Terrain Analysis in Strategy Games

CS 395GAI

Spring, 2005

Overview

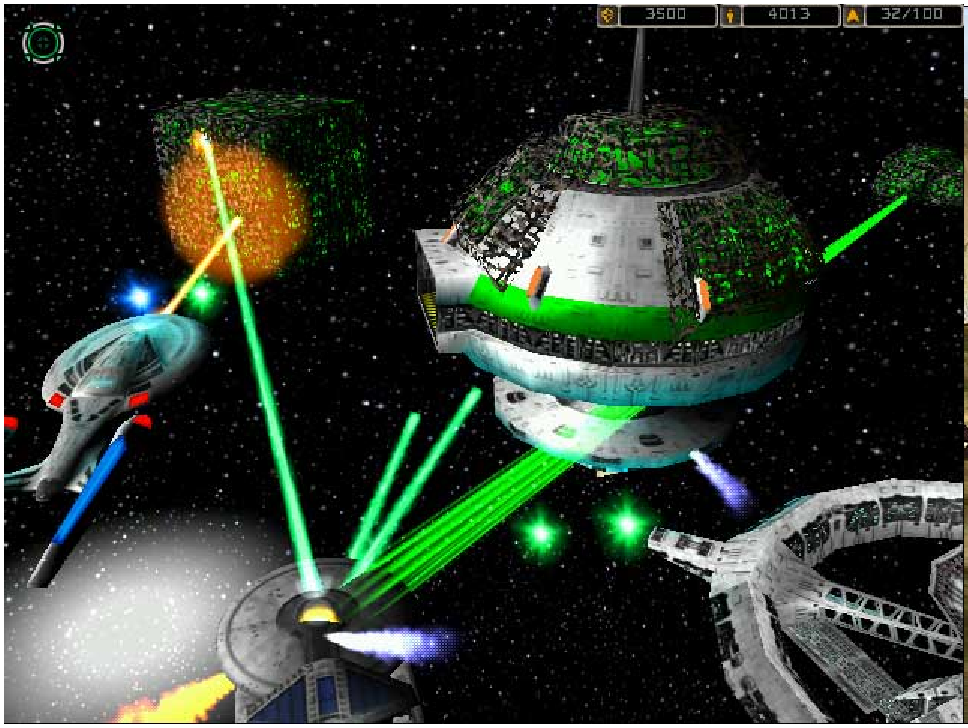
- Review
  - Baseline representations of space in games
  - Path-finding
    - Example: A*
  - Position-finding
    - Example: Influence maps
- Terrain problems in strategy games

From the developer's side

- "Unfortunately, we had to tweak the quality/heuristics of the basic pathfinding algorithm [in AOE1] to make it work effectively for the CP AI canPath checks. As a result, we ended up with a one-size-didn't-quite-fit-all implementation for the pathfinding. To put it nicely, we got roasted for that."
- "*Age of Empires 2* spends roughly 60 to 70% of simulation time doing pathfinding"
  - Dave C. Pottinger, Ensemble Studios, in *Terrain Analysis in Realtime Strategy Games*

Three families of spatial solutions

- Tiles
- Waypoints
- Quad trees



Tiles

- Variations
  - Can be rectangular or isometric, depending on perspective
  - Some games use hexagonal grids to model distances traveled on diagonals more accurately

- Tradeoffs
  - Very simple
  - Uniform resolution can waste storage on uninteresting regions of space

Quad Trees

- Carve up space according to where objects aren’t
- Stop conditions:
  - Uniform contents
  - Maximum depth on recursion reached
- Tradeoffs
  - Provides variable resolution
  - More intricate to generate and use

Waypoints

- Annotate terrain with hand-selected places that movable entities can be in
  - Adjacency relationships between waypoints indicate ways to move from one to the other (including travel time)
  - Additional annotations can be used to indicate other properties
    - whether line-of-sight exists between two waypoints
    - Part of a room or a base or some interesting location
    - Environment conditions, such as light/dark, types of movement required
- Tradeoffs
  - Can analyze to derive many useful tactical properties
  - Generally must be entered by hand

Path-finding

- All three spatial solutions give rise to common formal framework for finding paths
  - Graph search
  - Costs on links of graph
- Results from early AI research universally used in game development
  - E.g., A* search and its successors
- Game developers have invented many improvements
  - Nothing like trying to live within a tight CPU budget to unleash creativity!

A*: Formalization

- Node = a state in your search corresponding to a place in your terrain representation
  - Node contains path to get from start to that place
  - Multiple paths can go through the same place, so there can be more nodes than places
- Children = nodes corresponding to adjacent places in your terrain representation.
- Links between nodes have *costs*.
  - Depends on distance
  - Depends on difficulty of movement
  - Can roll in other factors, e.g. concealment/visibility, to incorporate tactical factors

A* formalization, continued

- Start, Goal = nodes
- g(n) = cost to get to this node from your starting position
  - Sum of costs so far along this path
- h(n) = Estimate of cost remaining to goal
  - Intuition: Path cost estimate = g(n) + h(n)
  - Use estimate to explore cheapest paths first
  - If h never overestimates cost remaining, then h is *admissible*
  - If h is admissible, then A* is guaranteed to be optimal
    - Will always find the cheapest path
    - Will always examine the fewest nodes

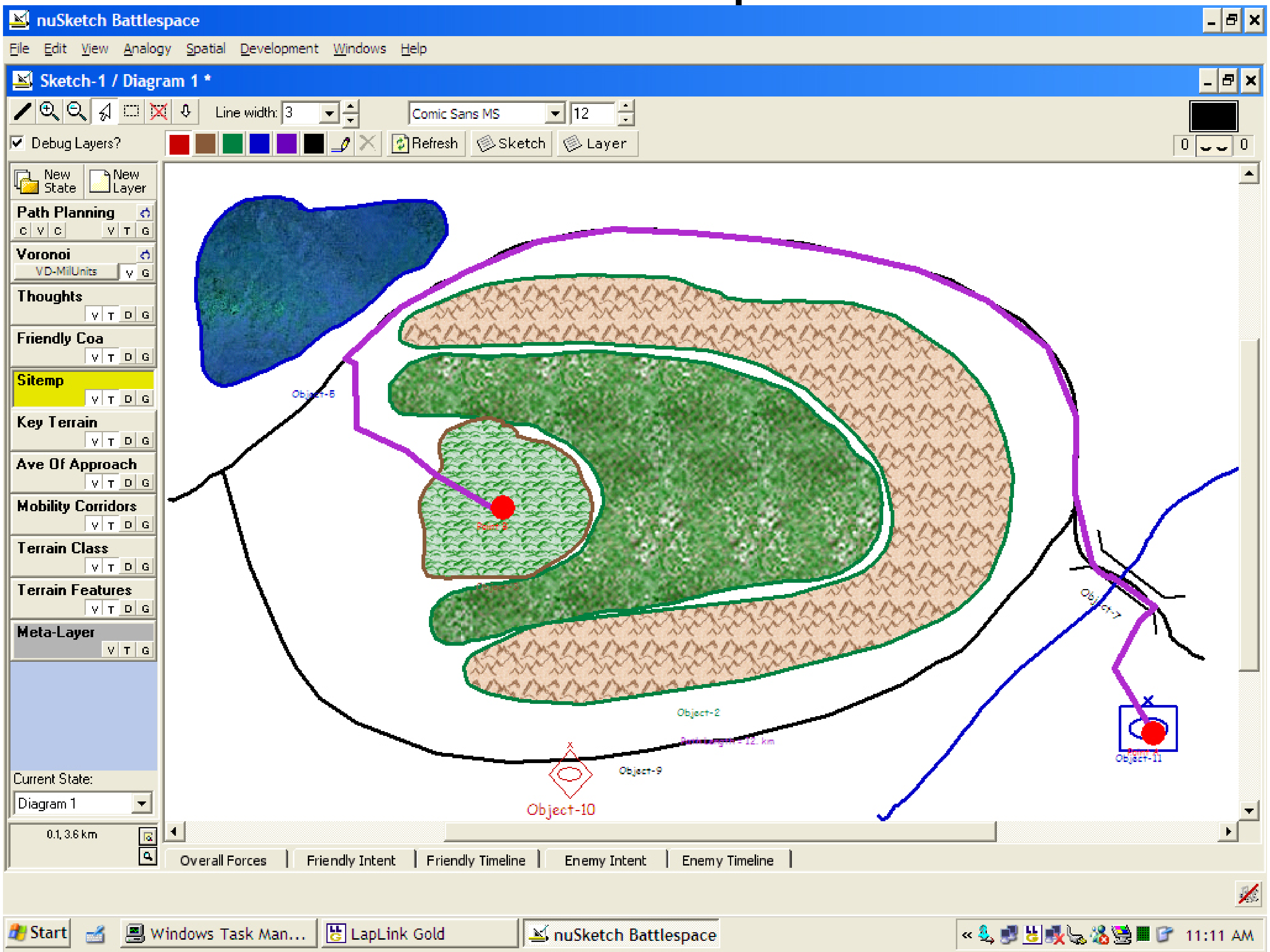
A*

1. Let Open = {make-node(start)}, Closed = {}
2. If Open = {} then return failure
3. Let N = best node from Open
   a) If place(N) = goal then return N
   b) For each child C of N,
      i. Is there a node N2 with place(N2) = place(C) in Open or Closed?
         a. If so, replace path(N2) with path(C) if f(N2) > f(C)
         b. Otherwise, add C to Open
   c) Move N to Closed

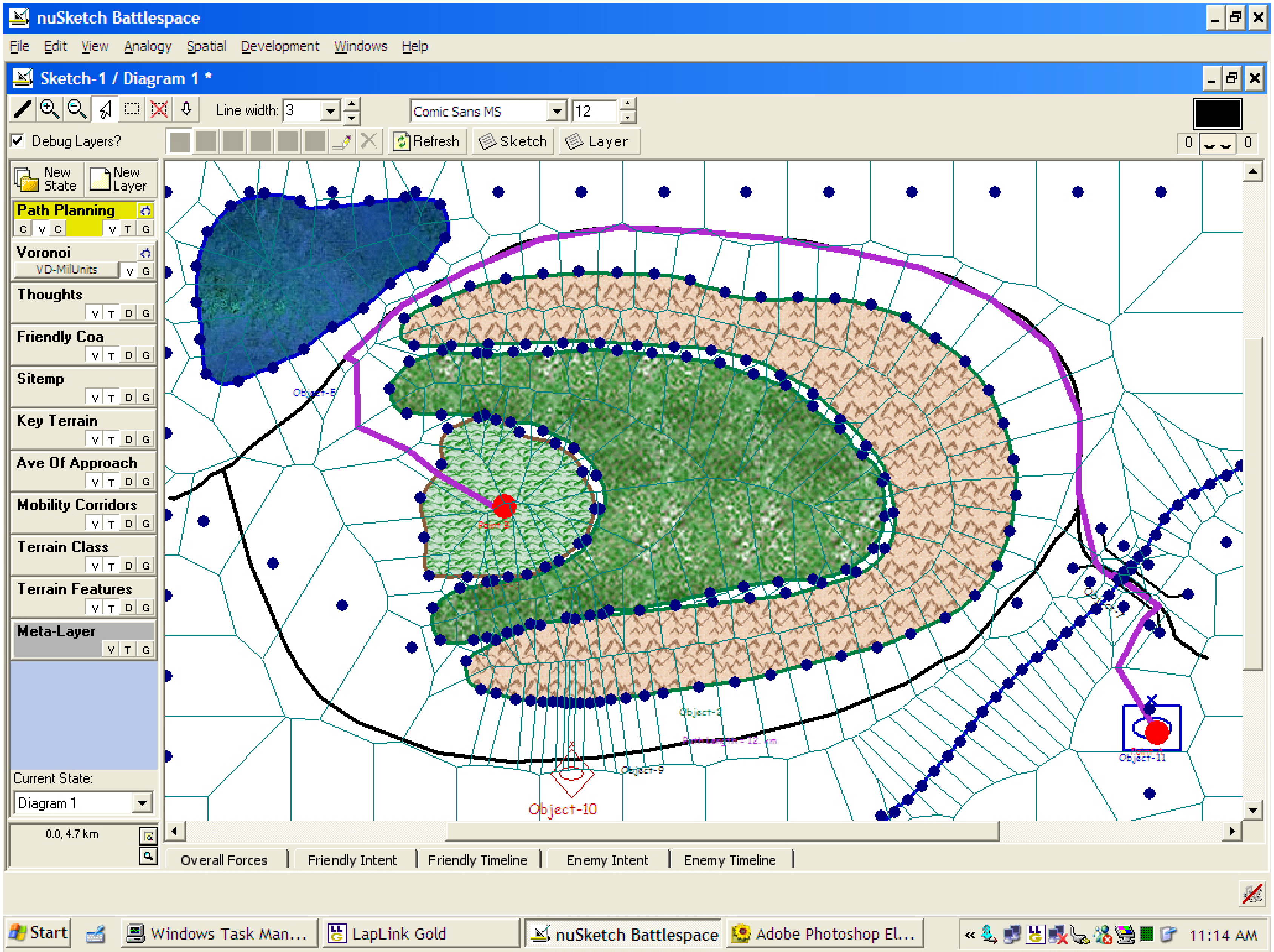
Demo

- http://www.ccg.leeds.ac.uk/james/aStar/

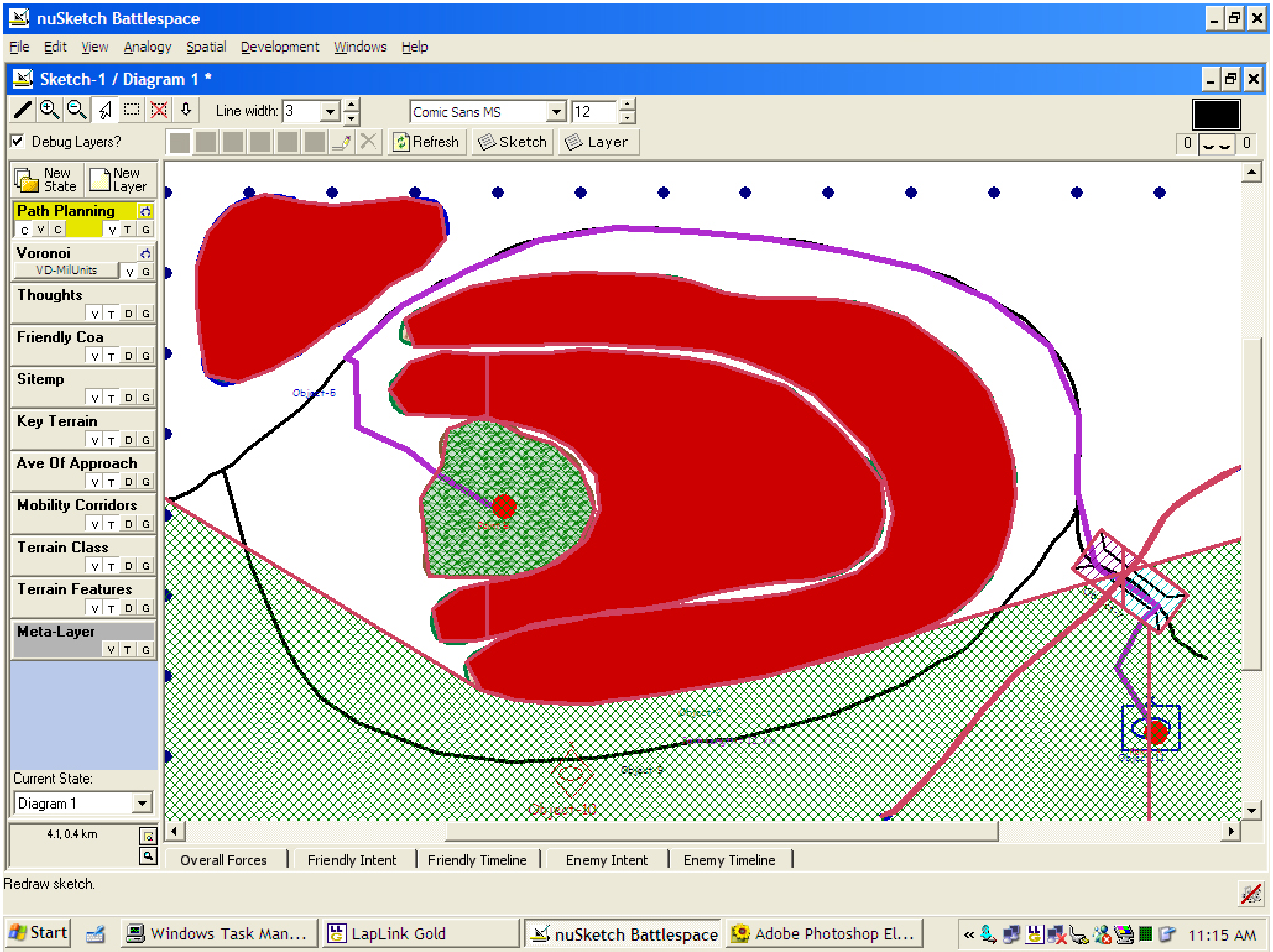
A* can involve multiple constraints



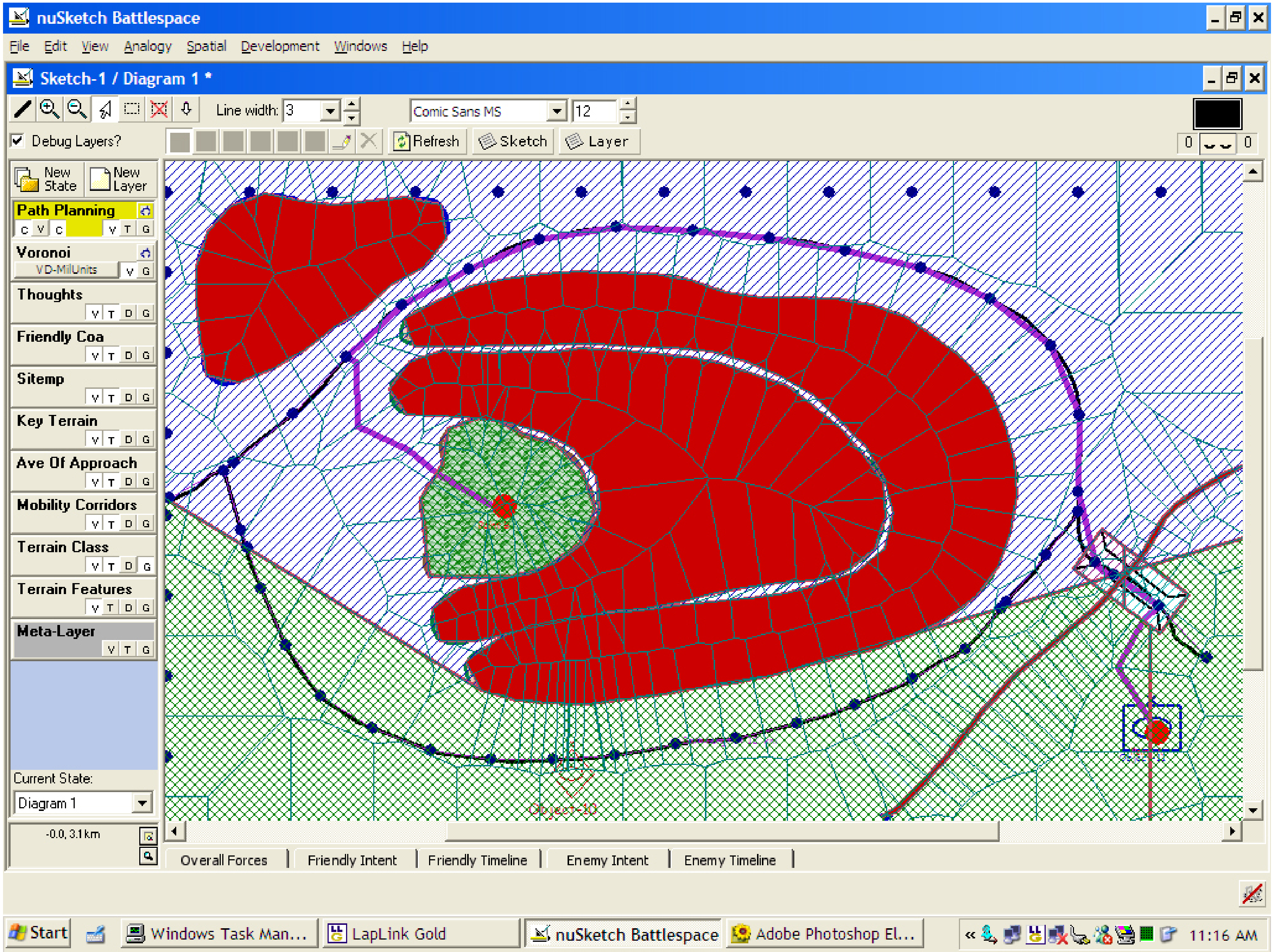
Free space represented as Voronoi



Visibility constraint regions



Intersect to compute constraint cells

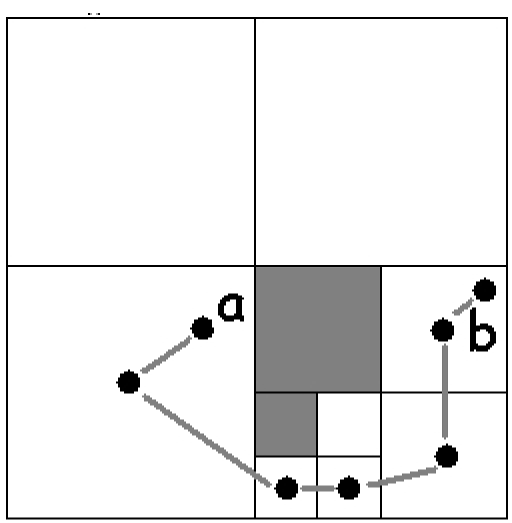


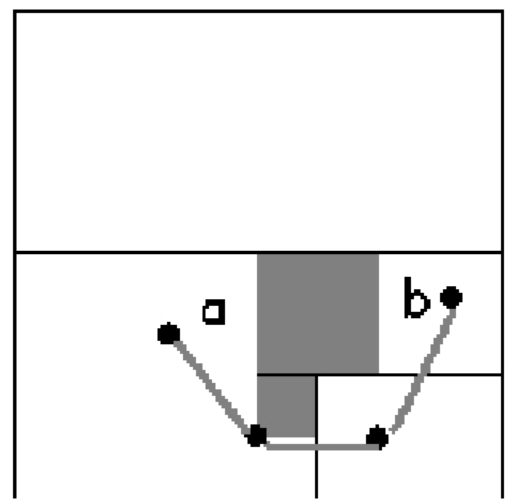
Modification: Iterative deepening

- Observation: For a search of depth *k*, there are many more nodes at the depth of *k* than the entire search tree for *k*-1
- Technique: Add a maximum depth of search
  - Start with small but semi-reasonable estimate
  - If failure, search again with larger maximum depth
- Tradeoffs
  - Search the same space near the start over and over again
  - Memory requirements can be dramatically smaller

Modification: Cleaning up paths

- With large pieces of space, paths generated can be unnatural
- Solution: Use a post-processing step to clean them up

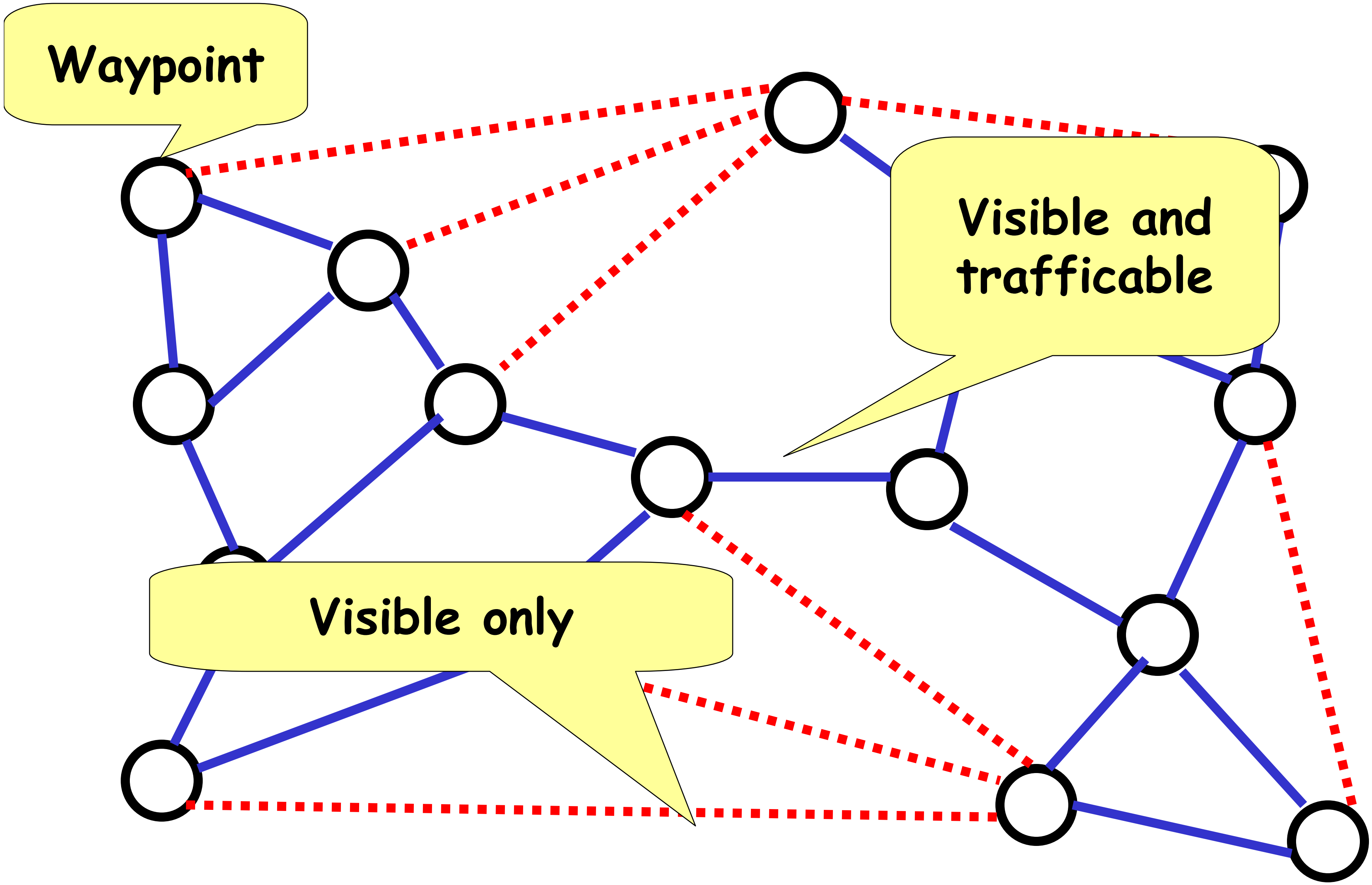




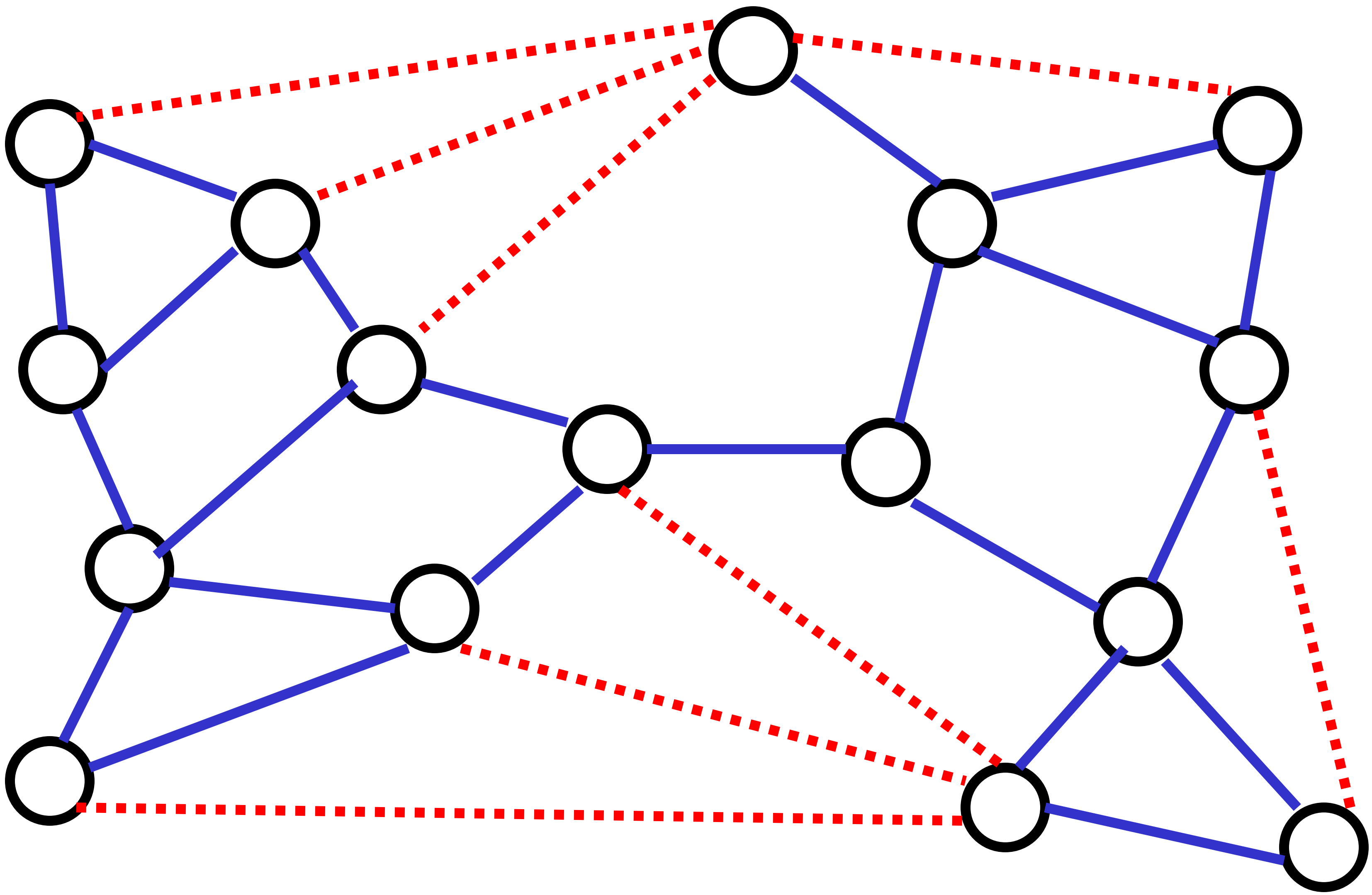
Position-Finding

- Many problems in games involving finding places
  - Where should I build cities?
  - How can I cut crime in my city?
  - Where could I ambush them?
  - Where would be a good place to hide?
  - What would be the most profitable place to put a ride?
- Position-finding = finding locations that satisfy (or optimize) particular criteria
  - Multiple constraints can be involved
  - What algorithms used depend on the available representations

Example: Using waypoints for finding tactical positions



Where would be good sniper posts?



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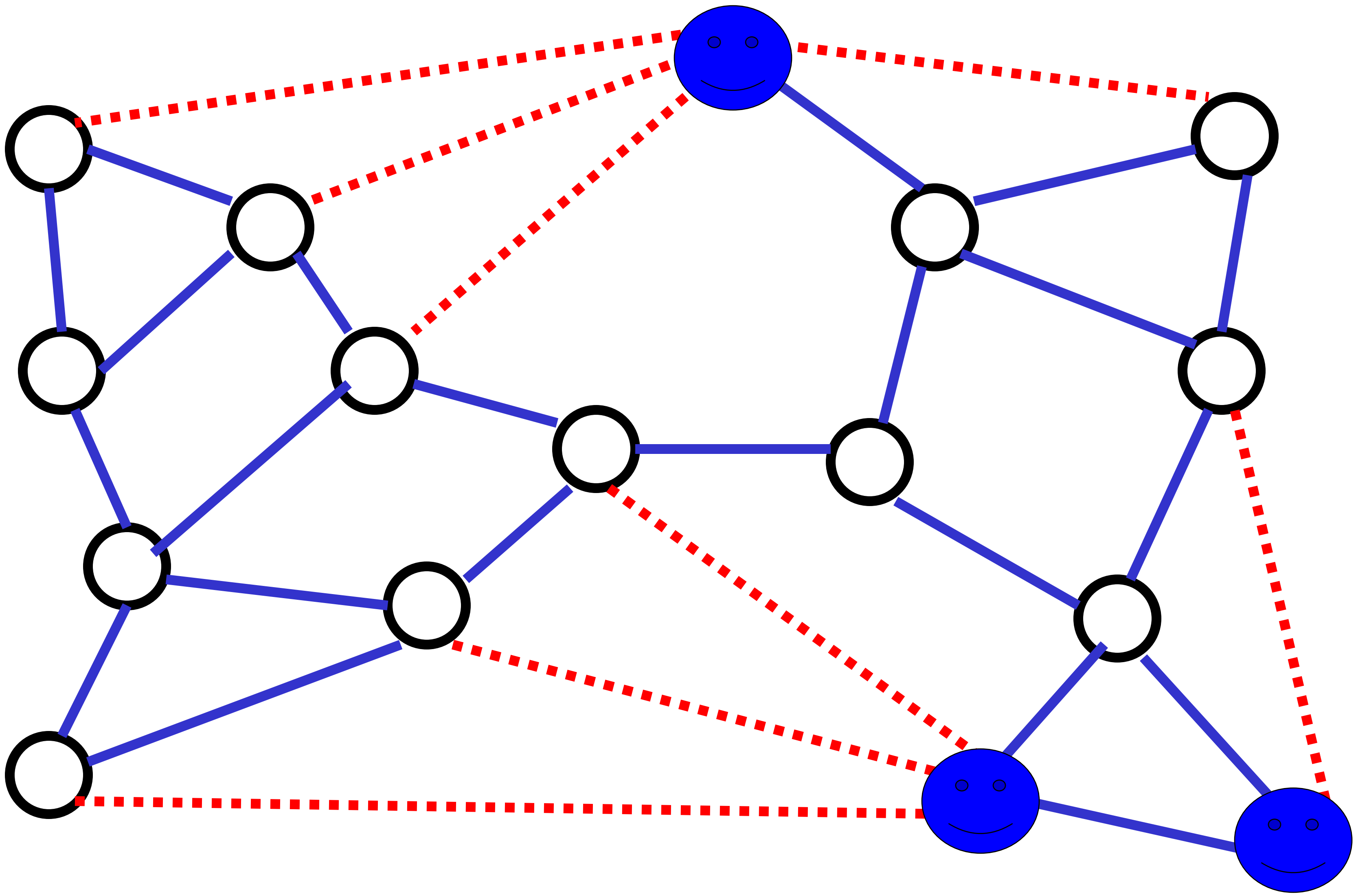
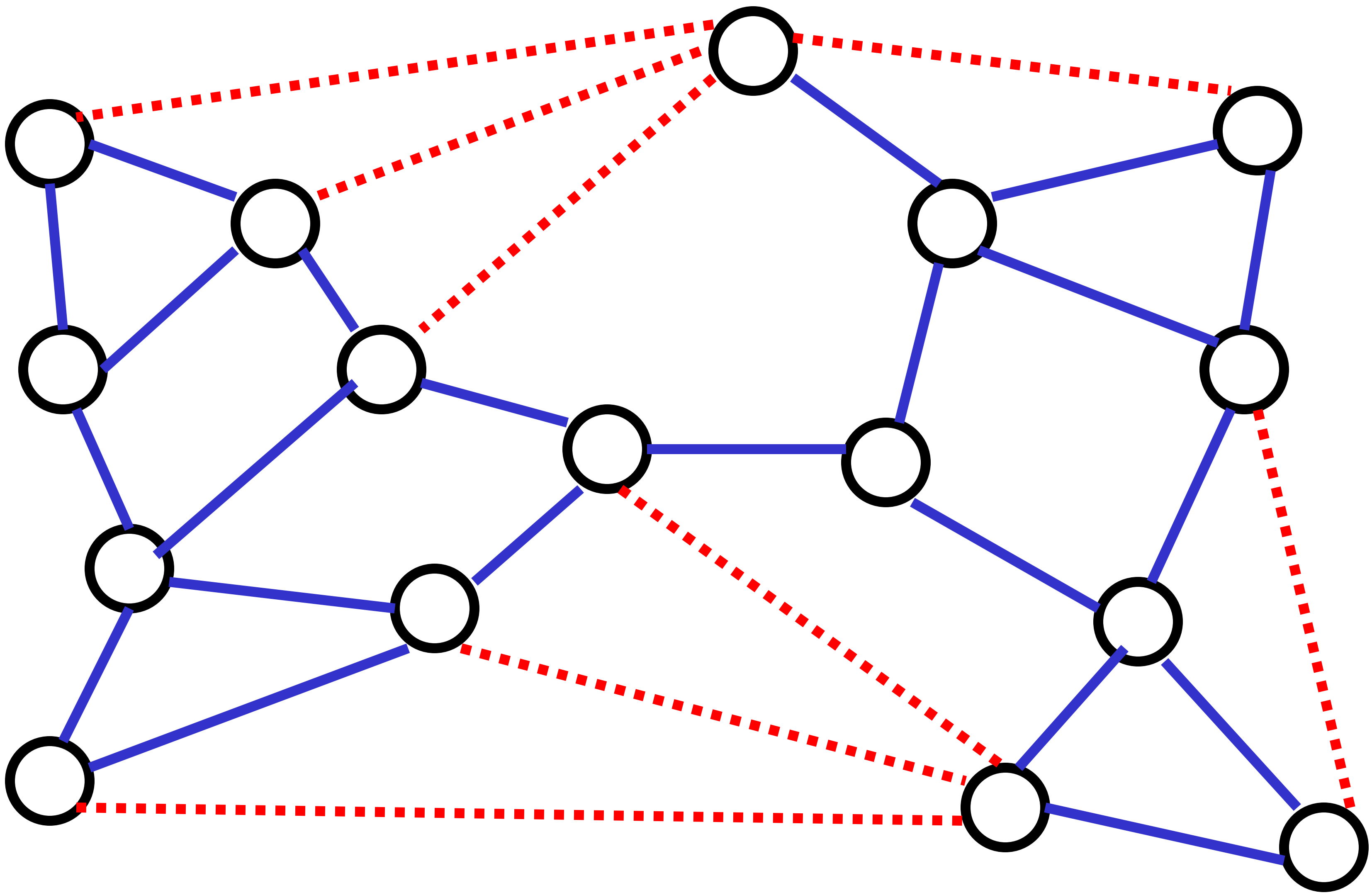


Where are the choke points?



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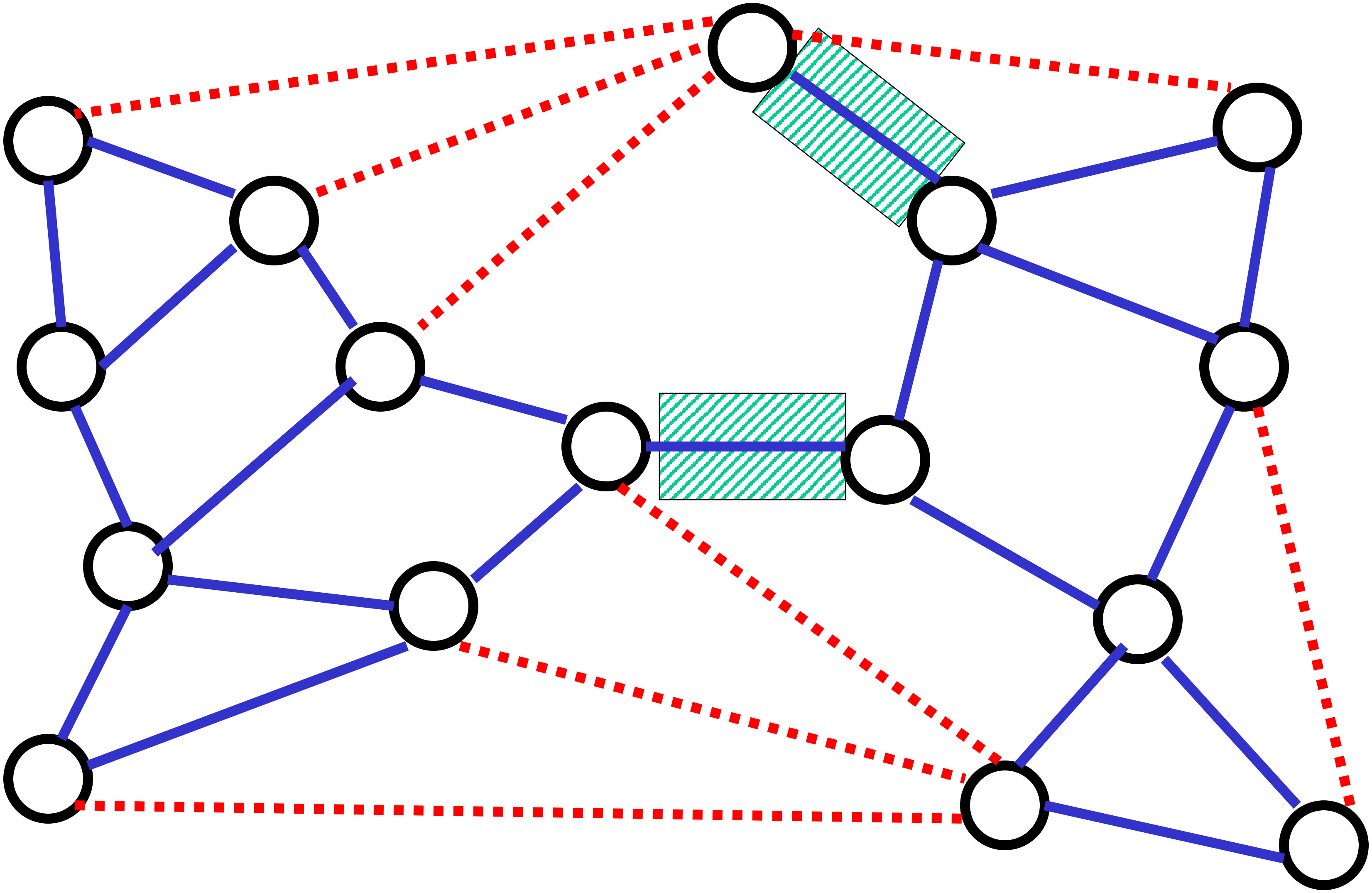
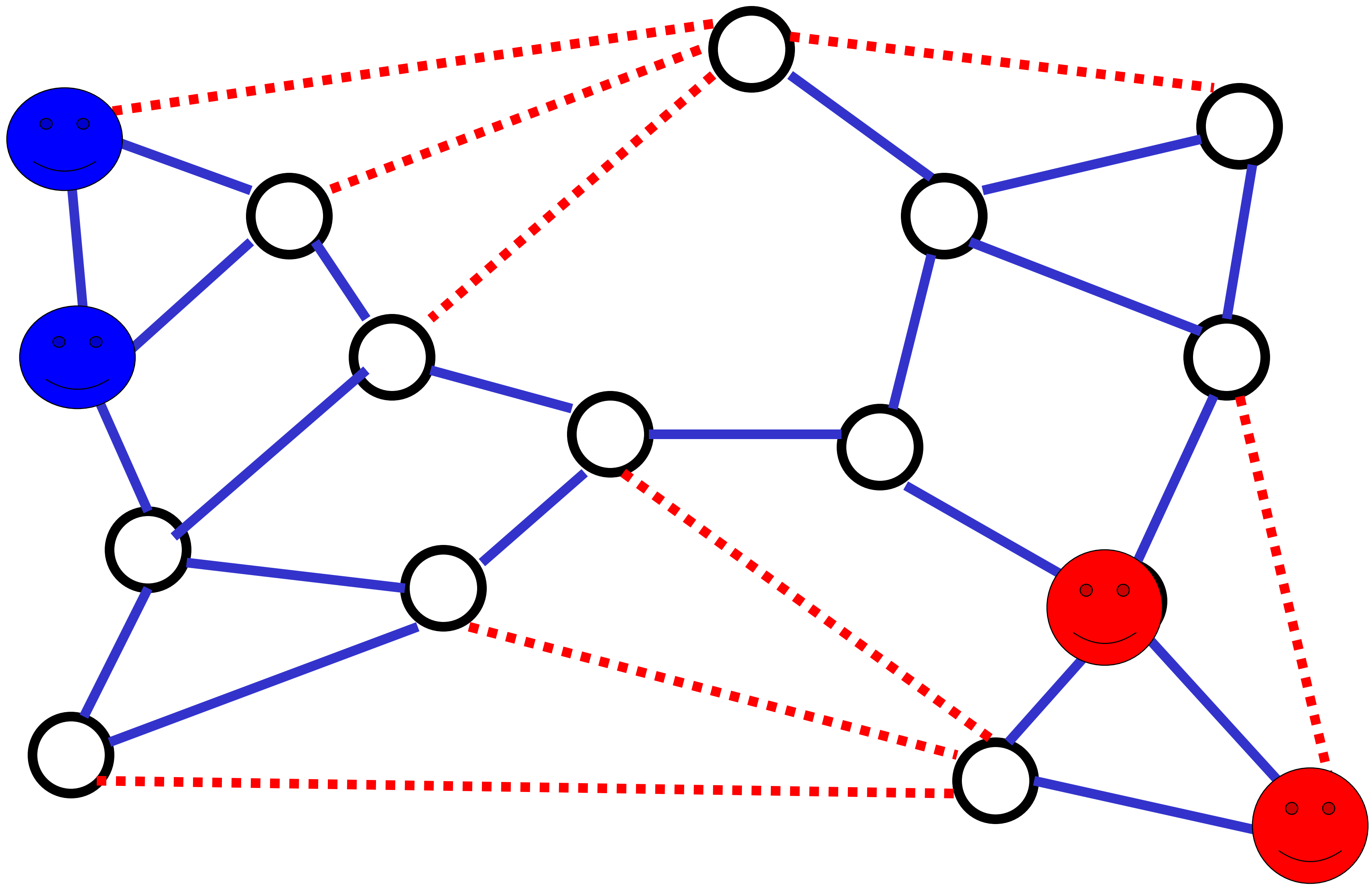


How would you sneak up on them?



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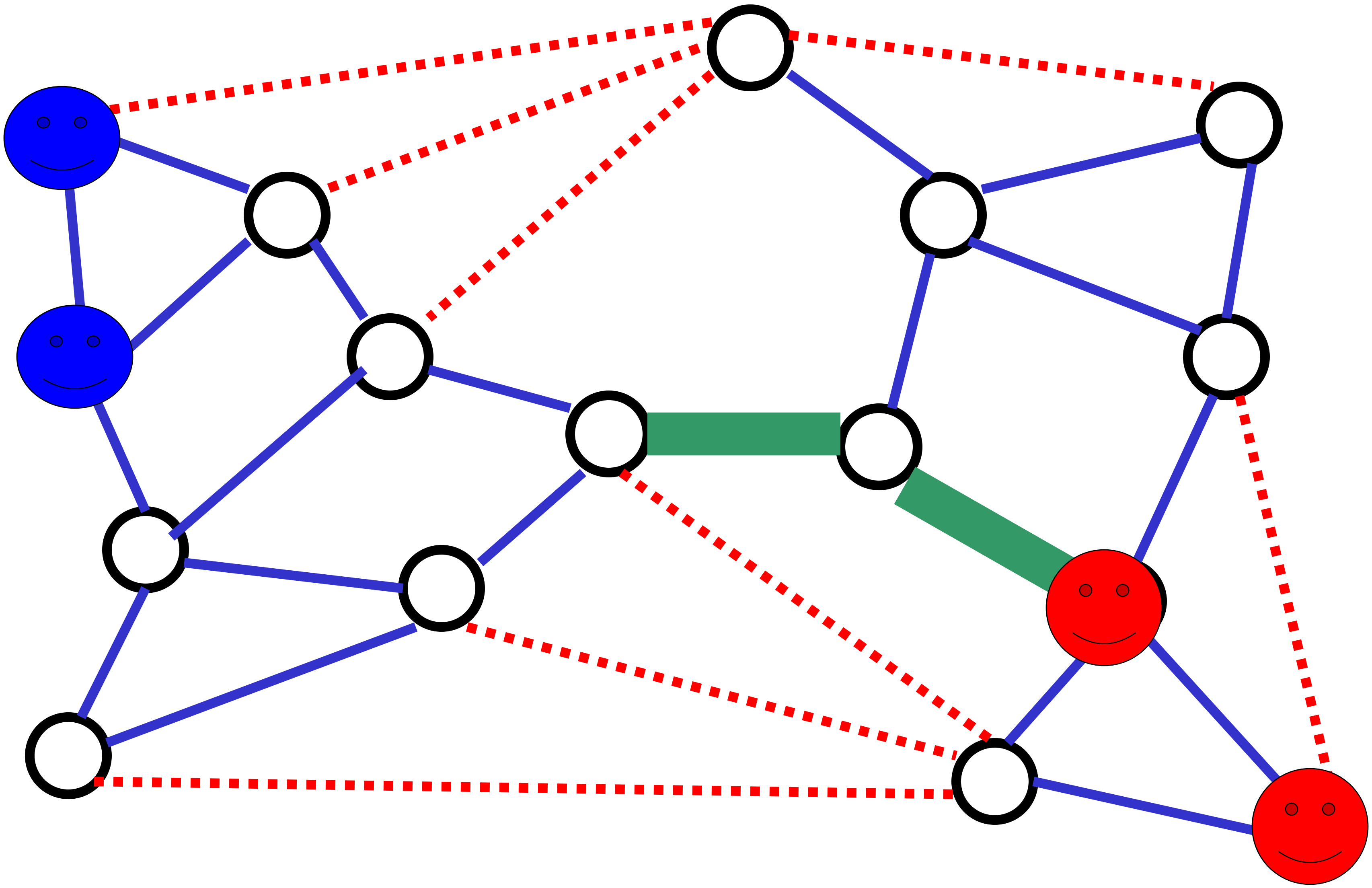
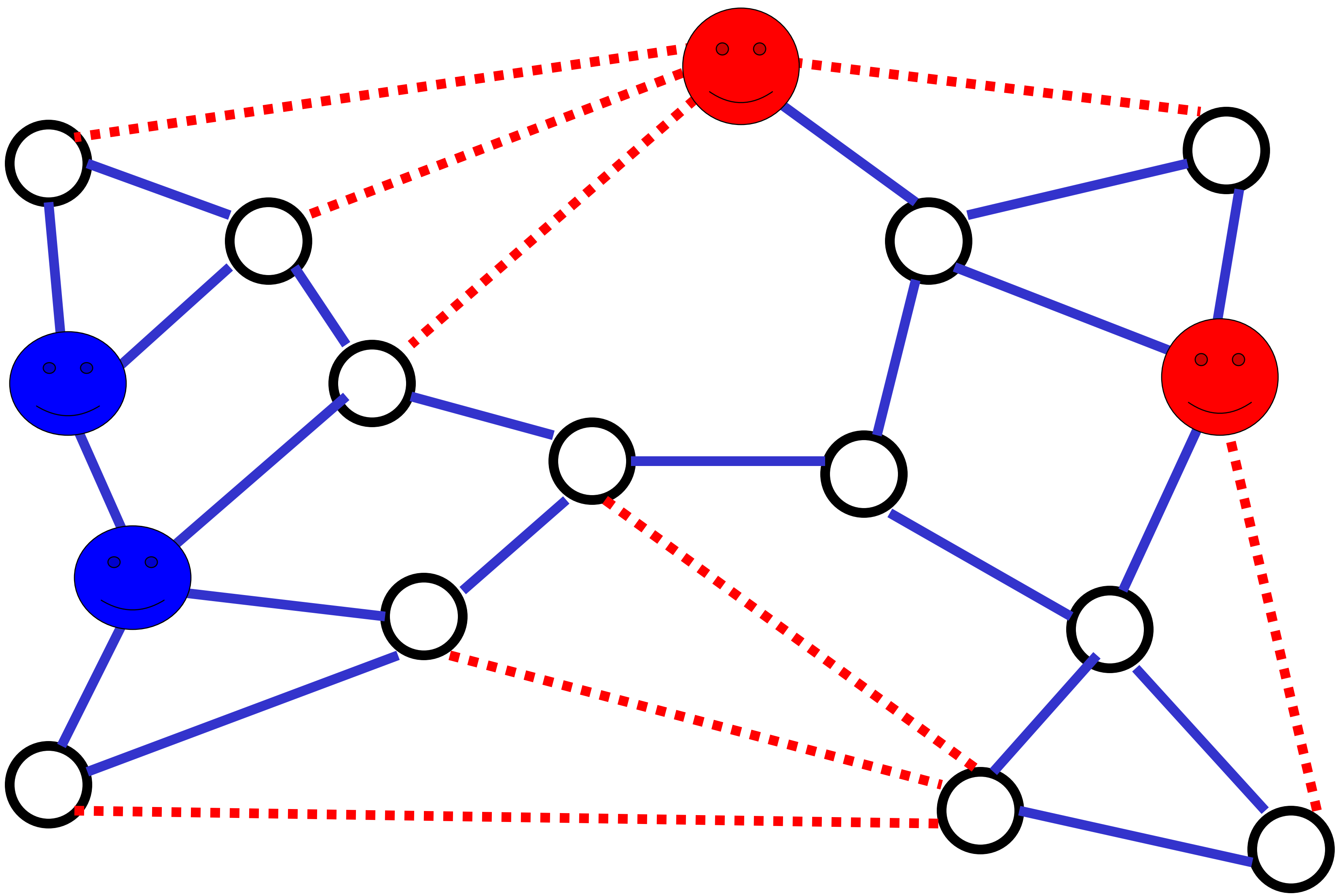


How would you trap them?



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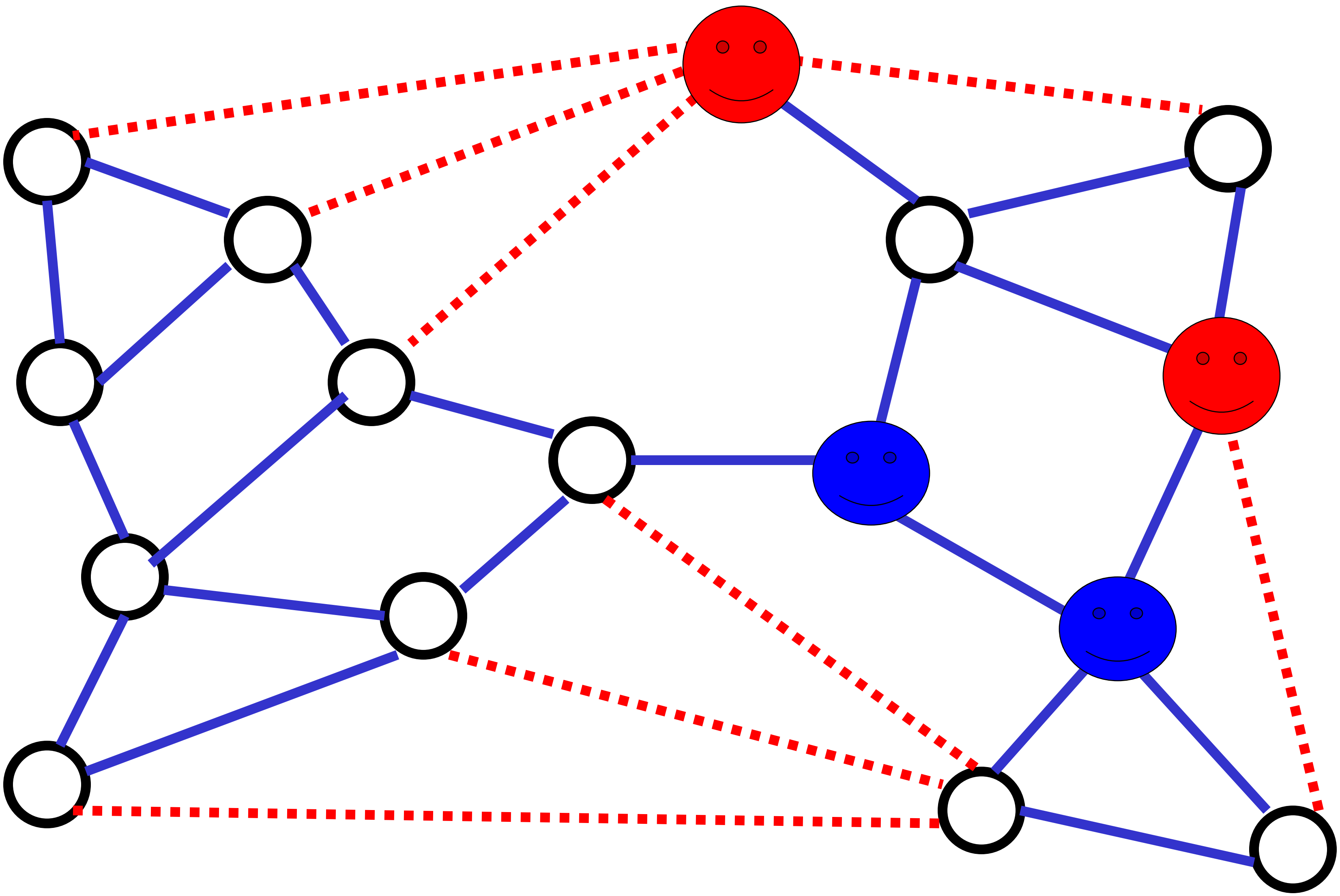
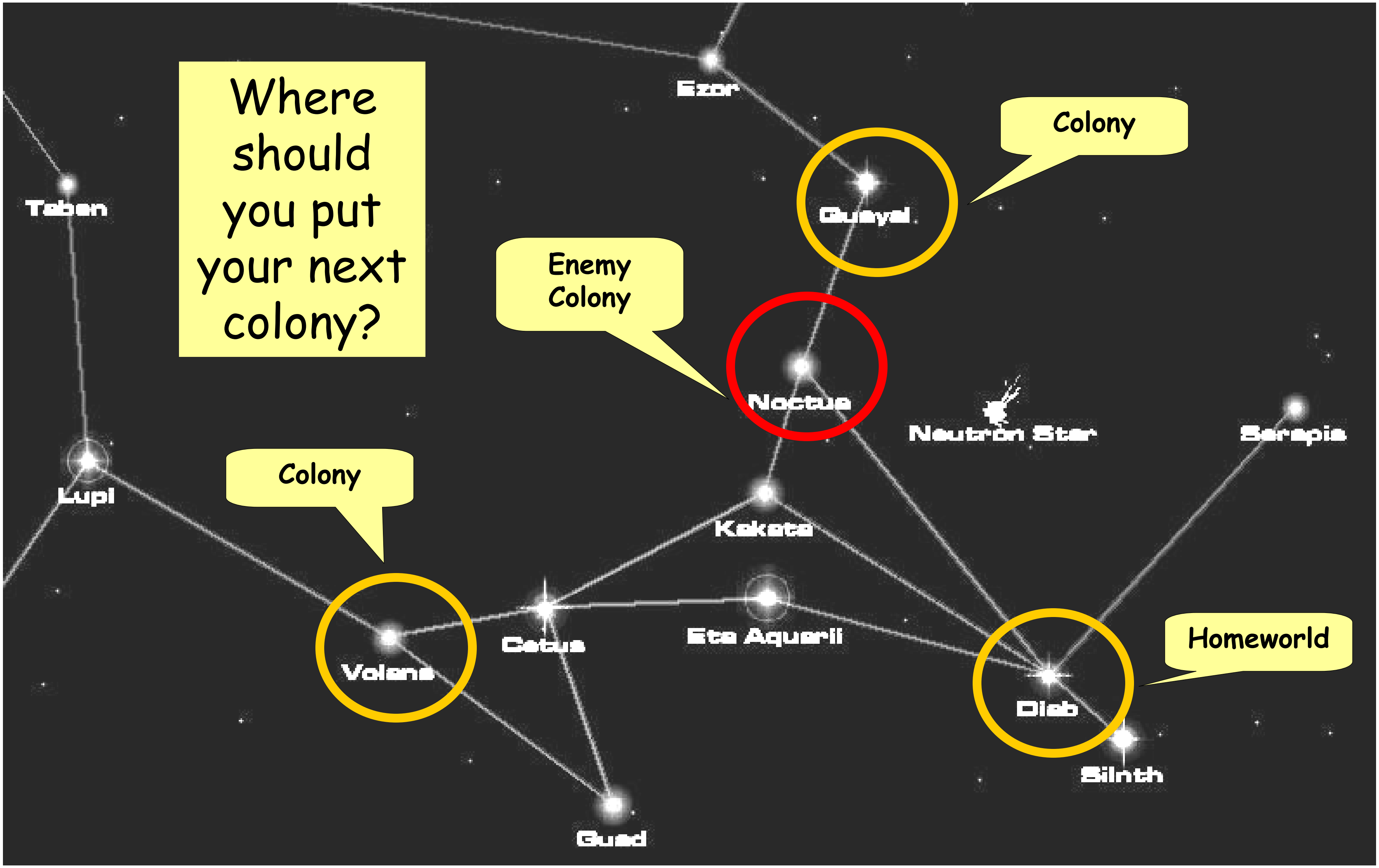
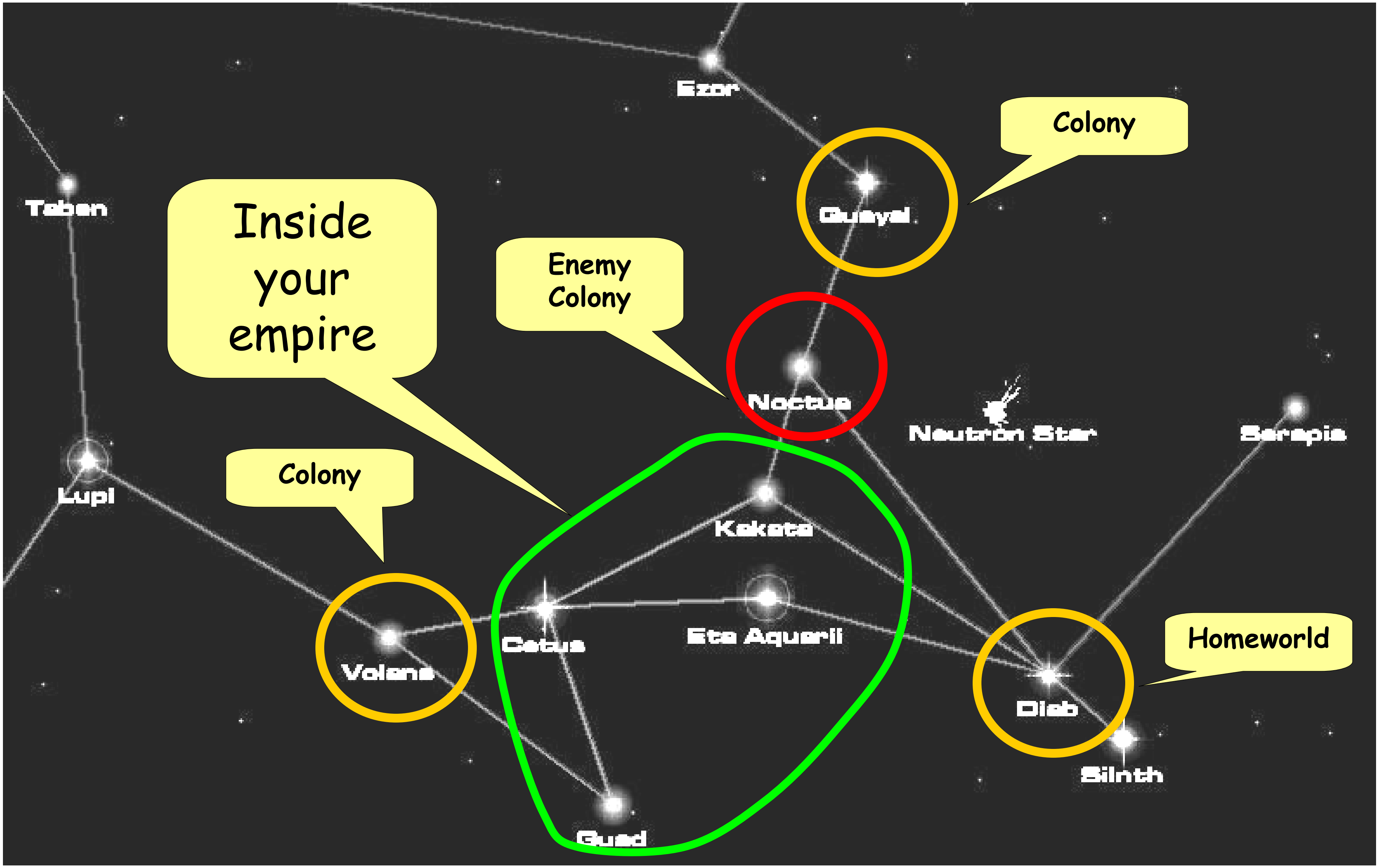


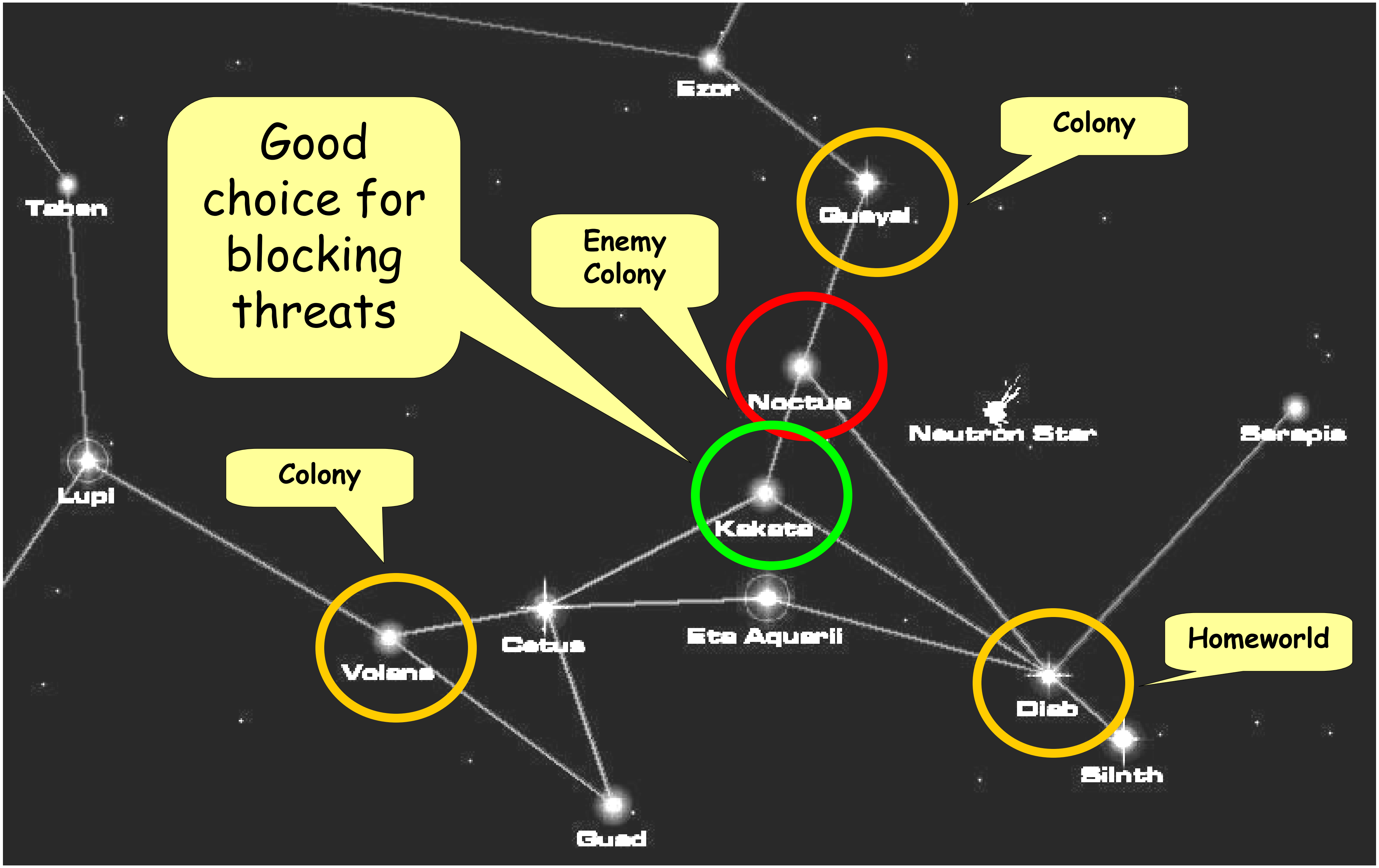
Example from MOO3



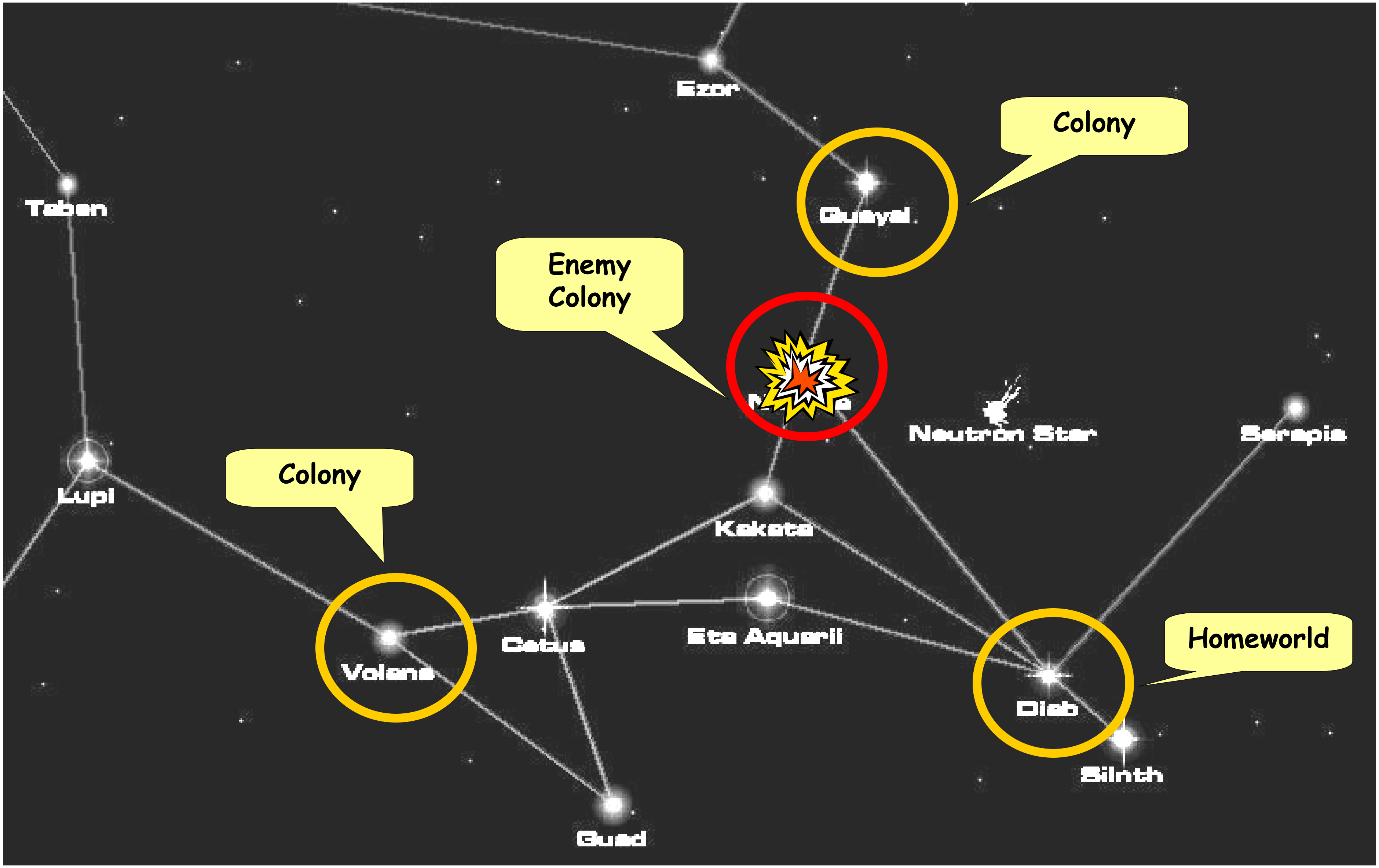
Understanding your terrain is key



Understanding borders prioritizes threats



Multiple ways to deal with threats



Influence maps

- Helps identify interesting positions on a map
  - Start from things of interest
    - E.g., friendly/enemy units, resources
  - Propagate numerical values to neighbors
    - Add/subtract values from different sources as appropriate
  - Analyze patterns of numerical values to select positions, boundaries
    - Where to put a mine or storage shed
    - The front between two warring nations

Demo

- http://www.ccg.leeds.ac.uk/james/influence/

Terrain Analysis Problems in FreeCiv

- What are they?
- How shall we solve them?

Exploration

- Solution 1: Cheat, AIs have full map knowledge
- Solution 2: Use a strategy for exploring the world

Creating the physical empire

- City site selection
- Infrastructure networks
  - Roads
  - Trade routes

War

- Where to attack your enemies
- How to use terrain to better defend yourself