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Perception

ME 2984

"There are things known and there are things unknown, and in between are the doors of perception."

— Aldous Huxley

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PERCEPTION VS. SENSING

- Sensing: collecting data about the robot/environment
    - Focuses on physical phenomena measured
    - Sensing modality
    - Accurate/precise/reliable measurement
- Perception: extracting higher level models of environment to accomplish some task
    - Connected to both sensing and desired task
    - Models are crucial
    - Assumptions about environment, task, and sensors

PERCEPTION APPROACHES

- Entire fields exist to investigate
  - Particular sensing modalities
  - Specific approaches
  - Solving particular problems
- For sensing modalities, we will focus on
  - Point Cloud Processing
  - Computer Vision

COMPUTER VISION

- Extracting useful information from images
  - Often visible light, but can use other parts of the electromagnetic spectrum
- Attractive properties
  - Dense data
  - Has infinite range
  - Intuitive to humans
  - Cheap sensors
- Harder than it seems

FACE RECOGNITION

- Given examples of faces with a name as a label
- Given a novel image, recognize faces, provide names
- Huge success in computer vision

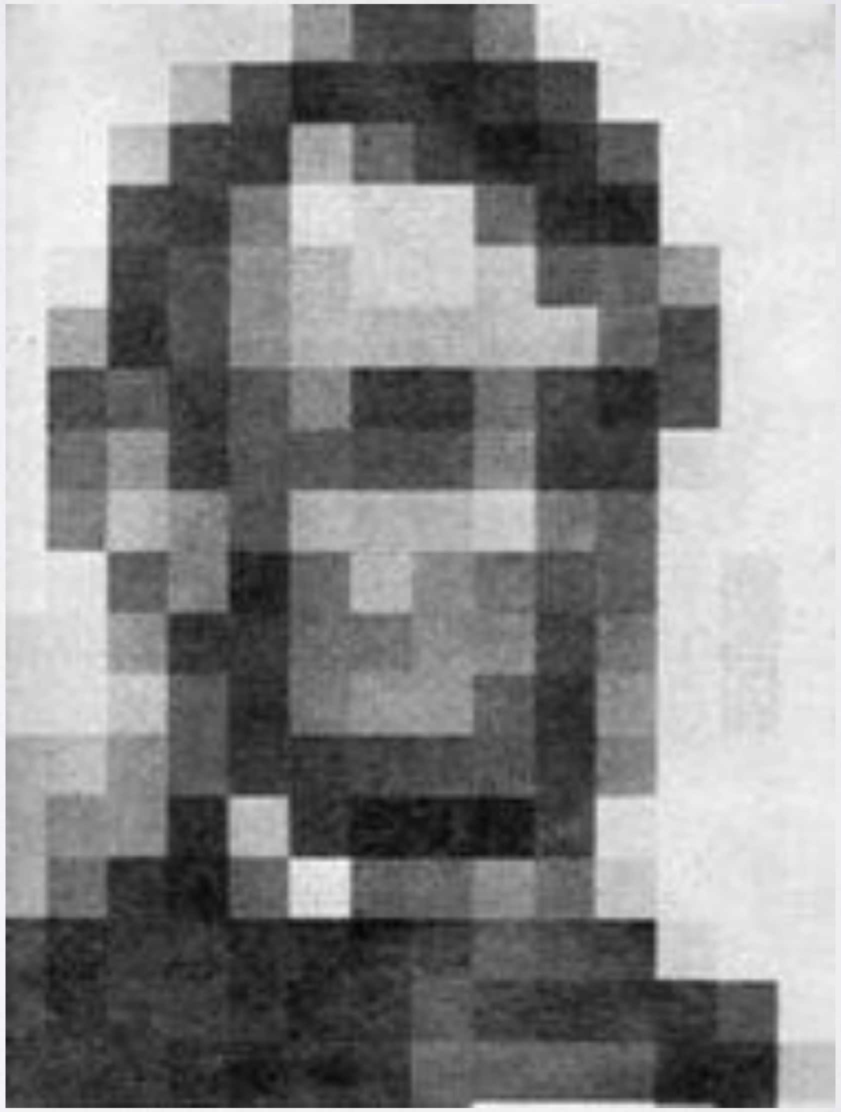


Image Credit: Science

VISION IS HARD

- Which square is brighter? A or B?

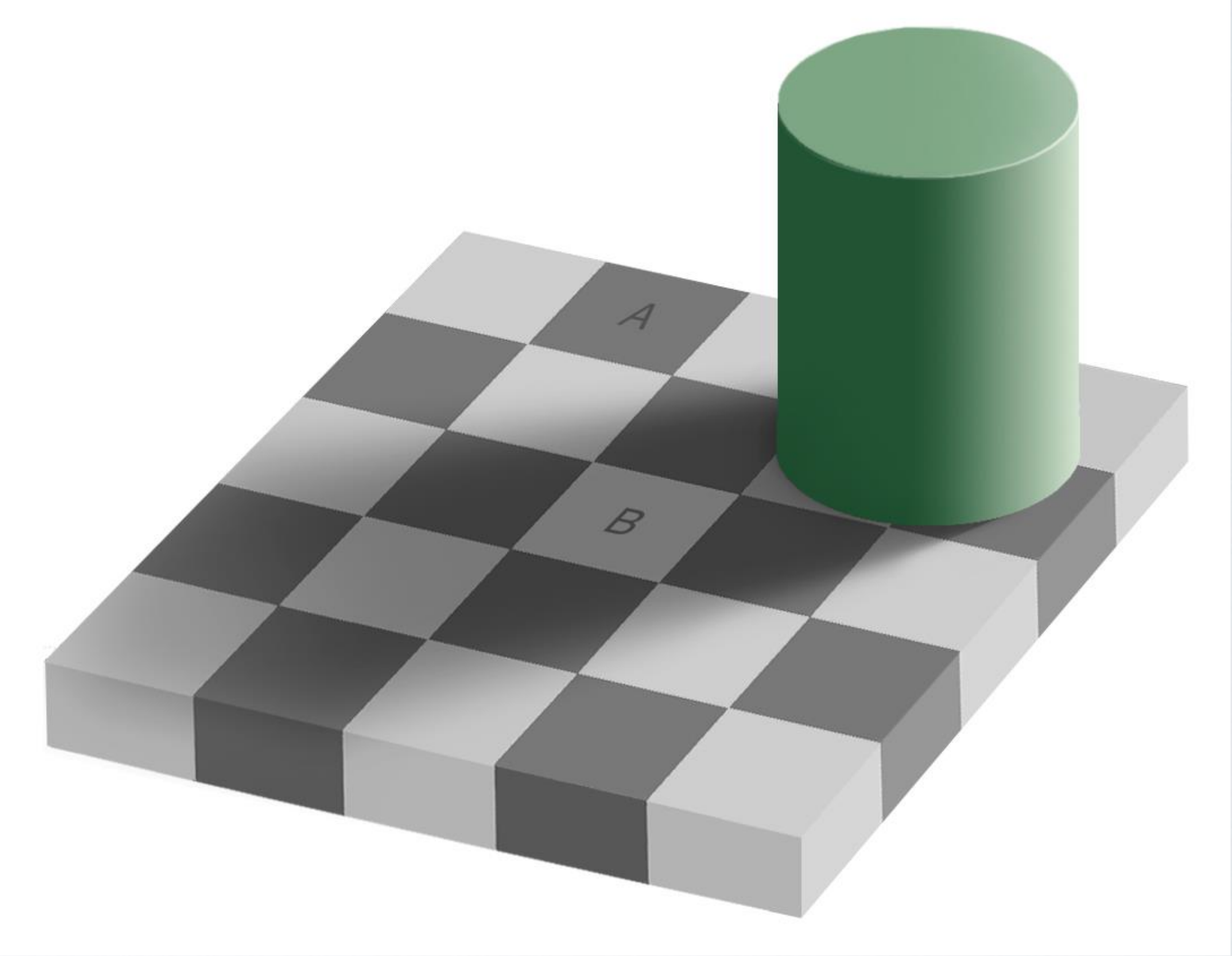


Image Credit: Wikipedia

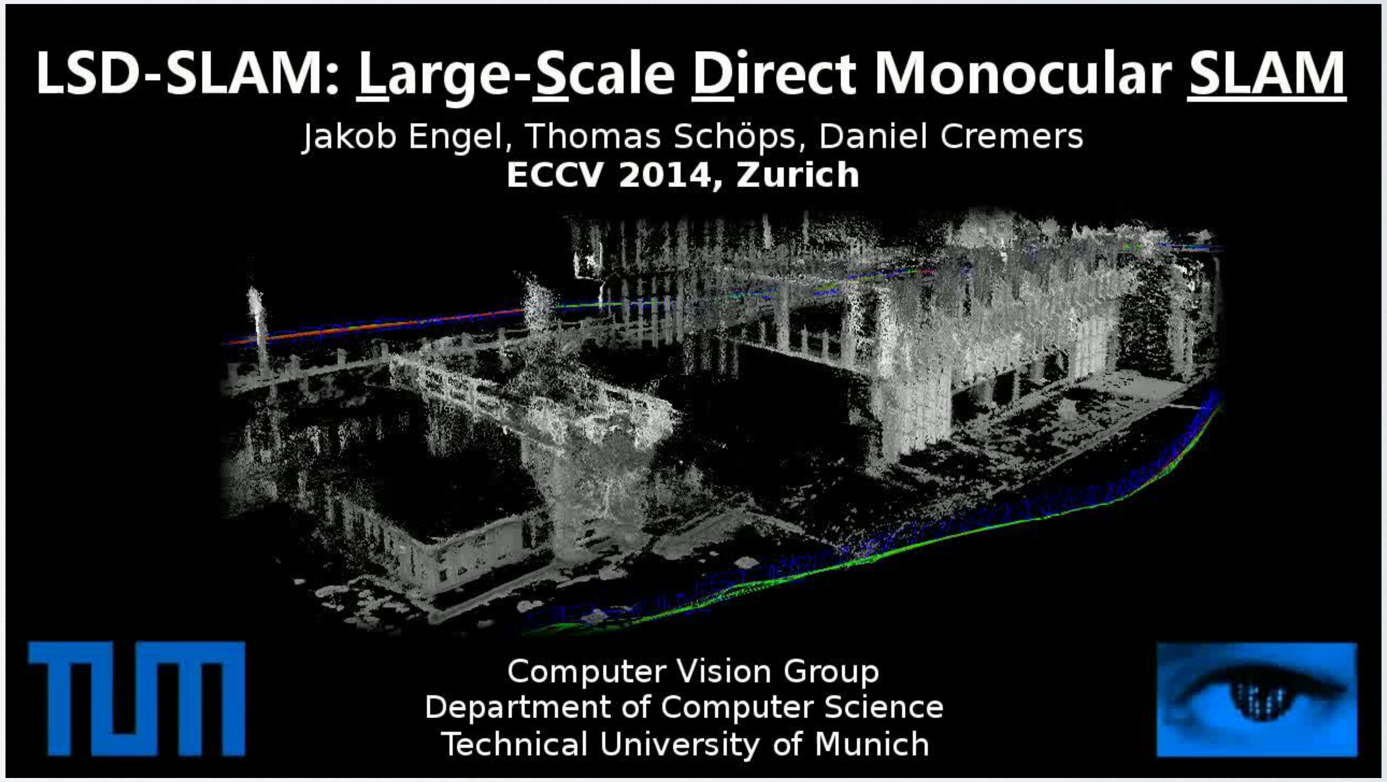
VISION IS HARD

- Challenges extend beyond simple illusions
- Who is taller in this scene?

Image Credit: [New Line Cinema]

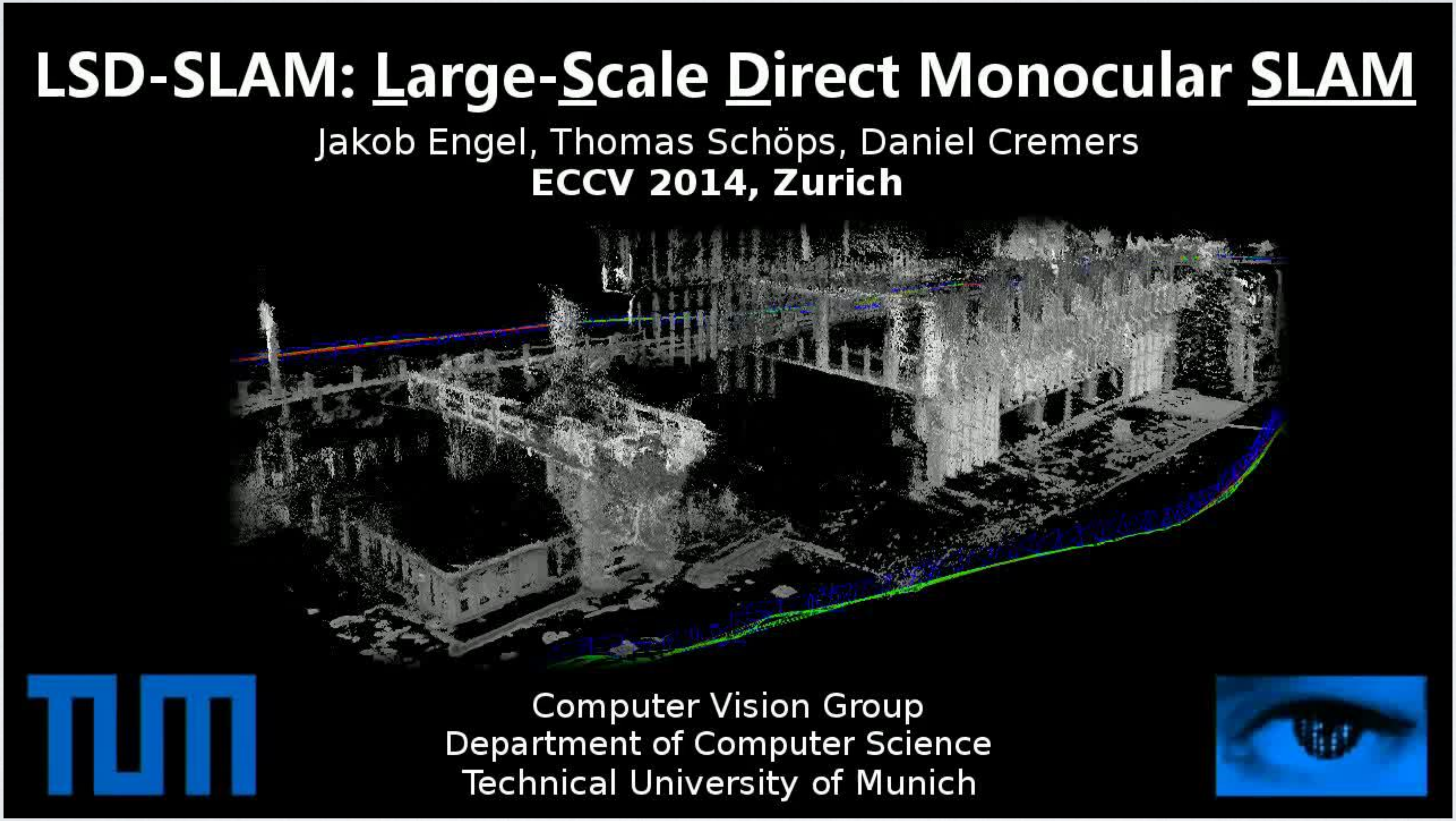
VISION IS POWERFUL

- Hard doesn't mean impossible
- Incredible things are possible with computer vision



Video Credit: [Engel et. al.]()

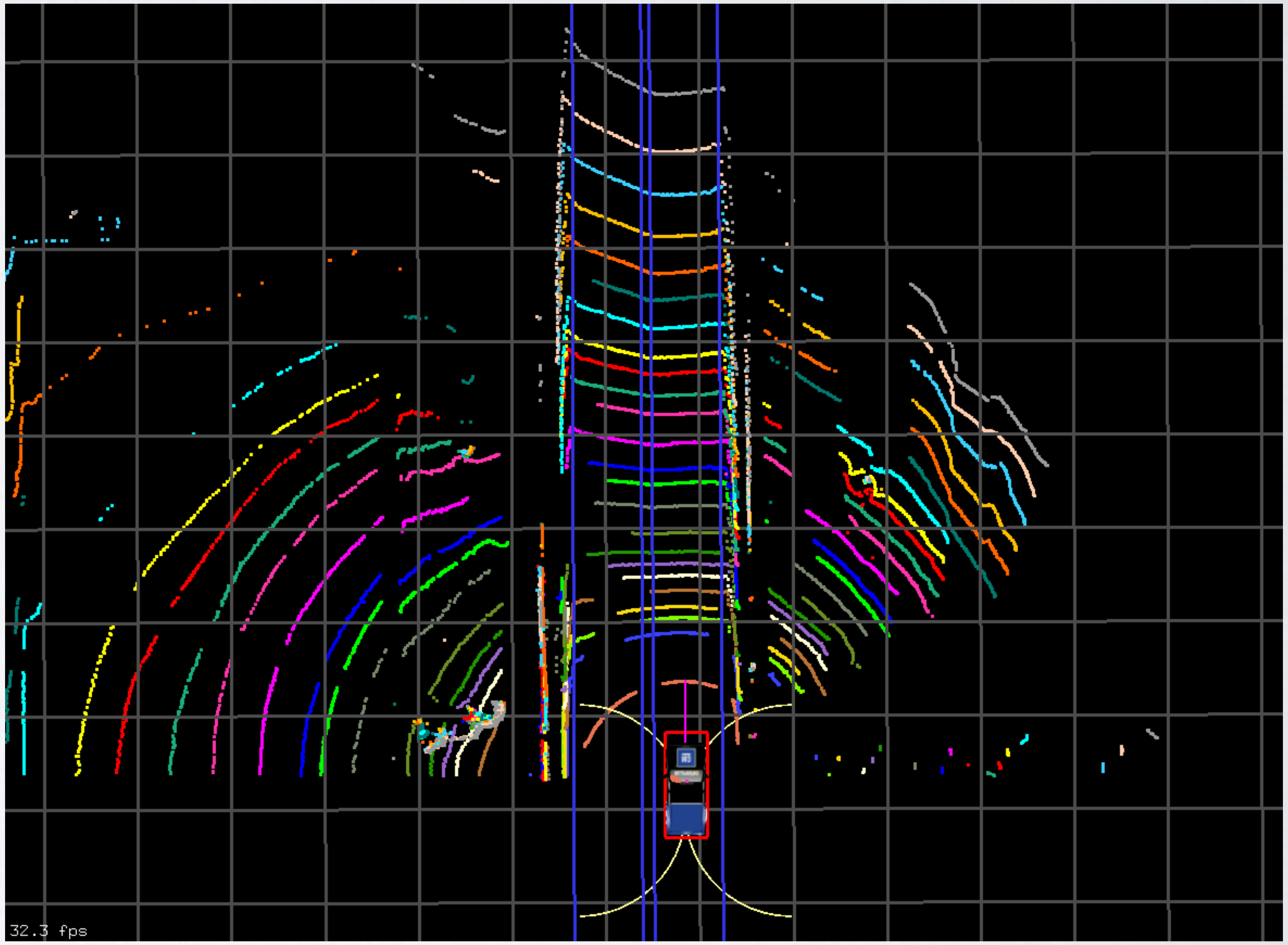
VISION IS POWERFUL



Video Credit: [Engel et. al.]

POINT CLOUD PROCESSING

- Processing geometric data
- Different advantages
  - Precise
  - Consistent
  - Fast

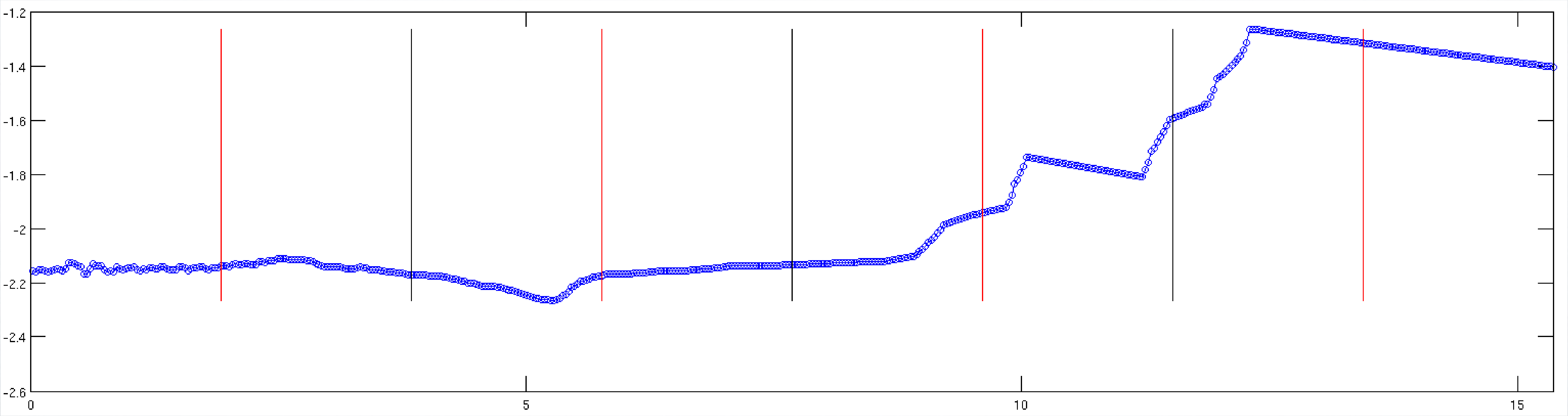


TERRAIN MODELING

- Estimating shape of environment from sampled points
- Many self-driving cars are based on this approach

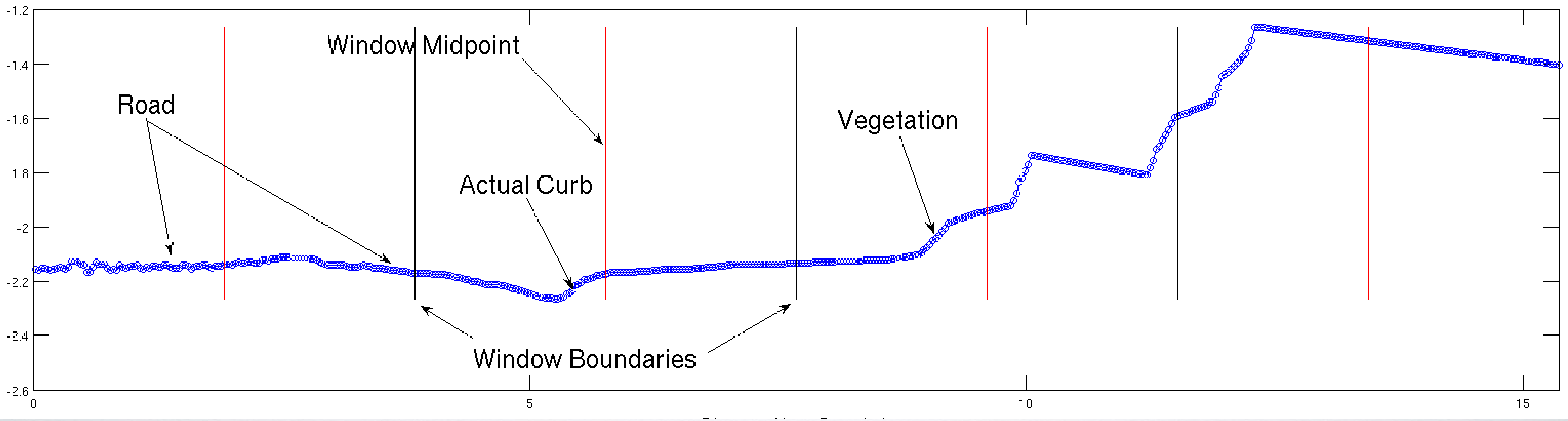
LIDAR IS HARD

- What does this data represent?



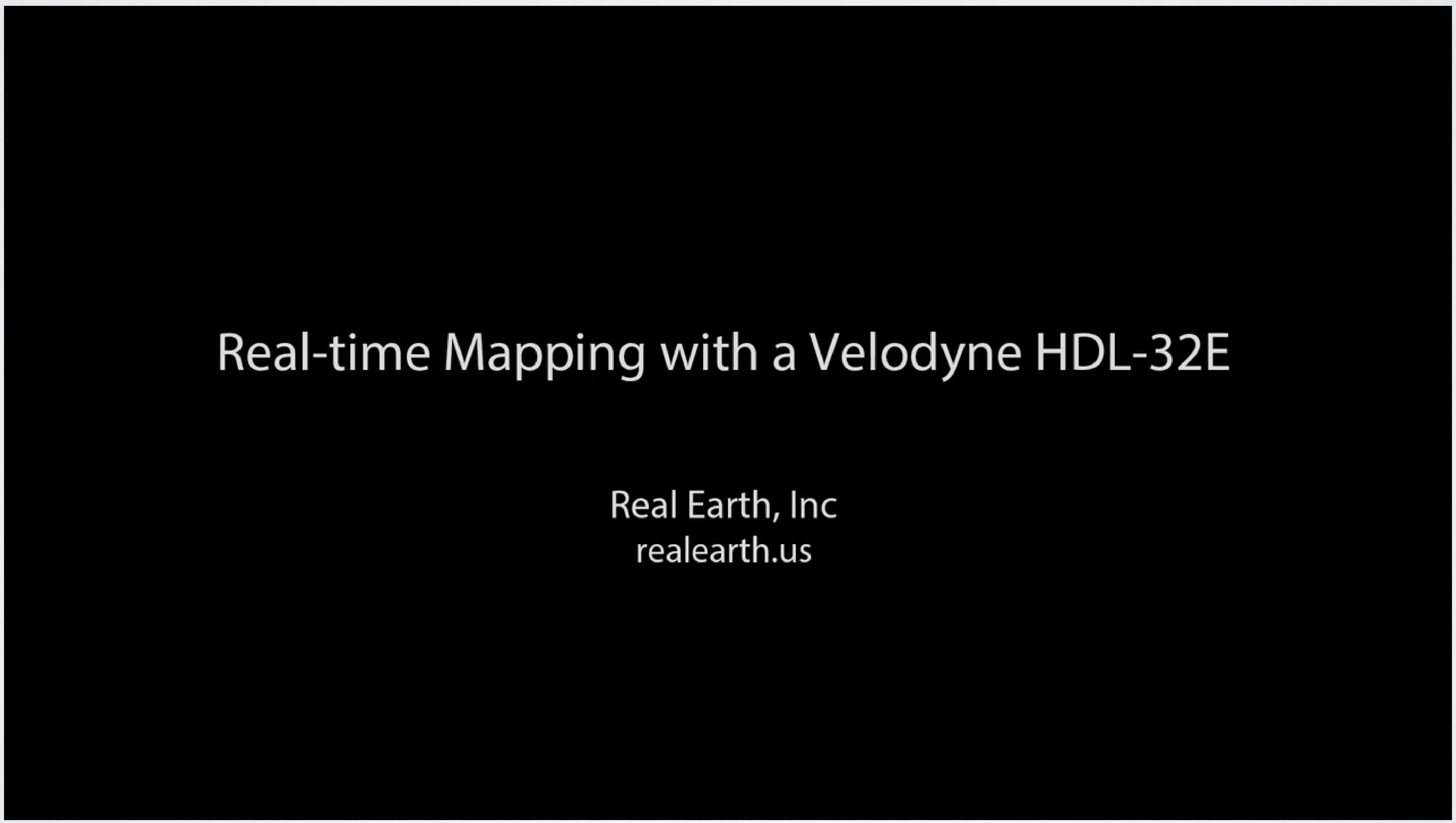
LIDAR IS HARD

- What does this data represent?
- Geometry can be deceiving



AND AWESOME

- Similar problem to computer vision example



Video Credit: [Ji Zhang]

OBJECT DETECTION

- Identifying if an object is present in sensor data
  - "Object" defined based on task
- Trivial model
- Examples
  - Face identification
  - Detecting gas leaks

Image Credit: [XKCD]

OBJECT LOCALIZATION

- Determining location of object of interest
- Includes solving detection

Video Credit: [Jacob Brunson]

OBSTACLE DETECTION

- Process of estimating cost of traversing different parts of the environment
- Start with binary obstacles, where locations cost
  - 0 - freely traversable
  - 255 - shall not pass
- Assume
  - K.H.A.N. is the robot we are discussing
  - Good enough localization

WHAT ARE OBSTACLES?

- What should K.H.A.N. avoid traversing?
  - Inversely, what should K.H.A.N. traverse?
- What can we measure about these objects?
  - What assumptions can we make to simplify the task?

Image Credit: [Sparkfun]

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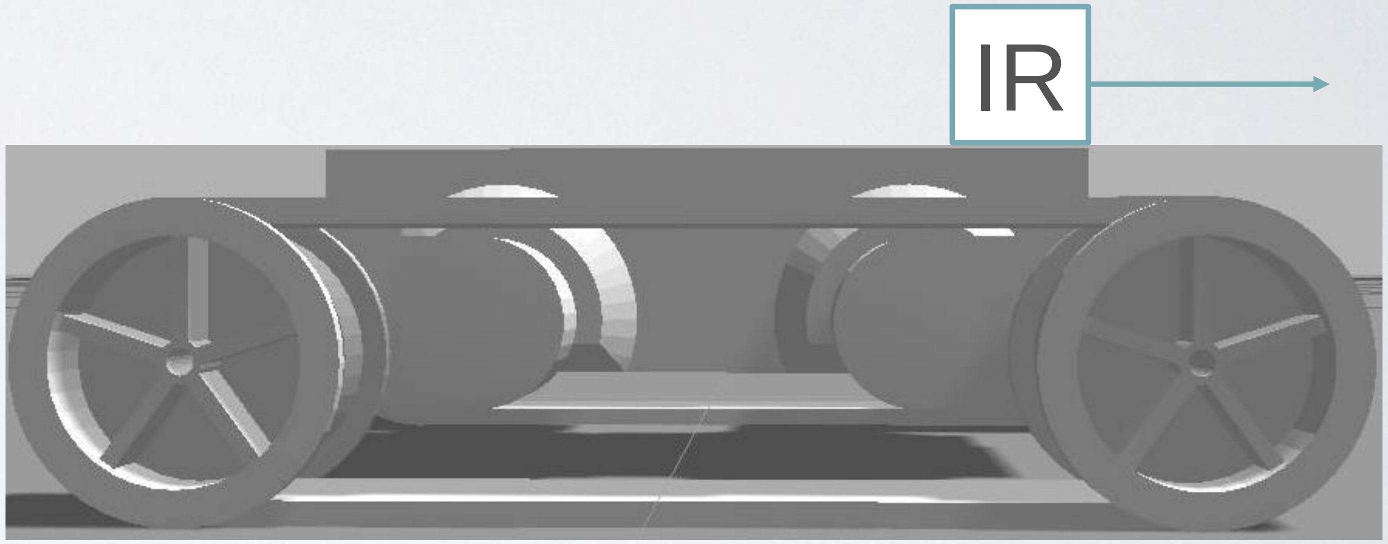
WHAT ARE OBSTACLES?

- Environment is
  - Indoors (dorms, classrooms, labs, etc.)
  - Somewhat dynamic
- Obstacles are
  - Anything solid
  - Roughly as tall as K.H.A.N.

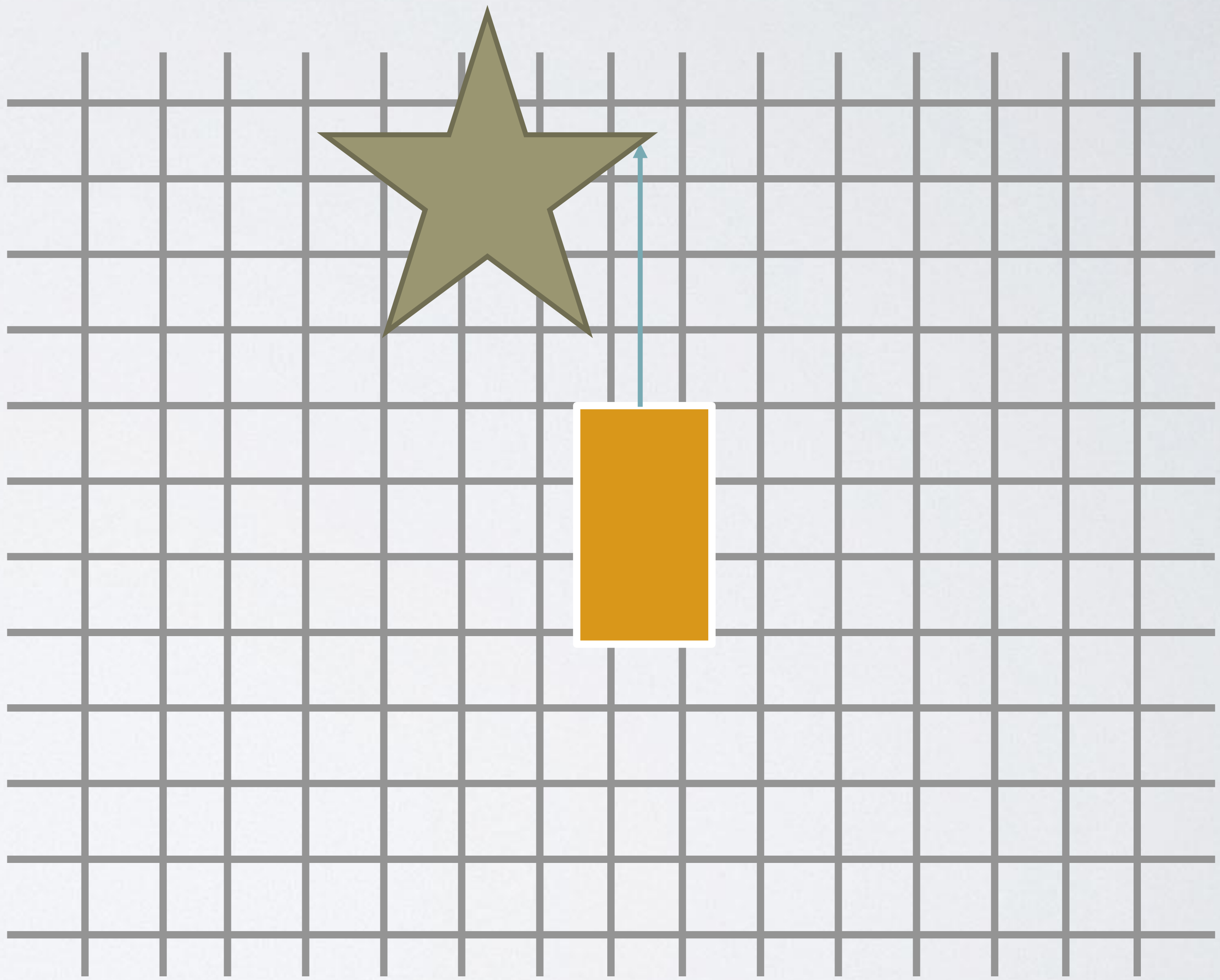
OBSTACLES V1

- Mount range sensor as shown
- Any measurement is an obstacle?
- Problems
  - Obstacle size
  - Accumulating data



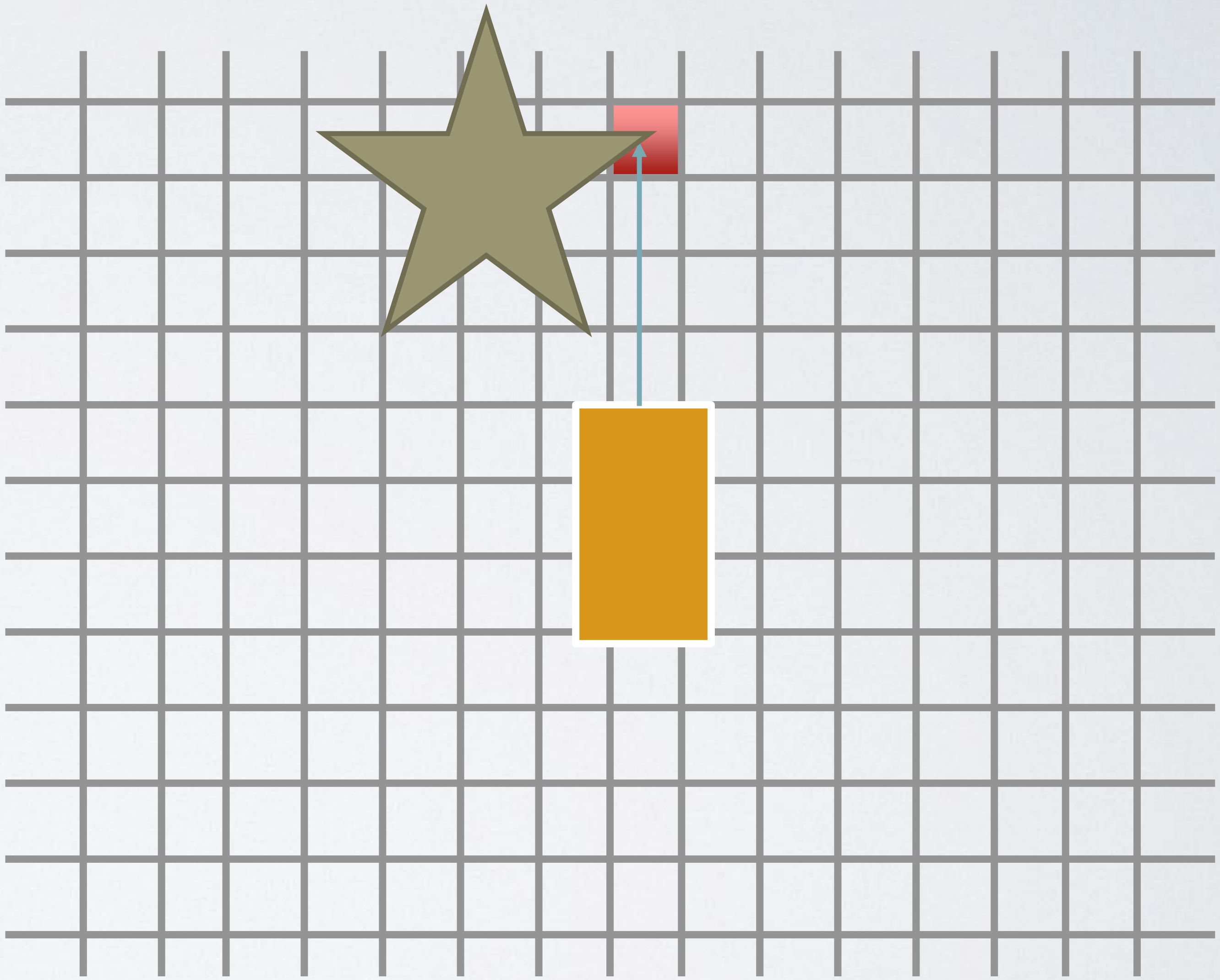
GRID MAPS

- Accumulate data based on location
- Data in a local region is likely somewhat related
- Break up world into small squares



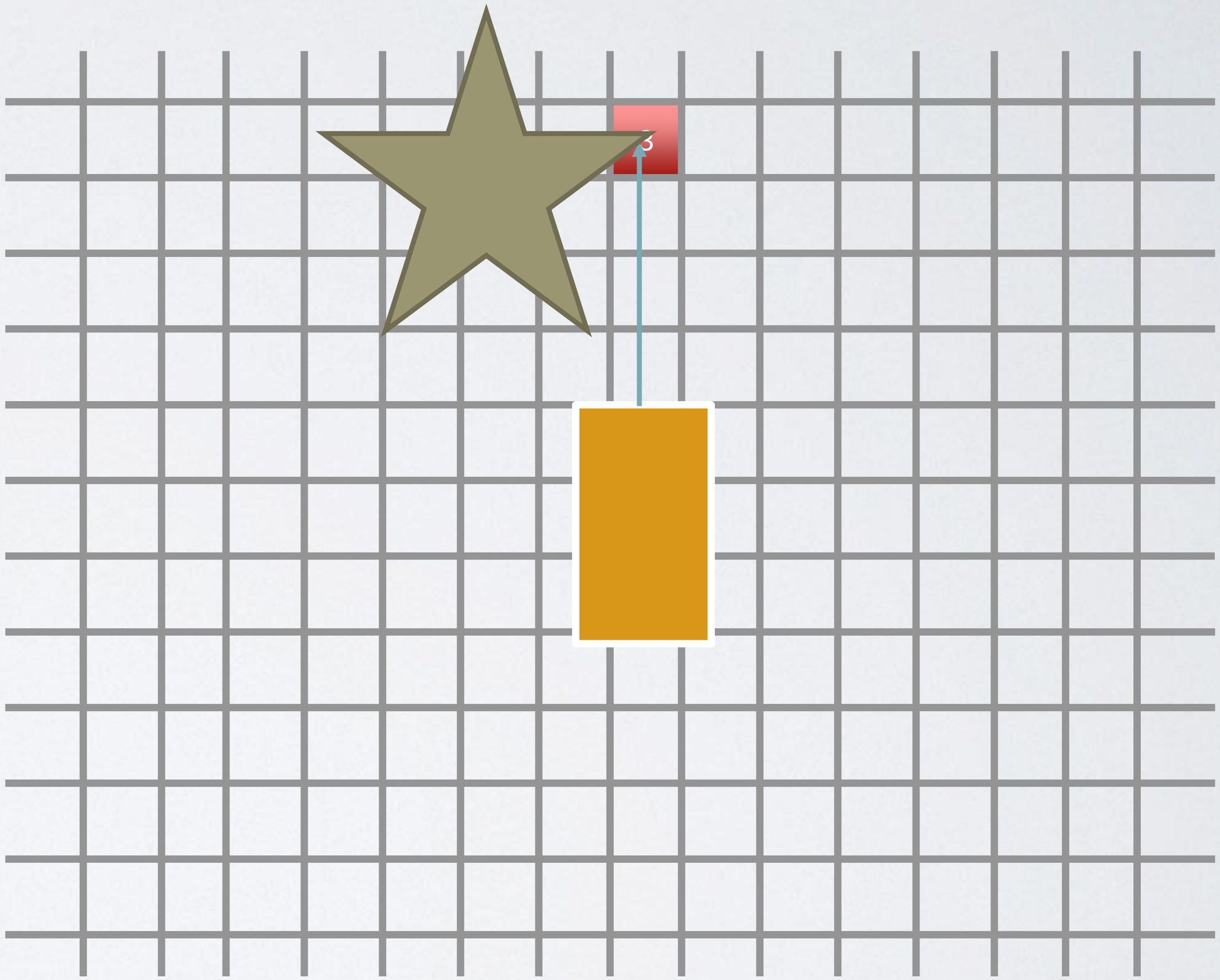
OBSTACLES V2

- Take sensor measurements
- Mark every cell a range reading falls in as an obstacle
- Never erase the map
- Problems?



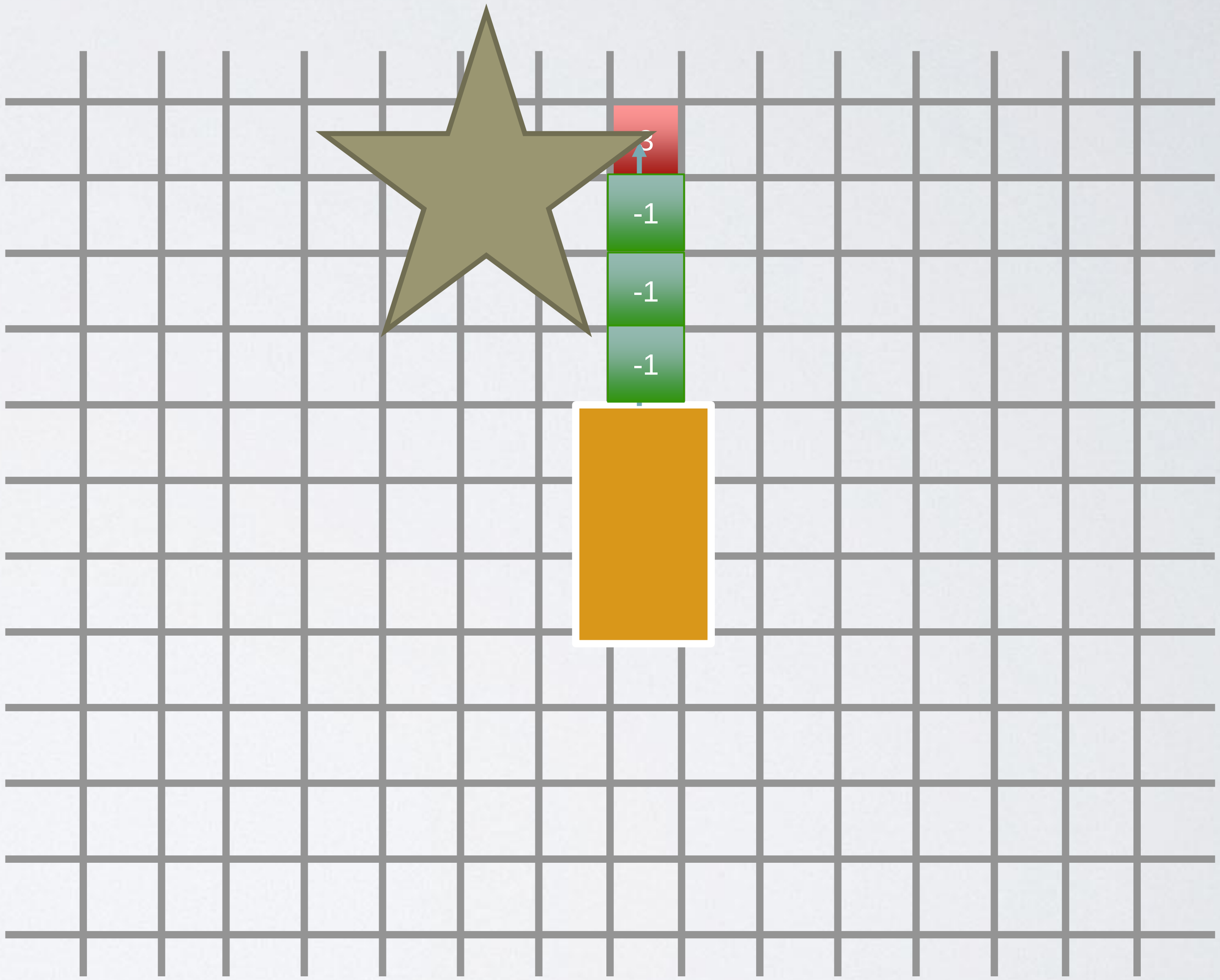
OBSTACLES V3

- Require some number of hits before marking obstacles
- Anything less than that number of hits is clear?
- Still never forget a mistake



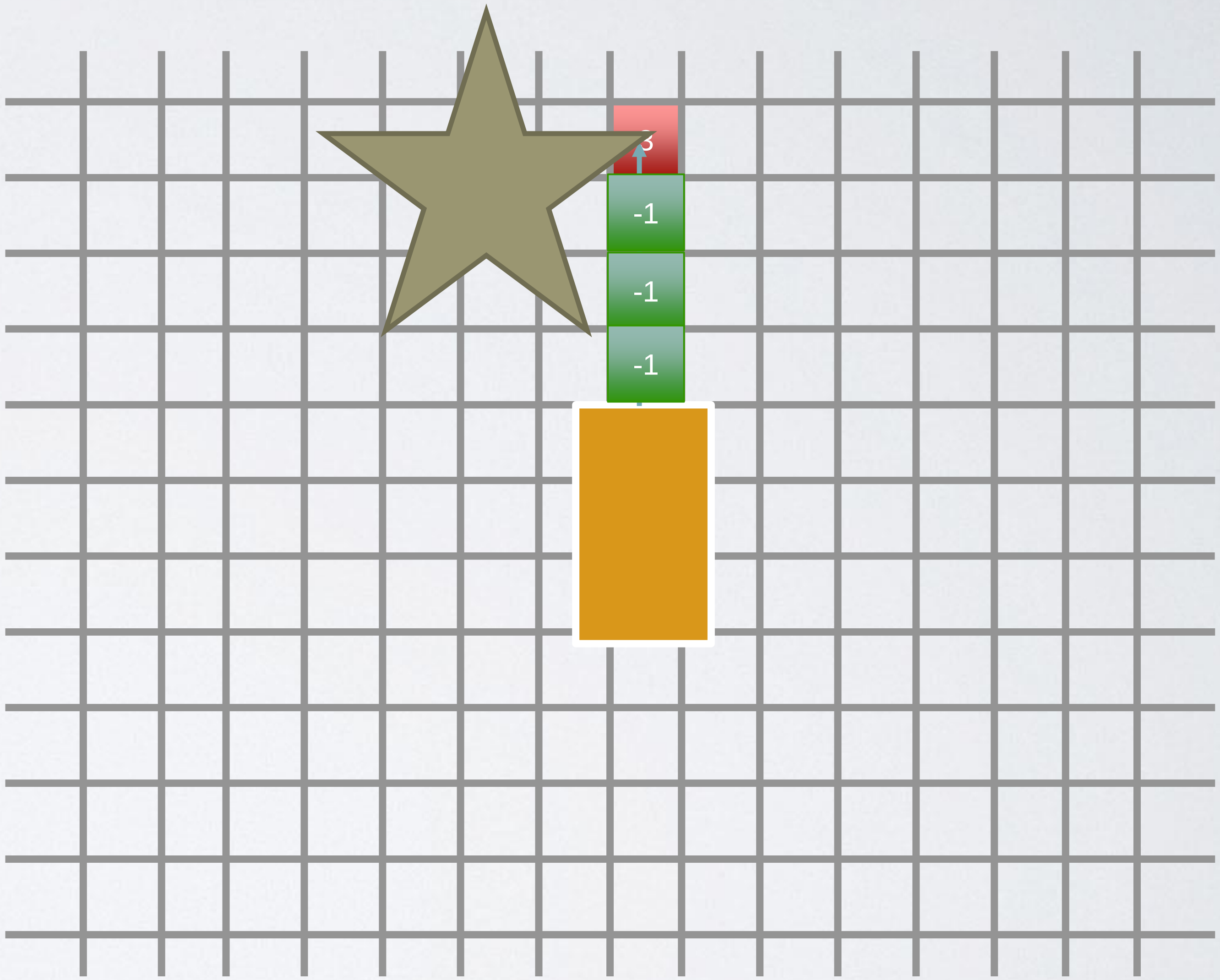
OBSTACLES V4

- Count hits and pass-throughs
- Obstacles are above some count
- Free space below another count



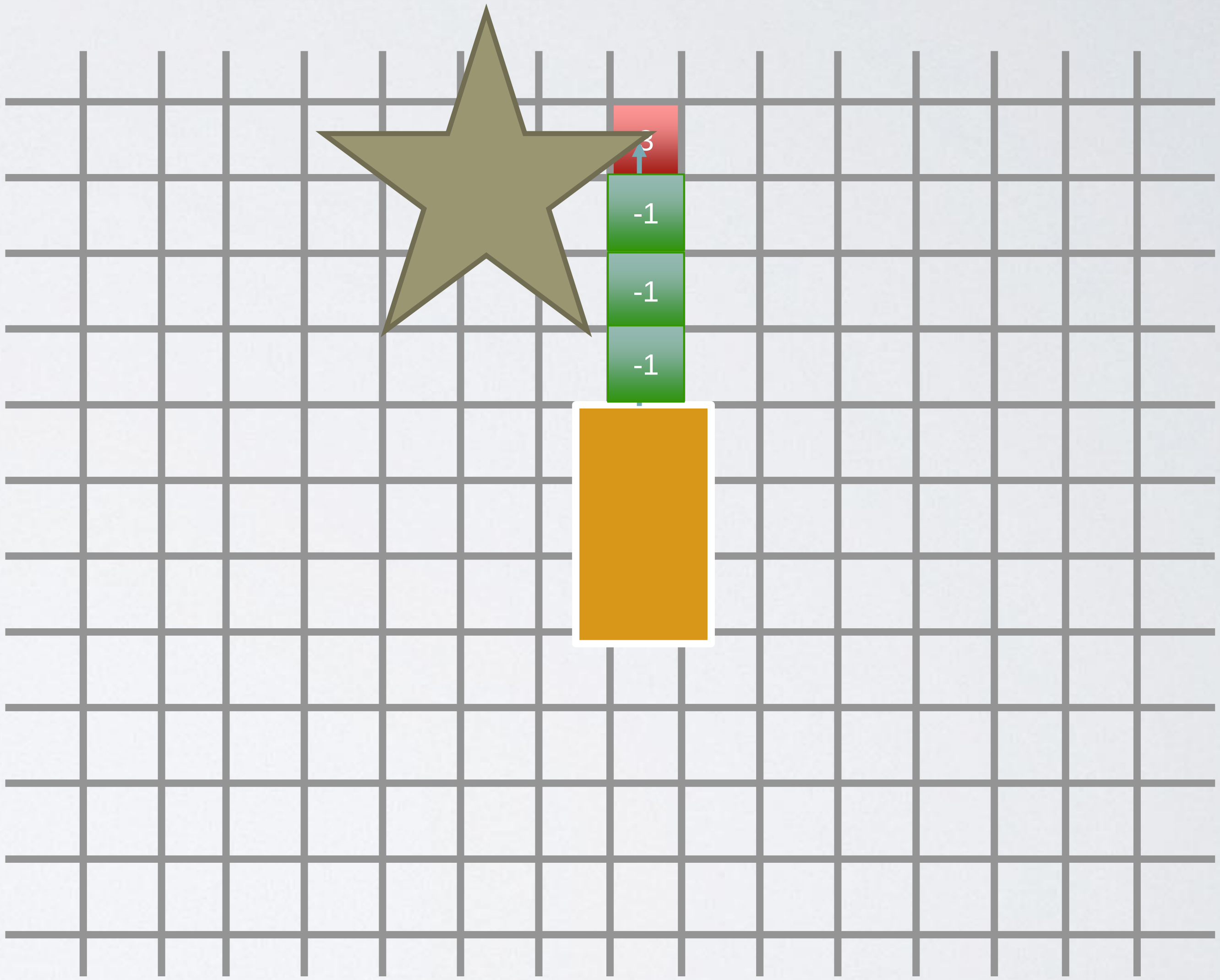
OBSTACLES V5

- Score for a hit and a miss need not be equal
- Hit counts for 1, miss for -2
- Cap scores to some range



OBSTACLES V6

- Consider this approach in terms of probability
- Sensor is providing evidence, not truth
- Scores are weighing the evidence



OBSTACLE MAPS

- Map fills in over time
- Implicitly includes connectivity
  - Adjacent cells are adjacent in real world
- Don’t forget assumptions

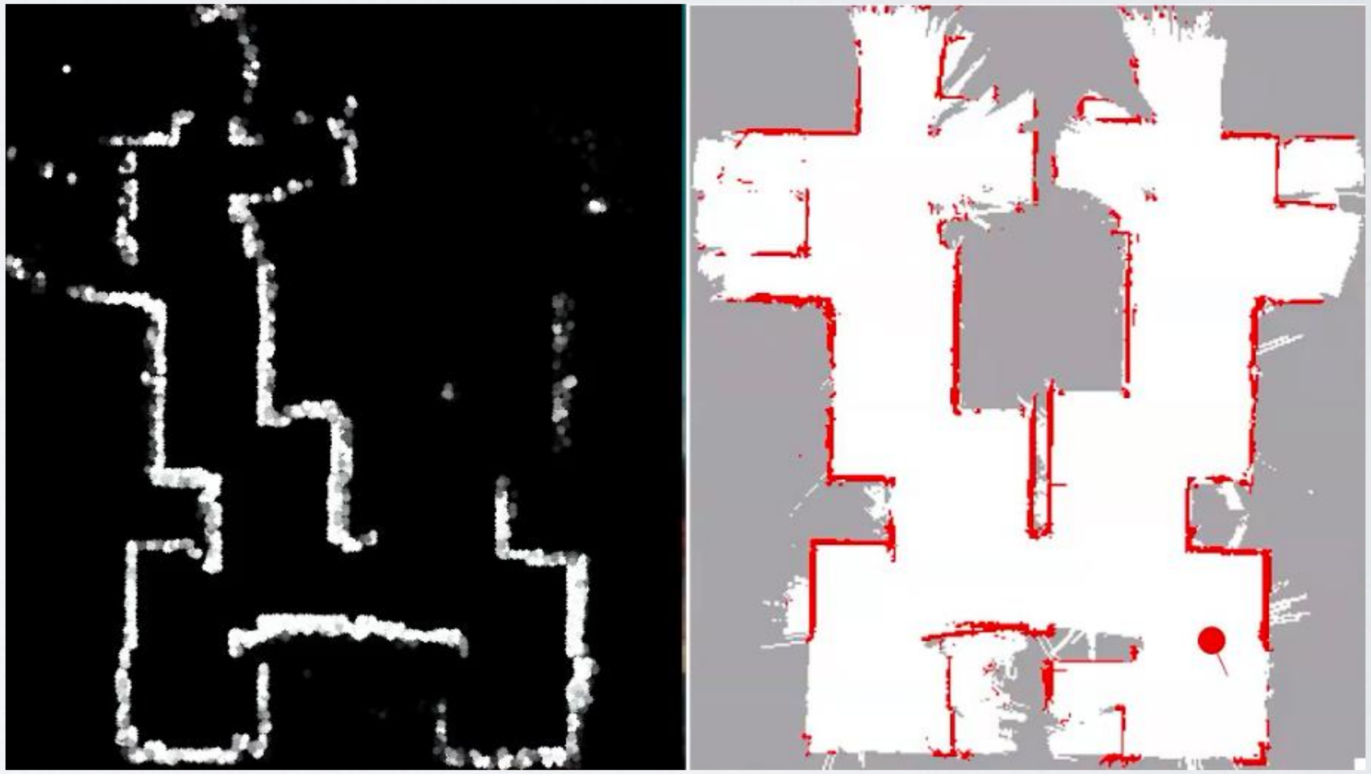


Image Credit: [Jay Chakravarty]

OCCUPANCY MAPS

- Same technique in use today
- Can easily extend technique to 3D environments

A. Hornung,. K.M. Wurm, M. Bennewitz, C. Stachniss, and W. Burgard, "OctoMap: An Efficient Probabilistic 3D Mapping Framework Based on Octrees" in Autonomous Robots, 2013

TERRAIN MODELING

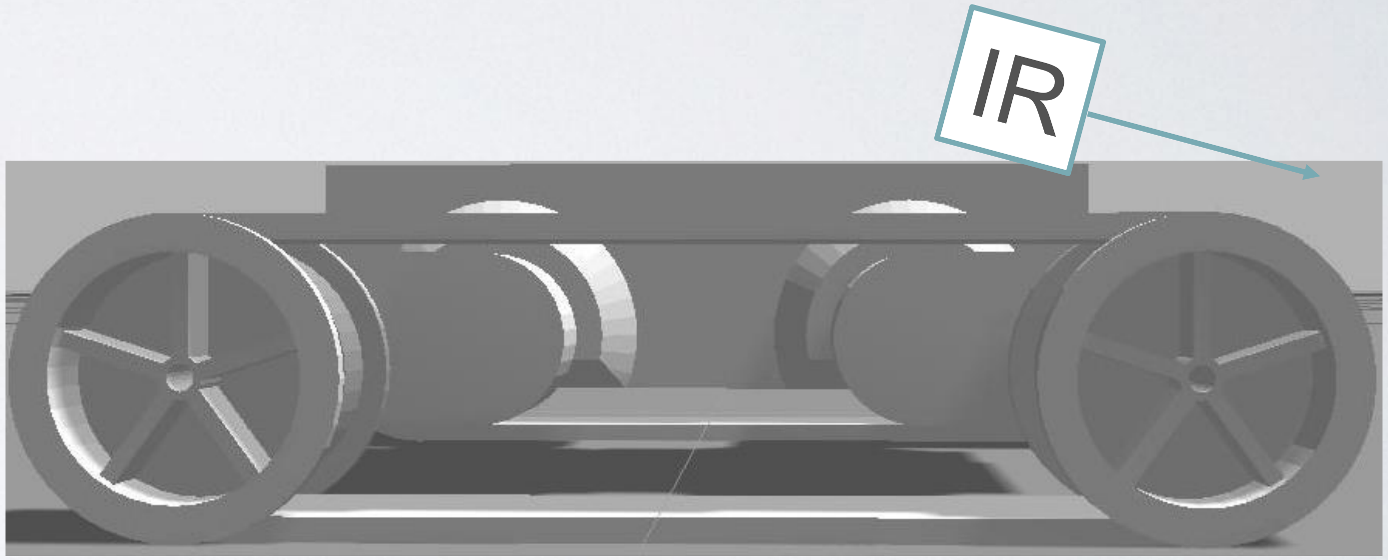
- Estimating properties of the local terrain
  - Typically shape, but not exclusively
- Useful to relax assumptions about the ground to be traversed
- What assumptions can be made about terrain?

TERRAIN ASSUMPTIONS

- The ground is down
  - In fact, it’s the lowest thing around
  - And there’s nothing below it
- Terrain is continuous
  - Shape doesn’t change rapidly
- Terrain is a surface
  - No holes

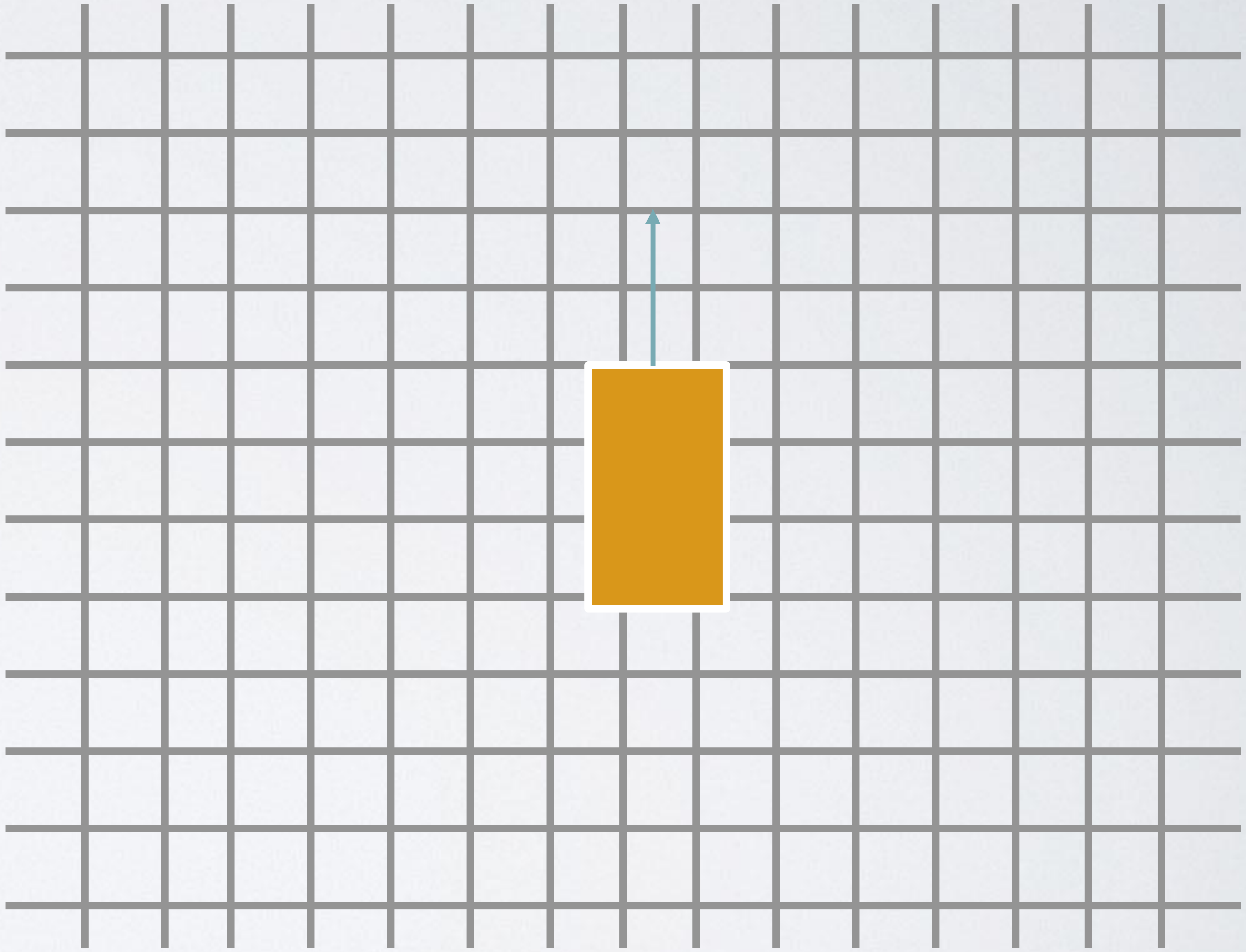
TERRAIN MODELING

- Tilt our range sensor down
- Measuring distance to ground now
- How do we represent shape?
- How do we estimate it?



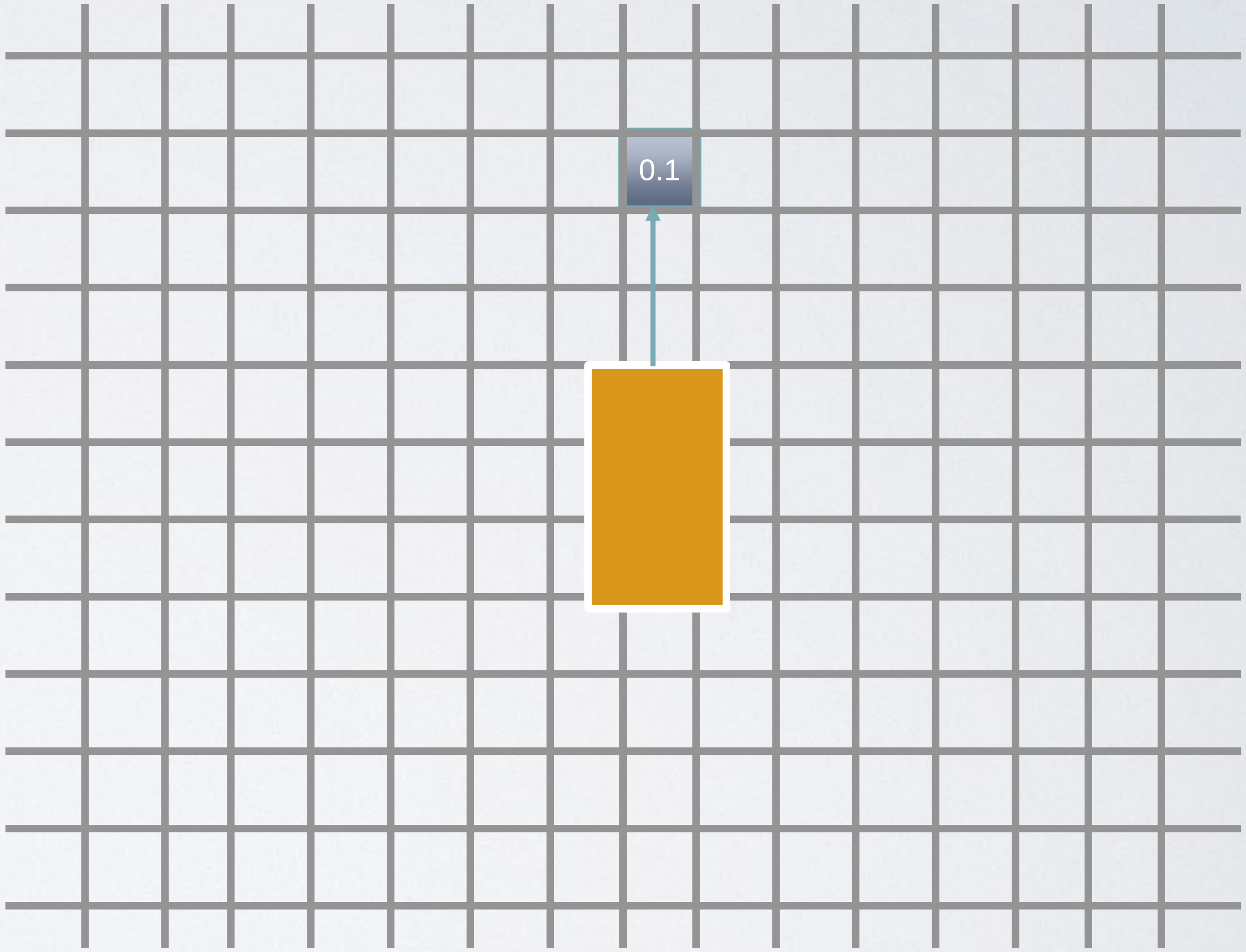
TERRAIN MODELING

- Maps are convenient
- Use the surface assumption
  - Store height of ground surface in each cell
- How to estimate height?



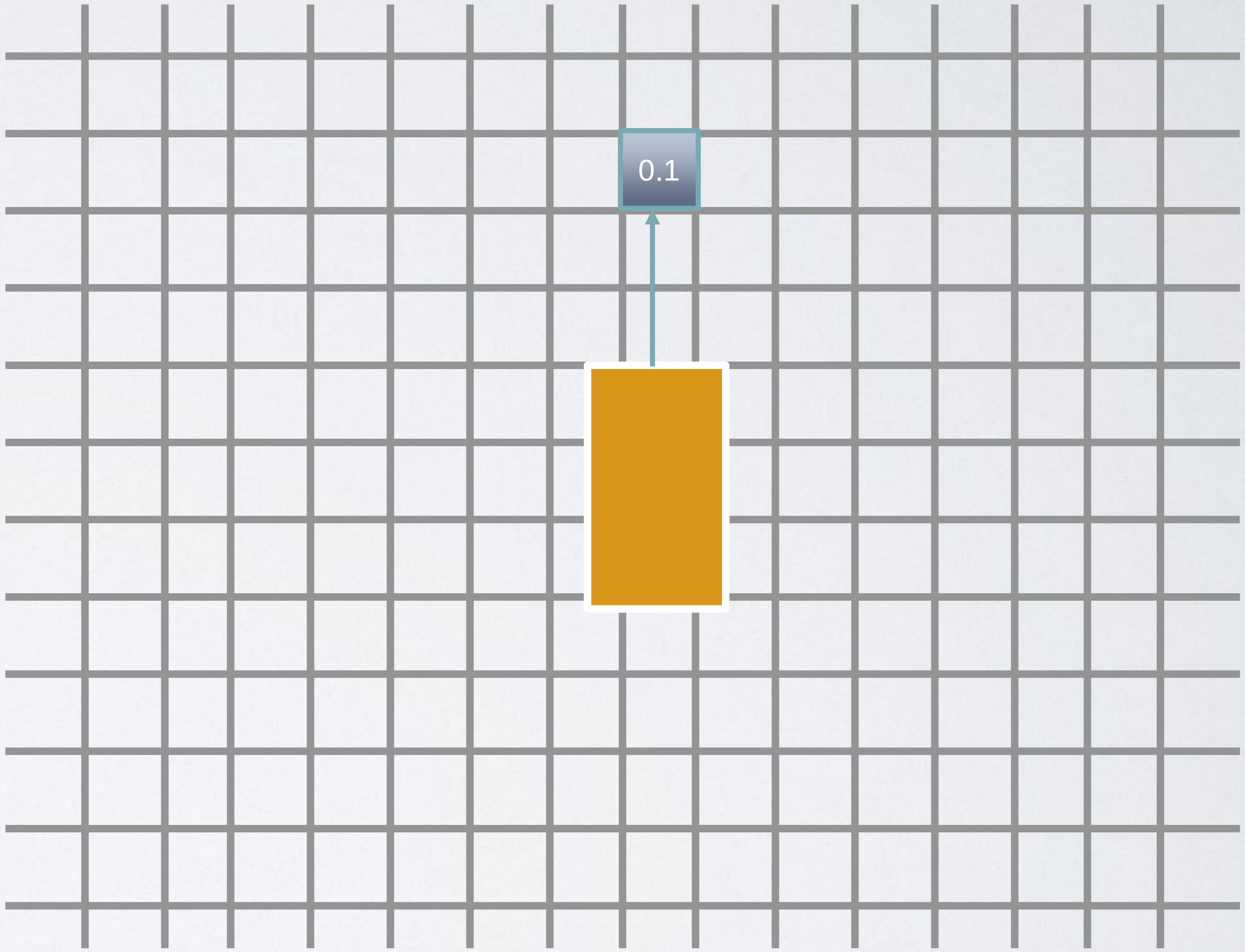
TERRAIN MODELING V1

- Counting doesn't work
  - But hits are geometric
- Record lowest height in each cell
- Problems?



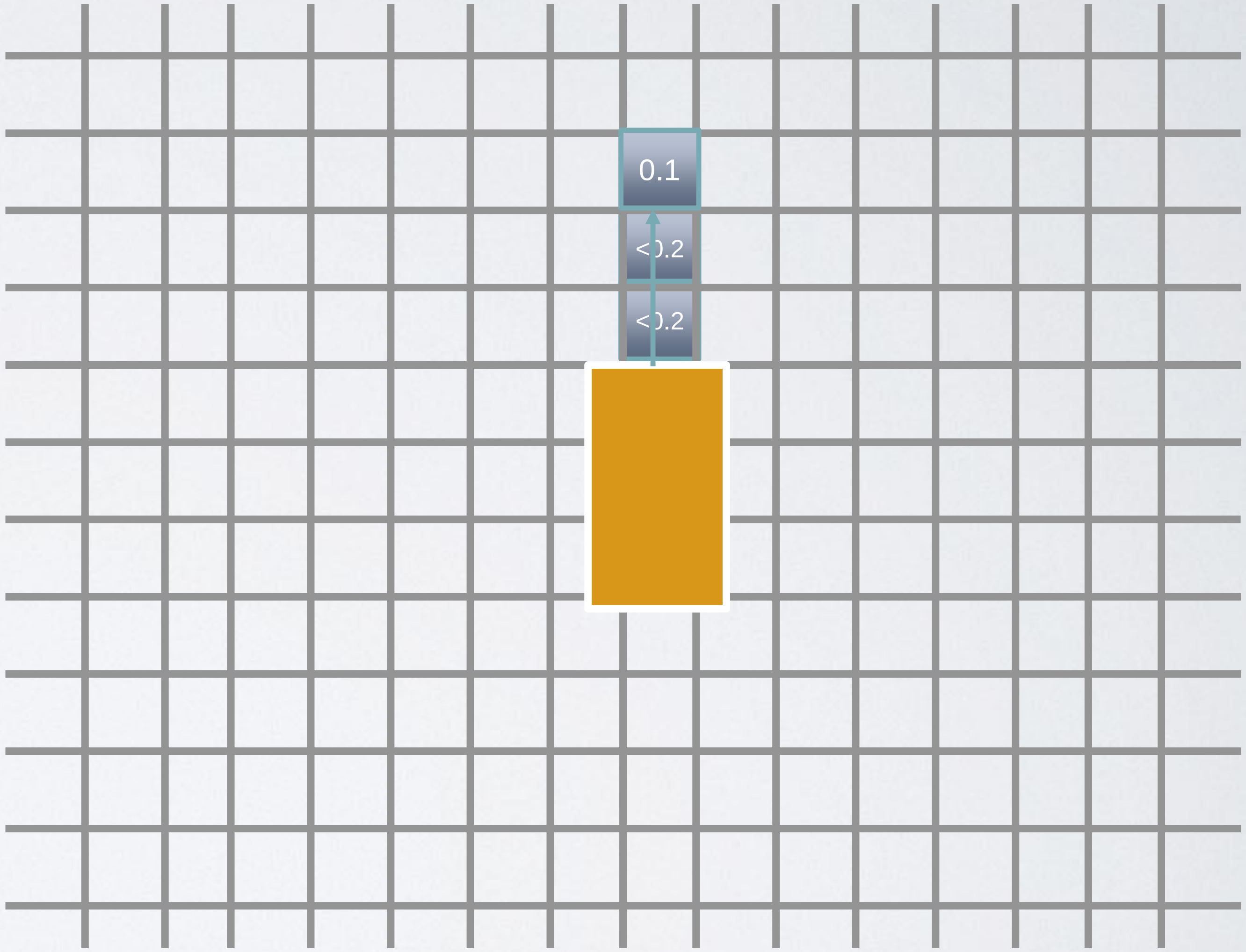
TERRAIN MODELING V2

- Make measurements more robust
- If measurements in a cell are similar, take average
- If difference is large enough, only take the lowest measurement



TERRAIN MODELING V3

- Exploit pass-throughs again
- Add flag indicating if height is equal to or less than number
- Use number to record lowest height



TERRAIN MODELING

- Look familiar?
- Fundamental approach is the same
- Includes fusing data from multiple sensors

BIG PICTURE

- Perception problems are based in sensing, driven by higher level tasks
- Assumptions/generalizations can simplify work, but also limit applicability
- Don’t forget this all is driven by actual math and computer science