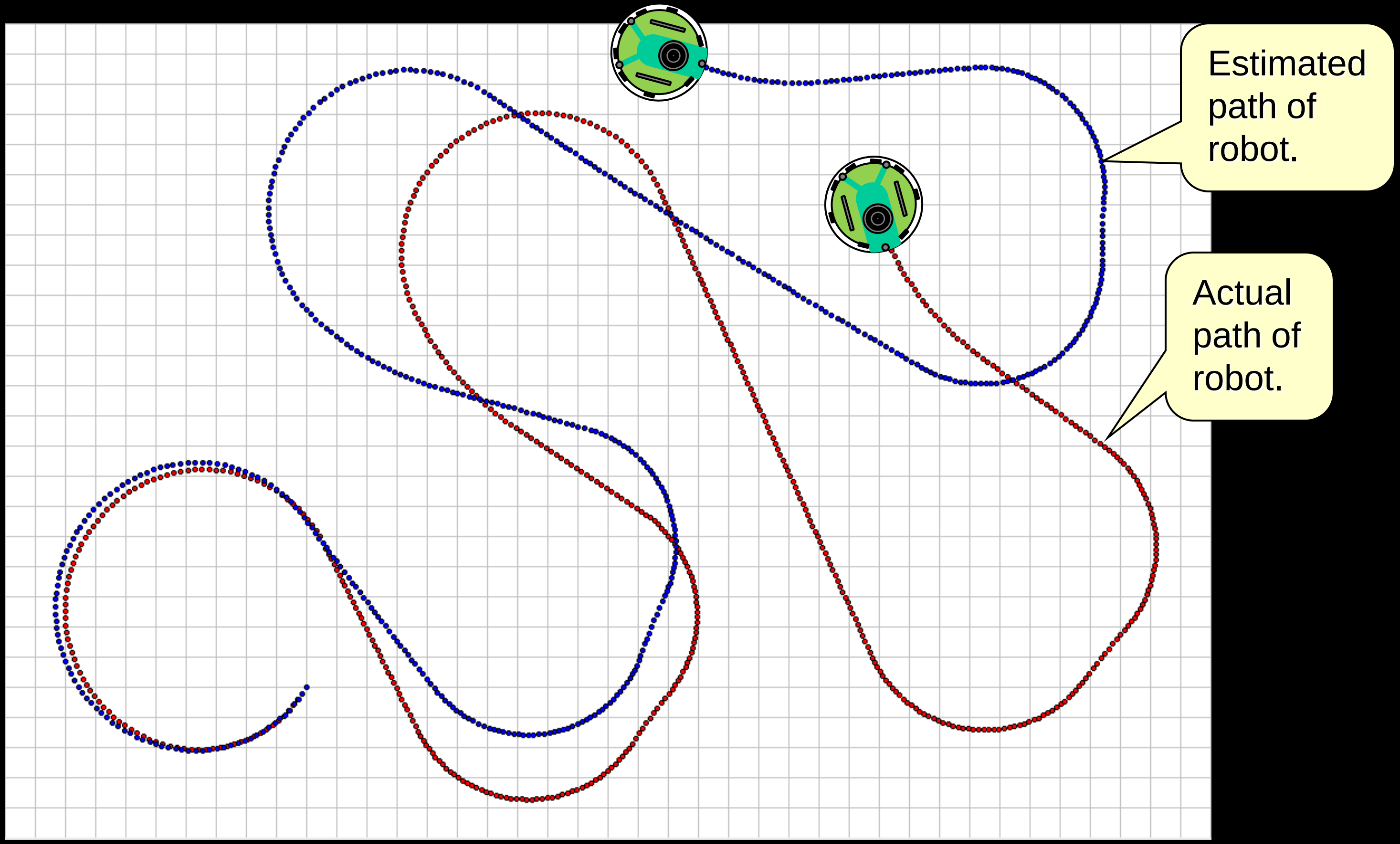
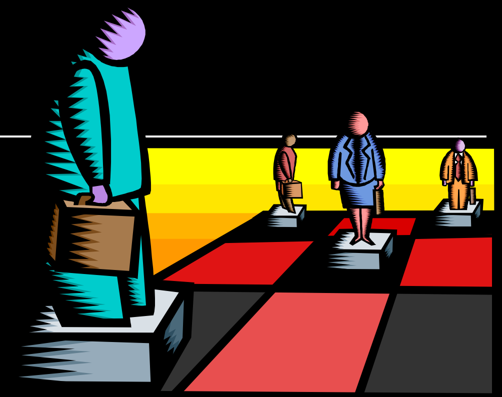
Grid-Based Estimation

Odometry Problems

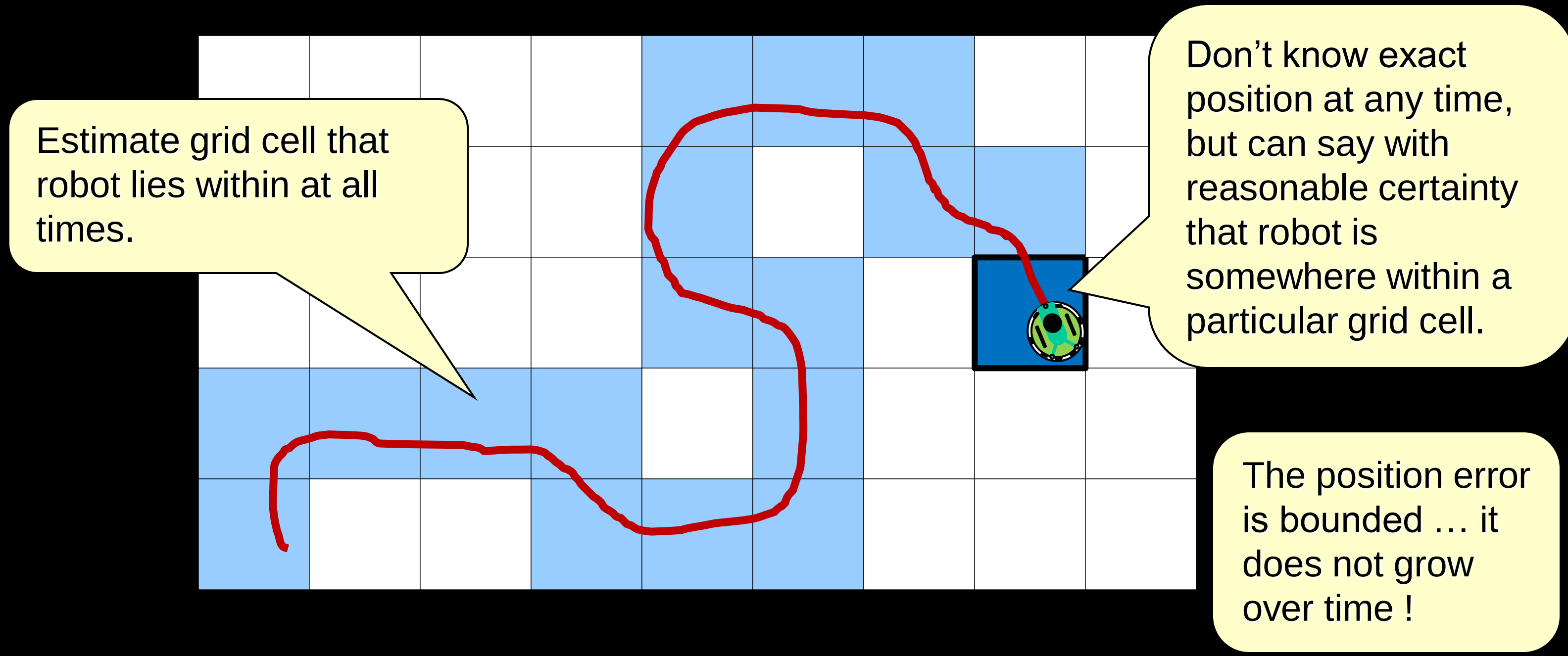
- Using forward kinematics calculations, the odometry error is unbounded and will grow over time.



Grid-Based Estimation

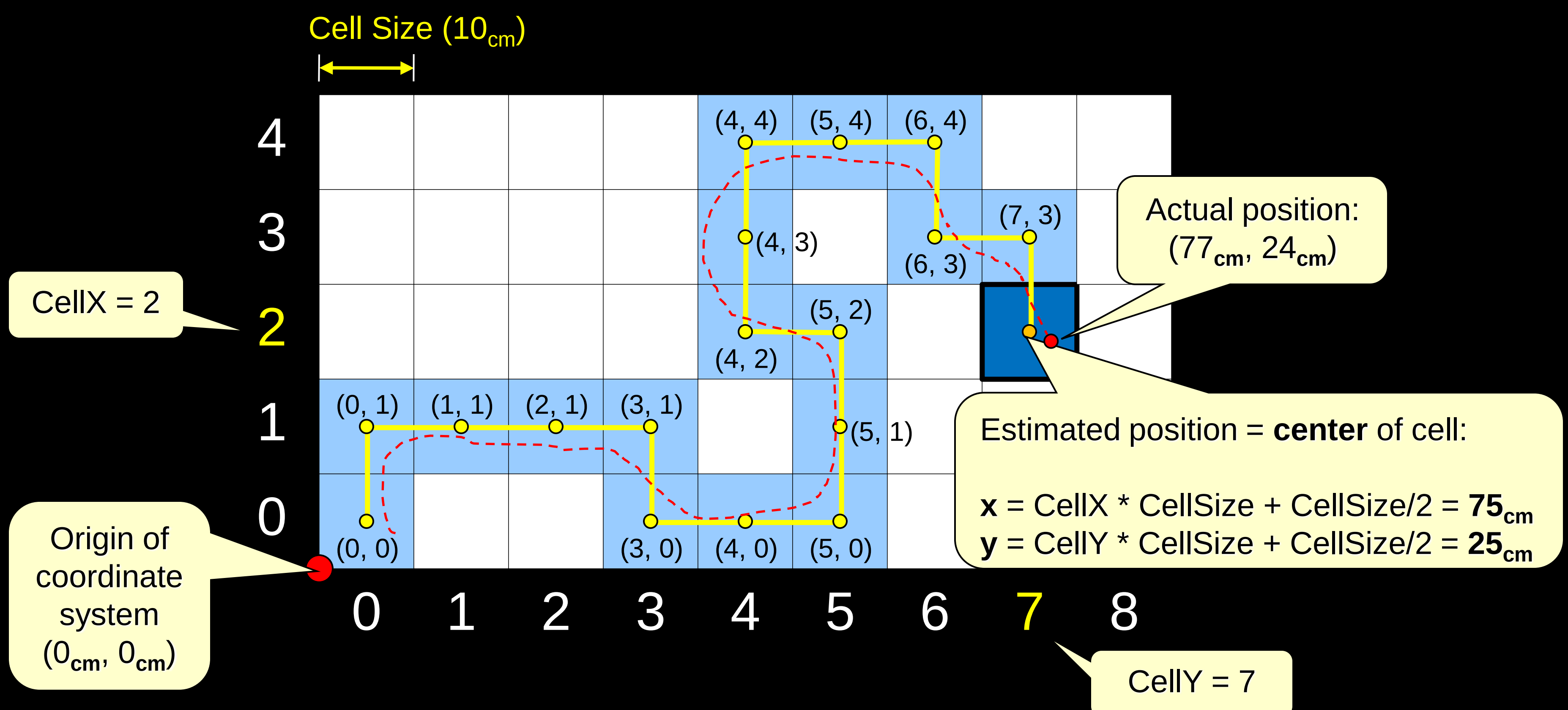


- Another position-estimation approach is to estimate the position of a robot according to its position within a fixed-size grid (just like a GPS grid cell).



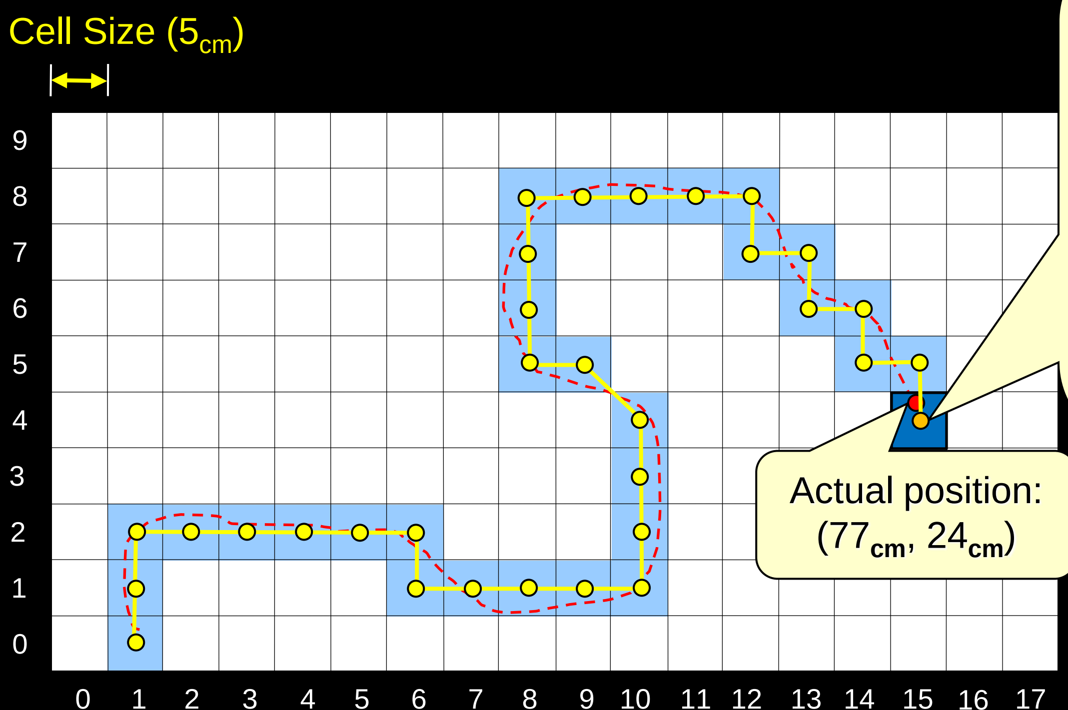
Grid-Based Estimation

- Always have rough idea of robot location at any time.
  - Need to detect when robot crosses from one cell to another, then update cell number accordingly. Assume only local sensors available.



Grid-Based Estimation

- A fine grid will produce a more accurate result.
- Path will be more “true” to actual robot path.



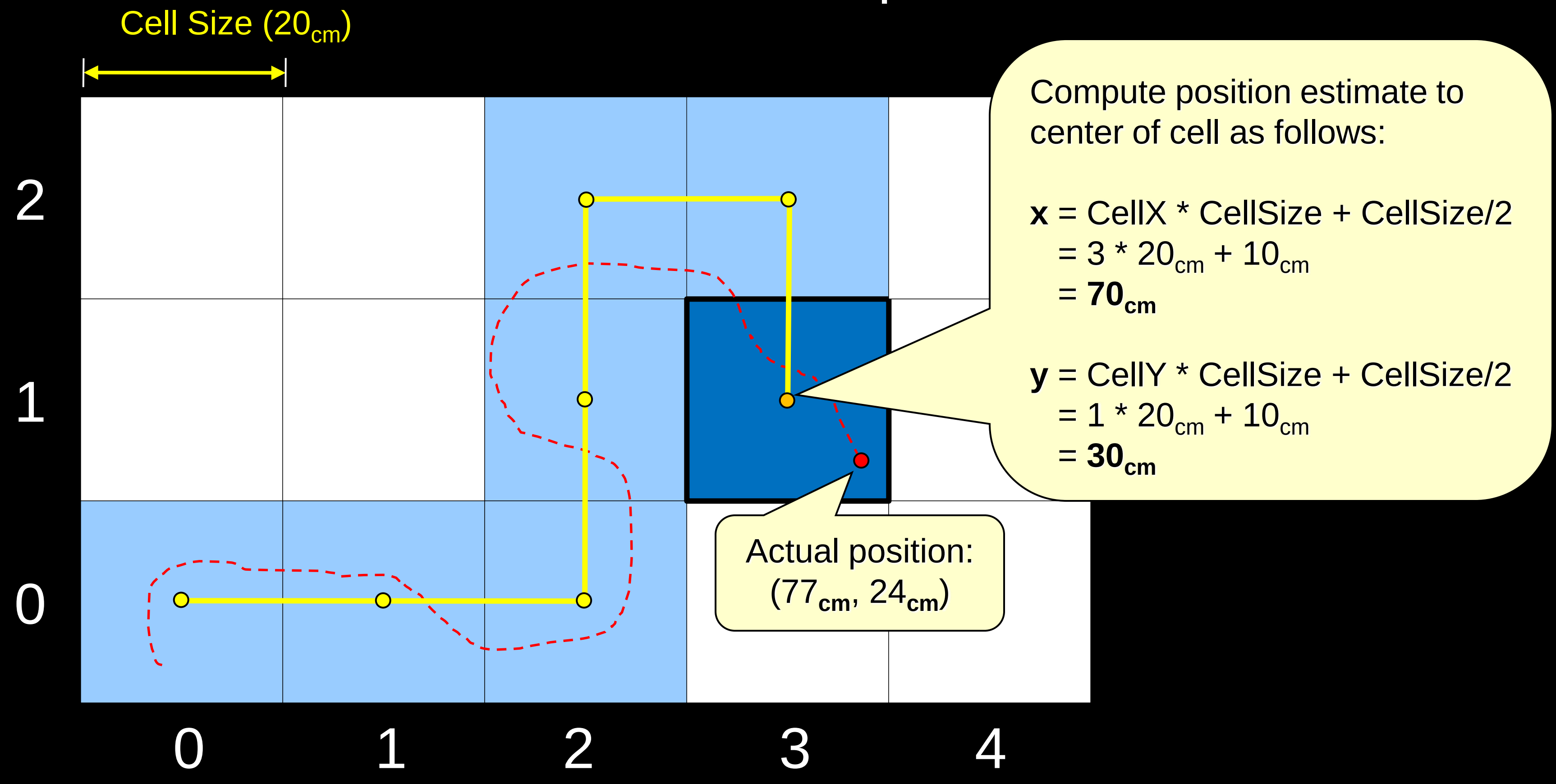
Compute position estimate to center of cell as follows:

x = CellX * CellSize + CellSize/2
= 15 * 5_{cm} + 2.5_{cm}
= $\mathbf{77.5_{cm}}$

y = CellY * CellSize + CellSize/2
= 4 * 5_{cm} + 2.5_{cm}
= $\mathbf{22.5_{cm}}$

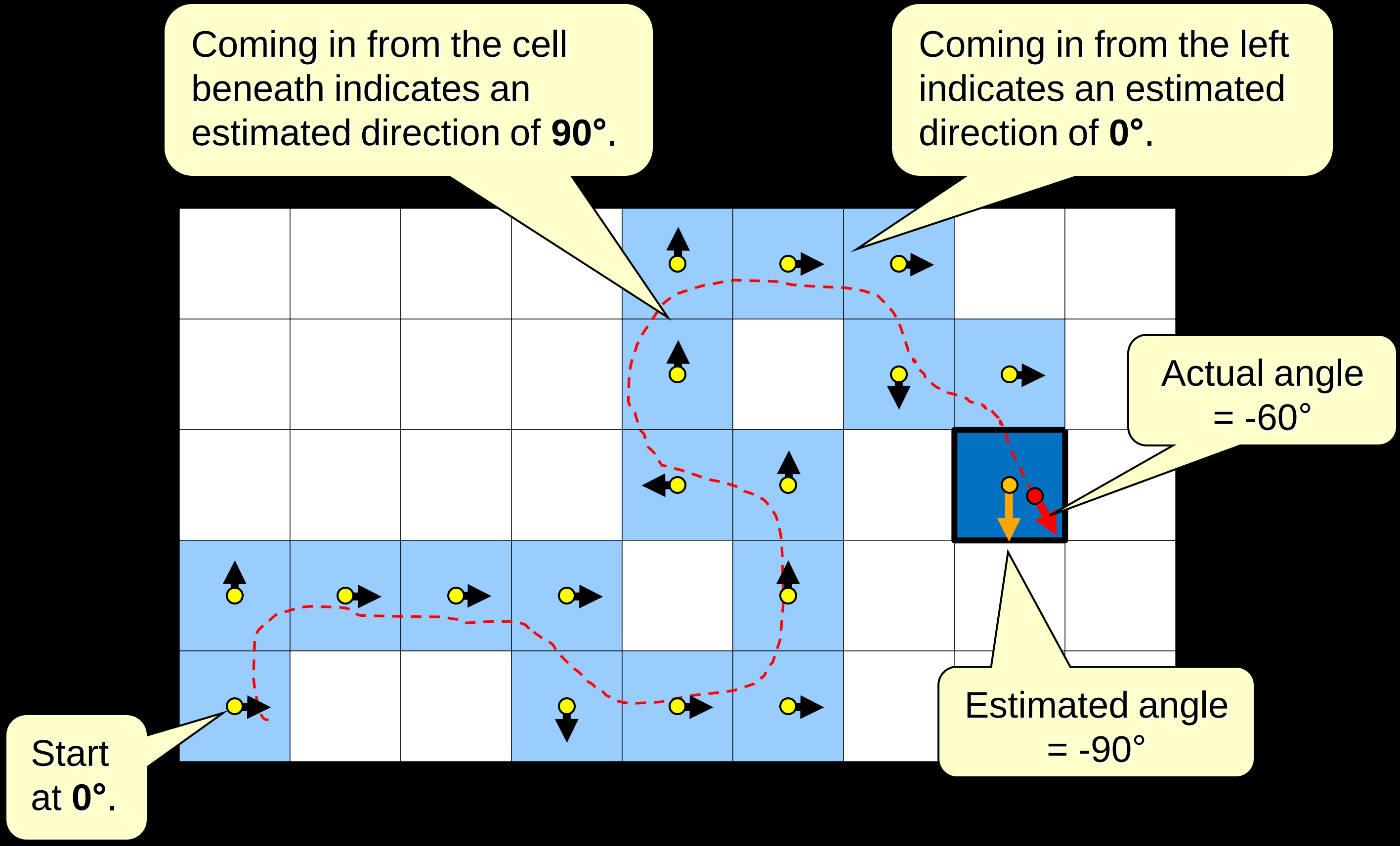
Grid-Based Estimation

- A course grid will be much less accurate.
- Path will be far off from actual robot path.



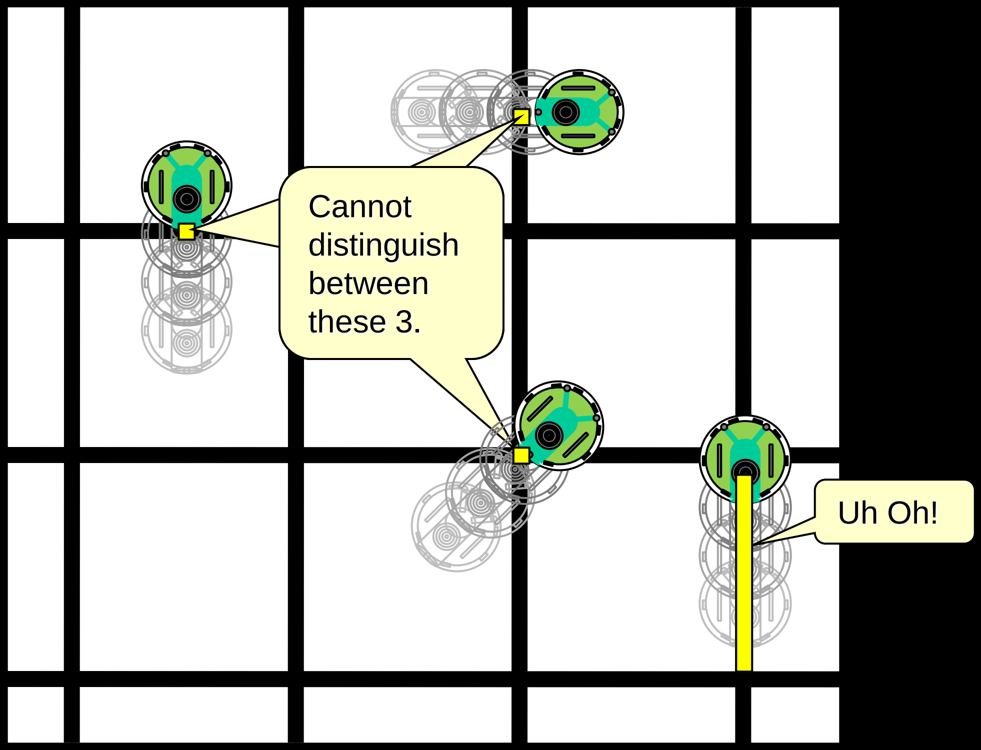
Grid-Based Estimation

- Can also “estimate” robot’s direction when the robot moves from cell to cell:



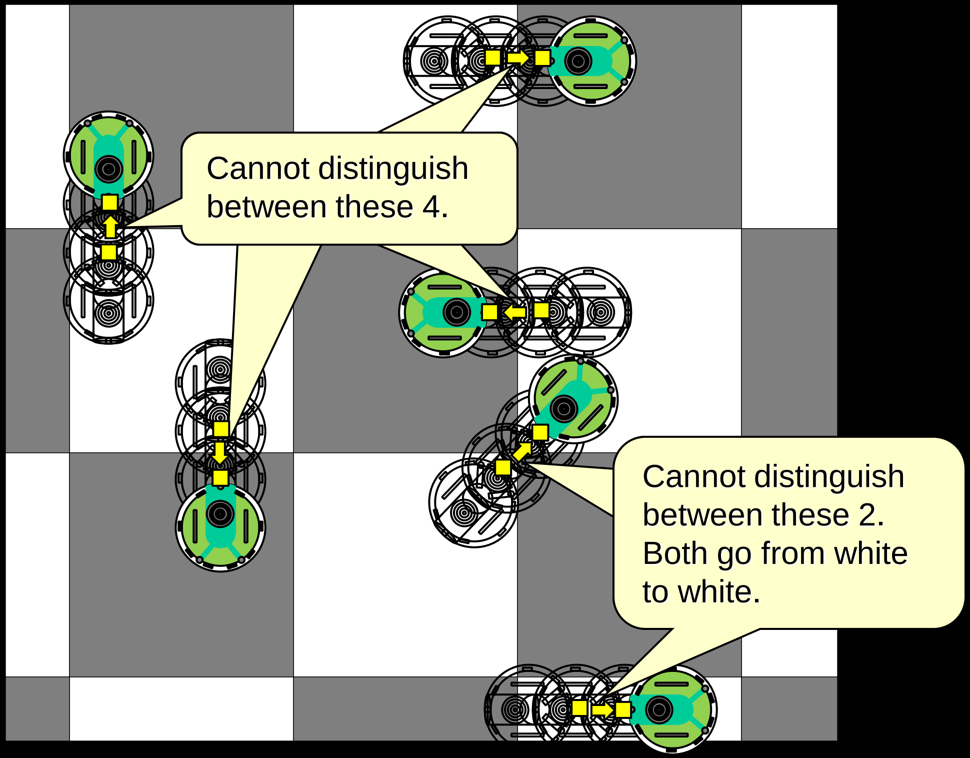
Detecting Grid Cell-Changes

- How do we know when we cross from one cell to another ?
  - Consider crossing black lines on floor with a light sensor



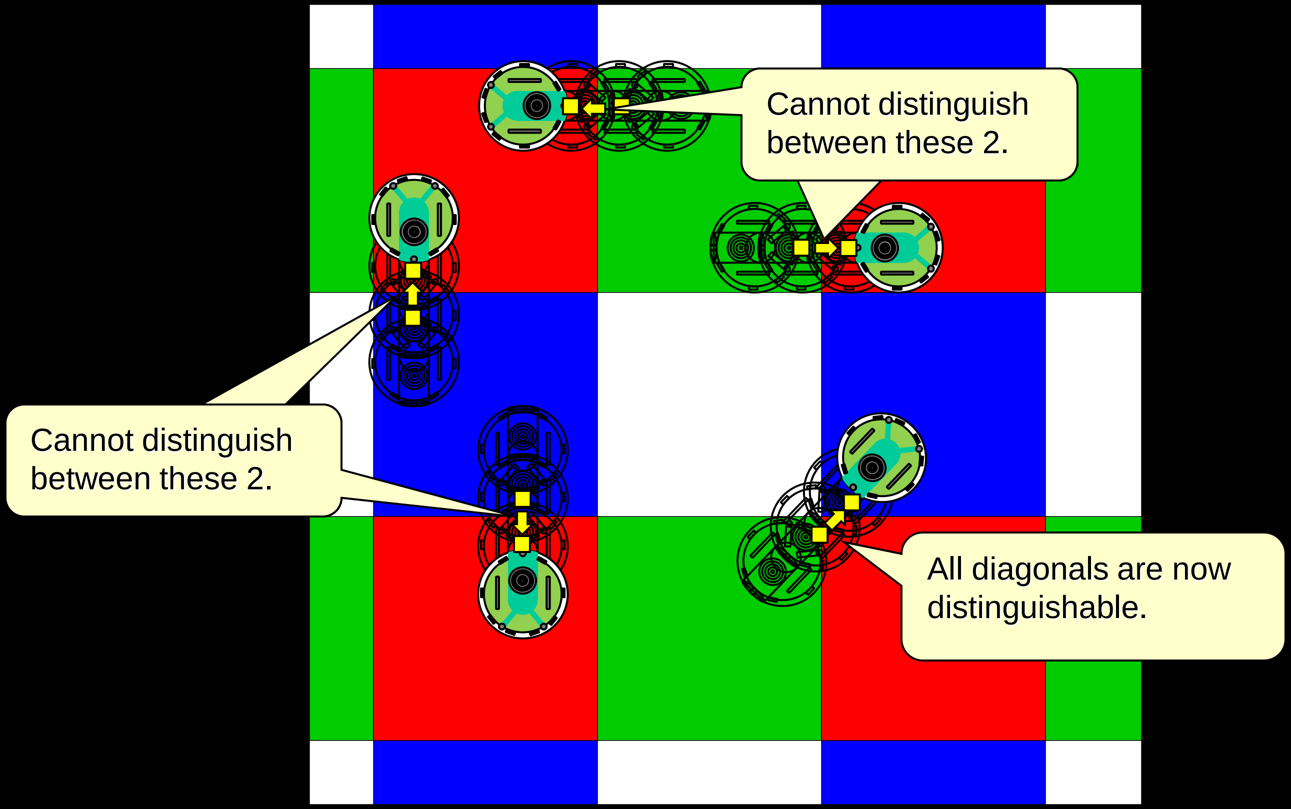
Detecting Grid Cell-Changes

- Can color cells using checkerboard pattern:
  - Can tell when going from white to black



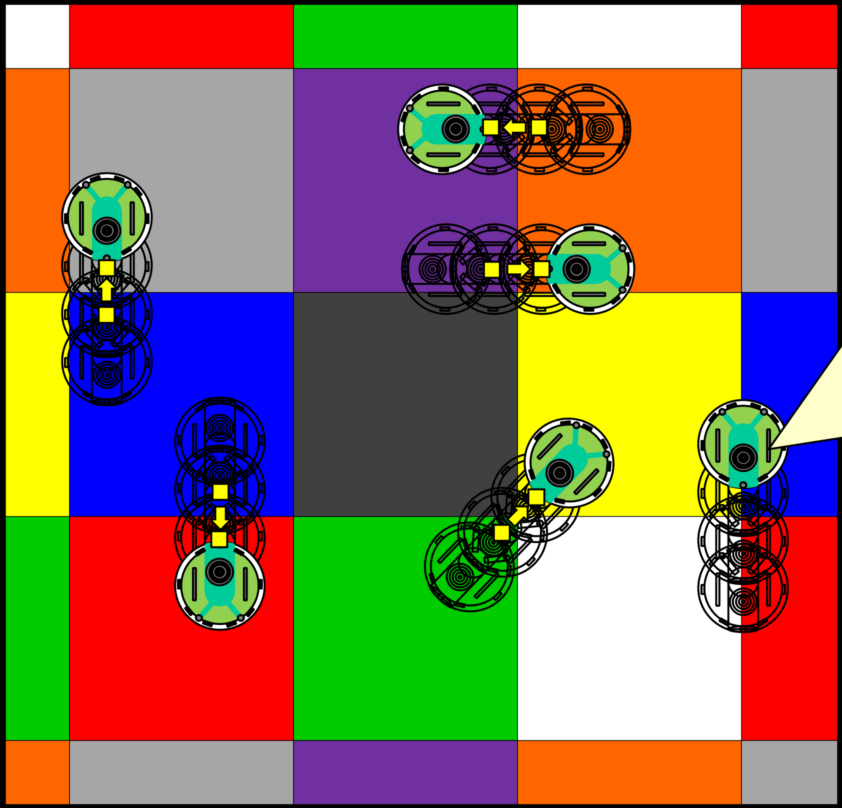
Detecting Grid Cell-Changes

- Can use 4 colors:
  - Able to detect difference between vertical and horizontal



Detecting Grid Cell-Changes

- Using 9 colors ensures unique cell-to-cell identification:

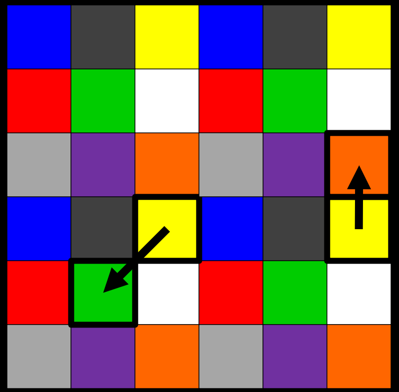


There will still be issues if the sensor lies evenly in two colors, as the reading will not match any one color.

This happens when travelling on the lines horizontally or vertically.

Detecting Grid Cell-Changes

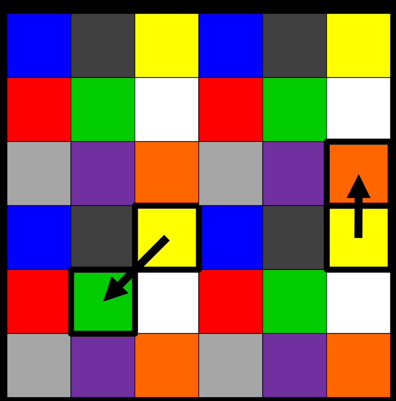
- Can define OffsetTable representing grid cell offsets when travelling from one color to each other color.
  - Elements in table indicate (x,y) cell offset when moving from cell to cell.



from\to	Red	Green	White	Blue	Black	Yellow	Gray	Purple	Orange
Red	(0,0)	(1,0)	(-1,0)	(0,1)	(1,1)	(-1,1)	(0,-1)	(1,-1)	(-1,-1)
Green	(-1,0)	(0,0)	(1,0)	(-1,1)	(0,1)	(1,1)	(-1,-1)	(0,-1)	(1,-1)
White	(1,0)	(-1,0)	(0,0)	(1,1)	(-1,1)	(0,1)	(1,-1)	(-1,-1)	(0,-1)
Blue	(0,-1)	(1,-1)	(-1,-1)	(0,0)	(1,0)	(-1,0)	(0,1)	(1,1)	(-1,1)
Black	(-1,-1)	(0,-1)	(1,-1)	(-1,0)	(0,0)	(1,0)	(-1,1)	(0,1)	(1,1)
Yellow	(1,-1)	(-1,-1)	(0,-1)	(1,0)	(-1,0)	(0,0)	(1,1)	(-1,1)	(0,1)
Gray	(0,1)	(1,1)	(-1,1)	(0,-1)	(1,-1)	(-1,-1)	(0,0)	(1,0)	(-1,0)
Purple	(-1,1)	(0,1)	(1,1)	(-1,-1)	(0,-1)	(1,-1)	(-1,0)	(0,0)	(1,0)
Orange	(1,1)	(-1,1)	(0,1)	(1,-1)	(-1,-1)	(0,-1)	(1,0)	(-1,0)	(0,0)

Detecting Grid Cell-Changes

- Can define AngleTable representing estimated angle when travelling from one color to each other color.
  – Value in table is new angle estimate.



from\to	Red	Green	White	Blue	Black	Yellow	Gray	Purple	Orange
Red	---	0°	180°	90°	45°	135°	-90°	-45°	-135°
Green	180°	---	0°	135°	90°	45°	-135°	-90°	-45°
White	0°	180°	---	45°	135°	90°	-45°	-135°	-90°
Blue	-90°	-45°	-135°	---	0°	180°	90°	45°	135°
Black	-135°	-90°	-45°	180°	---	0°	135°	90°	45°
Yellow	-45°	-135°	-90°	0°	180°	---	45°	135°	90°
Gray	90°	45°	135°	-90°	-45°	-135°	---	0°	180°
Purple	135°	90°	45°	-135°	-90°	-45°	180°	---	0°
Orange	45°	135°	90°	-45°	-135°	-90°	0°	180°	---

Computing Grid-Based Estimate

0	1	2
3	4	5
6	7	8

$x = 0_{cm}$, $y = 0_{cm}$, $\theta = 0°$

Can be any starting location and angle.

r = read ground sensor

i_p= getColorIndex(r) as an int from **0-8**, or **9** if no match

i_p = previous index

repeat {

  move robot in some way …

  r = read ground sensor

  i_c= getColorIndex(r) as an int from 0-8, or 9 if no match

i_c = current index

  if (i_p != i_c) **then** {

Only calculate new position if color changed

    $x = x + \text{OffsetTable}[i_p][i_c].x * \text{CELL\_WIDTH}_{cm}$

cell width & height are constants

    $y = y + \text{OffsetTable}[i_p][i_c].y * \text{CELL\_HEIGHT}_{cm}$

    $\theta = \text{AngleTable}[i_p][i_c]$

Angle does not depend on previous angle

    if ($\theta > 180°$) **then** $\theta = \theta - 360°$

    if ($\theta < -180°$) **then** $\theta = \theta + 360°$

Keep angle within -180° to +180° range

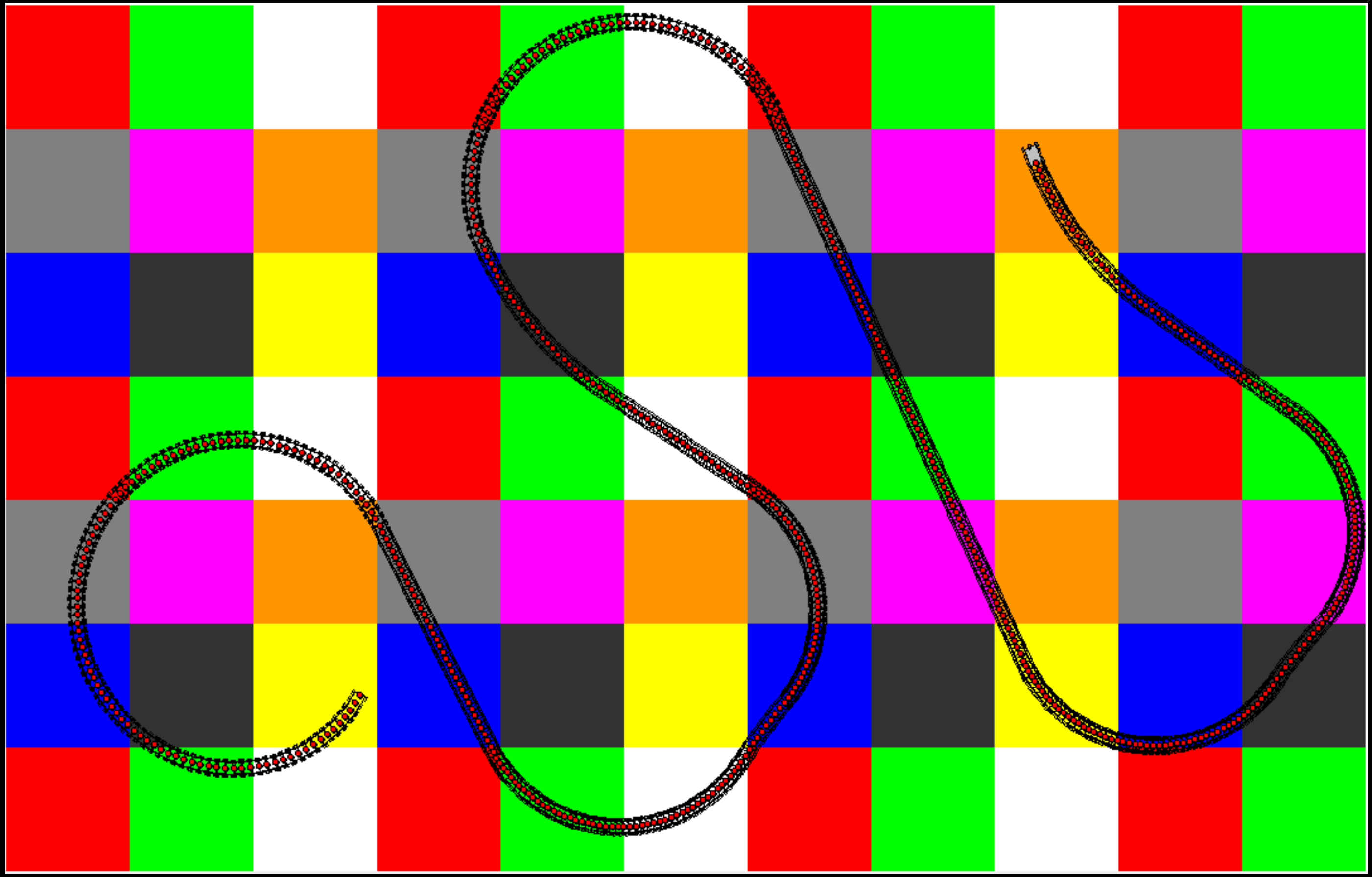
  }

  $i_p = i_c$

}

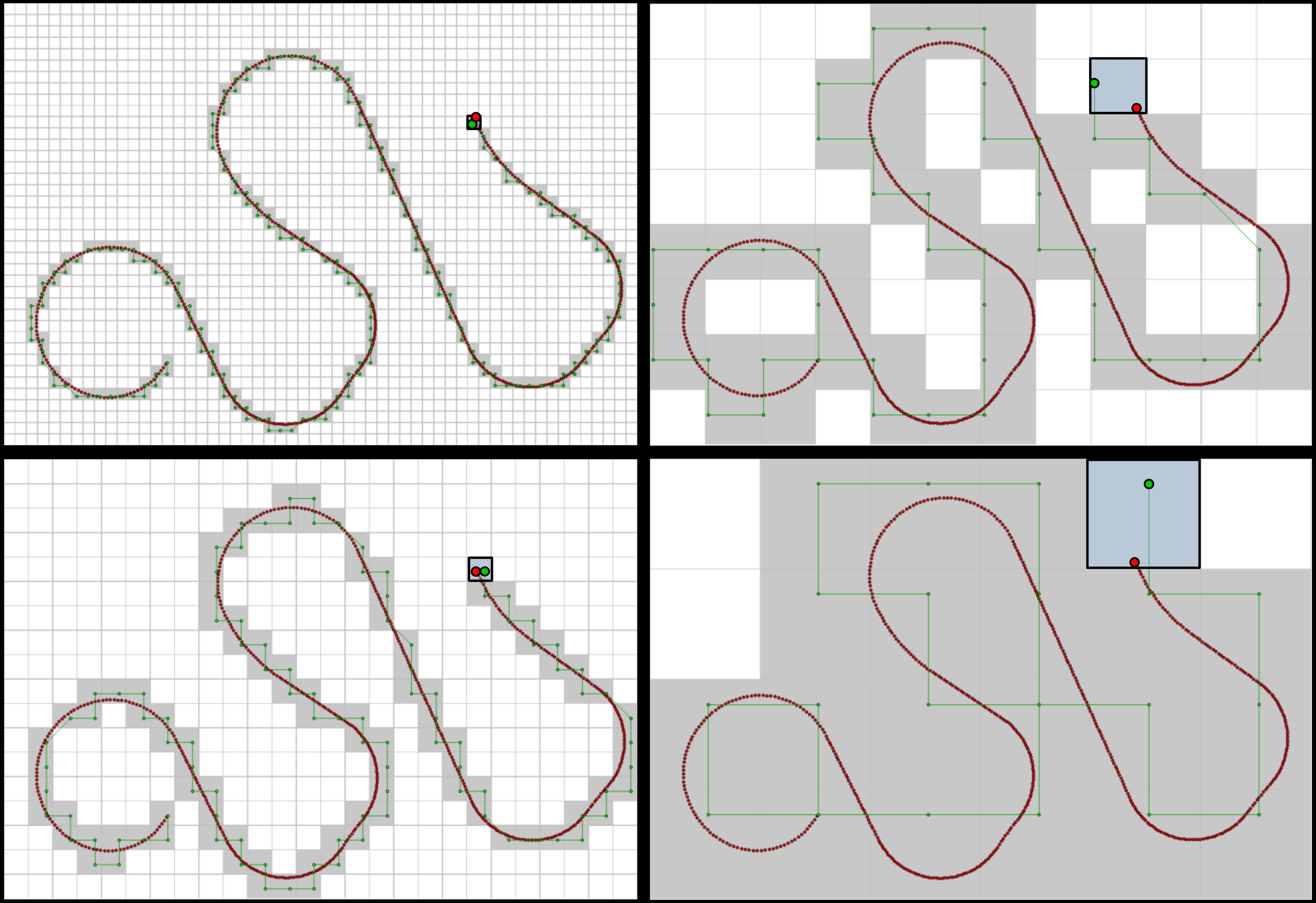
Grid-Based Experiments

- Consider an entire floor with the colored tile pattern:



Grid-Based Results

- Here are some results for various cell sizes:

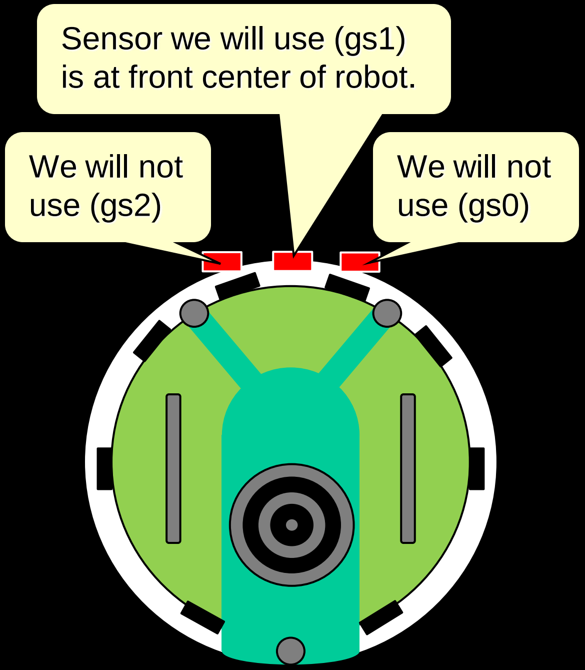


E-Puck Ground Sensor

- The e-puck has an expansion pack that allows 3 ground sensors to detect the amount of light under the front of the robot.

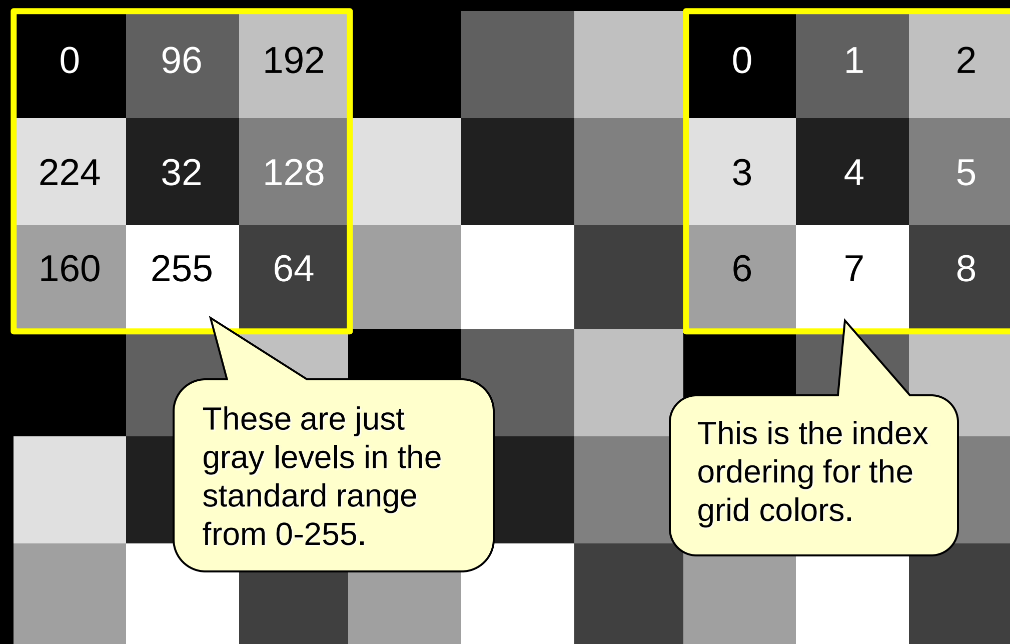
```java
import com.cyberbotics.webots.controller.Device;

// Ground sensor is a Device that behaves like a DistanceSensor
DistanceSensor  groundSensor;

// Go through the devices and look for sensor named "gs1"
// because it is not part of the standard e-puck robot
int   numDevices = robot.getNumberOfDevices();
for (int i=0; i<numDevices; i++) {
  Device d = robot.getDeviceByIndex(i);
  if (d.getName().equals("gs1")) {
    groundSensor = (DistanceSensor)d; // Typecast is needed
    groundSensor.enable(timeStep);
  }
}

// while (…) {
     // Read the sensor like a distance sensor
     // returns value from 0 to 1000
     double reading = groundSensor.getValue();
// }
```

You MUST read the sensor from INSIDE the WHILE loop



Webots – Positioning Grid

- Cover the entire floor with a grayscale grid pattern (since ground sensors detect light intensity, not colors).
- 9 gray levels at furthest range apart is 255/9 ~= 32 gray shades apart from each other.
- Shades scattered to maximize gray level changes when moving horizontal and vertical



Here is a typical ground sensor reading for the given gray shades. However, the values will fluctuate quite a bit.

300	720	822
842	525	767
800	858	644

Start the Lab …