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Praha & EU: investujeme do Vaší budoucnosti!

STEERING BEHAVIORS

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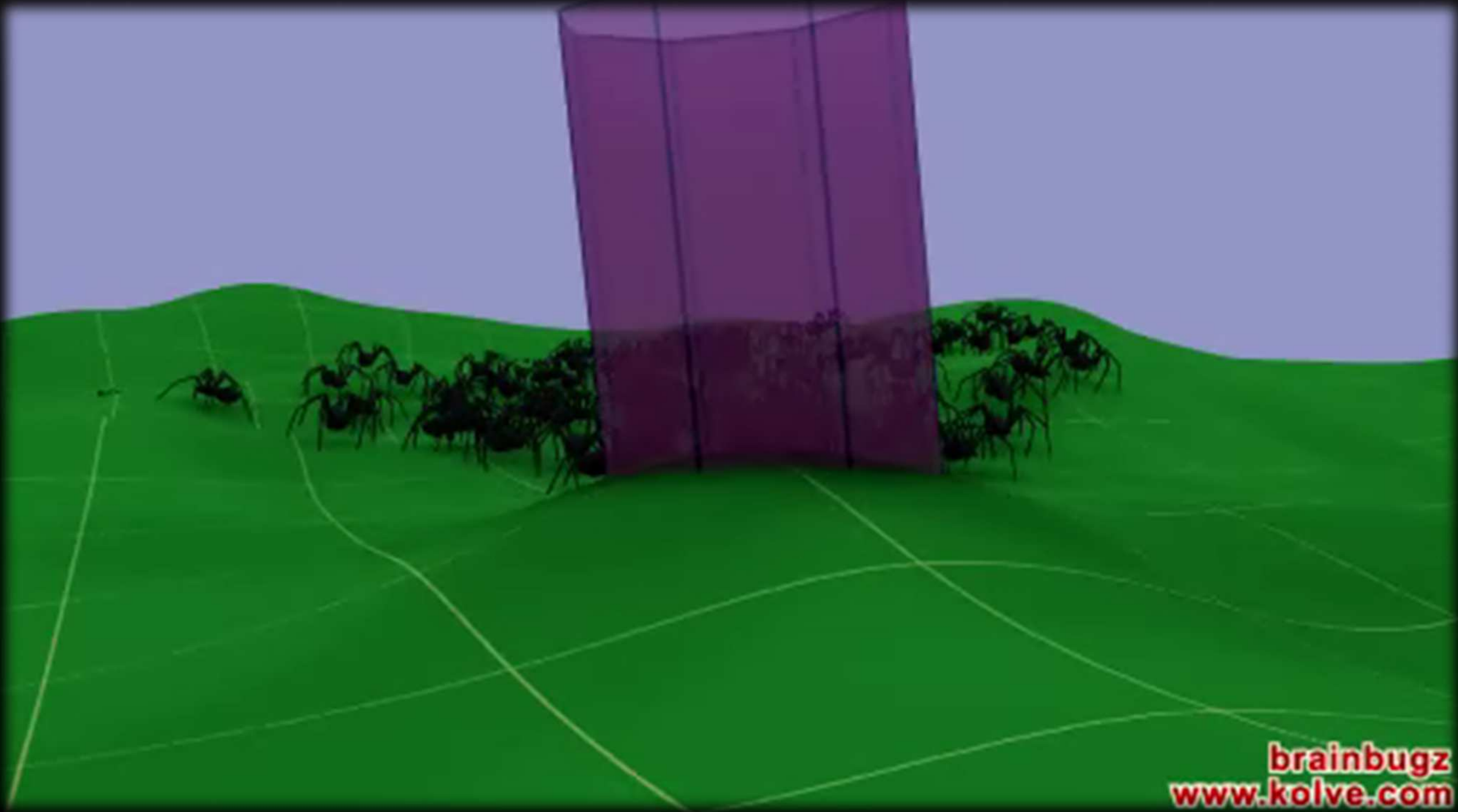
2012, Umělé Bytosti, MFF UK

MOTIVATION

MOTIVATION

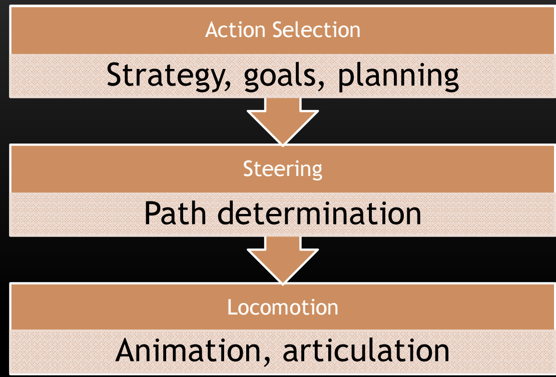


REQUIREMENTS FOR MOTION CONTROL

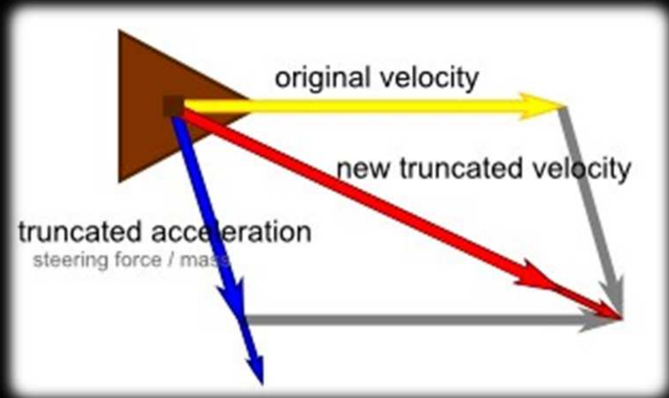
- Responding to dynamic environment
  - Avoiding obstacles and other agents
  - Interaction with environment and other agents
- Motion believability
- Speed of computation

- → 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
- Steers boid from too close flockmates

Alignment

- Try to move at the same speed and direction (velocity) as nearby flockmates
- Steers boid to have the same velocity as the average of velocities of nearby flockmates

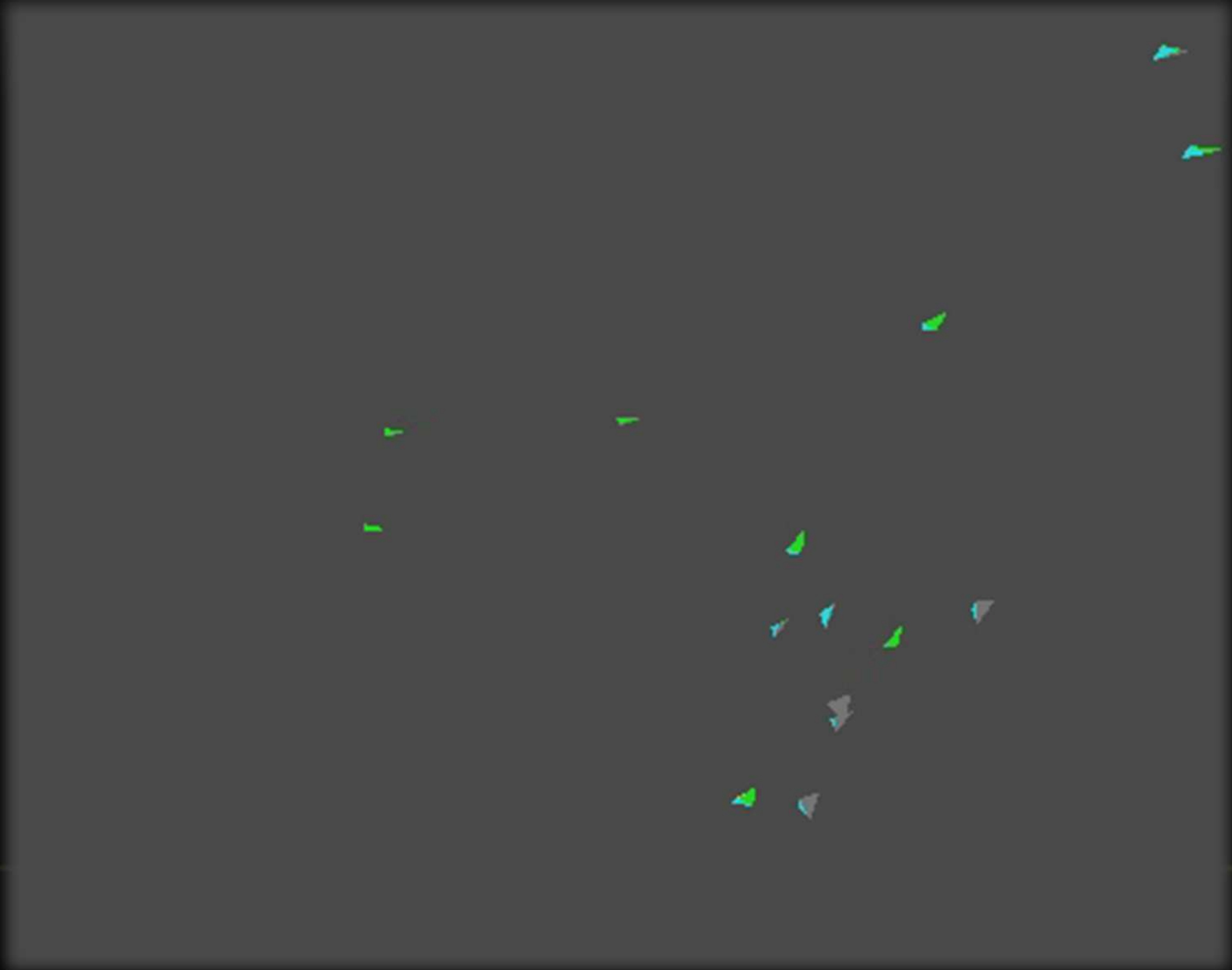
Cohesion

- Prefer to be at the center of the local flockmates
- Steers agent to the center of nearby flockmates

For figures and video see Craig Reynolds‘ web site
http://www.red3d.com/cwr/boids/ [3]

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

FLOCKING DEMONSTRATION I.

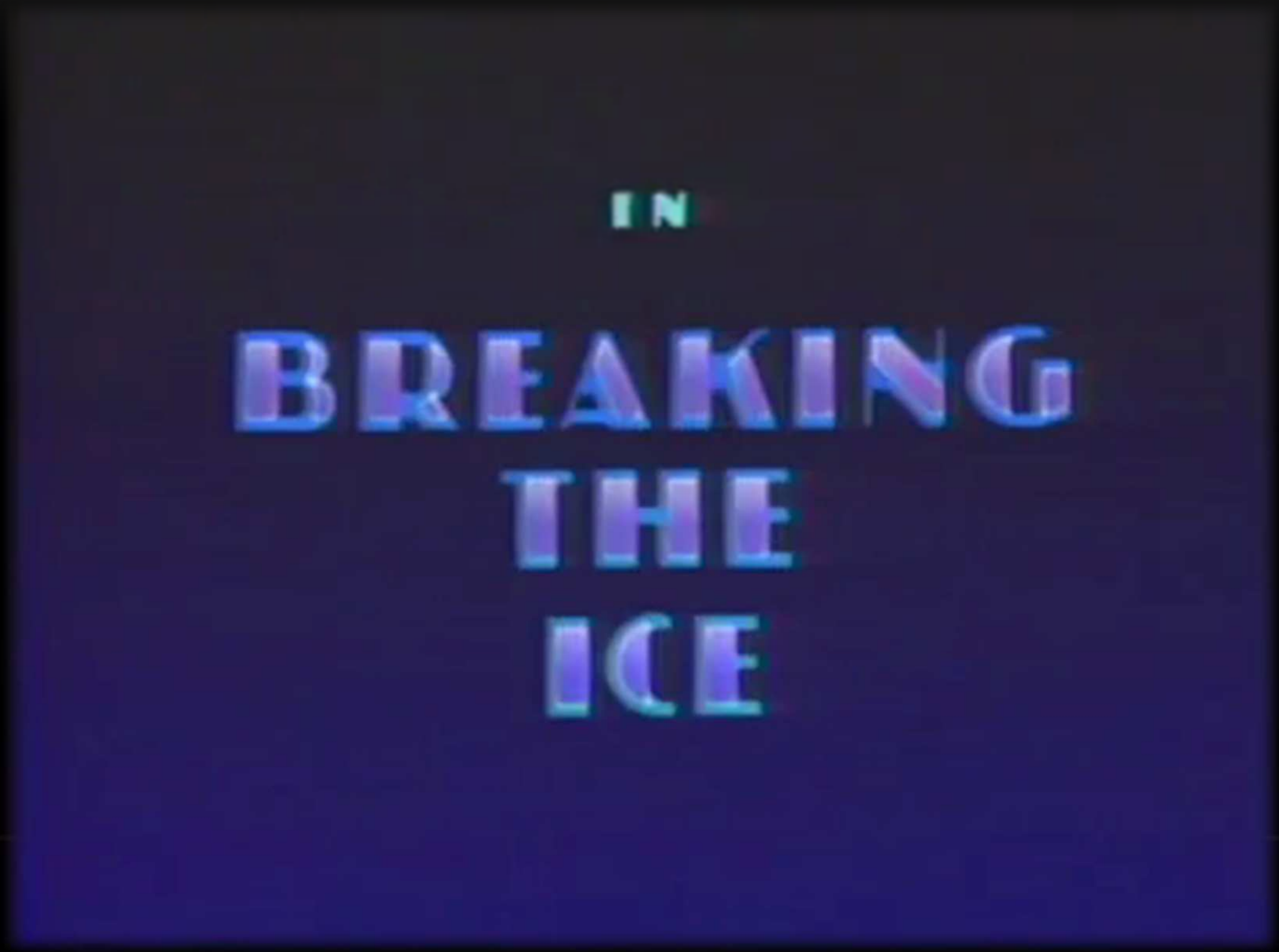


FLOCKING MODEL - FEATURES

- 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

For figures and video see Craig Reynolds‘ web site
http://www.red3d.com/cwr/steer/SeekFlee.html [3]

PURSUE & EVADE

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

For figures and video see Craig Reynolds' web site
http://www.red3d.com/cwr/steer/PursueEvade.html [3]

ARRIVAL

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
```

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

For figures and video see Craig Reynolds‘ web site
http://www.red3d.com/cwr/steer/Arrival.html [3]

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:
  - At each time step a random offset is added to the wander direction
  - The modified wander direction is constrained to lie on the big circle
- Constriction of the steering: big circle
- Constriction of the offset: small circle

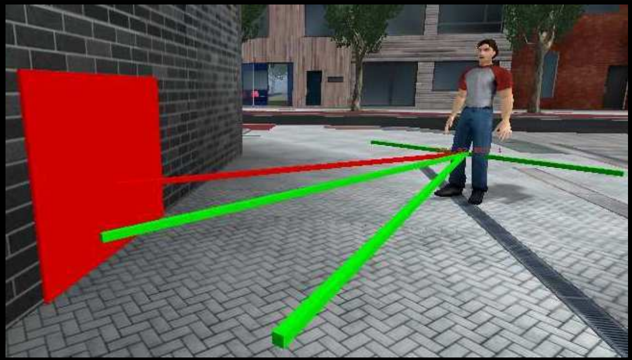
For figures and video see Craig Reynolds‘ web site http://www.red3d.com/cwr/steer/Wander.html [3]

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

For figures and video see Craig Reynolds‘ web site
http://www.red3d.com/cwr/steer/Unaligned.html [3]

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

For figures and video see Craig Reynolds' web site
http://www.red3d.com/cwr/steer/Obstacle.html [3]
http://www.red3d.com/cwr/steer/Containment.html [3]

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

For figures and video see Craig Reynolds‘ web site http://www.red3d.com/cwr/steer/Wall.html [3]

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

For figures and video see Craig Reynolds' web site
http://www.red3d.com/cwr/steer/PathFollow.html [3]
http://www.red3d.com/cwr/steer/CrowdPath.html [3]

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

For figures and video see Craig Reynolds' web site
http://www.red3d.com/cwr/steer/LeaderFollow.html [3]

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

For figures and video see Craig Reynolds' web site
http://www.red3d.com/cwr/steer/FlowFollow.html [3]

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.

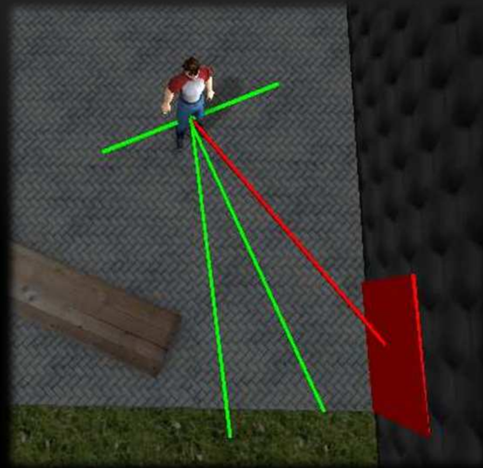
Primitive (and slow) collision avoidance
Knights and Merchants, 1998
http://www.youtube.com/watch?v=IZpgMnu_lAk

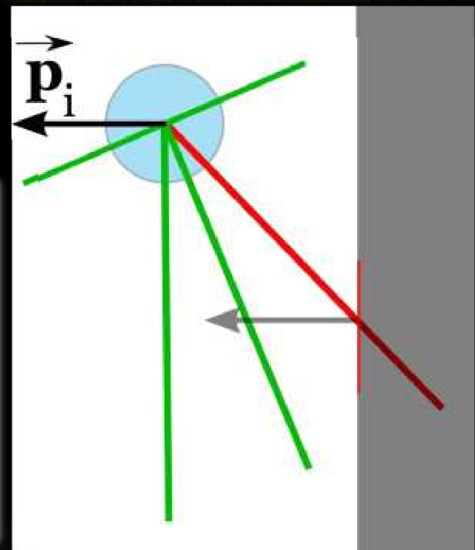
EXAMPLE IV.

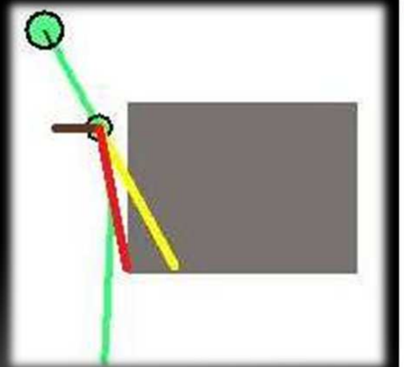
Getting stuck
Empire Total War, 2009
http://www.youtube.com/watch?v=IZpgMnu_lAk

OBSTACLE AVOIDANCE

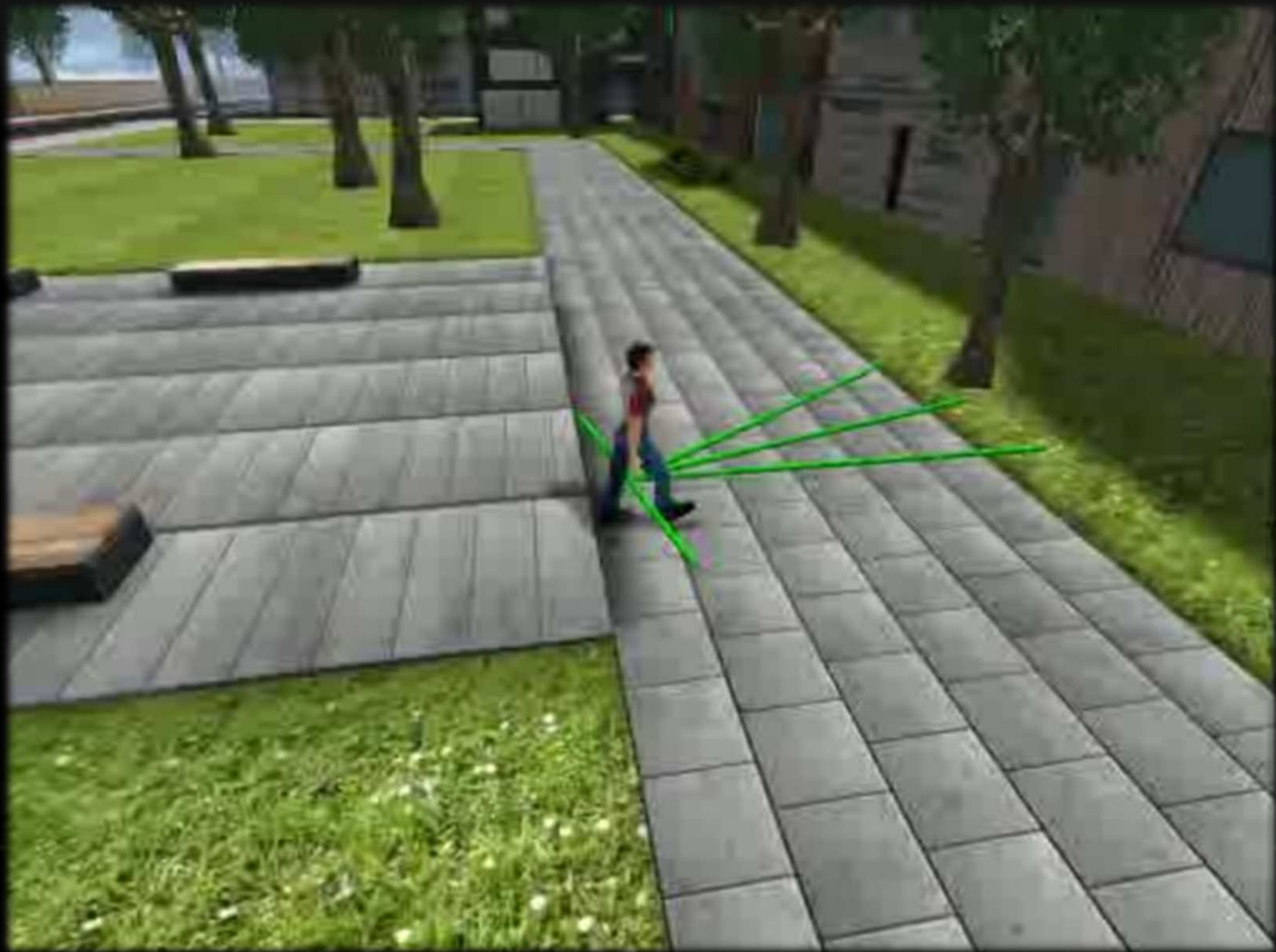
- Obstacle detection – typically fixed rays
- Possible implementation:
  - Steering force = $\sum_{i \in I} \left(\overrightarrow{p_i} \cdot W_i \cdot F \cdot \left(\frac{2 \cdot D_i}{R_i} \right)^O \right)$
  - $I = \text{set of colliding rays}$
  - $W_i = \text{weight of the ray (front – bigger, side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





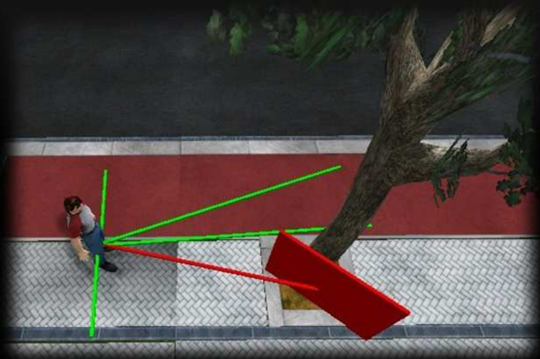


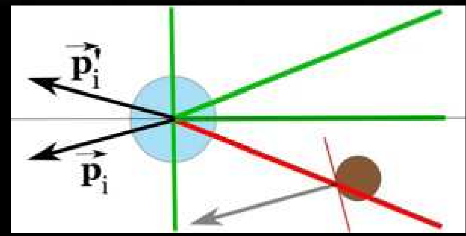
OBSTACLE AVOIDANCE - DEMONSTRATION

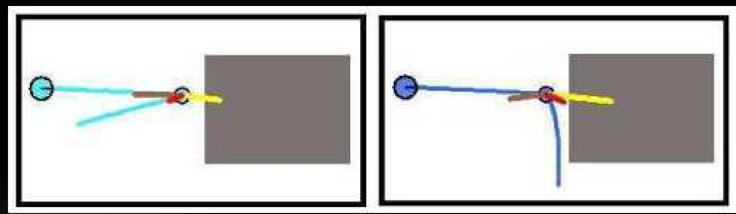


PROBLEMS AND DISCUSSION OF OA USE

- 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





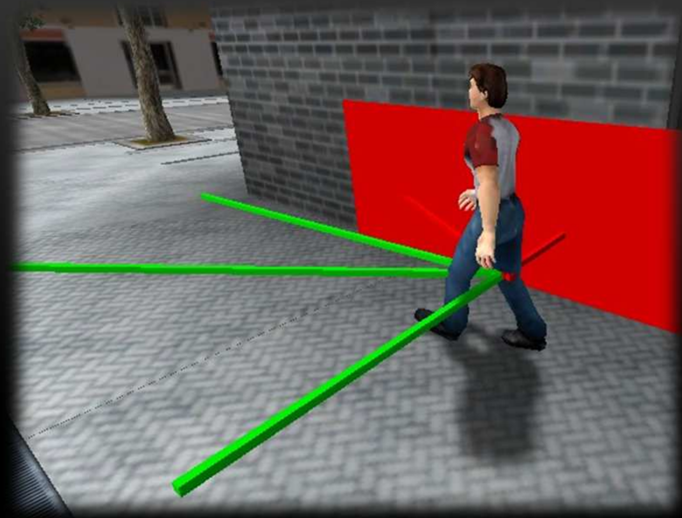


OBSTACLE AVOIDANCE & LOCAL TRAPS

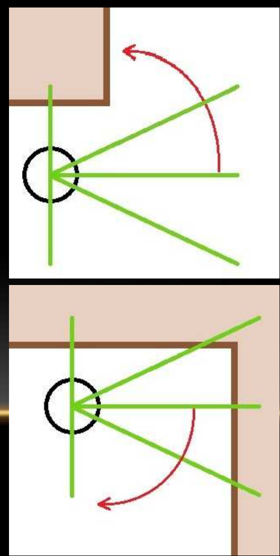
OBSTACLE AVOIDANCE & LOCAL TRAPS

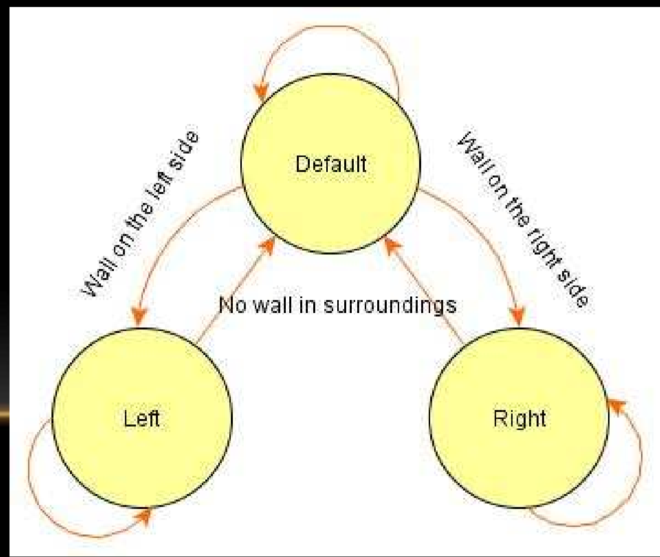
OBSTACLE AVOIDANCE & LOCAL TRAPS

WALL FOLLOWING

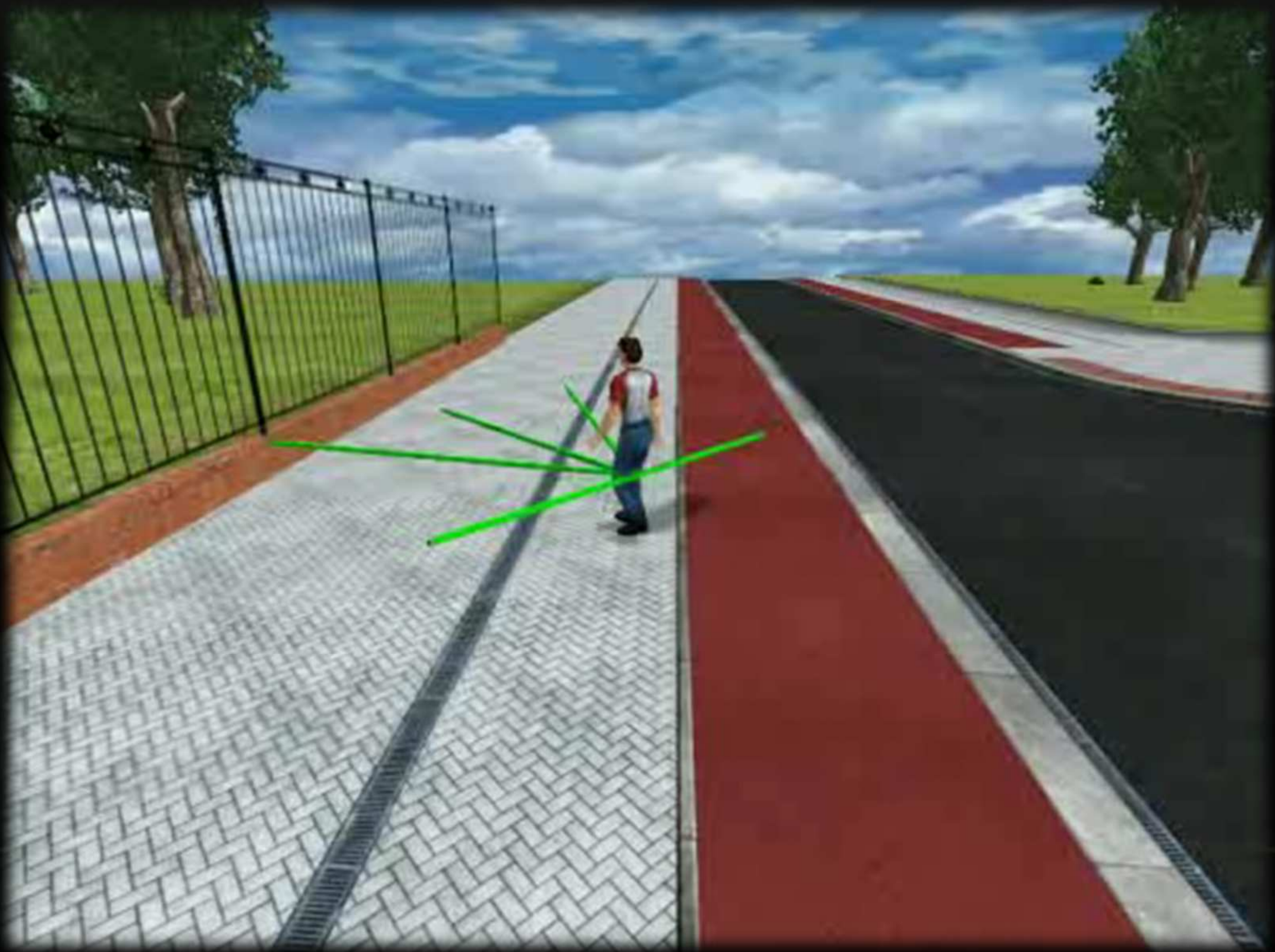


- Notes on possible implementation:
  - Wall is detected by rays
  - Attractive force to wall
    - The farther from wall an agent is, the bigger the attractive force is
  - Repulsive force from wall – if the agent is too close to wall
    - The closer to wall the agent is, the bigger is the repulsive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

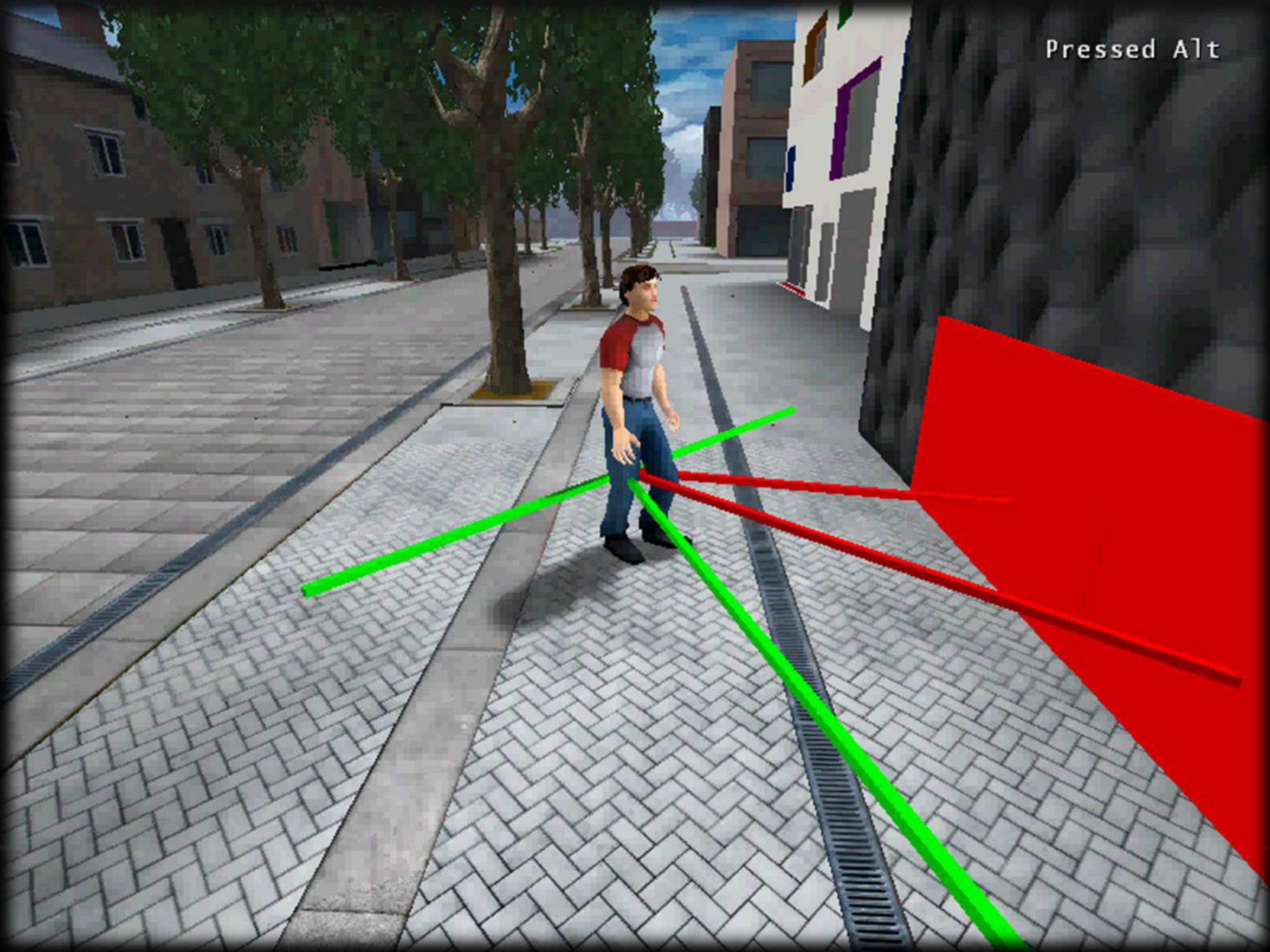




WALL FOLLOWING – DEMO I.



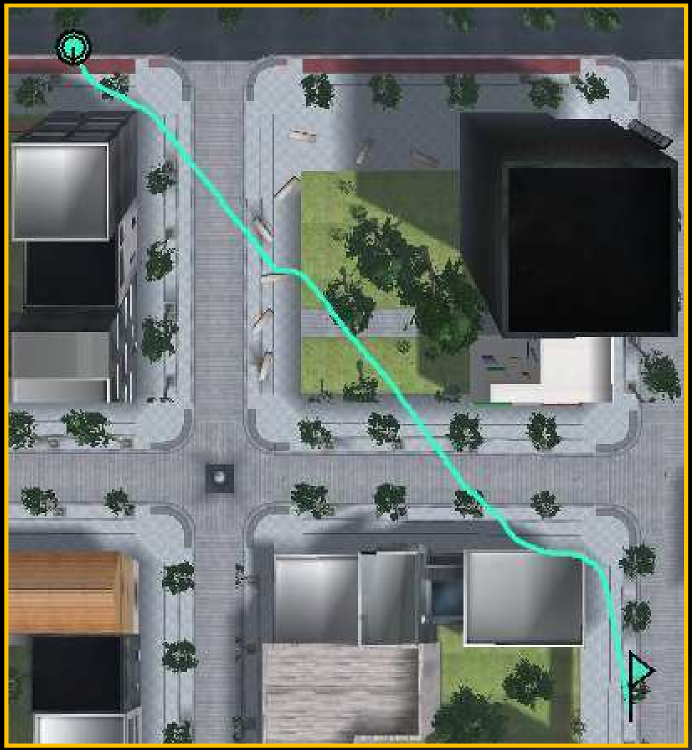
WALL FOLLOWING DEMO II.



WALL FOLLOWING IN COMBINATION

TA + OA

➔ directly through city



TA + WF

➔ on the sidewalks

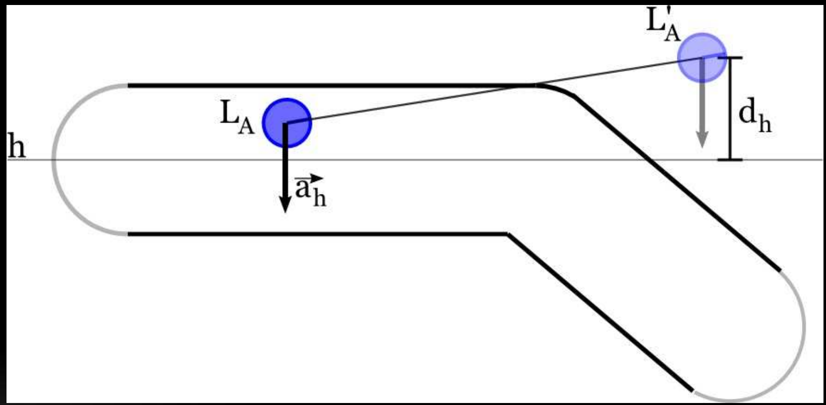
PROBLEMS OF LOCAL INFORMATION

- 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

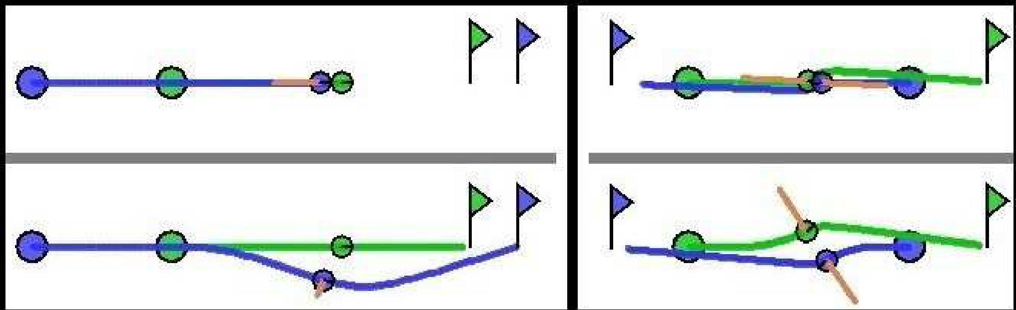
DYNAMIC OBSTACLES AVOIDANCE

PEOPLE (COLLISION) AVOIDANCE

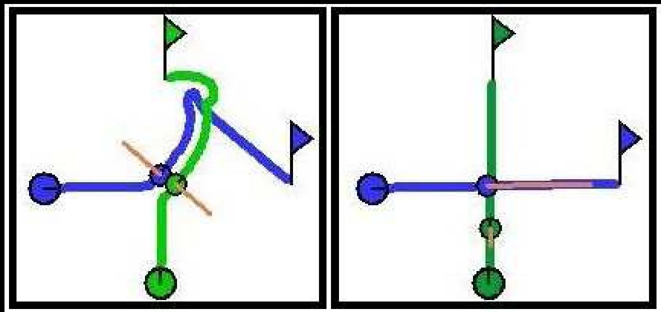
- Basics
  - Repulsive force from other too close agents
- Problems

→ Circumvention (rotational force)

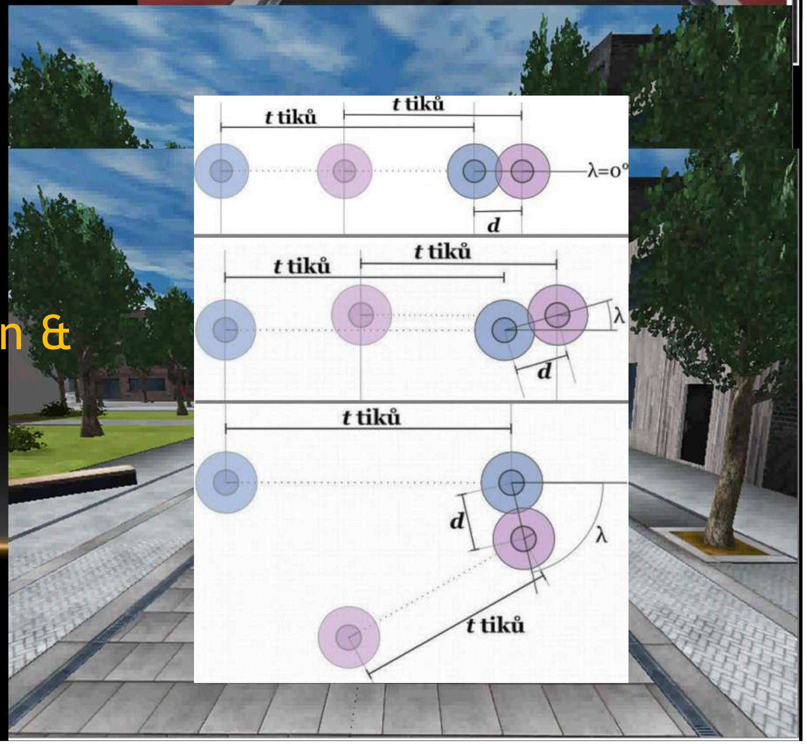
1



2



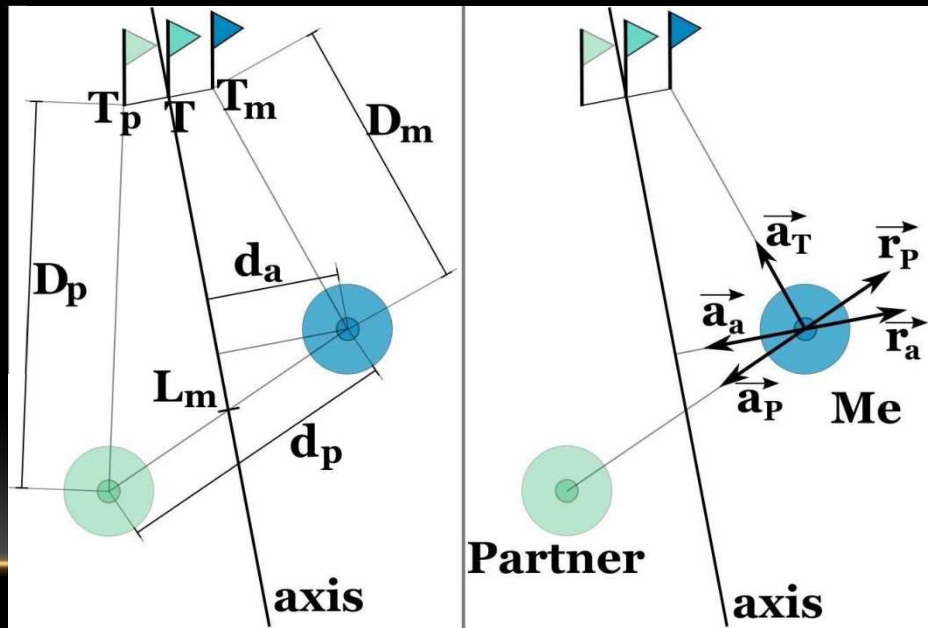
→ Acceleration & deceleration



PEOPLE AVIDANCE – DEMONSTRATION

OTHER SOCIAL INTERACTIONS

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

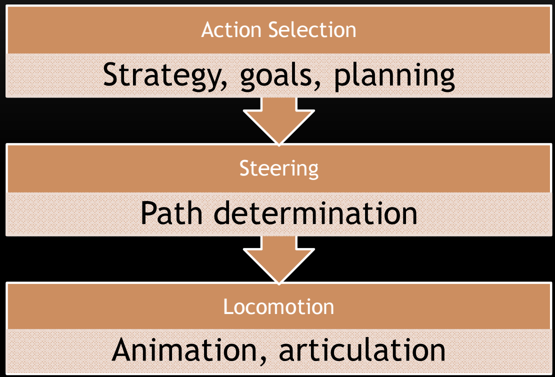


- Other…?

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.)

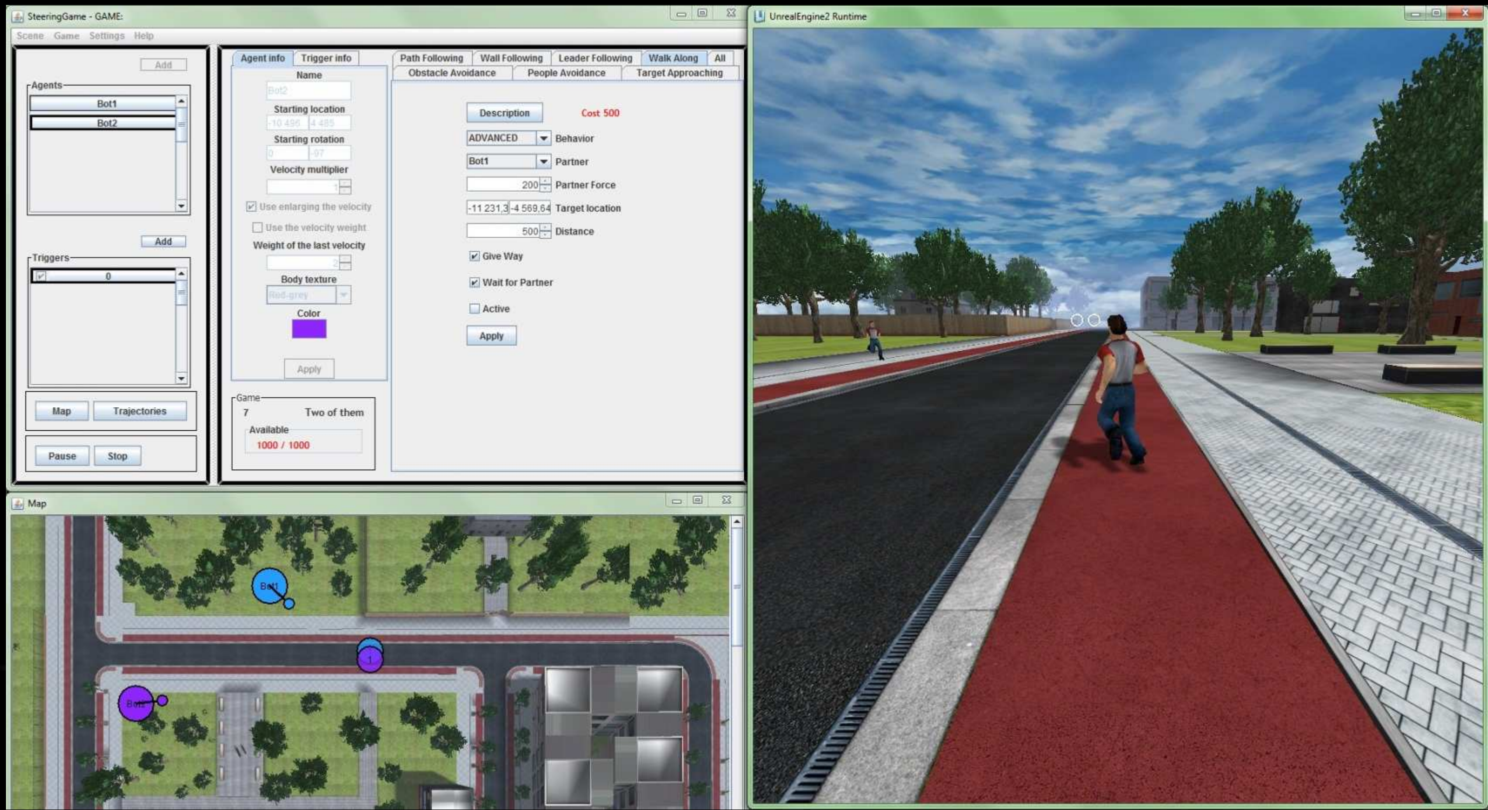
PRACTICALS

- 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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