2.5 Gravitational Search algos

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- The GSA is based on the low of gravity and mass interactions.
- The solutions in the GSA population are called agents, these agents interact with each other through the gravity force.
- The performance of each agent in the population is measured by its mass.

Gravitational search algorithm (History and main i

- Each agent is considered as object and all objects move towards other objects with heavier mass due to the gravity force.
- This step represents a global movements (exploration step) of the object, while the agent with a heavy mass moves slowly, which represents the exploitation step of the algorithm.
- The best solution is the solution with the heavier mass.

Gravitational search algorithm

The main steps of the GSA can be summarized as follows.

➢ Step 1. The algorithm starts by setting the initial values of gravitational constant G_0, α, ε and the iteration counter t.

➢ Step 2. The initial population is generated randomly and consists of N agents, the position of each agent is defined by:

$$X_i(t) = (x_i^1(t), x_i^2(t), \ldots, x_i^d(t), \ldots, x_i^n(t)), \quad i = 1, 2, \ldots, N,$$

➢ Step 3.1. All agents in the population are evaluated and the best, worst agents are assigned.

➢ Step 3.2. The gravitational constant is updated as shown in Equation 1

•The gravitational constant G at iteration t is computed as follows.

$$G(t) = G_0 e^{-\alpha t/T} \qquad (1)$$

•Where G_0 and α are initialized in the beginning of the search, and their values will be reduced during the search. T is the total number of iterations.

➢Step 3.3. When agent j acts on agent i with force, at a specific time (t) the force is calculated as following:

$$F_{ij}^d(t) = G(t)\frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t) + \epsilon}(x_j^d(t) - x_i^d(t)) \qquad (8)$$

Where M_{aj} is the active gravitational mass of agent j, M_{pi} is the passive gravitational mass of agent i, $G(t)$ is gravitational constant at time t

➢Step 3.4. At iteration t, calculate the total force acting on agent i as following:

$$F_i^d(t) = \sum_{j \in Kbest, j \neq i} rand_j F_{ij}^d(t) \qquad (9)$$

Where $Kbest$ is the set of first K agents with the best fitness value and biggest mass

➢Step 3.5. Calculate the inertial mass as following:

$$m_i(t) = \frac{fit_i - worst(t)}{best(t) - worst(t)} \qquad (10)$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \qquad (11)$$

➢Step 3.6. The acceleration of agent i is calculated as following:

$$a_i(t) = \frac{F_i(t)}{M_{ii}(t)}. \qquad (12)$$

Where M_{ii} is inertia mass of agent i.

➢Step 3.7. The velocity and the position of agent i are computed as shown in Equations 6, 7

•During the search, the agents update their velocities and positions as shown in Equations 6, 7, respectively.

$$V_i(t+1) = rand_i \times V_i(t) + a_i(t). \qquad (6)$$

$$X_i(t+1) = rand_i \times V_i(t) + a_i(t). \qquad (7)$$

Quantum Gravitation search algo

Imagine each solution (agent) as a **mass in space**.

- Heavier (better fitness) → stronger gravity.
- Lighter → gets pulled toward heavy masses.
- Over time, the swarm of masses converges toward better regions.

In classical GSA, movement is deterministic (based on force and acceleration).
In **Quantum GSA**, movement is *probabilistic* — each particle moves according to a **quantum probability field**, not classical velocity.

In **Quantum GSA**, we *remove velocity*) and introduce **quantum-based motion**.
The idea is:
Particles *don't move deterministically* — instead, each particle exists in a **probability cloud** centered around the gravitational center.
So we model **position** probabilistically.

Quantum Position Update

$$x_i^{t+1} = x_i^t \pm L_i(t) \cdot \ln\left(\frac{1}{u}\right)$$

where:

- $u \sim U(0,1)$
- $L_i(t)$: quantum "radius" or **characteristic length**
- The ± symbol means a random direction

The quantum length $L_i(t)$:

It controls **exploration** — how far the particle can jump.

A common definition:

$$L_i(t) = \alpha \cdot |X_{gbest}(t) - X_i(t)|$$

or sometimes,

$$L_i(t) = \alpha \cdot |X_{center}(t) - X_i(t)|$$

where:

- X_{center} = center of mass (weighted mean of positions)
- α: contraction–expansion coefficient (decreases over time)

Center of Mass:

$$X_{center}(t) = \frac{\sum_i m_i(t) \cdot x_i(t)}{\sum_i m_i(t)}$$

So heavier (better) agents pull the "center" more toward them.
