**Original ACO (AntColonyClustering)**

• What it does: Mimics ants finding food by using "pheromones" (like a scent trail) to

guide data points to clusters. It balances exploration with a heuristic (based on K-

Means centroids) to group similar data points.

• Key feature: Uses a standard approach where all ants contribute to pheromone

updates based on how good their clustering is (measured by silhouette score).

• Summary: A classic ant-based clustering method that’s steady and reliable, using

K-Means to start and pheromones to refine clusters.

**ACO Variation 1 (AntColonyClusteringV1 - Random Centroids)**

• What it does: Similar to the original, but instead of using K-Means to set initial

centroids, it picks random data points as starting centroids. Only the best ant’s

solution updates the pheromones.

• Key feature: Random starting points make it more unpredictable, and the "elitist"

update focuses on the top-performing clustering.

• Summary: A bolder version of ACO that starts with random guesses and trusts only

the best ant to guide the clustering.

**ACO Variation 2 (AntColonyClusteringV2 - Davies-Bouldin)**

• What it does: Uses a different way to judge clustering quality, called the Davies-

Bouldin index, which prefers compact and well-separated clusters. Pheromone

updates are based on this score.

• Key feature: Focuses on minimizing the Davies-Bouldin score instead of maximizing

the silhouette score, aiming for tighter clusters.

• Summary: A pickier ACO that’s all about making clusters as distinct and compact

as possible, using a unique quality measure.

**ACO Variation 3 (AntColonyClusteringV3 - Exploitation)**

• What it does: Adds a switch where ants can either explore (try random clusters) or

exploit (pick the best-known cluster) based on a probability (q0).

• Key feature: The q0 parameter (e.g., 0.9) makes ants more likely to stick with the

best cluster choice, balancing exploration and confidence.

• Summary: A smarter ACO that can act decisively by often choosing the best cluster

but still explores new possibilities occasionally.

**ACO Variation 4 (AntColonyClusteringV4 - Density-Based)**

• What it does: Instead of using distances to centroids, it guides ants based on how

dense the data is around each point (using nearest neighbors).

• Key feature: The heuristic focuses on data density, so clusters form around areas

with many close points.

• Summary: A neighborhood-focused ACO that groups data based on crowded areas,

like clustering people in busy parts of a city.

**ACO Variation 5 (AntColonyClusteringV5 - Dynamic Evaporation)**

• What it does: Adjusts how quickly pheromones fade over time (evaporation rate)

and resets pheromones if the clustering gets stuck.

• Key feature: The evaporation rate decreases as iterations progress, and

pheromones can restart to avoid dead ends.

• Summary: A flexible ACO that adapts over time and shakes things up if clustering

stalls, like refreshing a strategy when stuck