Flocking – Part 2
Formations and Crowds

Keeping formation and simulating crowd movement

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Flocking Recap

- 3 Forces are calculated:
  - Coherence
  - Separation
  - Alignment
- The forces are weighted:
  - Weighted Truncated Running Sum with Priority.
  - Distance based scaling.
- The forces are combined and applied to the agent.

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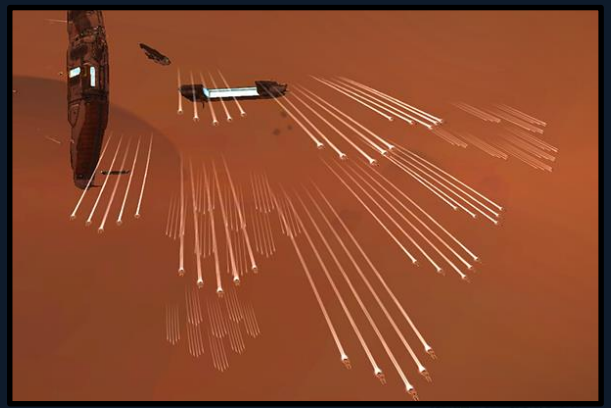
Formations

- Formations are another form of A.I. movement similar to flocking.
  - Common in strategy and air/space combat games.

Age of Empires

Ace Combat

Homeworld



Formations

- There are many ways to implement formations.
  - The exact approach will vary based on your needs.
- We'll take a look at a simple implementation.
  - Steering behaviours + an offset target from leader.

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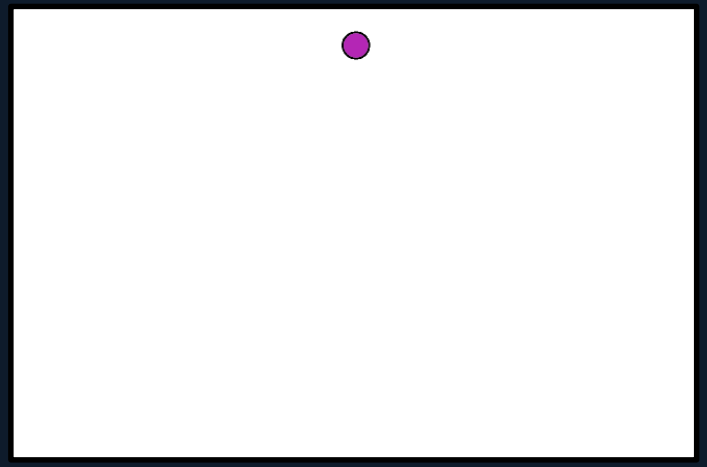
Formations

- First assign an agent as the formation leader



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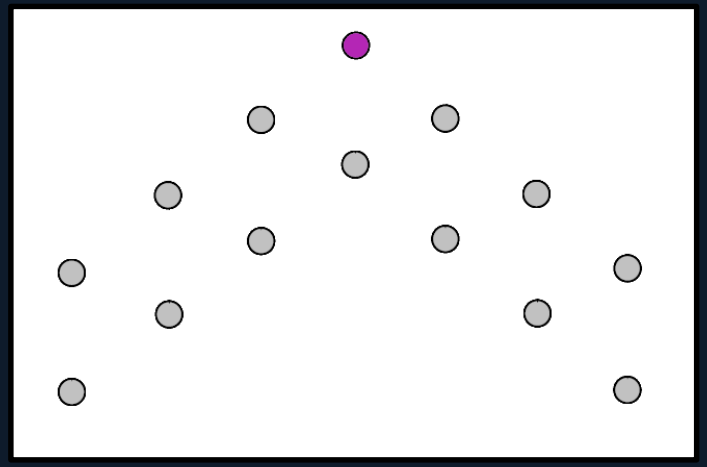
Formations

- Then assign other agents to the formation, and give them an offset position from the leader.



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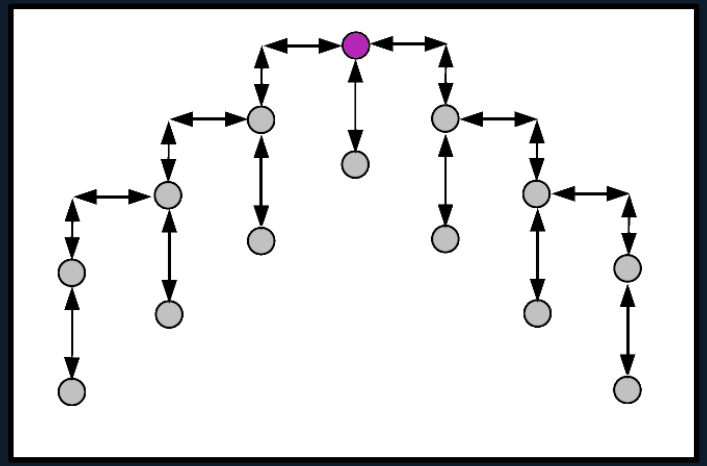
Formations

- An agent can now calculate their target position
  - *targetPosition = leader.transform * offset*



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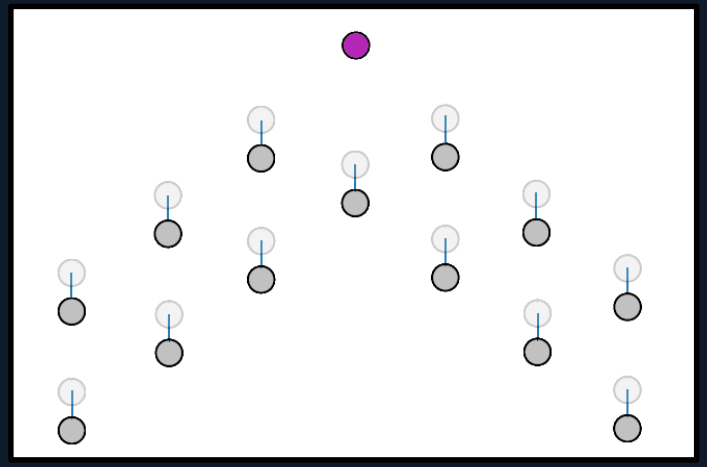
Formations

- Agents can then use Seek/Arrive to head towards their designated position within the formation.



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Formations

- What happens if the leader is removed?
  - Someone's gotta do it!
- Will agents in a formation collide with each other?
  - Apply a Separation force or similar.
- Should prevent potential gaps in the formation?
  - See references for a more advanced approach.

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Crowd Simulation

- Flocks/Formations:
  - Groups of agents travelling in unison (birds, fish, soldiers, fighter jets).
- Crowds:
  - Groups of agents travelling independently (pedestrians, shoppers).

Hitman: Absolution

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Crowd Simulation

- Simple method: wander/seek + separation/evade.
  - Doesn’t guarentee no collisions.
  - Only suitable for rudimentary crowd simulations.

Atom Zombie Smasher

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Crowd Simulation

- There are many ways to tackle crowd simulation.
  - The exact approach will vary based on your needs.
  - Much harder than other steering behaviours!

- Lets look at a solution developed by Gamma UNC called *Force-Based Anticipatory Collision Avoidance.*
  - Be warned, the following is an overview of a **very** advanced steering behaviour.
  - See references for detailed resources.

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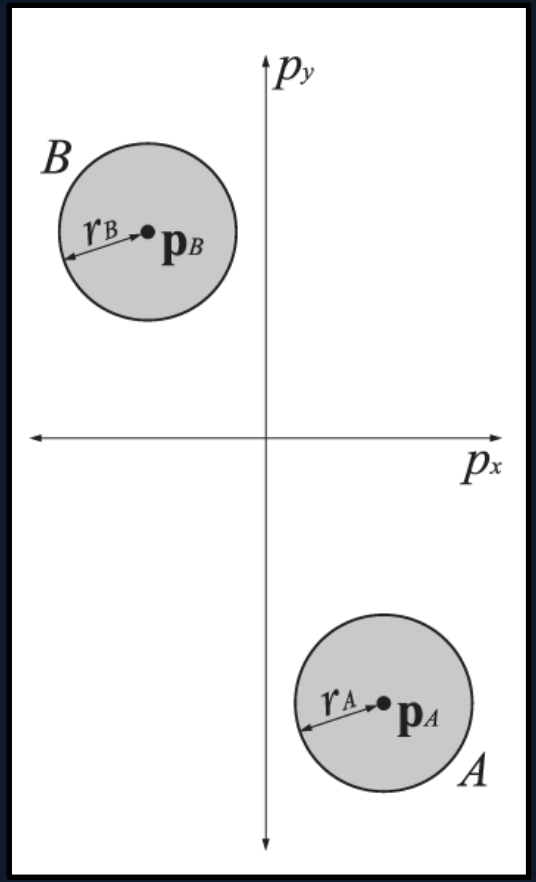
Crowd Simulation

- Given two agents, A and B with:
  - Position $\boldsymbol{p}$
  - Radius r
  - Velocity v
    - An agent's current velocity is not needed for the calculation. Our goal is to calculate a range of valid velocities to choose from, not alter an existing one.



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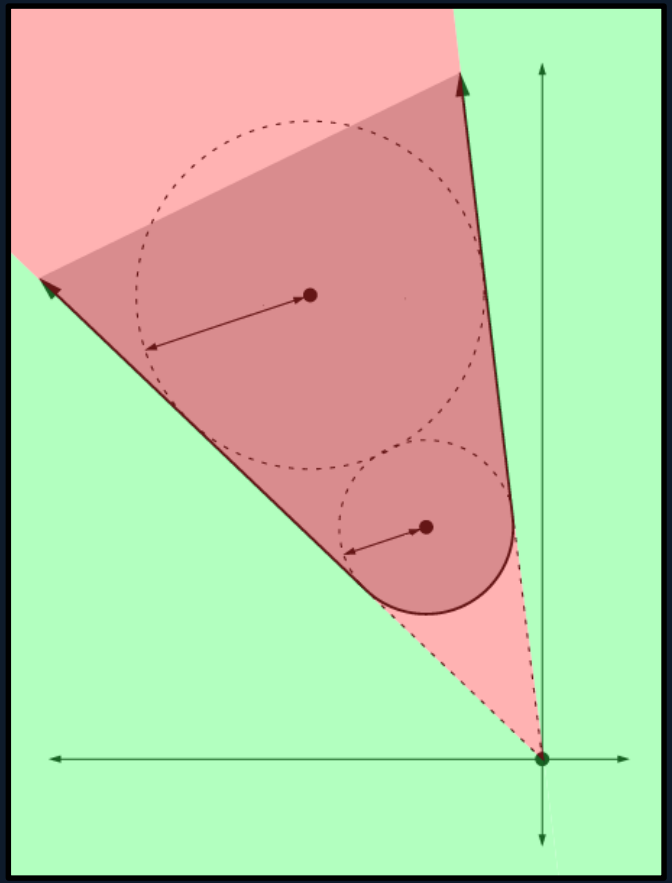
Crowd Simulation

[conceptual]

- Find the cone which defines all the possible relative velocities that would result in a collision.
  - We don't really need a cone shape, two lines that define an Isosceles triangle will serve our purpose.
  - This is velocity space, not coordinate space.



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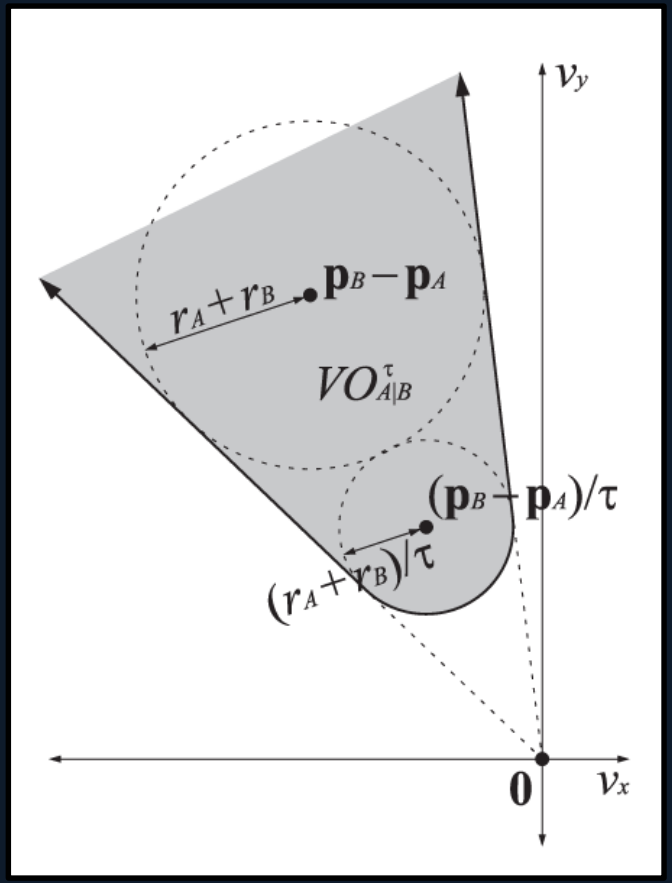
Crowd Simulation

[technical]

- Calculate the Velocity Obstacle, $VO^{\tau}_{A|B}$
  - The velocity obstacle for A induced by B for time window τ is the set of all relative velocities of A with respect to B that will result in a collision between A and B at some moment before time τ



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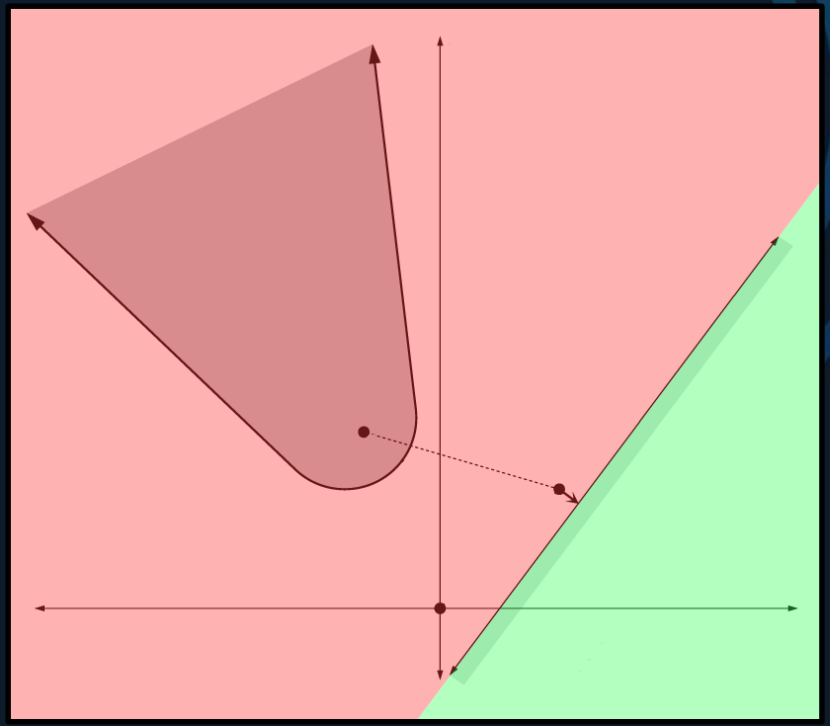
Crowd Simulation

[conceptual]

- Using the cone, create a line to mark the divide between collision-free velocities, and those that aren't.
  - The line is roughly perpendicular to the cone.
  - It is a reliable approximation.
    - (not 100% accurate but still guarantees no collisions).



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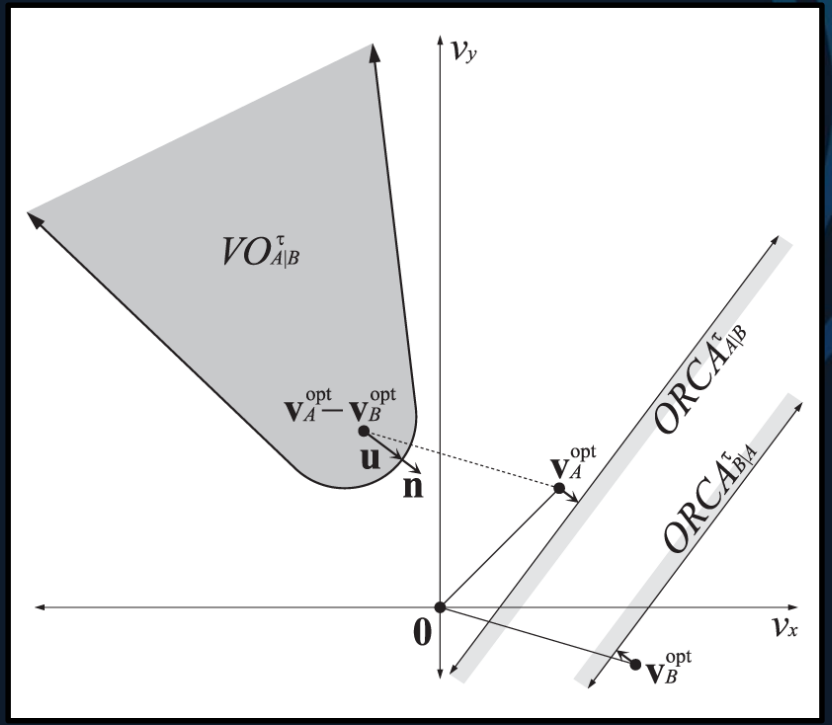
Crowd Simulation

[technical]

- Find the Optimal Reciprocal Collision Avoidance set $ORCA^{\tau}_{A|\{B\ldots n\}}$
  - The set of permitted velocities for A for optimal reciprocal collision avoidance with B is a half-plane delimited by the line perpendicular to $\boldsymbol{u}$ through the point $\boldsymbol{v_A^{opt}} + \frac{1}{2}\boldsymbol{u}$, where $\boldsymbol{u}$ is the vector from $\boldsymbol{v_A^{opt}} - \boldsymbol{v_B^{opt}}$ to the closest point on the boundary of $VO^{\tau}_{A|B}$



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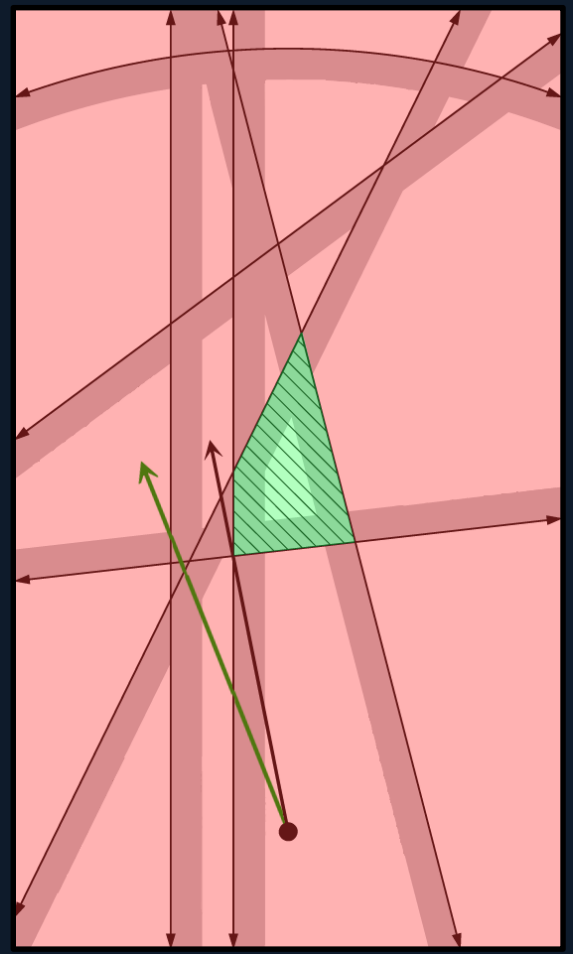
Crowd Simulation

[conceptual]

- Repeat this process to find all ORCA lines between a given agent and all other agents.
- Find the shape that defines all possible collision-free velocities.
- Choose the point within the shape that is closest to our desired velocity and use this as our current velocity.



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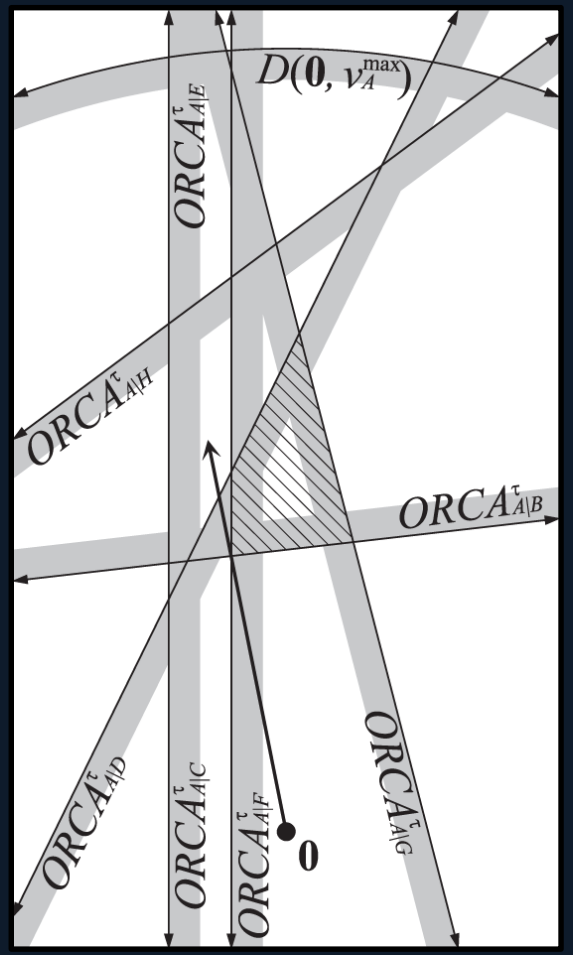
Crowd Simulation

[technical]

- Find the point with the closest heading to our desired velocity, as permitted by the $ORCA^{\tau}_{A|\{B\ldots n\}}$ set and assign to current velocity.
  - The dashed region is $ORCA^{\tau}_{A}$ and contains the velocities for A that are permitted with respect to all other agents. The arrow indicates the current velocity of A



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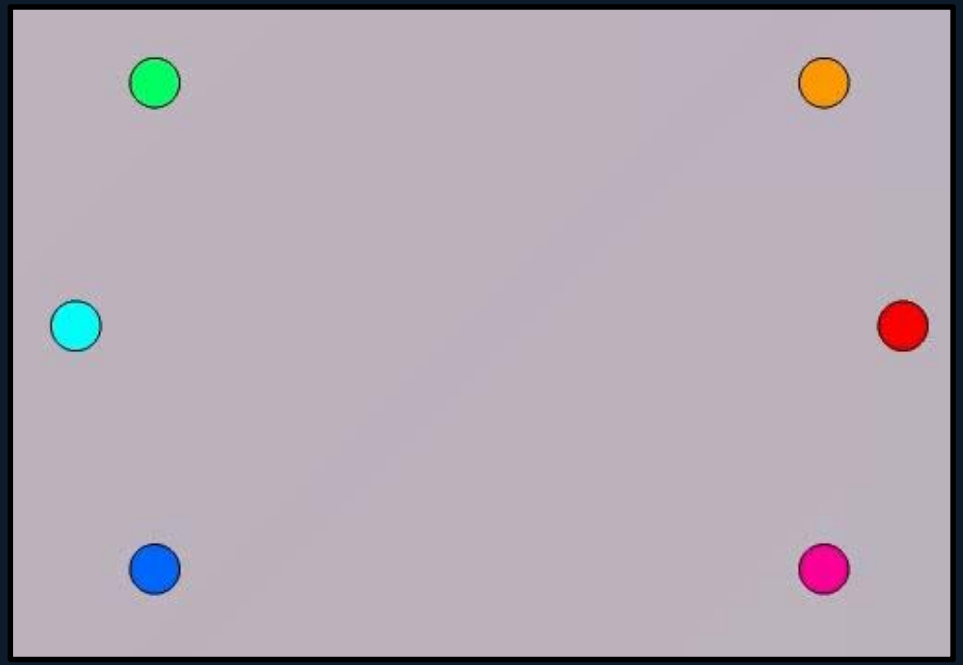
Crowd Simulation

- *Force-Based Anticipatory Collision Avoidance* in action!



http://gamma.cs.unc.edu/ORCA/videos/ORCA-1.wmv

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Crowd Simulation

- Fortunately Gamma UNC have created a publicly available code library which implements this technique, titled *RVO2 Library*
  - It's free to use for non-commercial purposes.
  - It's written in C++ and C#.
  - It's a great way to develop an understanding of how this technique really works when implemented.
  - See references for link.

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Summary

- Formations are a great way to create believable (often militaristic) movement and positional patterns.
- Crowd simulation allows large groups of agents to act independently with realistic and predictive movement behaviour.
  - And can be a very complex, academic subject.

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References

- Formation Techniques:
  - Millington, I. and Funge, J. (2009). *Artificial intelligence for games*. Burlington, MA: Morgan Kaufmann/Elsevier, pp.144 -166.
- Crowd Simulation:
  - Guy, S., Snape, J., Lin, M. and Manocha, D. (2015). *Optimal Reciprocal Collision Avoidance (ORCA)*. [online] Gamma.cs.unc.edu. Available at: http://gamma.cs.unc.edu/ORCA/
  - Gamma.cs.unc.edu, (2015). *RVO2 - Reciprocal Collision Avoidance for Real-Time Multi-Agent Simulation*. [online] Available at: http://gamma.cs.unc.edu/RVO2/

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