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Automated Instantaneous Performance Assessment for Marine-Squad Urban-Terrain Training

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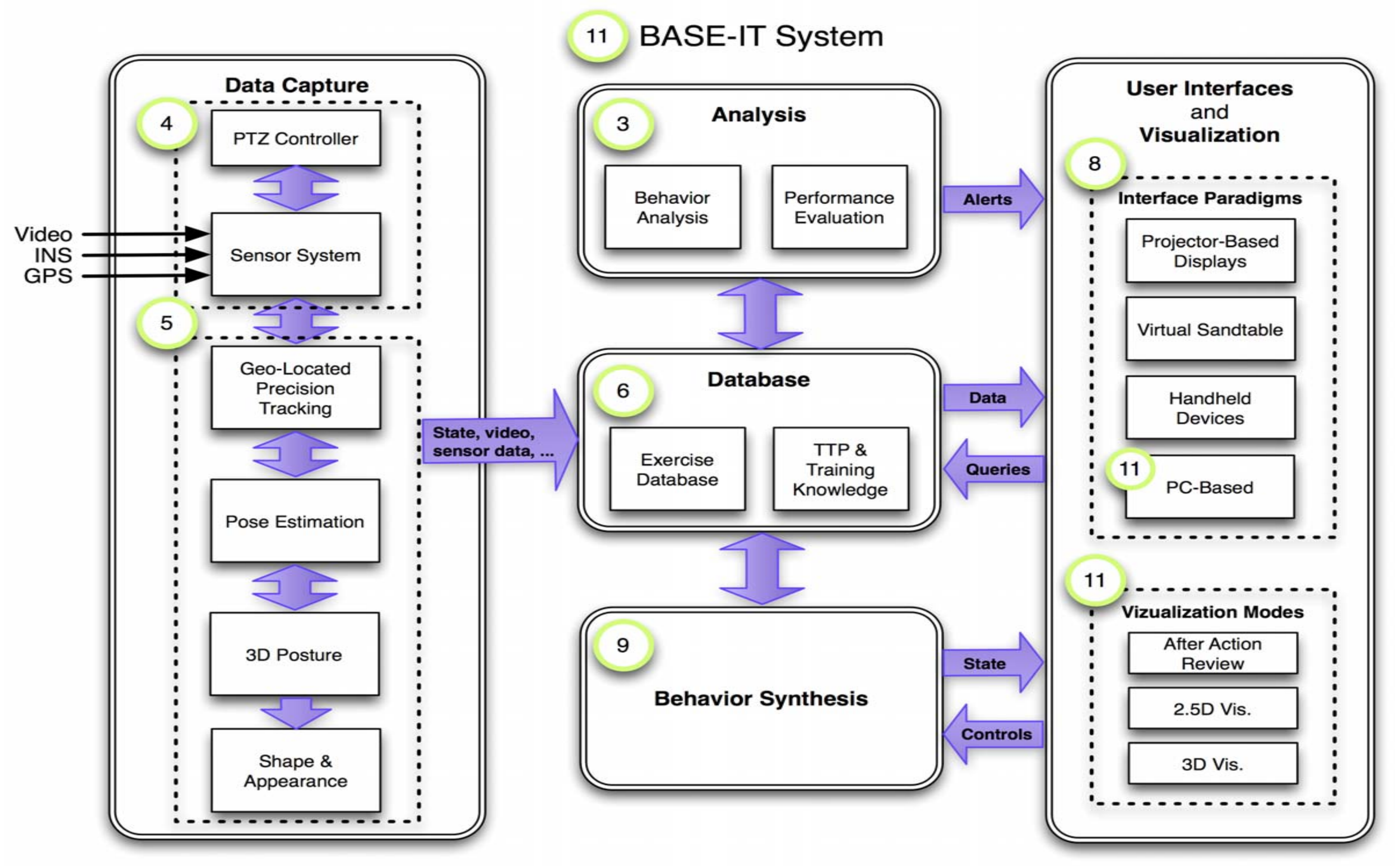
Automated performance evaluation is part of Task 3, Analysis

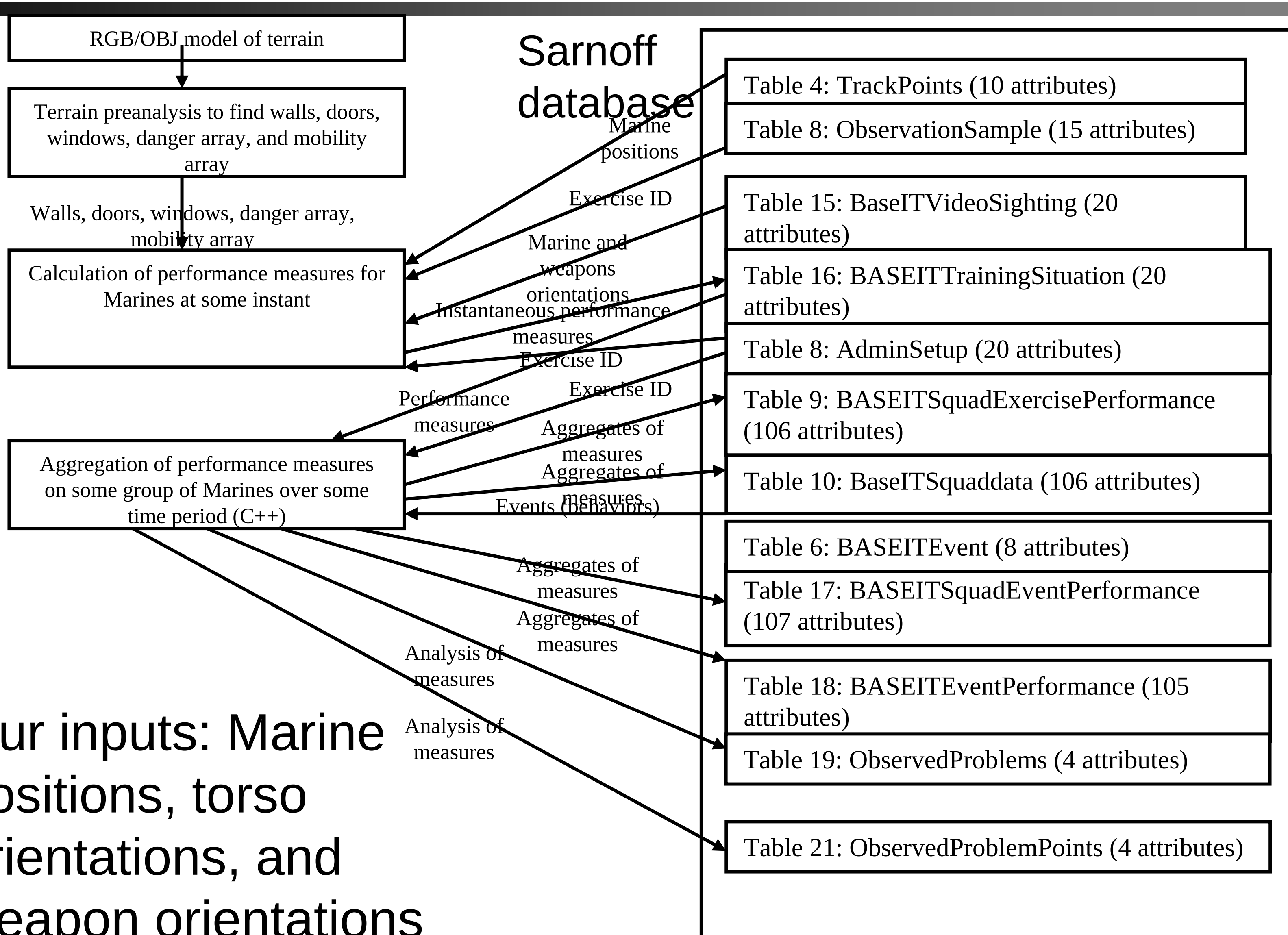


Visual surveillance of Marine training

13 proposed "instantaneous" (time-instant) performance metrics

- Dispersion: Distances between Marines
- Collinearity of Marines
- Number of clusters of Marines (at 3 levels of granularity)
- Number of interactions with role players
- Dangerousness: Visibility to unsearched sniper positions
- Closeness: Too close to windows or doors?
- Situation awareness: Are Marines scanning their surroundings?
- Mobility: Ability to escape threats
- Speed: Too fast or too slow?
- Weapons safety: Are weapons pointed at other Marines?
- Weapons coverage: Are Marines covering threats?
- Surrounding: Is it being conducted properly?
- Leadership: Is leader communicating with subordinates?

Calculating metrics



Our inputs: Marine positions, torso orientations, and weapon orientations

Defining the metrics (1)

- Dispersion: Measure average distance between N Marines, then apply sigmoid function.

$$F2 = (1/N) \sum_{i=1}^{N} [\min_{j=1, j \neq i}^{N} d(x_i, y_i, x_j, y_j)]$$

$$F3 = s(|\log(F2/d_0)|, 0.5), s(x,\mu) = x^2/(x^2+\mu^2)$$

- Collinearity: Use Person correlation coefficient.

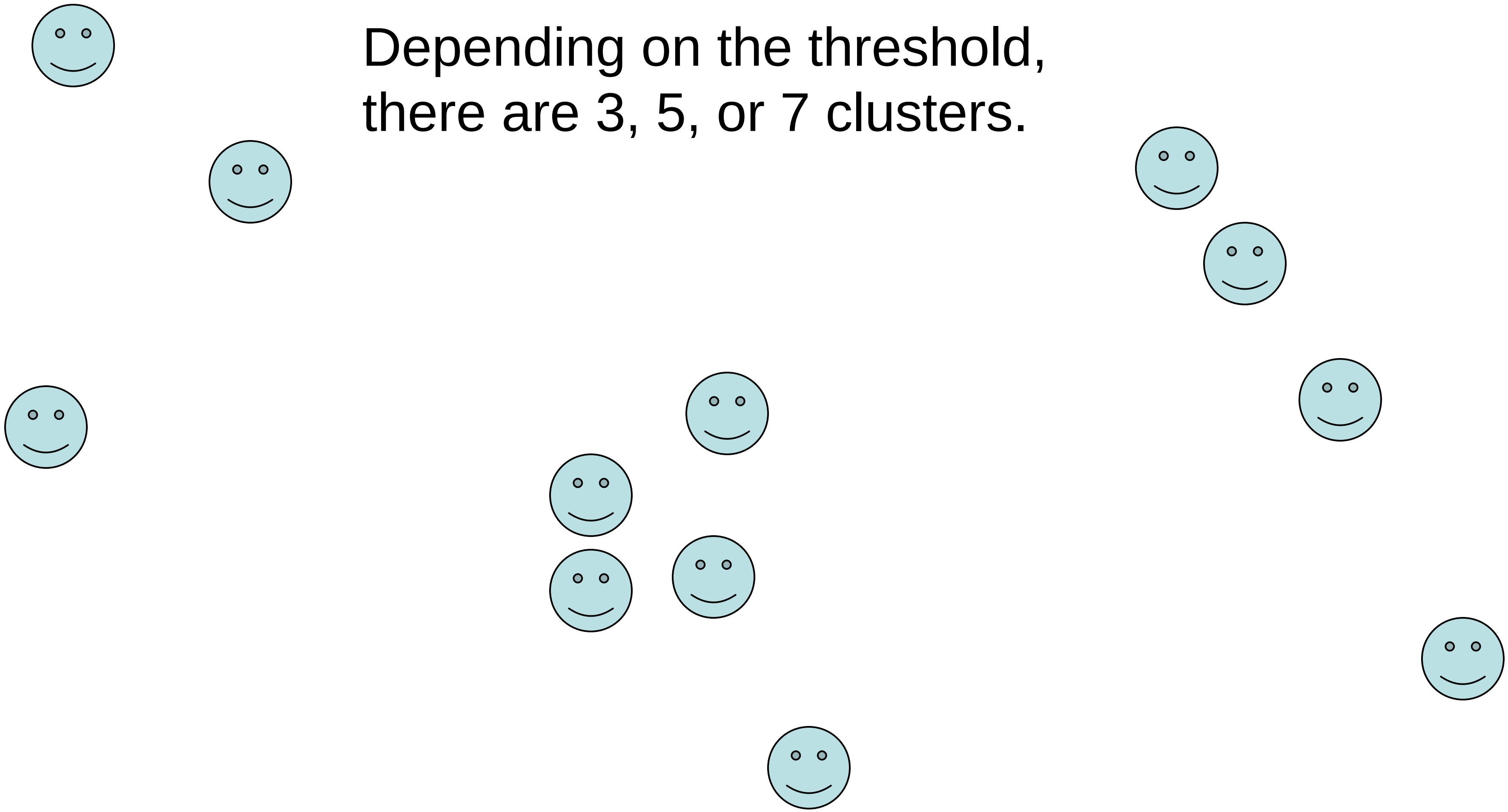
$$L4 = \rho^2, \rho = [\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})] / N \sum_{i=1}^{N}(x_i - \bar{x})^2 \sum_{i=1}^{N}(y_i - \bar{y})^2,$$

$$\bar{x} = \sum_{i=1}^{N} x_i / N, \bar{y} = \sum_{i=1}^{N} y_i / N$$

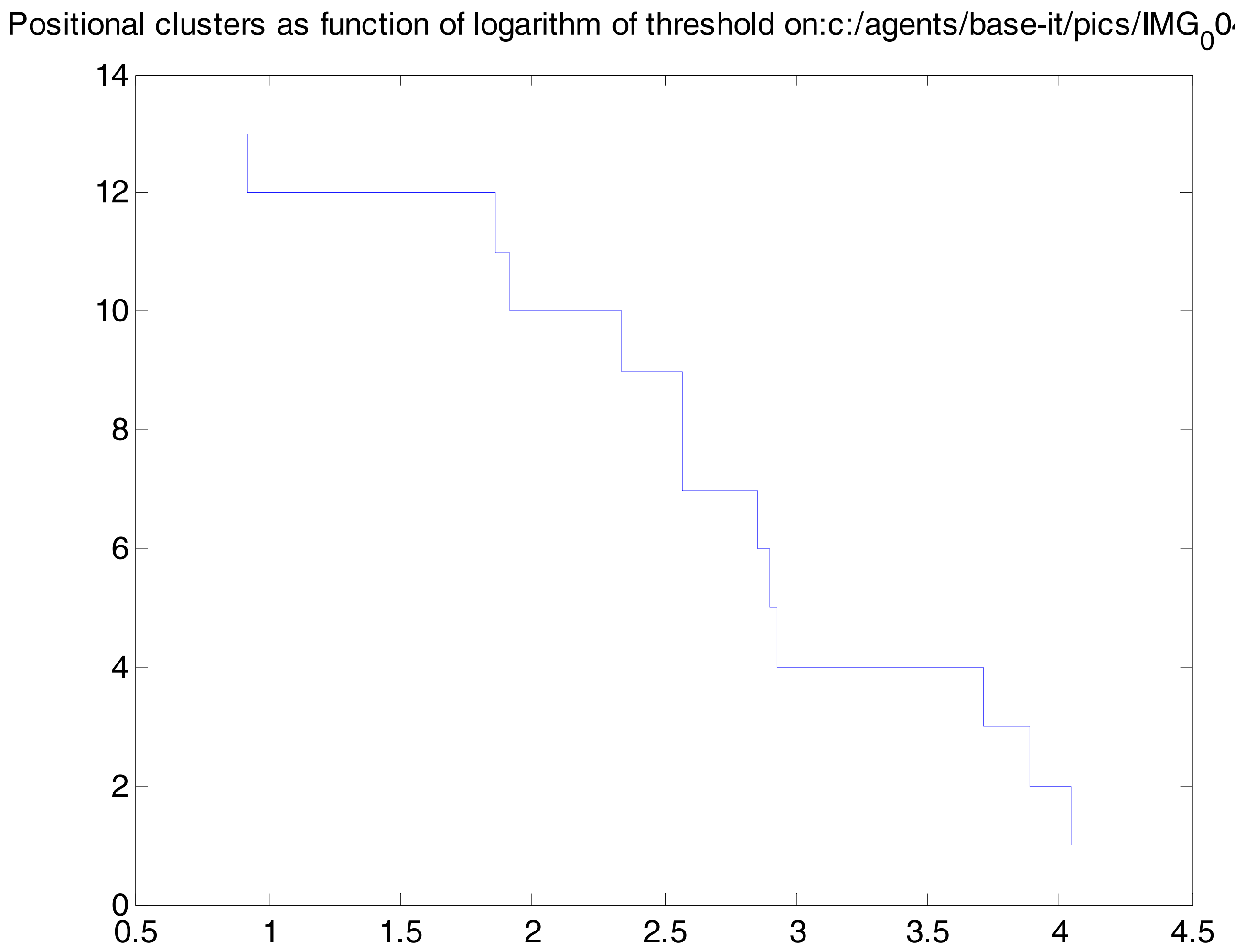
- Number of clusters: Construct minimum spanning tree on Marines with a distance threshold, then count number of clusters (use 3 thresholds for 3 results).
- Role players: Count face-to-face encounters within 10m.

Clustering depends on the scale

Depending on the threshold, there are 3, 5, or 7 clusters.



Number of clusters versus threshold for the first Marine image



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An example image

- Marine dispersion: 0.48 (on 0 to 1 scale)
- Number of clusters: 5
- Number of conversations with role players: 2

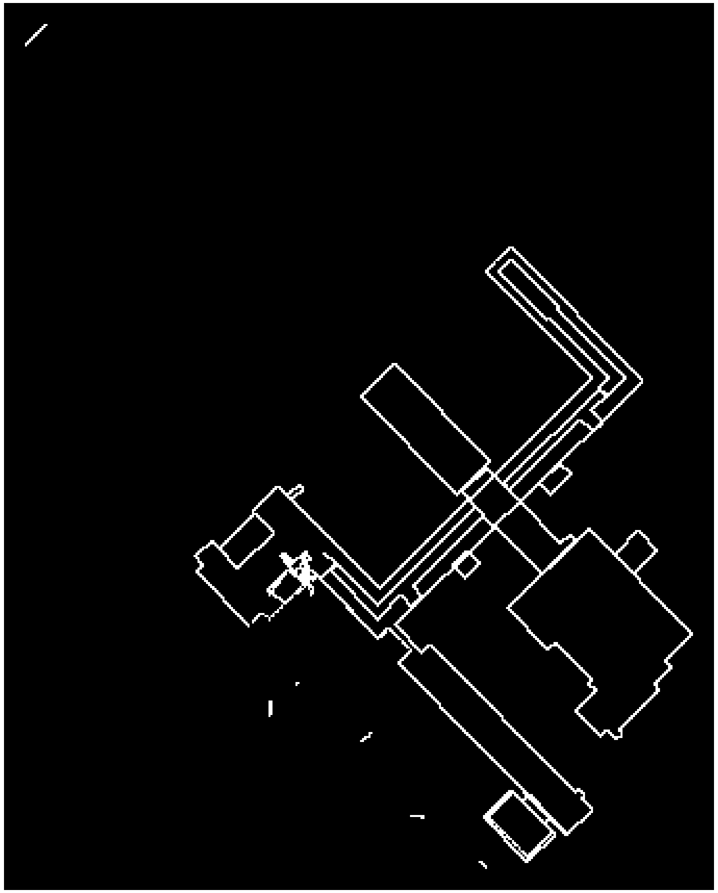
Defining the metrics (2)

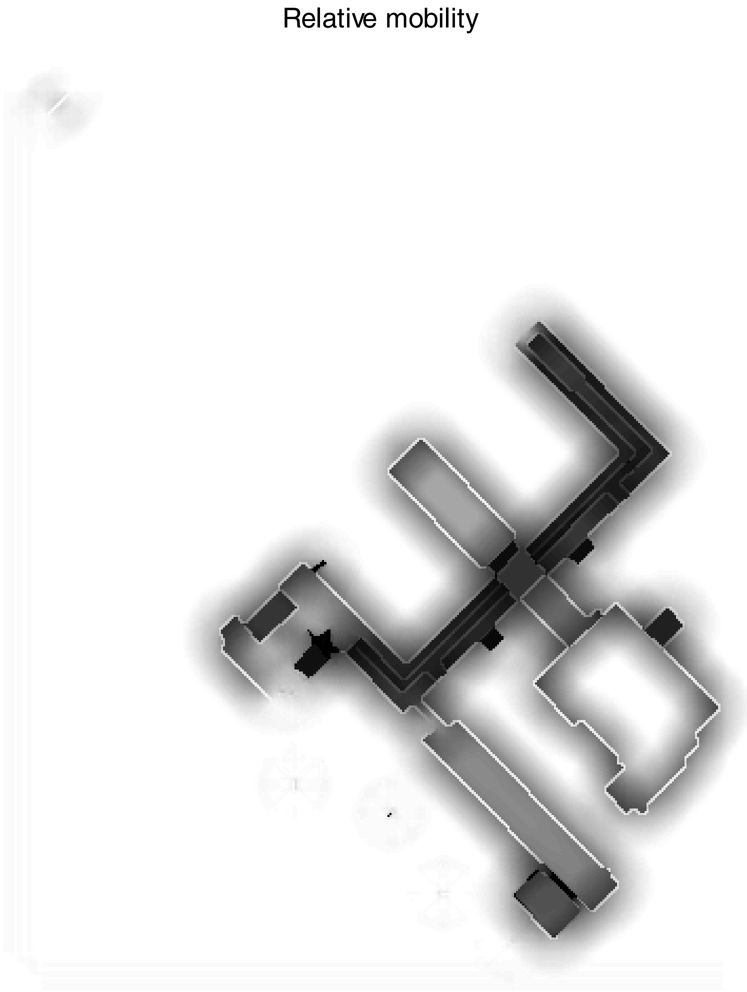
- Mobility: Do fixed-duration wavefront-propagation grid search in the vicinity of each point; calculate ratio of cells reached in that time to number on an unobstructed grid (approximating a circle).
- Speed: Calculate motion of the center of gravity of the Marines between time steps, apply a sigmoid function.
- Weapons safety ("flagging"): Calculate degree to which Marines are pointing weapons at one another:

$$WS1 = \sum_{i=1}^{N} \max_{i2=1, i \neq i2}^{N} [\cos^3(\omega_i \text{-} b(x_i, y_i, x_{i2}, y_{i2}))]$$

- Here ω_i is direction of weapon in 2D, and b is bearing to a location. The cosine cube seems to work well here in modeling the difficulty of aiming.

Example terrain and mobility grid





Defining the metrics (3)

- Too close or too far from windows or doors: Measure distance and angle to nearest one.
- Surrounding: If the task is to surround a building, calculate the degree to which the Marines are successful by computing maximum gap between Marines on contour around building.
- Leadership: Calculate the degree to which the leader of the team deviates from the centroid of the team, and apply a sigmoid:

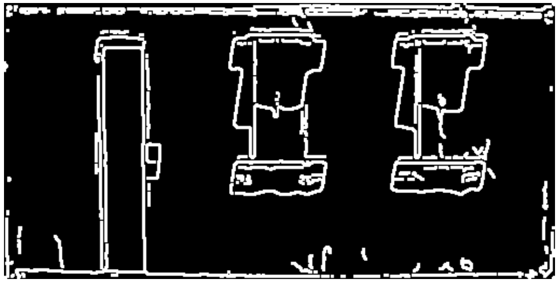
$$LD1 = (1/N-1)\sum_{i=1, i\neq L}^{N} v(x_i, y_i, x_L, y_L)/[1+0.0025*d(x_i, y_i, x_L, y_L)^2]$$

- Here L is the leader, v is visibility, and d is distance.

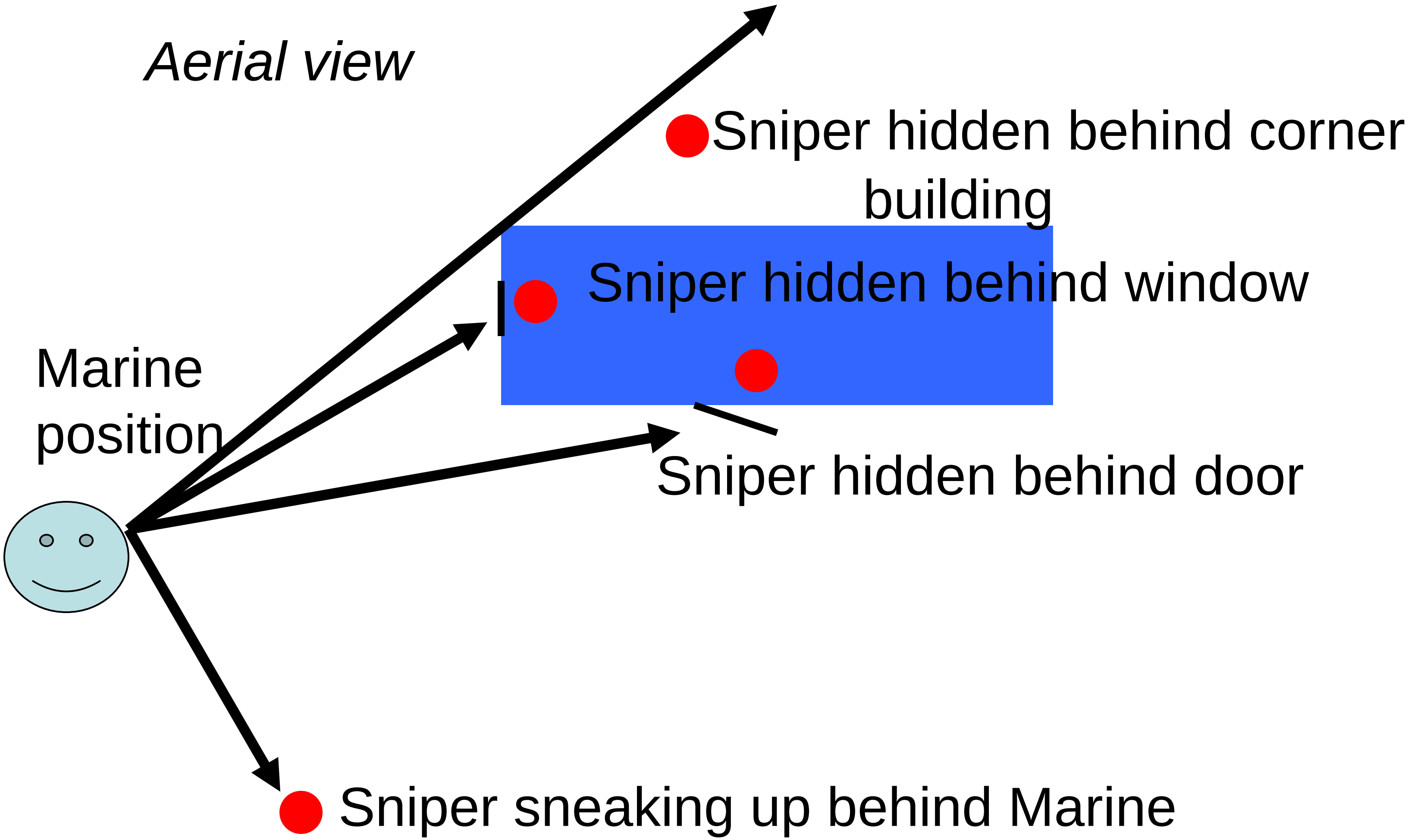
Defining the metrics (4): the hard ones

- Preanalyze terrain at evenly spaced points for dangers: visible (1) windows, (2) doors, (3) building corners, and (4) centers of large areas.
- Calculate danger as intrinsic danger divided by 25 meters plus the distance. Ignore weak dangers to create a sparse matrix.
- Get wall endpoints from graphics model of terrain.
- Find doors and windows in images of the graphics model. Correlate them with walls.
- Sweep terrain with rays at each sample location to find occluding corners.

Extracting windows and doors

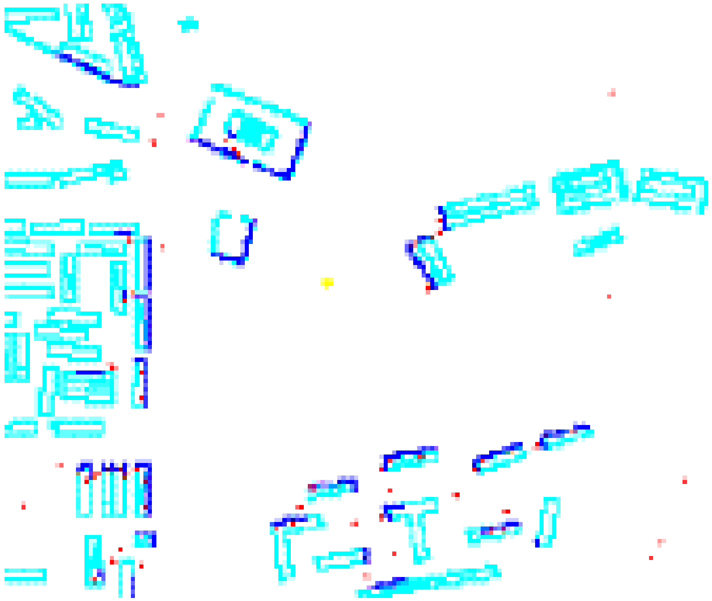


Four kinds of threats



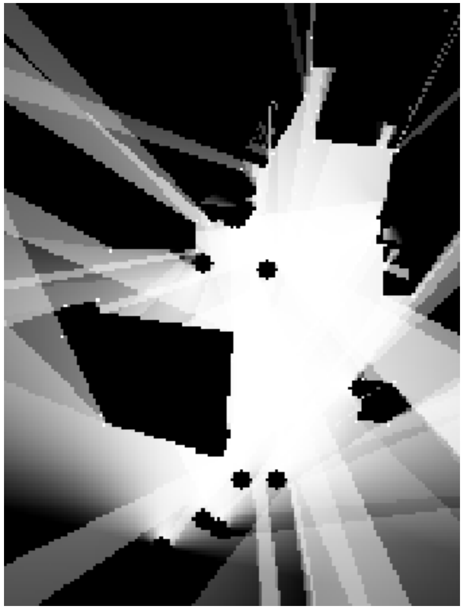
Example visibility analysis

- Yellow is Marine position.
- Light blue are walls at Camp Pendleton.
- Dark blue are visible portions of walls.
- Red are first three kinds of danger points (windows, walls, and corners).
- In this version, corner threats are located at centers of occluded areas – now we just use the corners to save time.

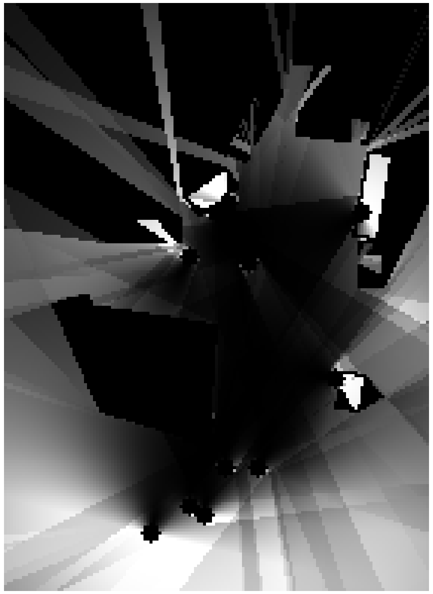


Visibility analysis

We computed danger for the picture shown earlier. Diagrams show view from above, and dangerousness of terrain and “obliviousness” of Marines.



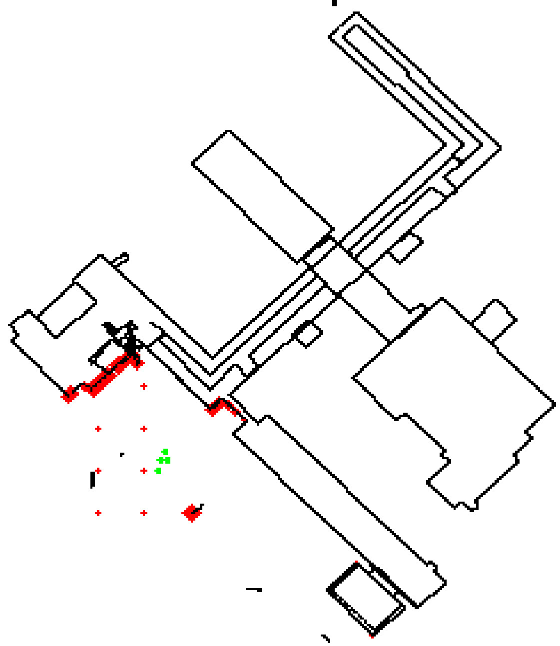
Visibility by adversary times Marine obliviousness



Threat analysis on position data

- This shows four people (green dots) marching southeast.
- Red indicates dangers; size represents degree of danger.
- Note people were facing southeast so danger in that direction is reduced.

nondispersion: 0.694 linearity: 0.560 clusters 4 danger 0.481 obliviousness 0.151 mobility 1.000 speed 0.537 flagging 0.360 weapons coverage 0.353 too-close 0.000 too-far 0.875 surrounding 0.000 nonleadership 0.161



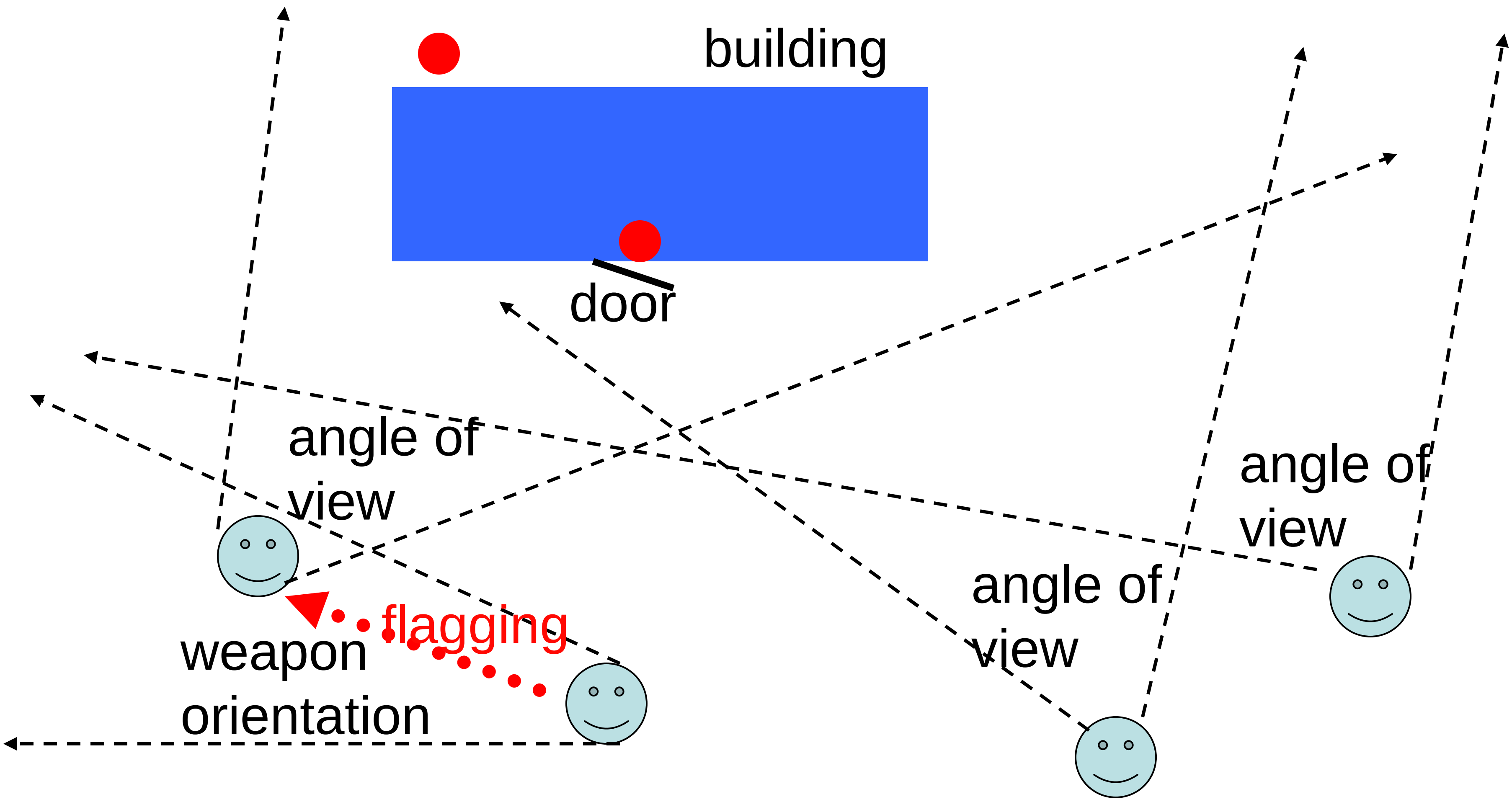
Computing dangerousness

- Danger to a Marine i from threat j is h(j)v(i,j)/(25meters+distance(i,j) where h(j) is intrinsic dangerousness of the threat and v(i,j) is 1 if j is visible by i, else 0.
- We assume h(j) = 1 for windows, doors, and occluding corners, and h(j) = area/9-square-meters for centers of unoccupied areas).
- Then average danger for a set of Marines over all threats is: $$E = (1/N)\sum_{i=1}^{N} s[\sum_{j=1}^{M} (h(j)v(i,j)/(25+d(i,j))),1]$$
- Here s is a sigmoid function to make range 0-1.
- This can be averaged over a path to rate paths.

Blurring danger to model finding cover

- Of two locations equally exposed to threats as defined above, one may be much preferred by Marines if it provides better cover.
- To implement this effect, we “blur” the danger array.
- Mathematically: Set danger to weighted average of current danger and minimum of danger of its neighbors.
- A good weighting is 0.5 if the distance between neighbors can be traversed in 2 seconds (time for a sniper to aim), 0.75 on current danger for 4 seconds, etc.

Situation awareness and flagging



Defining Marine “obliviousness”

- Define o(j,t) be the obliviousness (opposite of situation awareness) of the group of N Marines to threat j at time t:

$$o(j,t) = \prod_{i=1}^{N} [0.95 - 0.5 * unitstep(\cos^3(\phi_{i,t} - b(i,j,t)))]$$

- Here “unitstep” is the function that is 1 for positive numbers, else 0; φ_i is the direction the Marine is facing; 0.95 means 5% chance of being aware of something behind you; and b(i,t) is the bearing angle from the Marine i to threat t.
- Here the cosine cube models operation of fovea.
- If we substitute weapon angle, we get weapons coverage.

Persistence of safety over time

- Once Marines see a potential threat and decide it is safe, that safety slowly decays when Marines aren’t looking at it.
- A few threats will be confirmed and won’t decay, but that is rare.
- Just one Marine seeing something for an instant helps only some – the longer they see it, and the more Marines, the better.
- Use:

$$O(j,t+1) = 0.9 * O(j,t) + 0.1 * o(j,t+1)$$

Computing situation unawareness

- Calculation of situation unawareness can combine the formulas for dangerousness and obliviousness (i.e., take a weighting on dangerousness):

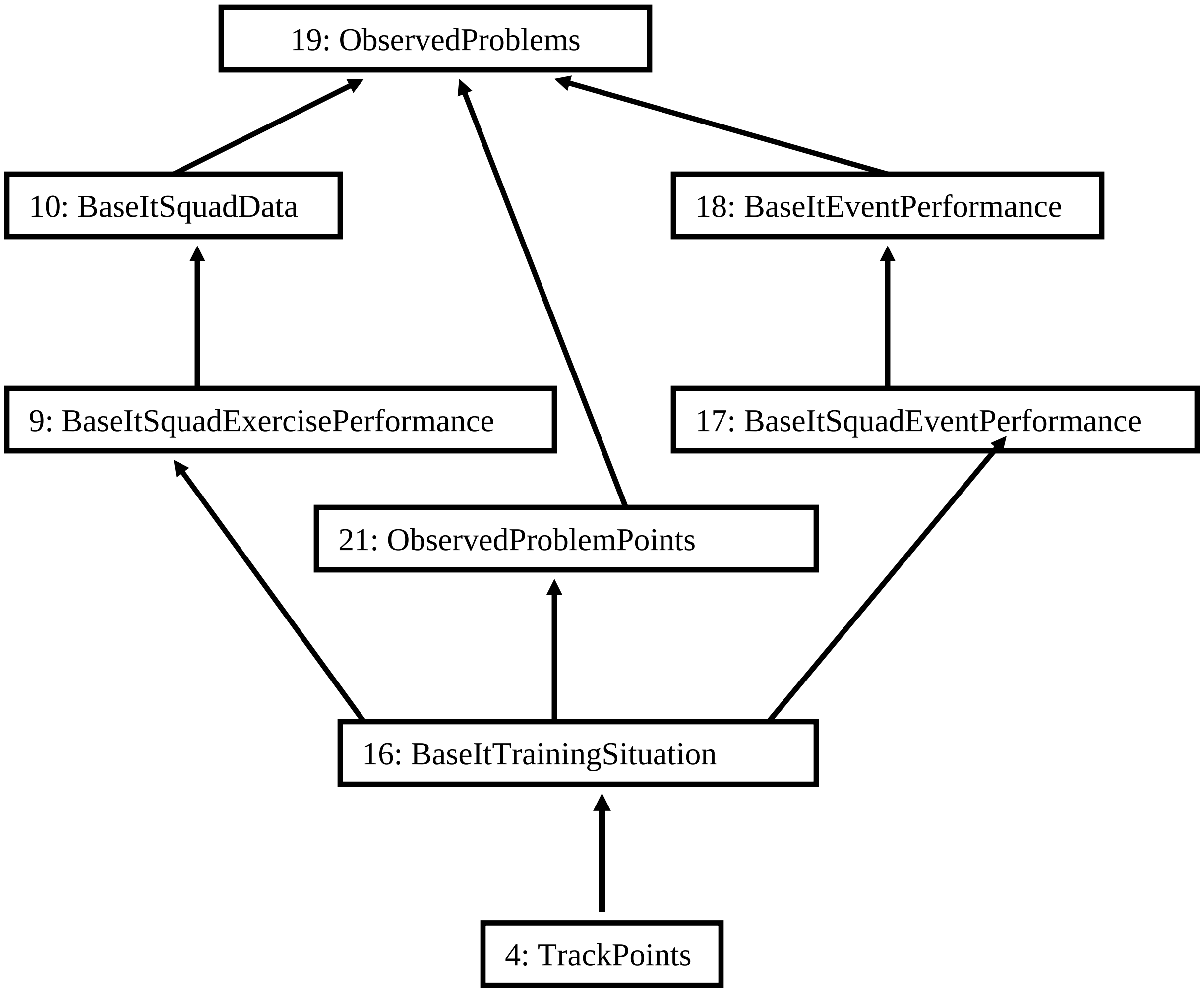
$$A = (1/N)\sum_{i=1}^{N} s[\sum_{j=1}^{M}(h(j)v(i,j)o(i,j)/(25+d(i,j))),1]$$

- Then to get relative unawareness to the danger, use A/E.
- A similar formula can compute weapons coverage by substituting the angle of the weapon for torso angle.

Aggregating metrics over time periods

- We systematically aggregate metrics over time periods to measure overall performance.
- For each instantaneous metric, we aggregate sums, minimum, maximum, and counts in 3 ranges (low, medium, and high). (Divide sum by overall count for mean.)
- We display these at the end of each exercise.
- In addition, there are special overall metrics like time of exercise and number of errors of a given type, like duration spent failing to cover threats.
- We also aggregate over exercise type and squad to provide data for analysis of historical trends.

Aggregation scheme



Conclusions

- This is second year of a three-year project.
- We will have our first test run in August.
- Though we are trying hard to interpret Marine doctrine, a lot isn't written down.
- Thus we will likely get valuable feedback from our Marine experts after the exercise.
- This will refine the metrics and their parameters.
- Also, we need to speed the danger calculation – it's one simulated second per real second in Matlab right now.