GAME ENGINE II

Crowd Simulation

Hamzah Asyrani Sulaiman

What is Crowd Simulation?

Crowd simulation is the process of simulating the movement and behavior of large groups of characters in virtual environments.

Used in:

- Computer Games
- Film & Animation
- Military Training
- Architecture & Urban Planning
- Emergency Evacuation Simulation

Ref: Helbing, D., & Molnár, P. (1995). Social force model.

Why Do Games Need It?

- To make environments **feel alive and immersive**.
- To **populate open worlds efficiently** without manual placement.
- To **guide NPCs** in a believable manner.
- To **avoid collisions** and chaotic movement.
- To deliver **realistic group behaviors** (cheering, panic).

Types of Crowds

Type	Description	Examples
Casual	Walking, shopping, slow-paced.	City passersby, mall shoppers.
Expressive	Cheering, chanting, specific actions.	Concert audience, sports fans.
Aggressive	Riots, panic, fighting, chaotic.	Rioters, high-stress evacuation.
Organized	Coordinated, following a specific path.	Pilgrims, stadium lines, military.

Ref: Brown, R. (1958). Crowd Taxonomy in Sociology.

Three Major Approaches

Fluid / Continuum

Treats crowd as a continuous flow, like liquid or gas. Good for mass movement.

Flocking / Boids

Simulates local rules (separation, alignment, cohesion) for natural grouping.

Cellular Automata

Grid-based discrete simulation. Agents move between cells based on rules.

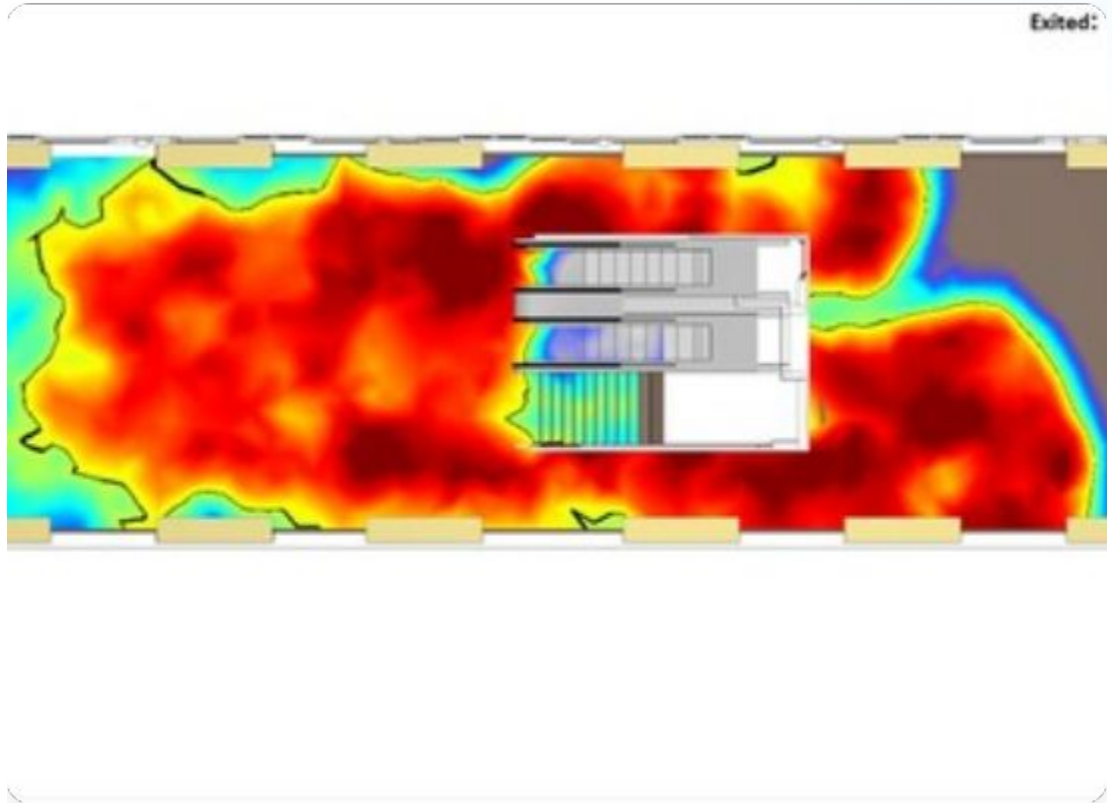
Ref: Leggett, J. (2004). Crowd Simulation Approaches.

Fluid (Continuum) Model

Crowd is treated like flowing liquid or gas, ideal for large-scale simulation.

Characteristics:

- **Smooth global movement** (mass flow).
- Good for **thousands of characters** (computationally efficient).
- Used heavily in **evacuation** and mass movement planning.



Flocking Model (Craig Reynolds)

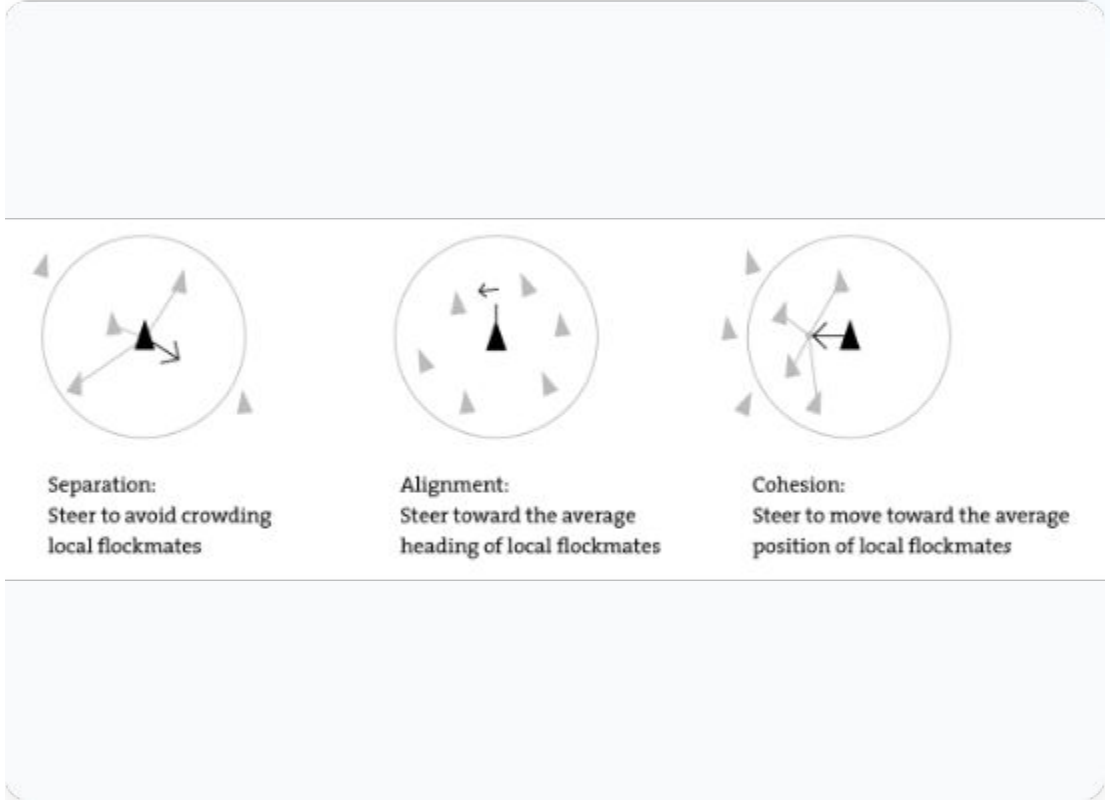
Simulates natural movement of birds, fish, and human clusters.

The Three Core Rules:

1. **Separation:** Avoid crowding neighbors.
2. **Alignment:** Follow group direction.
3 **Cohesion:** Stay near the group.

.

Ref: Reynolds, C. (1987). Flocks, Herds, and Schools.



Why Flocking Works in Games

Used to create believable group dynamics without calculating individual paths.

Applications:

- Group chasing/defending in sports games (e.g., FIFA).
- Enemy squads moving together (RTS/FPS).
- City crowd clustering.
- Animal herd behaviors.

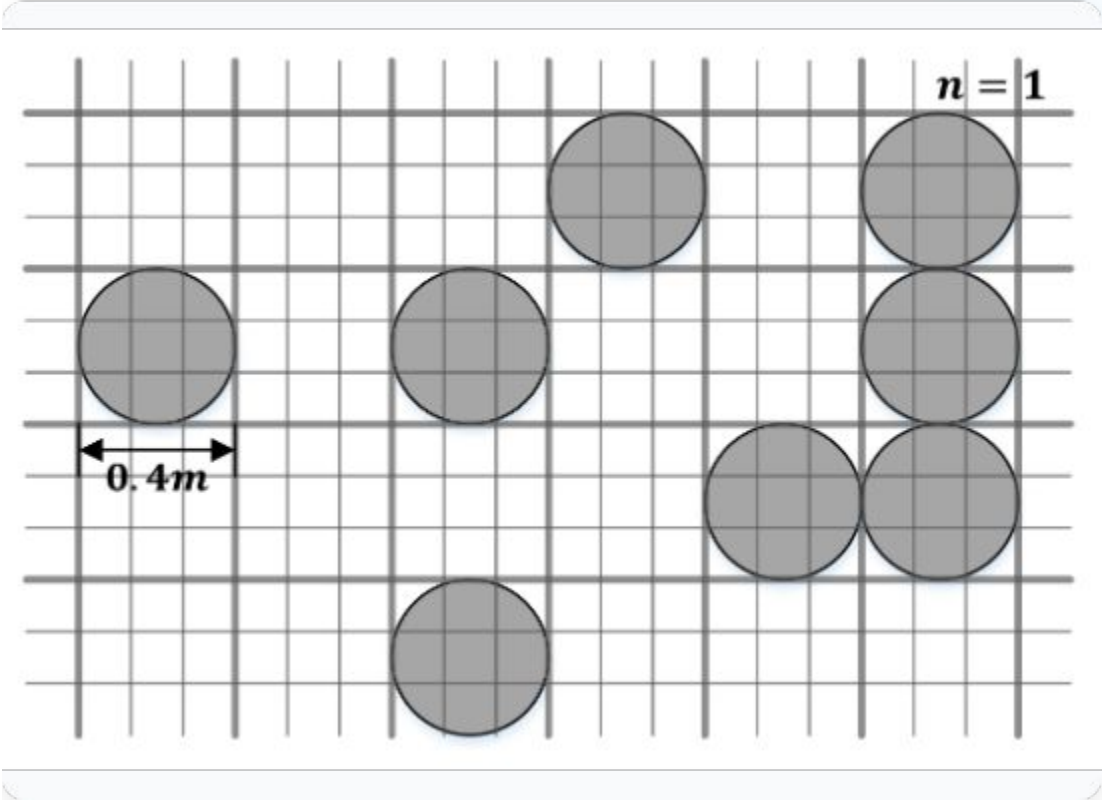
Cellular Automata (CA)

World is divided into grids. Each grid contains a pedestrian/NPC and updates every "tick".

Rules:

- Move if the next cell is empty.
- Avoid obstacles (blocked cells).
- Adjust direction based on surroundings.

Works best in corridors or structured spaces.



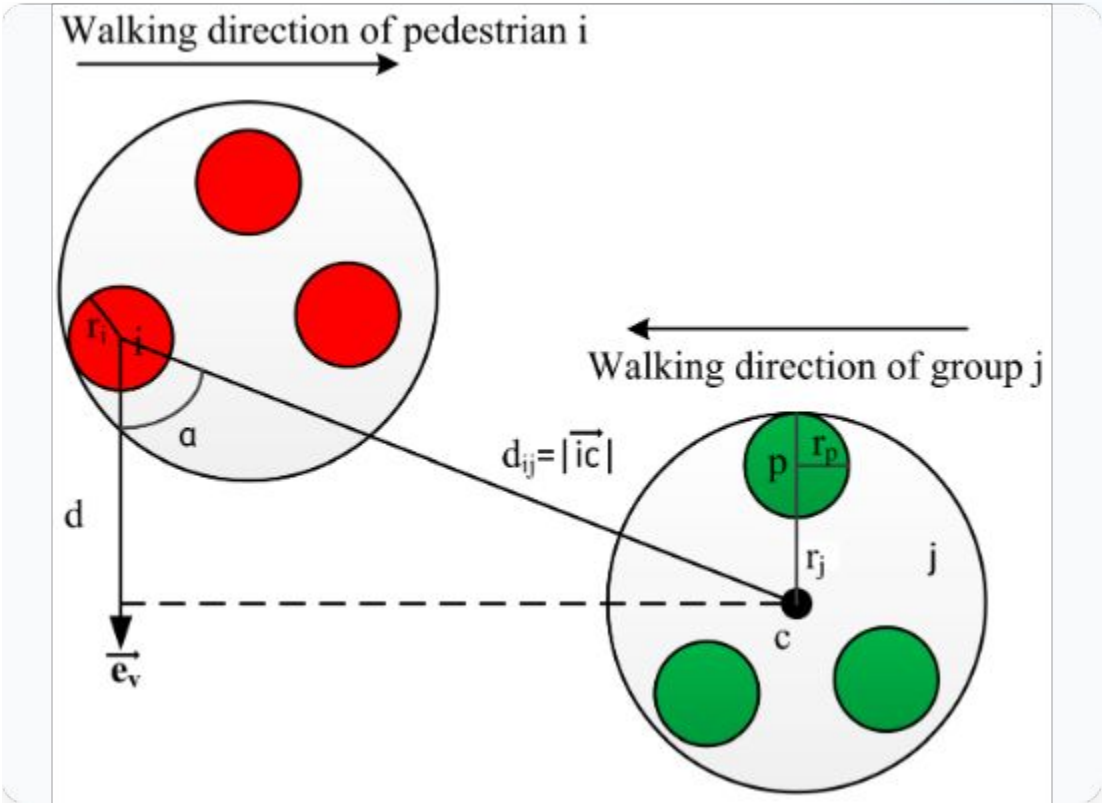
Social Forces Model

Each NPC is influenced by "forces":

- **Attractive force** → toward goal.
- **Repulsive force** → avoid other agents.
- **Obstacle force** → avoid walls/objects.

Important for:

- Panic simulations.
- High-density environments.



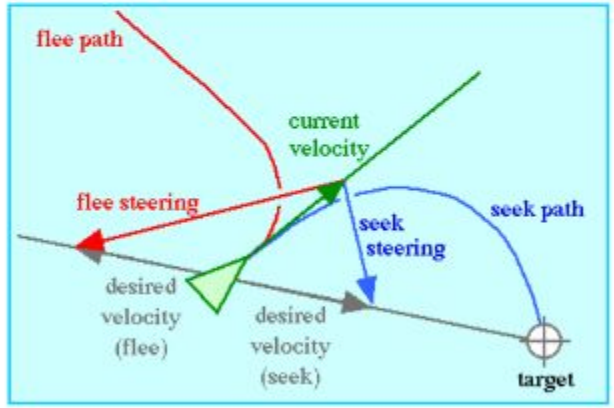
Steering Behaviors

Used to control individual NPC movement.

Includes:

- Seek / Flee
- Pursue / Evade
- Wander
- Path following
- Collision / Obstacle avoidance

Ref: Millington, I. (2019). Artificial Intelligence for Games.



Behavior Layer in Crowds

Crowd behavior is more than just walking. It is influenced by:

- Fear, panic, curiosity states.
- Attraction to events or objects.
- Line formation (queueing).
- Decision-making (AI).
- Group behavior scripts.

How Game Engines Implement It

Unity

- NavMesh + NavMesh Agents
- AI Navigation System
- Third-party crowd plugins (A* Pathfinding, Apex)

Unreal Engine

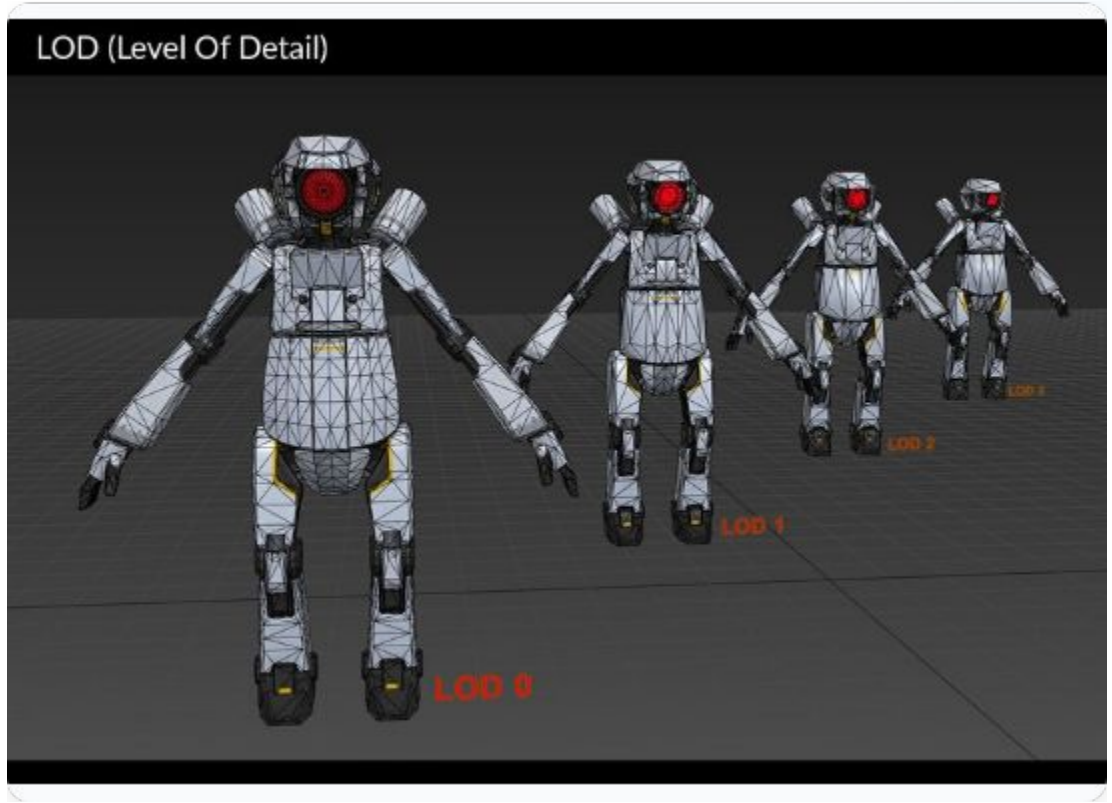
- Mass AI / Mass Crowd (ECS model)
- Can spawn thousands of agents
- Behavior Trees + EQS for decision making

Performance Optimizations

Games do NOT run full AI for every NPC.

Engine Techniques:

- **LOD (Level of Detail)** for animations/mesh.
- **Dummy NPCs** for background (no collision).
- Distance-based deactivation.
- GPU instancing.
- Navigation layers (active vs passive agents).



Case Studies

FIFA

Flocking for team movement & defense.

Assassin's Creed

Dense street crowd, state-based AI.

Hitman

Dynamic reactions & event detection.

Latest Advancements (2024–2025)

- **Reinforcement learning** for adaptive crowds.
- **Emotion-driven** simulation models.
- **Hybrid models** (Social Forces + AI).
- **GPU compute shader** crowd systems.
- Digital-twin crowd simulation for smart cities.

Tools for Students

Unity Tutorials

Unity Learn: Crowd Simulation Project

Unreal Mass AI

YouTube: "Unreal Engine Mass Crowd Demo"

Python Sim

GitHub: crowddynamics / crowddynamics-qtgui

Boids Demo

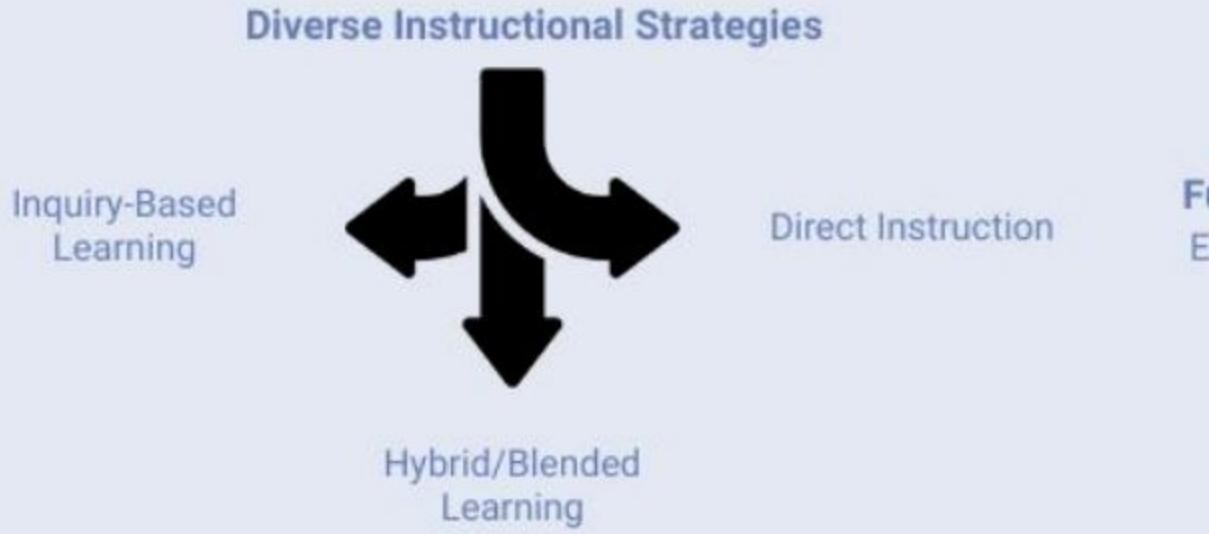
Search "Boids Algorithm" on GitHub.

Summary

Crowd simulation relies on:

- Movement Models (Fluid, Flocking, CA)
- Behavior Models & AI
- Navigation Systems
- Performance Optimizations

Used in: Games, Animation, Smart Cities, Evacuation.



Academic References

Reynolds, C. (1987). **Flocks, Herds, and Schools: A Distributed Behavioral Model.** SIGGRAPH.

Helbing, D., & Molnár, P. (1995). **Social Force Model for Pedestrian Dynamics.** Physical Review E.

Blue, V., & Adler, J. (2001). **Cellular Automata Microsimulation for Pedestrian Movement.**

Millington, I. (2019). **Artificial Intelligence for Games.** (Book)

Treuille, A. et al. (2006). **Continuum Crowds.** SIGGRAPH.

Thank You!

Questions? Discussion?

Image Sources

https://i.ytimg.com/vi/Rz2cNWVLncI/maxresdefault.jpg

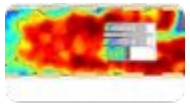
Source: www.youtube.com

https://i.redd.it/pjq7wgdy65l91.png

Source: www.reddit.com

https://static0.thegamerimages.com/wordpress/wp-content/uploads/2017/05/Assassins-Creed-Syndicate-Crowd.jpg?q=50&fit=crop&w=825&dpr=1.5

Source: www.thegamer.com



https://www.tandfonline.com/cms/asset/9212e4e0-5482-49a3-b8a2-2108b70a1c91/gtpt_a_2293056_f0013_oc.jpg

Source: www.tandfonline.com

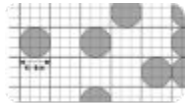
https://people.engr.tamu.edu/sueda/courses/CSCE450/2023F/projects/Frank_Martinez/boidsRules.png

Source: people.engr.tamu.edu

https://cdn.mos.cms.futurecdn.net/oKNRYevUHgNDNM6SqGf5fR.jpg

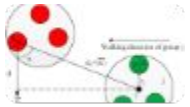
Source: www.gamesradar.com

Image Sources



https://www.mdpi.com/sustainability/sustainability-13-10621/article_deploy/html/images/sustainability-13-10621-g001.png

Source: www.mdpi.com



https://www.mdpi.com/ijgi/ijgi-07-00079/article_deploy/html/images/ijgi-07-00079-g001.png

Source: www.mdpi.com

https://edirlei.com/aulas/game-ai/GAME_AI_Lecture_07_Steering_Behaviours_2018_files/img_06.png

Source: edirlei.com

https://www.mdpi.com/digital/digital-05-00002/article_deploy/html/images/digital-05-00002-g005-550.jpg

Source: www.mdpi.com

https://www.cgspectrum.com/hs-fs/hubfs/different-LODs-3d-modeling.jpg?width=900&height=627&name=different-LODs-3d-modeling.jpg

Source: www.cgspectrum.com

https://i.redd.it/urlnp1pnd0if1.jpeg

Source: www.reddit.com

Image Sources

https://preview.redd.it/working-on-new-features-for-our-ue5-crowd-simulation-plugin-v0-za5m8j9wcrda1.jpg?width=1080&crop=smart&auto=webp&s=bf8d9e6aecf12d202625c5929c02fe2915374dfd

Source: www.reddit.com

https://pub.mdpi-res.com/encyclopedia/encyclopedia-05-00010/article_deploy/html/images/encyclopedia-05-00010-ag.png?1736996076

Source: www.mdpi.com