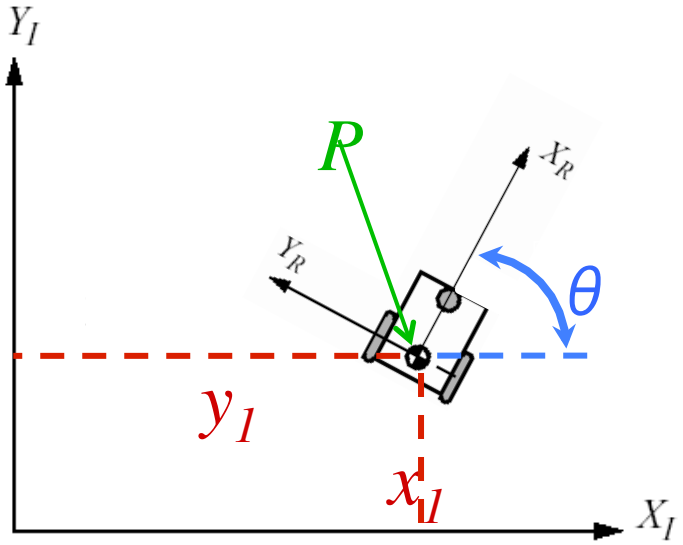
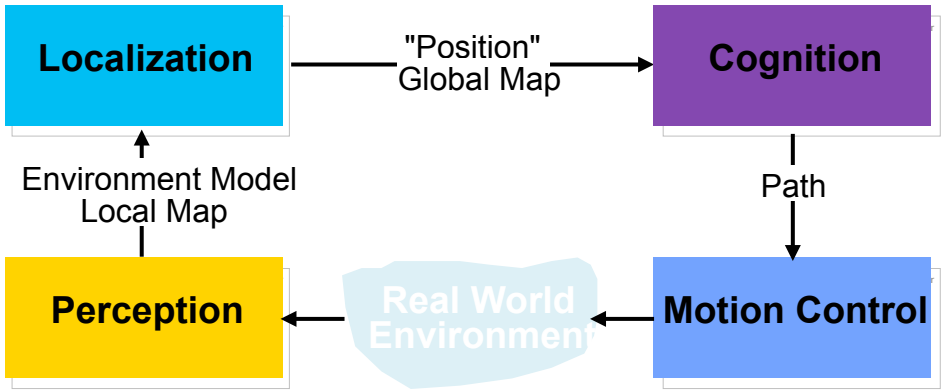
Kinematics

Mobile Kinematics



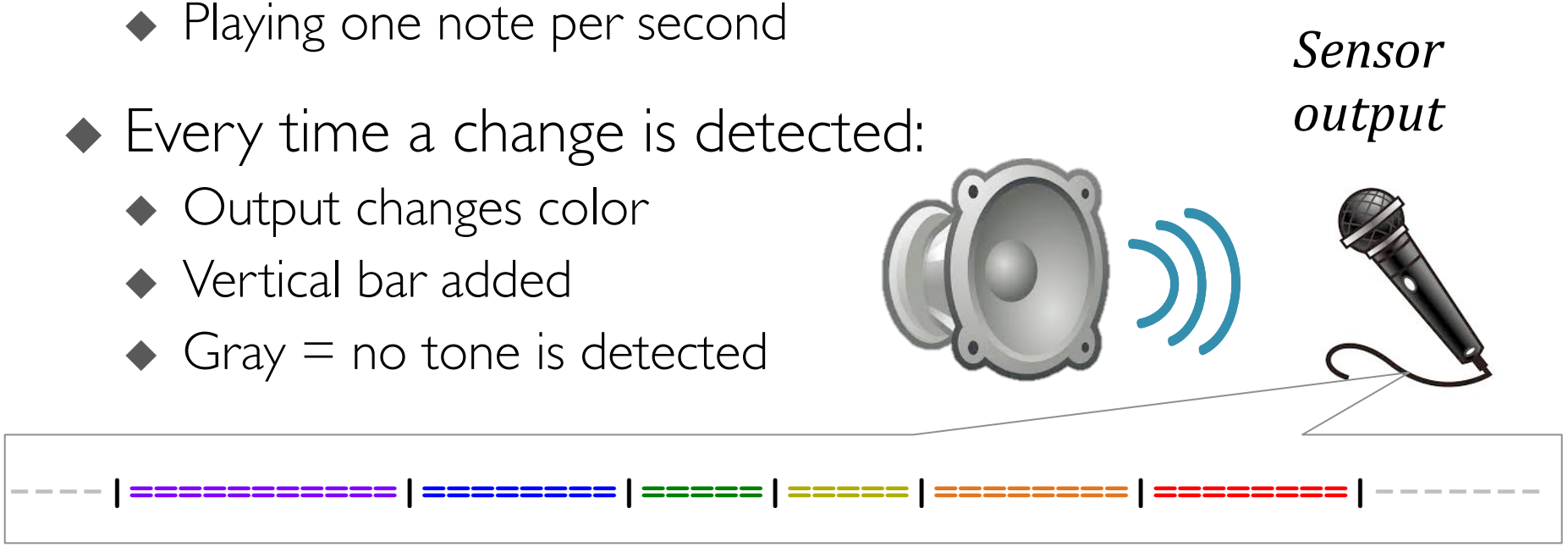


Bookkeeping

- Upcoming
  - Assignment 2
- Quiz 2
  - Curve TBD: probably ~8%
  - A note on number/length of answers
- Today
  - Quiz 2 review
  - Mobile Robot Kinematics
- Reading: SNS 3.2 (should now have 3.1-3.3)

About That Microphone

- 5-hertz sampling rate
- Sequential notes
  - Playing one note per second
- Every time a change is detected:
  - Output changes color
  - Vertical bar added
  - Gray = no tone is detected



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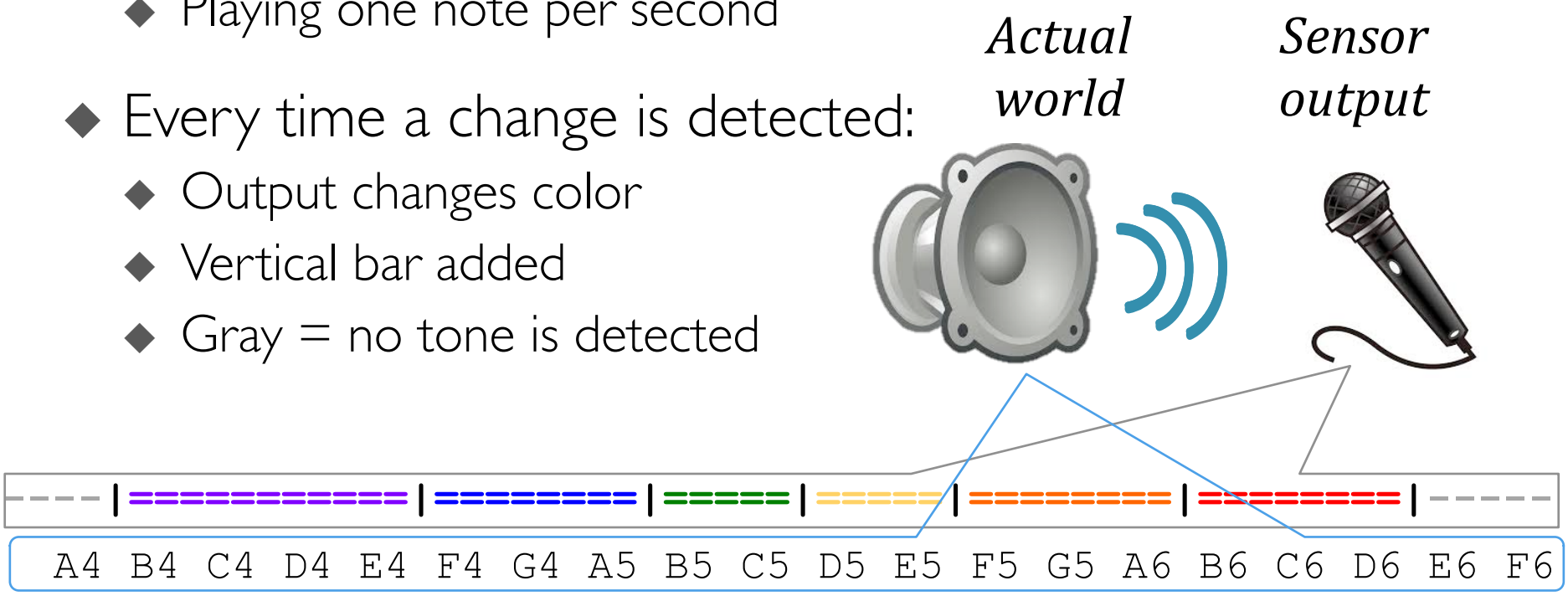
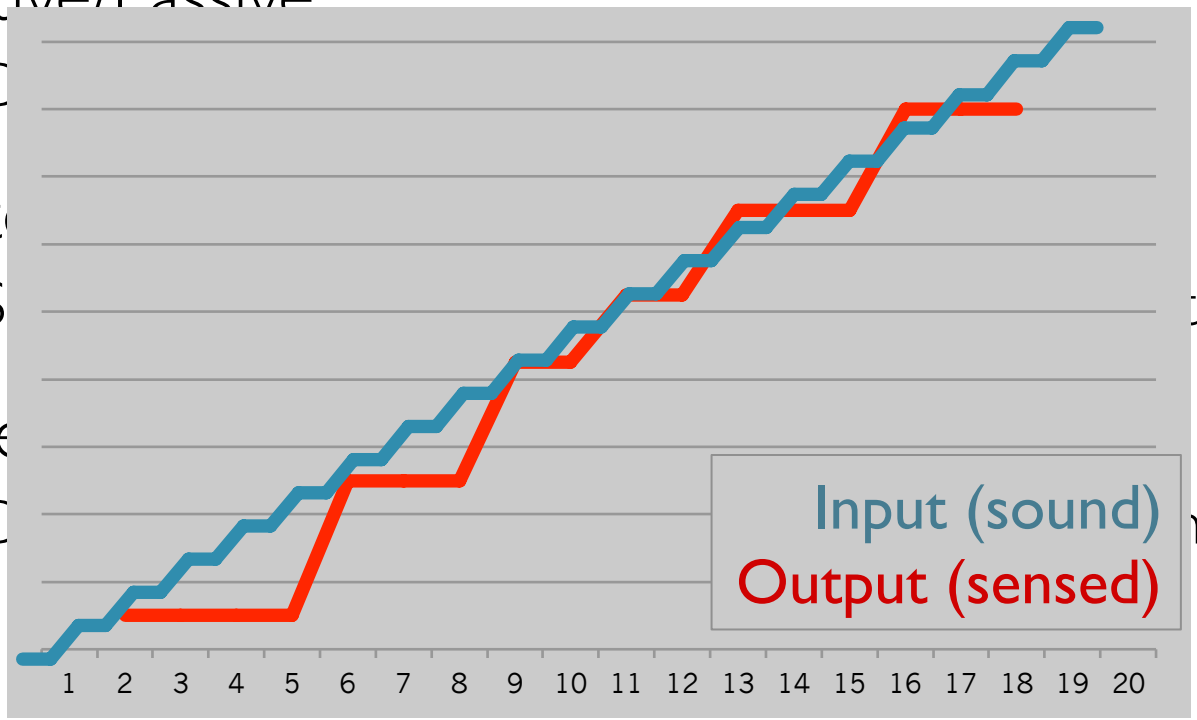


Characterizing Sensors

- Active/Passive
  - Does it put energy out into the world?
- Exteroceptive/Proprioceptive
  - Senses the world around it, *vs.* sensing internal state
- Linear/Nonlinear
  - Does the output function vary with respect to input function?

Characterizing Sensors

- Active/Passive
  - D
- Ext
  - S
- Line
  - D



tate

nput function?

Detecting Changes

7 **Doesn't detect a change every note because…**

- Sampling Rate: how often the sensor can take a reading
  - Notes are playing 1/second
  - Sensor is 5 Hz – 5 samples per second
- Cross-Sensitivity: sensitive to something *other than* target signal
  - E.g., a mic is supposed to pick up sound but also picks up EM noise
- Sensitivity: Ratio of output change to input change
  - How much change in world affects change in sensor readings
  - E.g., does the reading change every note? Every 1/10th note?

Classification

8 The way this microphone reports output suggests that it is an:

- Incremental sensors
  - Reports an incremental change (up/down, warmer/cooler)
- Absolute sensors
  - Unambiguously reports its state
- This mic:
  - Every time a change is detected, output changes color, vertical bar added

Sidebar: is this how microphones work?

Range and Resolution

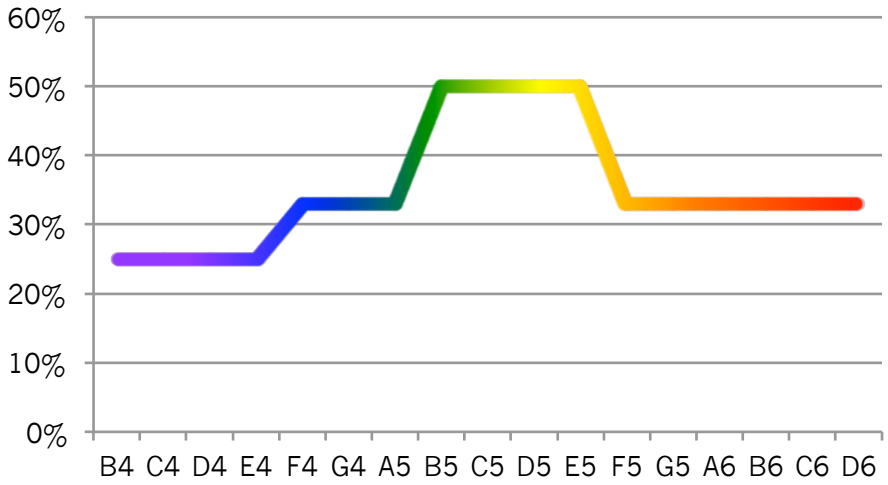
- Range of a sensor:
  - Upper limit to lower limit
- Resolution
  - Minimum measurable difference between any two values

Representing Uncertainty

- "A *probability mass function* gives the **probability** that a discrete random variable is **equal to** some value."
  - Given green output, what is the probability the input is B5?
  - What is the hidden variable we want?
    - The thing we don't know for certain but are trying to sense.
- Given some input, what is the probability of the output being a particular note?
- What does that look like across all notes in the range?

Representing Uncertainty

- Graph: given some input, likelihood of knowing the correct output



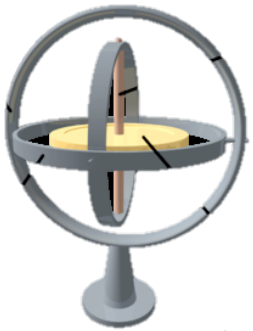
- **Unimodal?**
  - One hump
- **Bimodal?**
  - Two humps
- **Zero mean?**
  - Equally likely to be wrong up or down
- **Asymmetric?**
  - Same error distribution above and below zero

Depth / Range Sensing

- Structured Light: display a known pattern of light and dark and measure geometric distortion.
  - Kinect
- Time-of-flight: emit a wave and measure time for it to reach something and reflect back.
  - Laser range-finder, Sonar, Kinect 2
- Stereo: two calibrated cameras see a scene from different angles and calculate depth based on disparities.
  - Humans, Bumblebee sensor

Heading Sensor

- Tells you what direction you are pointed
  - With respect to some frame of reference
  - Is this **position** or **orientation**?
- What do the following tell you?
  - Compass
  - Gyroscope
  - Inclinometer
  - GPS
  - Location beacons



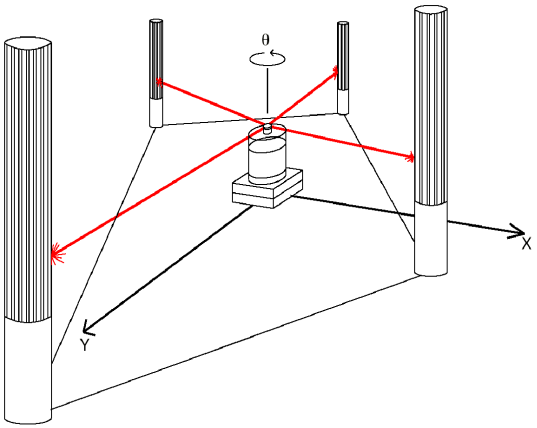


Image Processing

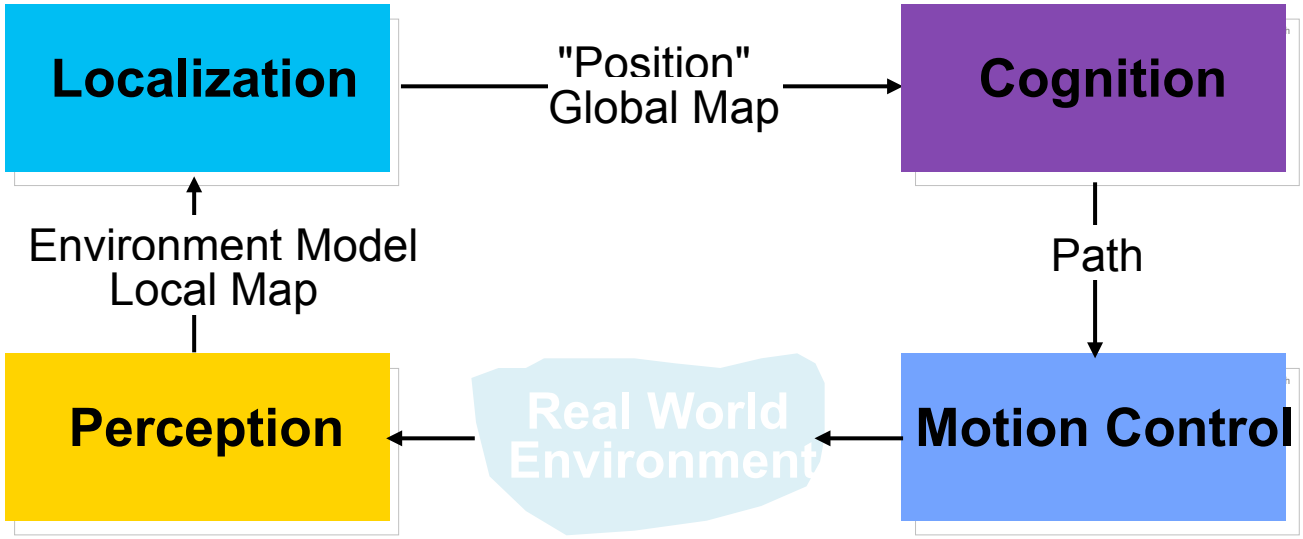
- What type of processing has been performed here?
- We looked at edge detection, corner detection, blob finding

Types of Errors

- Systematic error → deterministic failures
  - Caused by factors that can (in theory) be modeled
  - Can be corrected with calibration
- Random error → non-deterministic failures
  - No modeling or prediction possible
- How would you correct for…
  - "Fisheye" distortion on a camera lens.
  - Background noise picked up by a microphone.
  - Thermometer readings that are occasionally too high or too low.
  - A range-finding sensor that reads things as being too close.
  - Sonar distortion in an unfamiliar underwater environment.

Wheeled Motion Control

- Requirements for Motion Control
  - Kinematic / dynamic model of the robot
  - Model of interaction between the wheel and the ground
  - Definition of required motion → speed & position control
  - A control law that satisfies the requirements



Mobile Robot Kinematics

- Aim
  - Description of mechanical behavior of the robot for:
    - Design purposes – how do we design it to do what we need?
    - Control purposes – how do we then get it to do that?
  - Mobile robots can move with respect to environment
    - No direct way to measure the robot's position
    - Position must be integrated over time
    - Leads to inaccuracies of the position (motion) estimate
  - Understanding mobile robot motion starts with understanding constraints on the robot's mobility

Mobile Position & Orientation

Frames of reference:

$\{X_I, Y_I\}$: Global
$\{X_R, Y_R\}$: Robot

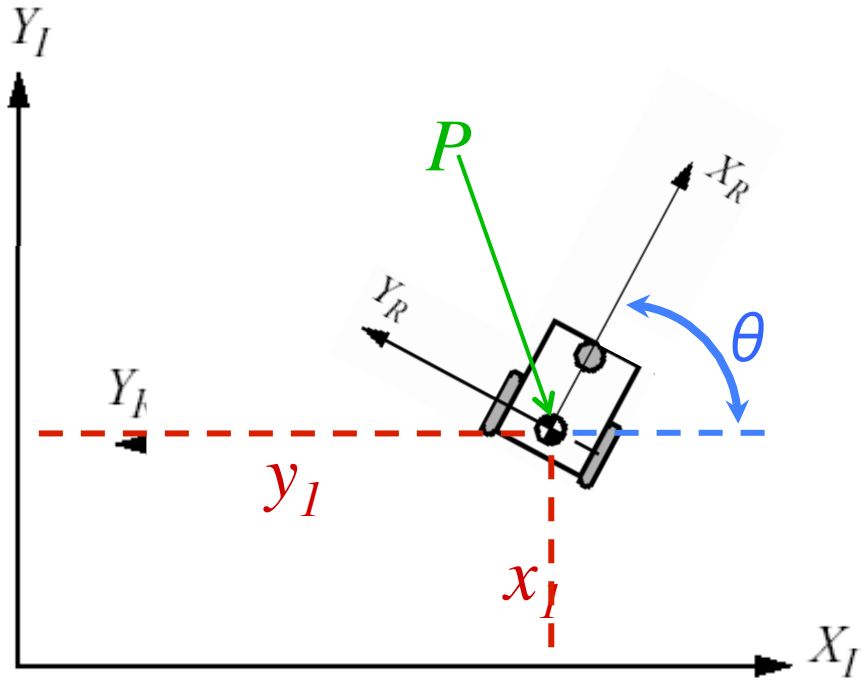
Robot: point P

Position (of P):

$\{x_{I,1}, y_{I,1}\}$

Heading:

$\{\theta\}$: I ∠ R



$$\xi_I = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix}$$