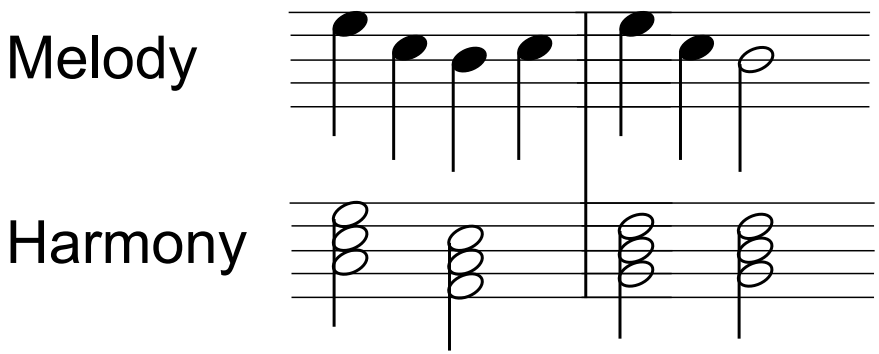
- Music can be represented as scores.
- A score consists of rests and notes with their octave and duration.
- Notes are C, D, E, F, G, A, B, and their respective sharps. Duration can be whole, half, quarter, etc.
- Other concepts, such as compasses and key and time signatures, are not considered in the problem formulation.





The harmonic music composition problem

- Harmonic music composition is the process of defining a set of notes representing melodies and harmonies.
- A melody is defined as an ordered set of notes.
- Harmony is the union of two or more melodies that generate harmonic intervals.



The harmonic music composition problem

- Mathematical formulation

  Find a score s_G, given:

  - A set of reference scores $S = \{s_1, \ldots s_N\}$, $|S| = N$;
  - A function $f : \{s_G\} \times S \rightarrow \mathbb{N}$ that evaluates similarity between two scores.

  The goal of the problem is to maximize the objective function OF, where $\alpha, \beta \in [0, 1]$ and $\alpha + \beta = 1$.

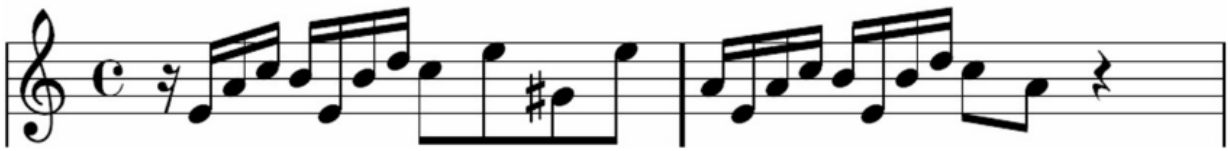
$$OF = \max \left\{ \alpha \times \underbrace{\frac{\sum_{s \in S} f(s_G, s)}{N}}_{\text{average similarity}} + \beta \times \underbrace{\max_{s \in S} f(s_G, s)}_{\text{closest score}} \right\}$$

Related work

- Studies on automatic music generation date back to the late 1950s.
- Several proposals, including: random numbers, formal grammars, cellular automata, fractals, and evolutionary computation.
- A summary of methods on automatic music composition is presented in Miranda (2001).
- Three main approaches:
  - generate completely random music.
  - construct compositions based on music rules, considering either melodies or harmonies.
  - generate compositions using entry sounds or scores.
- No previous attempts using EA to exploit the similarity between compositions by the same author.

EA for harmonic music composition

- We propose a parallel evolutionary algorithm, following the distributed subpopulations model.
- Solution encoding:
  - A musical score is represented by a string.
  - A note is represented by a set of characters: i) the note ii) "#" if the note is sharp; iii) the octave iv) the duration: *w*–whole, *h*–half, *q*–quartet, *i*–eighth and *s*–sixteenth.
  - *R* represents a rest, followed by its duration.
  - *V* represents a new voice.

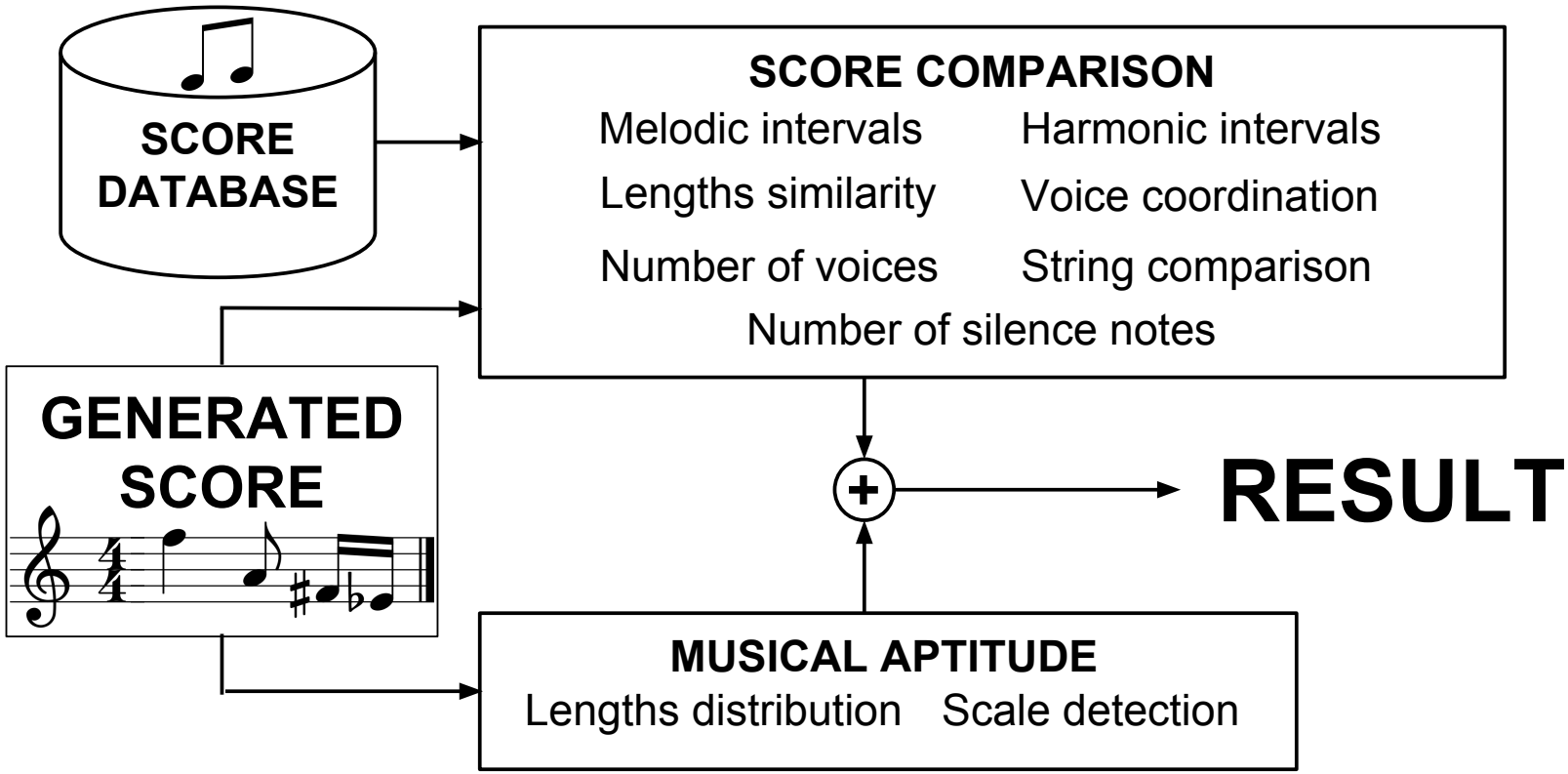


"Rs E5s A5s C6s B5s E5s B5s D6s C6i E6i G#5i
E6i A5s E5s A5s C6s B5s E5s B5s D6s C6i A5i Rq"

Example: extract of Bach's Inventio 13

EA for harmonic music composition

- Fitness function: seven score comparison criteria and two musical aptitude metrics.



EA for harmonic music composition

- Evolutionary operators:
  - *Selection.* Stochastic universal sampling operator.
  - *Recombination.* Single point list crossover.
  - *Mutation.* Four operators:
    1. random note modification.
    2. add or delete note.
    3. split or join note.
    4. voice order permutation.
  - *Migration.* Periodically exchanges randomly selected individuals between demes, considering an unidirectional ring topology.
- Evolution strategy: generational gap of populations, with elitism.
- Stopping criterion: stagnation during 10 epochs.

Results and discussion

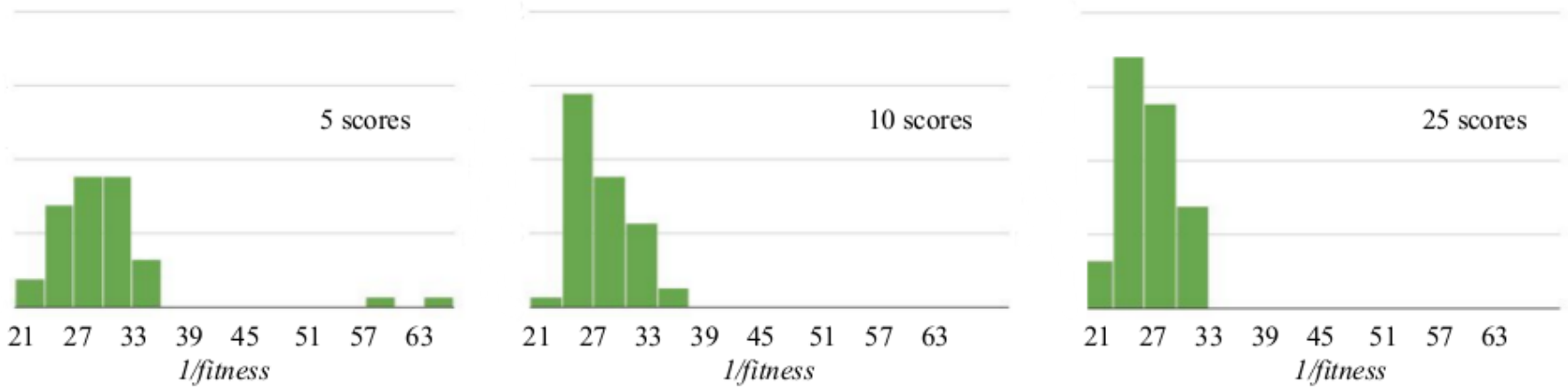
- Software and hardware platform:
  - EA implemented in Java using the Watchmaker framework.
  - Executions performed on a core i7-3770, 16 GB RAM, and Fedora 19.
- Parameter configuration experiments.
  - Preliminary experiments:
    - ★ Weights: $\alpha = 0.3, \beta = 0.7$.
    - ★ Number of demes: 8.
    - ★ Recombination probability: 0.75.
    - ★ Elite population: 5%.
  - 20 independent executions on a set of 10 scores by Bach and a stopping criterion of 400 generations.
    - ★ Mutation probability: $\{0.001, 0.005\}$.
    - ★ Generations per epoch: $\{40, 50\}$.
    - ★ Population per deme: $\{80, 100, 120\}$.
    - ★ Migrants per epoch: $\{5, 10\}$.

Results and discussion

- 3 databases with 5, 10, and 25 scores by Bach.
- 50 independent executions for each instance.

# scores	*1/fitness* ($\mu \pm \sigma$)	*time (s)* ($\mu \pm \sigma$)
5	30.1±2.6	454.8±113.4
10	27.3±2.6	413.6±108.9
25	27.1±2.9	378.9±95.5

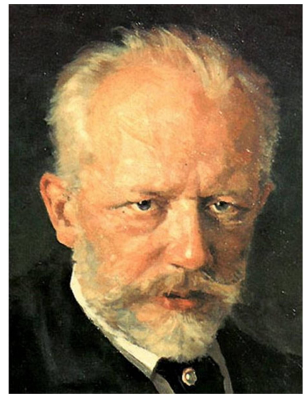
Better musical properties achieved with larger reference databases.



Results and discussion

- Similar results when using other composers as reference, on classical and rock music.






	Mozart	*Beethoven*	*Chaikovsky*	*The Beatles*
1/fitness ($\mu \pm \sigma$)	31.5±2.6	28.5±2.0	32.1±2.7	30.1±2.5
time (s) ($\mu \pm \sigma$)	414.2±101.1	393.5±99.3	418.31±109.7	390.67±96.4

Conclusions and future work

Conclusions:

- A parallel EA for harmonic music composition was presented.
- Fitness function uses score comparison against a reference database and musical aptitude metrics.
- Better musical attributes are obtained with larger reference databases.
- Accurate results are reported for three different Bach databases and for other classic and rock composers.

Future work:

- Include other musical aptitude criteria.
- Execute in cluster/cloud to deal with larger databases.
- Evaluate other metaheuristics for harmonic music composition.

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Thanks for your attention