the gamedesigninitiative at cornell university

Lecture 20

Optimizing Behavior

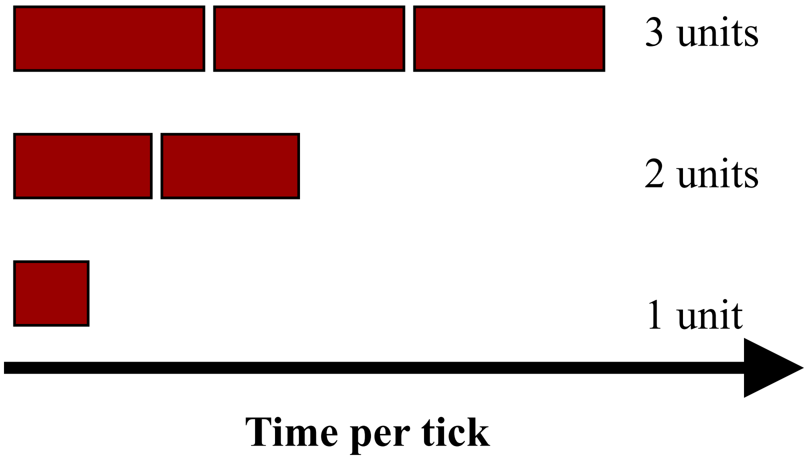
Stealth tip: Use WALK to move slowly and very quietly. Use CREEP to move even more slowly and be completely silent.

Review: Sense-Think-Act

- **Sense**:
  - Perceive the world
  - Reading the game state
  - **Example**: enemy near?
- **Think**:
  - Choose an action
  - Often merged with sense
  - **Example**: fight or flee
- **Act**:
  - Update the state
  - Simple and fast
  - **Example**: reduce health

Recall: Sensing Performance

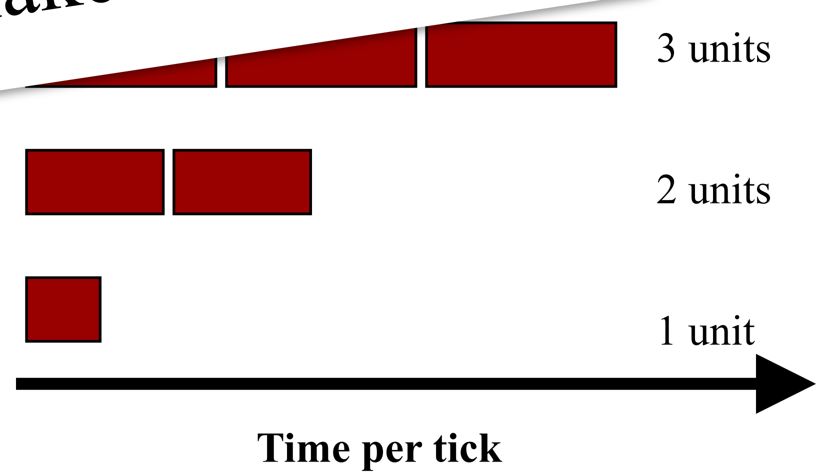
- Sensing may be slow!
  - Consider *all* objects
- Example: morale
  - n knights, n skeletons
  - Knights fear skeletons
  - Proportional to # seen
- Count skeletons in view
  - $O(n)$ to count skeletons
  - $O(n^2)$ for all units



Recall: Sensing Performance

- Sensing may be slow!
  - Consider *all* objects
- Example: morale
  - n knights, n skel…
  - I…
  - P… seen
- Count skeletons in view
  - O(n) to count skeletons
  - O(n^2) for all units

How Do We Make it Faster?

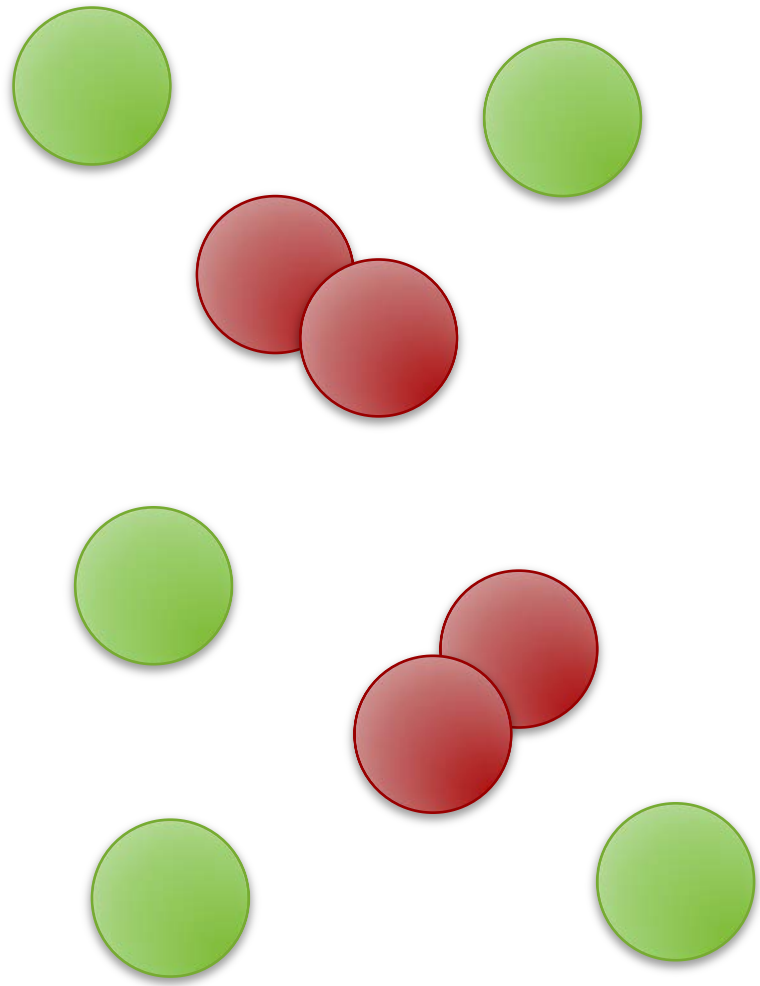


Example: Collision Detection

Naively O(n^2)

```
for each object x:
    for each object y:
        if x not y and x, y collide:
            resolve collision of x, y
```

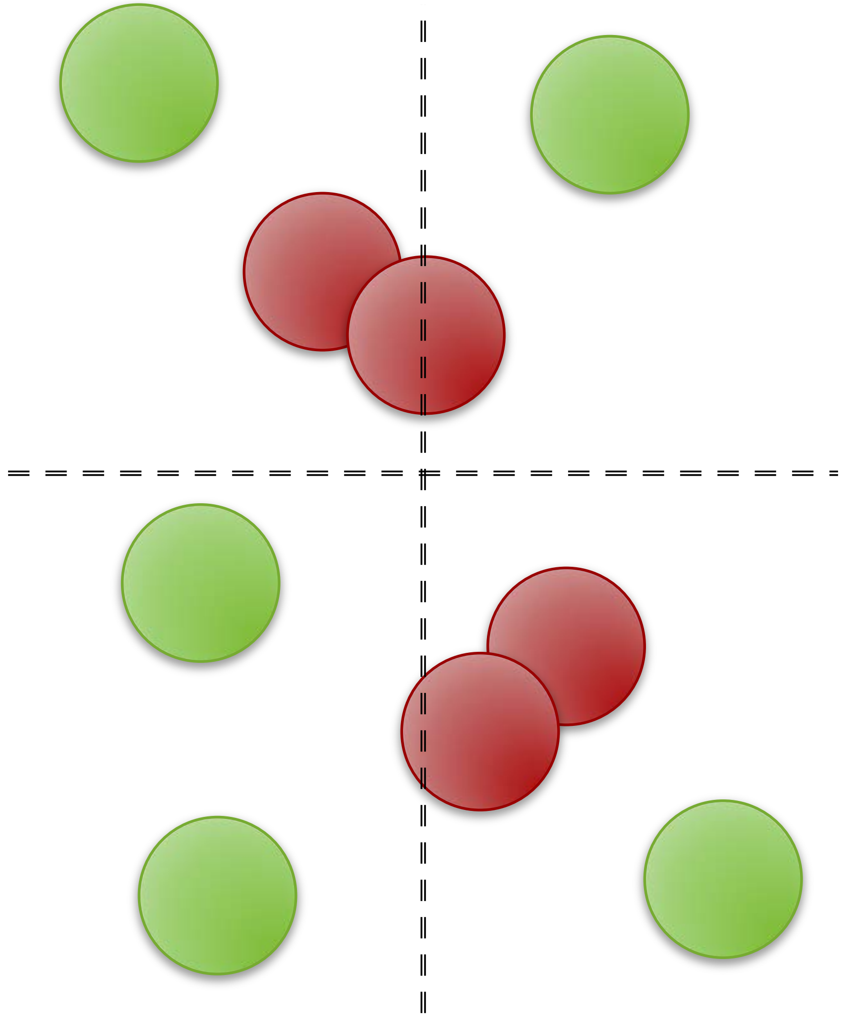
Checks objects obviously far apart from each other



Example: Collision Detection

Lab Optimization

```
for each object x:
    put x into cell slot
for each cell location:
    for each object x:
        for each object y:
            if x != y and x, y collide:
                resolve collision
```



Similar Ideas Exist in AI

- **Area of Interest**
  - Limit the sensing range
  - Only “see” what in range
  - Used in targeting, stealth
- Works in both directions
  - **Nimbus**: “can see” radius
  - **Aura**: “can be seen” radius
- Can use cell optimization

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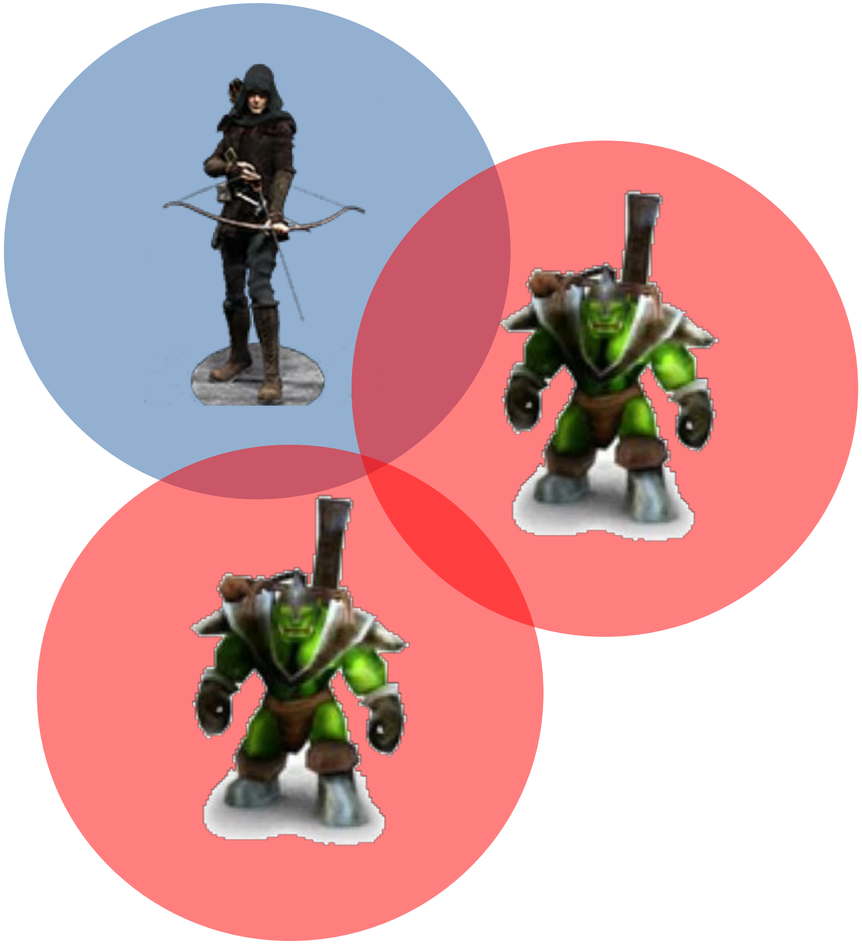
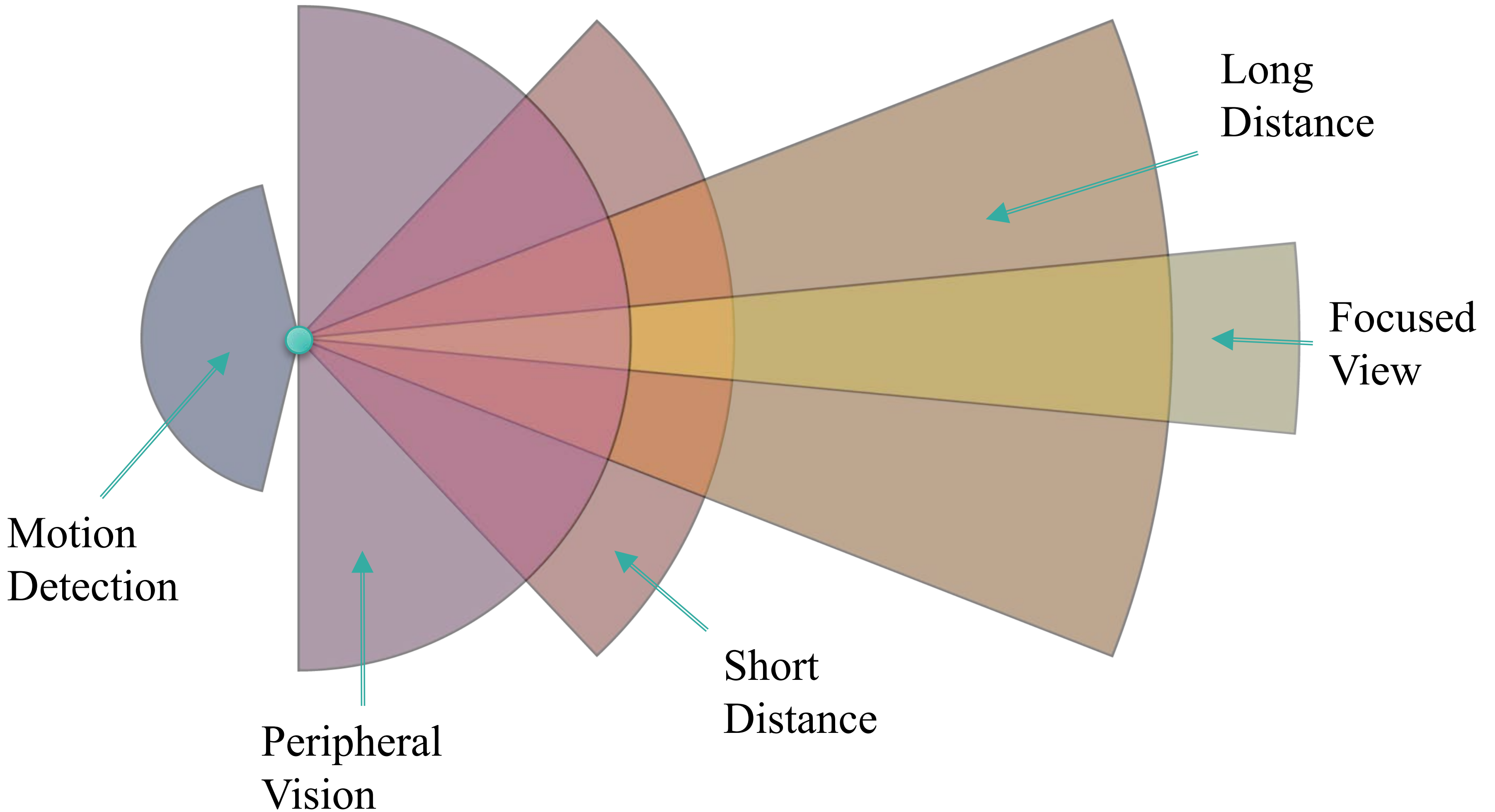


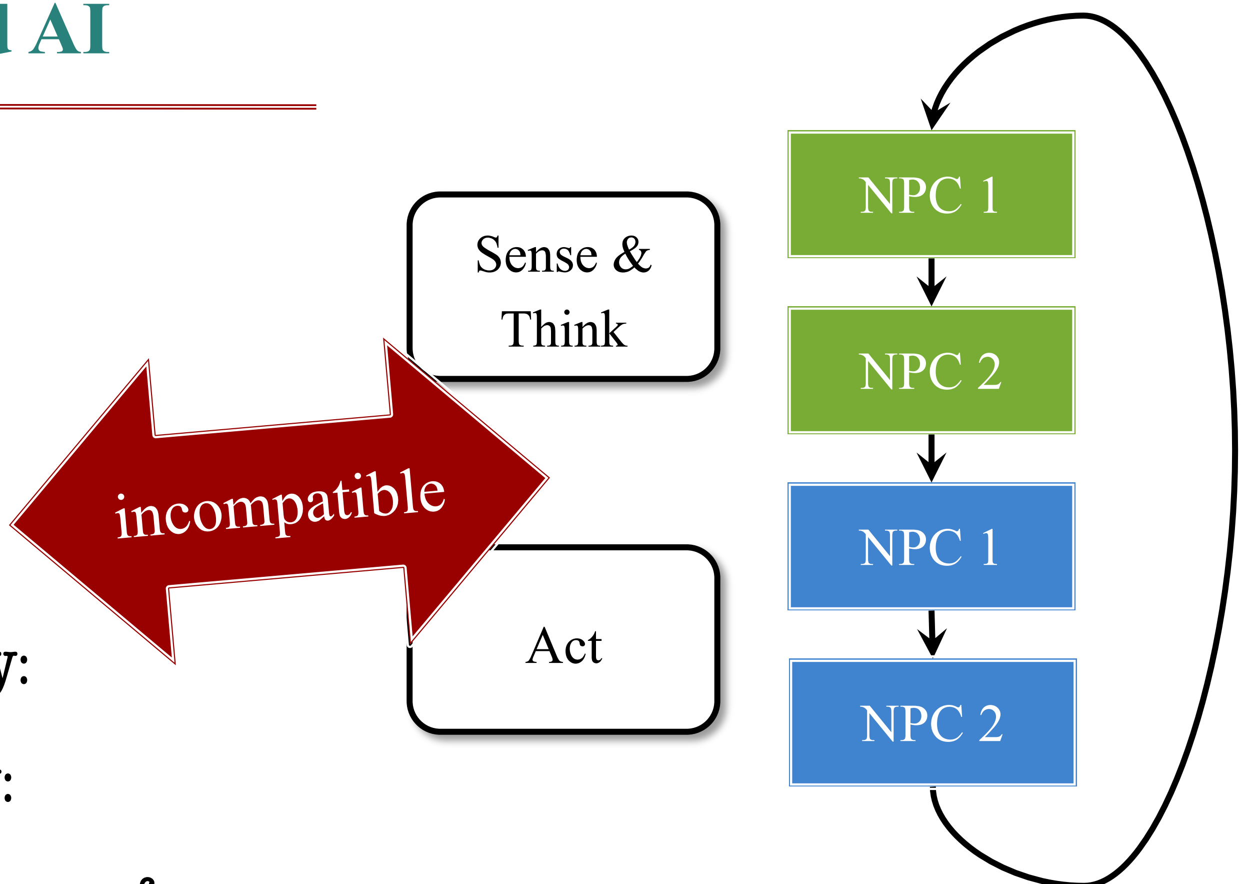
Area of Interest Management *Thief*



Problem with this Idea

Cell-Based AI

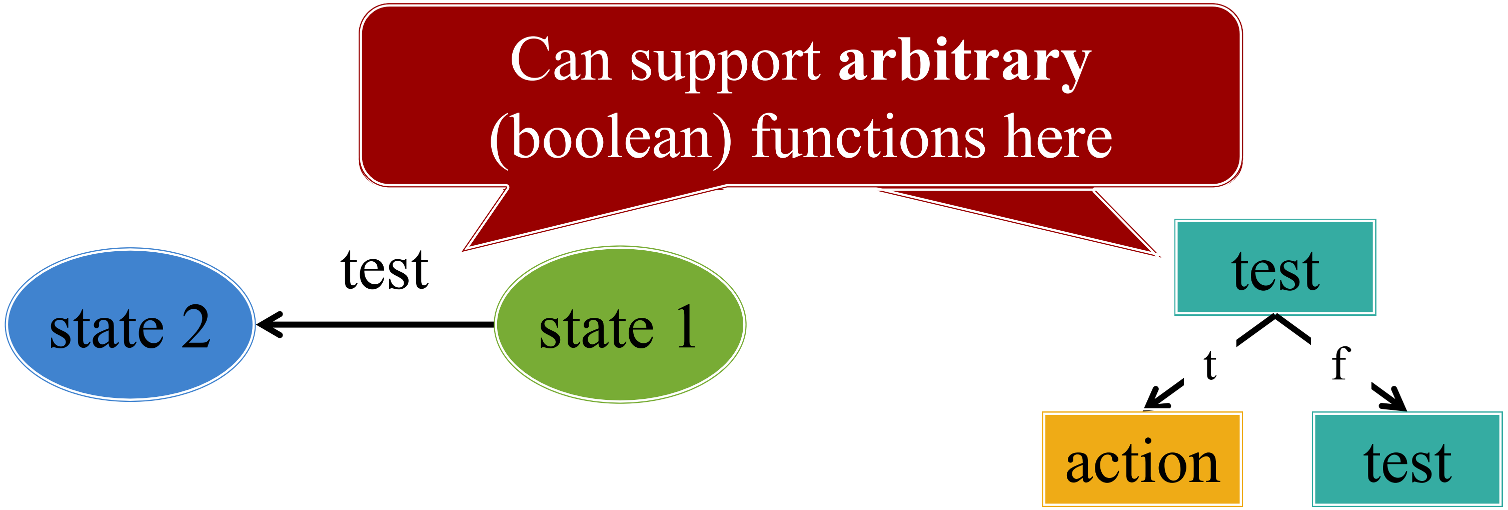
```
for each entity x:
    put x into cell slot
for each cell location:
    for each entity x:
        for each entity y:
            if x can see y:
                add y to sense of x
```



Solution: Event Driven AI

Finite State Machines

Decision Trees

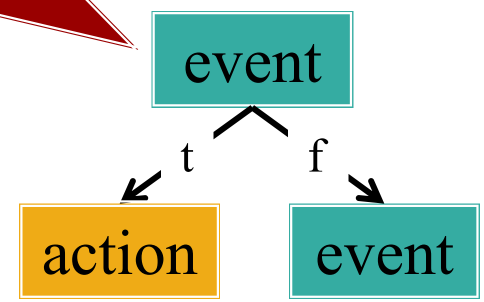


Solution: Event Driven AI

Finite State Machines

Decision Trees

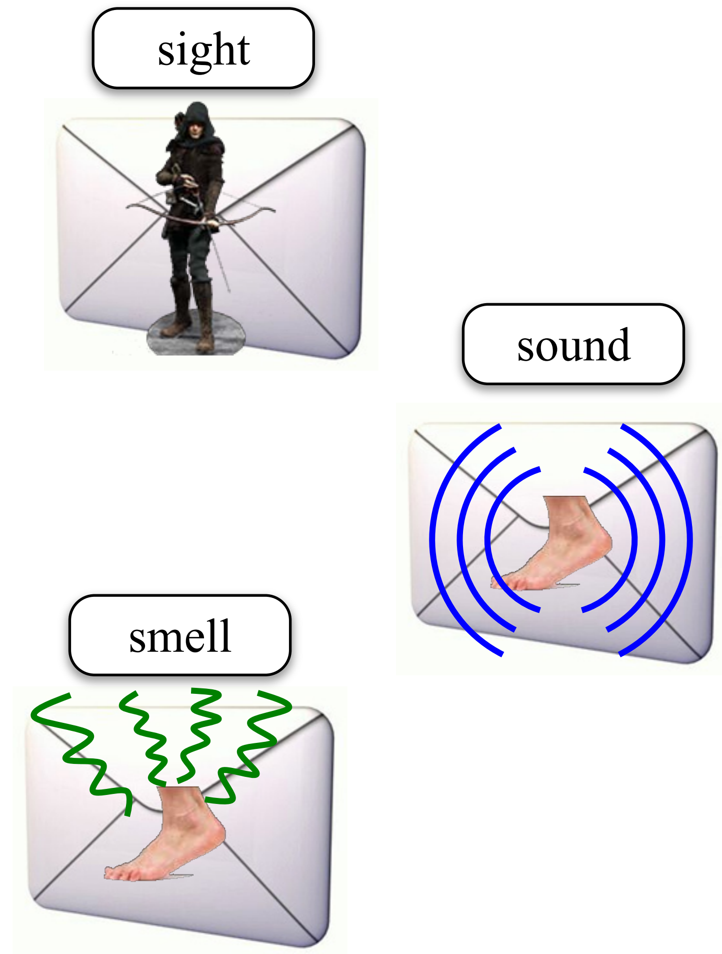
But we only want simple tests!



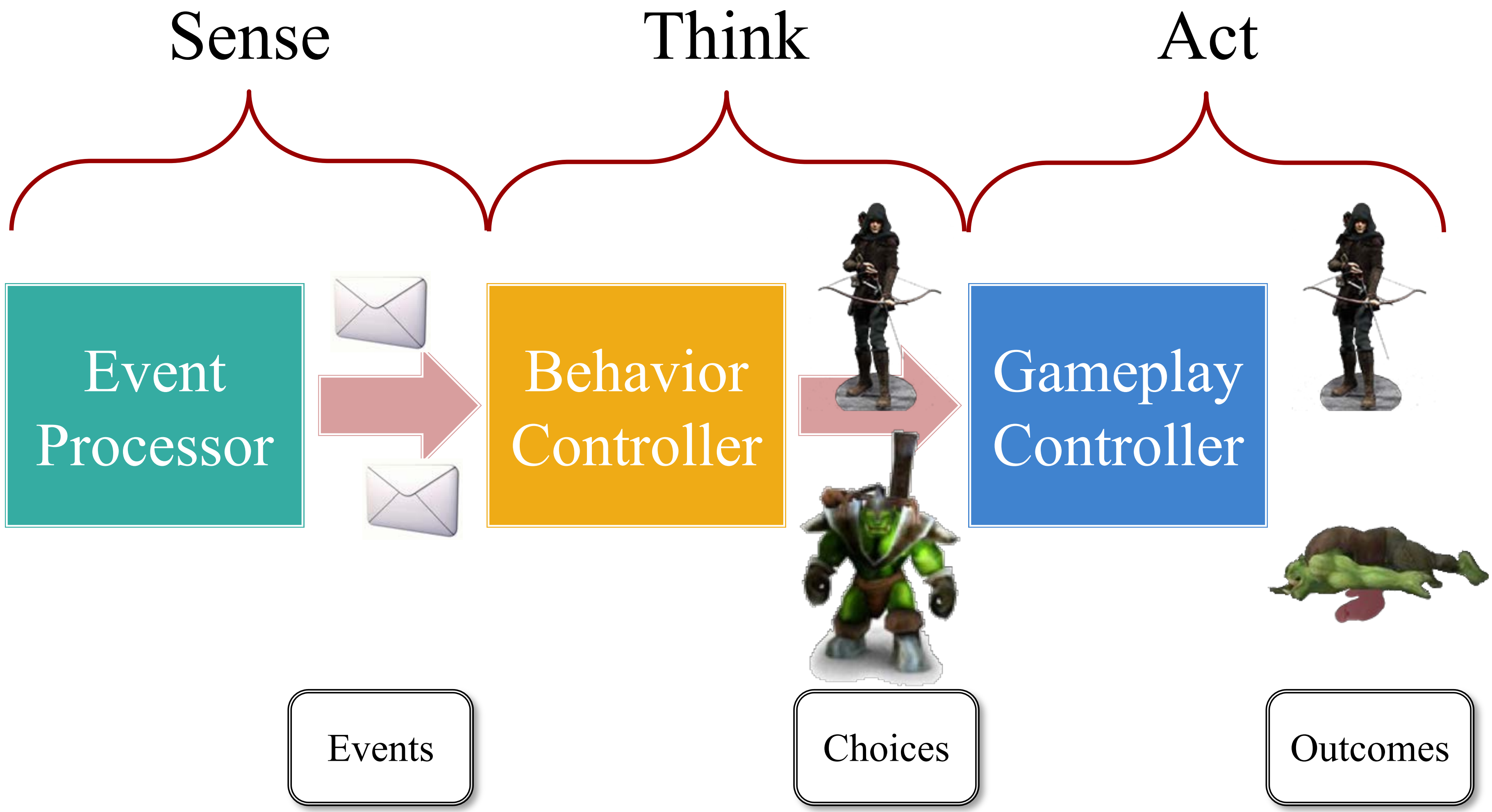
Event: *Precomputed* result before AI thinking starts

Event: Encoded Sense Data

- **Sight Event**
  - Type of entity seen
  - *Location* of entity seen
- **Sound Event**
  - Type of sound heard
  - *Direction* of sound heard
- **Smell Event**
  - Type of smell perceived
  - *Proximity* of the smell

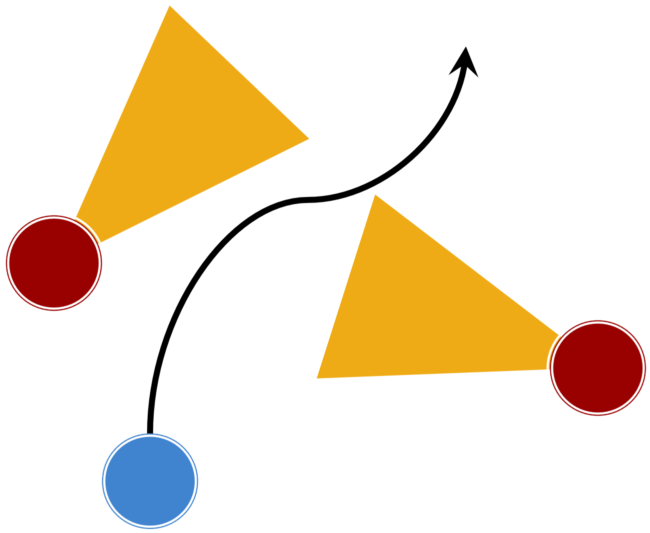


Sense-Think-Act Revisited

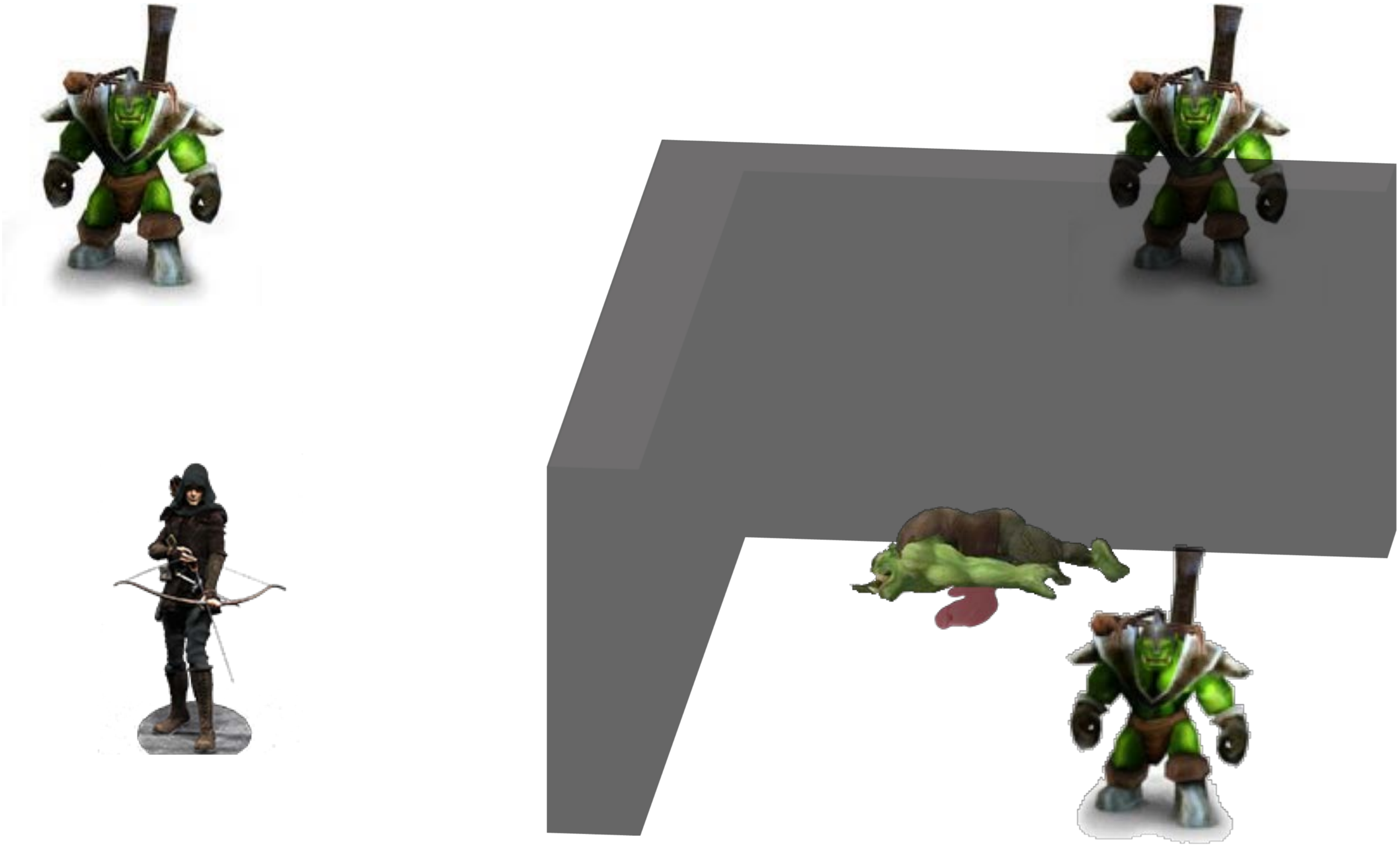


Example: Line-of-Sight

- Use **Box2D** for sensing
  - Method `rayCast` in `World`
  - Provide a `RayCastCallback`
- Think inside the **callback**
  - *Parameters* are sense events
  - Use this to choose an action
- Act in **main update** method
  - Do after all physics done
  - Ensures all thinking done



Communicating Sense Events



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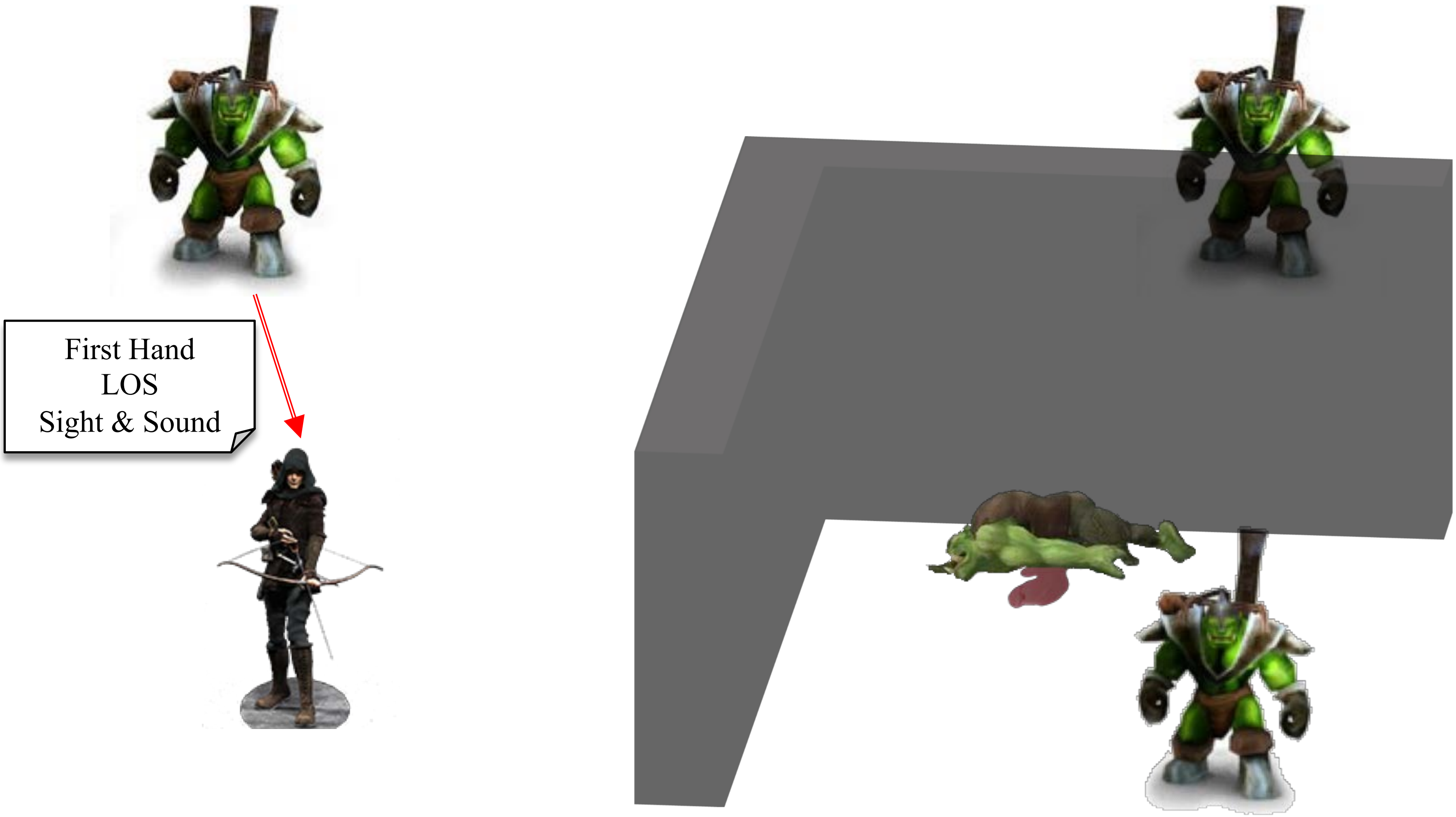

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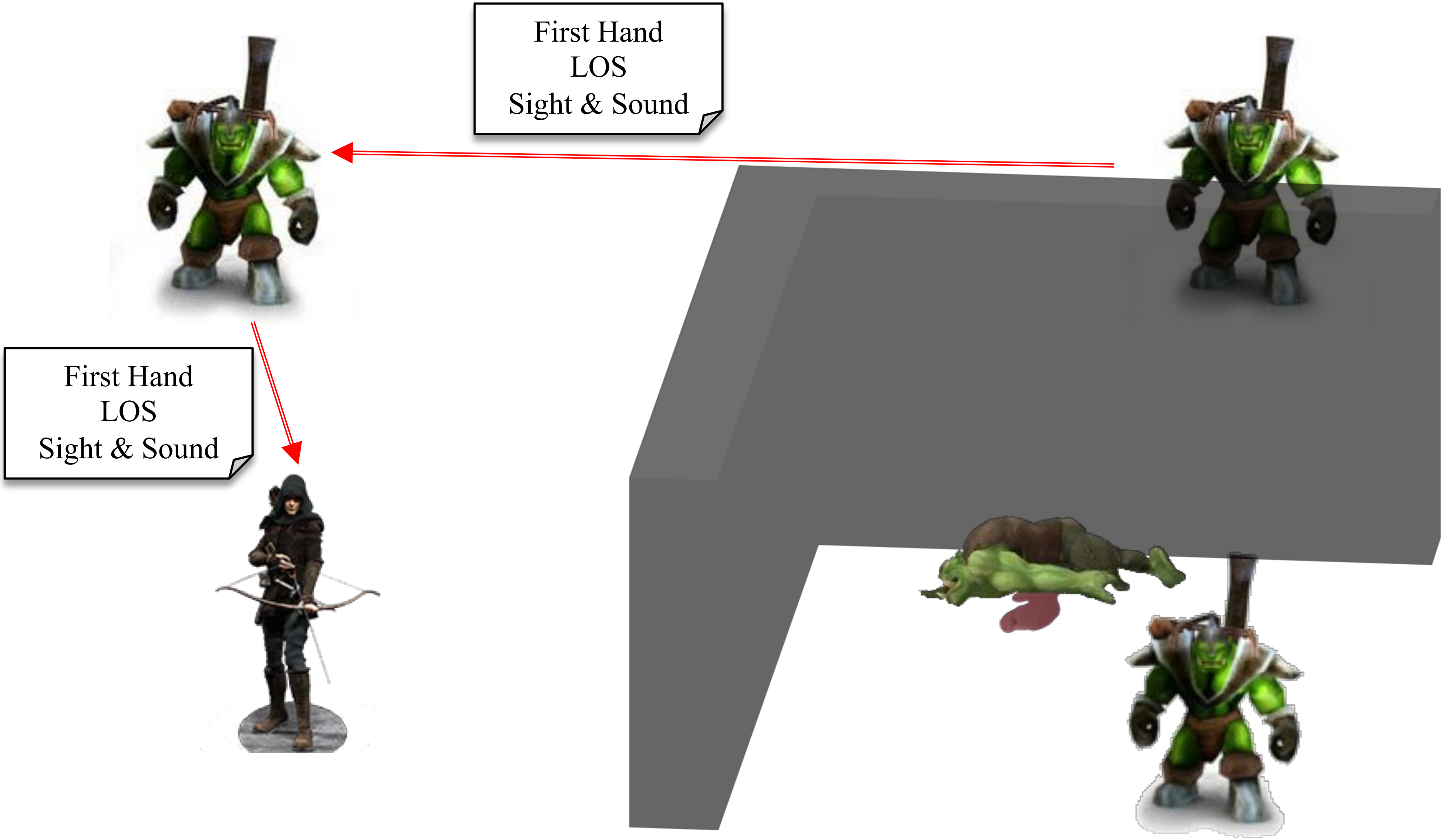

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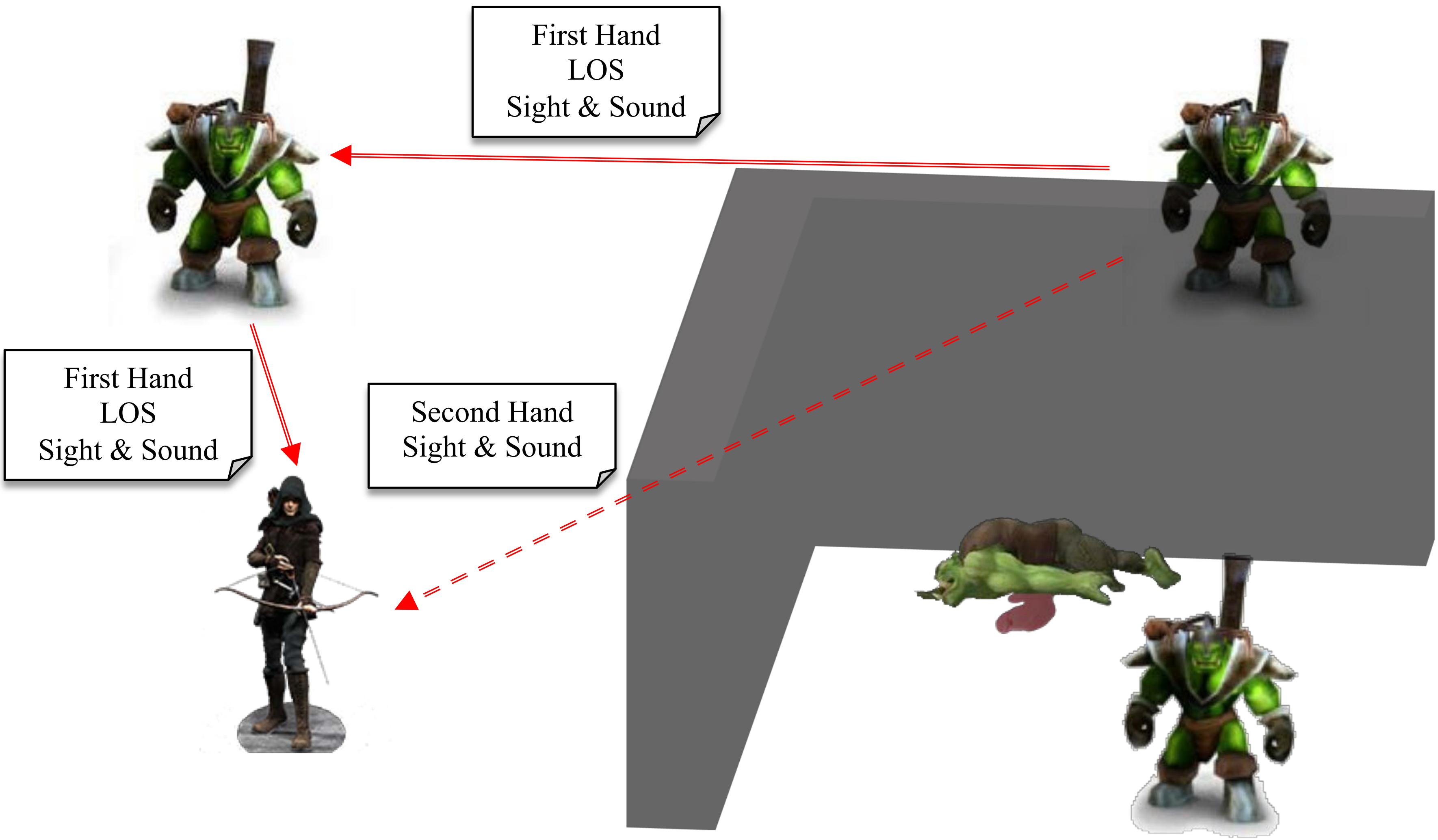

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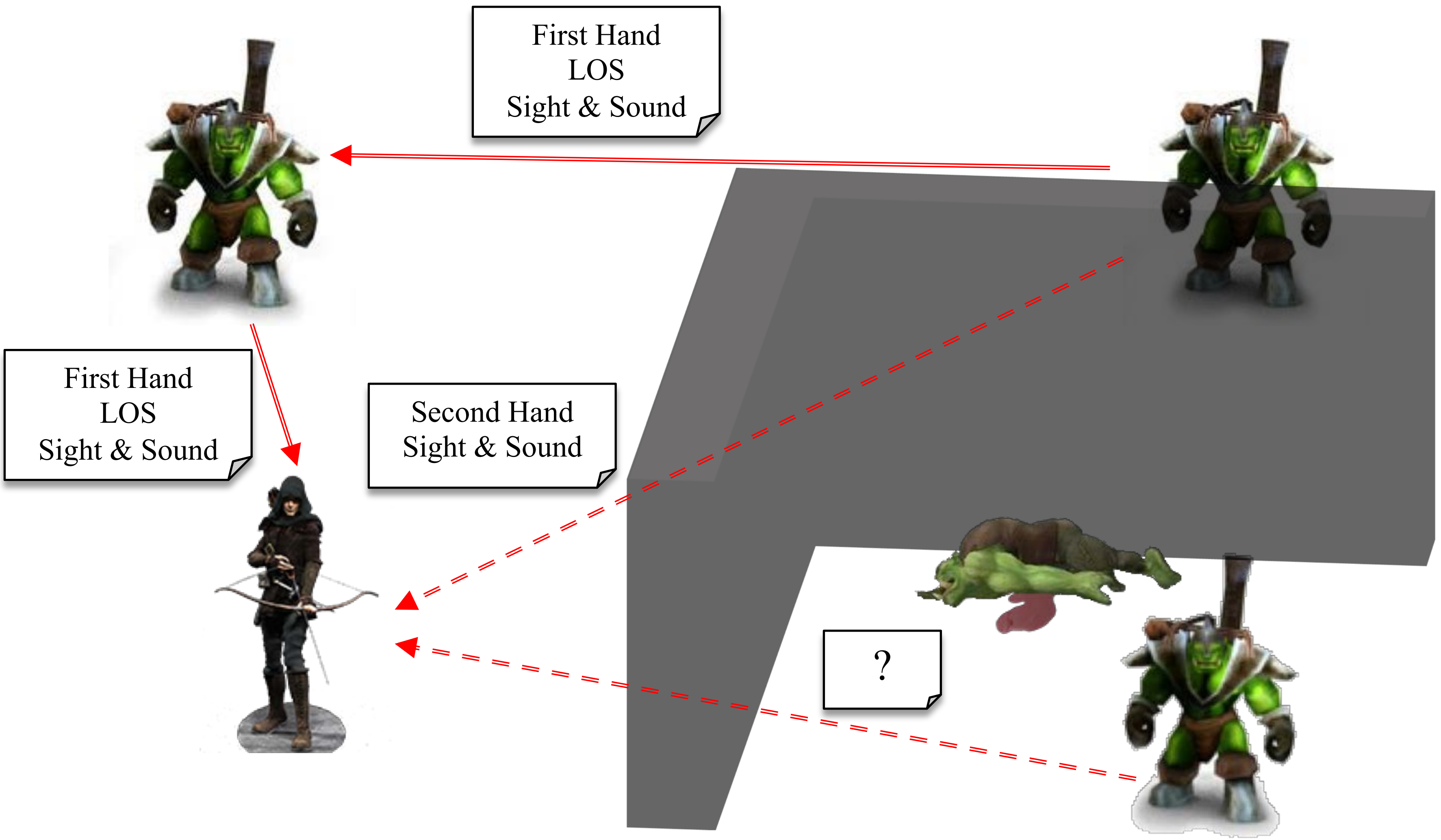

Event Communication in LibGDX

MessageDispatcher

- Send with `dispatchMessage`
  - `delay` (0 if immediate)
  - `sender` (can be null)
  - `target` (null for subscribers)
  - `type` (user defined int code)
  - `data` (object, like Box2D)
- Subscribe with `addListener`
  - NPC to receive message
  - Type (int) to subscribe to

Telegram

- Stores the event message
  - Entries of `dispatchMessage`
  - Except for the `delay` value
  - Preaggregated sense in `data`
- Received by `Telegraph`
  - Interface for the receiver
  - Implemented by the NPC
  - One method: `handleMessage`

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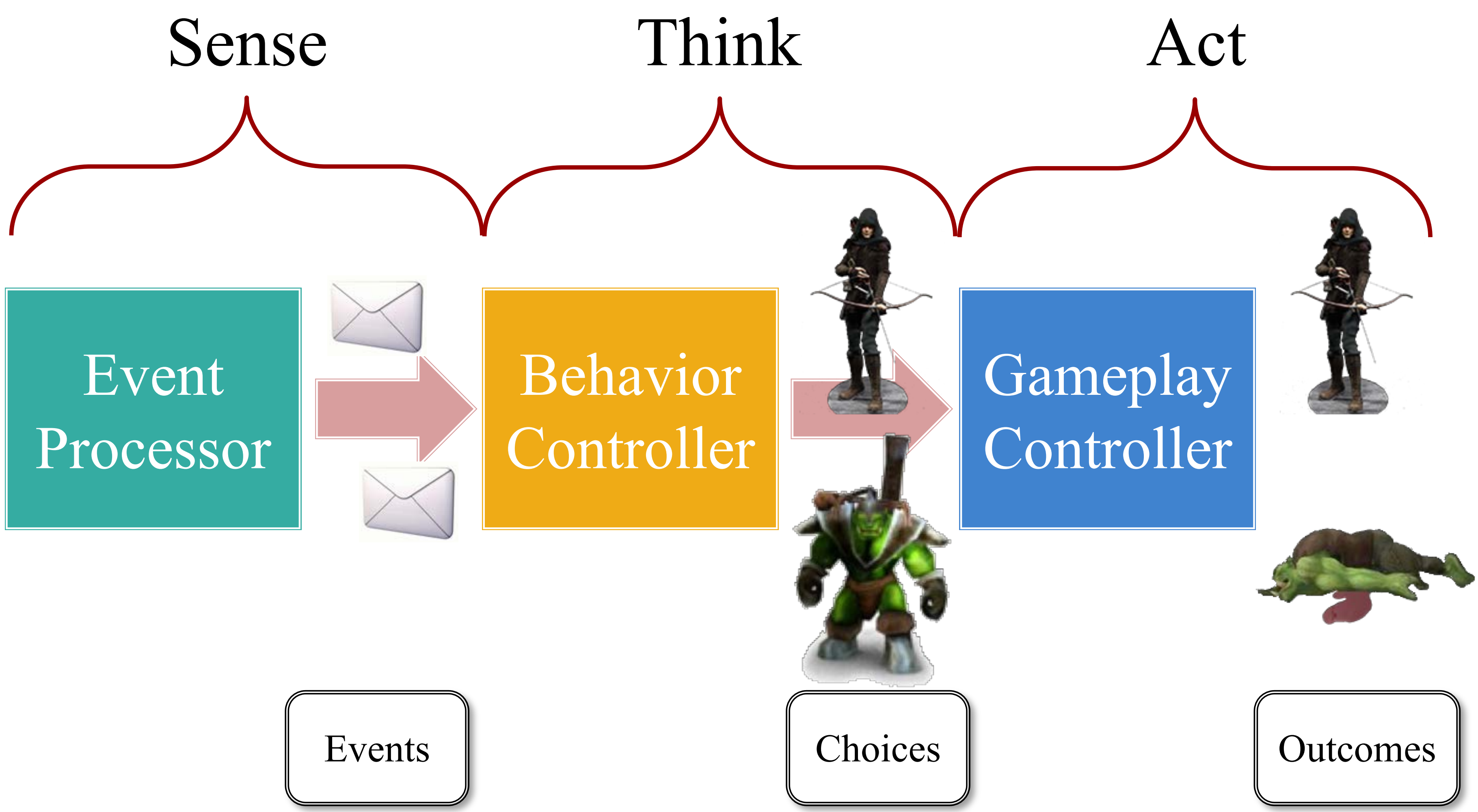
Separation Allows Many Optimizations



Compression: Aggregation Trees

Slide courtesy of Dave Mark

Number of Allies

Strength of Allies

Number of Enemies

Strength of Enemies

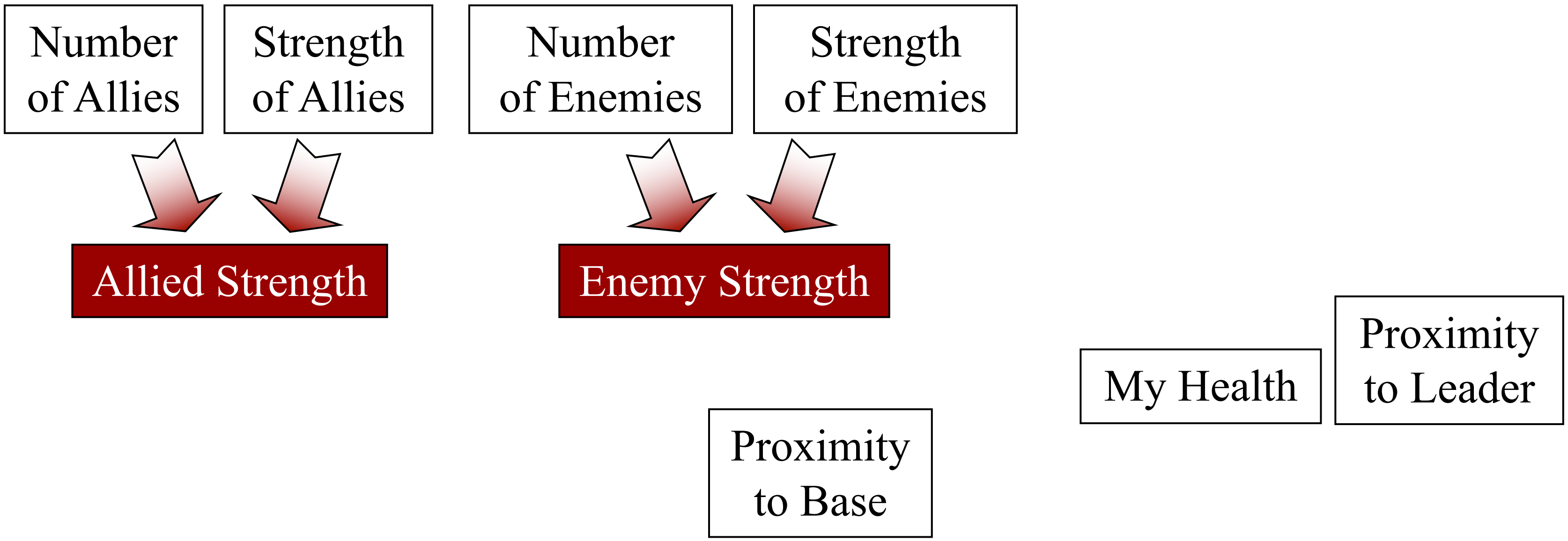
My Health

Proximity to Leader

Proximity to Base

Compression: Aggregation Trees

Slide courtesy of Dave Mark



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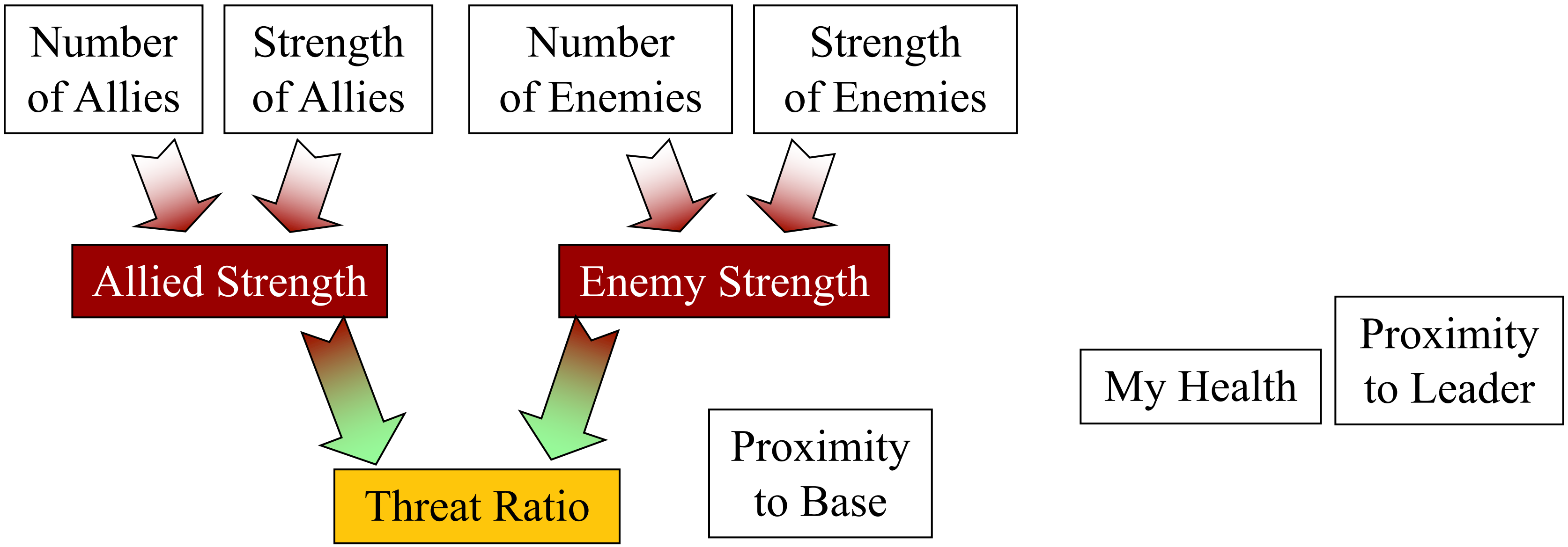

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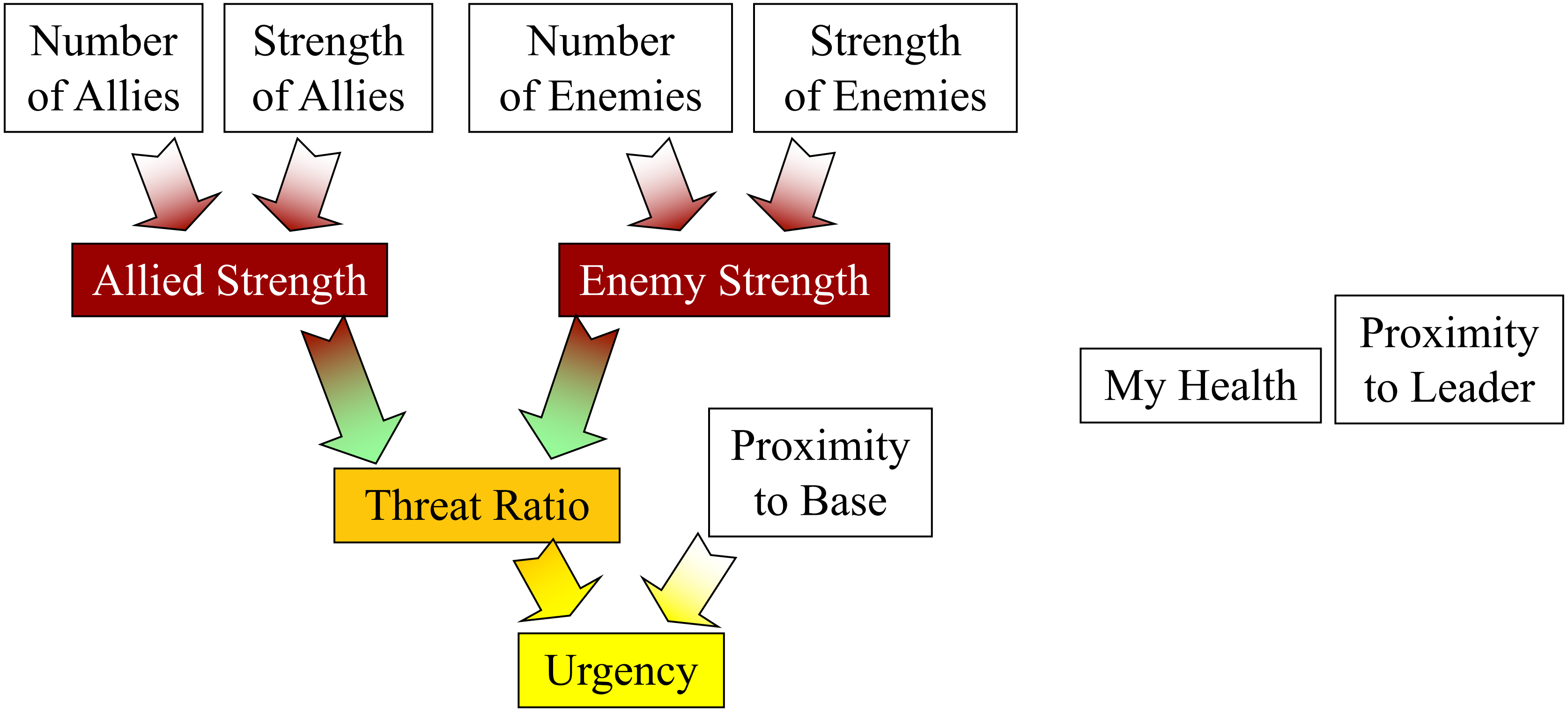

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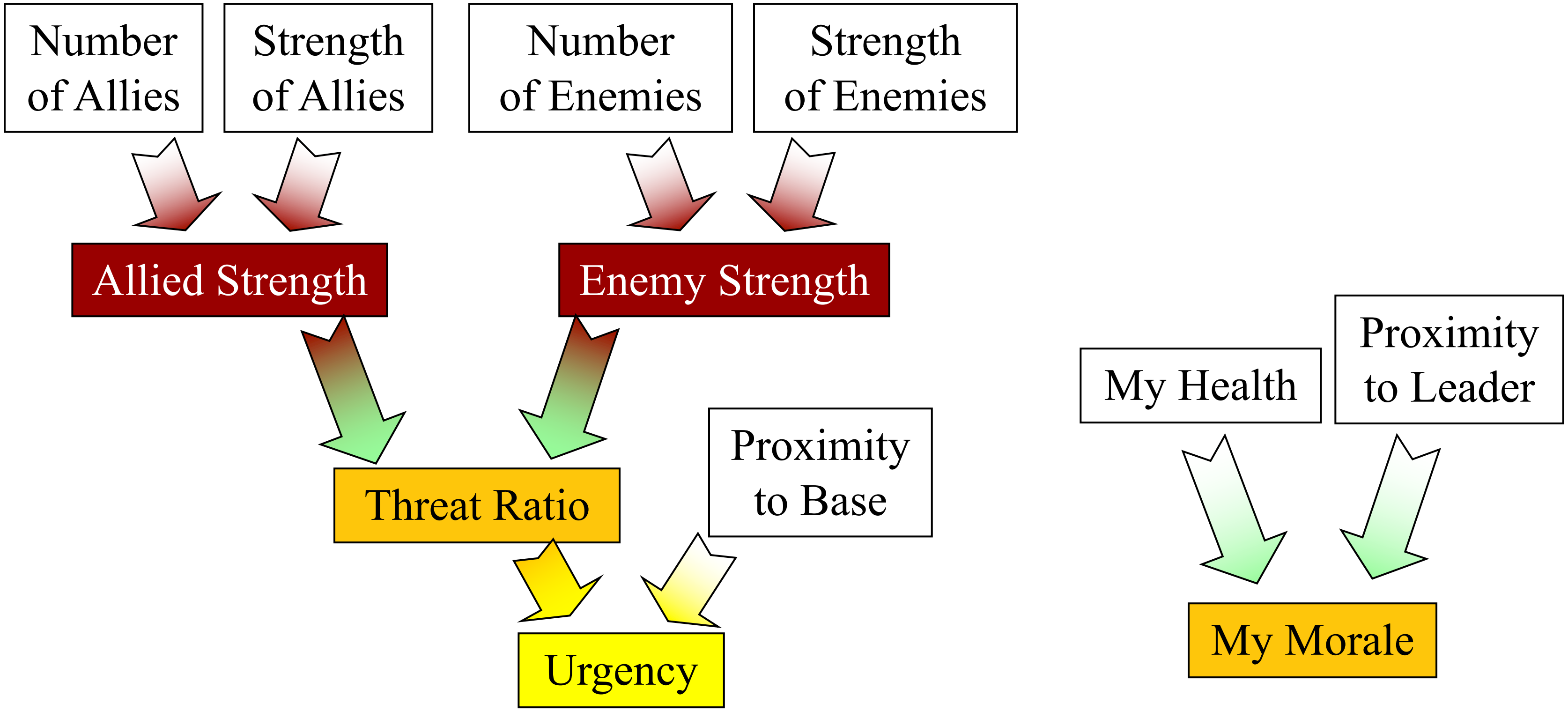

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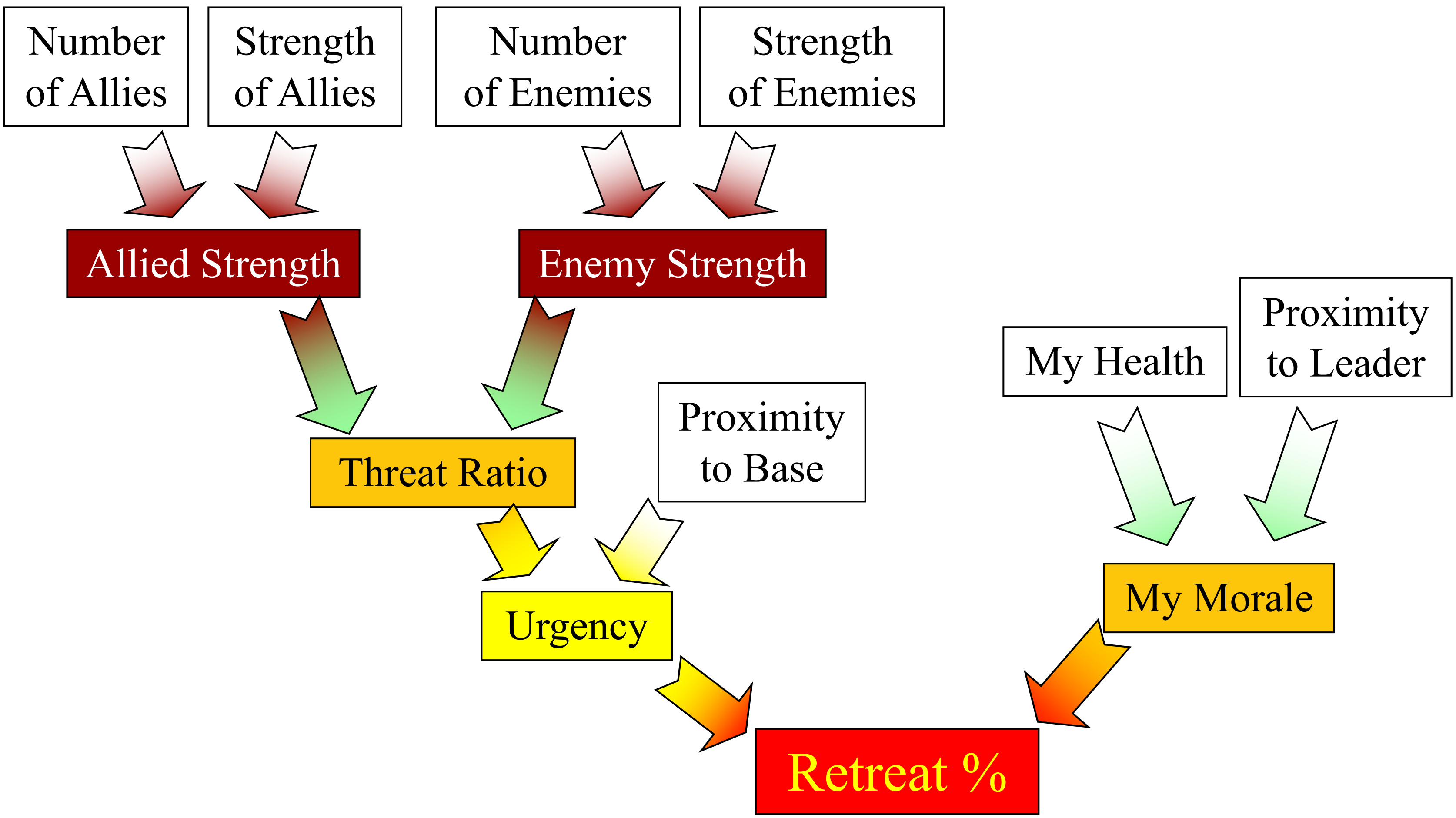

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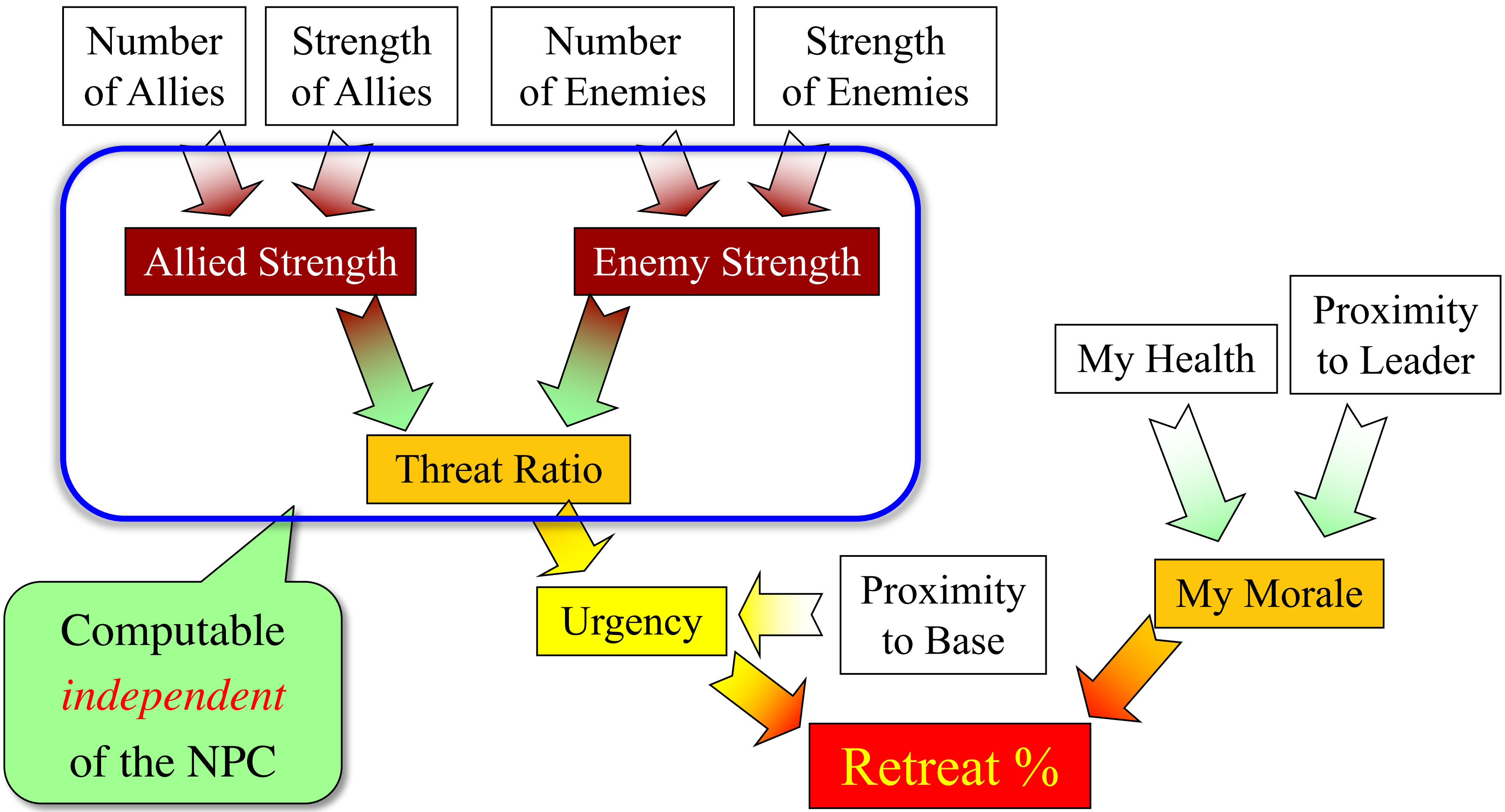
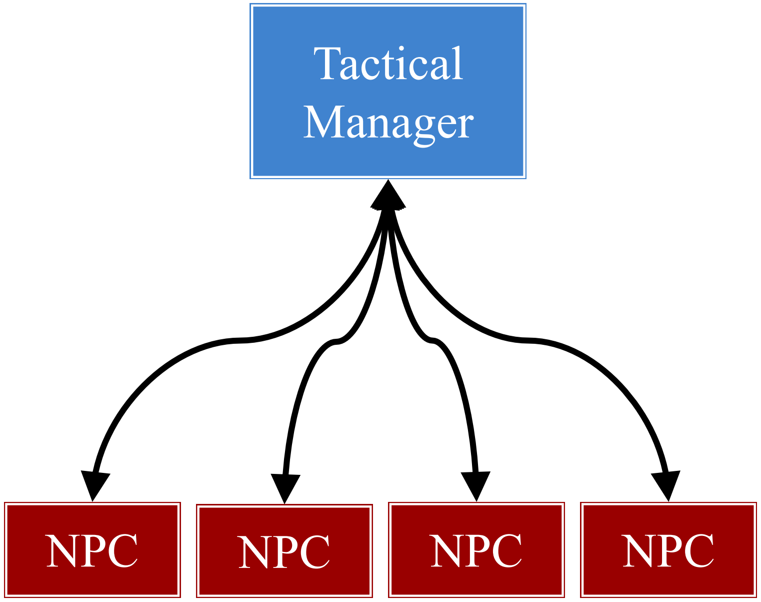
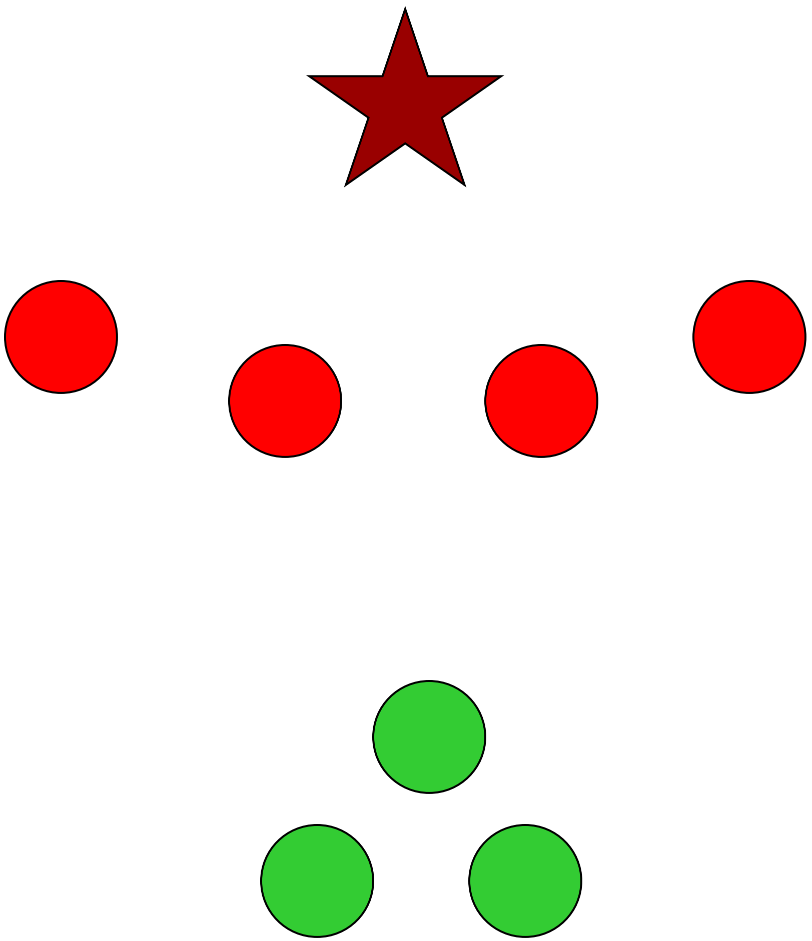


Delegation: Tactical Managers

- "Invisible NPC"
  - Assigned to NPC Group
  - Both *senses* and *thinks*
  - Sends *commands* as events
- **Applications**
  - Protecting special units
  - Flanking
  - Covering fire
  - Leapfrogging advance



Protecting Special Units



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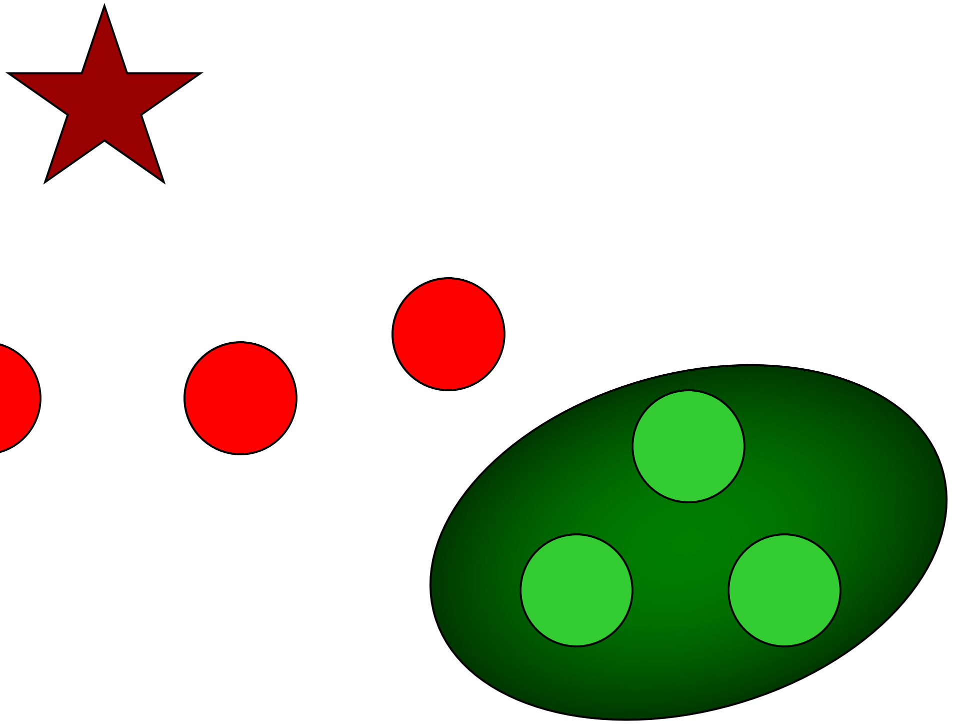

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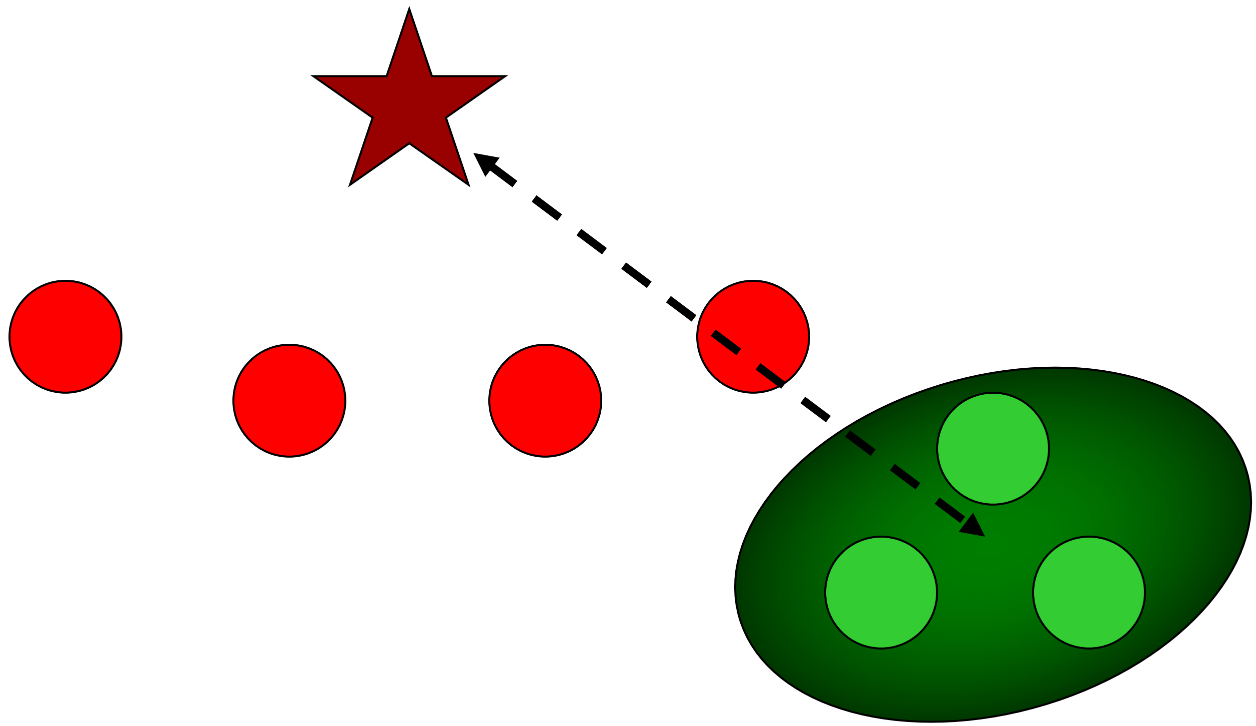

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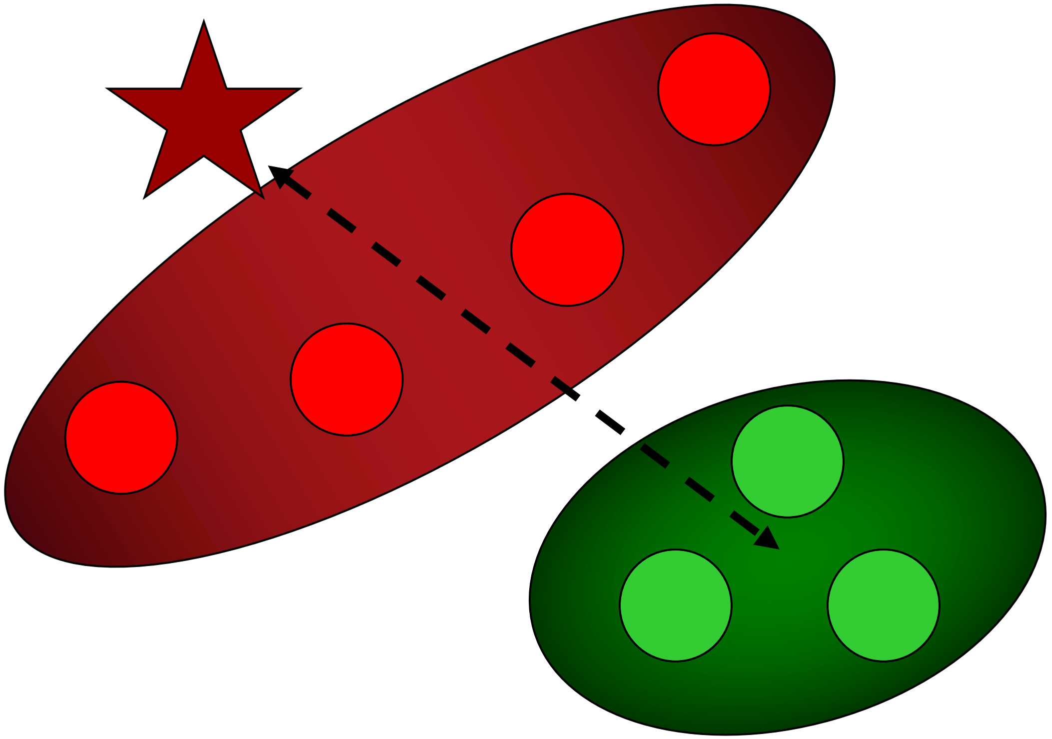

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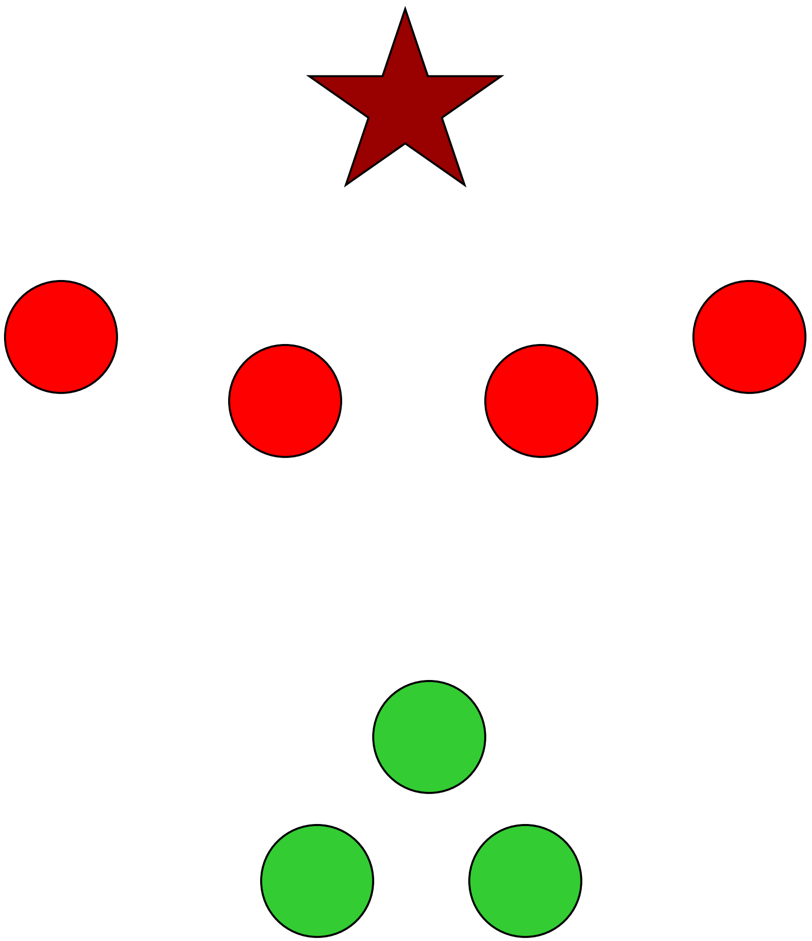

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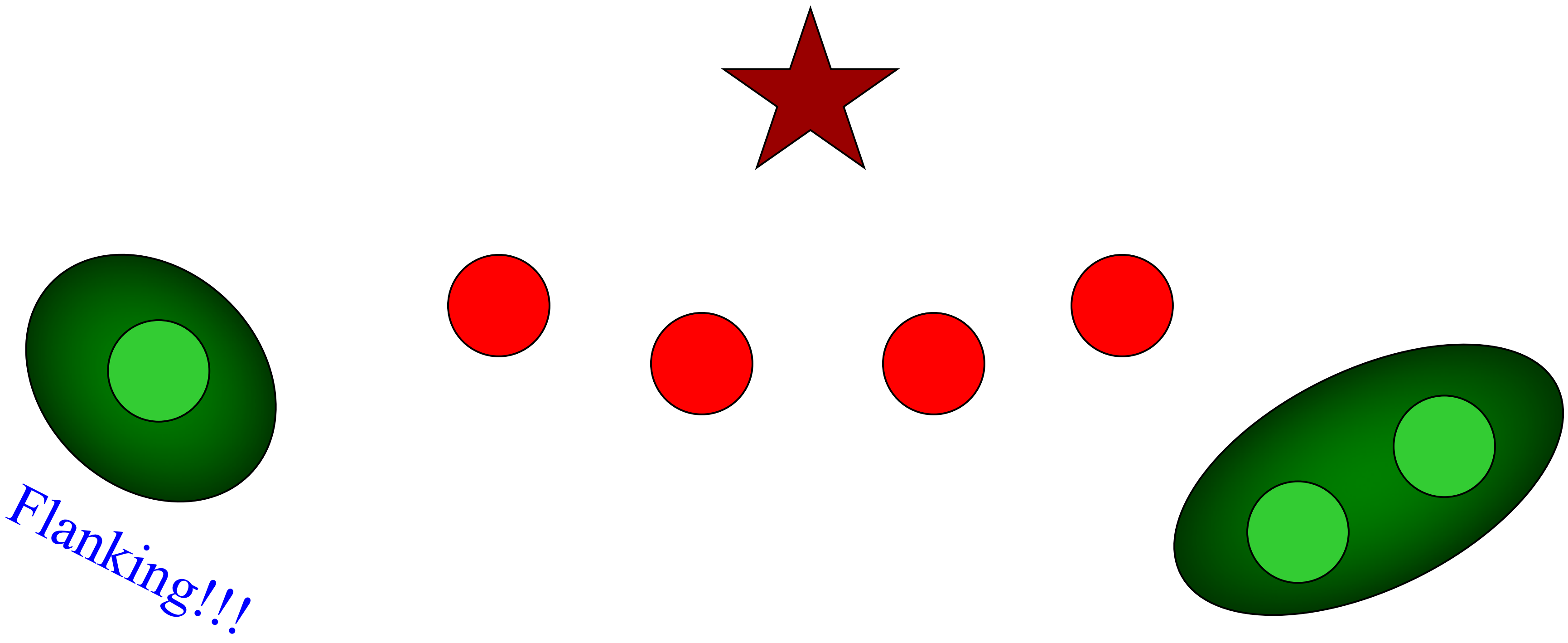

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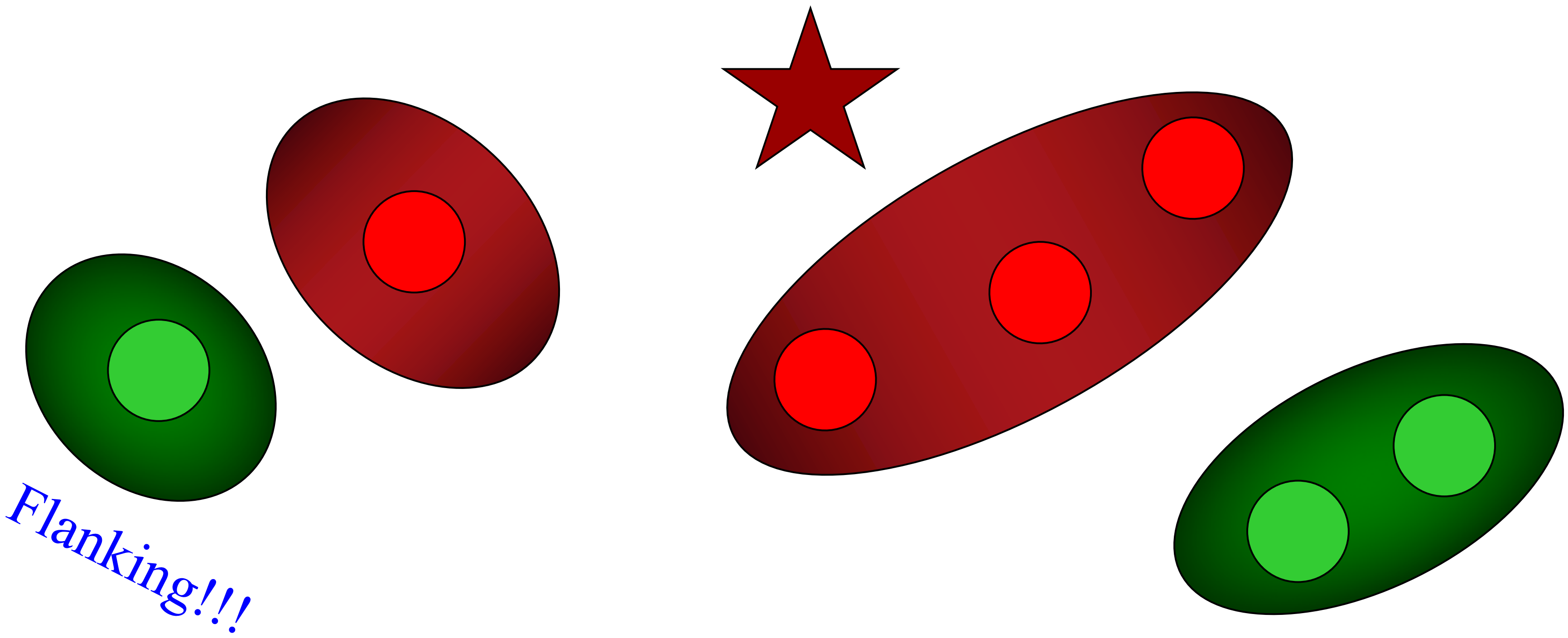

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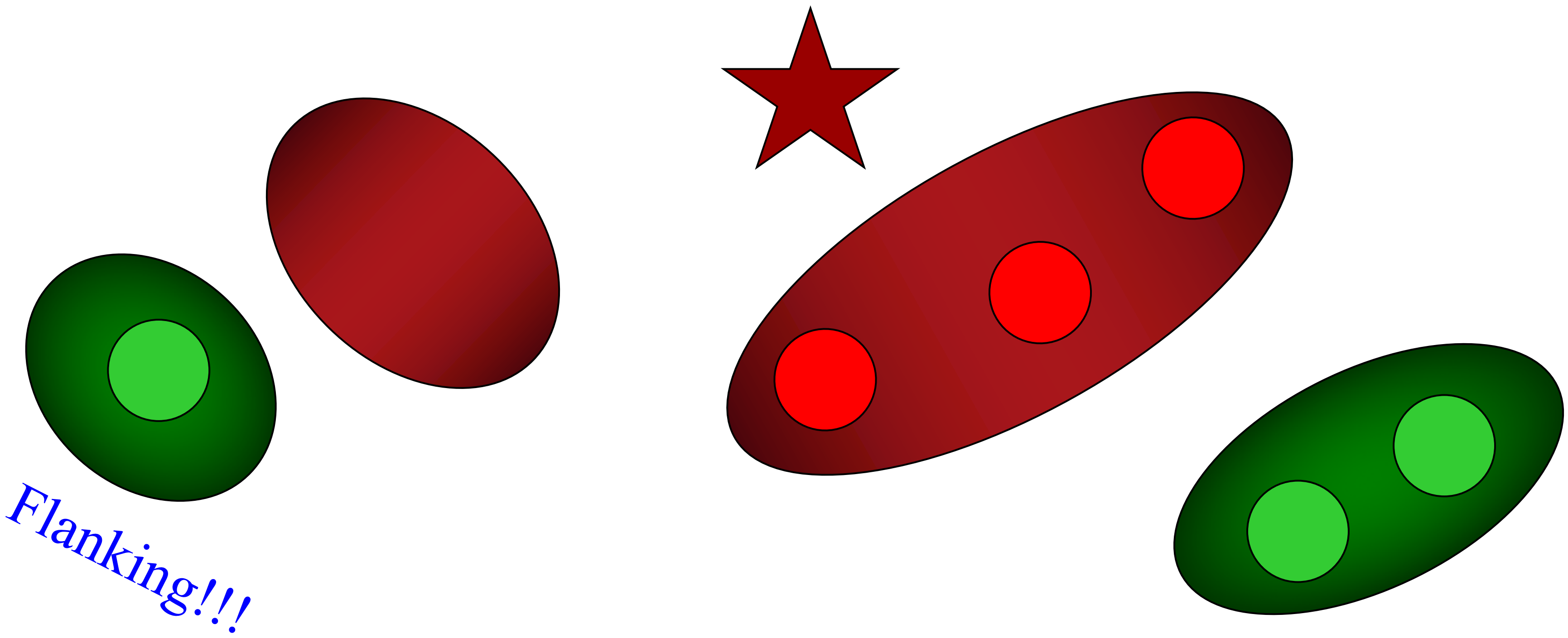

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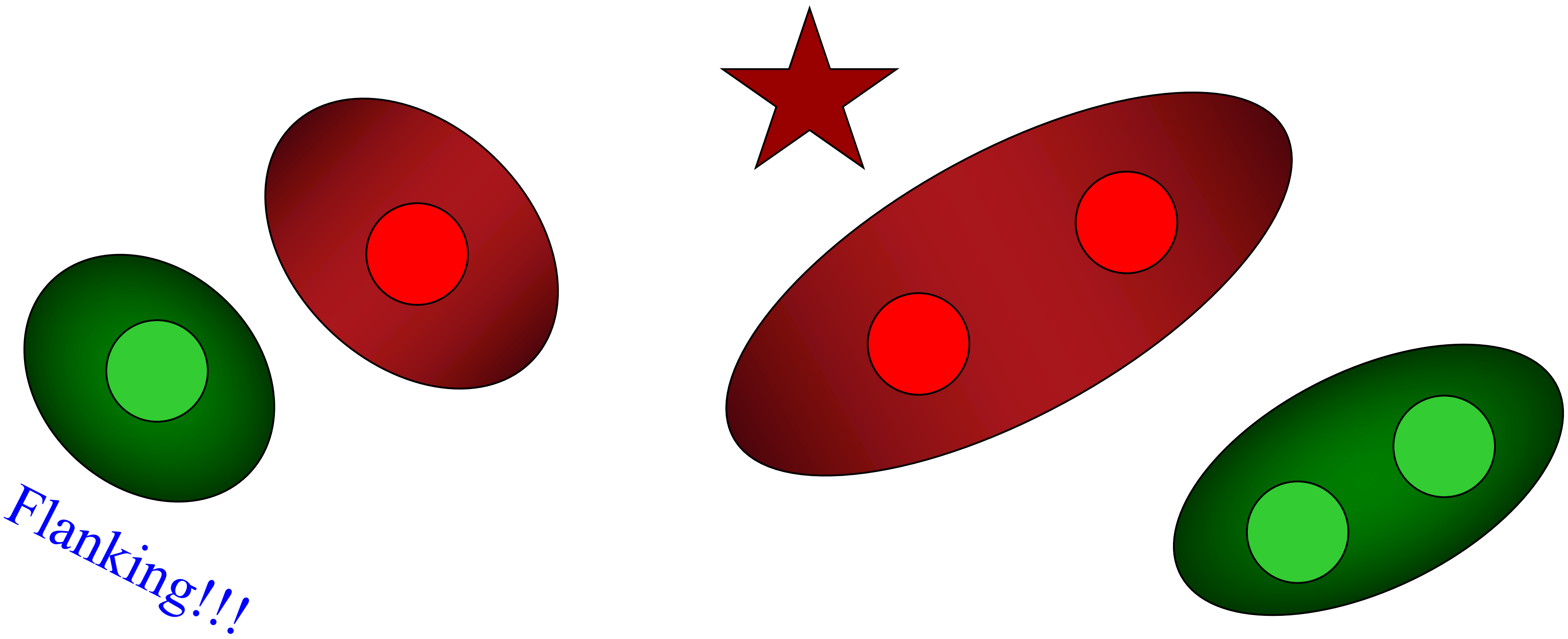
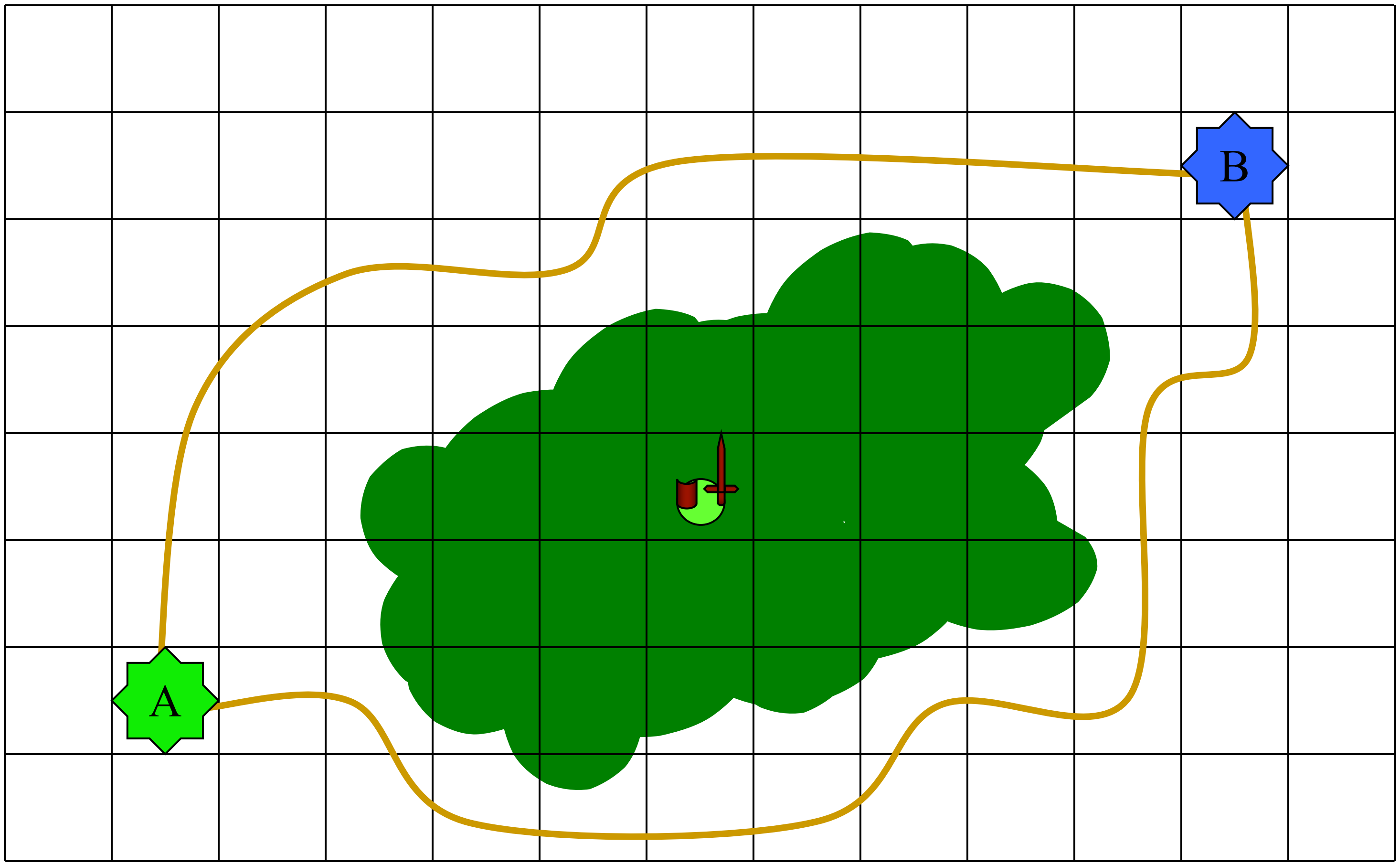


Slide courtesy of Dave Mark

Inversion: Influence Maps



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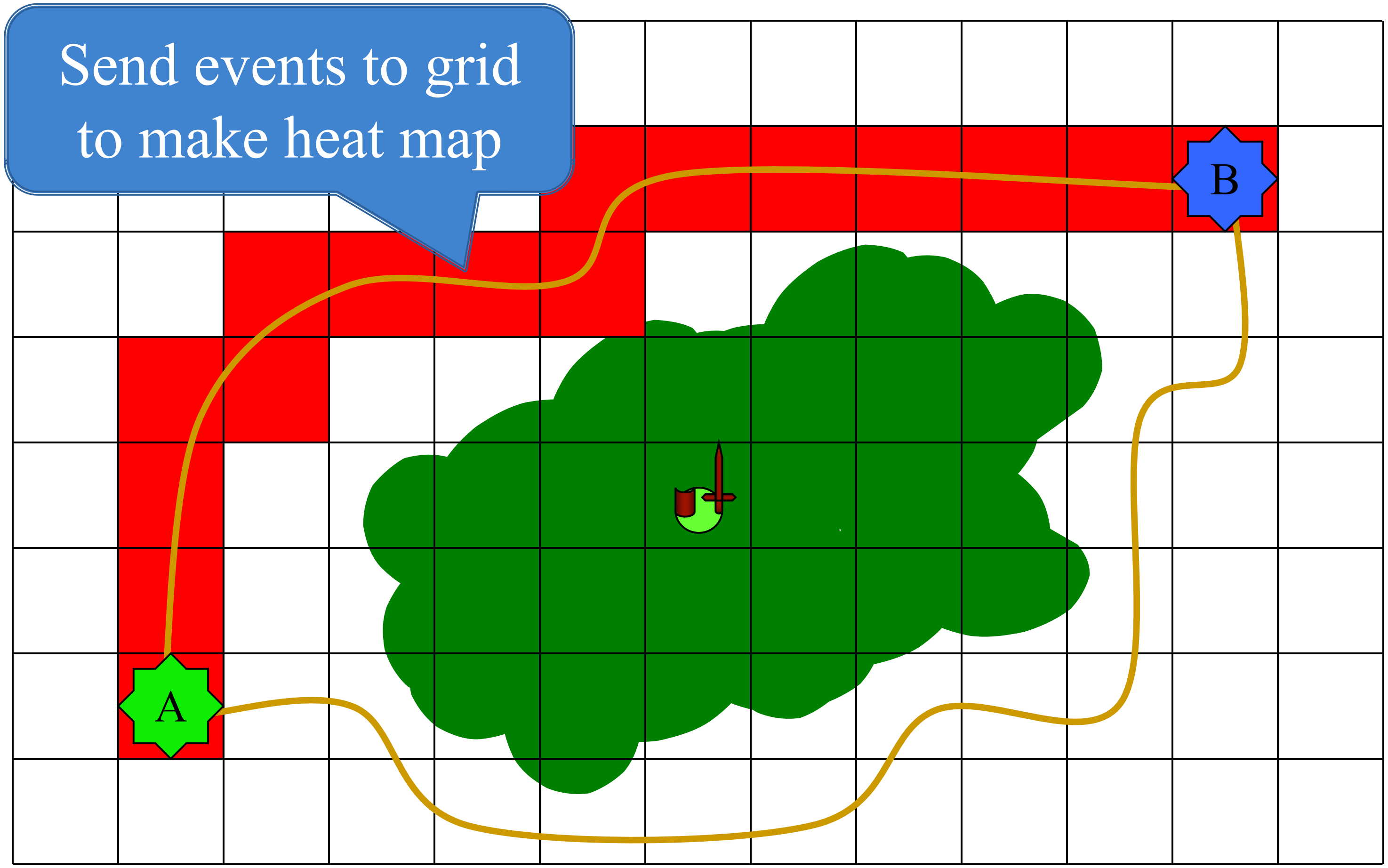

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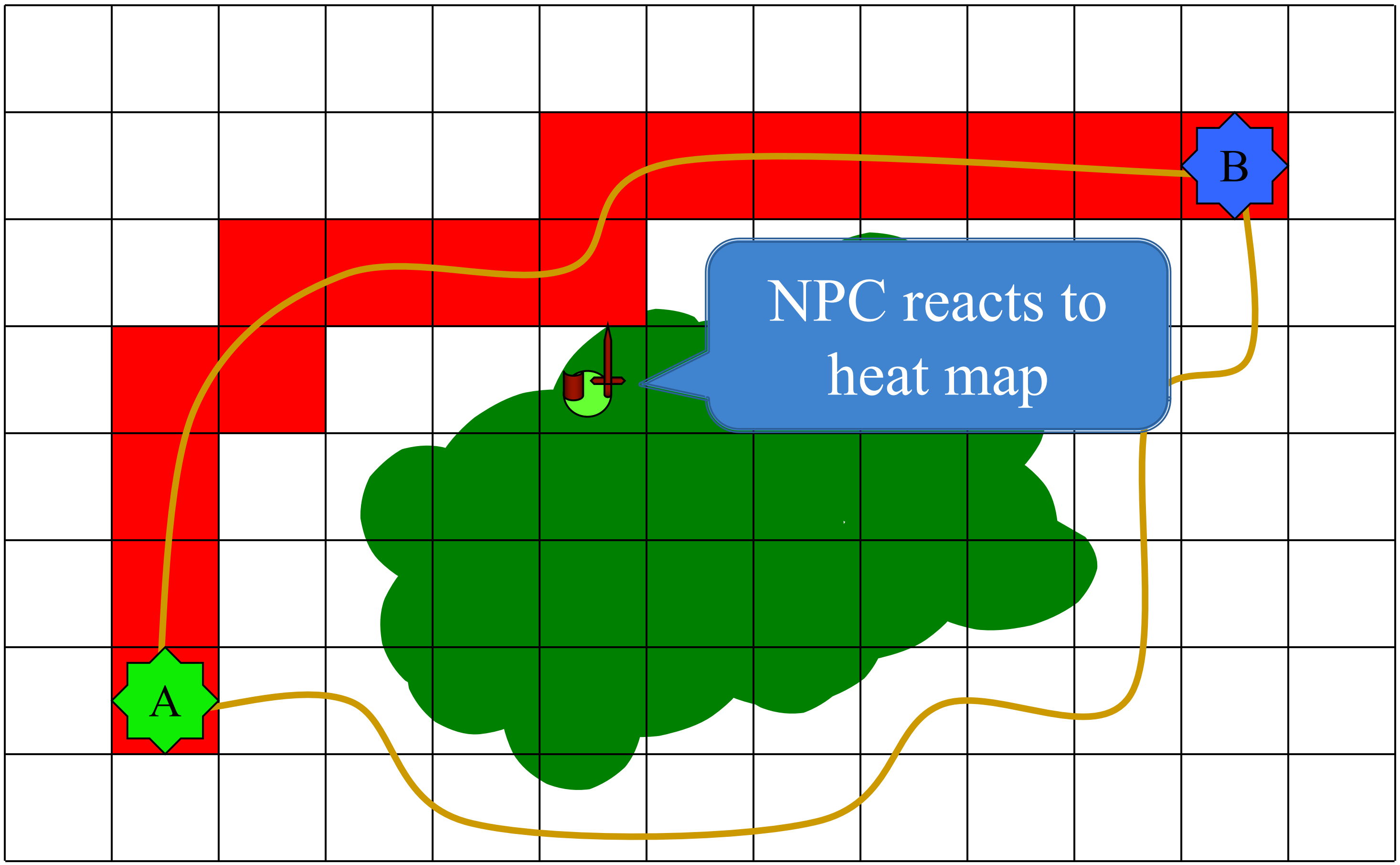

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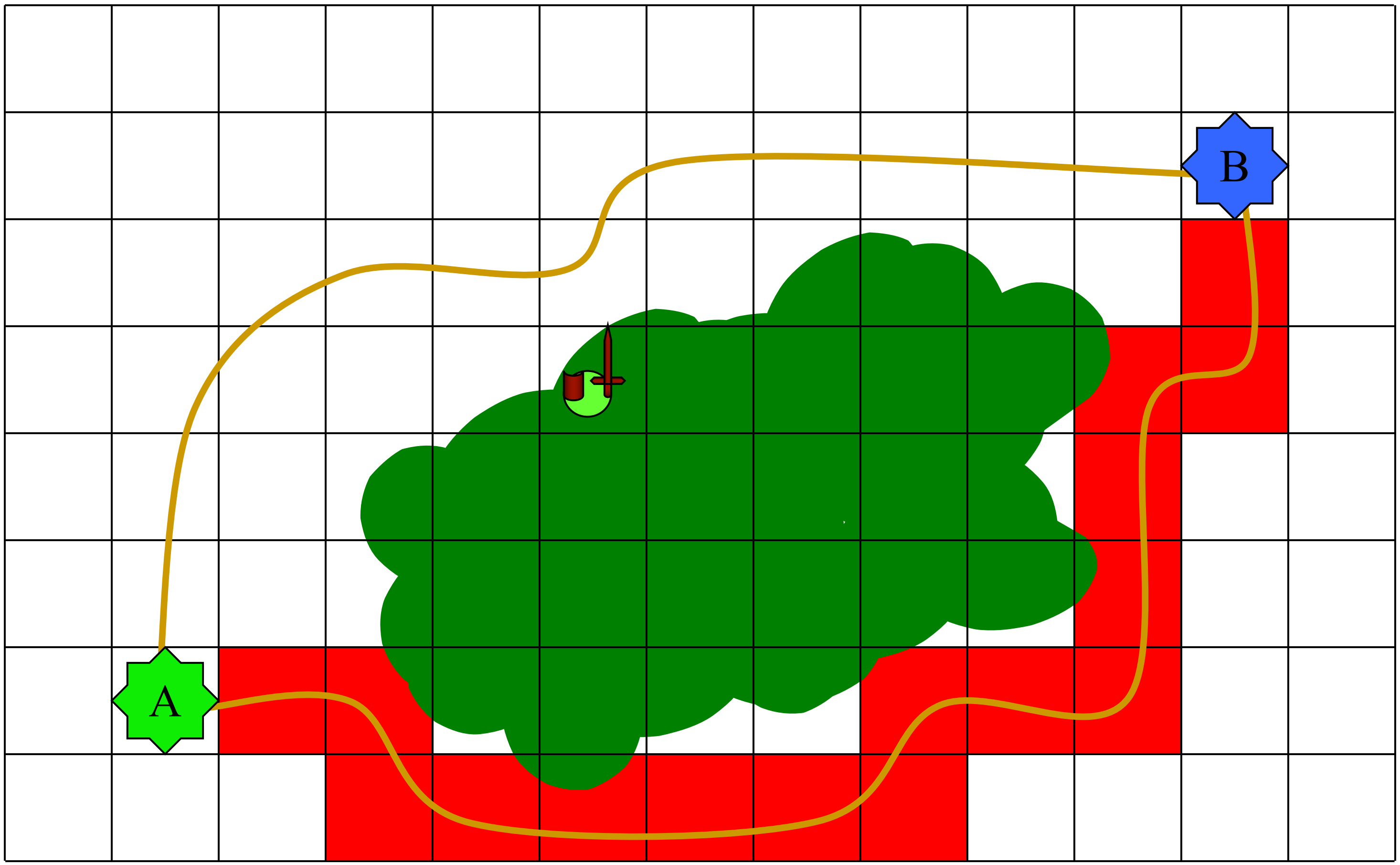

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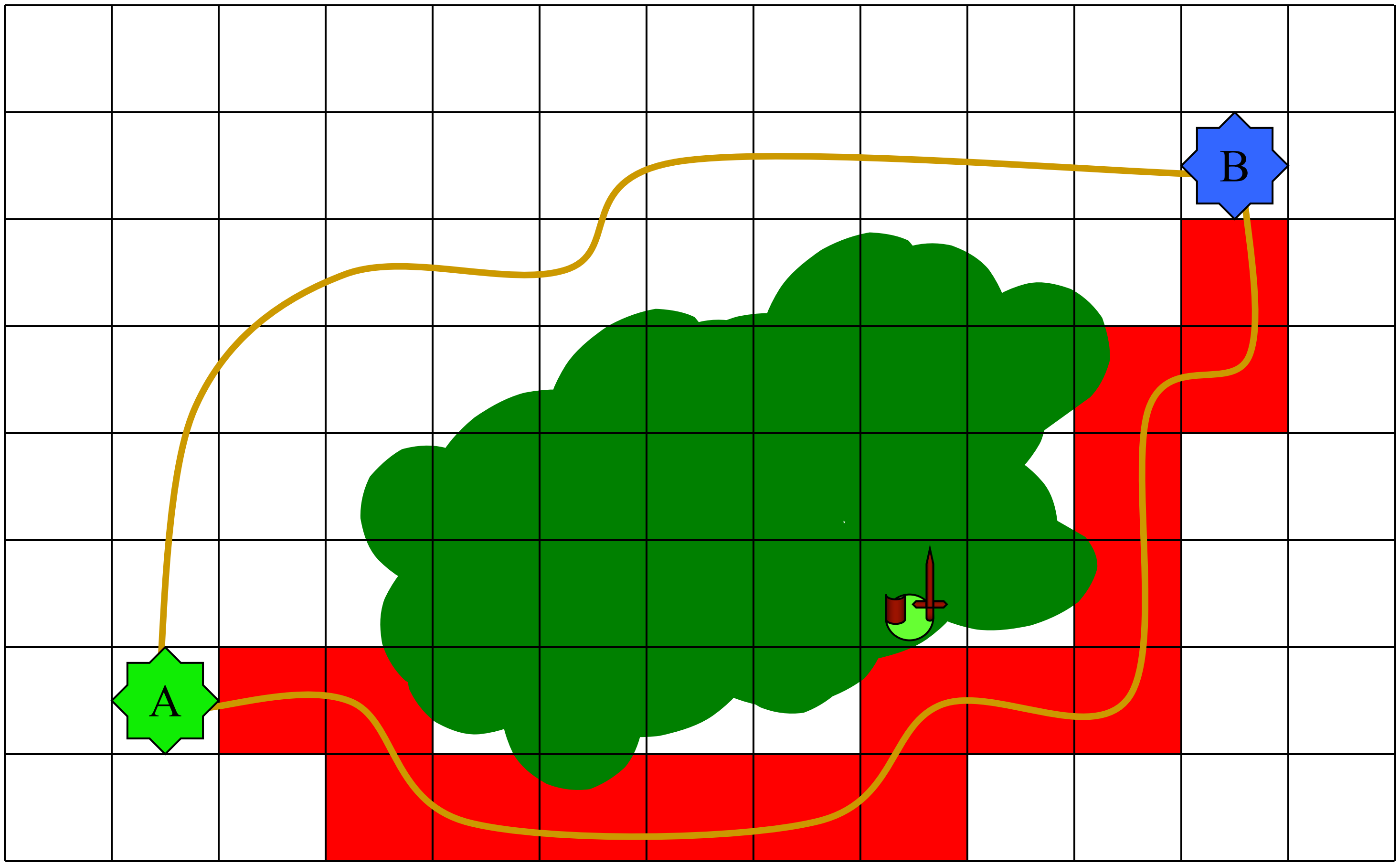

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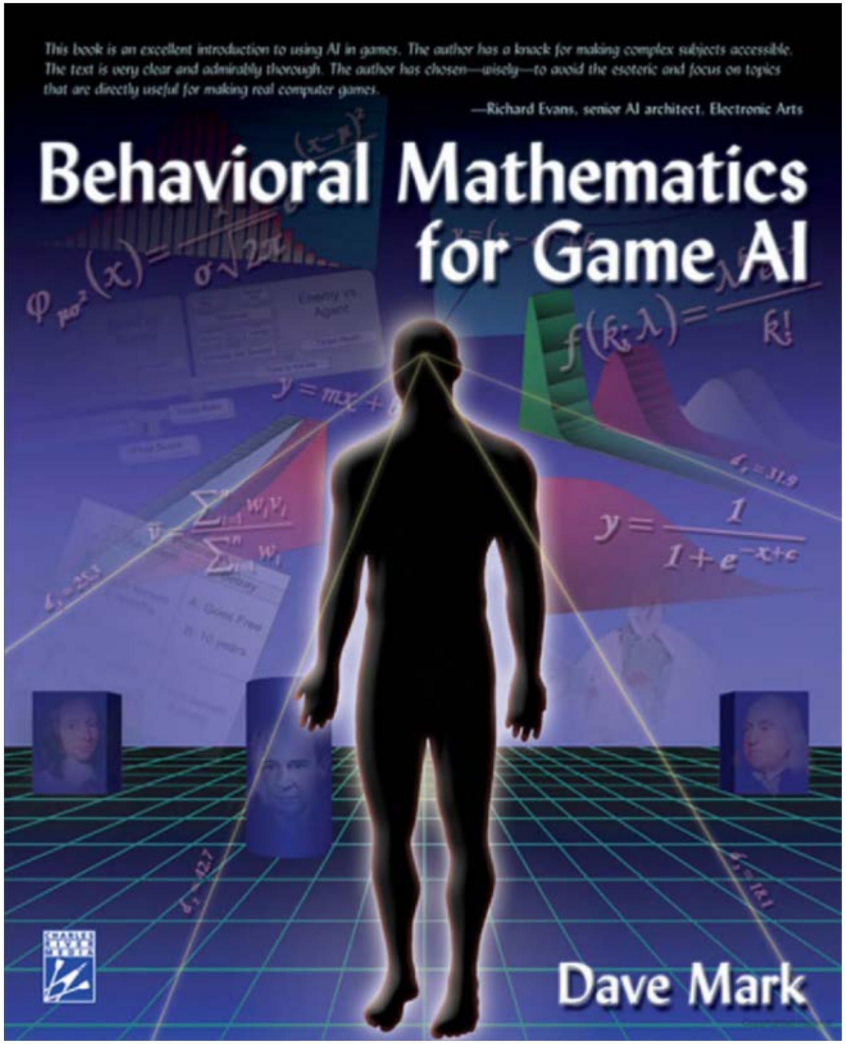
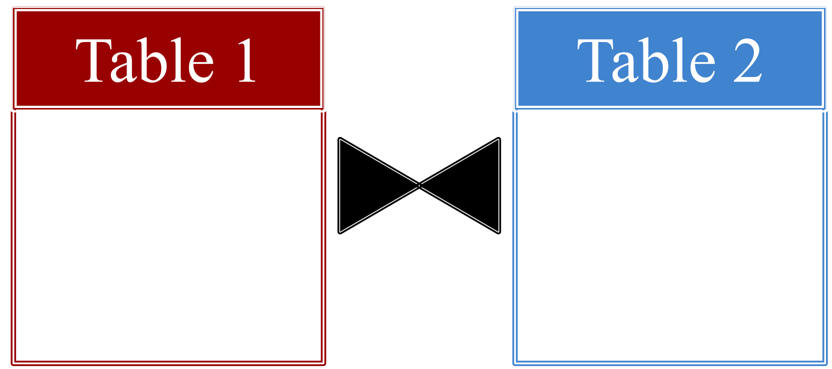
Resource for Sense Optimization



A Final Observation

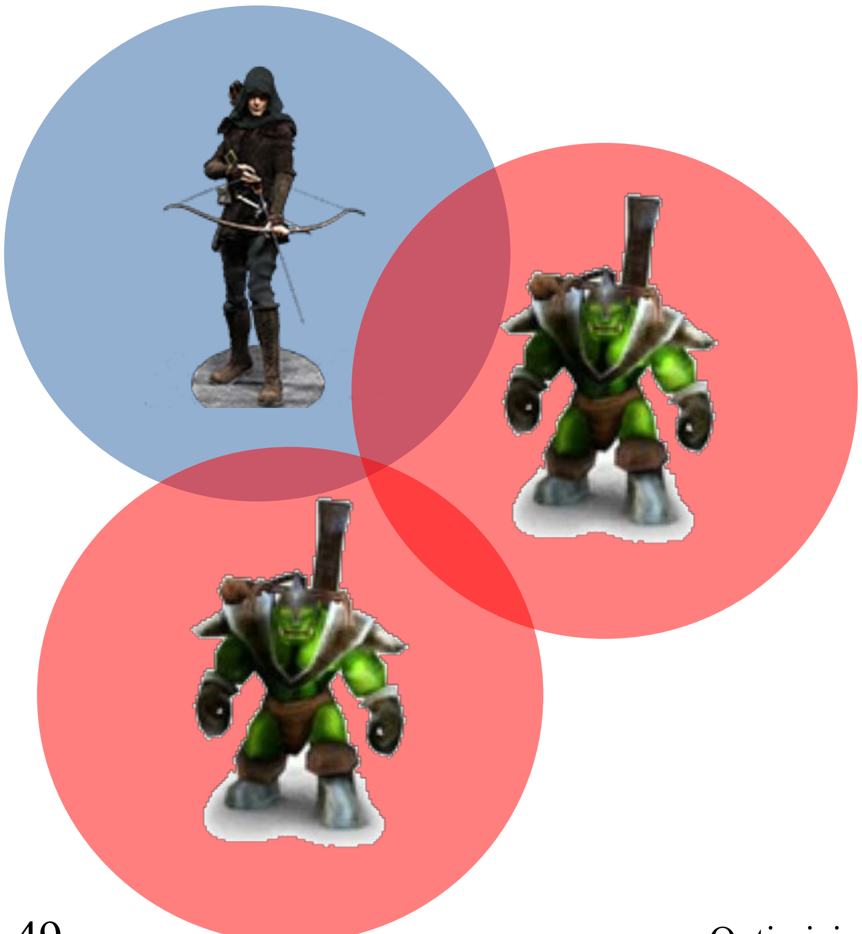
```
for each entity x:
    for each entity y:
        if x senses y:
            output event
```



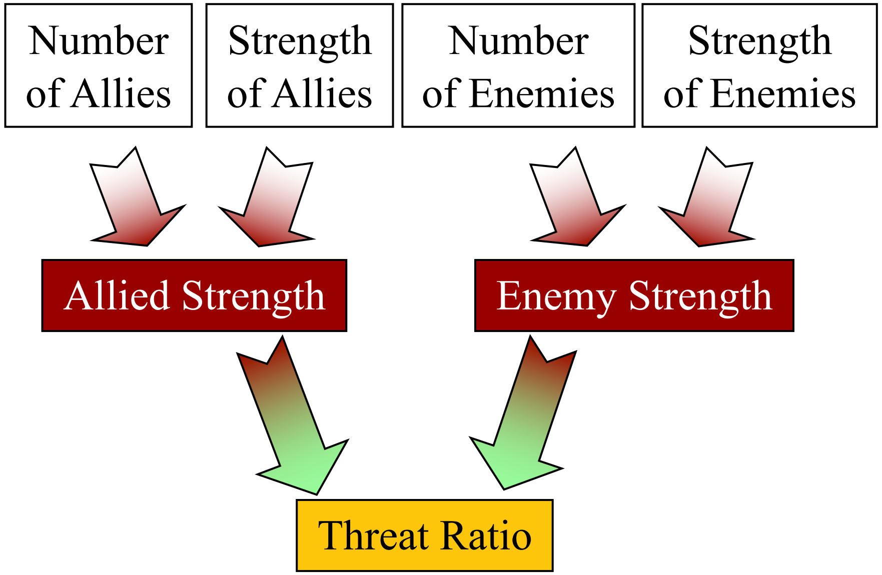
Sensing is a database table join

These are all DB Optimizations

Selection Pushing

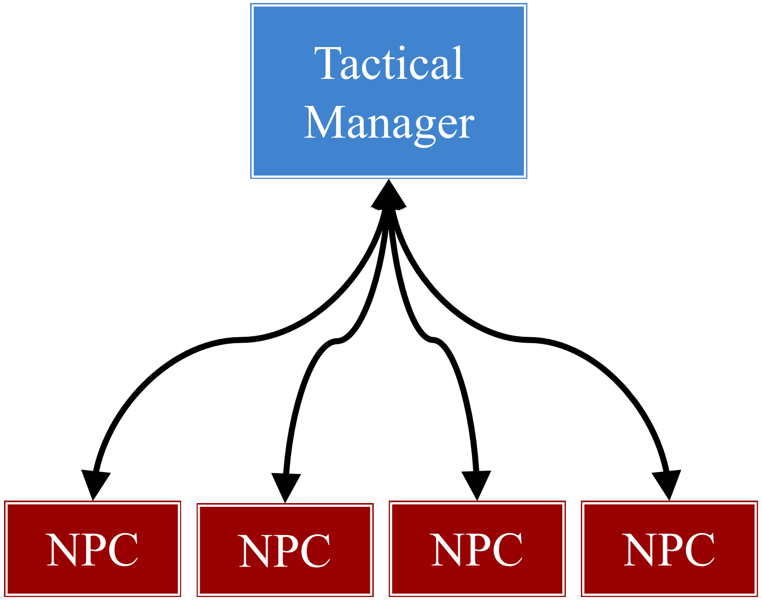


Aggregation Pushing

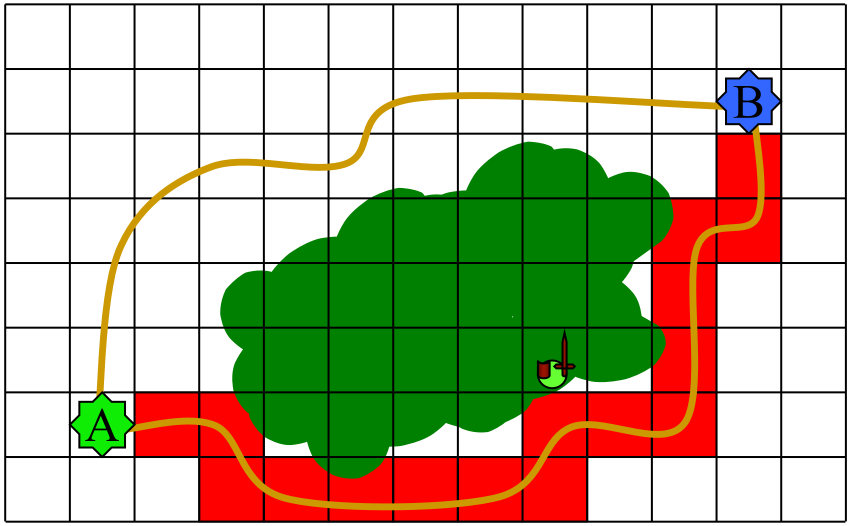


These are all DB Optimizations

Data Normalization



Query Rewriting



And This is Where it All Began

- *Scaling Games to Epic Proportions* (**SIGMOD 2007**)
  - Allow designers to write code naively as $O(n^2)$ loop
  - Use DB technology to optimize processing
- Requires that **behaviors** << **NPCs**
  - NPCs have different state, but use similar scripts
  - Each NPC is a tuple in database query
- **Challenge**: Making the language user-friendly
  - Requires major restrictions to language
  - Similar issue with Microsoft LINQ