



On Harmony Search

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Learning from Musicians and Improv

- Music-inspired metaheuristic
 - *Observation*: aim of music is to search for perfect state of **harmony**
 - *Harmony* = finding optimality
- Improvisation process = search process
 - Pleasing perfect harmony determined by audio aesthetic standard



Miles Davis!

Some random
musicians?
*What did you
think engineers do
in their free time?*



Harmonics and Frequencies

- Aesthetic quality of instrument determined by:
 - Pitch (frequency)
 - Amplitude (loudness)
 - Timbre (sound quality)
 - Largely determined by harmonic content
 - Harmonic content determined by waveforms/modulations of sound signal
 - Harmonics generated depend on pitch or frequency range of instrument



Music, a search process
you did not know was a
search process all
along...

Note Frequency Analysis



Figure 15.2 Random music notes.

- Different notes have different frequencies
 - Note A4 (above middle C) has fundamental frequency $f_0 = 440$ Hz
 - Speed of sound in dry air $v = 331 \pm 0.6T$ m/s where T is temperature (degrees Celsius), @ room temp $T = 20$ °C so A4 has wavelength $\lambda = \frac{v}{f_0} \approx 0.7795$ m
- When we change pitch, we trying to change frequency
- Pitch p in Musical Instrument Digital Interface (MIDI) represented in a linear pitch space via:
 - $p = 69 + 12 \log_2\left(\frac{f}{440 \text{ Hz}}\right)$ or $p = 440 * 2^{(p-69)/12}$
 - A4 has pitch number 69 (octaves = size 12, semitone = size 1),
 - Ratio of note frequencies one octave apart = 2:1, thus, frequency of note is doubled when raised an octave (or halved when lowered one octave)
 - Frequency of A2 is 110 Hz, A5 is 880 Hz

Creating Harmony

- Measurement of harmony when different pitches occur at same time is somewhat subjective (an aesthetic quality)
 - Can use Pythagoras' frequency ratio method to estimate quality
 - Octave w/ 1:2 ratio sounds pleasant when play together, notes w/ 2:3 ratio
 - Random notes put together unlikely to produce pleasant harmony

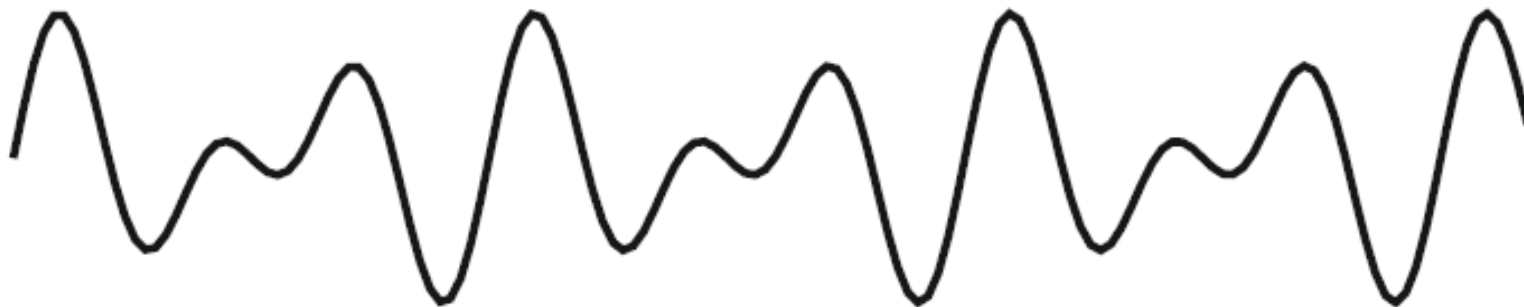


Figure 15.1 Harmony of two notes with a frequency ratio of 2:3 and their waveform.

Harmony Search Dynamics

Pseudo code of the Harmony Search algorithm (HSA)

Begin;

Define objective function $f(x)$, $x=(x_1, x_2, \dots, x_d)^T$

Define Harmony Memory Considering rate (HMCR) r_{accept}

Define Pitch adjusting rate (PAR) and other parameters

r_{pa} Generate Harmony Memory with random harmonies

while ($t < \text{max number of iterations}$)

while ($i \leq \text{number of variables}$)

if ($\text{rand} < \text{HMCR}$),

Choose a value from HM for the variable i

if ($\text{rand} < \text{PAR}$),

Adjust the value by adding certain amount

end if

else

Choose a random value

via ρ_a **end if**

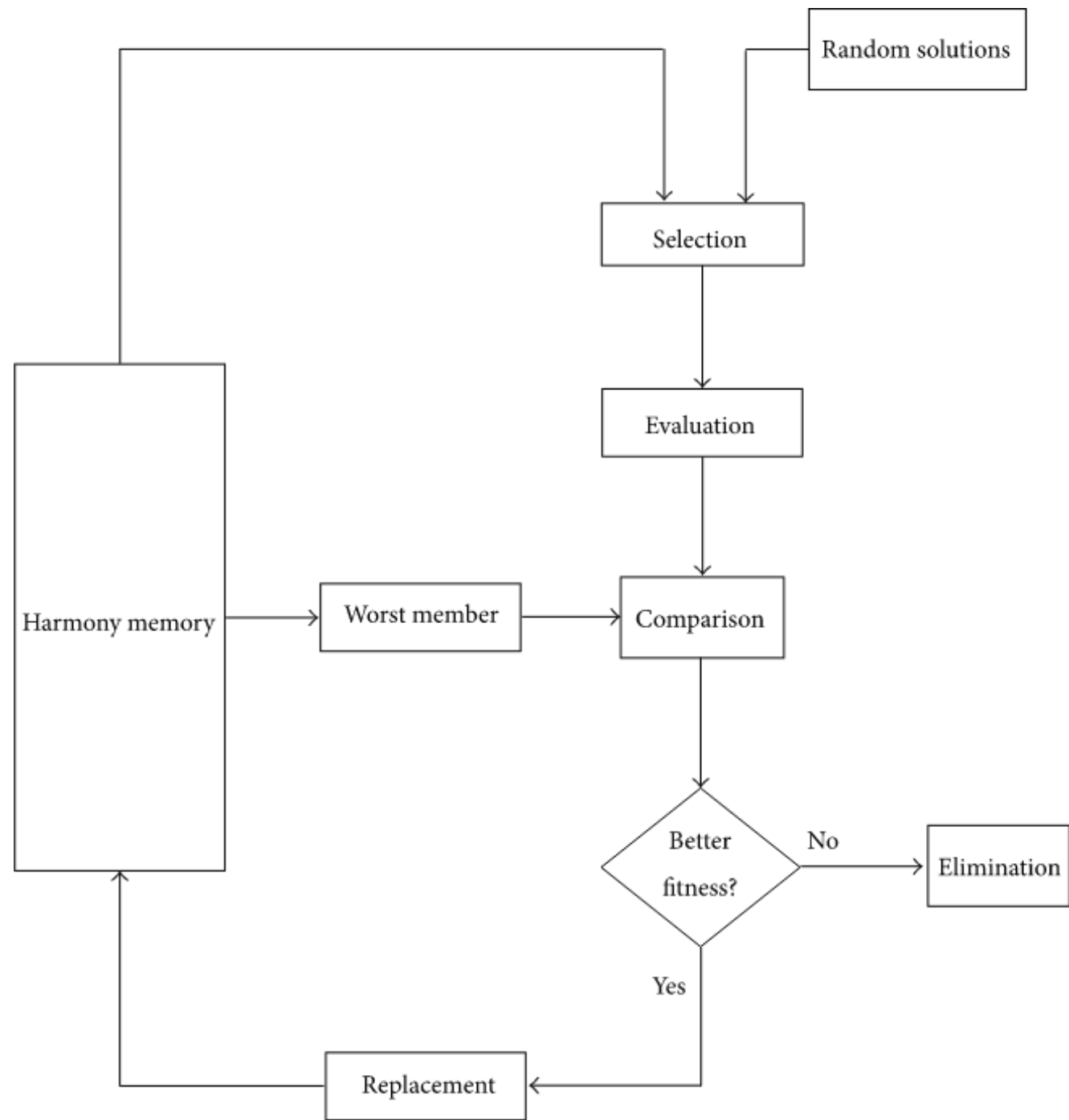
end while

 Accept the New Harmony (solution) if better

end while

Find the current best solution(s)

end



Harmony Search in Action

- <https://www.youtube.com/watch?v=4UqALf9mGas>

Applications

- Water distribution network optimization
 - Groundwater modeling
 - Energy-saving dispatch optimization
 - Structural design modeling
 - Vehicle routing
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- Often combined with genetic algorithms (GAs) and/or particle swarm optimization (PSO)

Questions?

