

Harmony Search Algorithm

Walter Squires



THE UNIVERSITY OF
TENNESSEE
KNOXVILLE

Test Questions

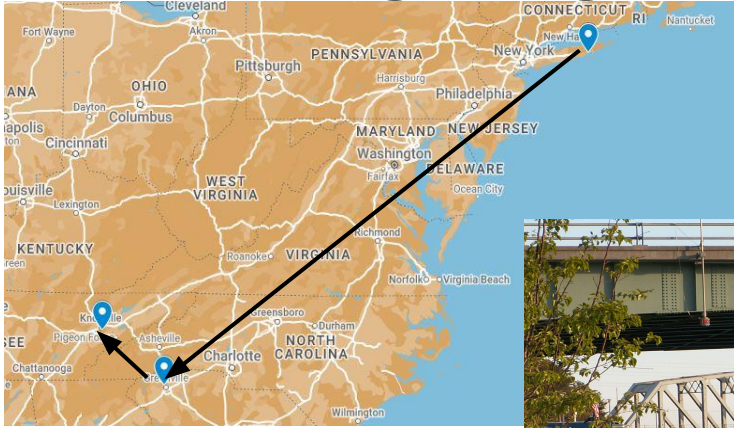
- What genre of music inspired the Harmony Search Algorithm?
- Is the Harmony Search Algorithm guaranteed to find the optimal solution?
- What were the *Harmony Memory Consideration Rate*, *Pitch Adjustment Rate*, and *Pitch Adjustment Magnitude* set to for the 0-1 Knapsack Problem Implementation?

Regarding Walter Squires, Professionally

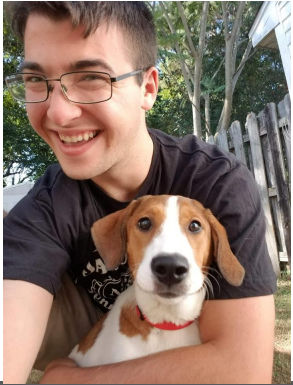
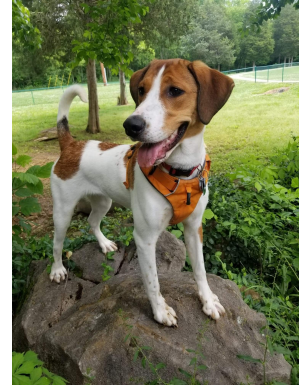
- Master's student (formerly PhD), Computer Science, Course Based
 - Advisor: Dr. James Plank (formerly Dr. Doowon Kim)
 - Research: None
 - GTA: 401 & 402 (this year and last)
- B.S., Computer Science (Iona College, now Iona University)
 - Advisor: Dr. Paolina Centonze
 - Research: Mobile Application Security
- Employment Fall '23
 - Assistant Teacher for the Adolescent Program at Knoxville Montessori School



Regarding Walter Squires, Personal Life



- Hometown: Hampton Bays, NY
- Engaged
- Dog Owner
- Vegetarian



- Don't travel much (might change)
- Board games
- Sustainability
- Too many half finished projects



Regarding Walter Squires, Consumption and Indulgence



Outline

- History of Optimization Algorithms
- Overview and Definitions
- Algorithm
- Applications
- Implementation
 - The 0-1 Knapsack Problem
 - Finding Global Maxima
- Open Issues
- References
- Questions

Optimization, A Brief History

- 1940's and 1960's
 - First algorithms for optimization problems developed
 - Examples: Simplex, Branch and Bound
- 1970's
 - Research in AI led to the exploration of heuristics to improve optimization algorithms
 - Evolutionary algorithms begin being explored
- 1980's and 1990's
 - Significant expansion of heuristic optimization problems
 - Simulated Annealing, Ant Colony Optimization, Particle Swarm Optimization, and more
- 2000's forward
 - Continued research and increased computational resources result in more sophisticated algorithms
 - 2001 - Harmony Search Algorithm

Optimization Algorithms vs. Heuristic Optimization Algorithms

- Optimization Algorithms are a class of algorithms used to find a optimal solution to a problem
 - Can be exact or approximate
- Heuristic Optimization Algorithms are a subset of optimization algorithms
 - Use heuristics in order to search for an optimal solution
 - Designed to scale to large scale, complex problems
 - Not guaranteed to find the optimal solution
 - Should find a close to optimal solution
 - Generally flexible and adaptable to different problem domains

Harmony Search Algorithm

- Introduced in 2001 by Dr. Zong Woo Geem
- Algorithm took inspiration from how Jazz musicians improvise and riff off of each other while playing
- Random Search Technique
 - Similar to Genetic and Swarm Intelligence algorithms



Image: Kellen Popo

Terminology and Abbreviations

- Musicians ~ Decision Variables
- Notes ~ Values
- Harmony ~ Solution to the fitness function
- Harmony Memory ~ HM ~ A stored note with an associated fitness score
- A Wrap ~ Meets Termination Criteria
- Harmony Memory Size ~ HMS
- Harmony Memory Considering Rate ~ HMCR
- Pitch Adjusting Rate ~ PAR
- Pitch Adjustment Magnitude ~ PAM

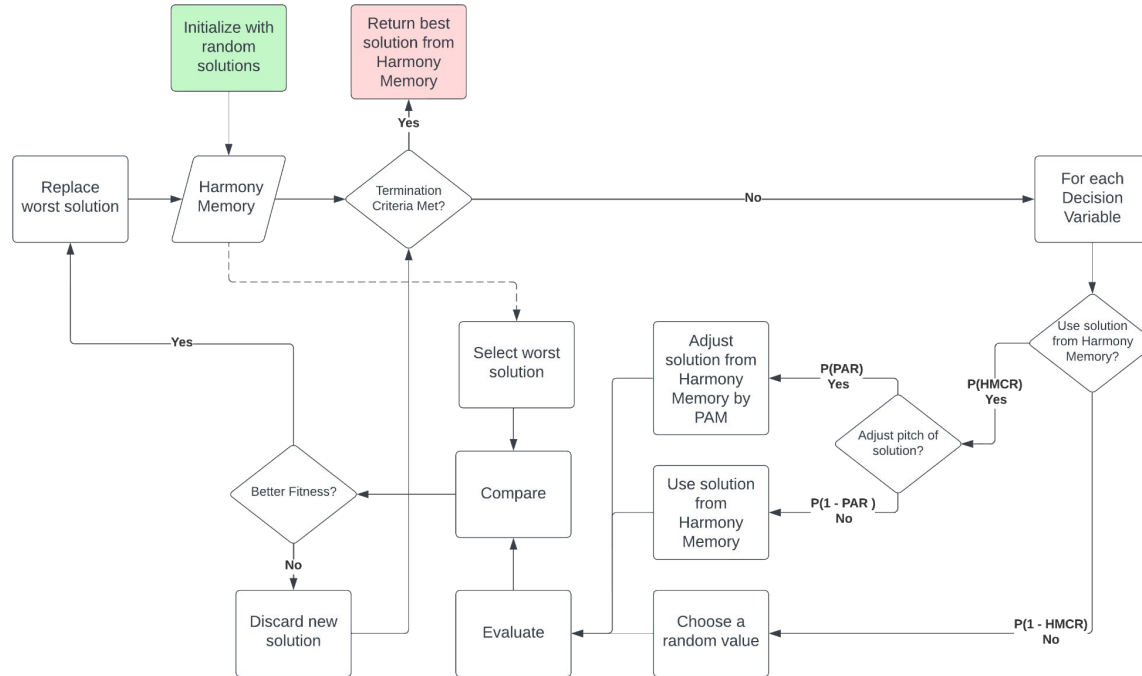
HSA, Conceptually

- Each musician writes down some notes on a piece of paper
- Then, until the band leader calls a wrap
 - Each musician plays a note
 - Most of the time, the note is from the piece of the piece of paper
 - Sometimes the musician changes the pitch of that note
 - Rarely, the musician will chose to just play a random note they are capable of producing
 - The band leader evaluates how well those notes sound together
 - If the new harmony sounds better than the worst harmony on the paper, replace the worst known harmony with this one
- The best known harmony gets made into a song



Image: uDiscoverMusic

HSA, In practice



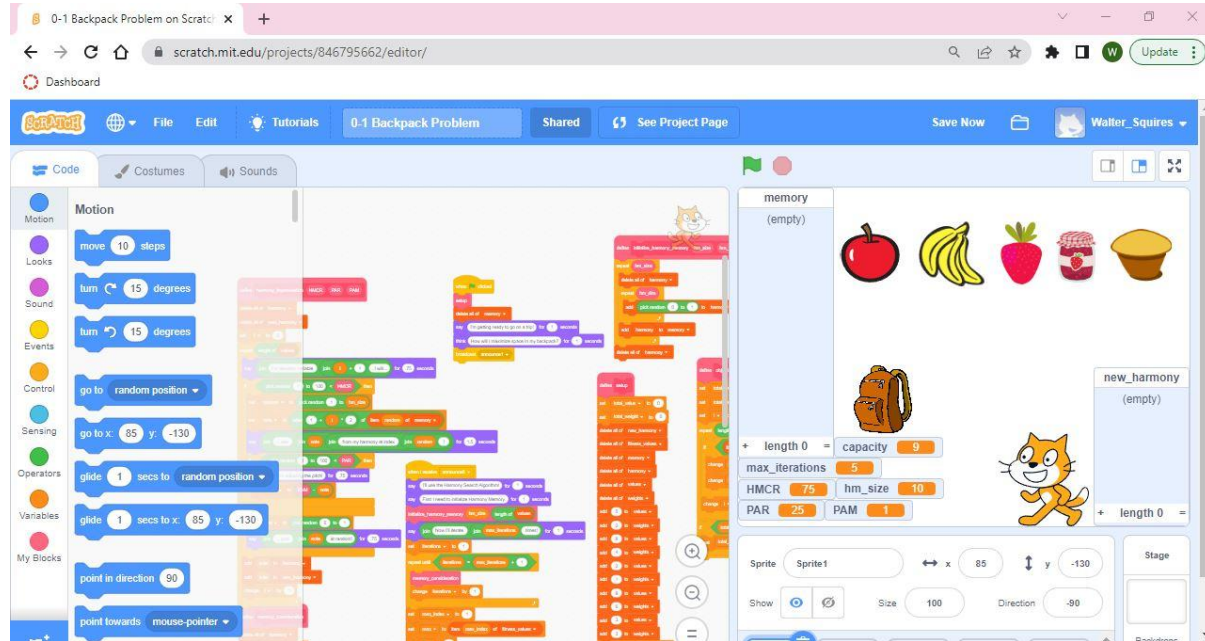
Applications

- Industry
 - HS algorithm by Saka finds optimal steel section designations while considering BS5950 design constraints.
- Power Systems
 - A modified HS algorithm has been proposed for nonconvex economic load dispatch in real-world power systems.
- Signal and Image Processing
 - Used in pre-training process of weight selection to make target more conspicuous saliency maps

0-1 Knapsack Problem Implementation

- 0-1 Knapsack Problem
 - Values = [5, 8, 2, 9, 3]
 - Weights = [2, 4, 1, 6, 3]
 - Capacity = 9
- Optimal Solution = 16 ([1, 1, 0, 0, 1] or [1, 0, 1, 1, 0])
- Greedy Solution = 15 ([1, 1, 1, 0, 0])
- Can the Harmony Search Algorithm do better?

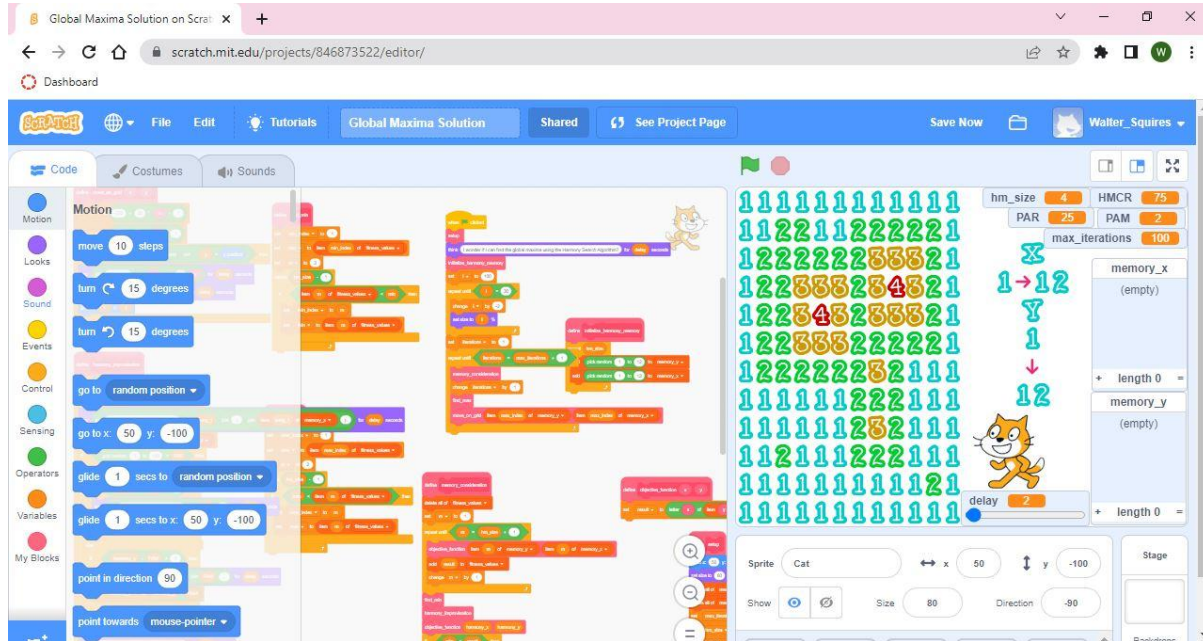
0-1 Knapsack Problem Implementation



Finding the Global Maxima

- Given a two-dimensional space with six local maxima, with two that are global...
- Can we find one of the global maxima without getting stuck in a local maxima?
 - Enumeration?
 - Greedy Algorithms?
- Can the Harmony Search Algorithm do better?

Finding the Global Maxima



Running Time Summarized

- Initializing HM: $O(HMS)$
- Harmony Improvisation: $O(\text{Decision Variables})$
 - Harmony Memory Consideration: $O(1)$
 - Pitch Adjustment: $O(1)$
 - Randomization: $O(1)$
- Memory Consideration: $O(HMS)$
 - Search: $O(HMS)$
 - Evaluation: $O(1)$
 - Comparison: $O(1)$
 - Replacement by Index: $O(1)$
- Termination Criteria:
 - Worst Case: Never
 - Best Case: $O(HMS)$
 - Average Case: Dependent on what your termination criteria is

Open Issues

- Incorporating problem-specific knowledge
- Convergence rate and speed
- Handling high-dimensional optimization problems
- Local optima avoidance
- Parameter tuning

Sources

- X. Z. Gao, V. Govindasamy, H. Xu, X. Wang, K. Zenger, "Harmony Search Method: Theory and Applications", *Computational Intelligence and Neuroscience*, vol. 2015, Article ID 258491, 10 pages, 2015. <https://doi.org/10.1155/2015/258491>
- M. K. Saka, "Optimum design of steel skeleton structures," in Music-Inspired Harmony Search Algorithm, Z. W. Geem, Ed., Springer, Berlin, Germany, 2009.
- B. Jeddi and V. Vahidinasab, "A modified harmony search method for environmental/economic load dispatch of real-world power systems," *Energy Conversion and Management*, vol. 78, pp. 661–675, 2014.
- J. Li and H. Duan, "Novel biological visual attention mechanism via Gaussian harmony search," *Optik*, vol. 125, no. 10, pp. 2313–2319, 2014.
- Cormen Thomas H and Charles E Leiserson. *Introduction to Algorithms 3rd Edition*. 2009.
- Mahima Dubey, Vijay Kumar, Manjit Kaur, Thanh-Phong Dao, "A Systematic Review on Harmony Search Algorithm: Theory, Literature, and Applications", *Mathematical Problems in Engineering*, vol. 2021, Article ID 5594267, 22 pages, 2021. <https://doi.org/10.1155/2021/5594267>
- Askarzadeh, Alireza & Rashedi, Esmat. (2017). Harmony Search Algorithm. 10.4018/978-1-5225-2322-2.ch001.
- Yang, X. S. (2010). Harmony search as a metaheuristic algorithm. In Music-inspired harmony search algorithm (pp. 1-14). Springer, Berlin, Heidelberg.
- Nasir, Mohammad & Sadollah, Ali & Yoon, Jin & Geem, Zong Woo. (2020). Comparative Study of Harmony Search Algorithm and its Applications in China, Japan and Korea. *Applied Sciences*. 10. 3970. 10.3390/app10113970.
- Mahdavi, M., Fesanghary, M., & Damangir, E. (2007). An improved harmony search algorithm for solving optimization problems. *Applied Mathematics and Computation*, 188(2), 1567-1579.

Questions (Revisited)

- What genre of music inspired the Harmony Search Algorithm?
- Is the Harmony Search Algorithm guaranteed to find the optimal solution?
- What were the *Harmony Memory Consideration Rate*, *Pitch Adjustment Rate*, and *Pitch Adjustment Magnitude* set to for the 0-1 Knapsack Problem Implementation?

Discussion

- Questions?
- Comments?
- Concerns?
- Love it?
- Hate it?
- Tell me!