

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

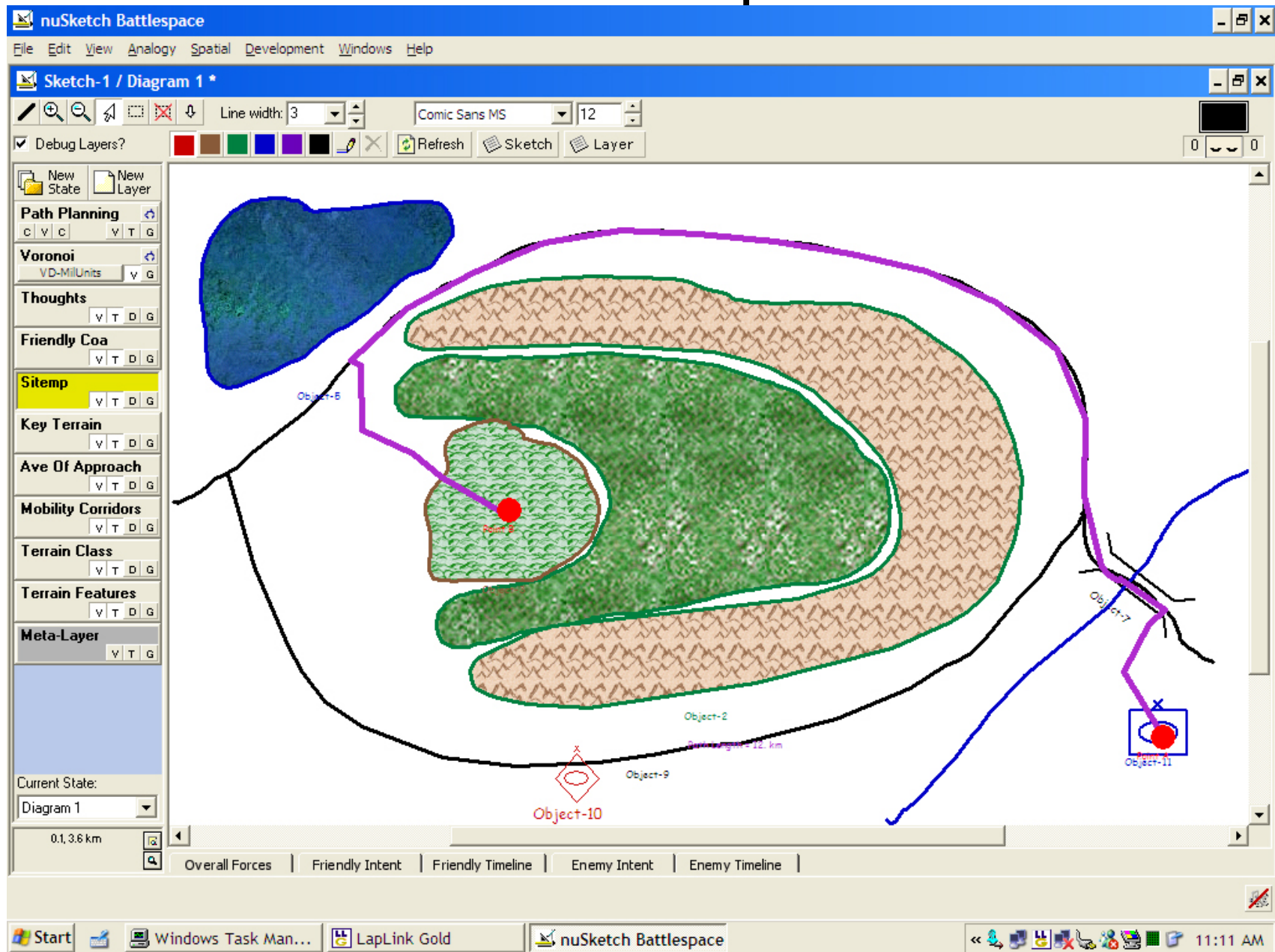
A^*

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

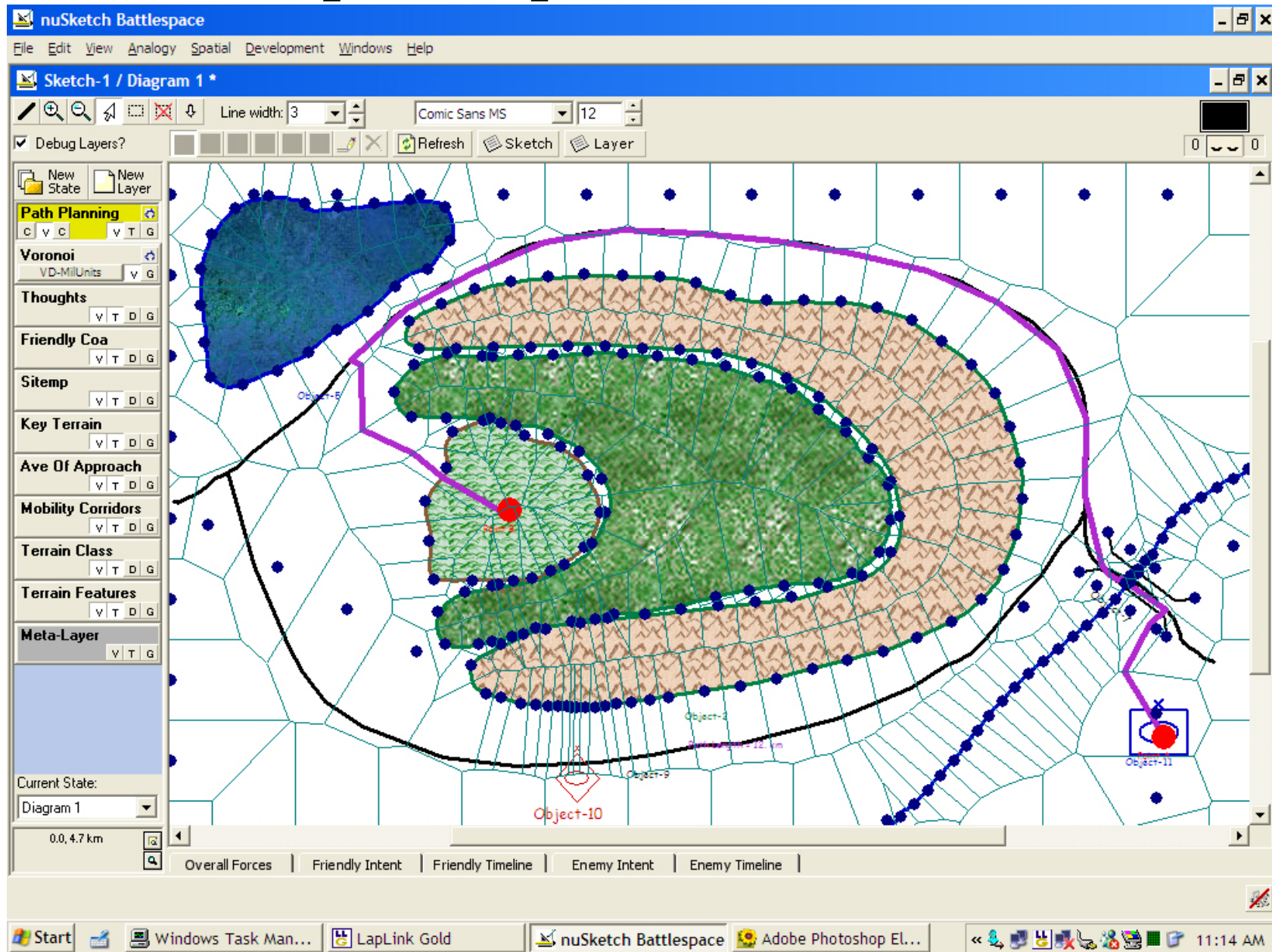
Demo

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

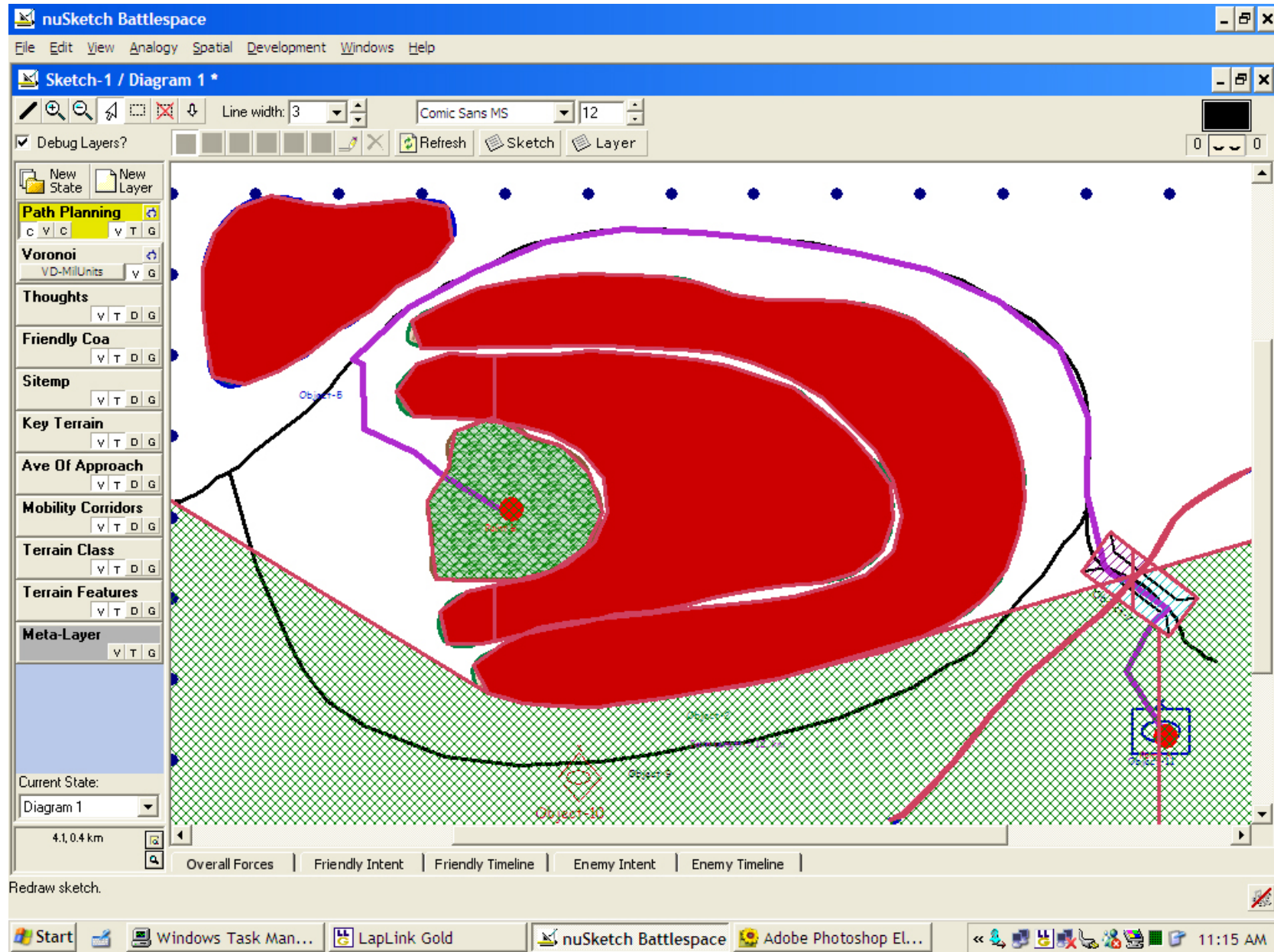
A* can involve multiple constraints



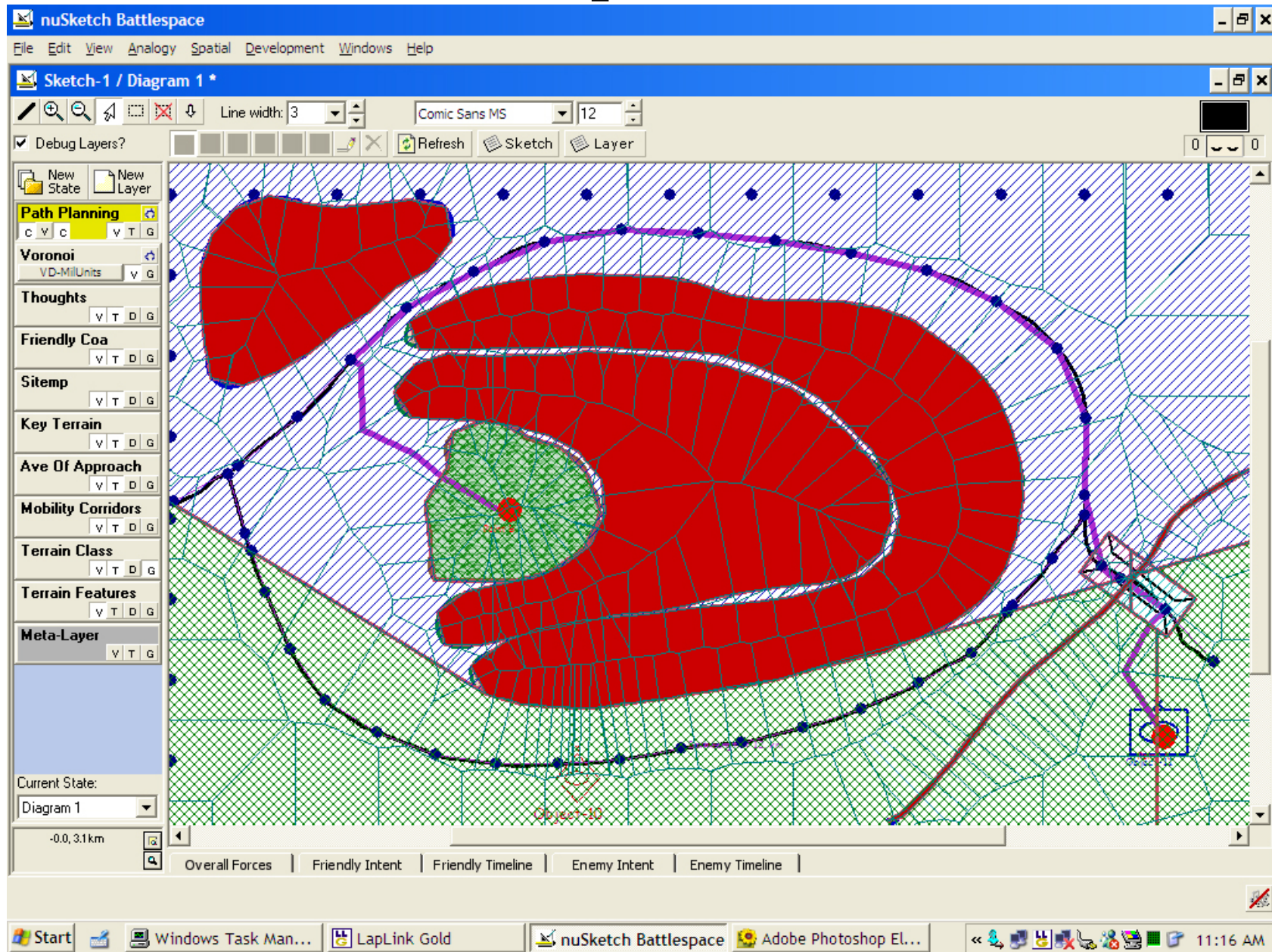
Free space represented as Voronoi



Visibility constraint regions



Intersect to compute constraint cells

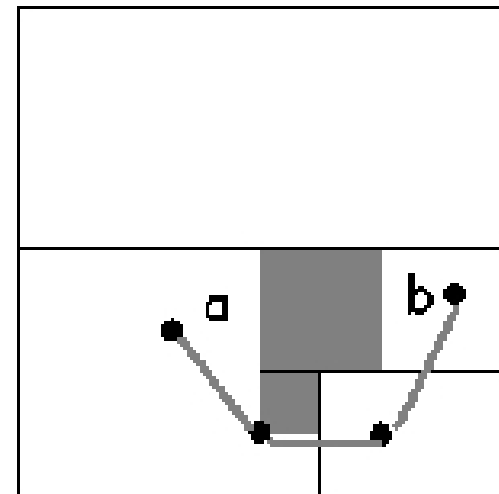
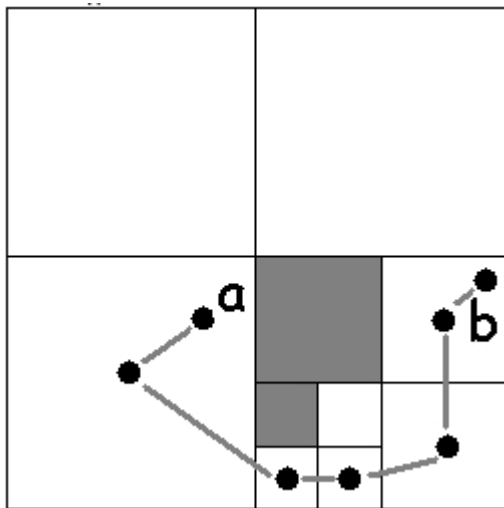


Modification: Iterative deepening

- 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

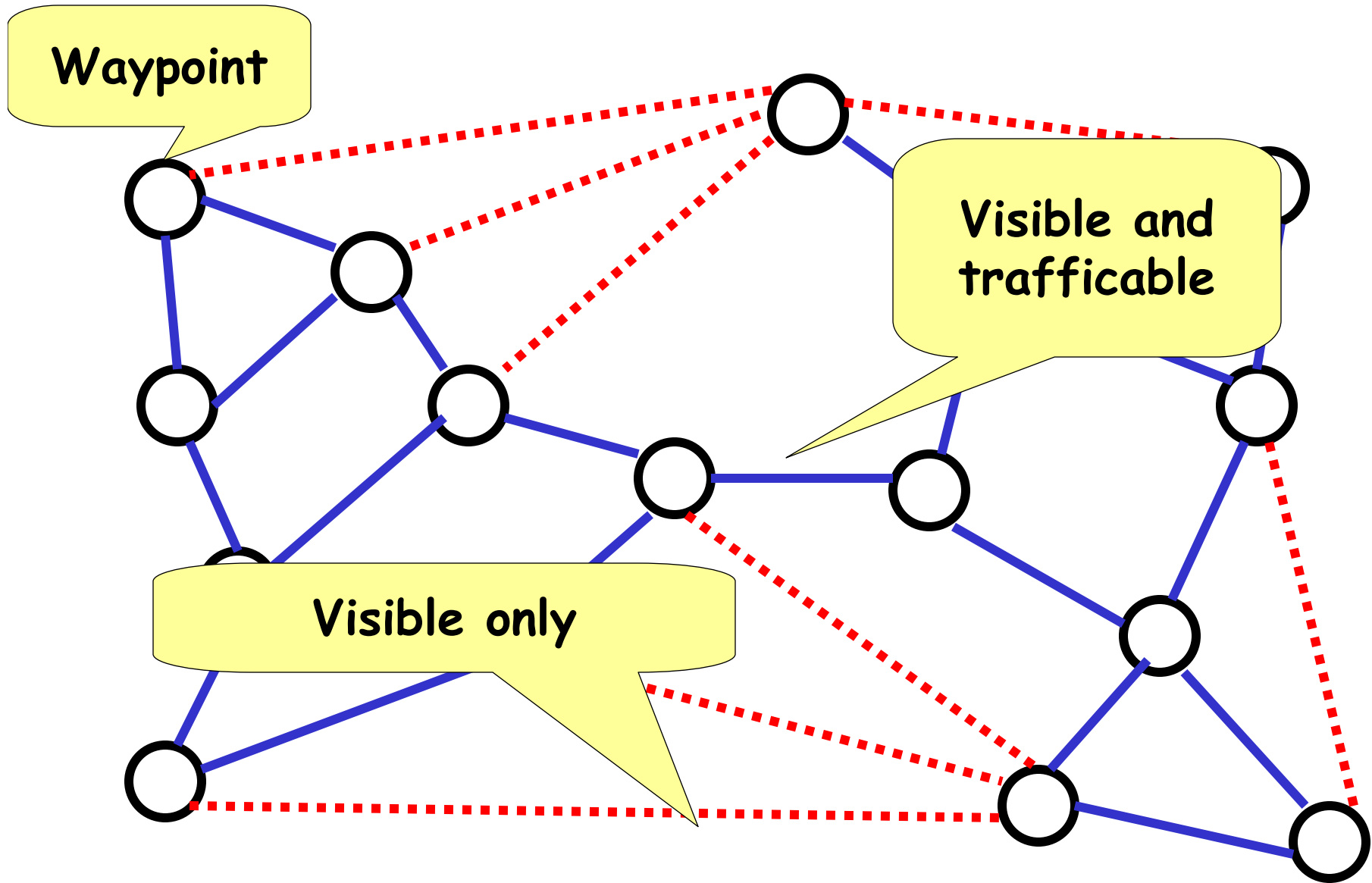
- With large pieces of space, paths generated can be unnatural
- Solution: Use a post-processing step to clean them up



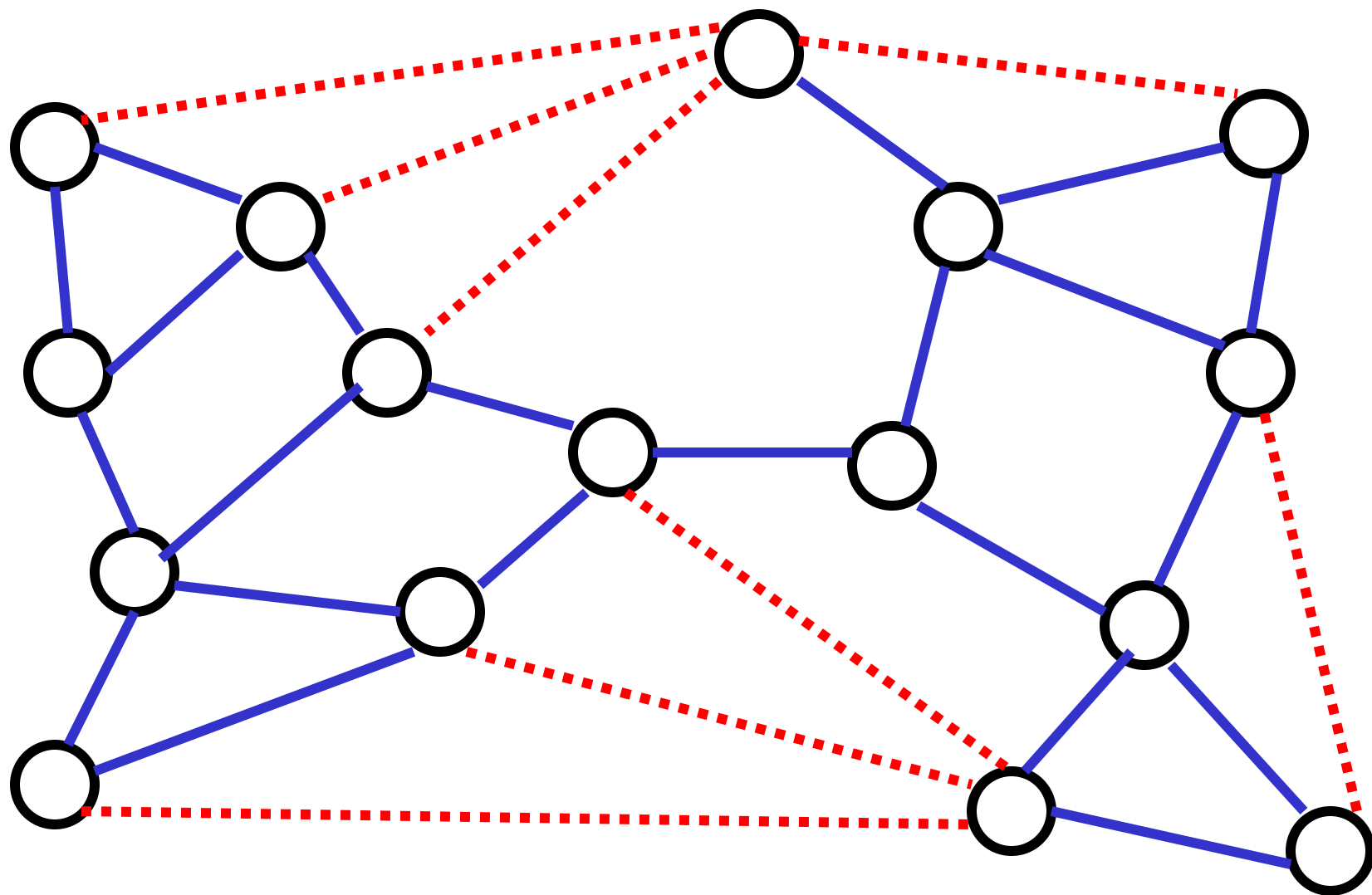
Position-Finding

- 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

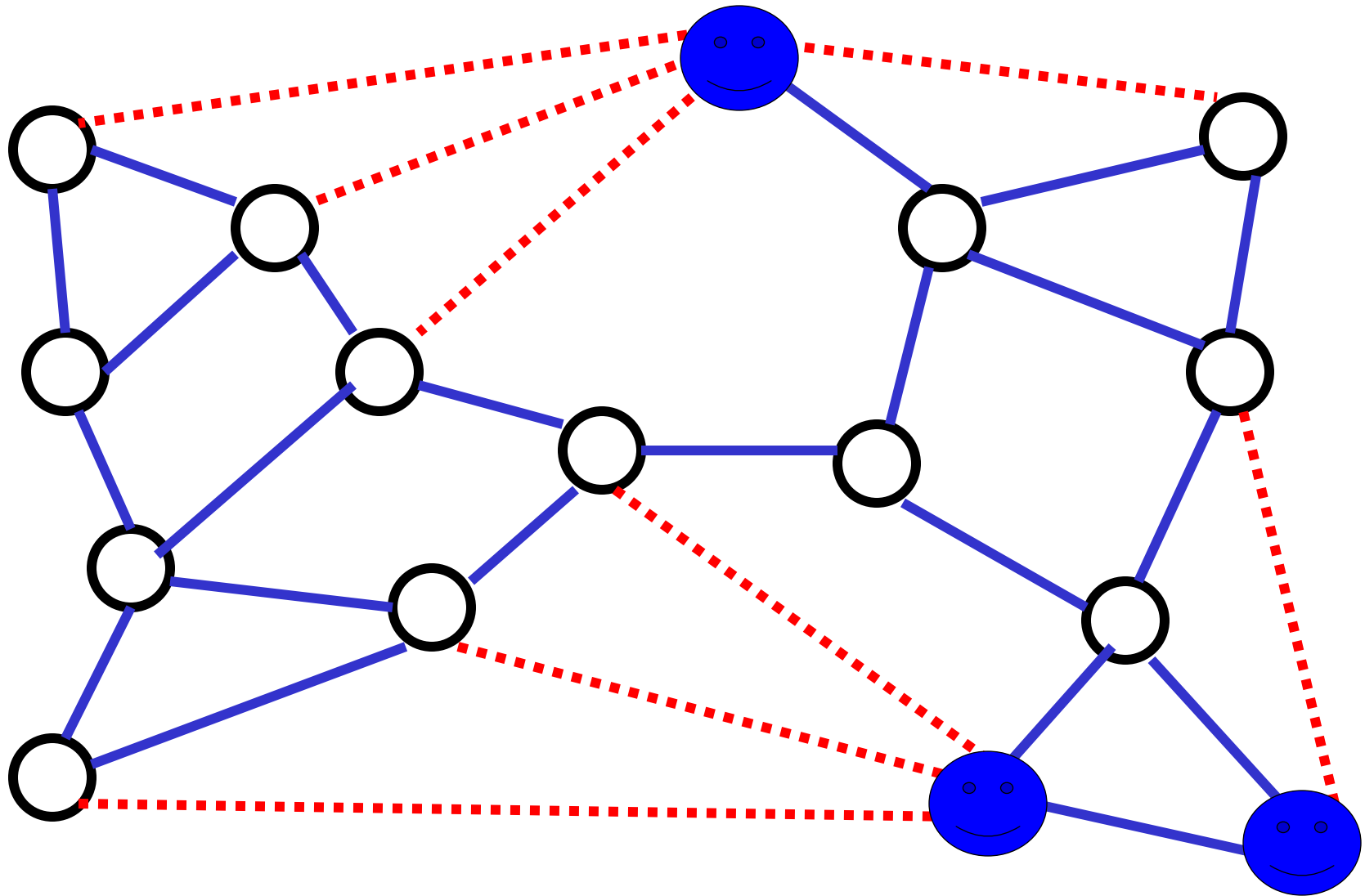
Example: Using waypoints for finding tactical positions



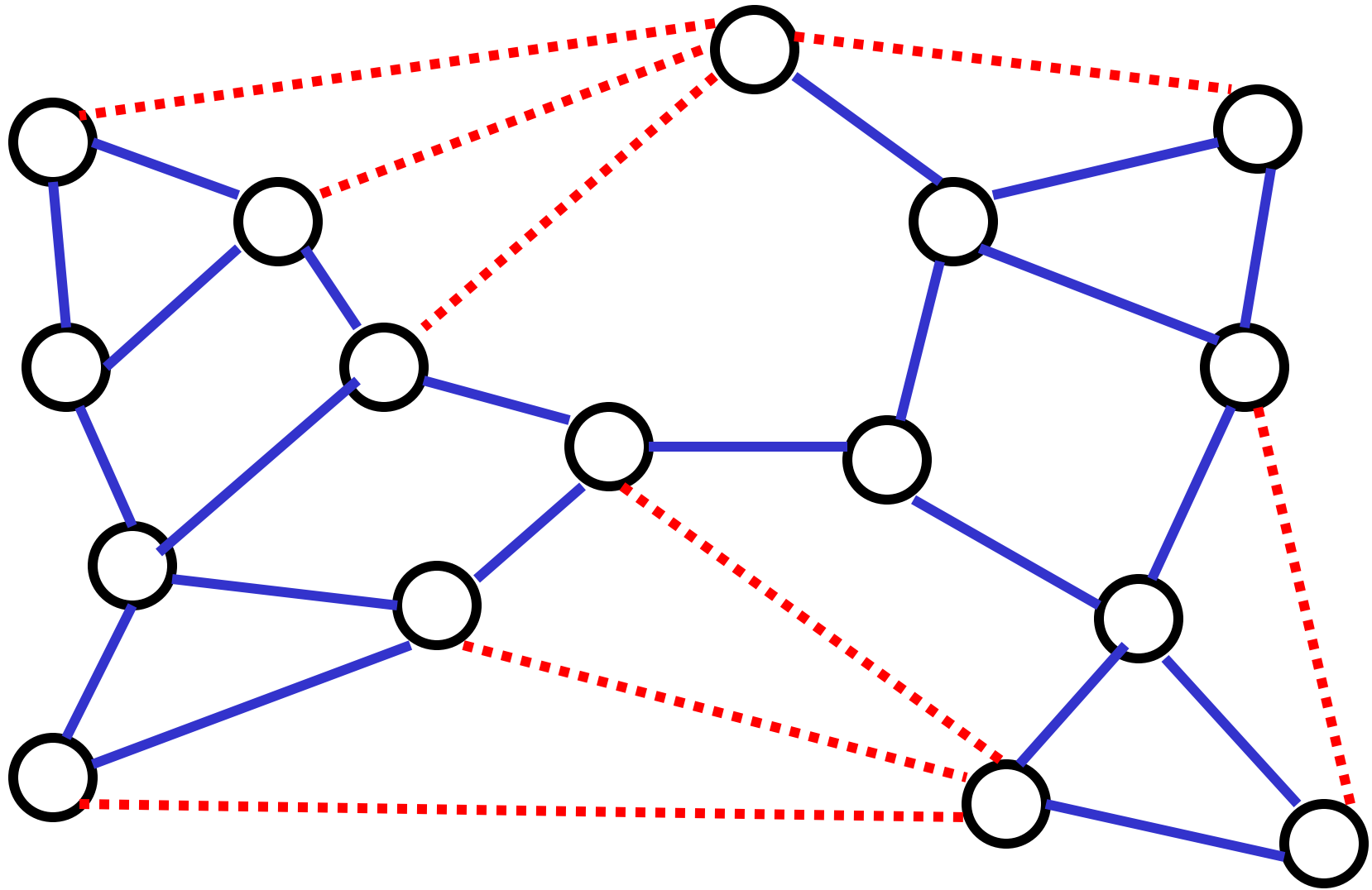
Where would be good sniper posts?



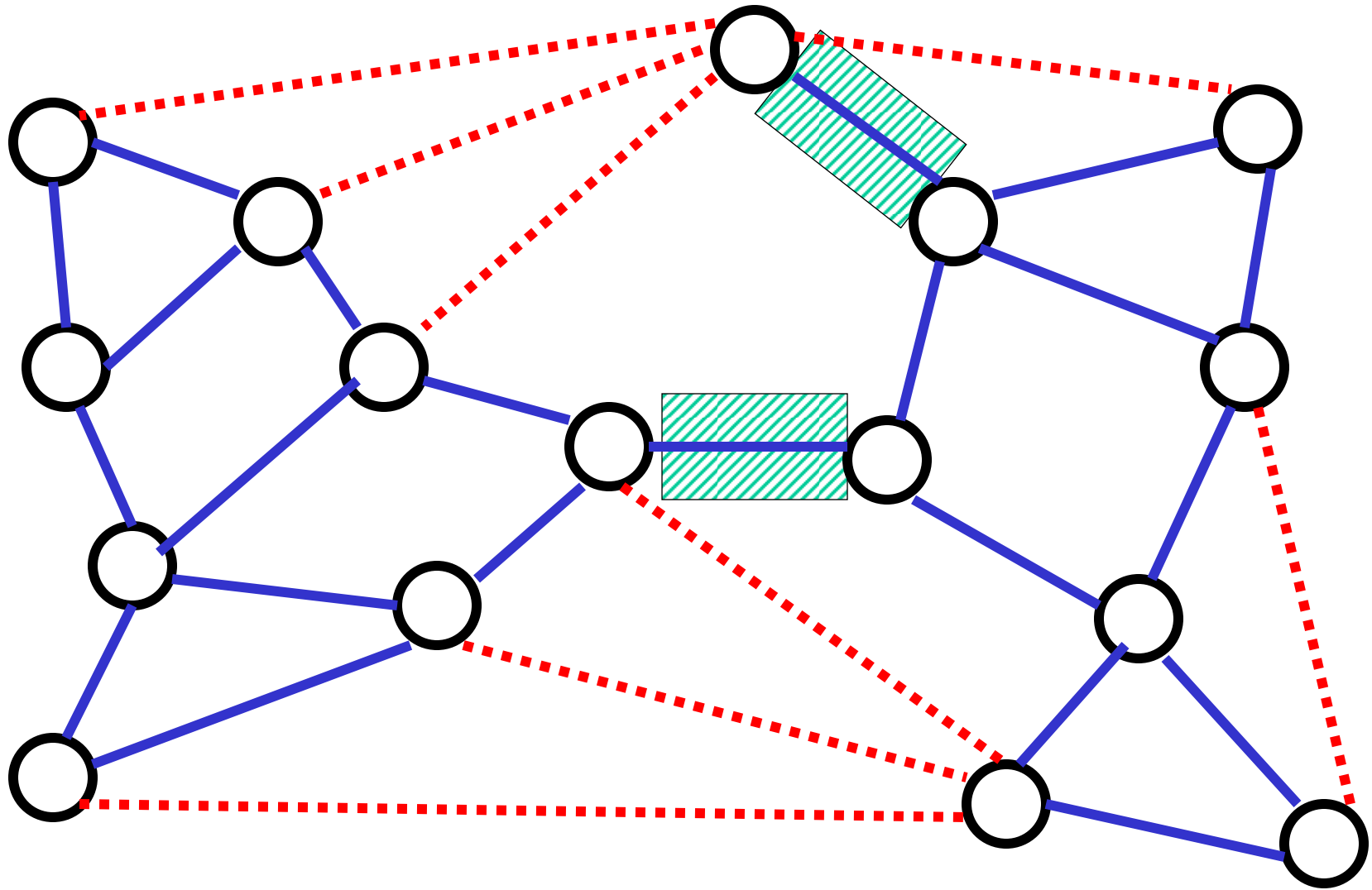
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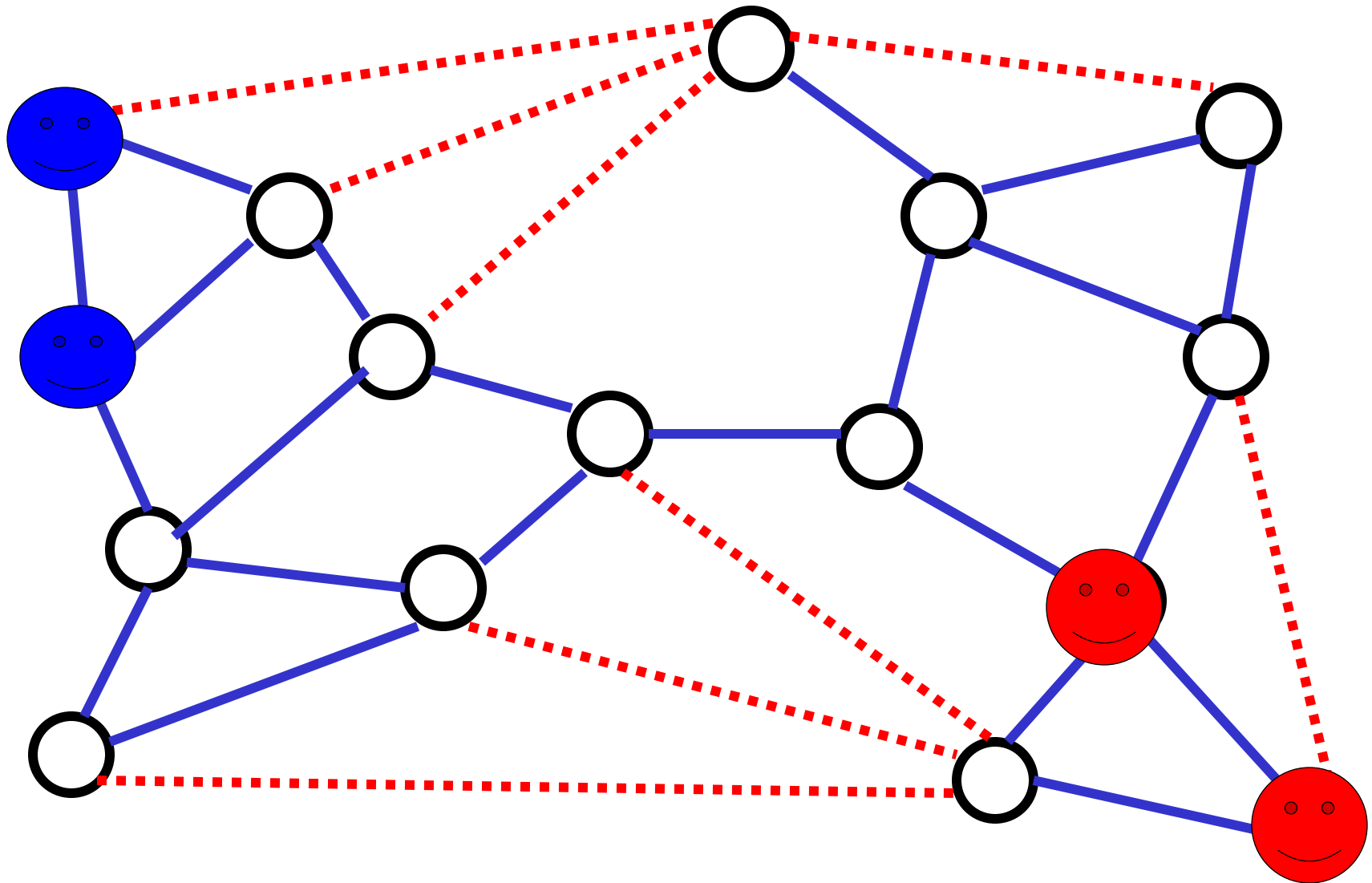
Where are the choke points?



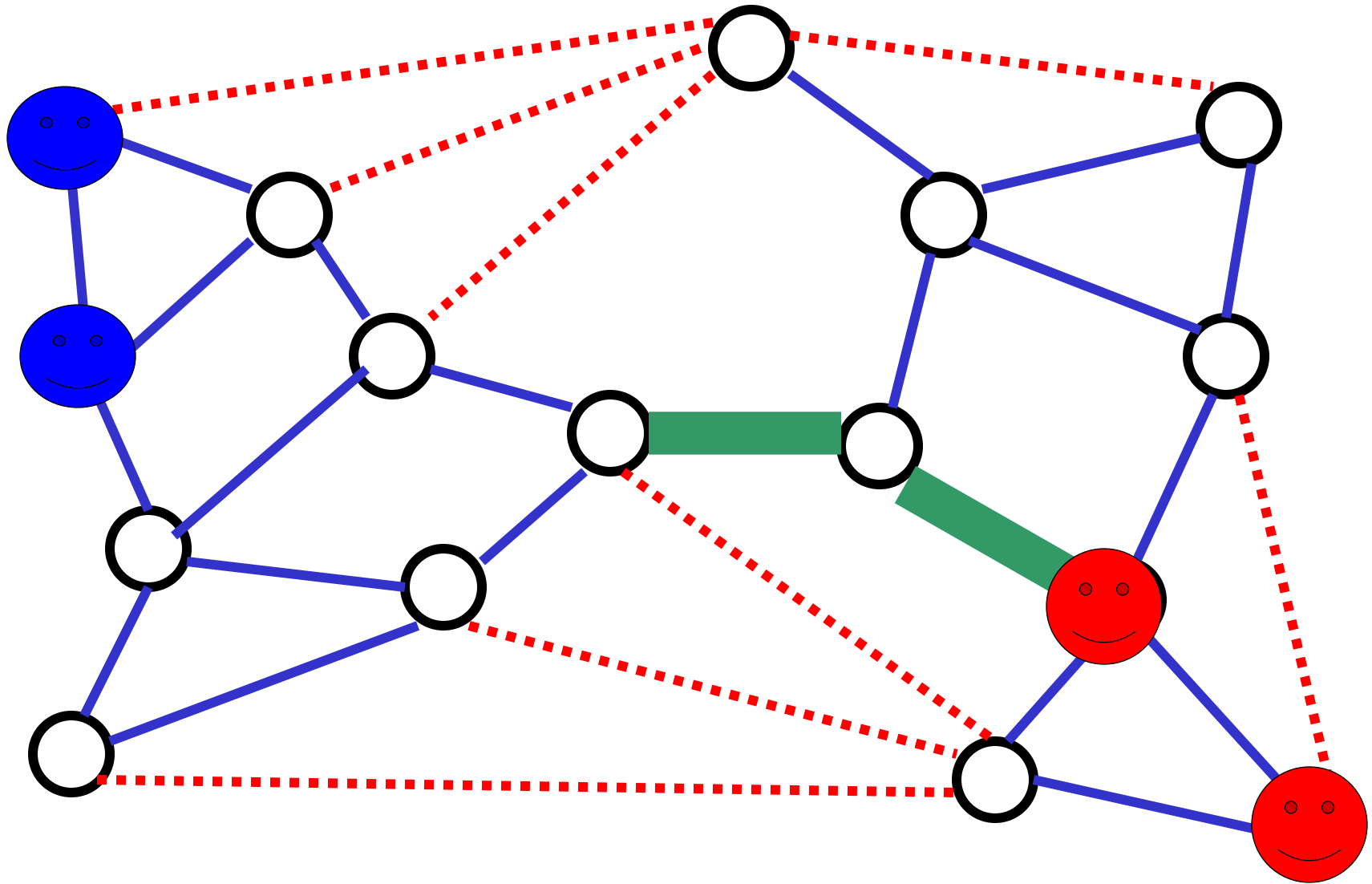
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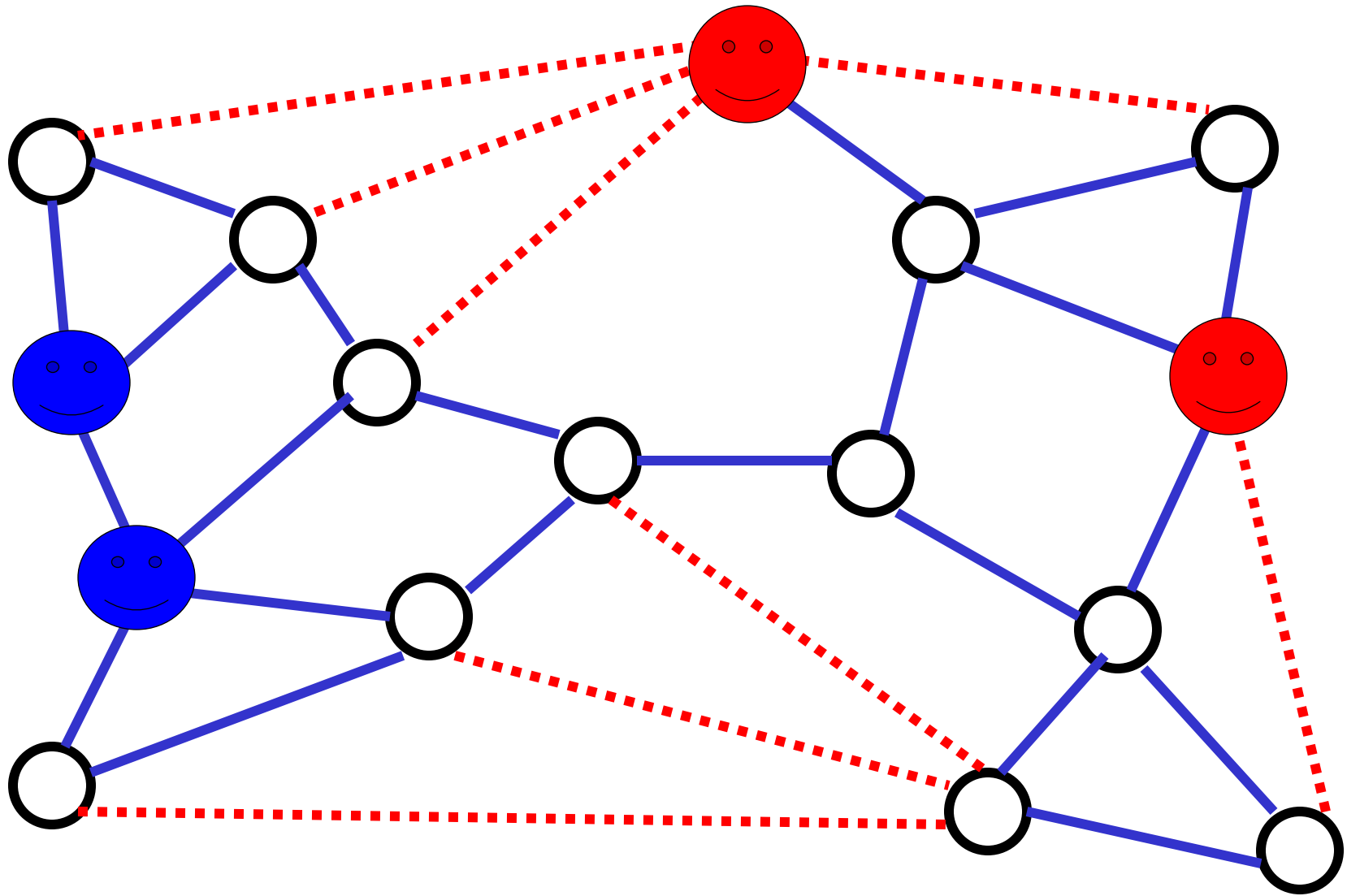
How would you sneak up on them?



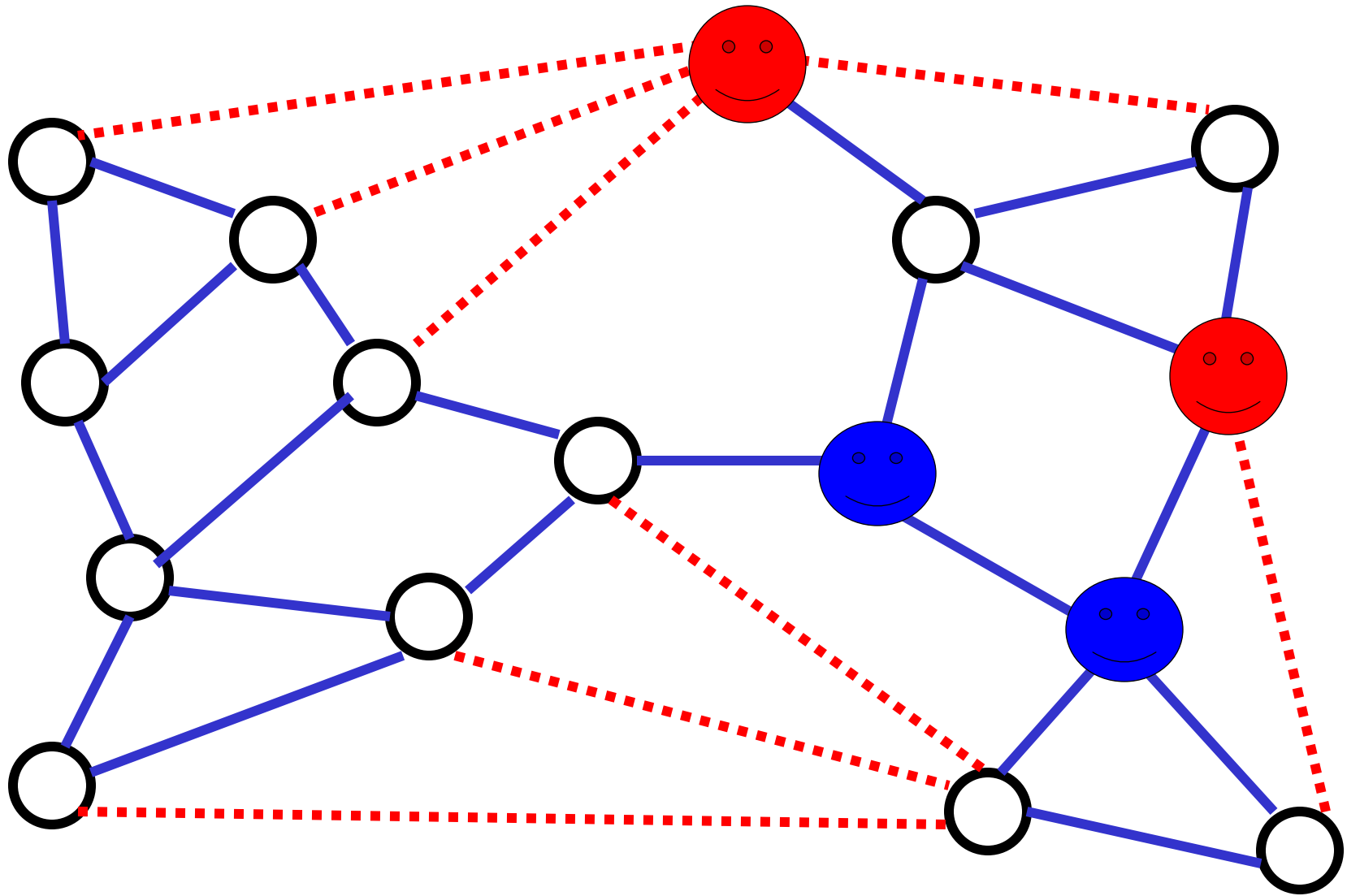
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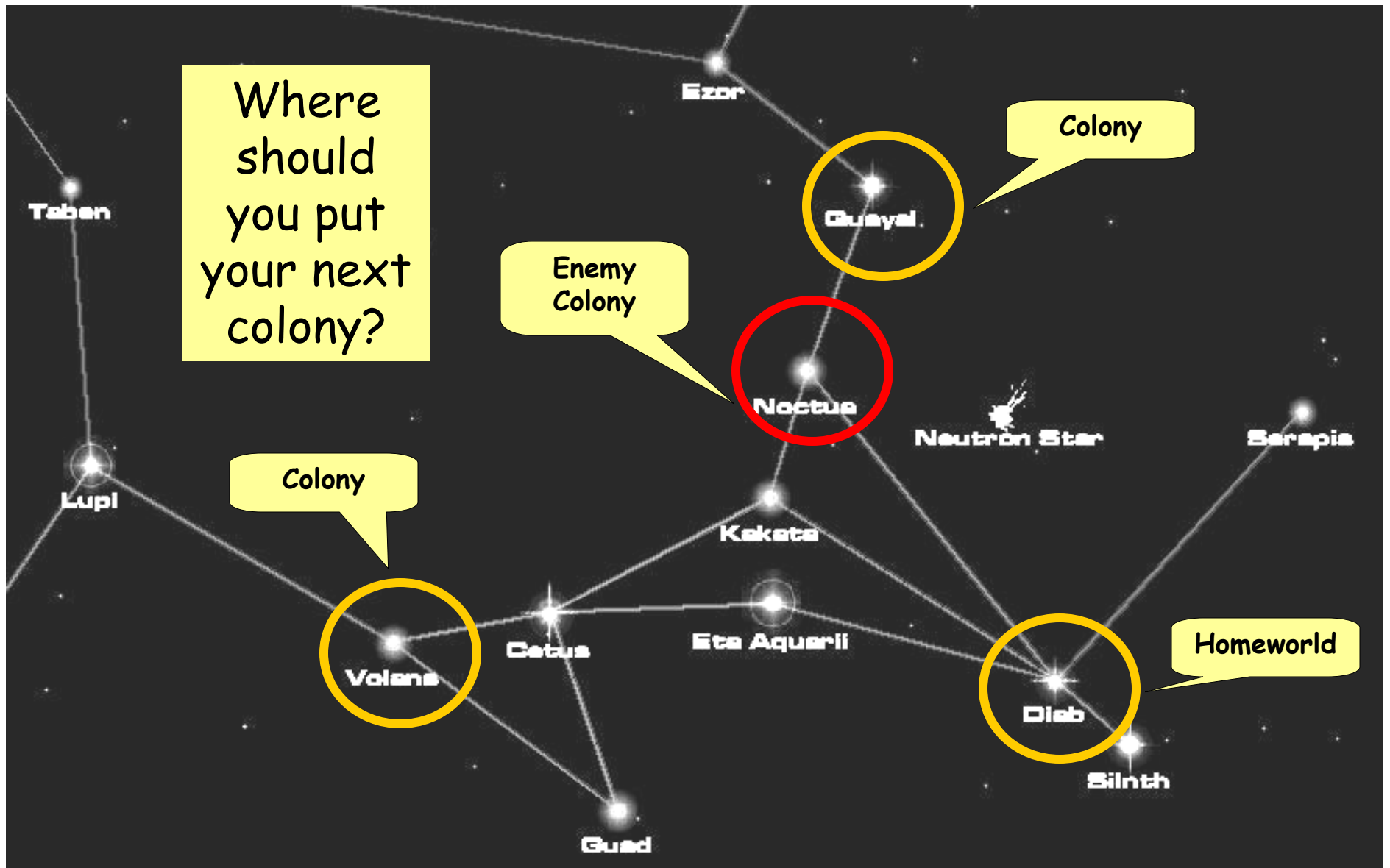
How would you trap them?



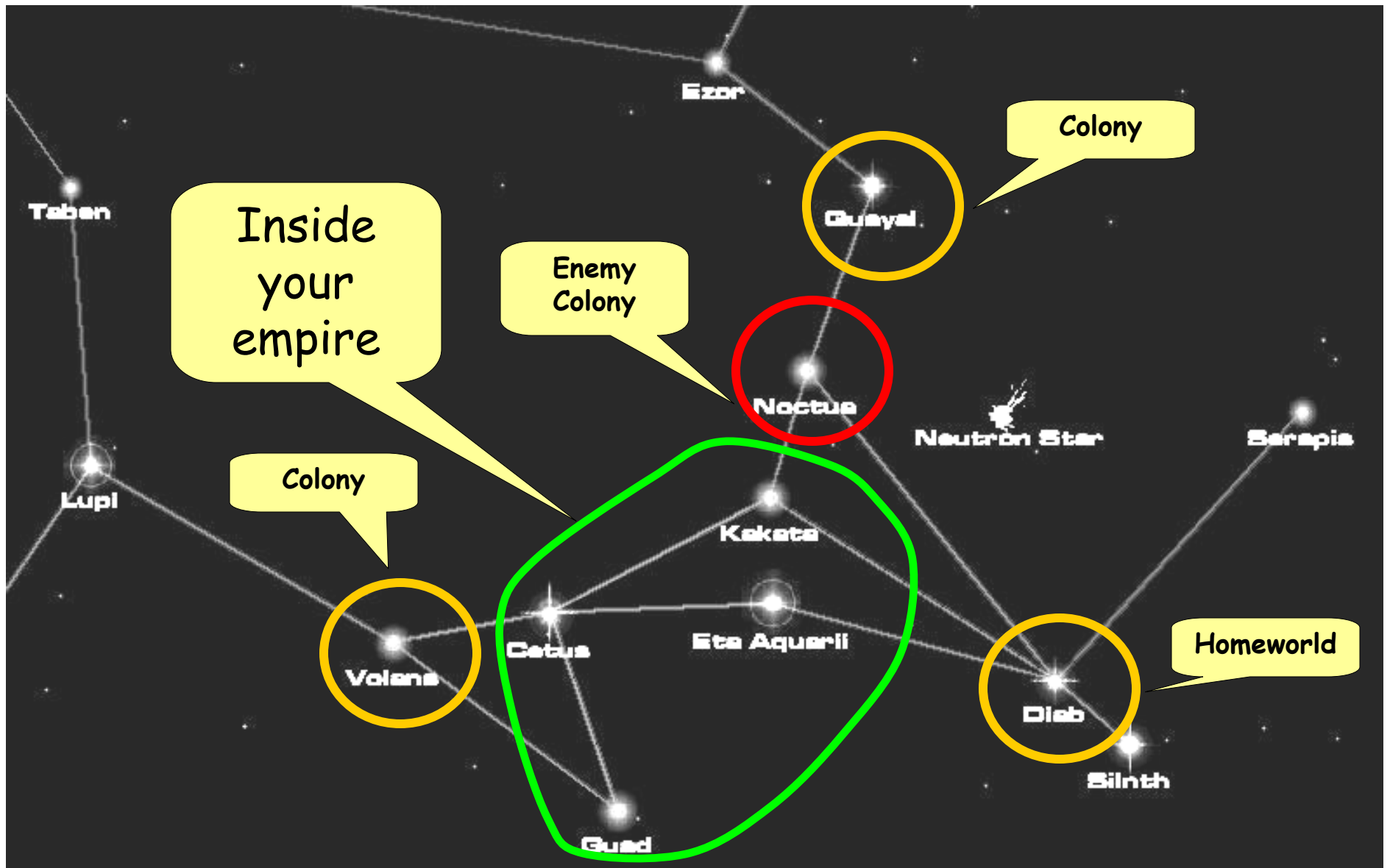
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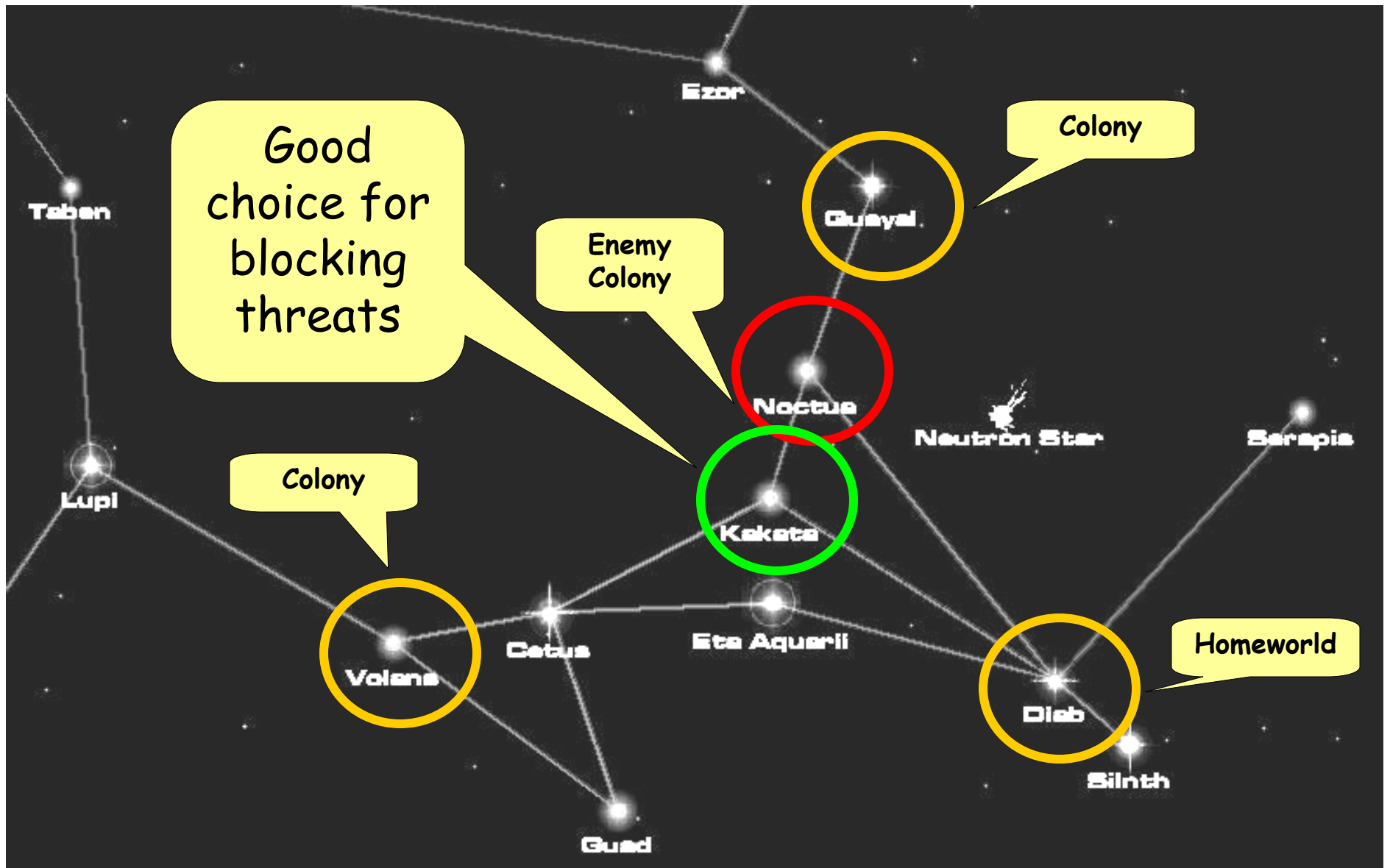
Example from MOO3



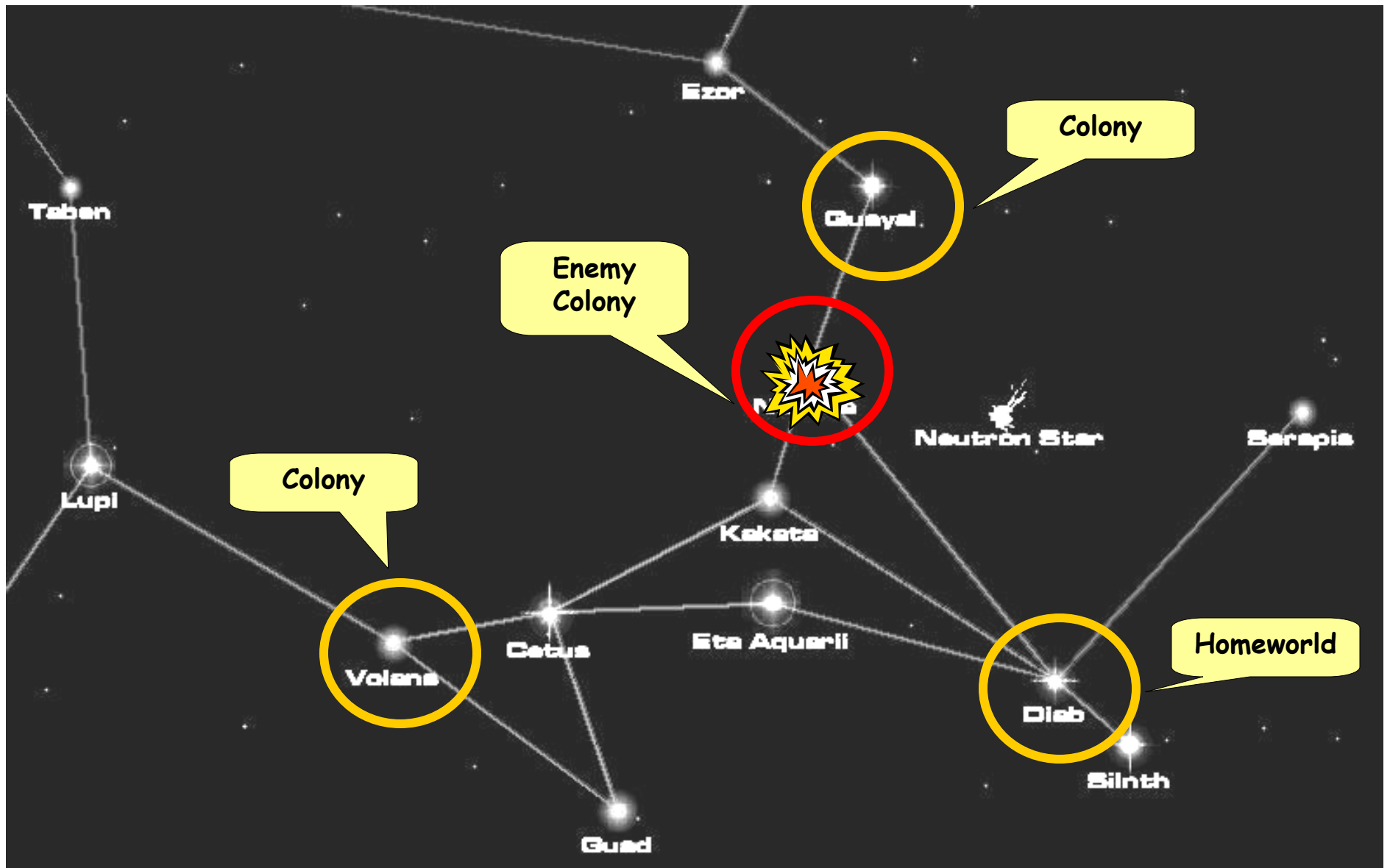
Understanding your terrain is key



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