# Chapter 11

## Behavioural Animation

# Behavioral Animation

**Knowing the environment**

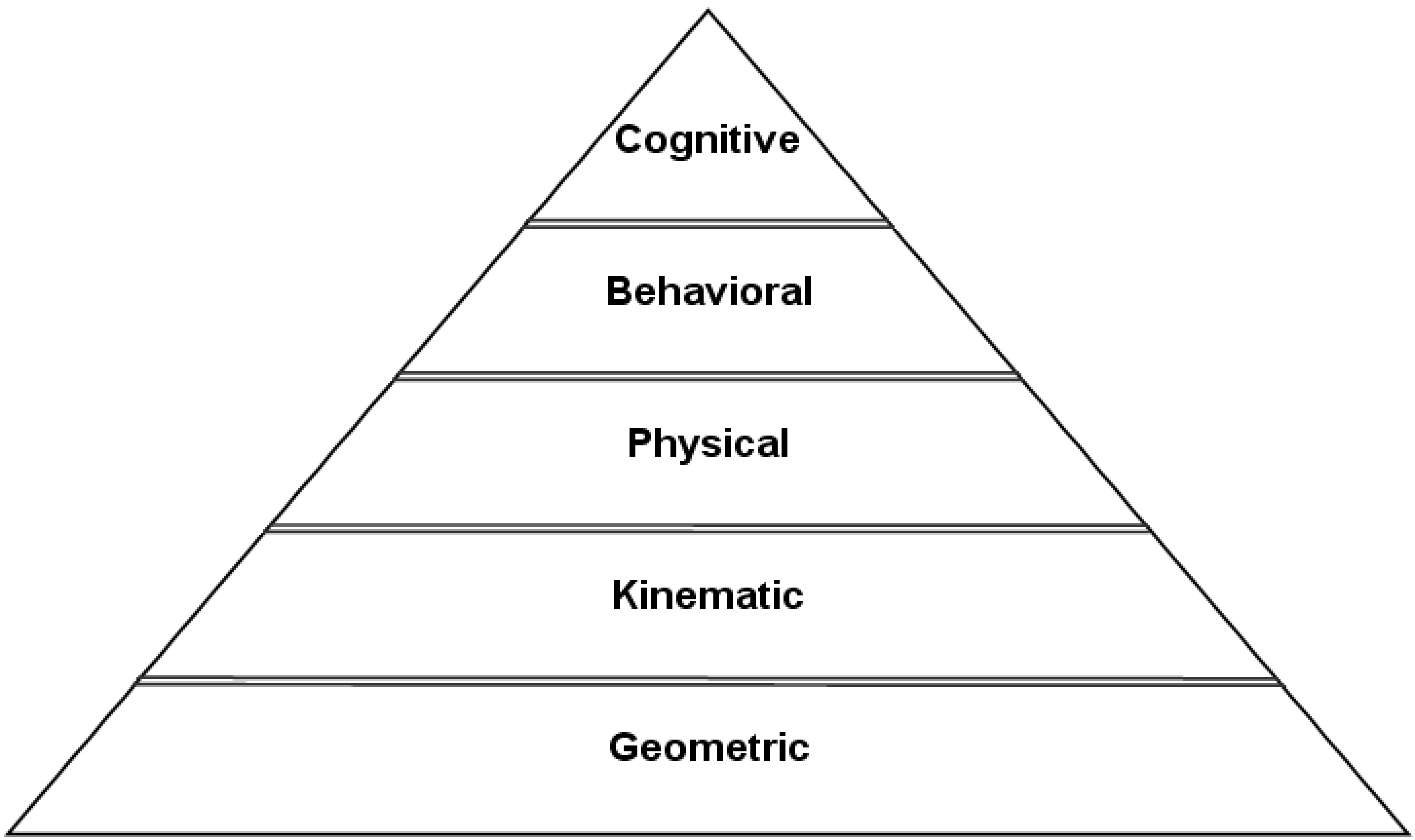
**Aggregate behavior**

**Primitive behavior**

**Intelligent behavior**

**Crowd management**

# Behavioral Animation



# Knowing the environment

**Vision – what do you know about the present**

**Memory – what is recorded about the environment**

**More about AI than graphics**

# Vision

**Geometric issue – what's in sight?**
**OR**
**Can I see X?**

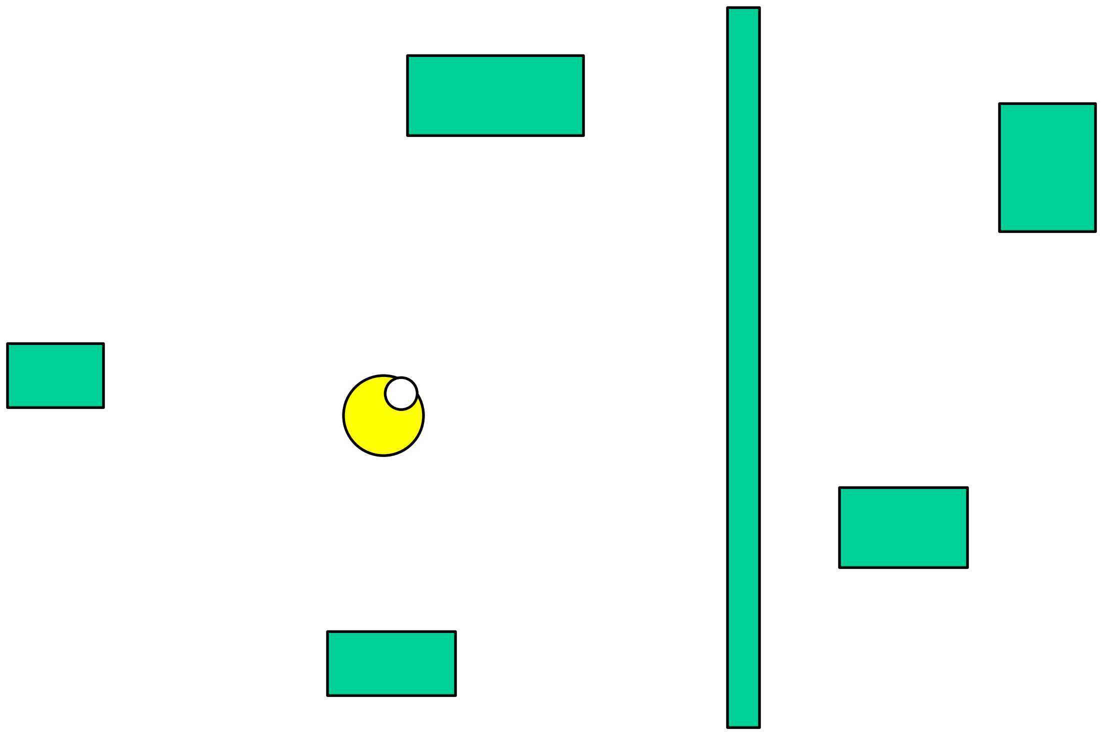
**Computation v. accuracy**

**Perceptual issue – what do you see?**

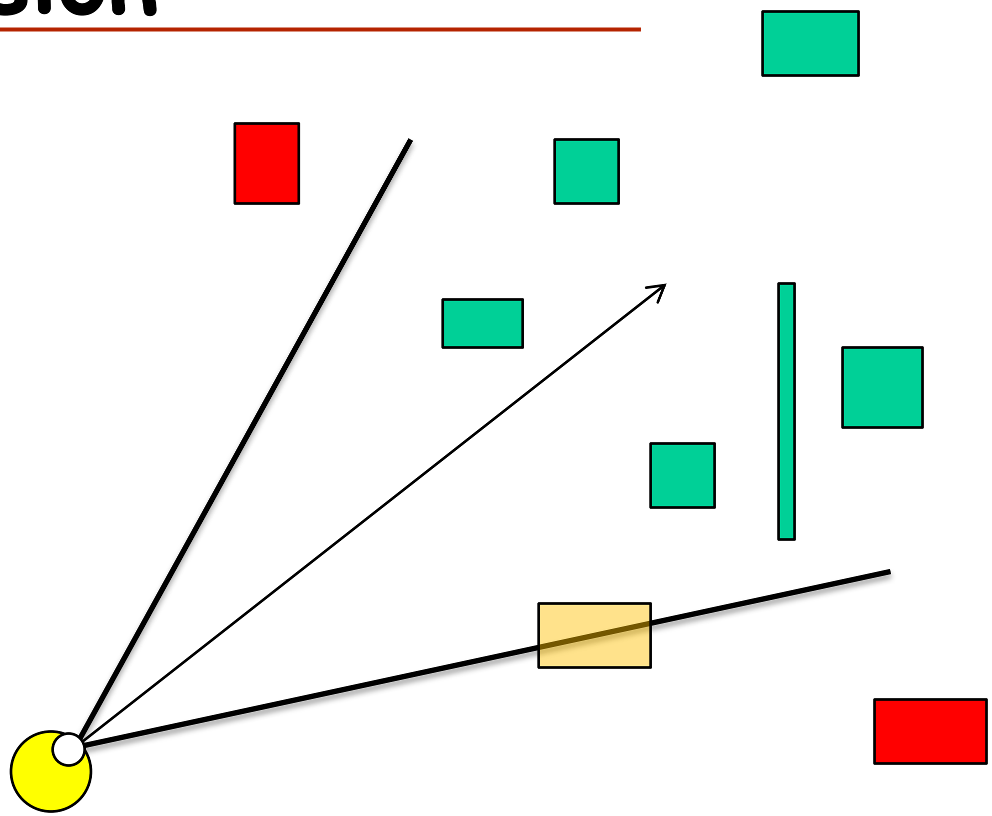
**Cognitive modeling – necessary? At what level?**

# Omniscience

**Everything in database is 'known'**

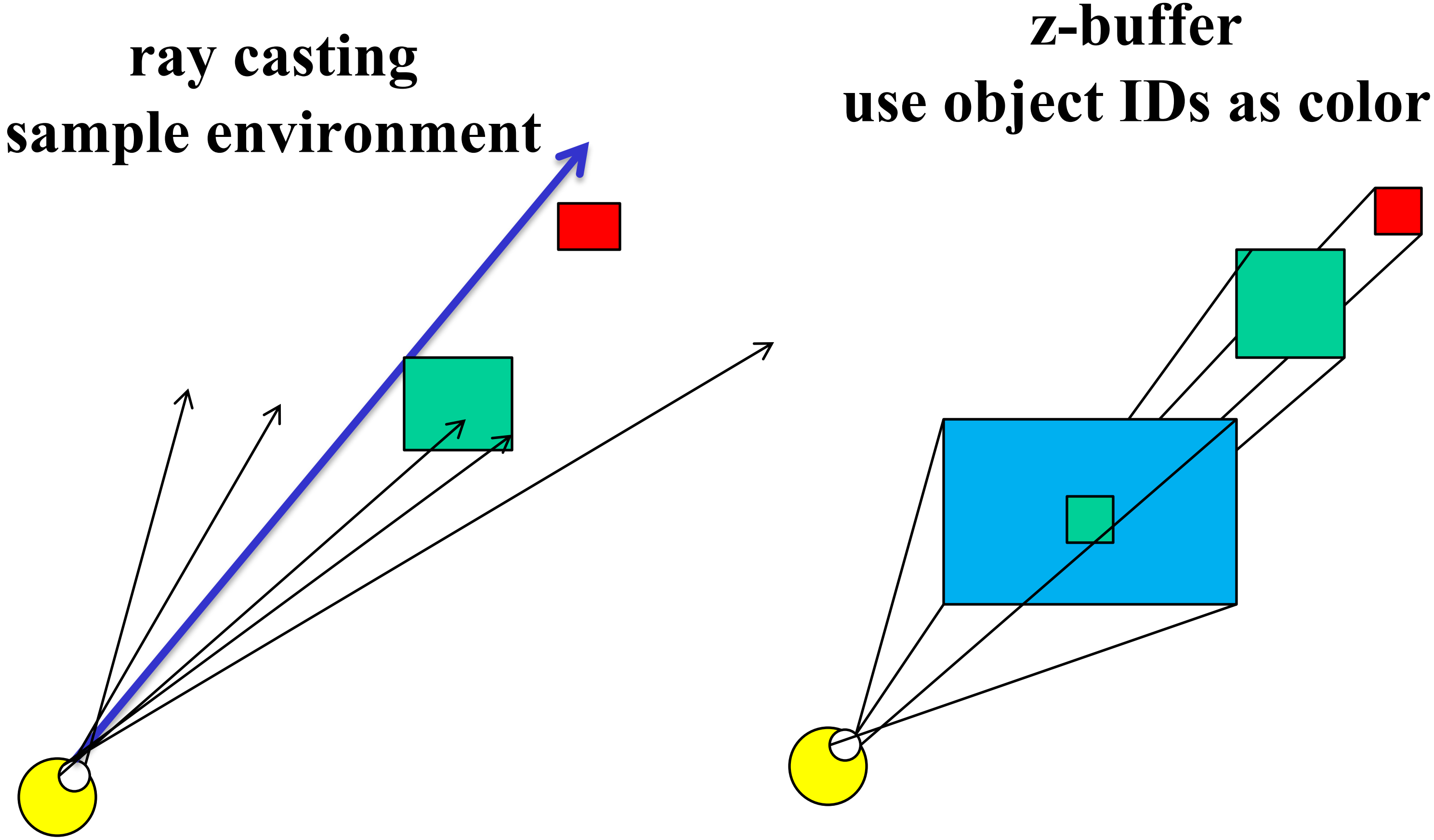


# FOV Vision



Use surrogate bounding volumes, or sample points

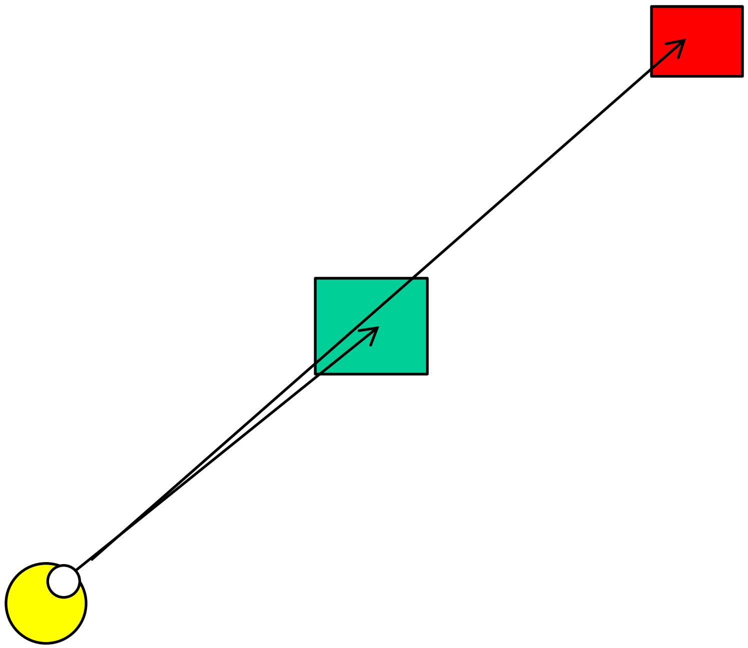
# Occluded Vision



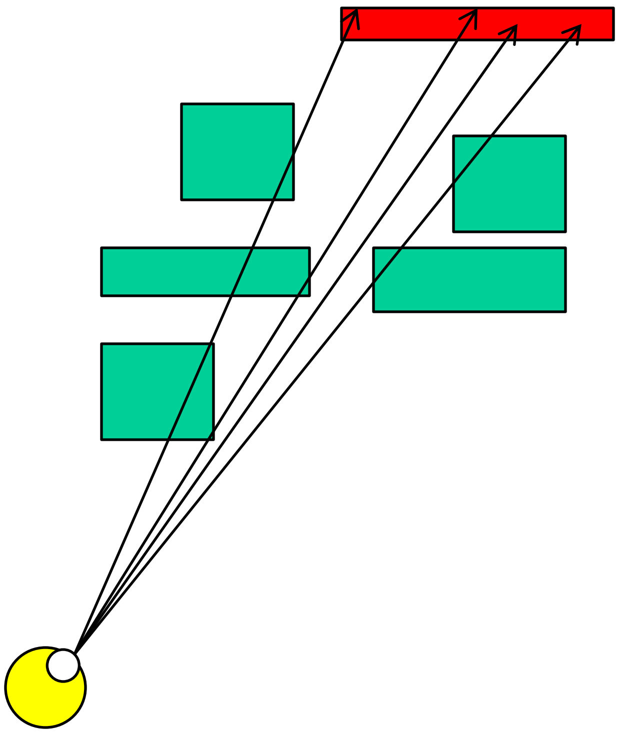

Use surrogate bounding volumes

# Target-testing vision

Can I see X?
Cast ray



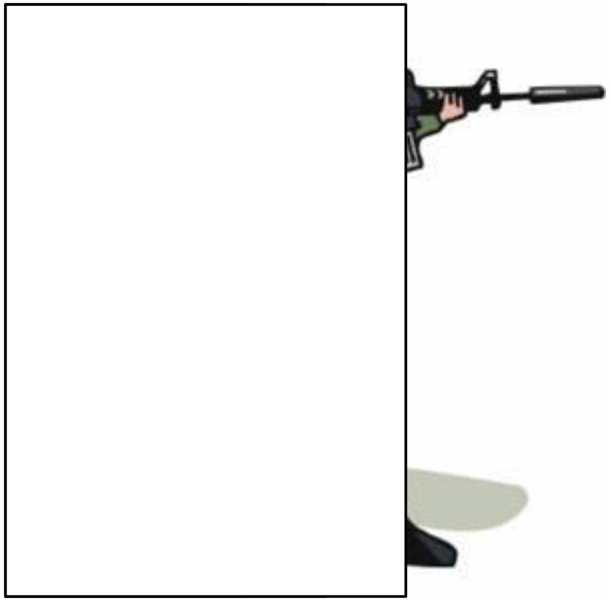
Sample object



Use surrogate bounding volumes

# Object Recognition

**Cognitive modeling**
**How much and what part is needed?**



**Application need?**
**Not yet addressed in literature**
**More AI than graphics**

# Other senses?

**Hearing?**
**Smell?**

**Model sensors & signal propagation**

**Spatial occupancy approach?**

**Applications?**

# Memory

**What is recorded about the environment**

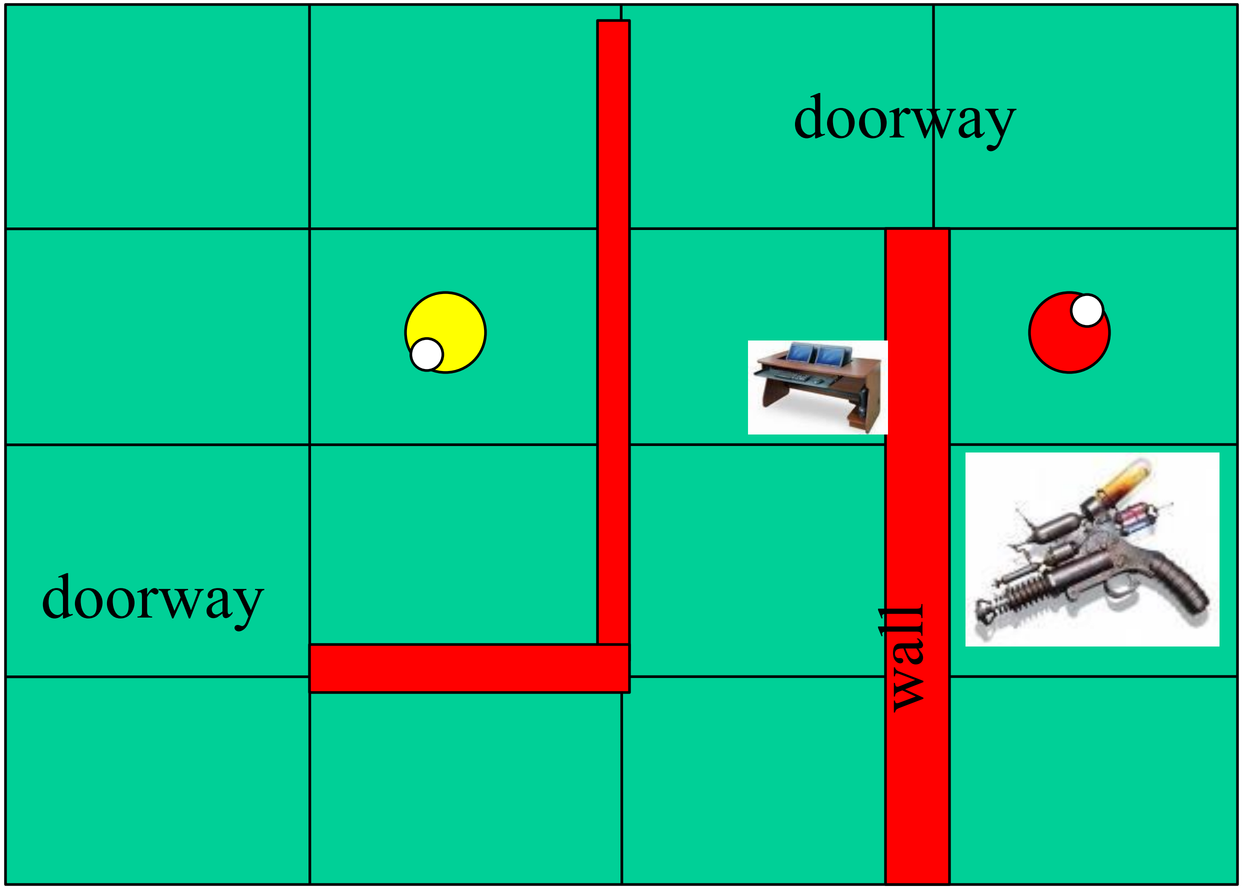
**Spatial occupancy**

**Transience of objects: time-stamps**

**hierarchy: short-term, long-term**

# Spatial Occupancy

**transiency**



# Aggregate Behavior: E pluribus unum Emergent Behavior

**Typical qualities**

| Type | Elements | Physics Env/Others | Intelligence |
|---|---|---|---|
| Particles | $10^2$-$10^4$ | Much/none | None |
| Flocking | $10^1$-$10^3$ | Some/some | Limited |
| Crowds | $10^1$-$10^2$ | Little/much | Little-much |

# Primitive Behavior - Flocking

**Local control – for realism, the flock member only reacts to locally accessible information**

**Perception – FOV vision – angle can change with speed**

**Interacting with other members – stay with friends, avoid bumping into each other**

**Interacting with the environment – collision avoidance is primary**

# Primitive Behavior - Flocking

**Original work by Craig Reynolds**

**Global control – need control of flock**

- **script flock leader**
- **global migratory urge**

**Negotiating the motion**

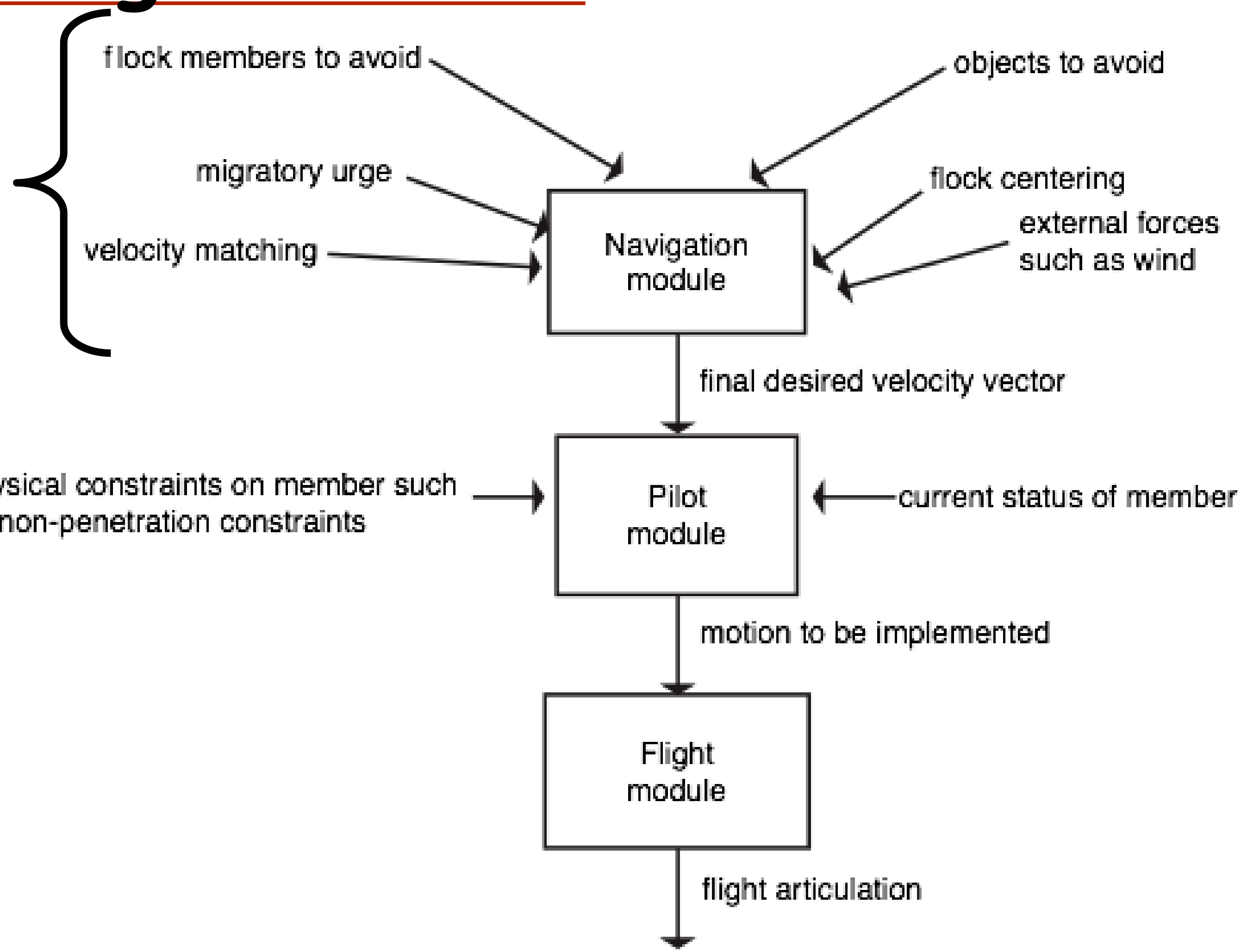
**Collision avoidance – steer to avoid**

**Splitting and rejoining – difficult to tune parameters**

**Modeling flight – e.g., banking into turns**

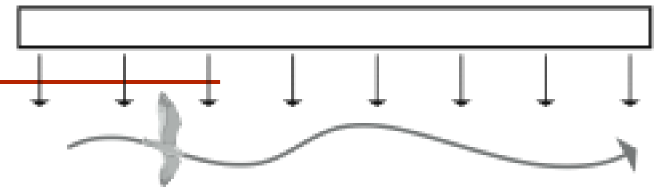
# Negotiating the Motion

**Forces**
**Or**
**"Reasoning"**
**(e.g. rule-based)**

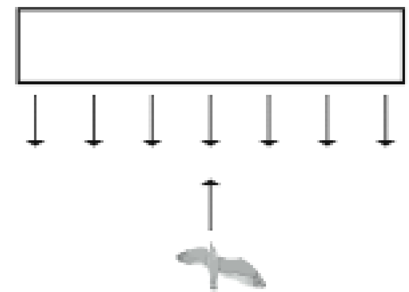


# Navigating Obstacles

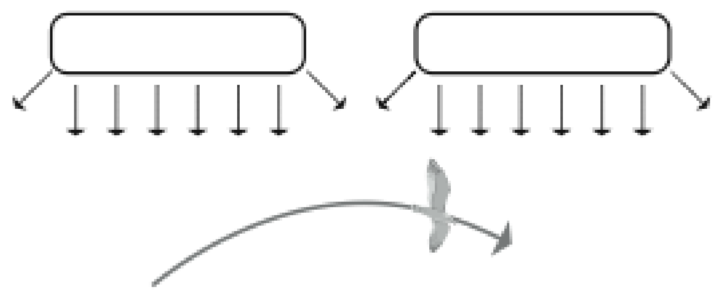
## Problems with repulsive forces



Attempt at parallel movement

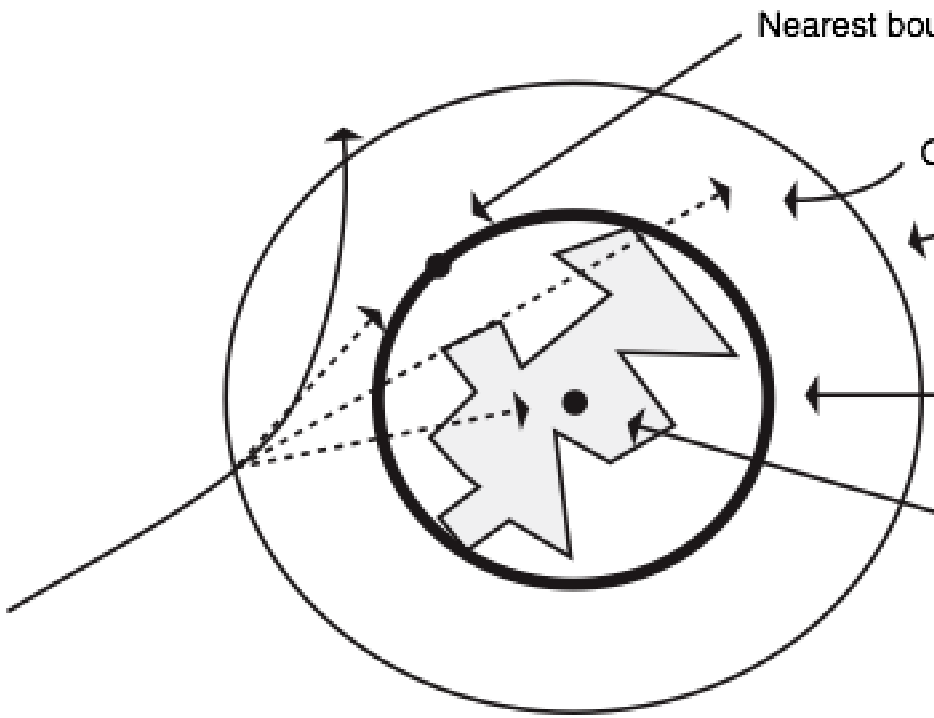


Attempt to fly directly toward a surface



Attempt at finding a passageway

# Navigating using bounding sphere



# Navigating

## Testing for being on a collision path with (bounding) sphere

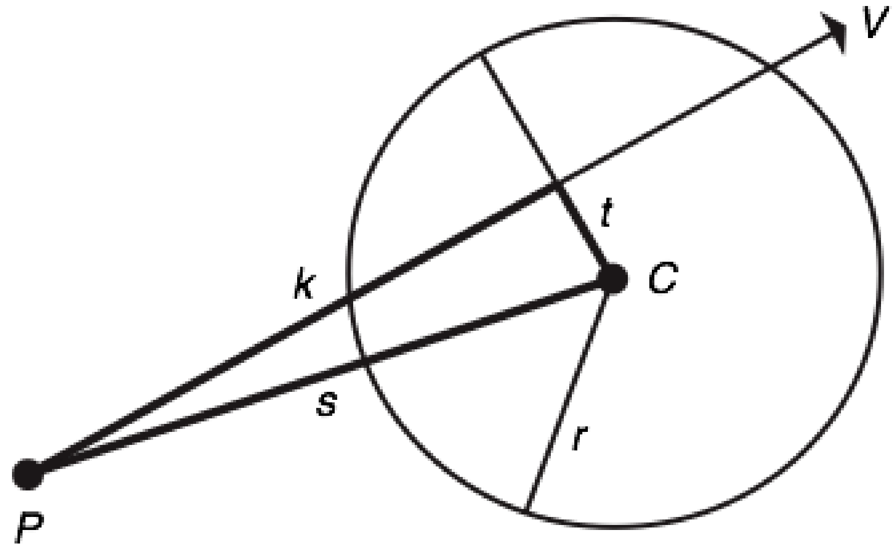
**Given: P, V, C, r**

$$k = (C - P) \bullet \frac{V}{|V|}$$

$$s = |C - P|$$

$$t = \sqrt{s^2 - k^2}$$

$$t < r$$



# Finding closest non-colliding point

Calculate s,t

$$k = \sqrt{|C - P|^2 - r^2}$$

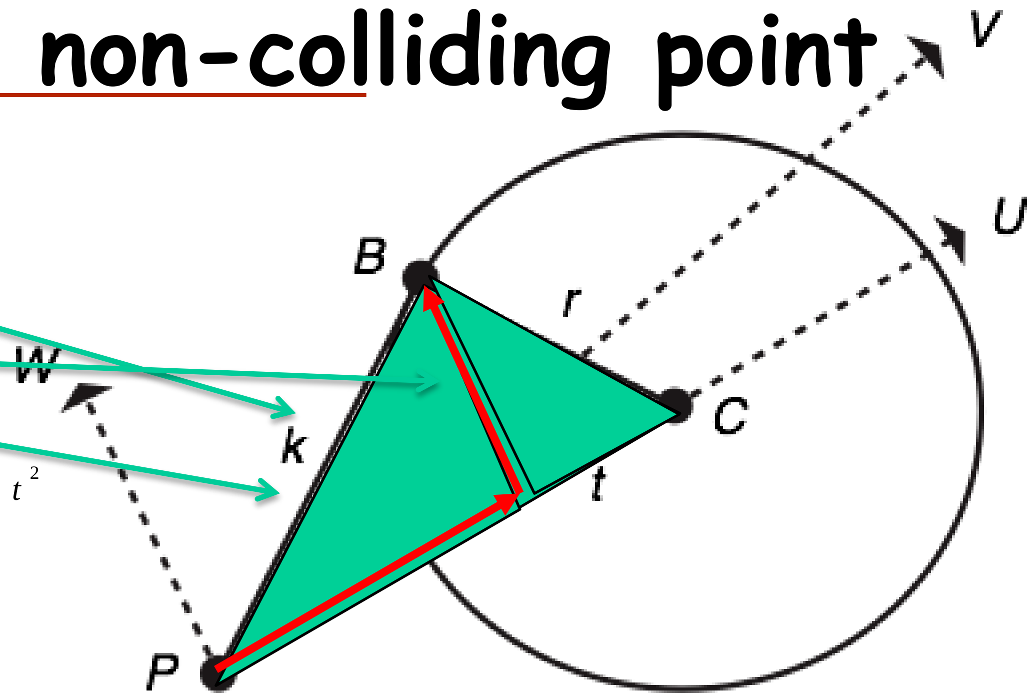
$$r^2 = s^2 + t^2$$

$$k^2 = s^2 + (|C - P| - t)^2$$

$$k^2 = r^2 - t^2 + |C - P|^2 - 2|C - P|t + t^2$$

$$t = \frac{k^2 - r^2 - |C - P|^2}{-2|C - P|}$$

$$s = \sqrt{r^2 - t^2}$$

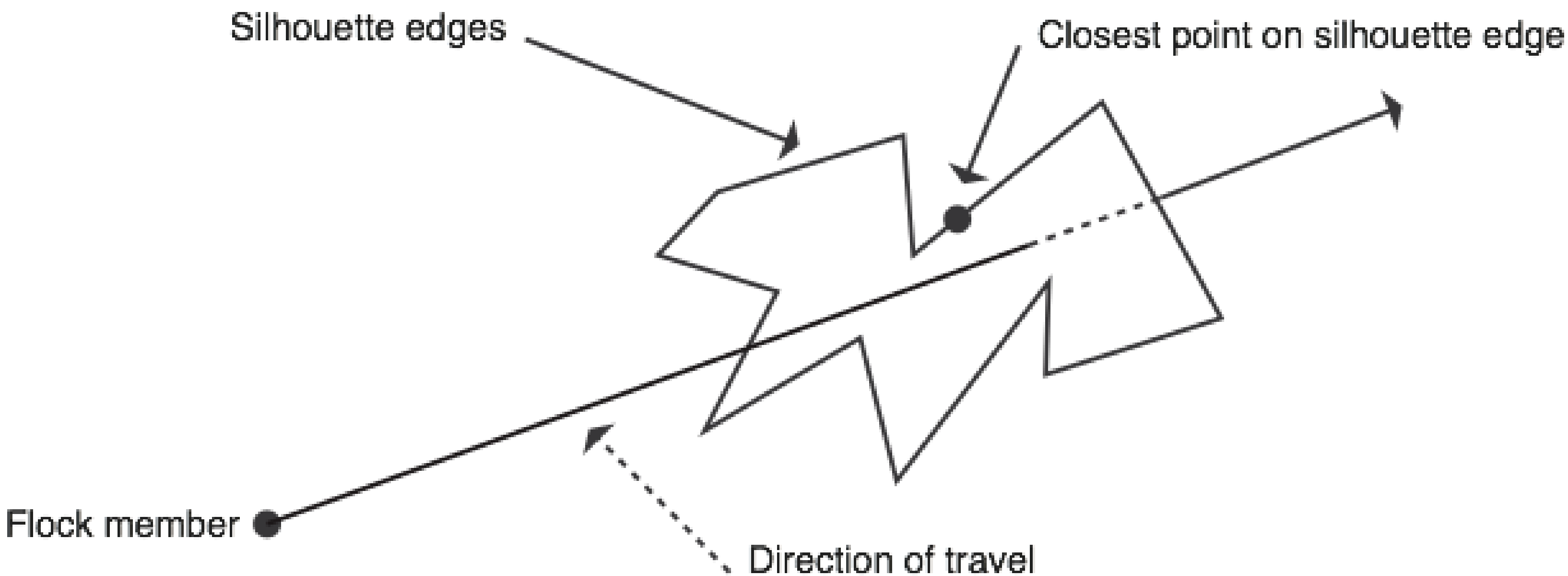



$$U = \frac{C - P}{|C - P|}$$

$$W = \frac{(U \times V) \times U}{|(U \times V) \times U|}$$

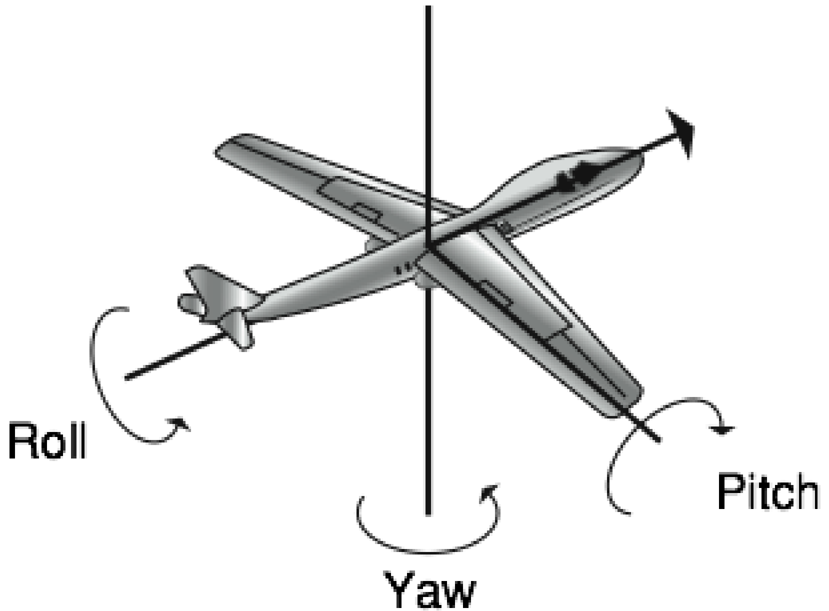
$$B = P + (|C - P| - t)U + sW$$

# Navigating – finding a pass

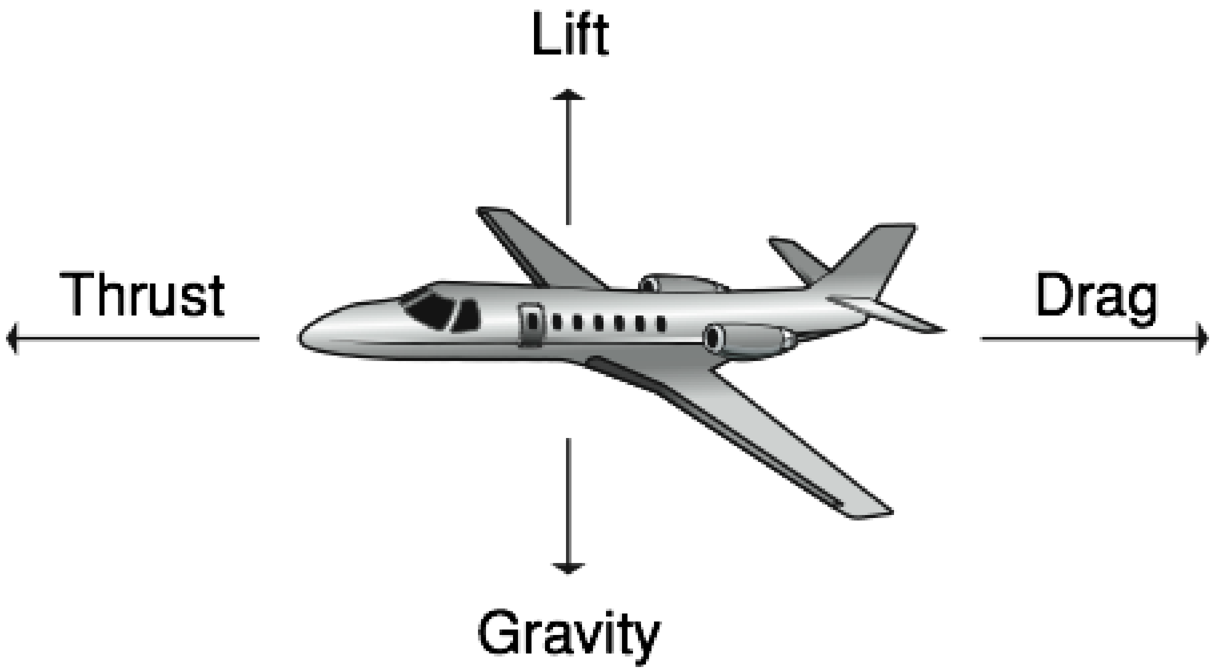



**Vision Options:**
**Render in z-buffer**
**Sample environments with rays**

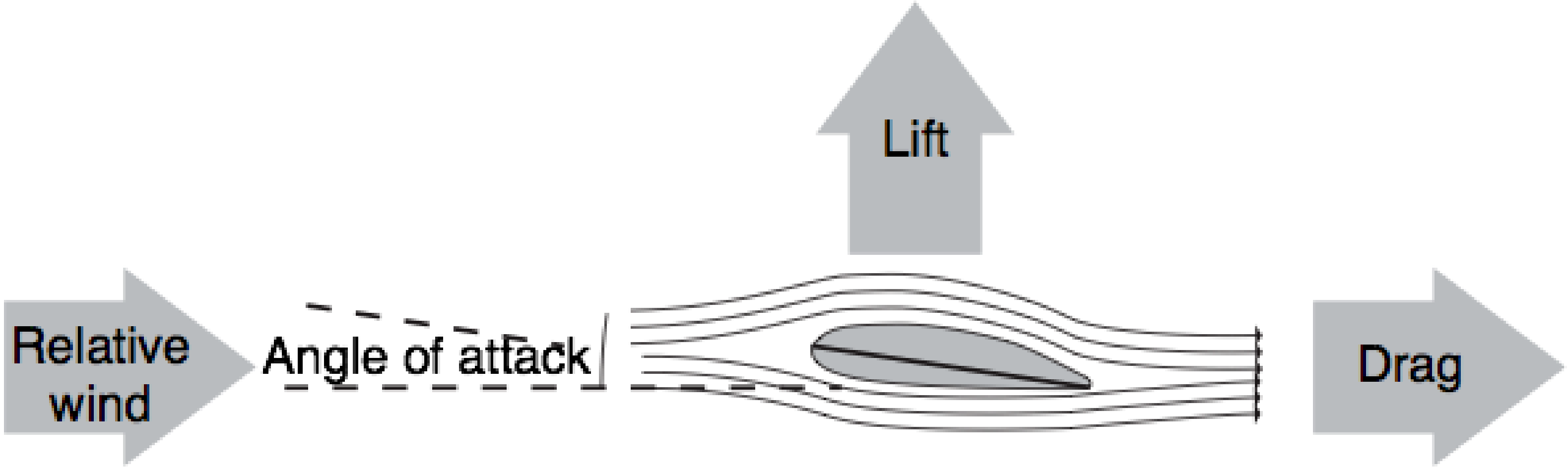
# Modeling Flight –common in flocking



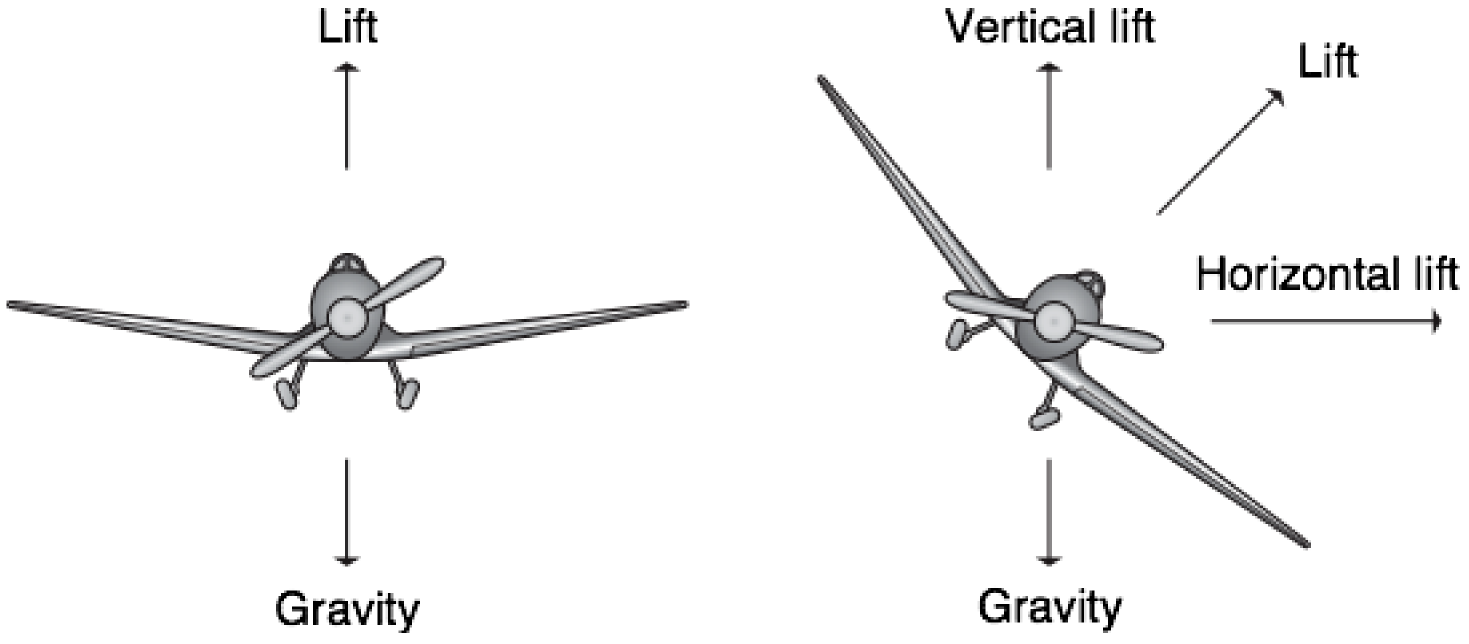
# Modeling Flight



# Modeling Flight



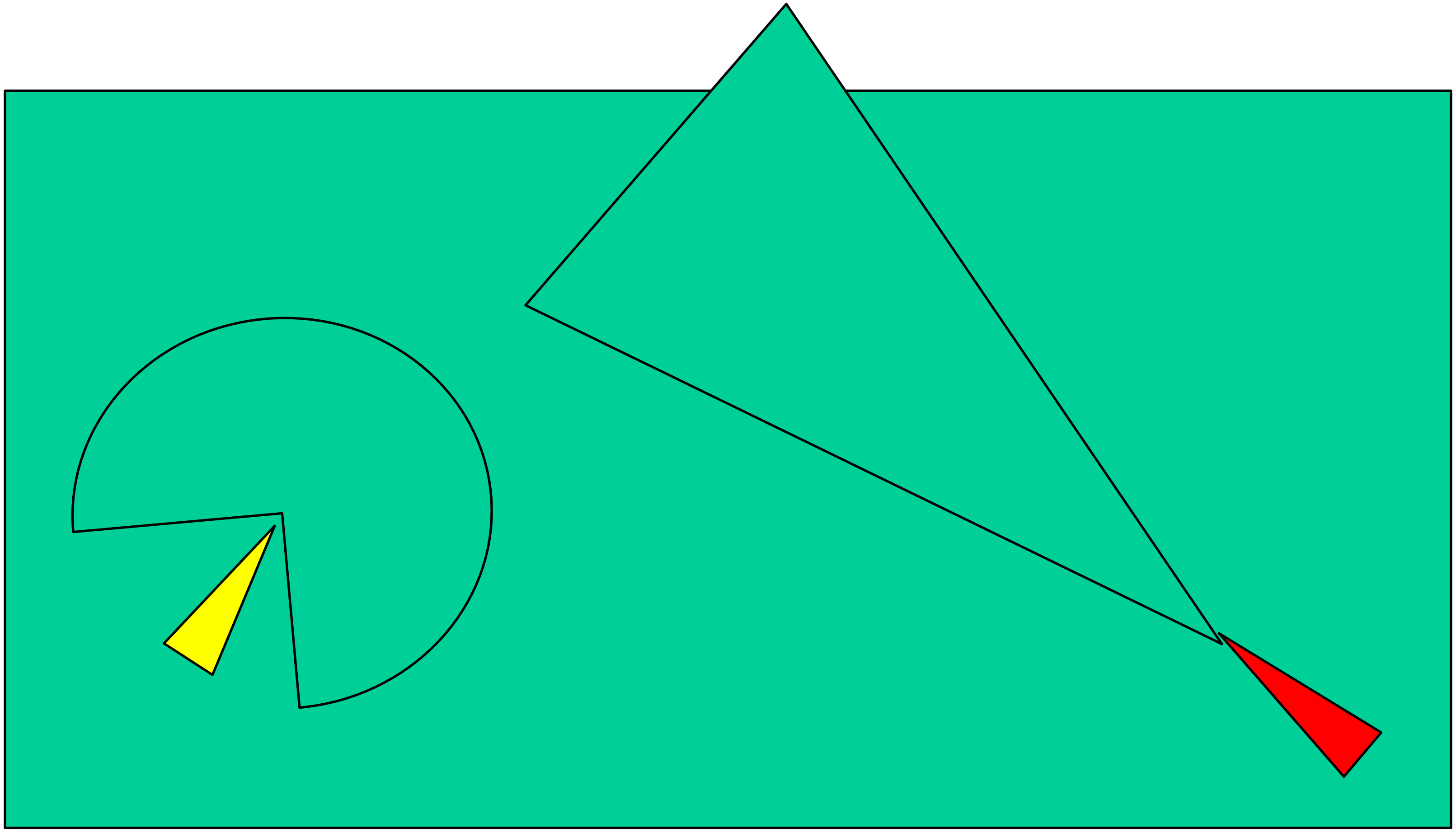
# Modeling Flight



# Primitive Behavior - Prey-Predator

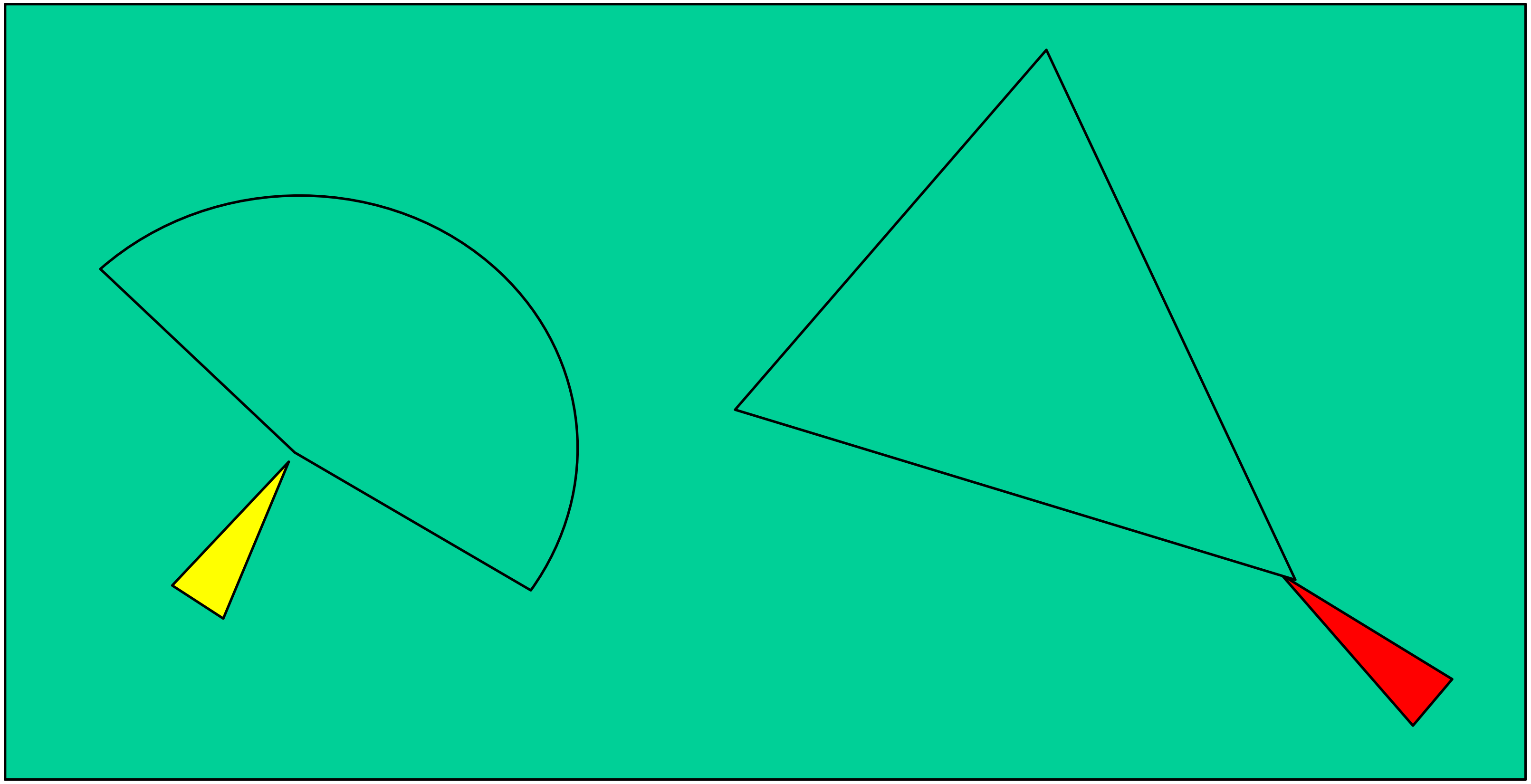
unbalanced abilities
- vision - distance, movement, fov
- maximum velocity
- maximum acceleration
- maximum angular velocity maximum angular acceleration

# Prey-Predator - vision



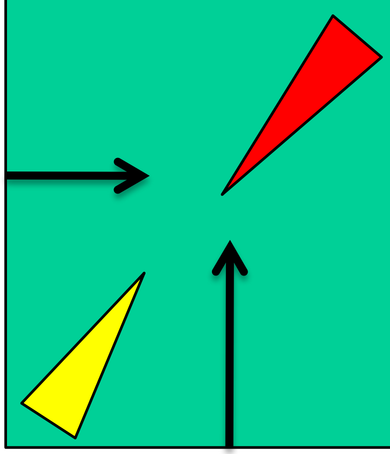
# Prey-Predator

## agility: speed and turning



# Prey-Predator - hidden by forces

**Using pure forces**
**May not prevent object penetration**
**Prey can be 'hidden' by environmental repulsive forces**



# Intelligent Behavior

- Autonomous behavior
  - ‘Self-animated’ characters
  - Perception & reasoning about environment
  - Personality, emotions, dispositions
- Manifestations of Individuality
  - Body Expressions and Gestures
    - Facial expressions
    - Speech

# Internal State

**Models what the agent needs to do**

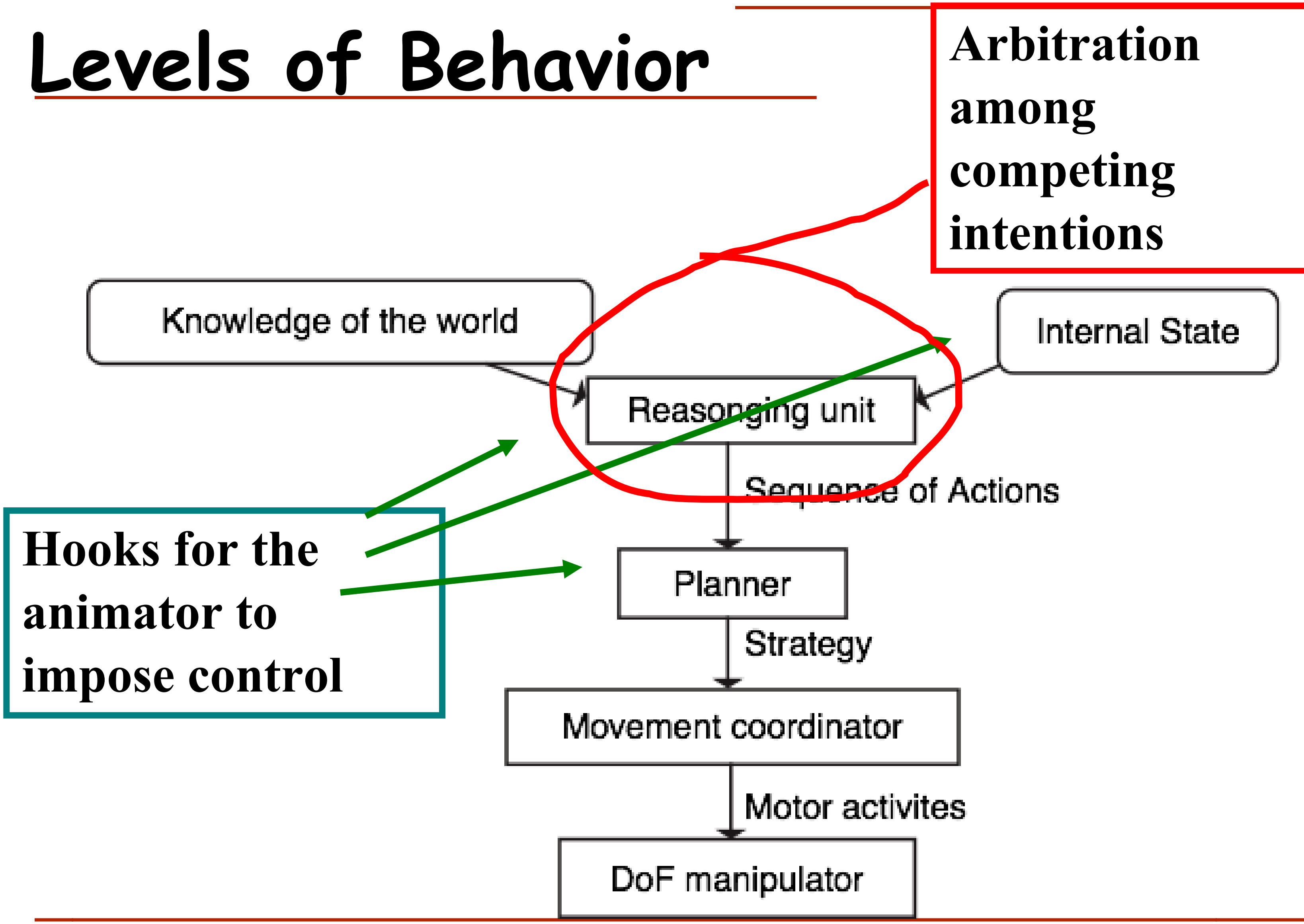
**<u>Suggested precedence classes of internal state variables</u>**

**Imperatives**

**Desires**

**Suggestions**

# Levels of Behavior



# Expressions and Gestures

**ToBI – Tones and Break Indices**
**LMA – Laban Movement Analysis**

**BEAT**
**EMOTE**
**RUTH**
**Greta**

# EMOTE

**N. Badler at U.Penn**

**Speech driven movement and gestures**
**Torso & arms**
**Laban Movement Analysis**
- **Effort**
- **Shape**

# BEAT

**J. Cassell at M.I.T.**

**Input text – marked up**

**Generate non-verbal behavior in sync with speech**

**Facial expressions,**
**head & body motions**
**gestures**

# Modeling Personality

**Personality – long term qualities**

**Emotions – short term**

**Mood – third level**

**Basic emotions: happy, sad, fear, disgust, surprise, anger**

# Personality Models

- Biology/evolutionary approaches
  - brain & anatomy
  - biochemistry & personality
  - genetics & personality
- Psychoanalytic approach
  - psychometrics
  - Freud, Adler, Jung
- Adaptation Theory:
  - traits: passive, aggressive, withdrawn
- Need theory: Freud + experiential learning
- Arousal Theory: absorb & discharge energy

# Type & Trait Theory

**Type: individuals slotted into a type**

**e.g. introvert v. extrovert**

**Trait: lie on gradation**

**combination defines behavior in situation**

**e.g.,**

**Internal states: how perceptions dictate emotional experience**

# Trait Theory

**OCEAN: openness, conscientiousness, extroversion, agreeableness, neuroticism**

**PEN: extraversion, neuroticism, psychoticism**

**OCC: how perceptions dictate emotional experience**

# Modeling Individuality

**Improv**
**AlphaWolf**

# Crowd Management

Emergent behavior
Statistical behavior v. believable individual behaviors
Homogeneous activity v. Internal structure

- For evaluation
  - Pedestrian traffic simulation
  - Traffic flow
  - Emergency response modeling
- For entertainment
  - Background crowds

# Crowds

- Emergent behavior:
  - similar to flocking
  - collision avoidance
  - ‘intelligent’ paths
- From a distance: statistical behavior
  - nonsensical detailed motion
  - reasonable visual effect
- Internal structure
  - limited interaction among members
  - group formation

# Crowd Applications

For evaluation

- Building evacuation, e.g. virtual fire drill
- Architecture evaluation, e.g. signage

For training

- Military scenarios, e.g. sniper training
- Emergency response, e.g. disaster response

For entertainment: e.g., background crowds

- games
- films, e.g., Titanic, Saving Private Ryan,
- Lord of the Ringss

# Qualities of crowd

Emergent behavior - similar to flocking, flocking system
Uniform – sameness of members
Quantity & density - average distance between members
Viewing distance – aggregate behavior, inspect individuals
Function – simple traversal, background activity, main actions

Individual processing – amount of computation per member
Physics – simulated reaction to environment
Intelligence - reasoning capability - agents

# Uniformity, granularity

**Background noise:**

**Activity without intention**

**Statistical behavior:**

**On average, intentional activity**

**Individuality:**

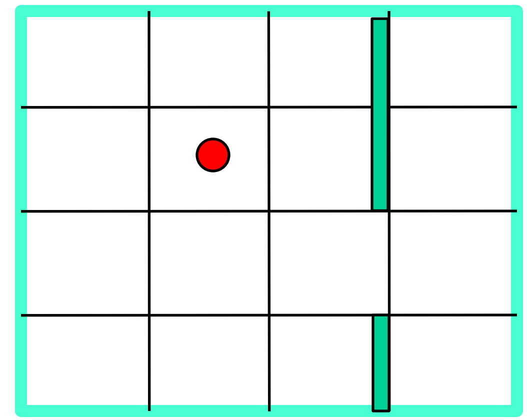
**Believable activity at level of individual**

# Execution environment

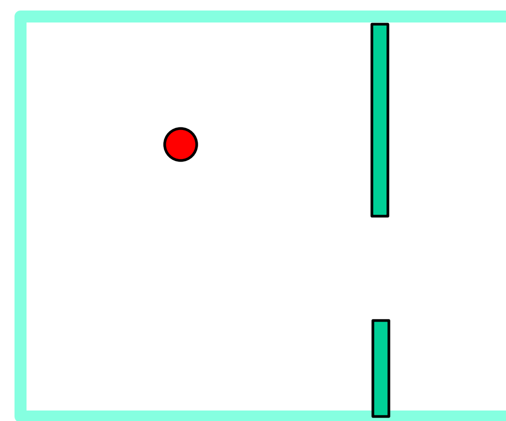
**Real-time v. Off-line computation**

- **simple computations**
- **avoid n-squared algorithms**
- **size limited**

# Spatial organization



**Cellular decomposition:**
- **Regular 2D grid**
- **Adjacency accessible**
- **Density limited**
- **Cells define obstructions**



**Continuous space:**
- **Step in any direction**
- **Need to decipher obstructions**
- **Perception needed**

# Perception Modeling

**Vision**

**Memory**

**Knowledge of environment**

# Navigation

**Fluid flow:**
  **density fields, potential functions**

**Particle systems:**
  **Individual navigation**

**Flocking systems:**
  **individual perception, navigation**

**Rule-based**

**Cognitive modeling**

**Cellular automata**

# Panic & Congestion handling

**Personal space**

**Packing people during evacuation**

**Stairwell traversal**

**Exit awareness**

# Motion & Navigation

**Path planning**

**Roadmaps**

**Passing on pathways**

**Potential fields**

**Forming & maintaining subgroups**

# Structure in crowds

**Homogenous – no individuality**

**Subgroups**

- **Group by belief systems**

**A collection of Individuals – personality modeling**

# Penn Station

See animations

# Other topics

**Heterogeneous – pedestrians and cars**

**Data driven crowds – image processing**

**Comparison to real-world situations**

# Massive

**http://www.massivesoftware.com/**

**Commercial de facto standard**

See animation