STEERING BEHAVIORS

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MOTIVATION

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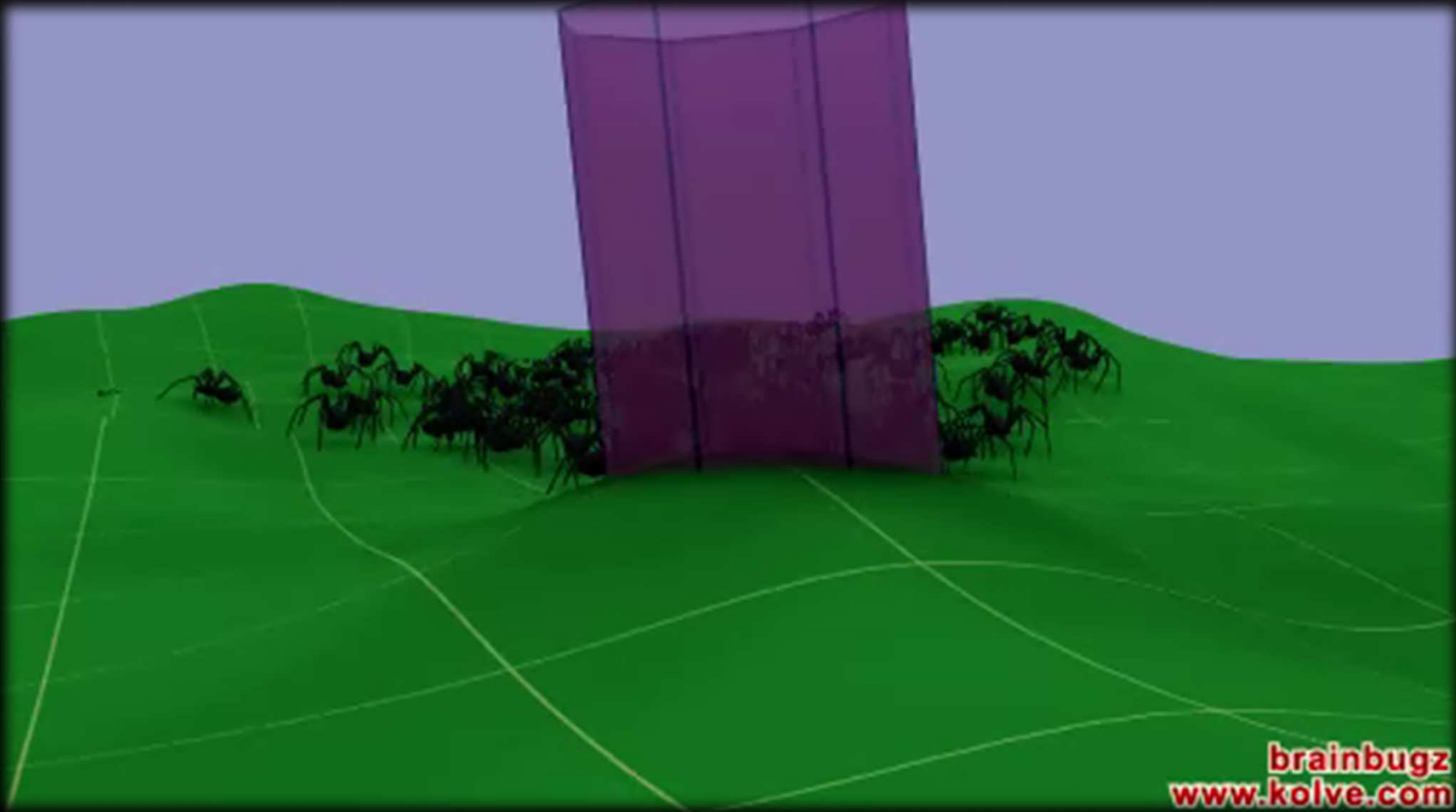
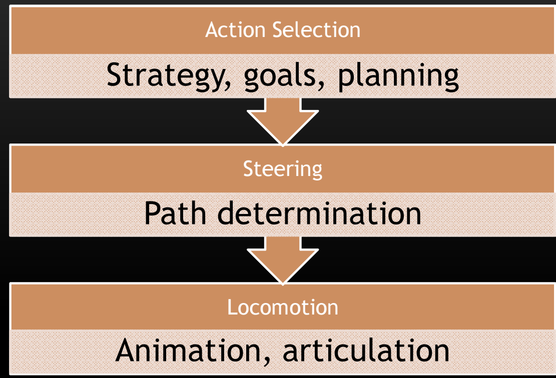


REQUIREMENTS FOR MOTION CONTROL

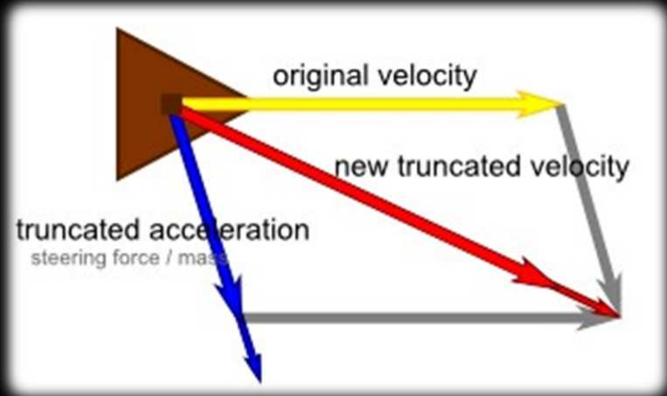
- Responding to dynamic environment
  - Avoiding obstacles and other agents
  - Interaction with environment and other agents
- Motion believability
- Speed of computation

- → One possible solution: Steering Behaviors by Craig W. Reynolds
  - 1986 Flocks, Herds, and Schools: A Distributed Behavioral Model [1]
    - Boids & Flocking Model
  - 1999 Steering Behaviors For Autonomous Characters [2]

STEERING BEHAVIORS - BASICS

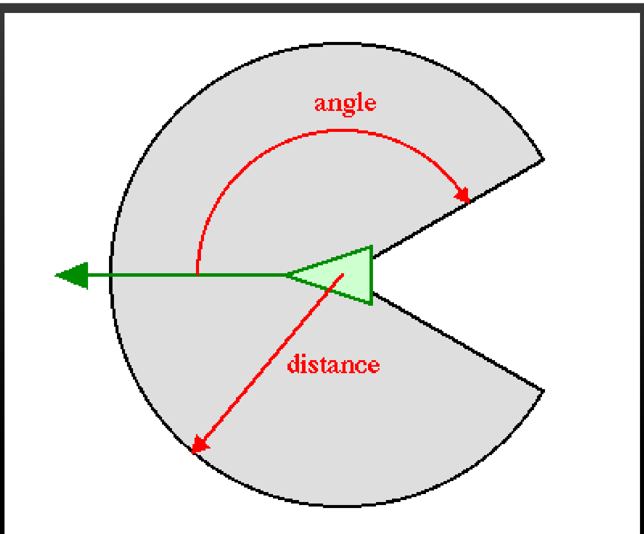


- Hierarchy of motion behavior
  - Action selection layer
  - Steering (navigation) layer
  - Locomotion layer
- Simple vehicle model
  - Scalars: mass, max_force, max_speed
  - Vectors: location, velocity, orientation
- One steering force:
  - acceleration = steering_force / mass → truncated by max_force
  - new_velocity = original_velocity + acceleration → truncated by max_speed
  - new_location = original_location + new_velocity



BOIDS & FLOCKING MODEL

- Boid (bird like object)
- Flocking Model → 3 steering rules



Separation

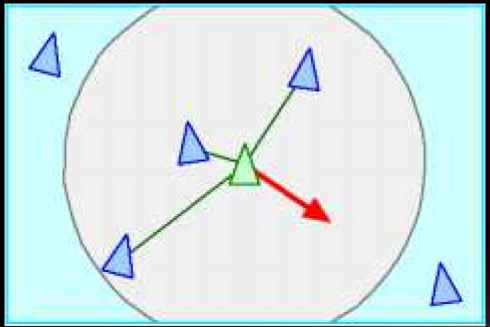
- Do not get too close to nearby flockmates

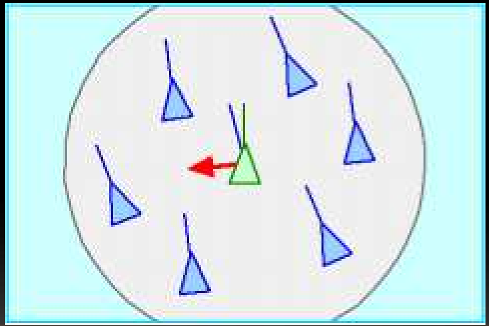
Alignment

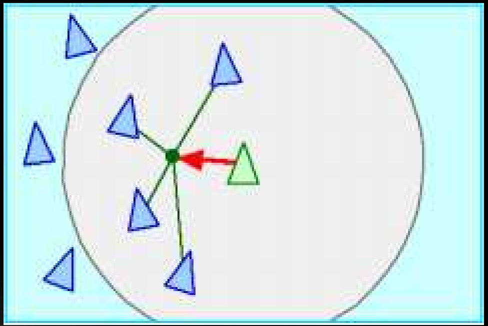
- Try to move at the same speed and direction (velocity) as nearby flockmates

Cohesion

- Prefer to be at the center of the local flockmates



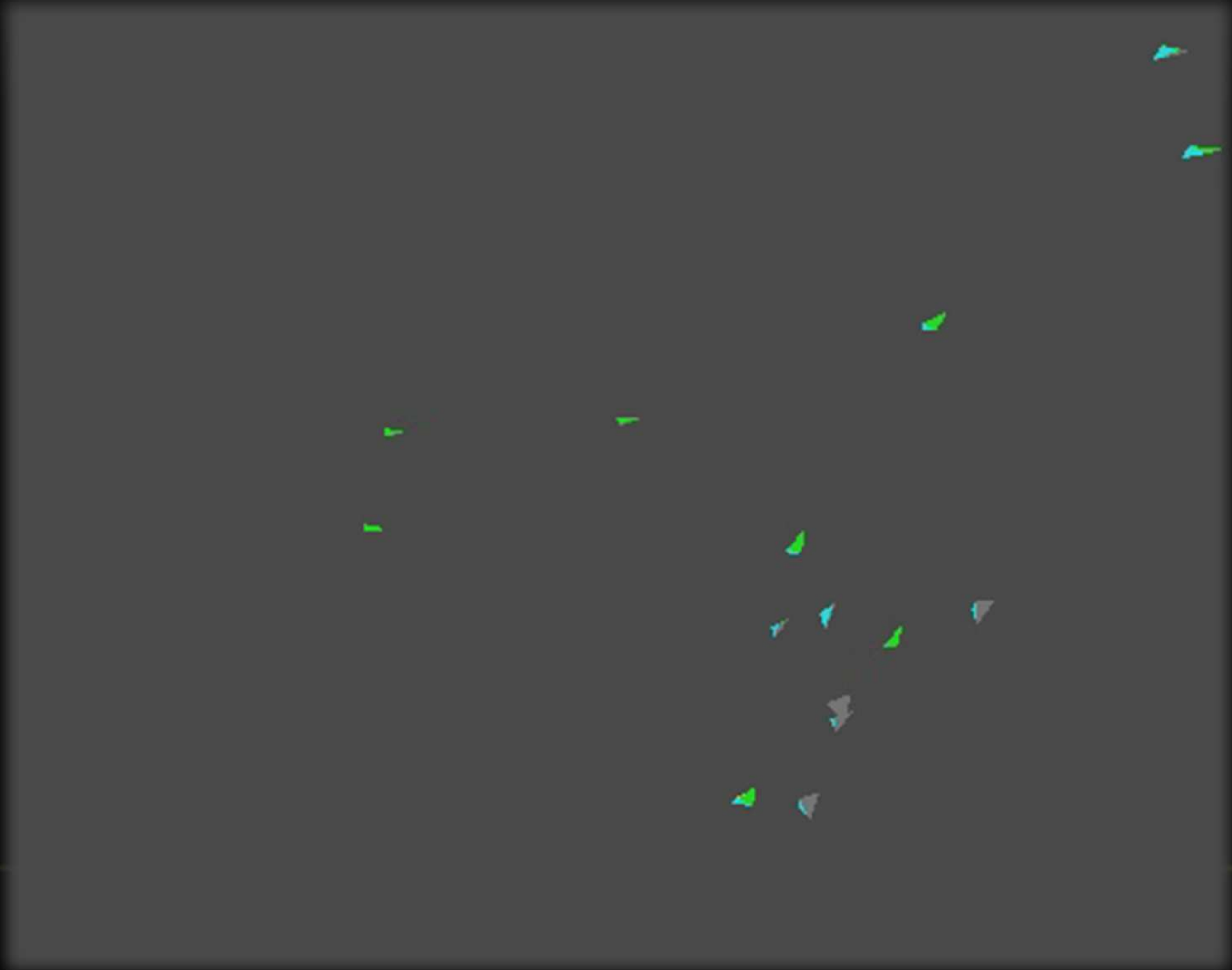




All figures of basic steering behaviors are from Craig Reynolds' web site http://www.red3d.com/cwr/steer/ [3]

C. Reynolds: Flocking
http://www.red3d.com/cwr/boids/

FLOCKING DEMONSTRATION I.

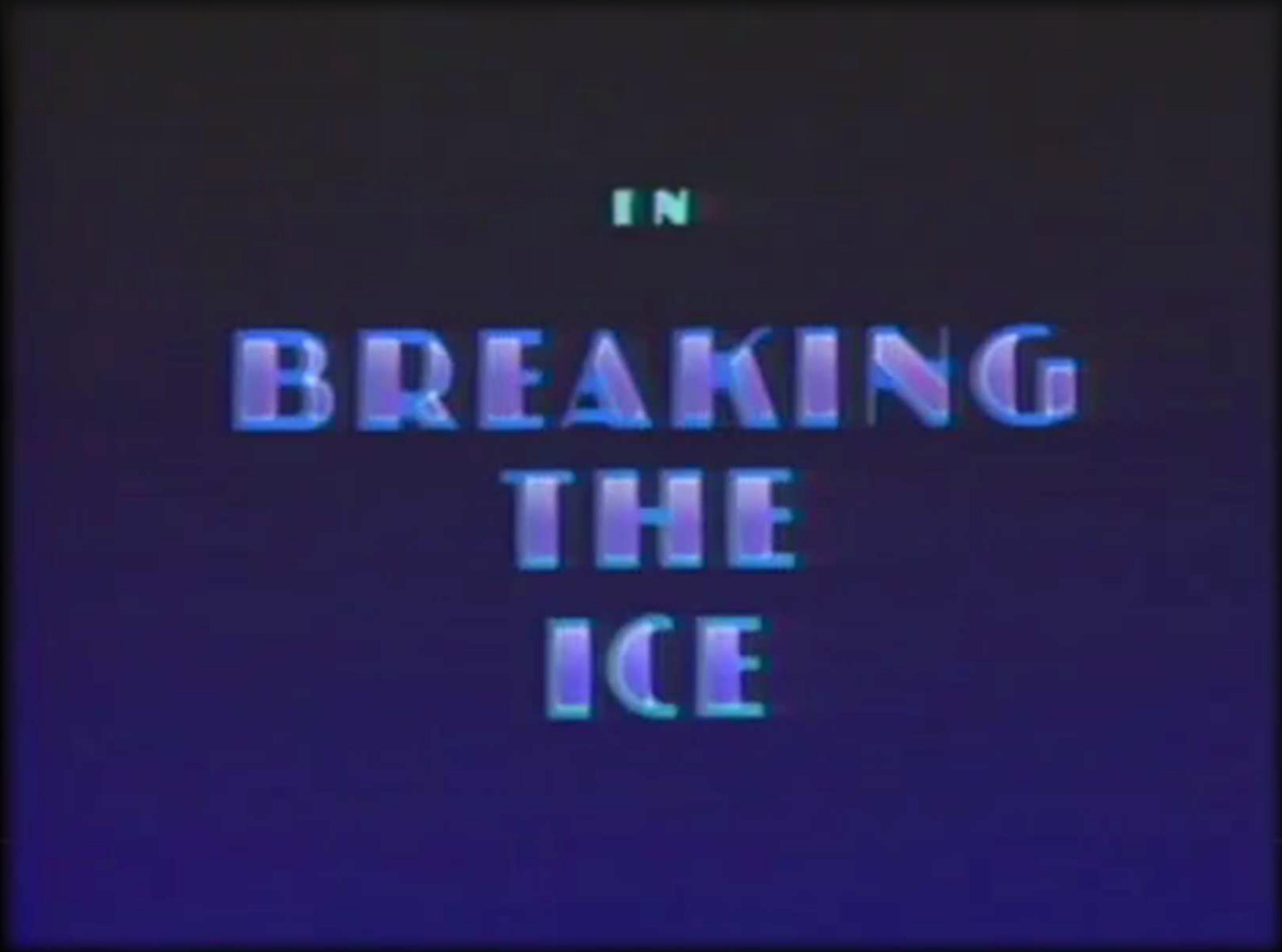


FLOCKING MODEL - FEATURES

- Relatively believable
- Relatively fast
  - Straightforward implementation → $O(n^2)$
  - Using spatial data structure for nearby flockmates detection → $O(n)$
- ➔ Used in films and games
  - E.g., Batman Returns

Stanley & Stella in: Breaking the Ice
http://www.youtube.com/watch?v=3bTqWsVqyzE

FLOCKING DEMONSTRATION II.



1999 C. REYNOLDS: STEERING BEHAVIORS FOR AUTONOMOUS AGENTS

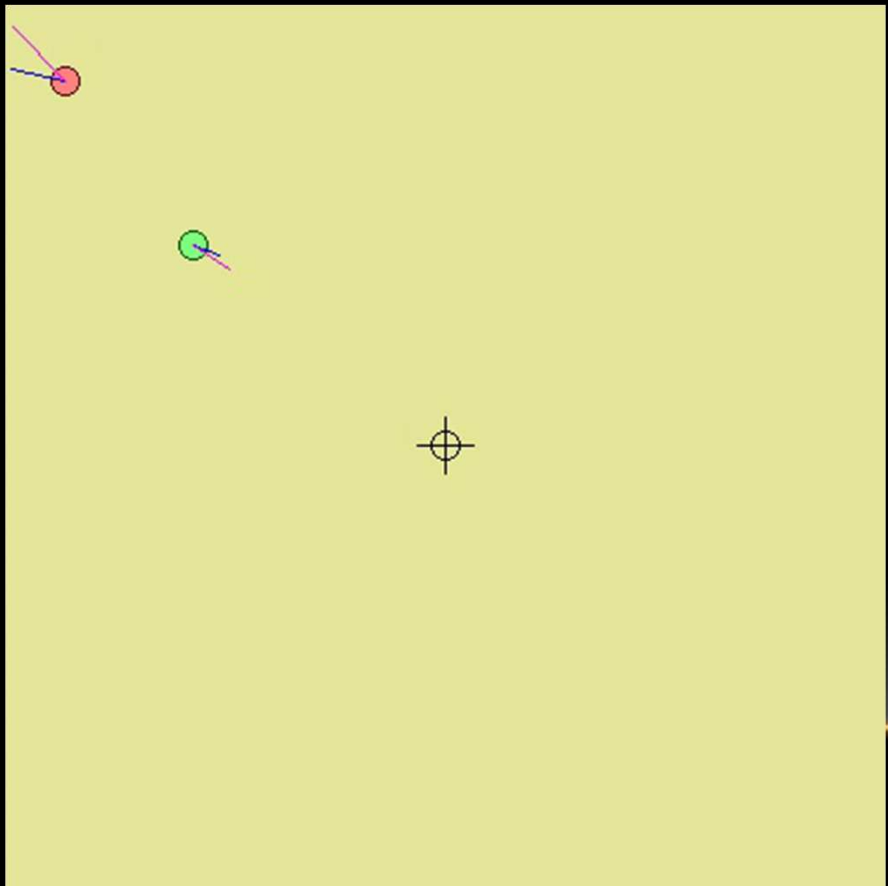
- Seek & Flee
- Pursue & Evade
- Arrival
- Wander
- Obstacle Avoidance & Containment
- Collision Avoidance & Unaligned collision avoidance
- Wall Following
- Path Following
- Leader Following
- Flow Field Following

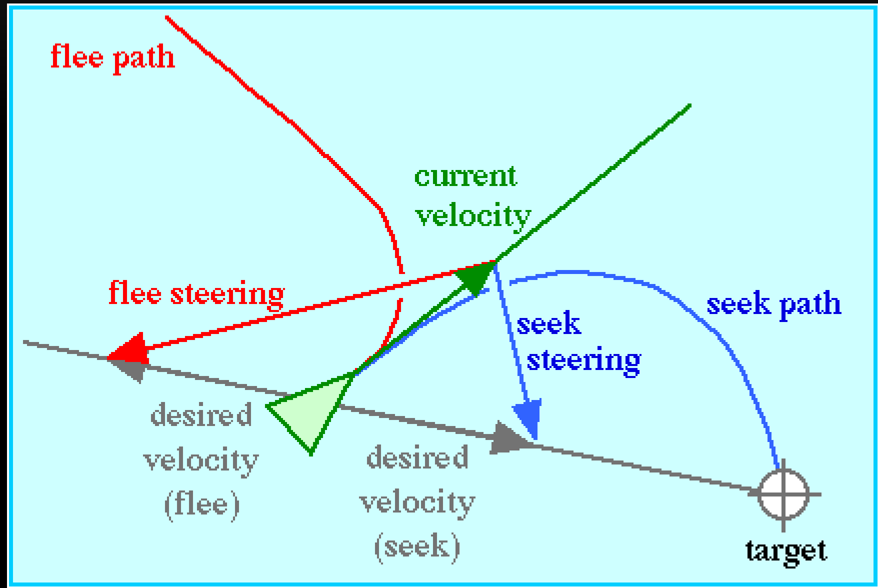
SEEK & FLEE

Seek steering force computation

to_target = target_position - my_positin
desired_velocity = normalize(to_target) * max_speed
steering_force = desired_velocity - velocity

- Seek
  - steers agent to a static target

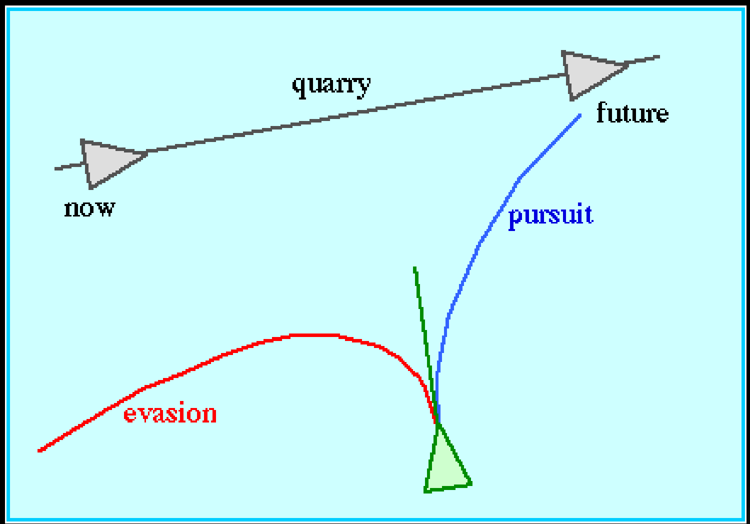


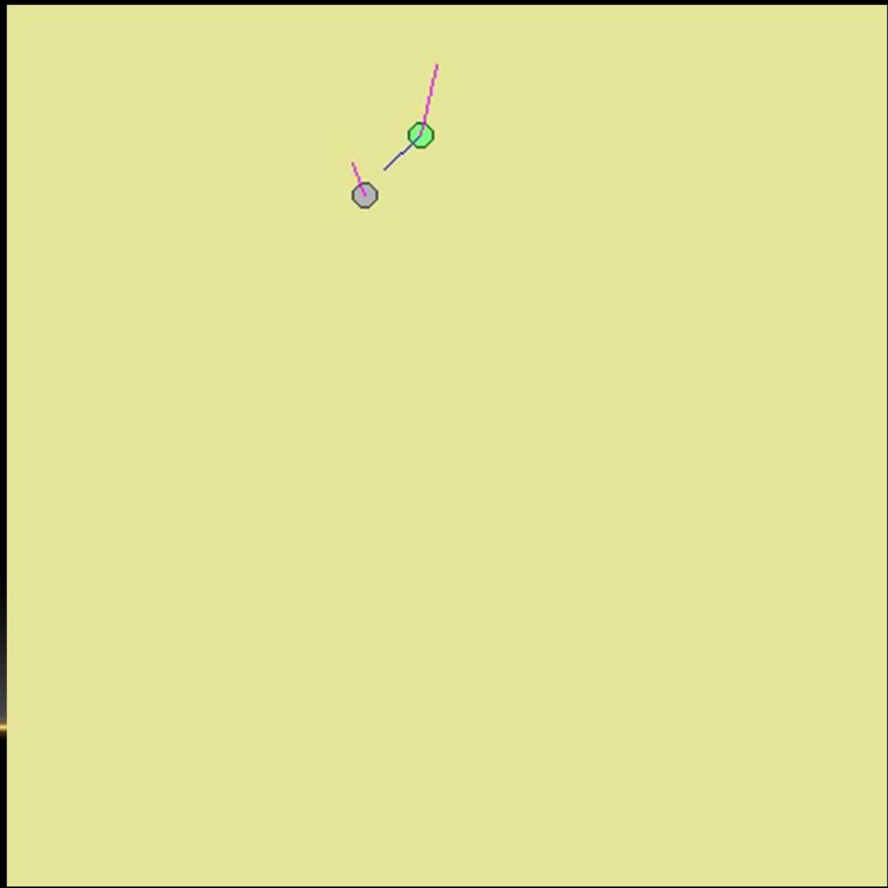


- Flee
  - steers agent from a static target

PURSUE & EVADE

- As seek & flee, except the target moves
- Agent predicts the location of the target in the next tick of the simulation



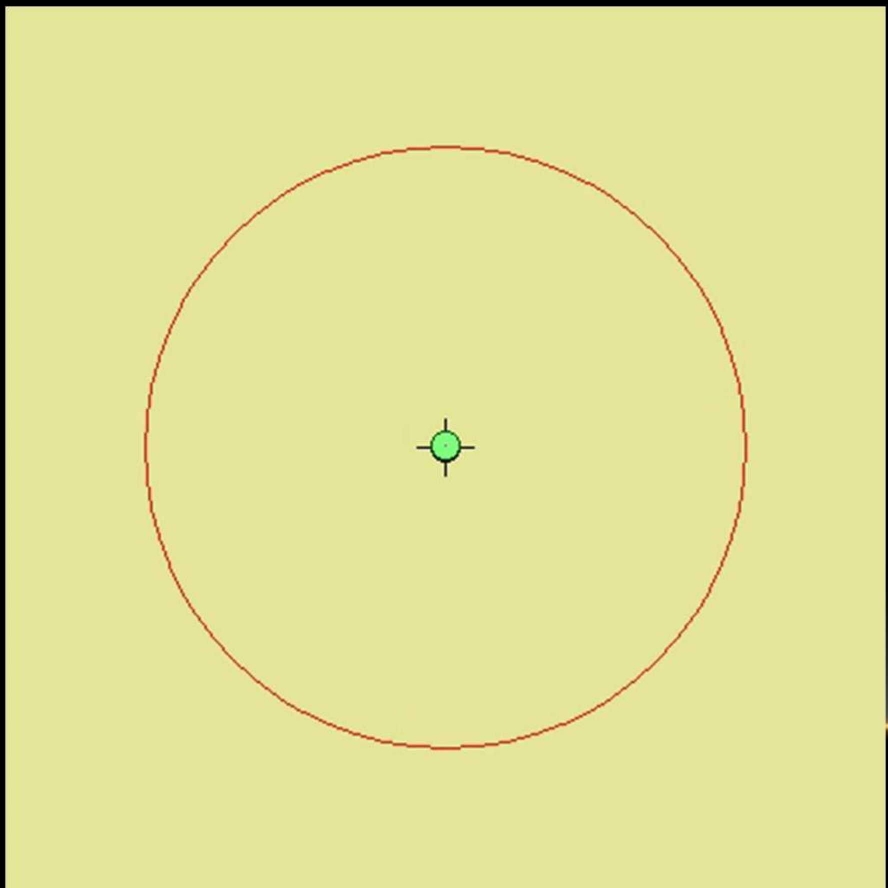


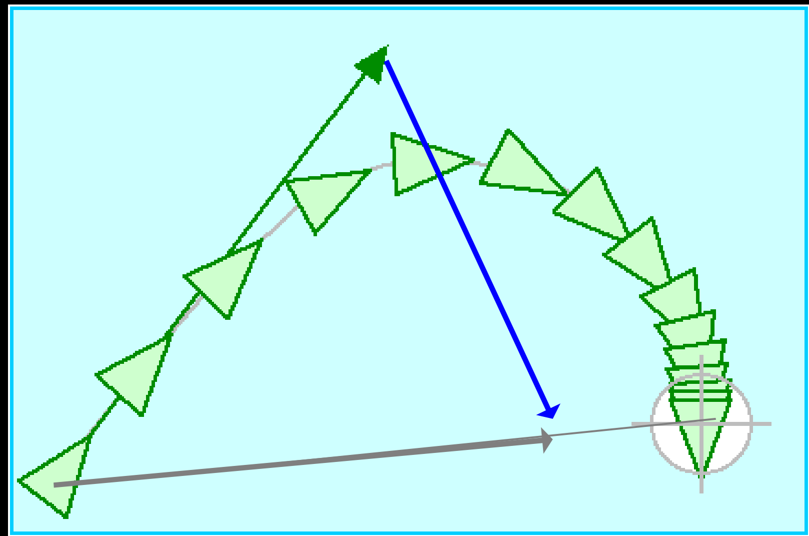
ARRIVAL

- As Seek, except the agent slows down as it approaches the target

Arrival steering force computation

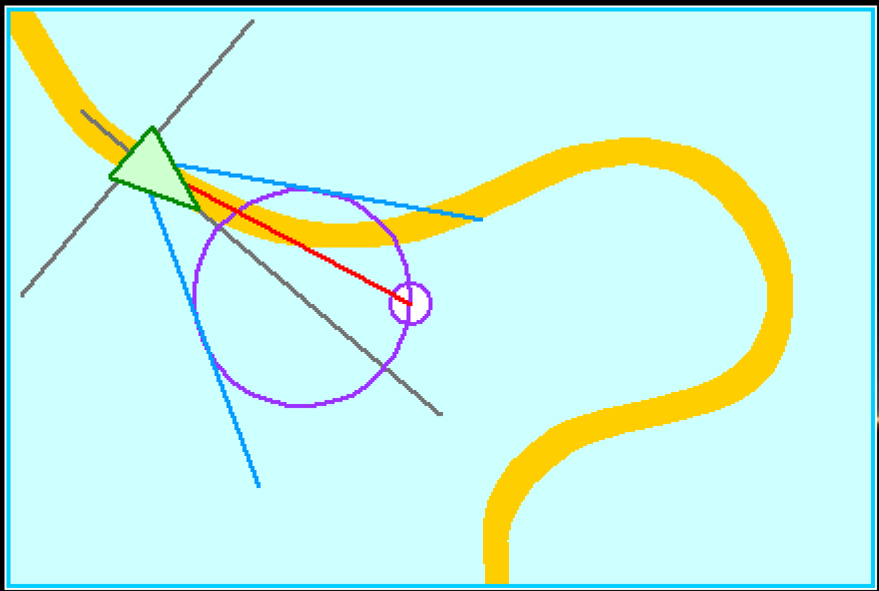
```
to_target = target_position – my_positin
distance = length( to_target )
ramped_speed = max_speed * ( distance / slowing_distance )
clipped_speed = min( ramped_speed, max_speed )
desired_velocity = to_target  * ( clipped_speed / distance )
steering_force = desired_velocity – velocity
```

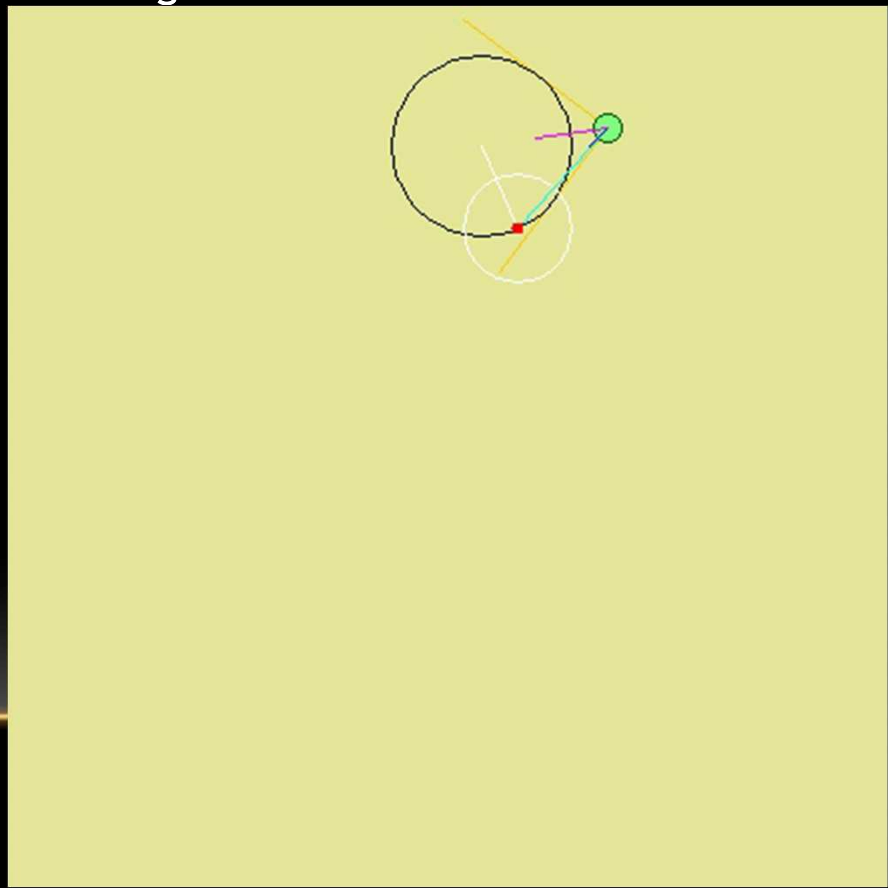




WANDER

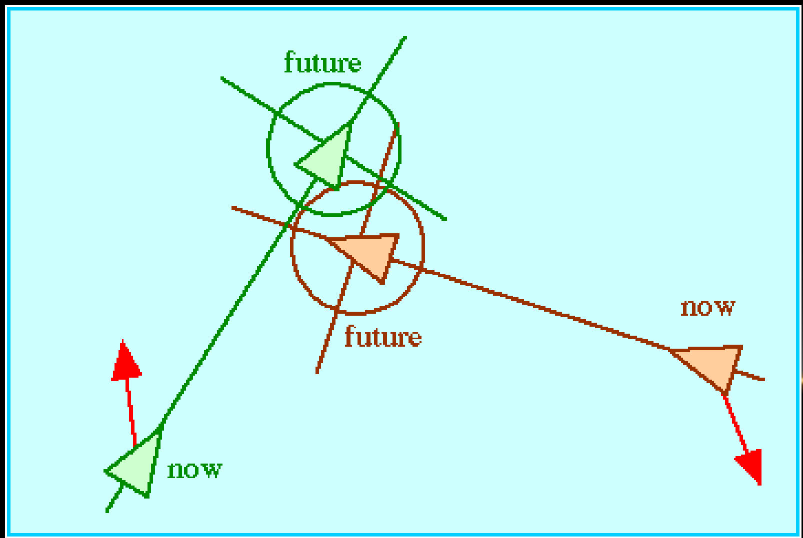
- Type of random steering: the steering direction on one frame is related to the steering direction on the next frame
- More believable than totally random steering forces
- Steering force
- Constriction of steering: big circle
- Constriction of offset: small circle

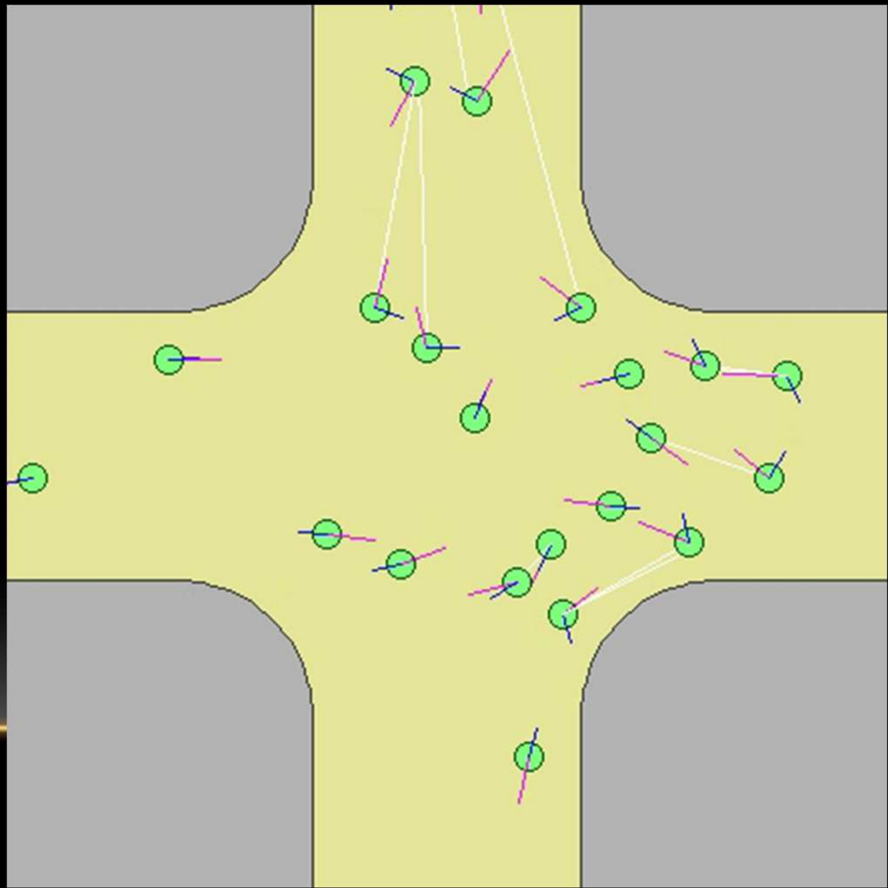




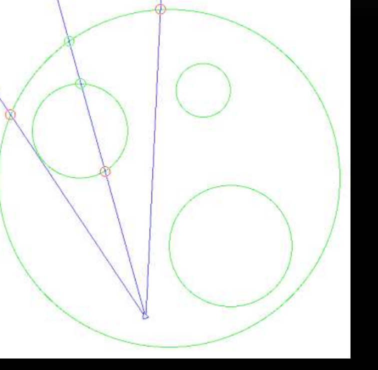
UNALIGNED COLLISION AVOIDANCE

- Separation
  - Agent is steered from too close neighbors
- Unaligned collision avoidance
  - Potential collisions with other agents are predicted
  - Agent is steered to avoid the site of the predicted collision

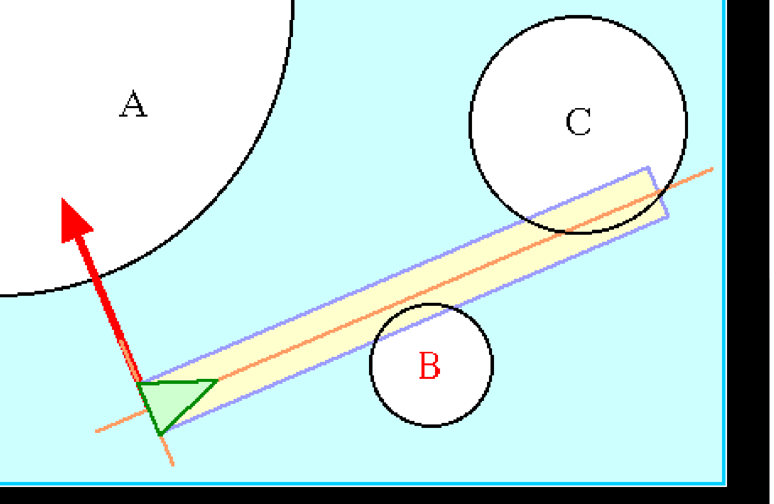




OBSTACLE AVOIDANCE

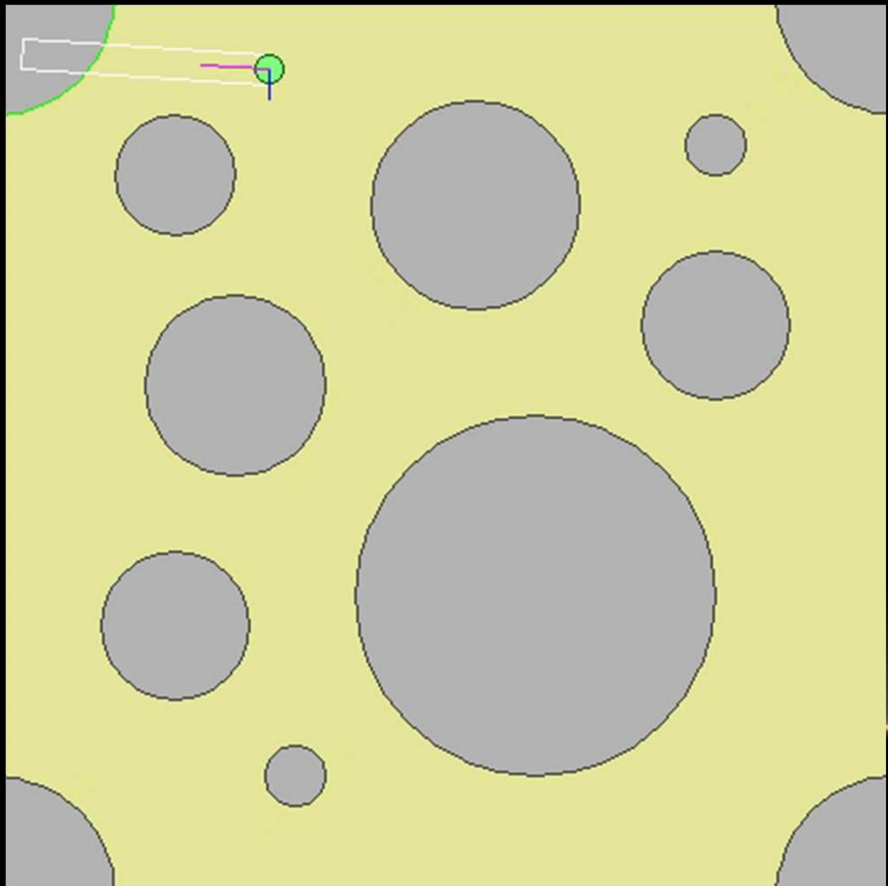


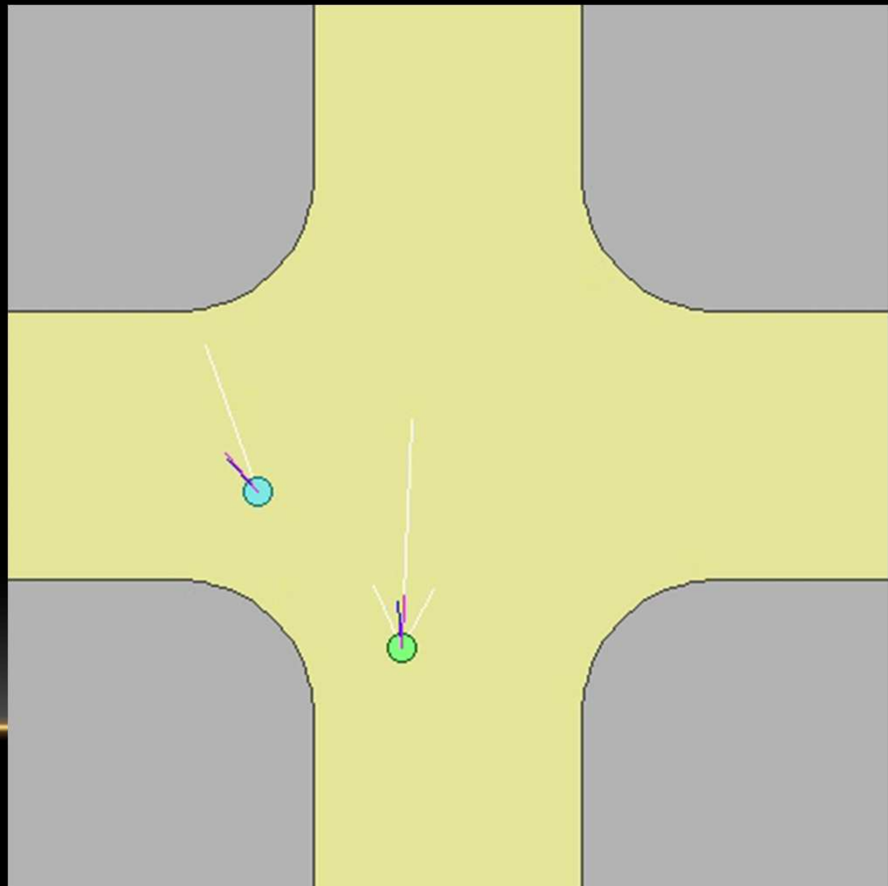
- Obstacle detection
  - Navigation graph, navigation mesh, etc.
  - Point content
  - Line traces
  - …
- Obstacle Avoidance by C. Reynolds
  - An imaginary cylinder in front of the agent should be free
  - If it is free, the steering force is zero vector
  - Otherwise it is the vector from the most threatening obstacle



OBSTACLE AVOIDANCE & CONTAINMENT

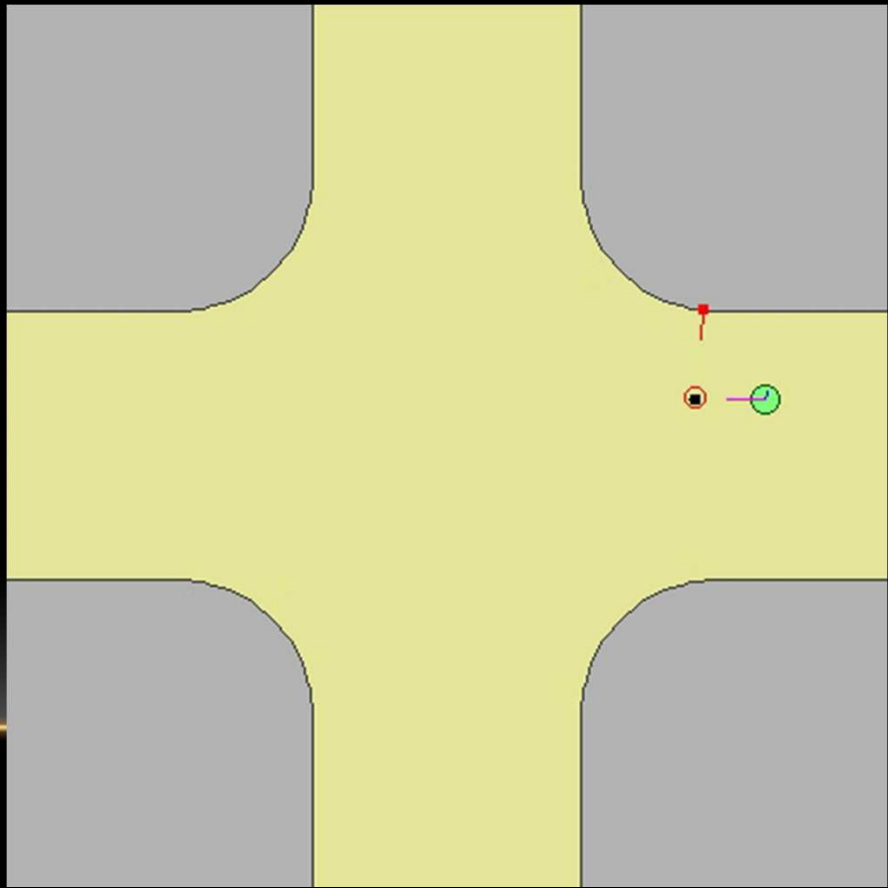
- The most threatening obstacle is detected and the agent is steered from it
- The agent‘s future position is predicted and the agent is steered towards the allowed region





WALL FOLLOWING

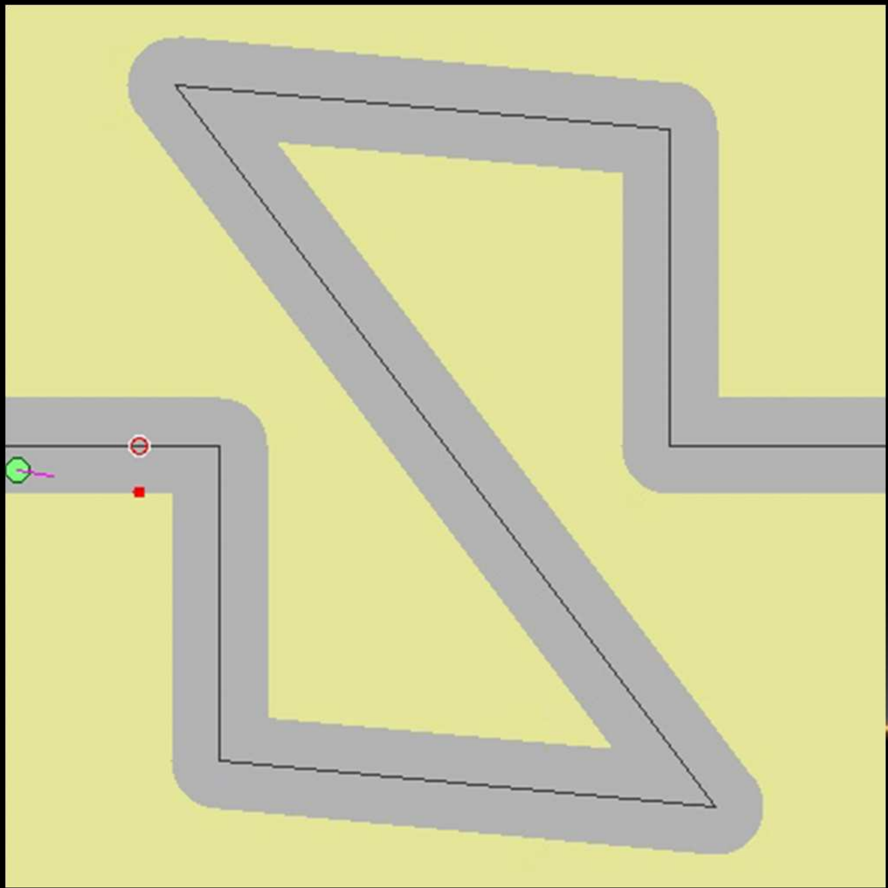
- Agent is steered to move in parallel with a wall
- The future agent's position is predicted (the black dot)
- This future position is projected to the nearest point on a wall (red dot)
- Red line represents the wall's normal and leads to the target point (red circle)
- Seek behavior is used to steer agent towards the target point
- Surface protocol:
  - the nearest point on the wall
  - the normal at that point

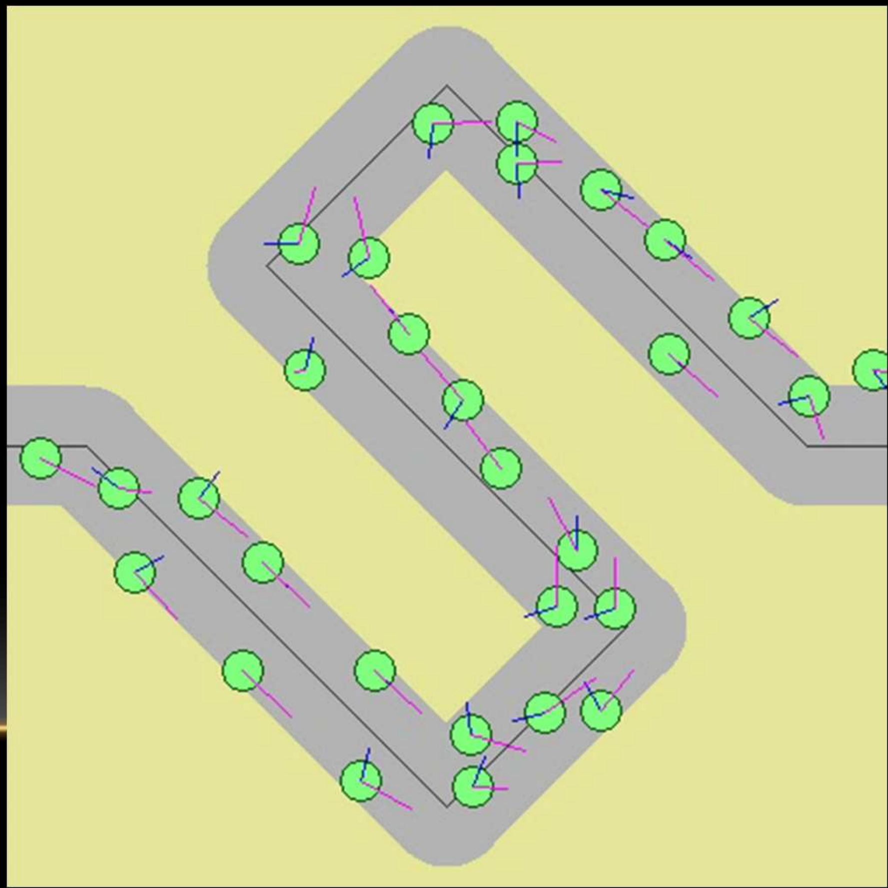


PATH FOLLOWING

Path Following steering force computation
If the predicted future position is outside gray region, the agent is steered to the target point (white circle) – and therefore stays inside.

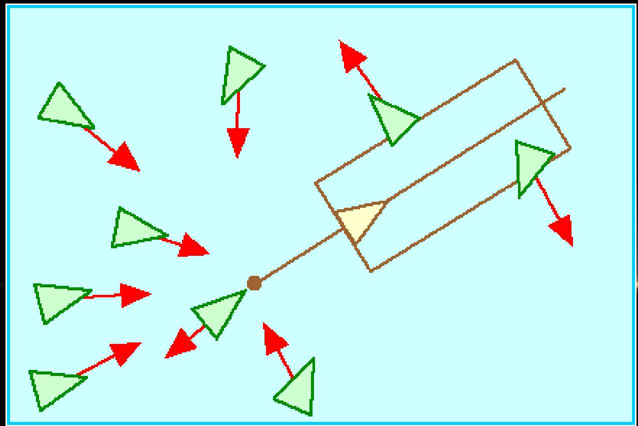
- Agent is steered to move along the path in the given direction while keeping its center in the gray region

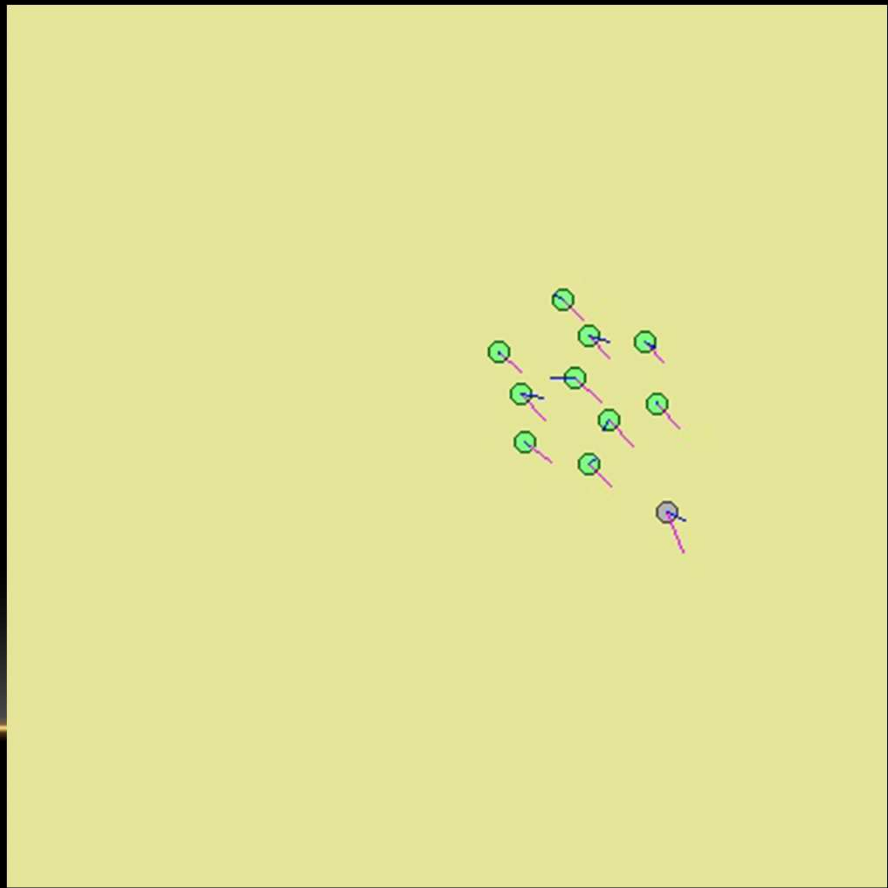




LEADER FOLLOWING

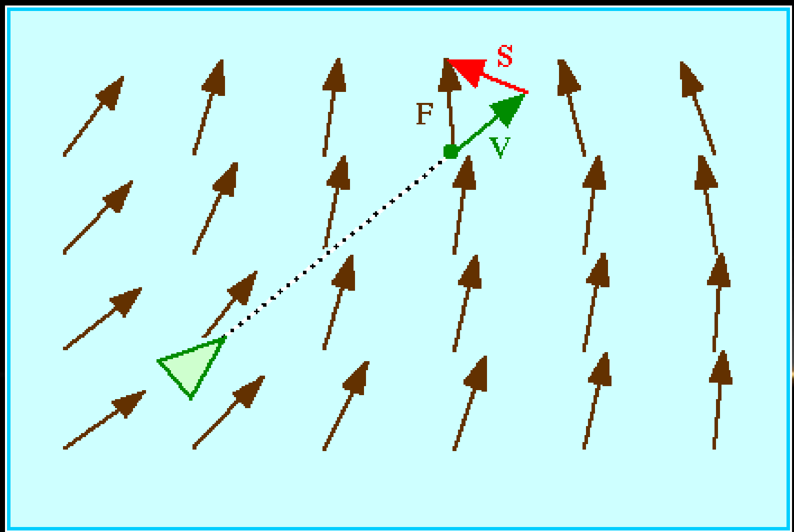
- Agent is steered to follow a Leader (grey).
- Steering force consists of:
  - Arrival – the target is slightly behind leader
  - Separation – to prevent collisions with other followers
  - If a follower finds itself in a rectangular region in front of the leader, it will steer laterally away from the leader's path

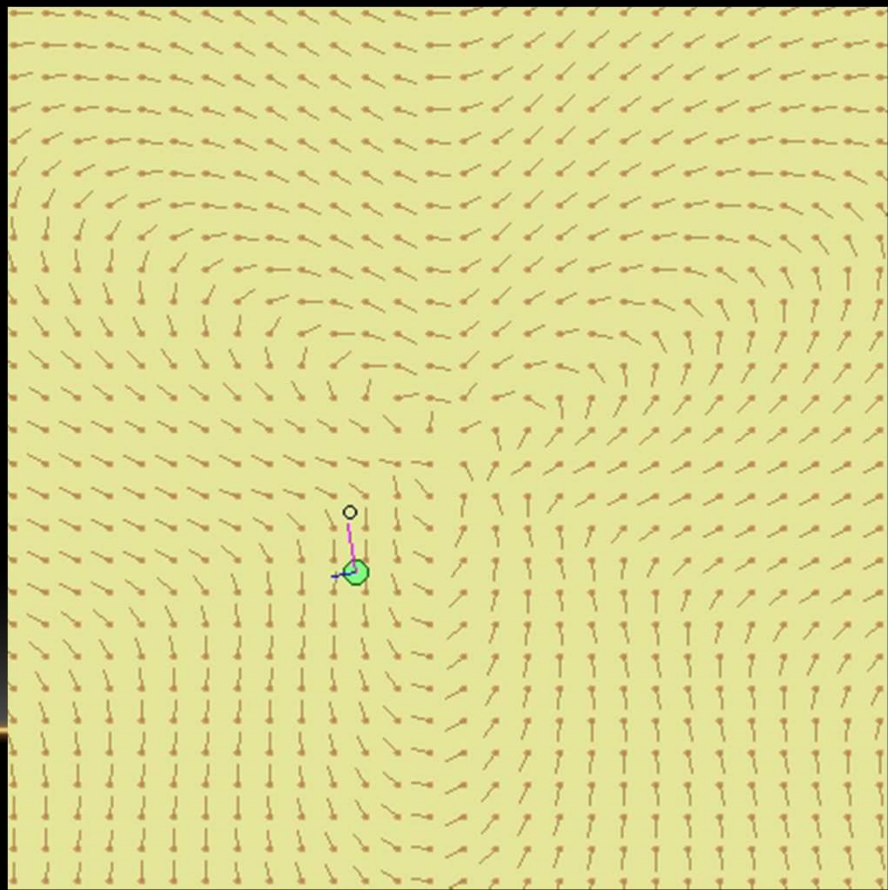




FLOW FIELD FOLLOWING

- Flow field defines mapping: location → flow vector
  - May be defined procedurally / based on data
  - May be static / time-varying
- The future location is predicted
- F = flow vector at this location
- steering_force = velocity - F





COMBINING STEERING BEHAVIORS

- Each steering behavior returns single vector (steering force)
- What to do with more steering behaviors?
  - Select and apply the most important steering behavior
  - Select random active steering behavior
  - Sum all forces together
    - → Average of all forces
    - → Average of all non-zero forces
    - → Weighted average of all non-zero forces

- $v_t = \frac{w_0 \cdot v_{t-1} + \sum_{i \in I}(w_i \cdot s_i)}{w_0 + \sum_{i \in I} w_i}$
- $I = \{i = 1, \dots, n \mid s_i \neq 0\}$

- v_t = velocity in time t
- $s_1, \dots, s_n$ = steering forces
- w_i = weight of steering force s_i
- w_0 = weight of original velocity
- I = set of non-zero steering forces

STEERING BEHAVIORS FOR IVA'S

- Which motion problems do we deal with in applications with IVA's?
- Where would be steering behaviors helpful?

EXAMPLE I.

No collision avoidance
Stronghold Crusader Extreme, 2008
http://www.youtube.com/watch?v=IZpgMnu_lAk

EXAMPLE II.

Small collision radius
Dawn of War, 2009
http://www.youtube.com/watch?v=IZpgMnu_lAk

EXAMPLE III.

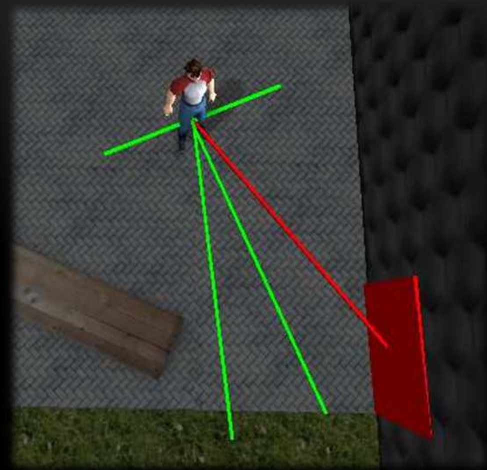
Primitive (and slow) collision avoidance
Knights and Merchants, 1998
http://www.youtube.com/watch?v=IZpgMnu_lAk

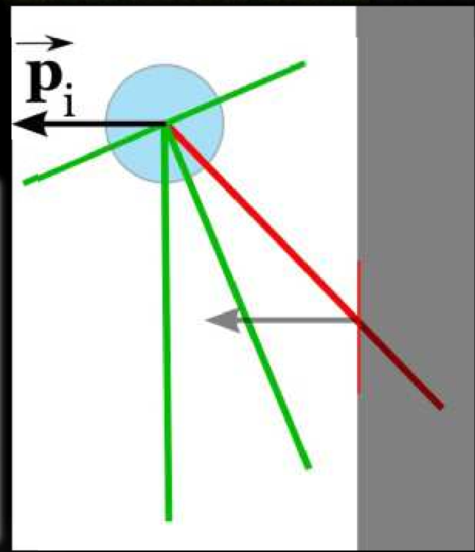
EXAMPLE IV.

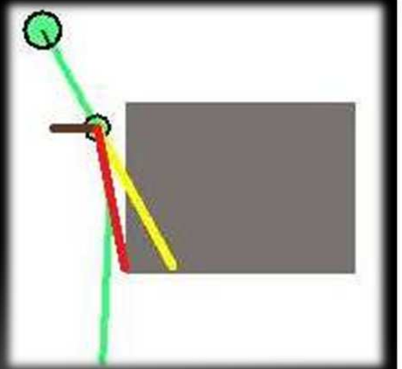
Getting stuck
Empire Total War, 2009
http://www.youtube.com/watch?v=IZpgMnu_lAk

OBSTACLE AVOIDANCE

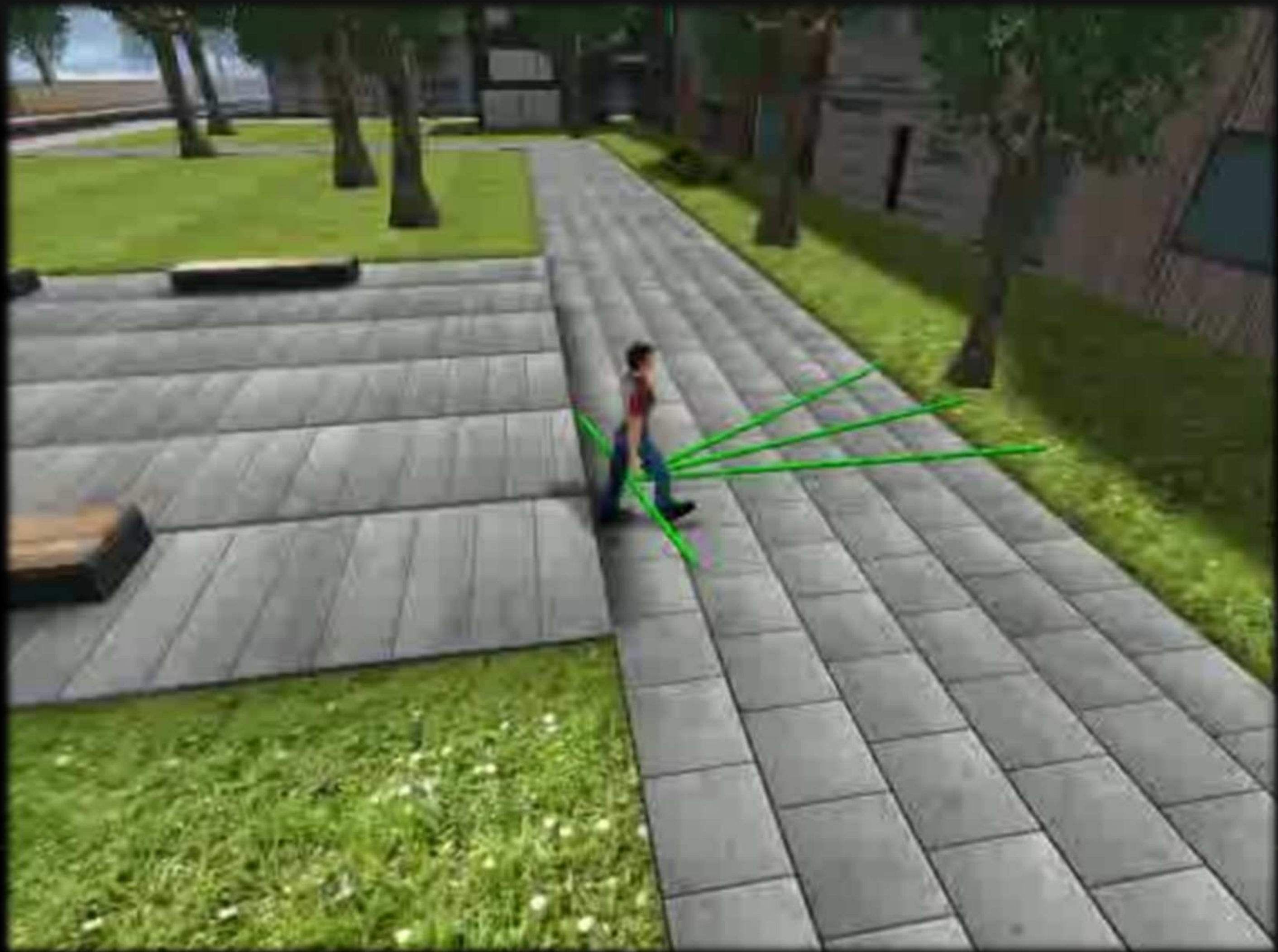
- Obstacle detection – typically fixed rays
- Possible implementation:
  - Steering force = $\sum_{i \in I} \left(\overrightarrow{p_i} \cdot W_i \cdot F \cdot \left(\frac{2 \cdot D_i}{R_i}\right)^O \right)$
  - $I =$ *set of colliding rays*
  - $W_i =$ *weight of the ray (front – bigger, side – lower)*
  - $D_i =$ *length of the colliding ray part*
  - $R_i =$ *ray length*
  - $\overrightarrow{p_i} =$ *normal of the obstacle*
  - $O =$ *force order*
  - $F =$ *basic magnitude of the force*





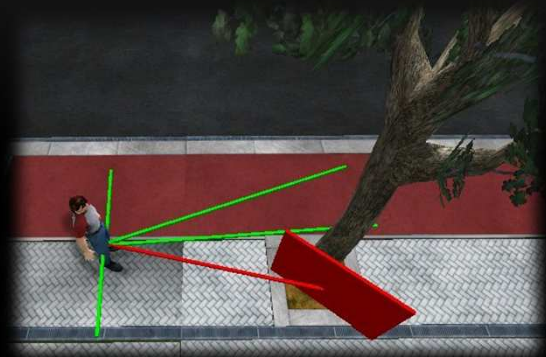


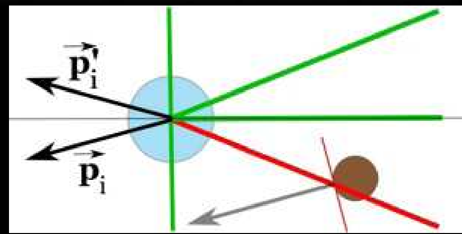
OBSTACLE AVOIDANCE - DEMONSTRATION

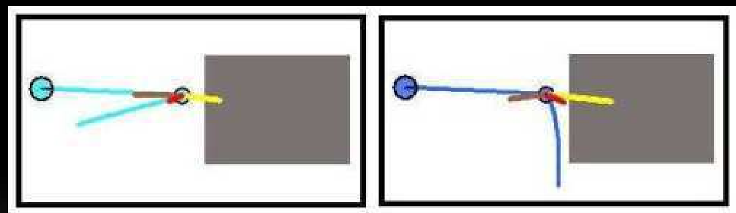


PROBLEMS AND DISCUSSION OF OA USE

- Problems with obstacles detection
  - Narrow obstacles
    - Obstacles may not be detected
    - Obstacles may be detected wrongly
  - Ray length
    - Quick reactions vs. narrow passages
  - Simulation frequency
- Specific situations
  - Front collisions
- Local traps and complicated situations
  - OA uses only local information







OBSTACLE AVOIDANCE & LOCAL TRAPS

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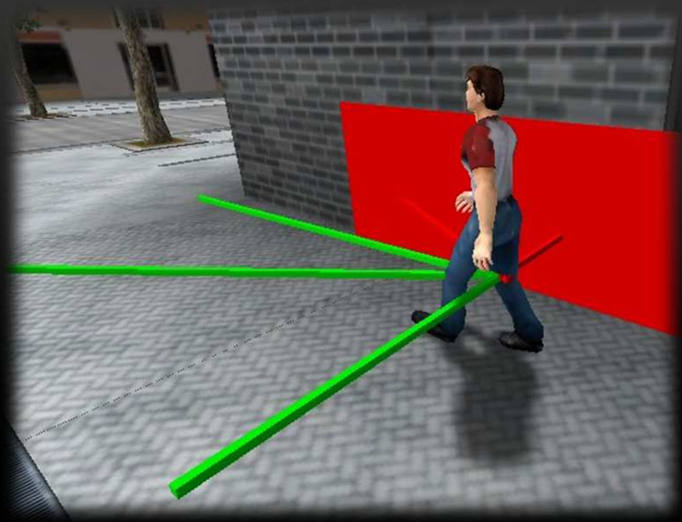
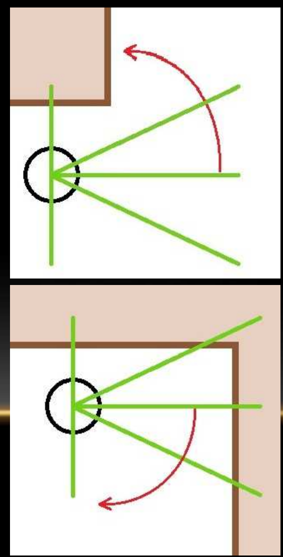
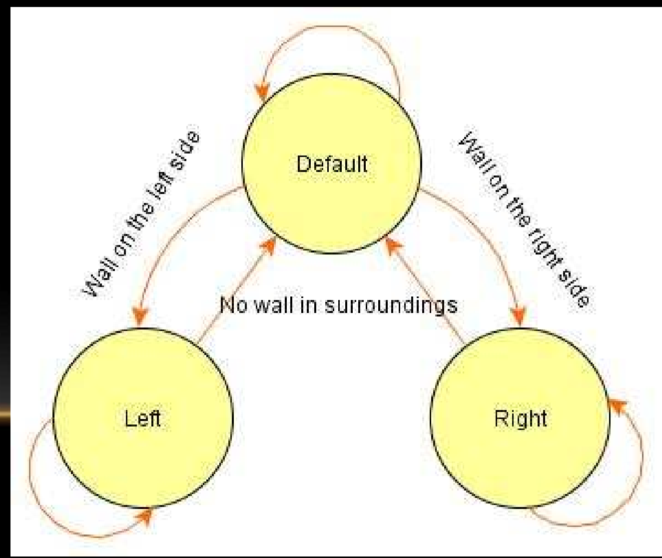
WALL FOLLOWING

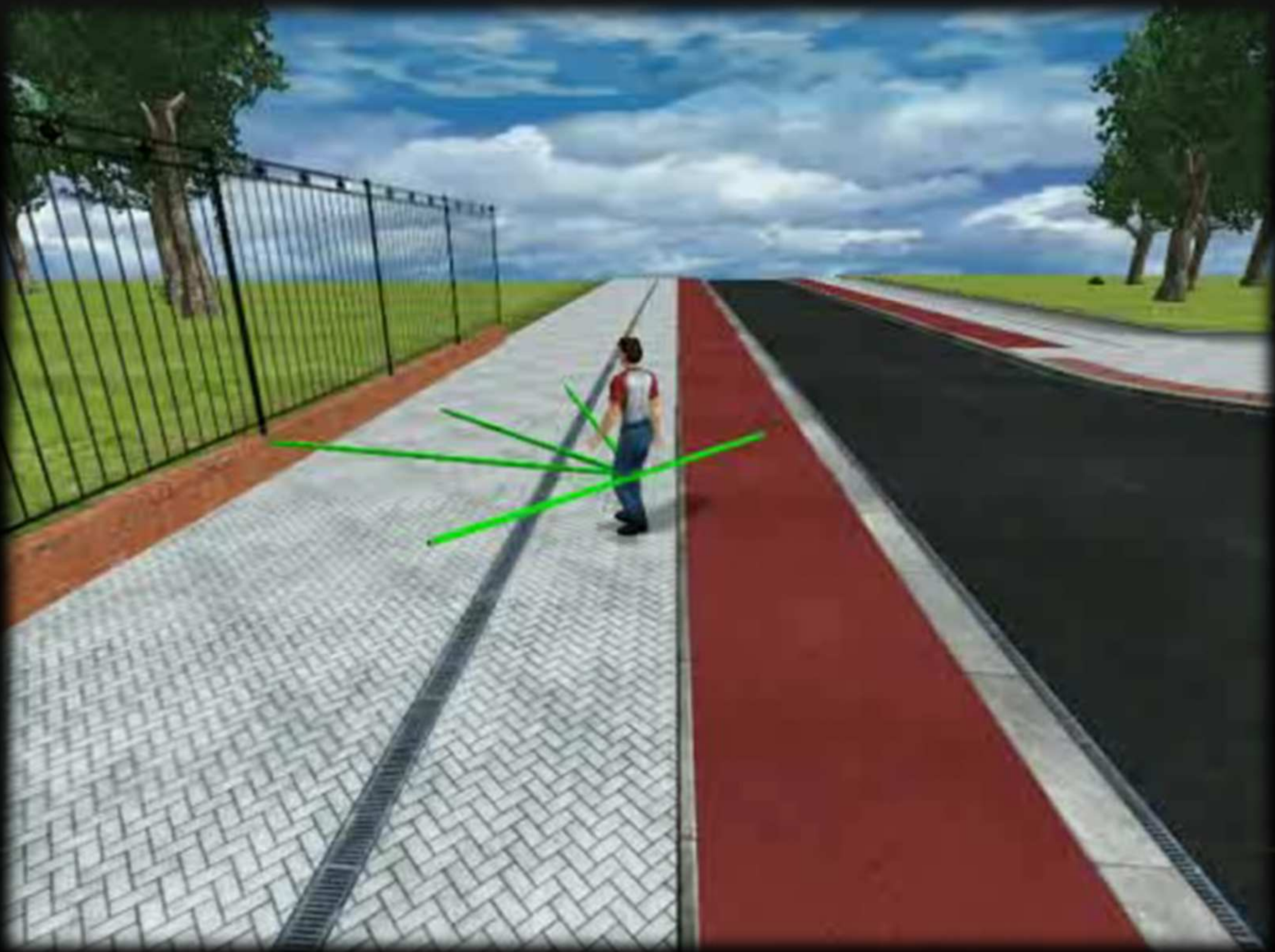


- Notes on possible implementation:
  - Wall is detected by rays
  - Attractive force to wall
    - The farther from wall an agent is, the bigger the attractive force is
  - Repulsive force from wall – if the agent is too close to wall
    - The closer to wall the agent is, the bigger is the repulsive force
  - Special situations
    - Edges
    - Front collisions

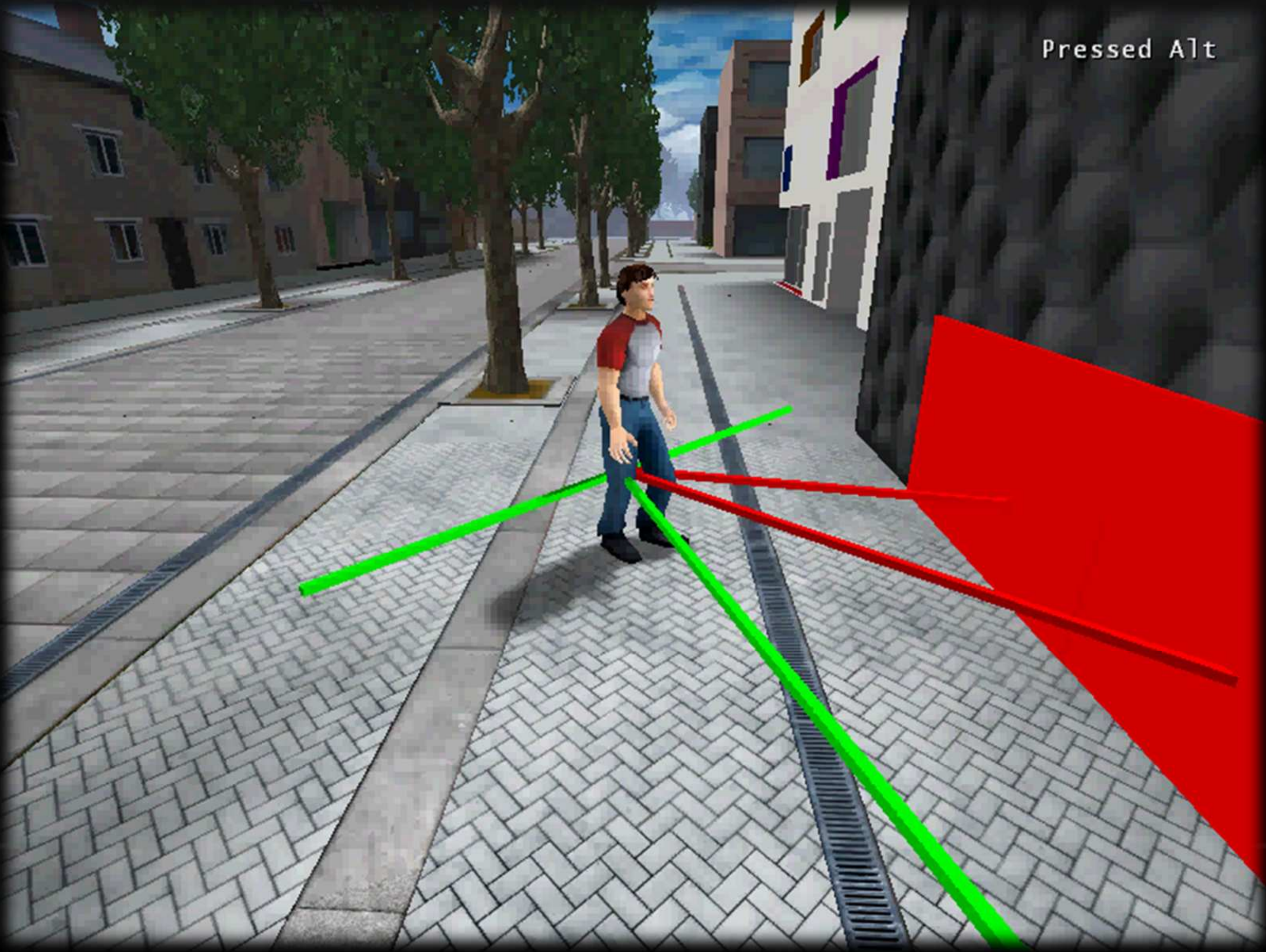




WALL FOLLOWING – DEMO I.



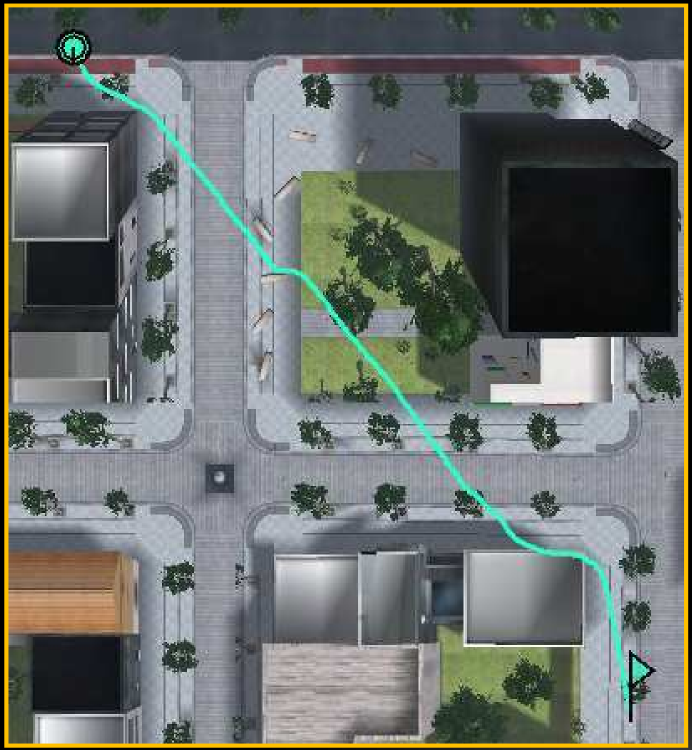
WALL FOLLOWING DEMO II.



WALL FOLLOWING IN COMBINATION

TA + OA

➔ directly through city



TA + WF

➔ on the sidewalks

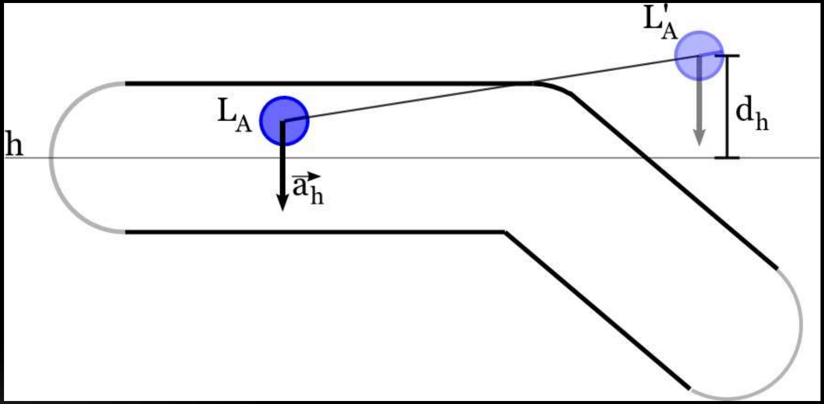
PROBLEMS OF LOCAL INFORMATION

- Complicated tasks can not be solved
- What to do?
  - → use global knowledge of the environment
  - → plan the path

DIRECT FOLLOWING OF THE PLANNED PATH

PROBLEMS OF DIRECT FOLLOWING

- Not believable
- Sometimes lacks smoothness
- What to do?
  - → steering behavior Path Following
    - Parameters: path (a list of locations), distance from path
    - Notes on implementation
      - Pair of path nodes
      - Force to the center axis
    - Improvements
      - Projection length
      - Regulation force



PATH FOLLOWING - DEMONSTRATION

Supreme Commander 2, 2010
http://www.youtube.com/watch?v=jA2epda-RkM

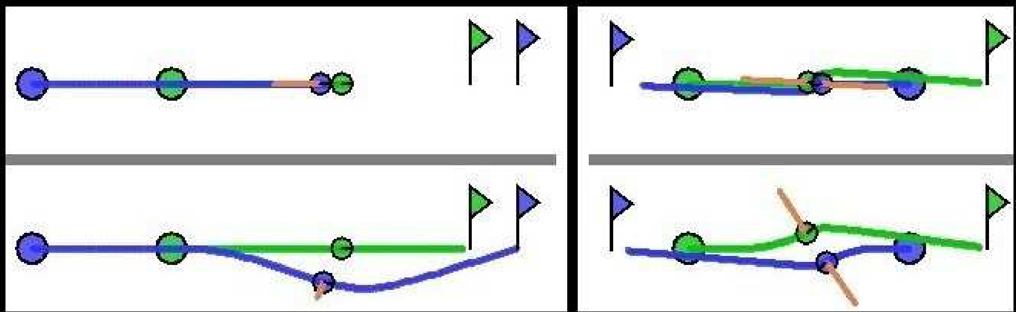
FLOW FIELDS

Hitman Blood Money, 2009
http://www.youtube.com/watch?v=ycDi7fK797U

DYNAMIC OBSTACLES AVOIDANCE

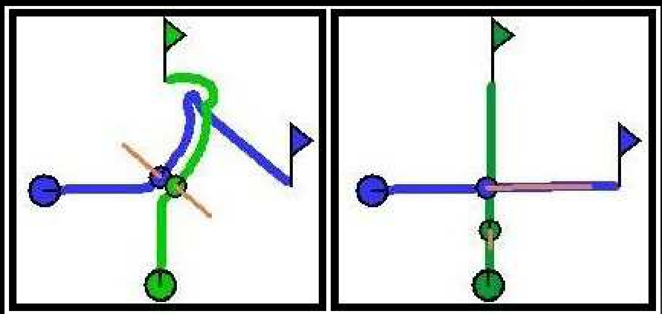
PEOPLE (COLLISION) AVOIDANCE

- Basics
  - Repulsive force from other too close agents
- Problems



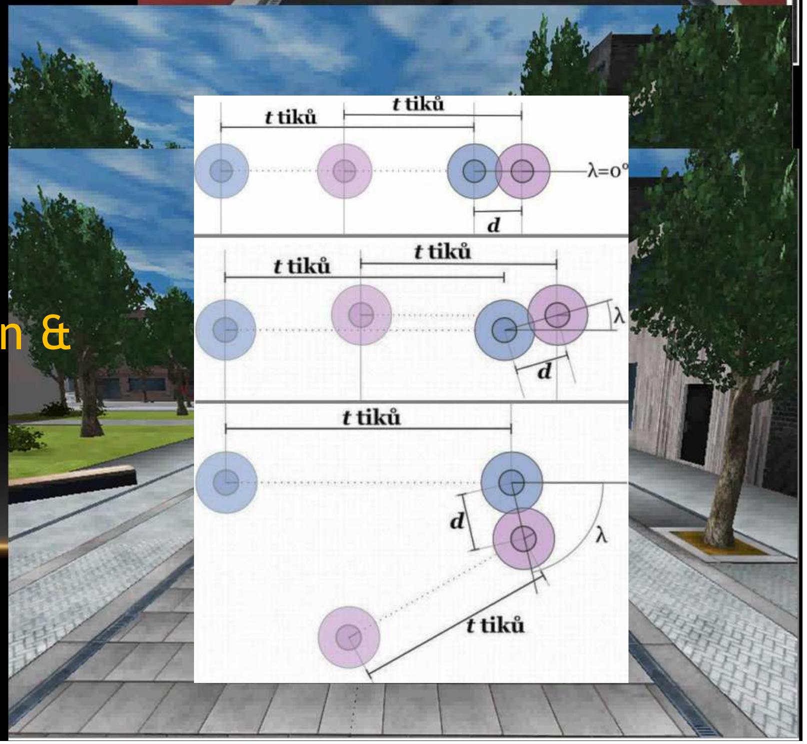
→ Circumvention (rotational force)

1



2

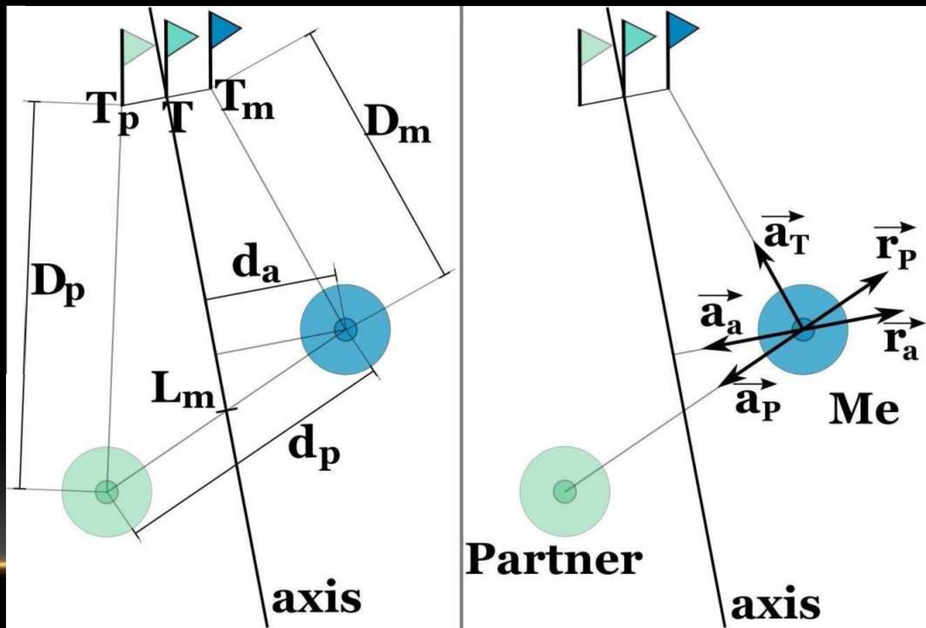
→ Acceleration & deceleration



PEOPLE AVIDANCE – DEMONSTRATION

OTHER SOCIAL INTERACTIONS

- Leader Following
- Walk Along [10]
  - Two friends go together to a certain place

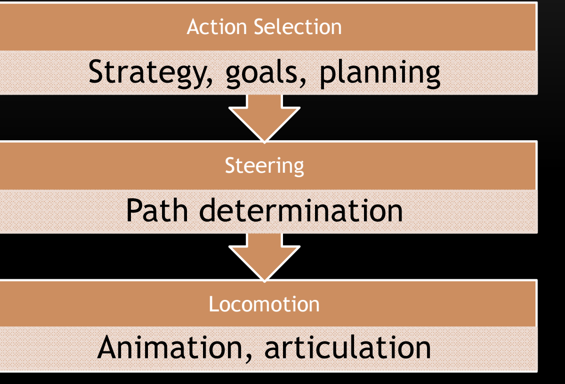


- Other…?

WALK ALONG - DEMONSTRATION

STEERING BEHAVIORS COMBINATION - DEMO

ACTION SELECTION LAYER



- Which steering behavior should be active?
- Parameters?
- Should be controlled by action selection layer
  - Autonomously vs. Centrally
- Some problems could be solved on the action selection layer
  - Path Following vs. Others
    - Commander and his regiment
    - Detection of being stuck, etc.
  - Setting parameters according to mood, emotions etc.

STEERING BEHAVIORS CONCLUSION

- Advantages
  - Simplicity → predictability (good for debugging)
  - Reactive behavior → efficiency (time, memory)
  - Forces → smoothness, combinability
- Disadvantages
  - Simplicity & Local Traps → low believability → sometimes we need higher-level prediction and planning
  - Scalability (modifying the behavior by hacking extra lines into code)
- Use
  - Computer games, Films
  - Crowd simulations (evacuations, shopping centers, etc.)

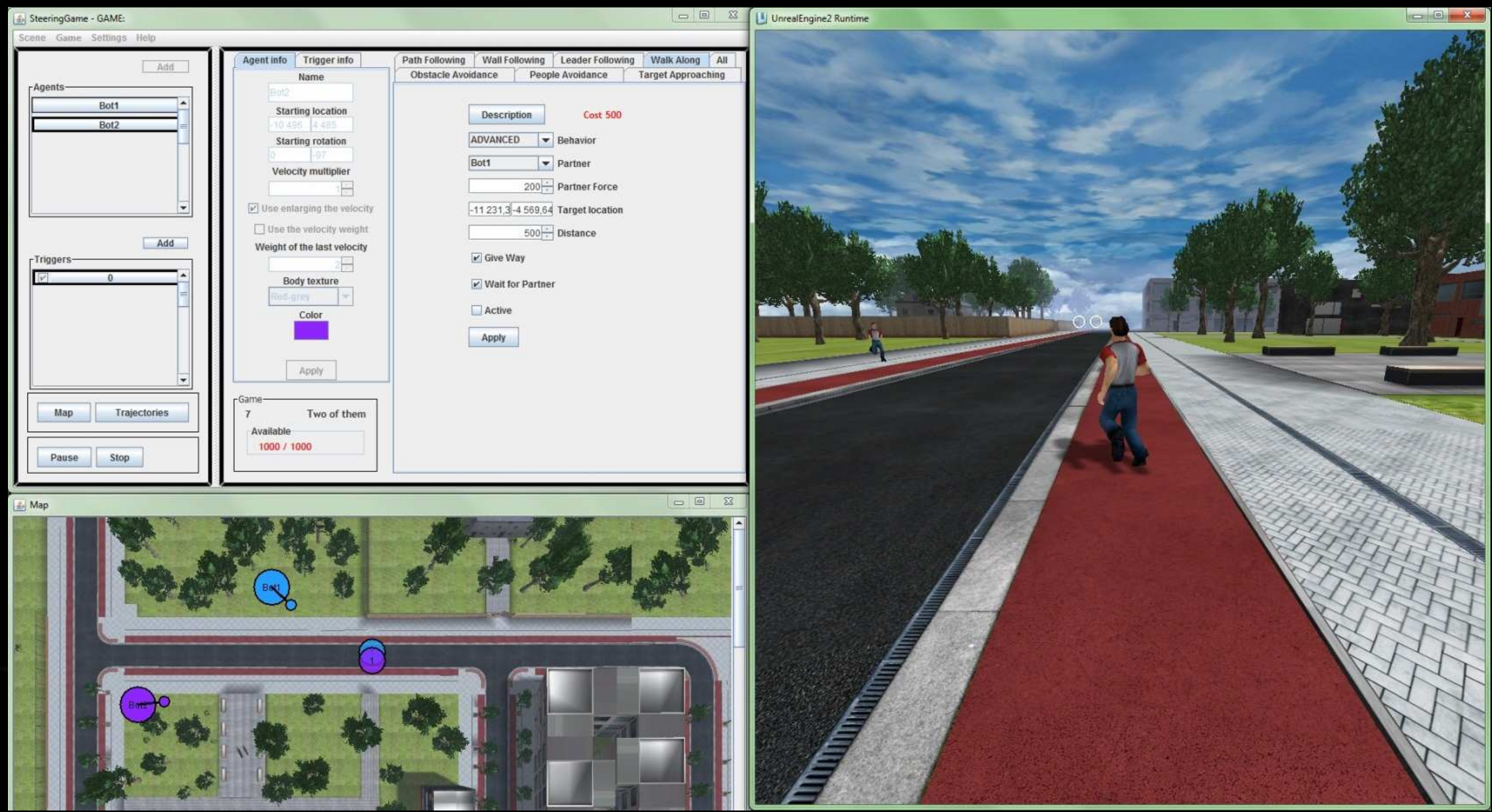
PRACTICALS

- SteeringTool
- SteeringGame
- UT2004SteeringLibrary

Web & Instalator:

http://diana.ms.mff.cuni.cz/pogamut-games

Project SteeringGame



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Related works, Benchmark for Steering Behaviors, Collision Avoidance Model

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