

Deconstructing a mobile robot

EE/CE 468/468: Mobile Robotics
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Arrange furniture in the room in a circle

- How will you go about this?

Look around and evaluate the situation.
How much furniture is there? Where are the chairs? Where are the tables?

Sense

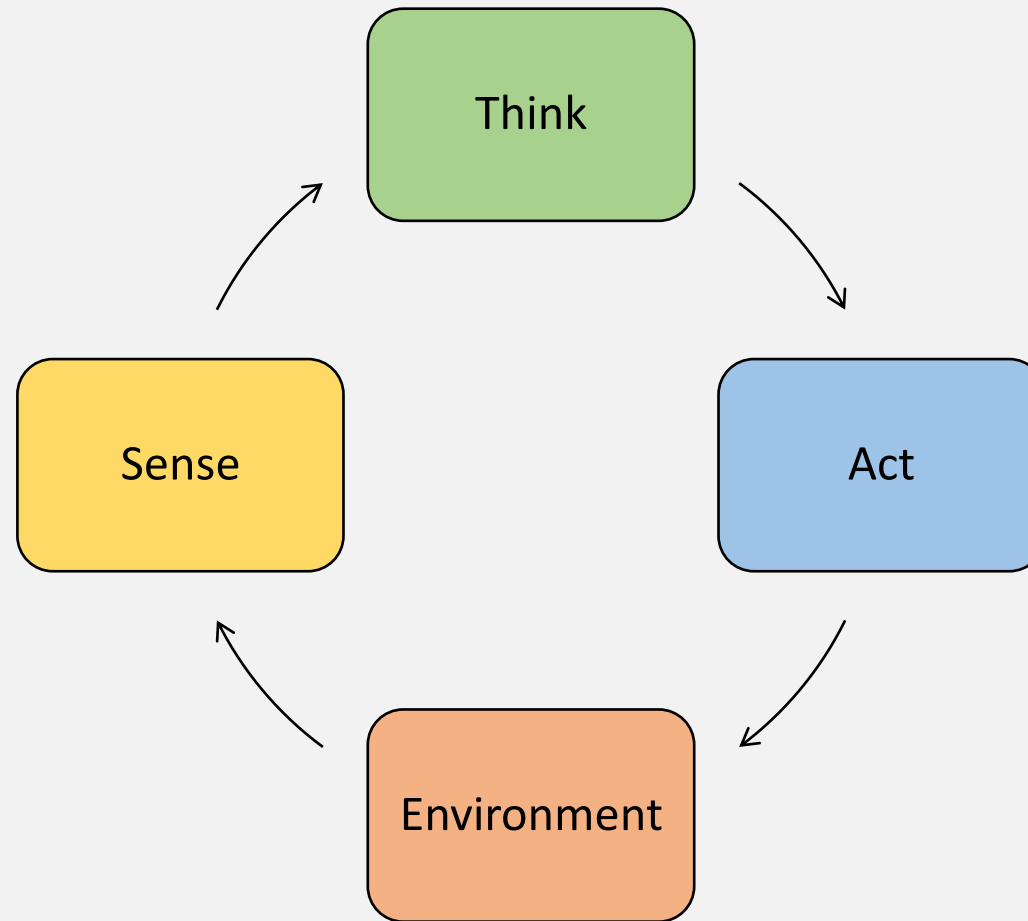
Make a plan.
Pick a chair and move it to desired position. Repeat for every piece of furniture.

Think

Execute the plan.

Act

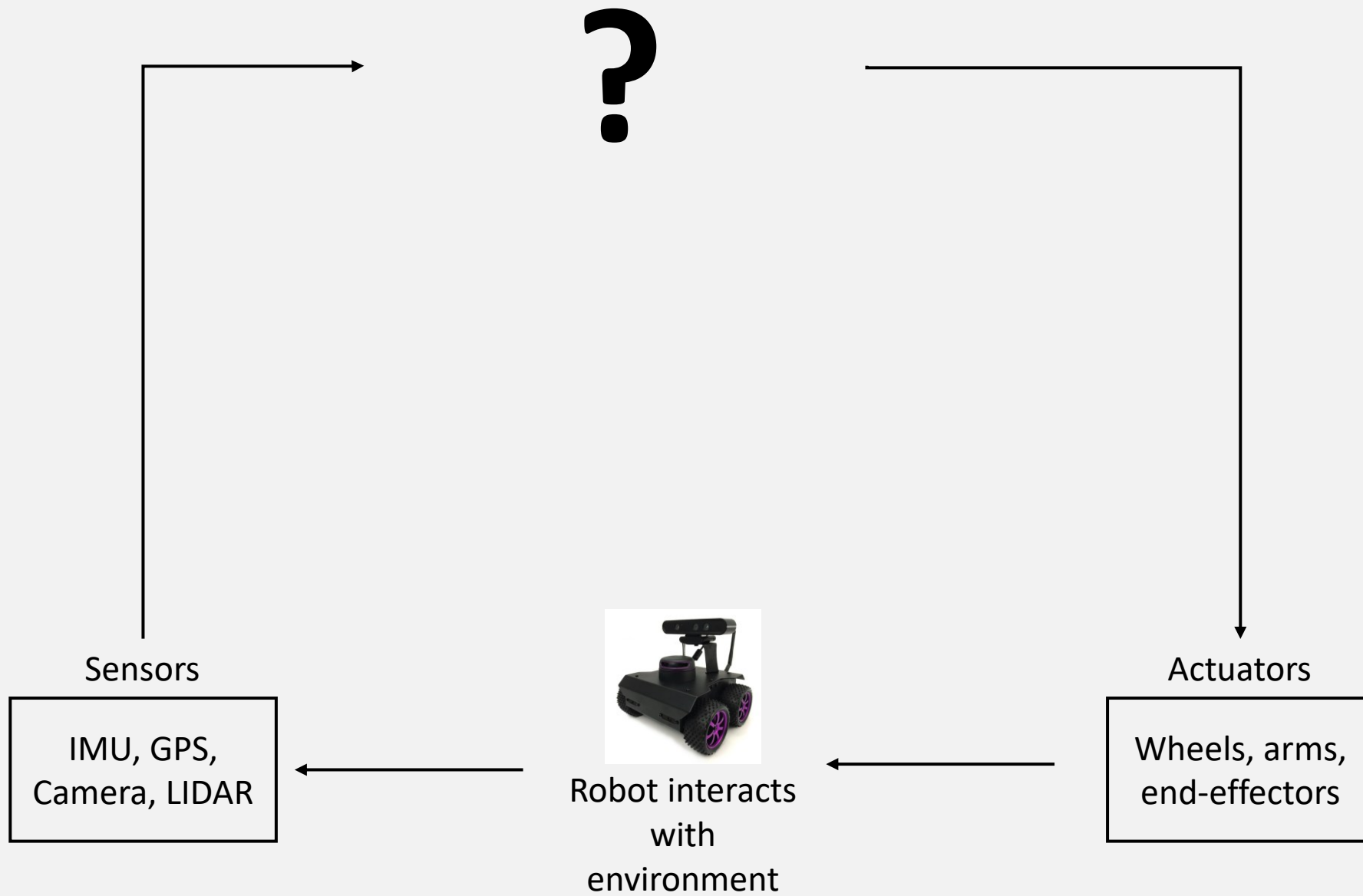
Basic strategy used by almost all robots



At different time scales

- Chess robot completing one cycle in minutes
- Self-driving car completes it in milliseconds

Deconstruct a wheeled helper
robot for our house:



?

Process of manipulating an internal model of the world, reasoning about which actions the robot could perform, and how these actions would change the state of the world.

Think

Sensors

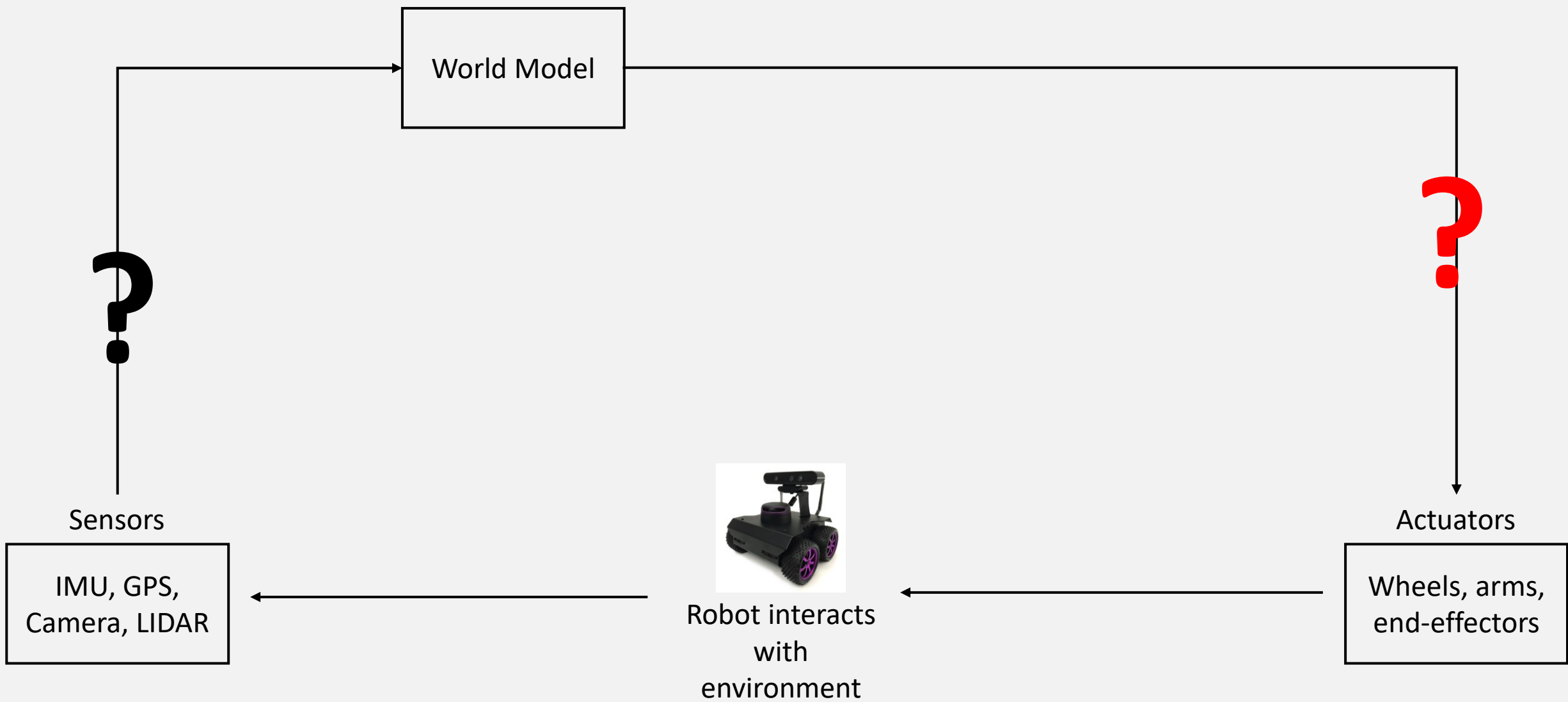
IMU, GPS,
Camera, LIDAR



Robot interacts
with
environment

Actuators

Wheels, arms,
end-effectors



What is the world model?

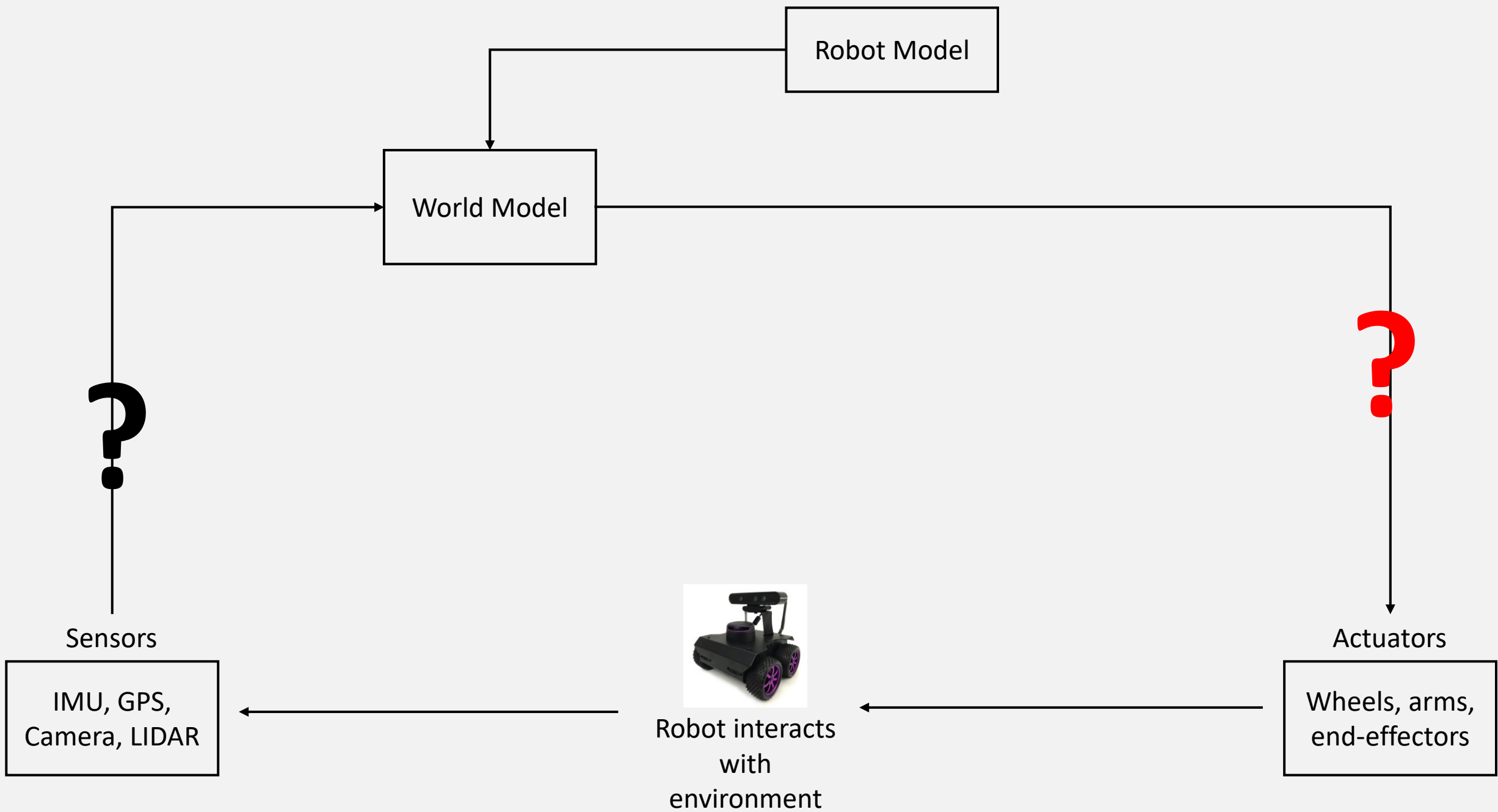
- Internal belief of the robot about the world, including itself – an abstraction.
- Does it include everything?
 - Everything that robot knows and is relevant to it for its mission.
- What does that include in our example?
 - Where is the robot in the world?
 - Obstacles (Furniture, etc.)
 - Where are the rooms?
 - Knowledge of where things are placed
 - Library of objects

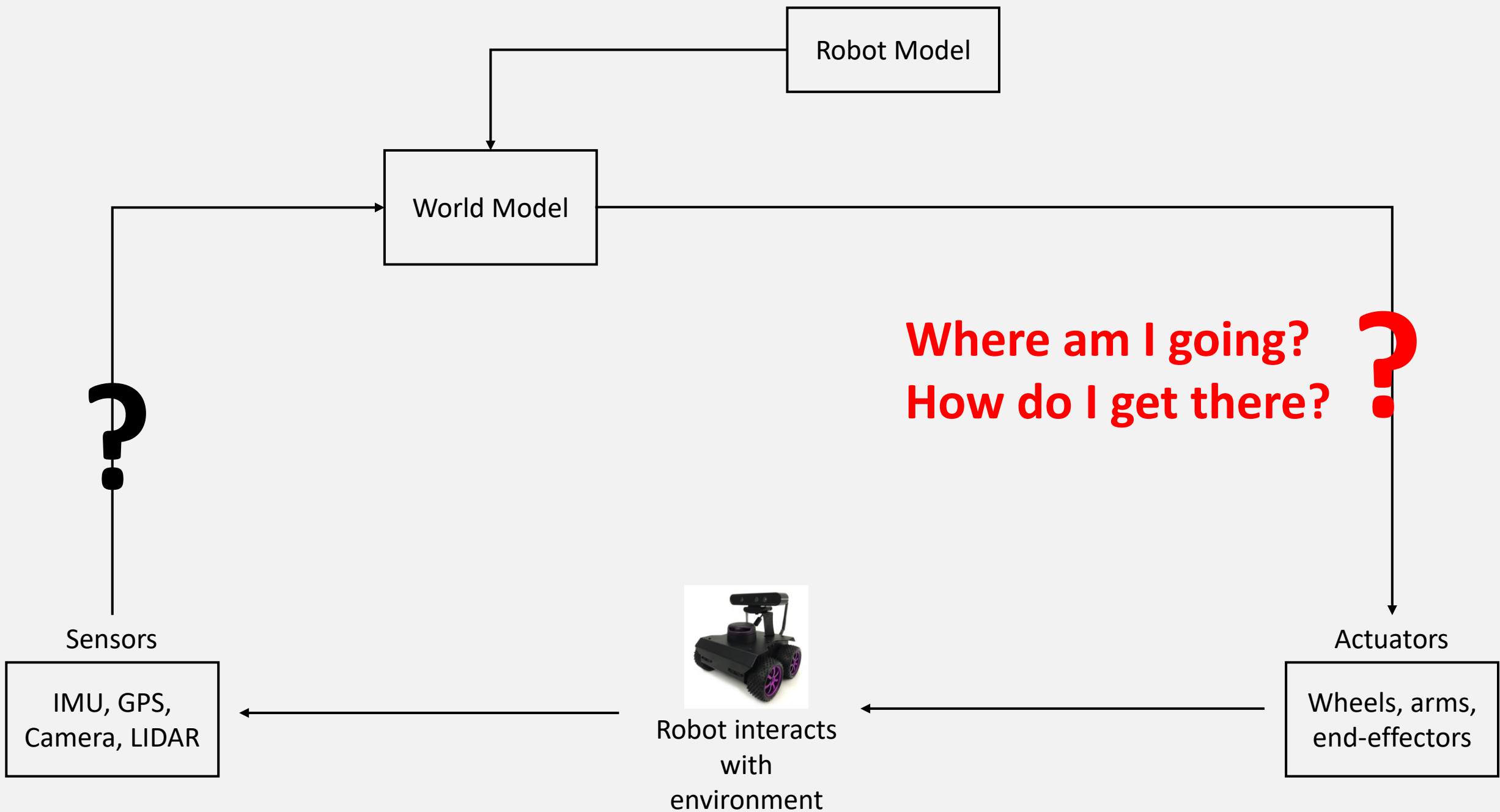
Look at one side at a time.

- Assume we know everything about the world, including the robot itself, what commands should we send to actuators?
- How do we use sensor data to update our understanding of the world?

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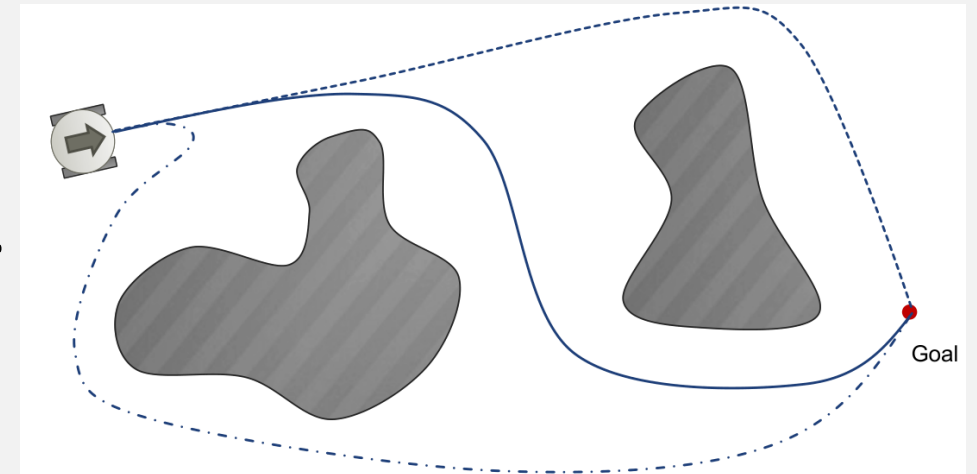
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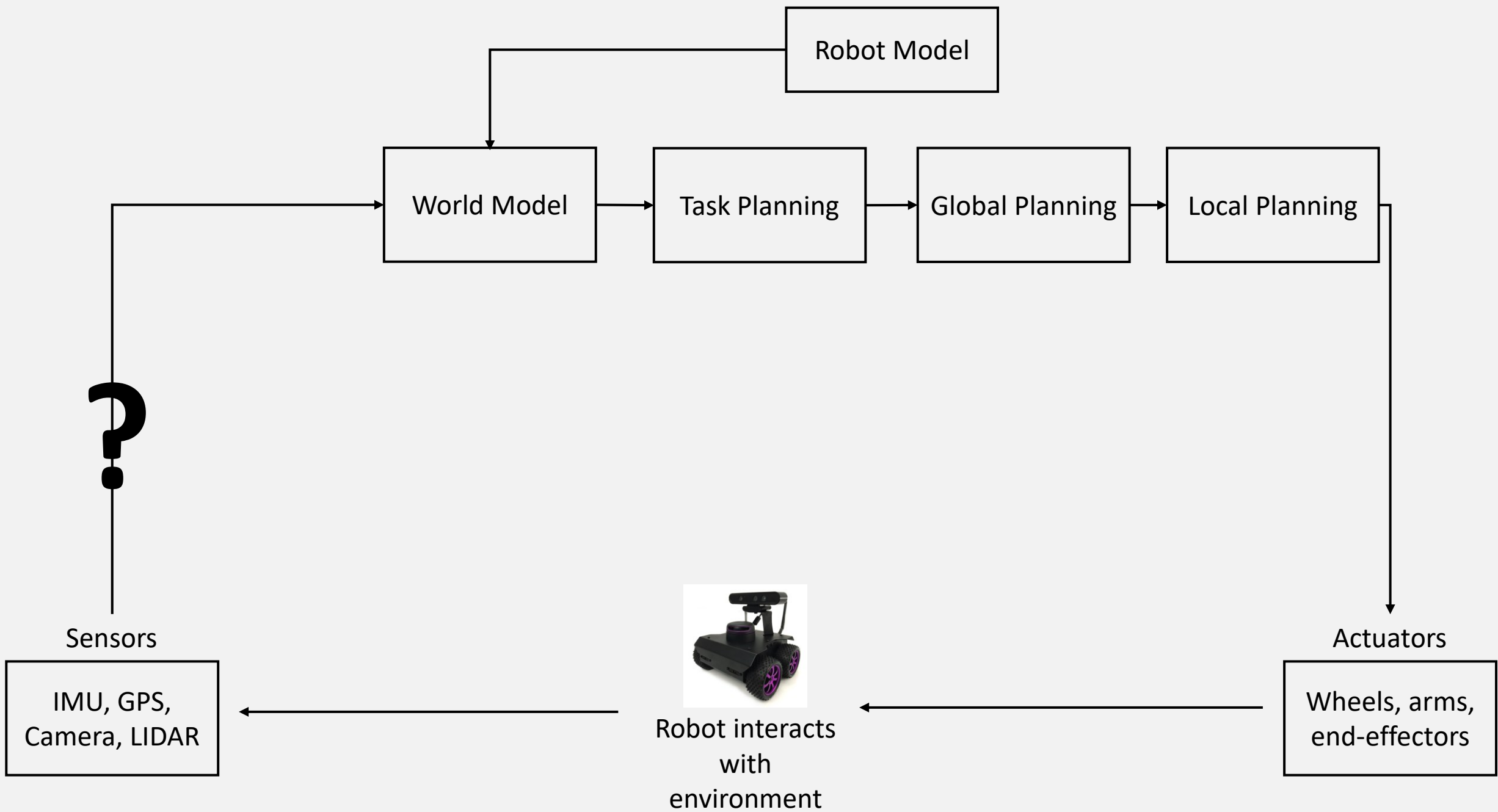


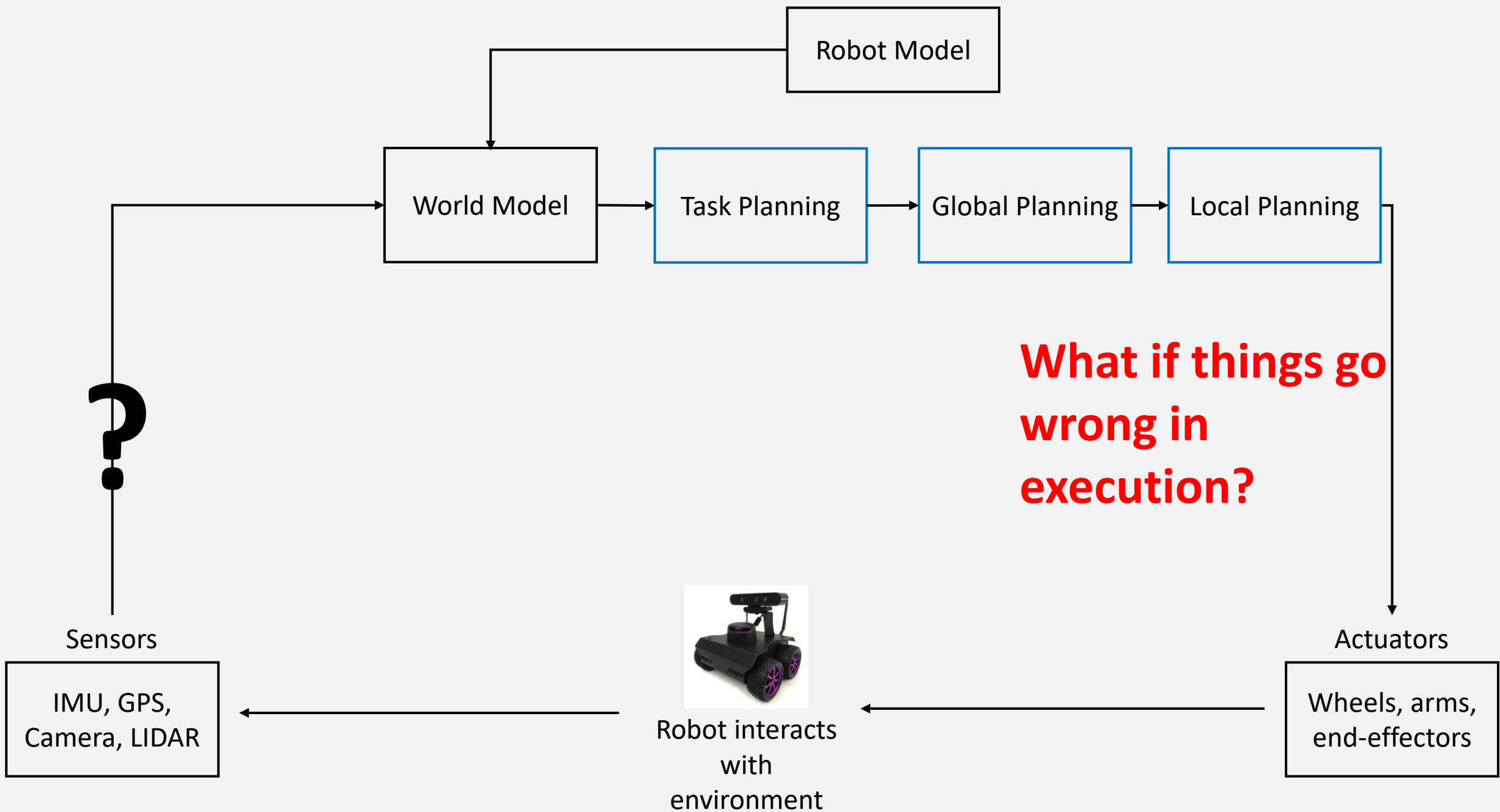


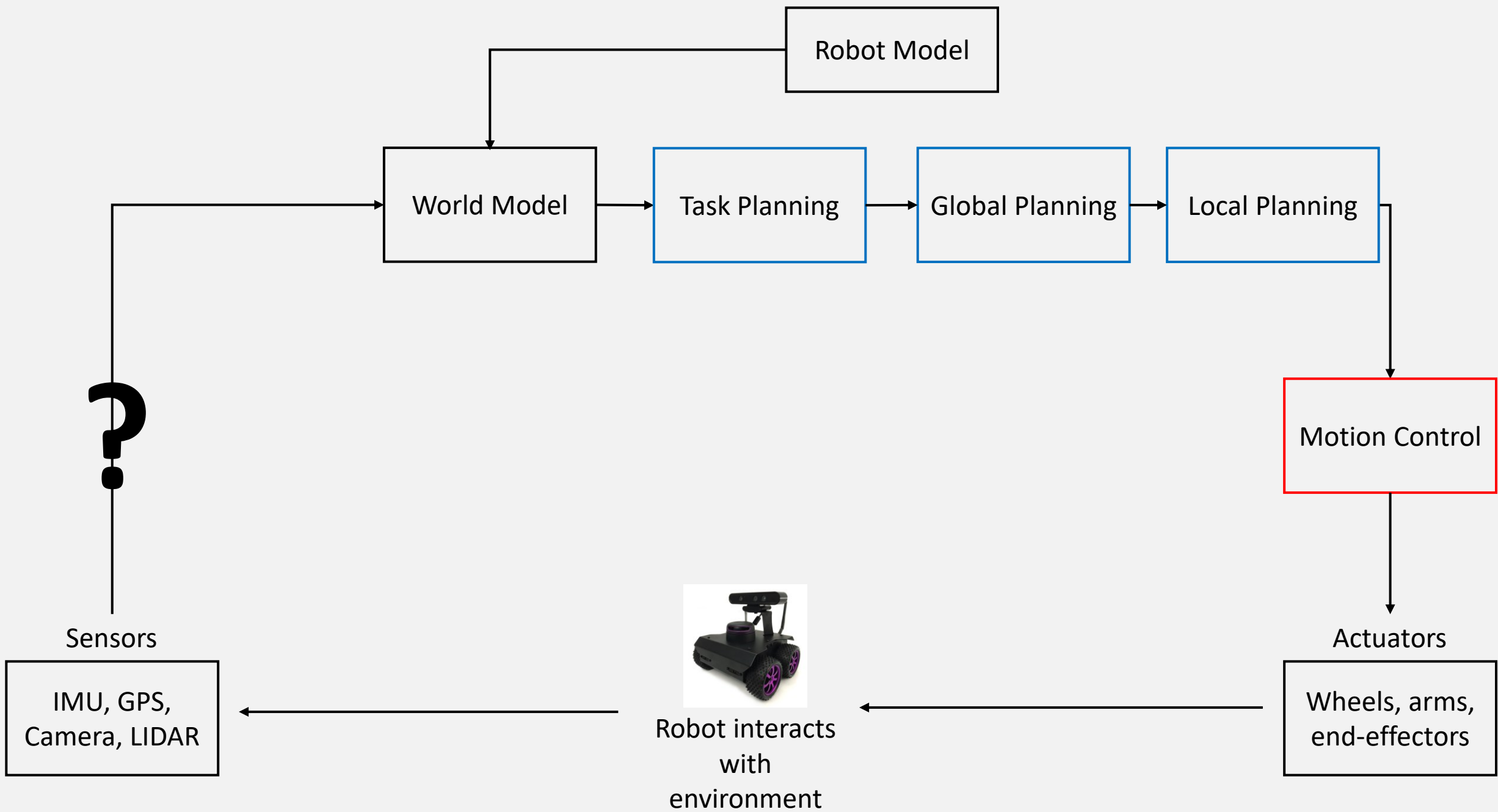
Answer: Plan

- Planning is exploring a range of actions available to the robot to find the best action to take.
 - The world model can be used to predict what will be the result of robot actions.
- Task Planning
- Path Planning
- Trajectory Planning
- It is essentially an optimization problem.



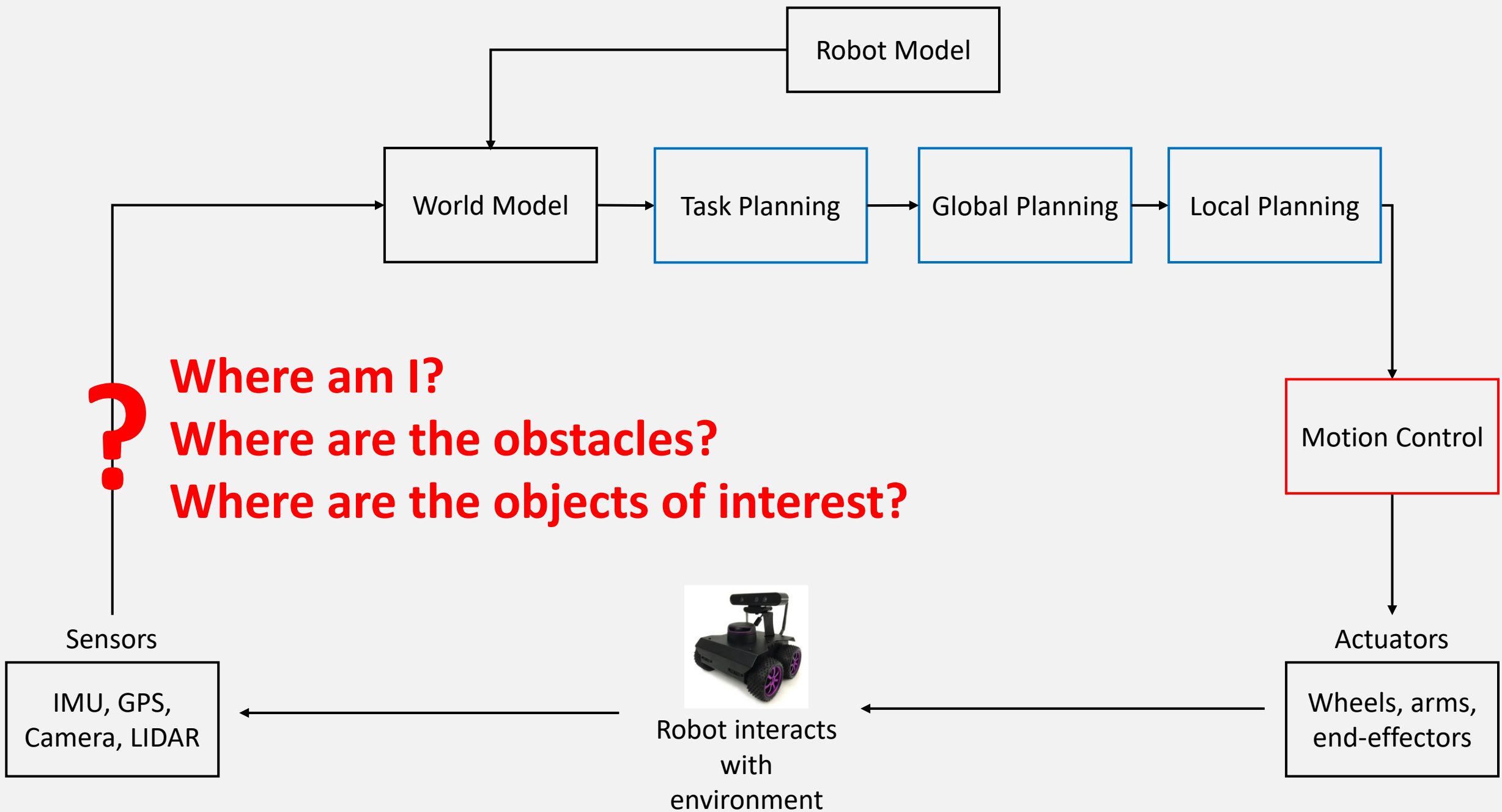


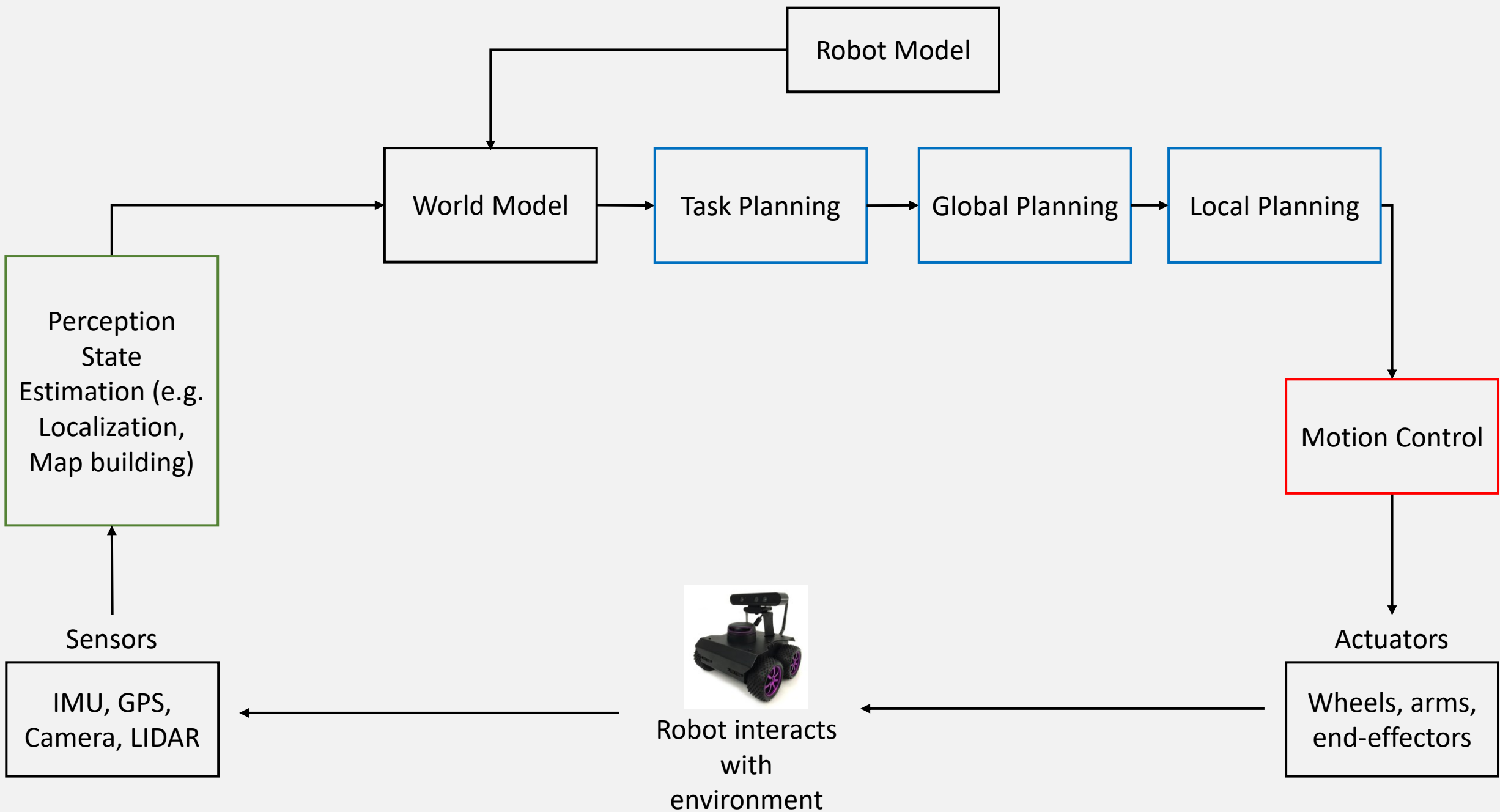




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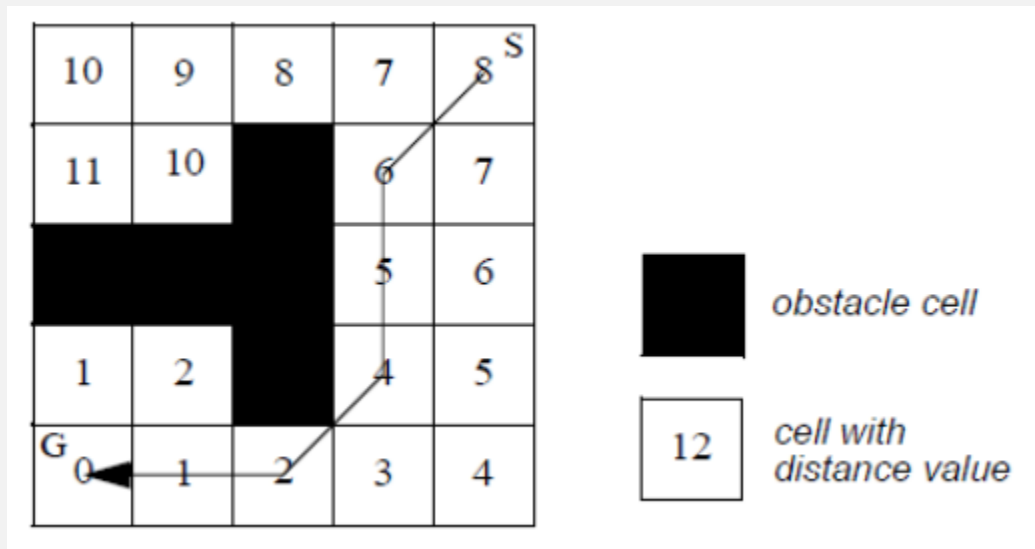


How do we get **model** of robot?

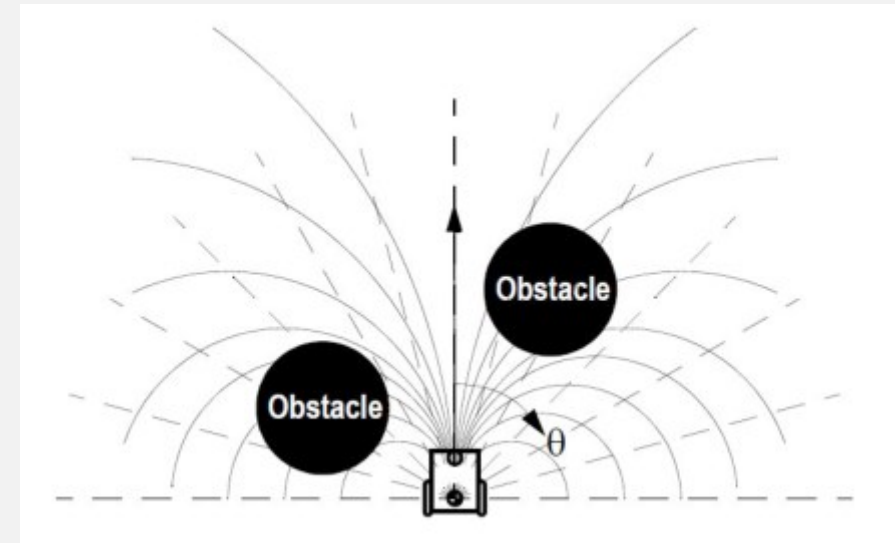
- Kinematics and Dynamics
- Robot model could be very complicated. What to do?
- The world model contains too much information. Planning will take forever. What to do?

Adjust resolution of models for various stages.

- Global Planner



- Local Obstacle Avoidance



Different representations of world for different tasks

State

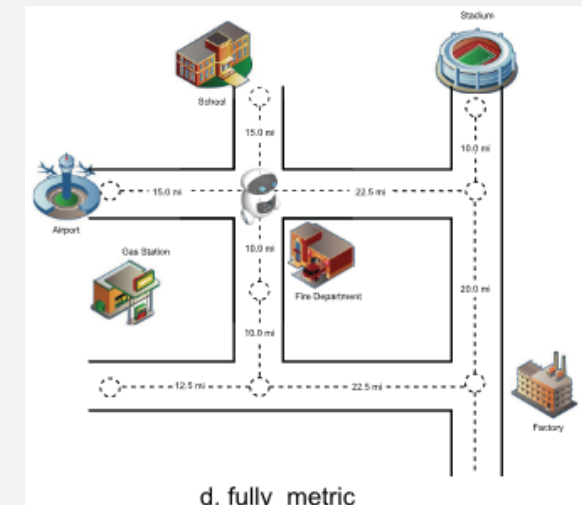
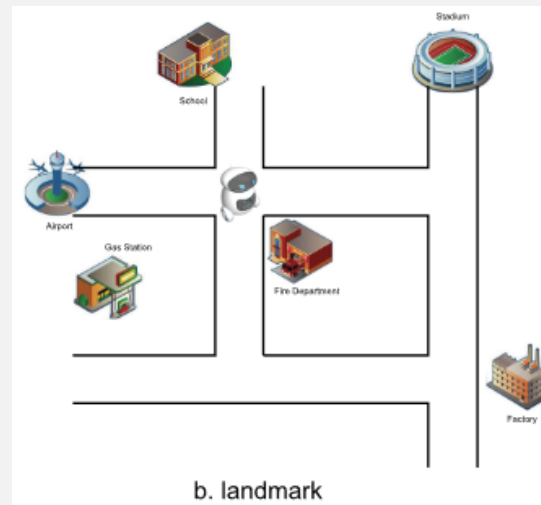
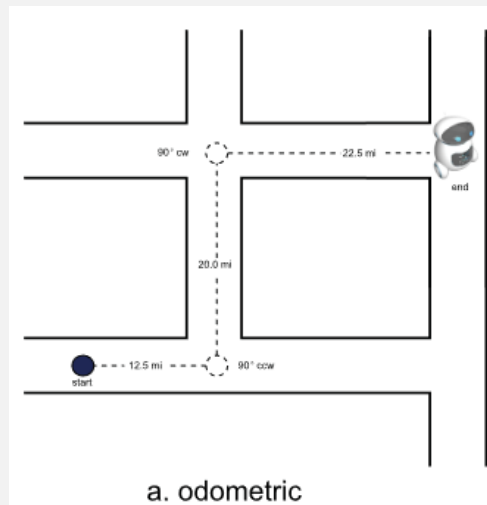
- World is characterized by state.
- **State:** Minimal relevant aspects of the environment and robot that can impact the success of mission.
 - **World state:** Map of rooms, location of furniture, location of objects, location of people
 - **Robot state:** Pose, Velocities, Accelerations, Battery Health, Joint angles
- Unnecessary information is not included in state
 - Colors of the walls
- Static or Dynamic

How to represent the world state?

- **Symbolic representation**

- Useful for task planning
- MOVE TO “Laundry room” -> PICK “Laundry” -> MOVE TO “Bedroom” -> PLACE “Laundry”
- Insufficient for motion

- **Maps**



How to represent the world state?

- **Photographs**
- **Point Clouds**
- **3D models**

How to represent robot state?

- Given a separate place because robot can directly change its state
- Vector of configuration variables in the kinematic case
- Vector of position and velocities in the dynamical model case

Where does the design complication lie?

- UNCERTAINTY
 - Sensor measurements (Forward model from world state to values)
 - Perception (Inverse – inferring world state from measurements)
 - Seldom unique solution
 - Models are always approximations
 - Environment is unpredictable
 - Actuation is imprecise
- How do we deal with this?

Probability is the major tool here.

$$P(\text{world model} \mid \text{data})$$

Robot Hardware