COL778: Principles of Autonomous Systems
Semester II, 2023-24

Physical Agent Representation - II

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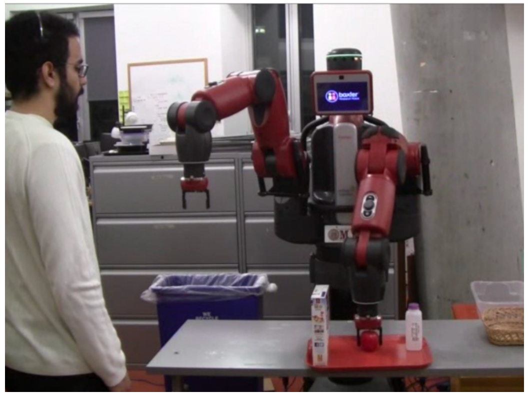
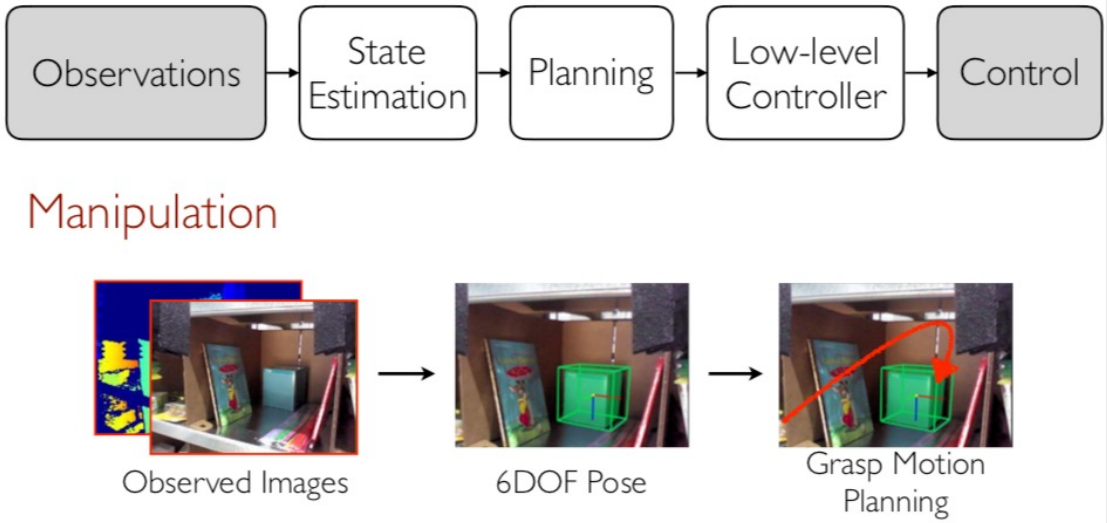
Today’s lecture

- Last Class
  - Physical Agent Representation - I
- This Class
  - Physical Agent Representation – II

From Observations to Physical Actions

- State Estimation
  - What is the state of the agent and the environment.
- Planning
  - (High-level)Sequence of actions to reach the goal.
- Low-level Control
  - Performing each action reliably.





Primer: How to sense the environment?

- Sensing
  - Exteroceptive Sensors
    - Extrinsic to the agent
  - Proprioceptive Sensors
    - Intrinsic to the agent

Visual Sensors

Static Sensors

The goal is to extract a low-dimensional representation from the sensor information.

Active Sensors

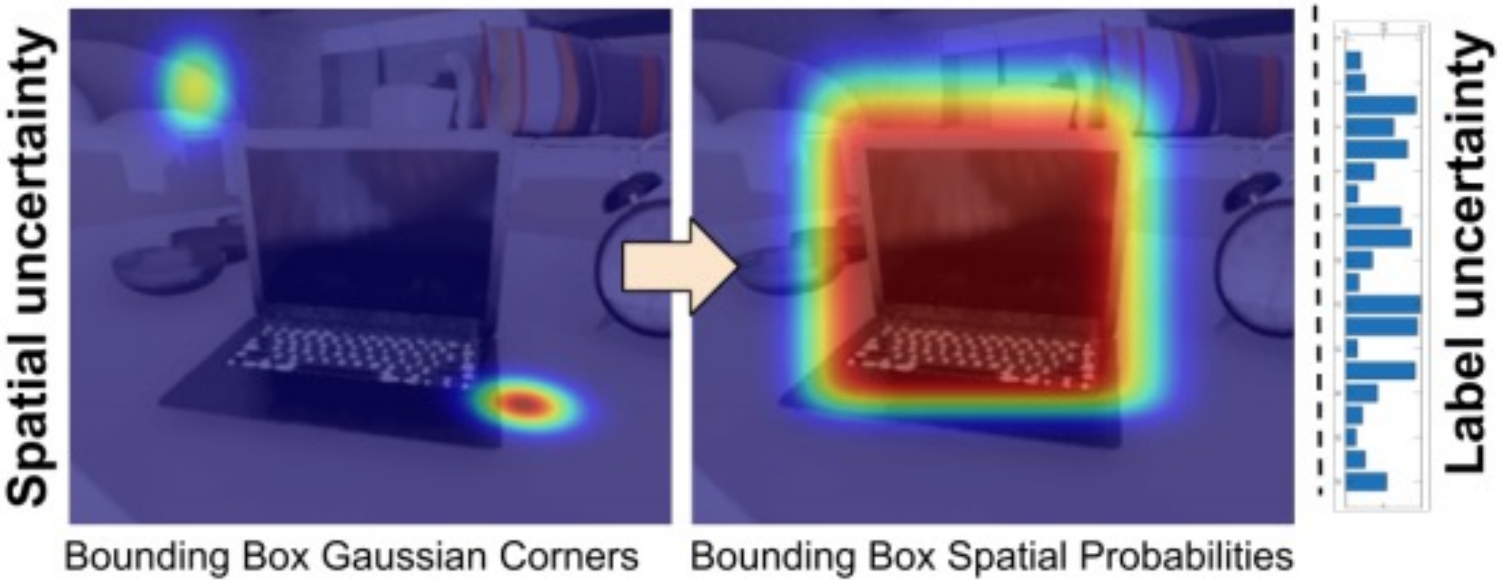
Examples

http://www.cvlibs.net/datasets/kitti/eval_semseg.php?benchmark=semantics2015

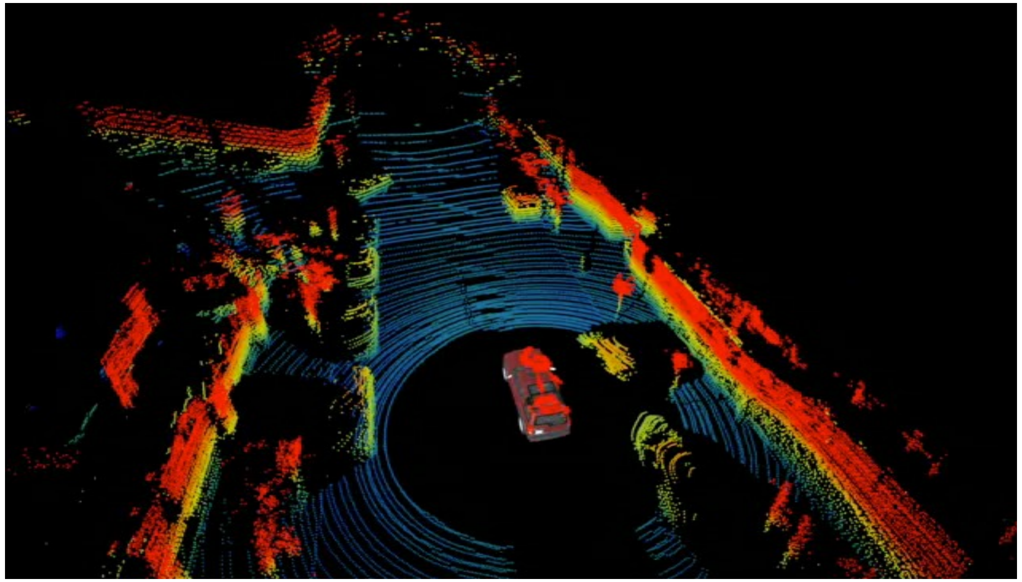
https://github.com/facebookresearch/detectron2

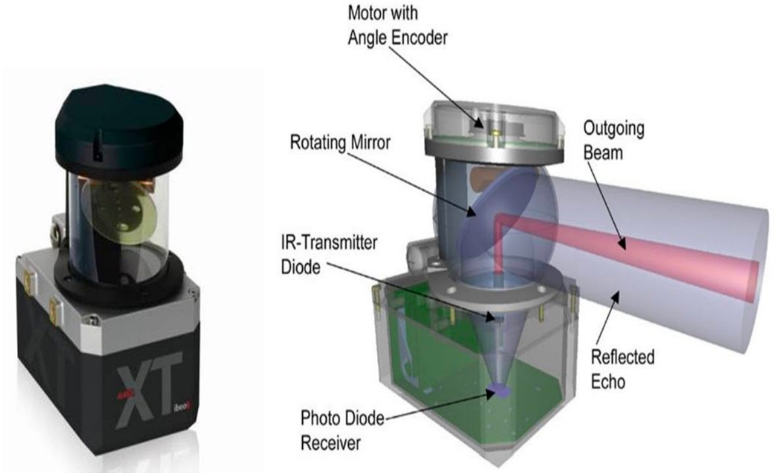
Uncertainty

- Spatial uncertainty
  - Ambiguity in the location of the object.
- Label Uncertainty
  - Uncertainty emanating from what the object is.

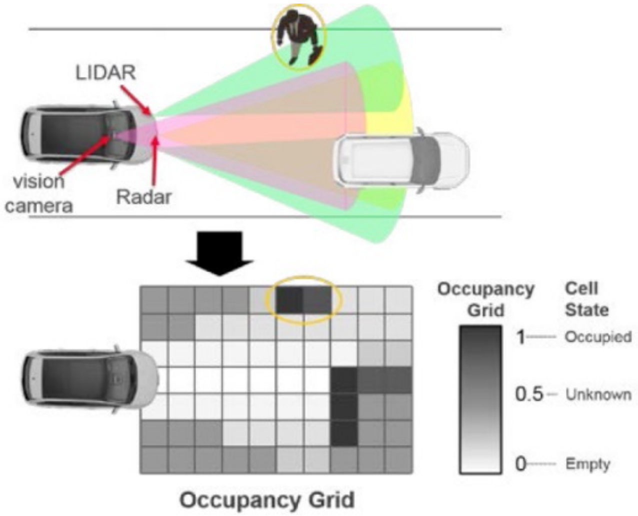


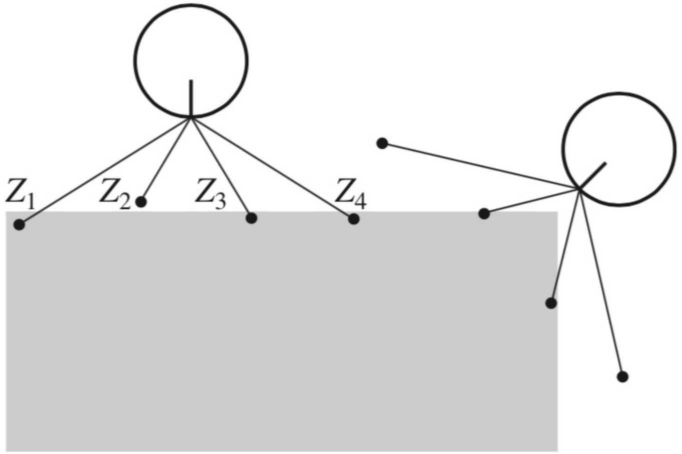
Lidar Sensors





Occupancy maps

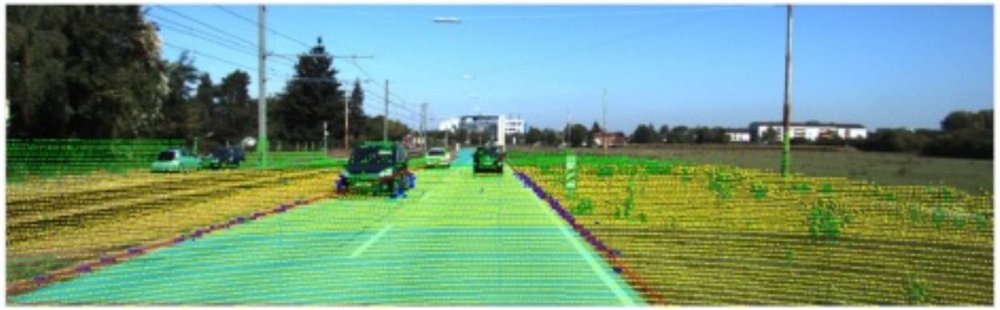




Scanning beams and returns

Multi-modality

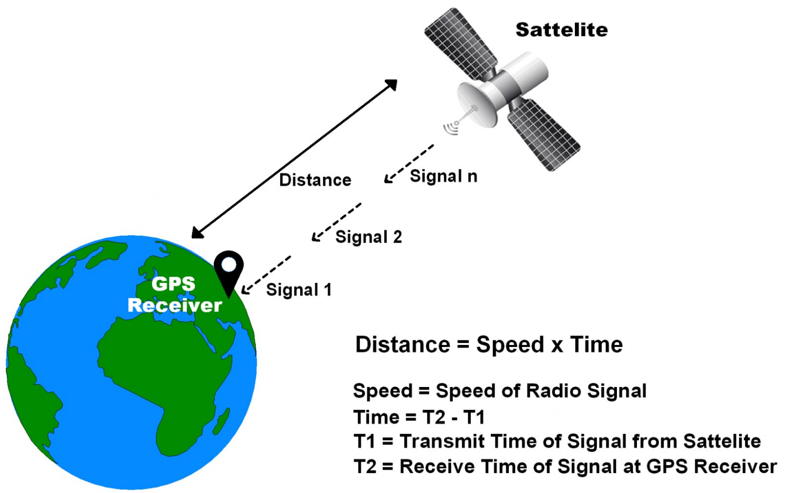
Often a combination of sensors are used. E.g., what portions are drivable? Generating hypothesis for a second modality.



(a) Result of ground surface extraction and boundary regression (The ground truth of drivable road region is presented in light blue. Yellow denotes ground surface. The green points represent obstacles. Feature points are denoted in blue, and the regressed road boundaries are plotted as red lines)

(b) Final result of drivable road region detection (The green color denotes true positives, blue color representing false positives and red color being false negatives)

Positioning: GPS



Time of flight measurements from in-sight satellites.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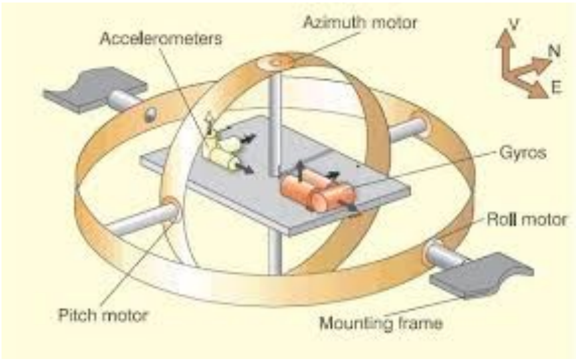
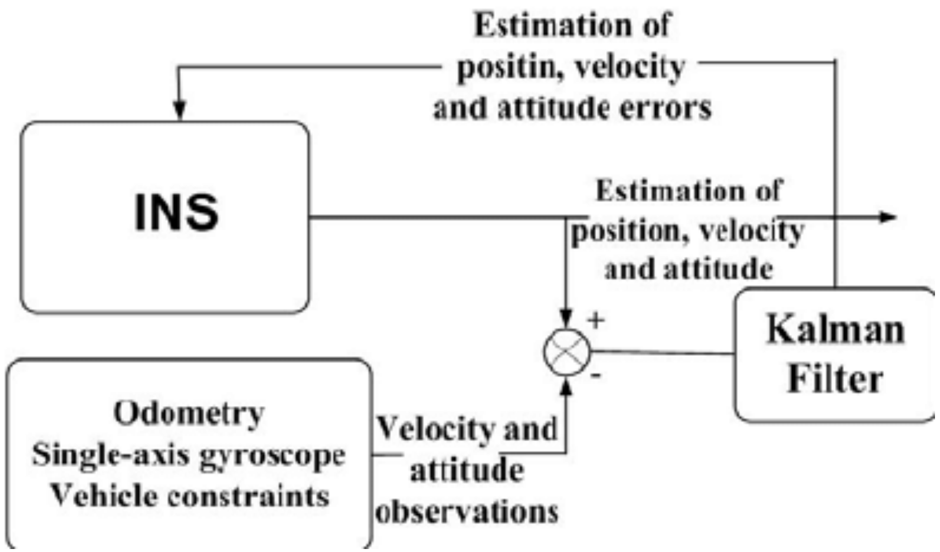
$GPRMC,235316.000,A,4003.9040,N,10512.5792,W,0.09,144.75,141112,,*19
$GPGGA,235317.000,4003.9039,N,10512.5793,W,1,08,1.6,1577.9,M,-20.7,M,,0000*5F
$GPGSA,A,3,22,18,21,06,03,09,24,15,,,,,2.5,1.6,1.9*3E
```

Time: 235317.000 is 23:53 and 17.000 seconds in Greenwich mean time
Longitude: 4003.9040,N is latitude in degrees. decimal minutes, north
Latitude: 10512.5792,W is longitude in degrees. decimal minutes, west
Number of satellites seen: 08
Altitude: 1577 meters

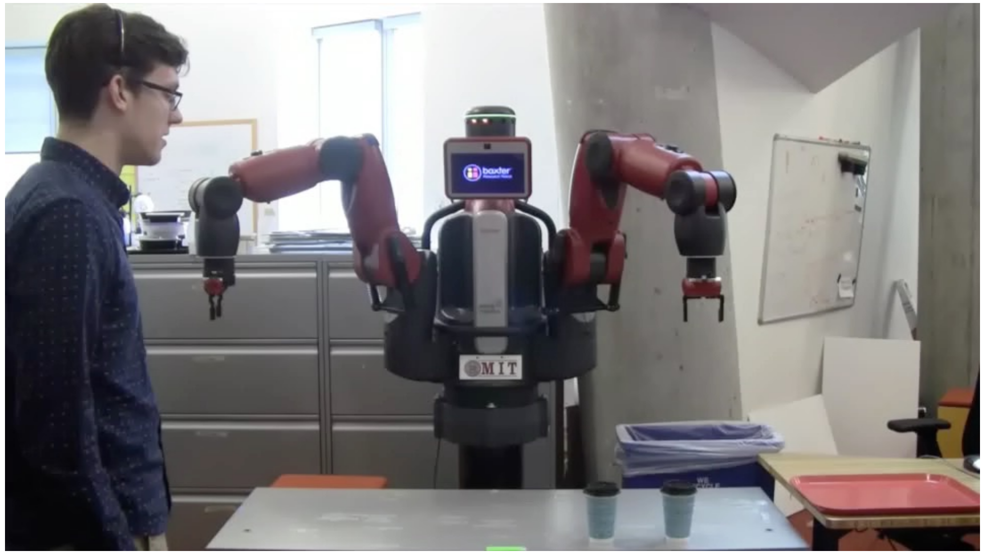
Proprioceptive Sensors

- Inertial Measurement Unit
- Detecting linear acceleration using accelerometers
- Rotational rate using gyroscopes.
- Measurements are fused.
- Provide a *measurement* of actions taken by the robot.

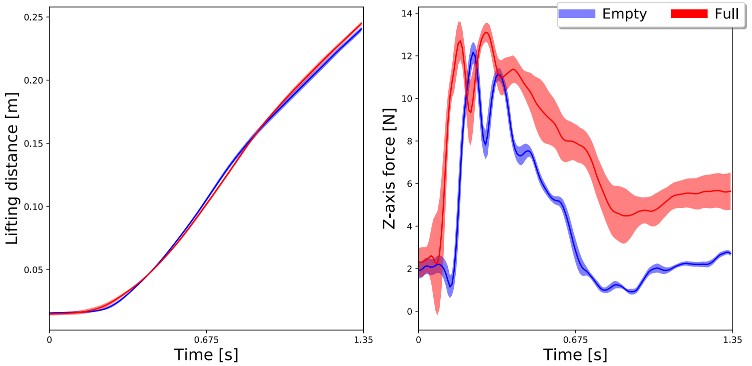


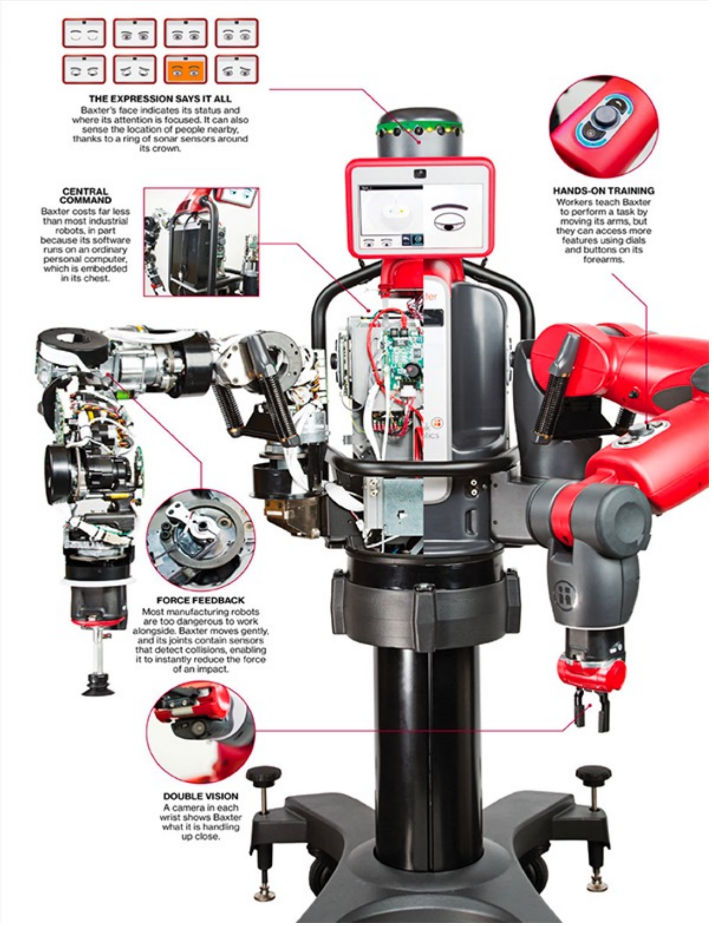


Force Sensors



Force signatures during interaction

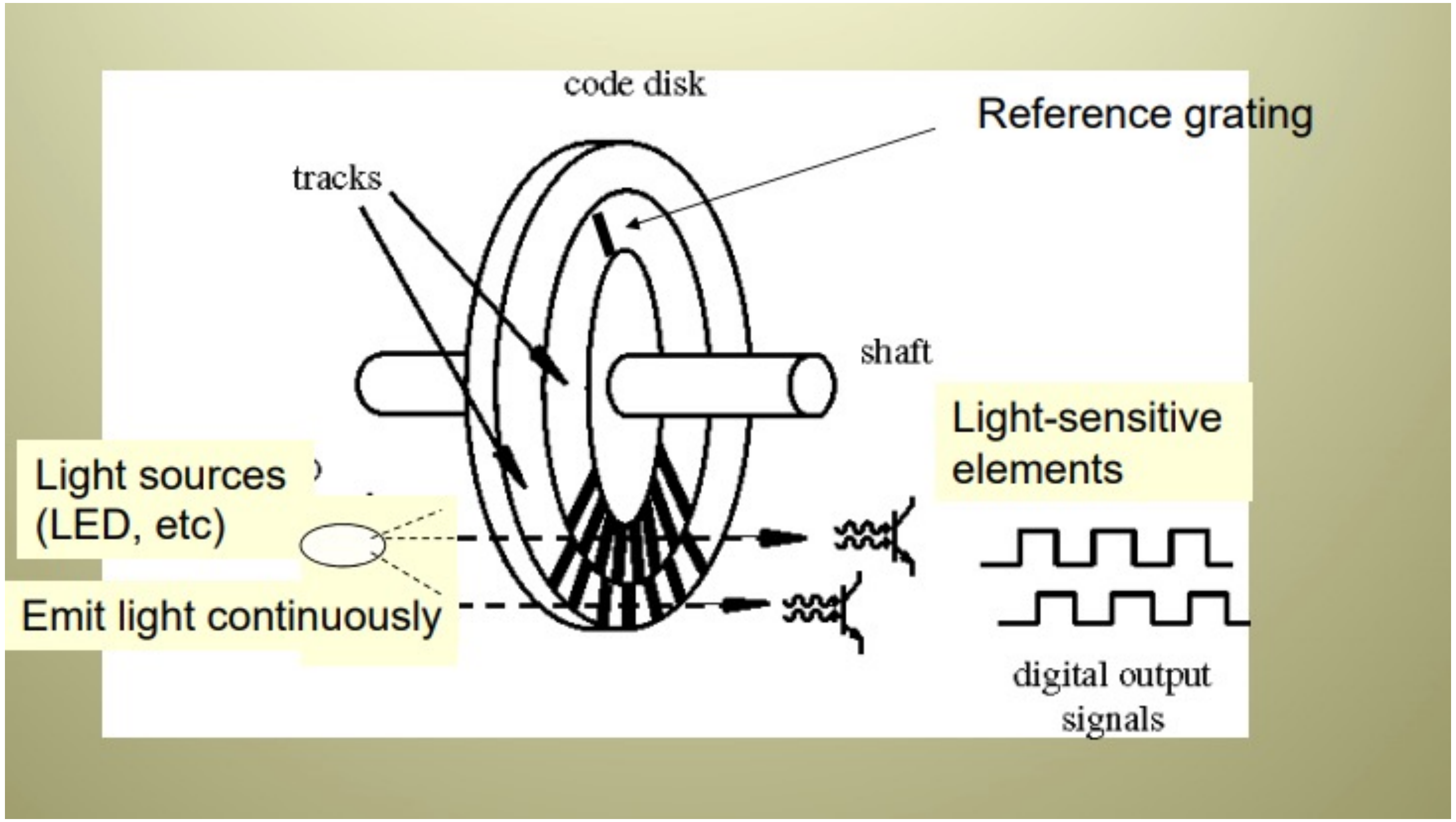




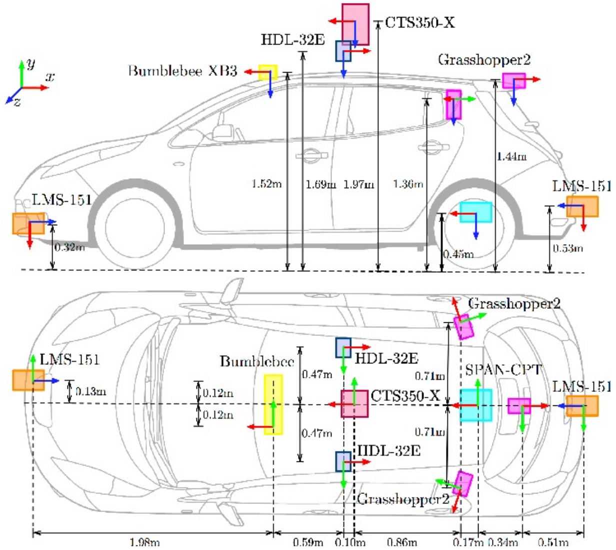
Internal mechanics of joints

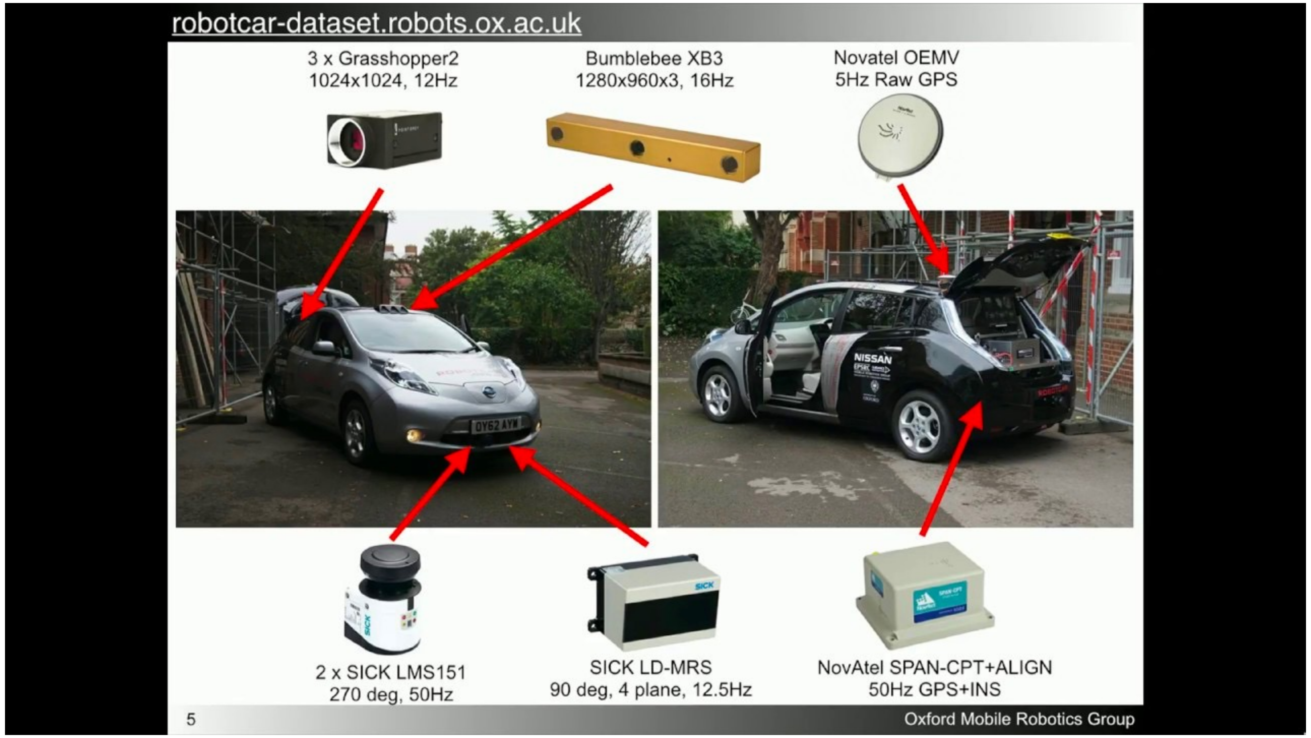
Measuring motion using encoders

- Wheel or joint encoders.
- Measure rotations on wheels and joints.
- Estimating how much the wheel has turned.



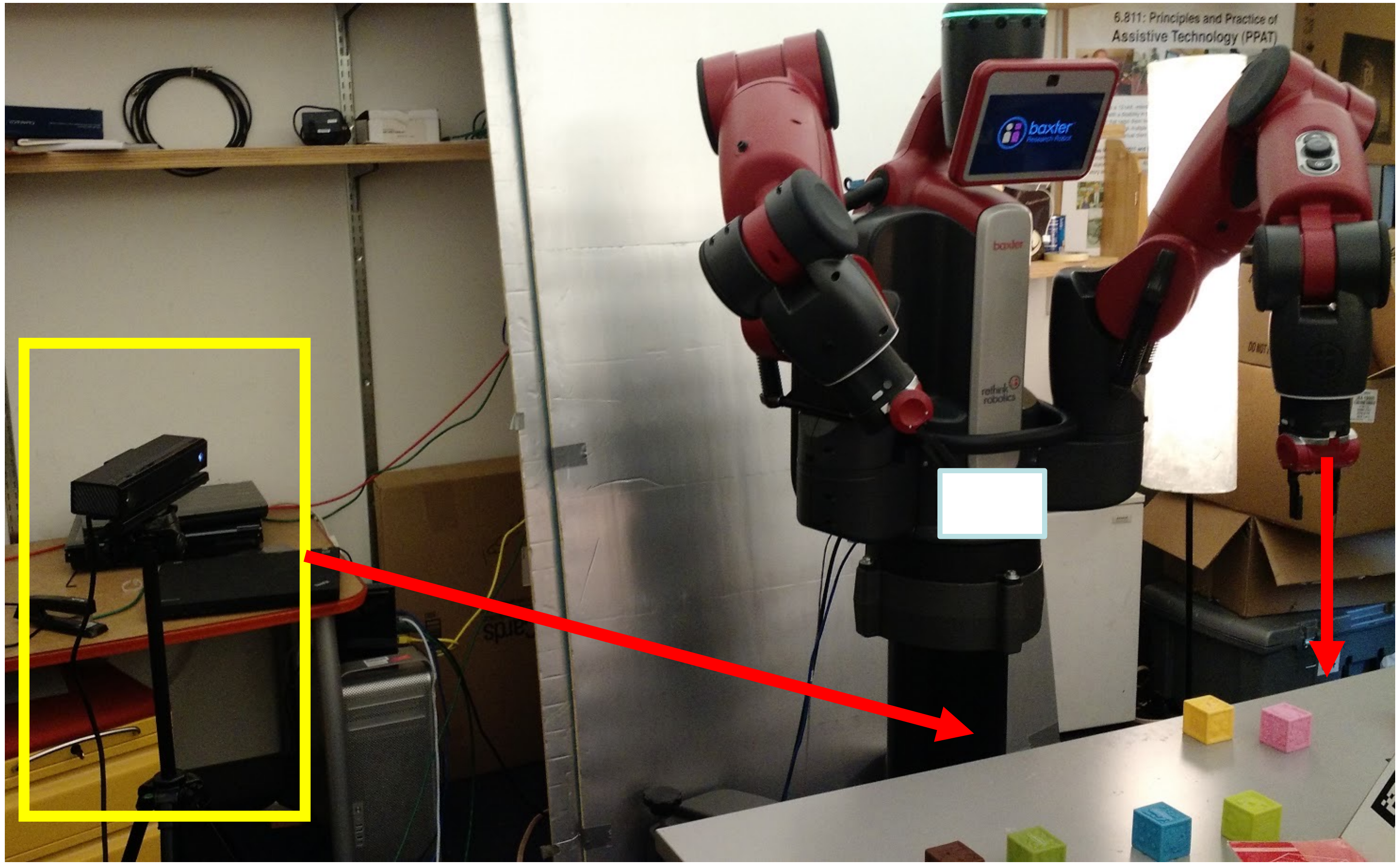
Example: Sensor and compute payload on real systems





Estimating where sensors are?

- The agent carries sensors to determine aspects of the world.
- How does it know where a sensor is w.r.t. itself?
- Calibration is an estimation problem.

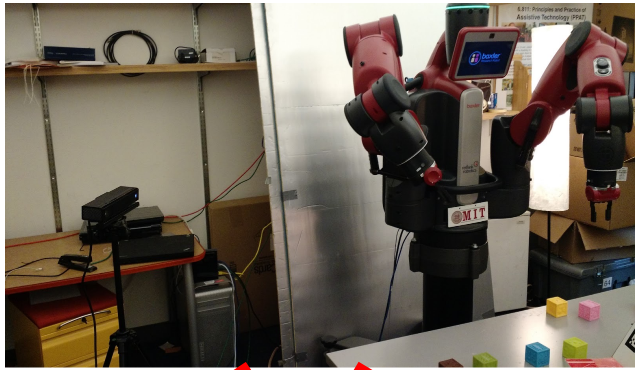


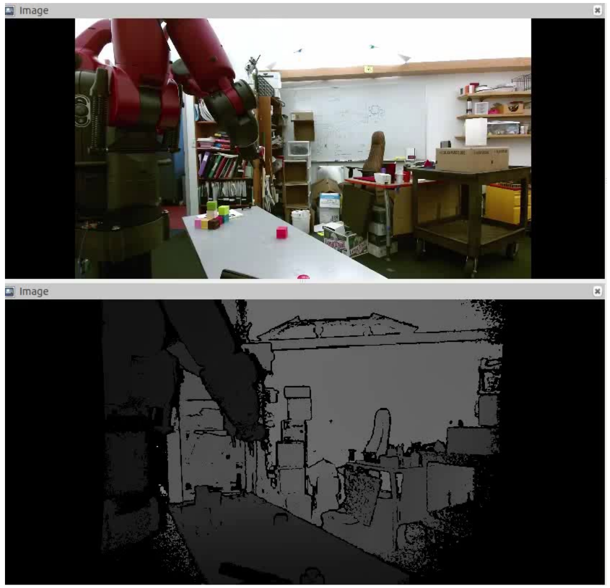
Kinect sensor

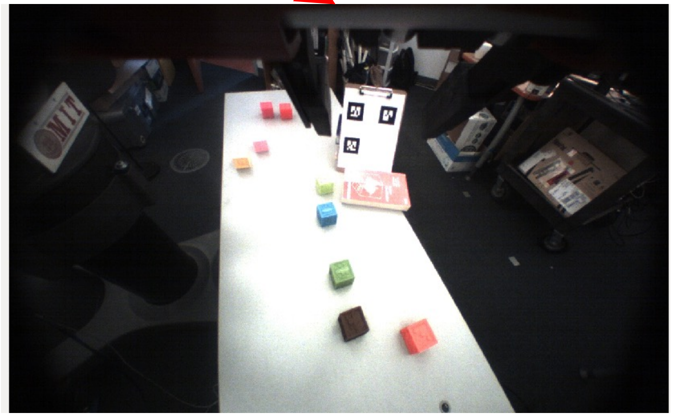
Agent (with another sensor in the hand) viewing the table.

Calibration Example

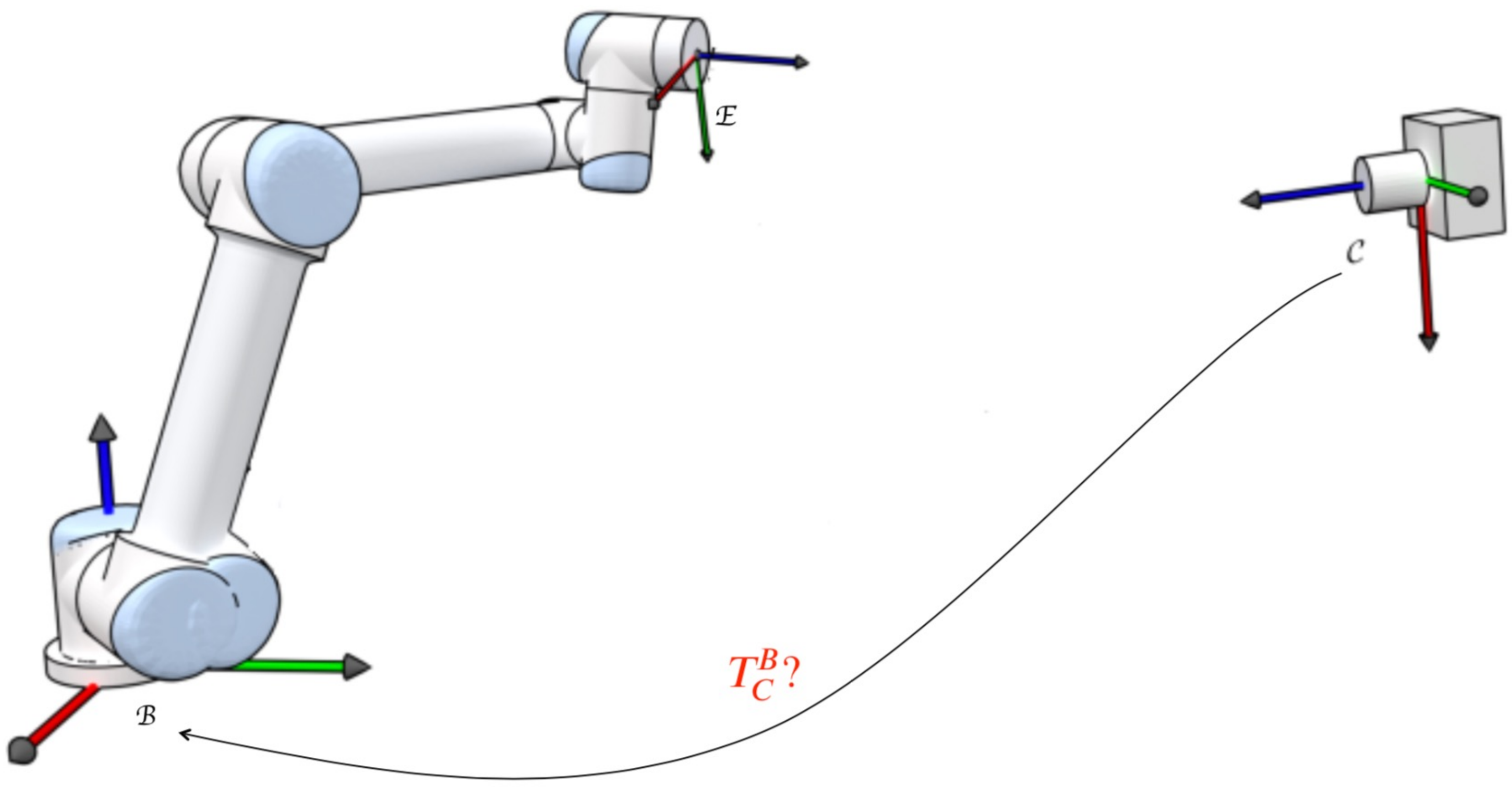
- There may be several sensors.
- How to determine their position w.r.t. the agent?



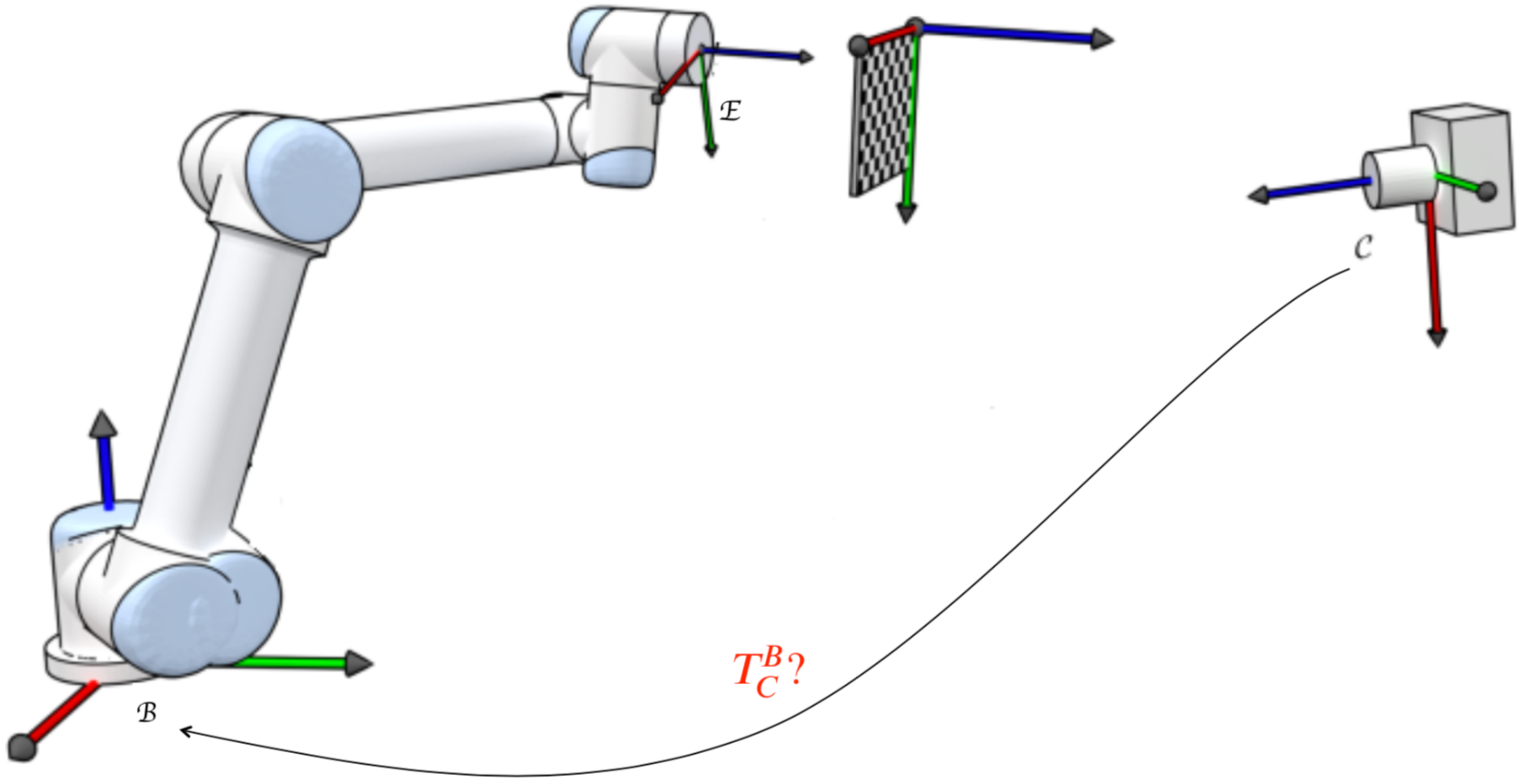




Estimating the Calibration

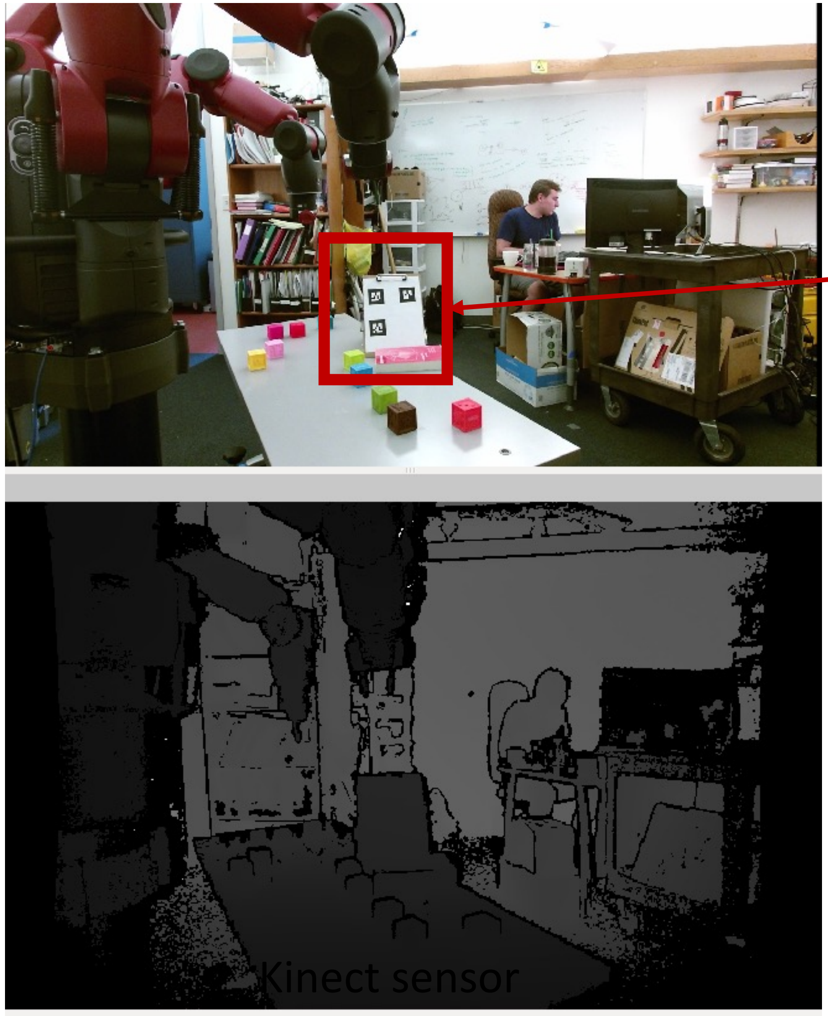


Estimating the Calibration

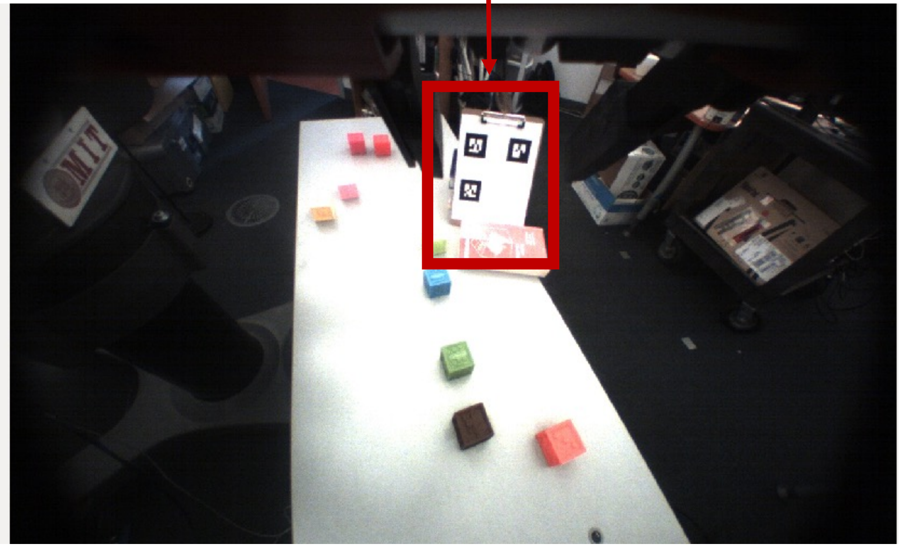


Co-visible Constraints

Calibration target



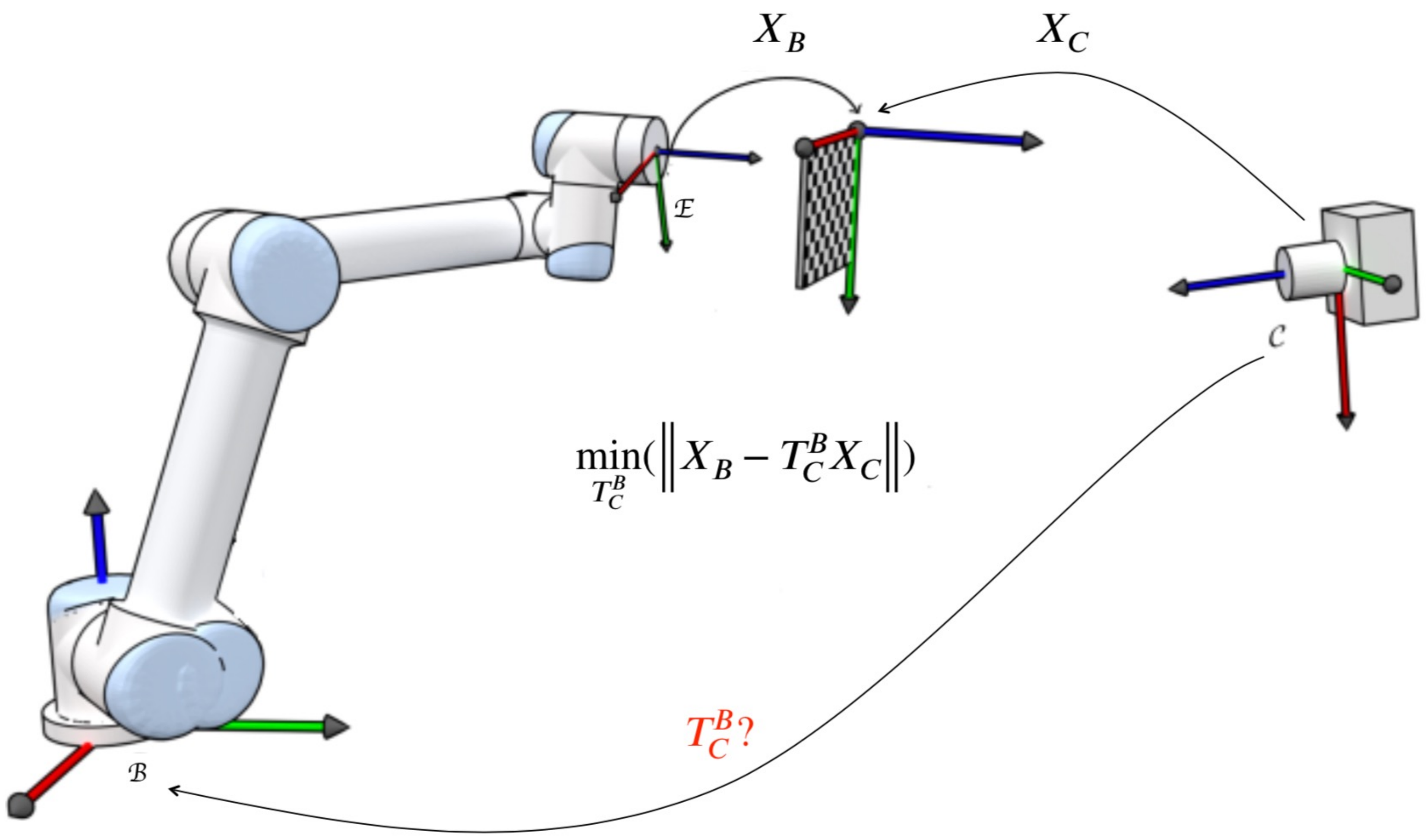
Camera view



Robot’s camera view

Estimating the Calibration

How to get the missing transform?
Describe the coordinate of a common point via two different kinematic chains.



Key Takeaways

- Sensors are used to measure
  - Environment – what is around the robot
  - Motions – encoders etc. measure what movement has occurred.
- Uncertainty
  - Uncertainty in measurement.
  - Incompleteness (partial observations of the environment)
- Sensor models characterize this uncertainty
- State estimation algorithms infer quantities for decision making by fusing noisy sensor observations.