Particle Swarm Optimization 

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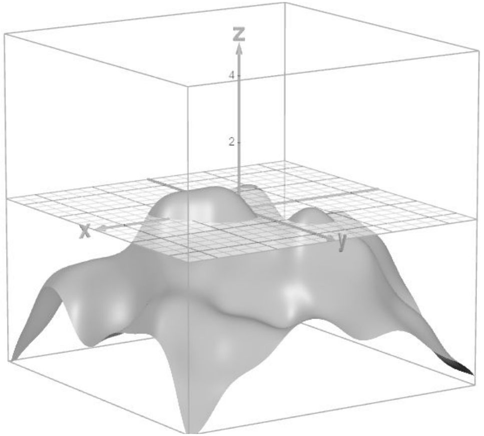
Motivation for Particle Swarm Optimization (PSO)

- Many models in ML, CS, Economics, and other fields are modeled by multivariable equations
  - E.g. how to properly allocate resources, designate tasks to employees, administer funding, etc
- Want to find the optimal solution to a problem/function
  - How can we find a good optimal solution? ML!
- Often in ML, algorithms converge to unintuitive or non-ideal solutions
- How can we create a model to find an optimal (or near optimal) solution to a problem?
  - i.e. a ‘metaheuristic’ model

Research Question

Is there a good enough machine learning model which allows us to find the global minimum/maximum of a function?

- James Kennedy (Social Psychologist) and Russell Eberhart (Electrical Engineer) - 1995
- Hard to find optimal solution in high-dimensional spaces or spaces with complex relationships between variables
- Need to explore all possibilities to find the global optimum
- Avoid bad solutions
- Converge towards ideal solution
- Computationally efficient



$$z = sin(x)cos(y) + 0.5sin(2x)sin(2y)cos(z) - 0.1(x^2 + y^2)$$

Algorithms which Aim to find Optimum

- Gradient Ascent/Descent
  - Finds gradient at current point which influences next step
  - Prone to ‘overstep’ and miss optimal soln

- Stochastic Searches
  - Randomly initializes points to find optimum
  - Often inaccurate

Both of the above models will often converge to local optimums depending on the functions and the tuning of hyperparameters

Conceptual Development of PSO

- Kennedy and Eberhart started looking at social models among different living beings to find optimal solutions

- Humans were too abstract and hard to model, so they turned to birds since they offer a more traceable pattern

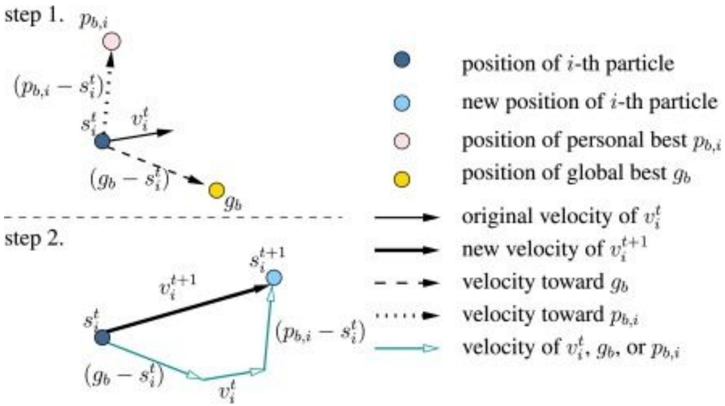
- Started off by copying one agents movement

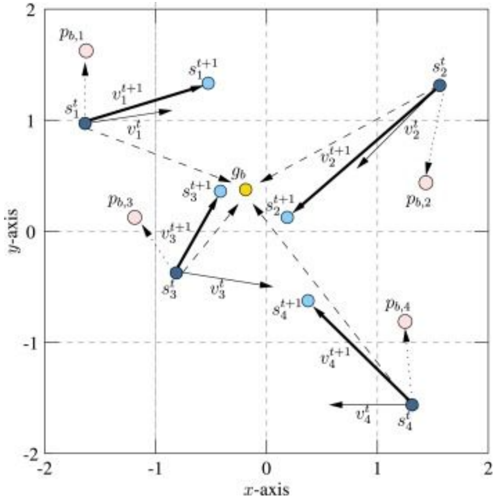
- Birds tend to ‘follow the leader’
  - To mimic this they added a variable of randomness

- Used contributions of Heppner to conclude that birds often find roosts to rest/rendezvous
  - Think of the roost as the global optimal solution
  - Implemented this instead of randomness
  - Many birds make pit-stops on the way to the roost
  - Kennedy and Eberhart modeled the above behaviors of birds into what we know as Particle Swarm Optimization (PSO)

How PSO Works Conceptually

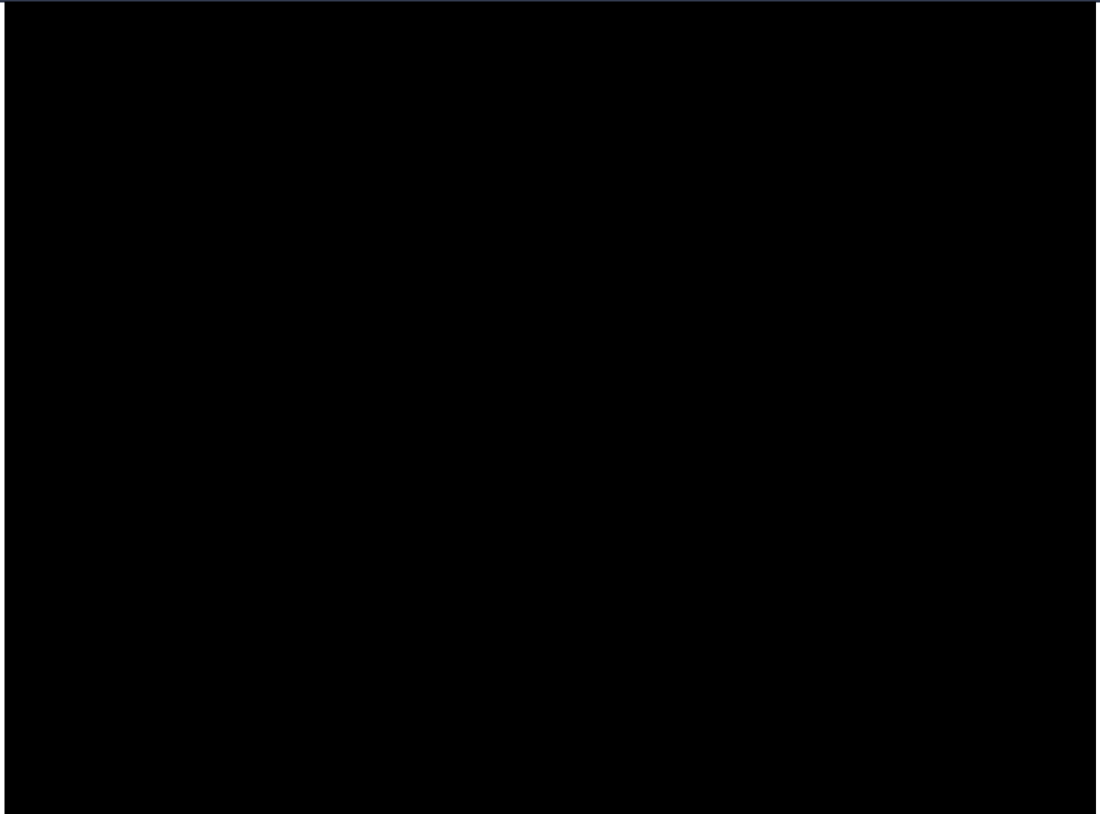
- Bird example
  - A flock of birds are migrating
  - Birds want to find the ‘updraft’ to fly higher
  - Each bird will move to try to find the best updraft in the area based on their current direction, their personal best updraft (which they’ve experienced), and the global best updraft (which the communicate with one another)
  - Keeps going until all birds reach updraft (converges)





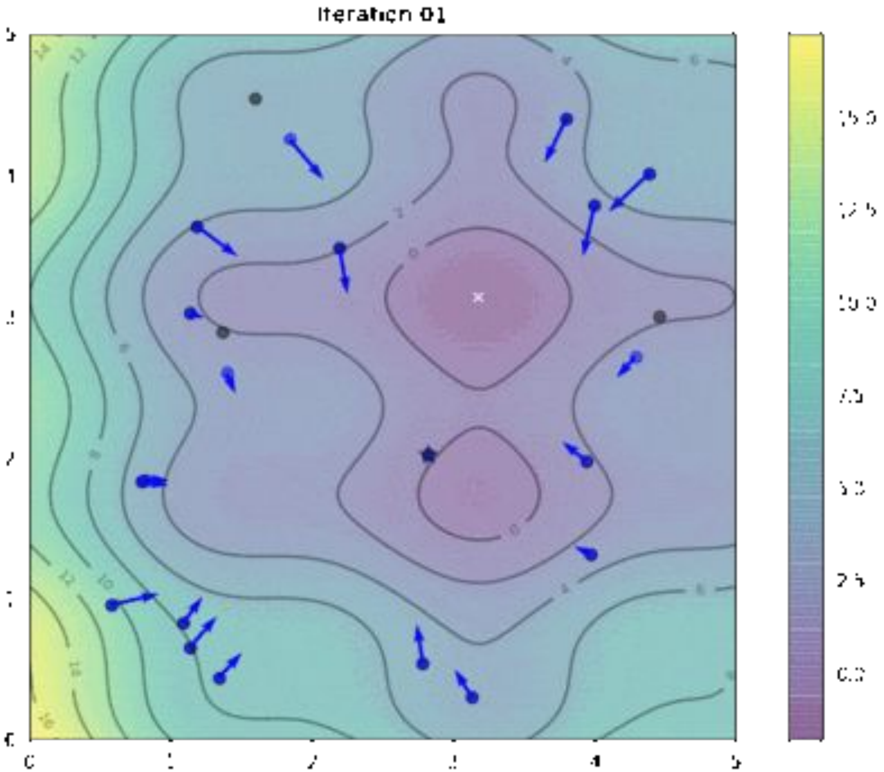
“In theory at least, individual members of the school can profit from the discoveries and previous experience of all other members of the school during the search for food.” – E. O. Wilson, sociobiologist on fish

Birds in Nature



PSO Algorithm

Initialize the positions s^0 and velocities v^0 of all particles $\boxed{\text{I}}$
Initialize the personal best of particles p_b^0 and global best g_b^0 $\boxed{\text{I}}$
While the termination criterion is not met
    $v^{t+1} = \text{NewVelocity}(s^t, v^t, g_b^t, p_b^t)$ using Eq. (9.1) $\boxed{\text{T}}$
    $s^{t+1} = \text{NewPosition}(s^t, v^{t+1})$ using Eq. (9.2) $\boxed{\text{T}}$
    $f^{t+1} = \text{Evaluation}(s^{t+1})$ $\boxed{\text{E}}$
    $p_b^{t+1} = \text{LocalBestUpdate}(s^t, s^{t+1}, f^t, f^{t+1})$ $\boxed{\text{D}}$
    $g_b^{t+1} = \text{GlobalBestUpdate}(s^t, s^{t+1}, f^t, f^{t+1})$ $\boxed{\text{D}}$
    $t = t + 1$
End
Output s $\boxed{\text{O}}$



Pros and Cons of PSO

Pros:

- Relatively Simple Algorithm
- Versatile
- Often reaches global optimization
- Less hyperparameters to be tuned than other models

Cons:

- Thrives in lower dimensions, has difficulty the more complex the model
- Can’t always guarantee the best solution
- Only limited to a certain region
- Sensitive to noise

Conclusion

- PSO aims to converge in certain environments where other algorithms fail.
- Biologically/Socially derived algorithm - modeled after birds
- Shows the power of evolutionary algorithms
- A simple and not-too intensive algorithm
- Used as a Neural Network training technique

Works Cited

- J. Kennedy and R. Eberhart, "Particle swarm optimization," *Proceedings of ICNN'95 - International Conference on Neural Networks*, Perth, WA, Australia, 1995, pp. 1942-1948 vol.4, doi: 10.1109/ICNN.1995.488968
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