Introduction to Hardware and Closed-loop System

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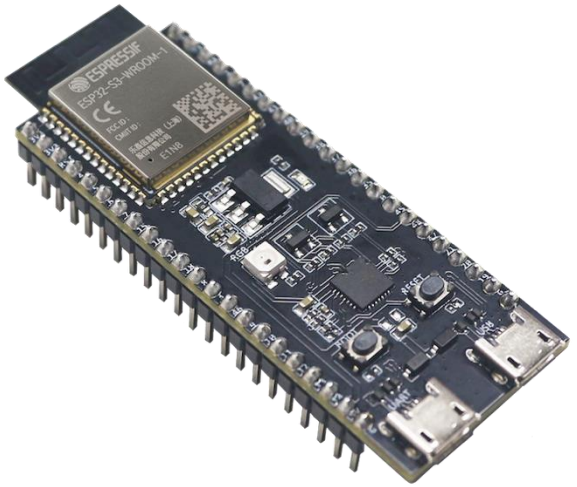
Introduction to Hardware

- **Hardware list**
  - **Already Provided**
    - Microcontroller: ESP32
      - Support Arduino ecosystem;
      - Bluetooth + WIFI communication;
      - Duo-core CPU;
    - Servo: 5V DC motor servo x 2
      - Read position;
      - Move using position/velocity commands;
    - Power supply
      - 5V USB power supply
      - Battery optional
  - **To be selected**
    - Sensors: at least 1 kind



Closed loop System

- **Closed loop System:** A system/device that can read its current state, and automatically process and regulate to maintain a desired state.

- **Essential hardware:**
  - Sensors: reading states
  - Controllers: computing and processing
  - Actuators: regulating states

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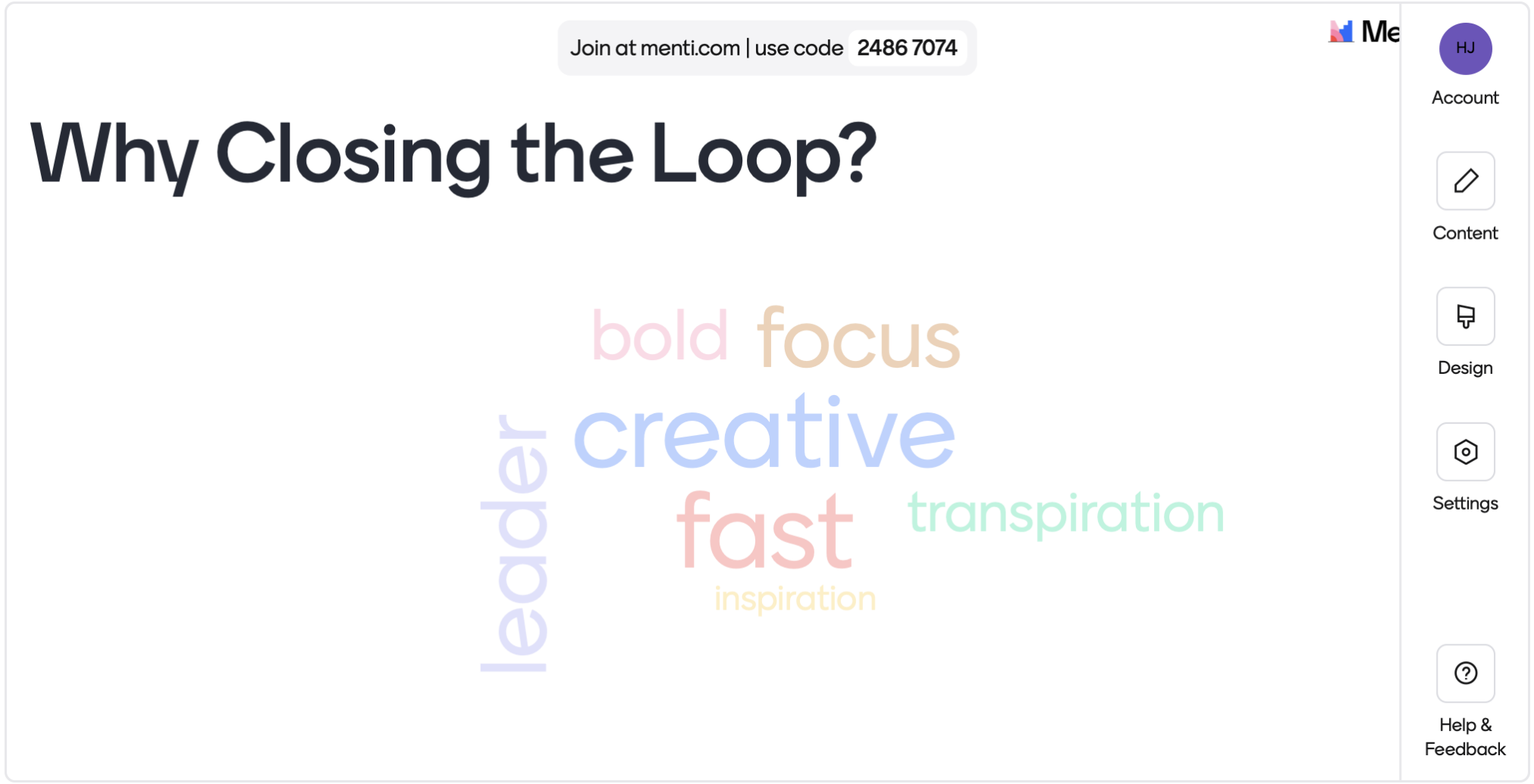
Why Closing the Loop?



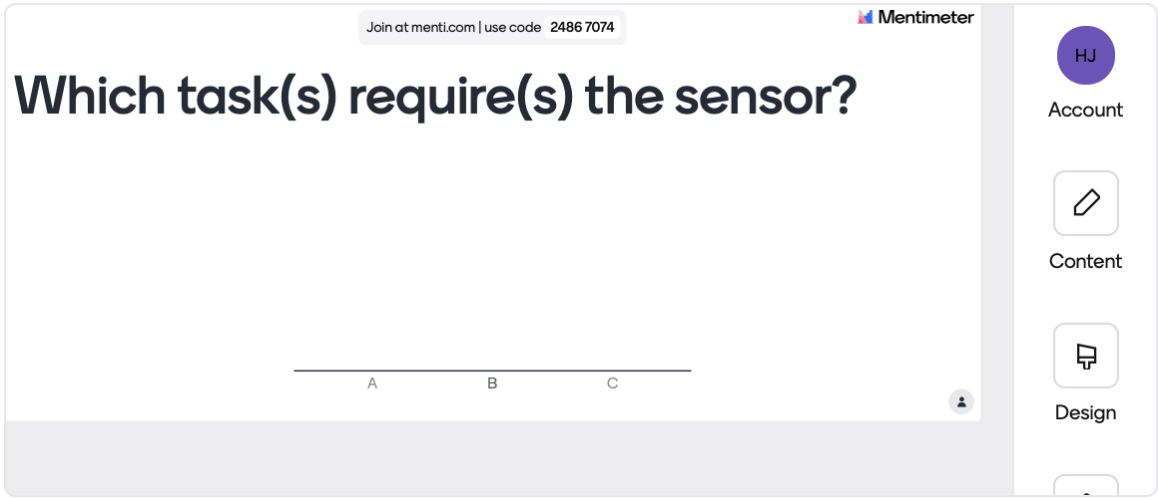
Why Closing the Loop?

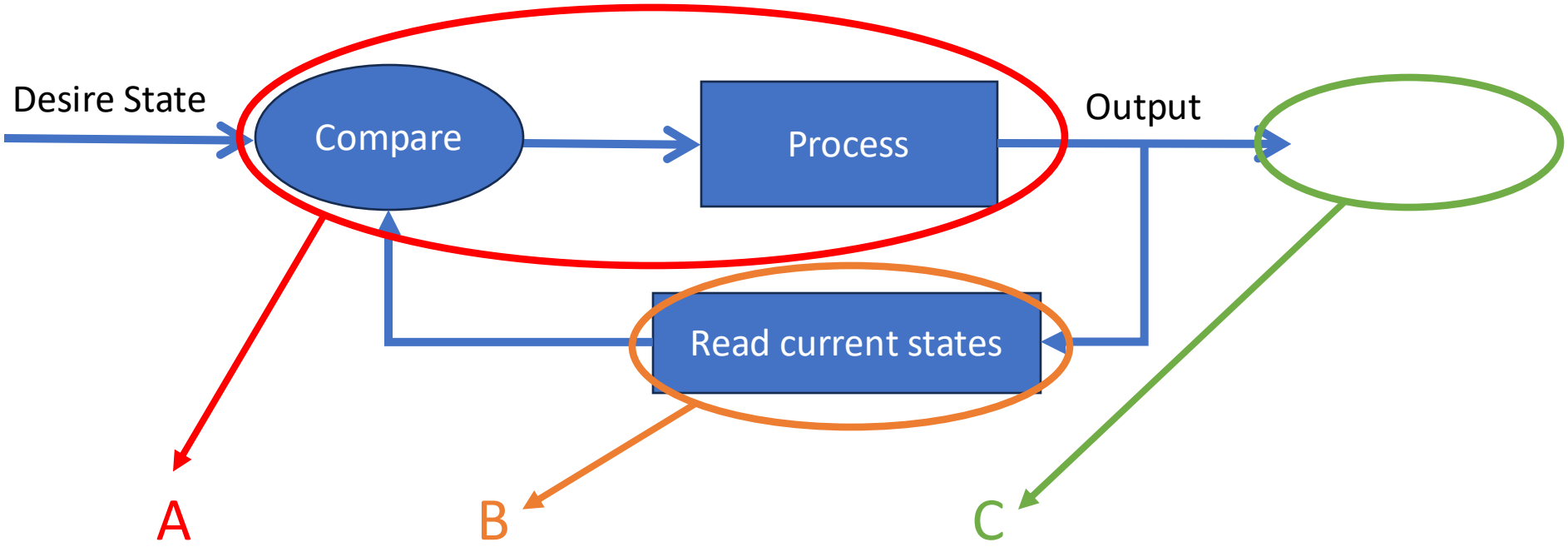
- Automatic and Sustainable
  - **Reducing human intervention**: accomplishing pre-set task automatically;
  - **Efficiency optimization**: advance control methods permit optimizations on energy usage and working conditions;
- Robust and Adaptable
  - **Disturbance Rejection**;
  - **Environment Adaptation**: automatically adjust to adapt environment changes and internal system malfunctions;
- Accurate and Rapid Response
  - **Reducing errors:** estimate error in real time and regulate;
- Safe
  - **Fail-Safe Operations**: force, speed limits;

Closed loop System

Essential hardware:

- **Sensors**: reading states
- **Controllers**: computing and processing
- **Actuators**: taking command from controller, regulating states





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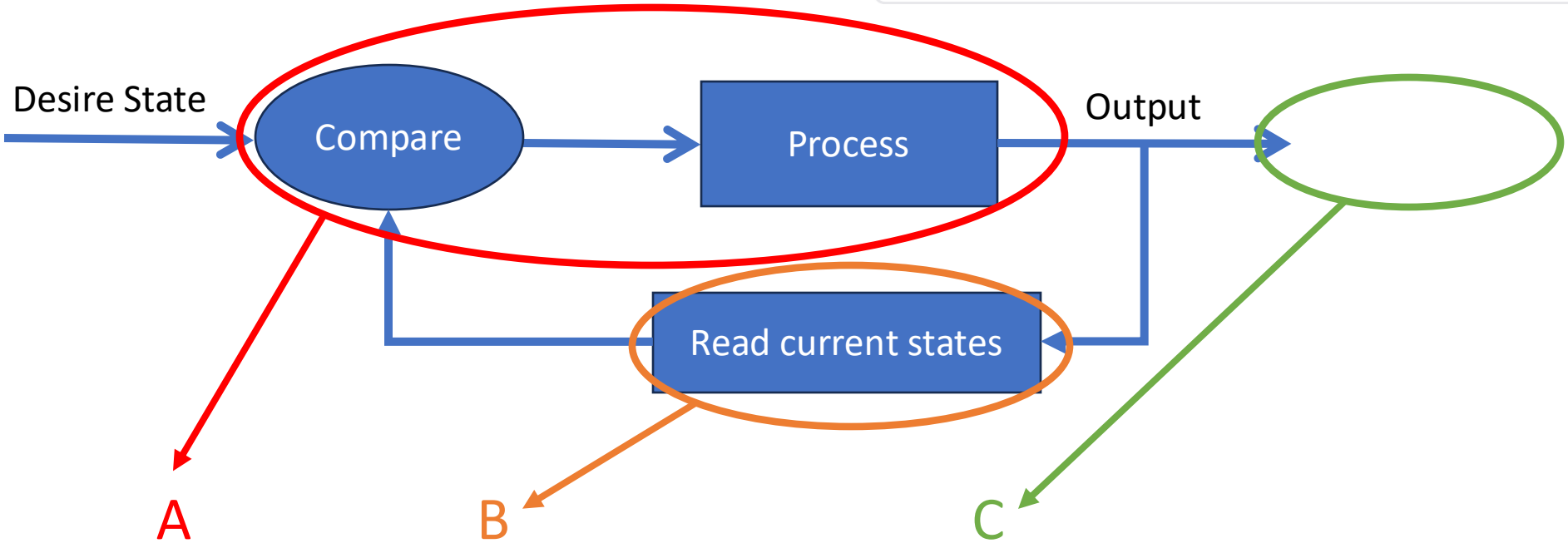

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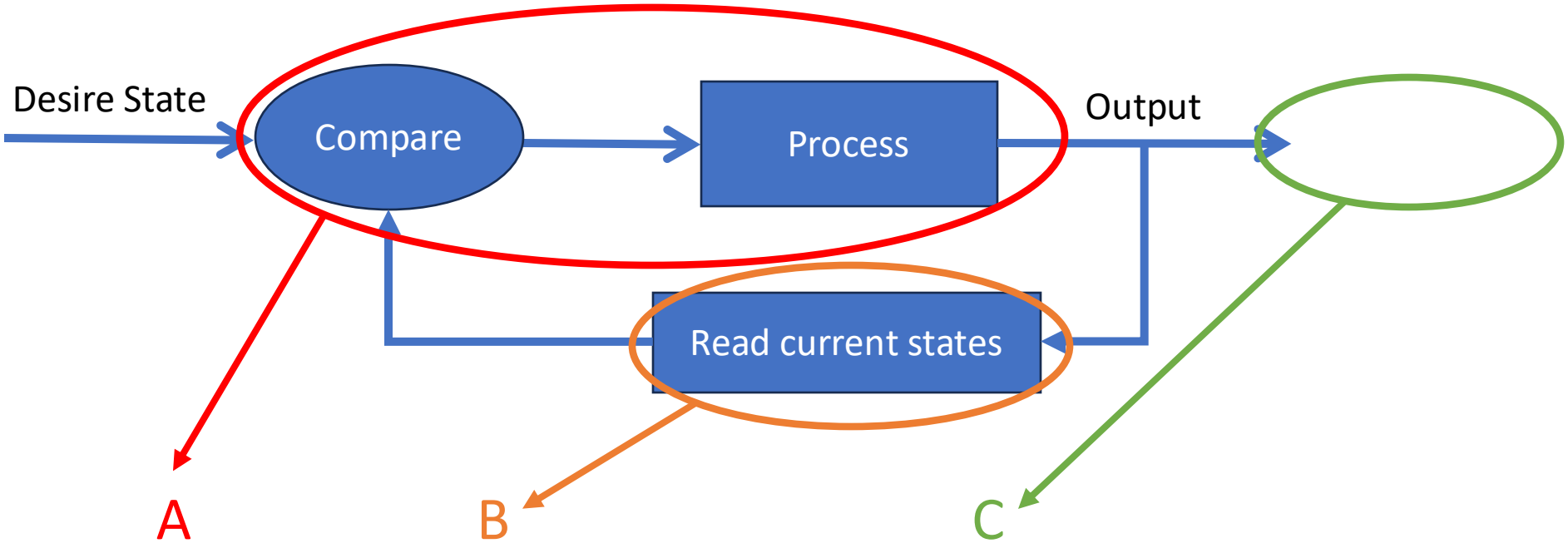


Examples

Autonomous Car

Smart Home

Closed-loop Systems

Autonomous Factory

Biology

Examples

Goal

- Autonomous cruising
  - Maintain speed
  - Stay in the lane
  - Avoid collision

Controllable Objects

- Engine / Motor throttle
- Steering
- Brake

Information

- Current location
- Map
- Speed
- Power state
- Road situation
- Traffic Info

Control Input

- Goal speed
- Goal heading

Control Output

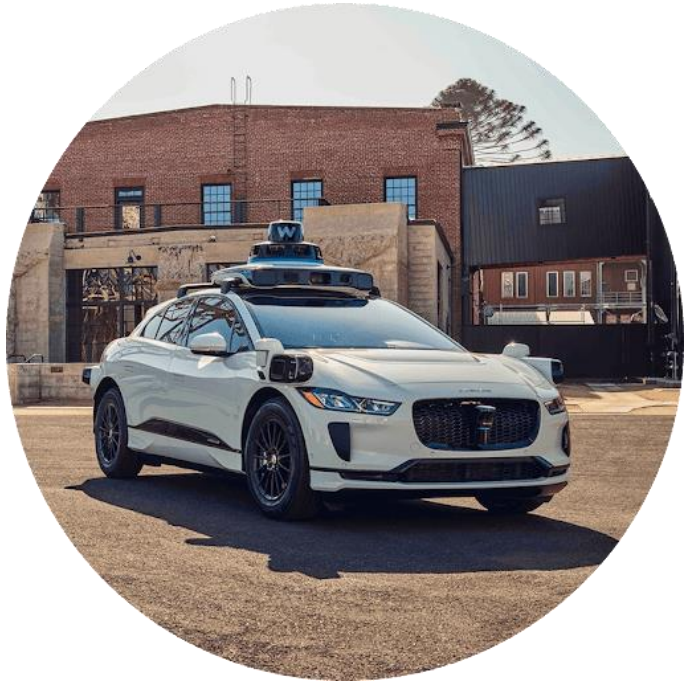
- Power output
- Steering angle
- Brake

Cost Factors

- Fuel efficiency
- Time
- Comfort
- Safety

Control Feedback State

- True speed
- True heading



Examples

Goal

- Maintain room temperature and humidity
  - Save energy
  - Comfortable, healthy
  - Economic

Controllable Objects

- AC system
  - Air flow rate
  - Air temperature
- Window, door
- Window shades

Information

- Outdoor climate
- Outdoor air condition
- Indoor air condition
- AC system state
- Electricity price
- Indoor people activity

Control Input

- Goal room temperature and humidity

Control Output

- AC air flow rate
- AC air temperature
- Window, door
- Window shades

Control Feedback State

- True room temperature and humidity

Cost Factor

- Economy
- Comfort
- Healthy

Examples

Goal

- Blood glucose regulation in human body
  - Maintain blood glucose level

Controllable Objects

- Pancreas
  - Insulin secretion
    - Reduce blood sugar
  - Glucagon secretion
    - Signal the liver to produce glucose
- Brain
  - Eat!
  - No more food!

Information

- Pancreatic Beta Cell
  - Glucose sensors
- Diet condition

Control Input

- Normal/healthy blood glucose level

Control Output

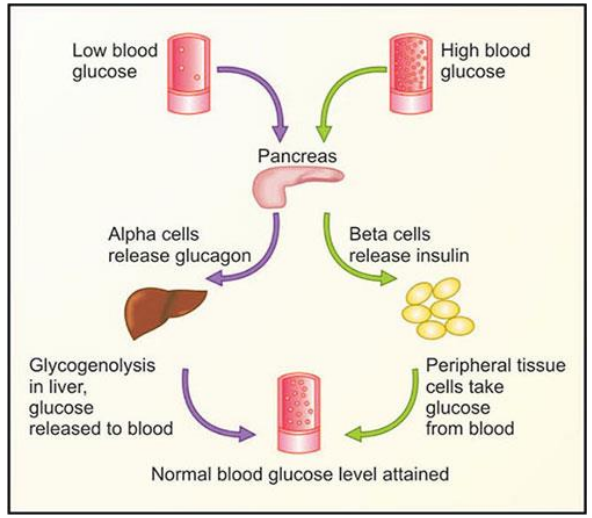
- Secretion speed of Insulin
- Secretion speed of Glucagon

Control Feedback State

- True blood glucose level

Cost Factor

- Diet condition



Exercise

Goal

- Anti-Lock Braking System (ABS) in vehicles
  - Prevent lock-up during braking
  - Maintain high braking power and traction

Controllable Objects

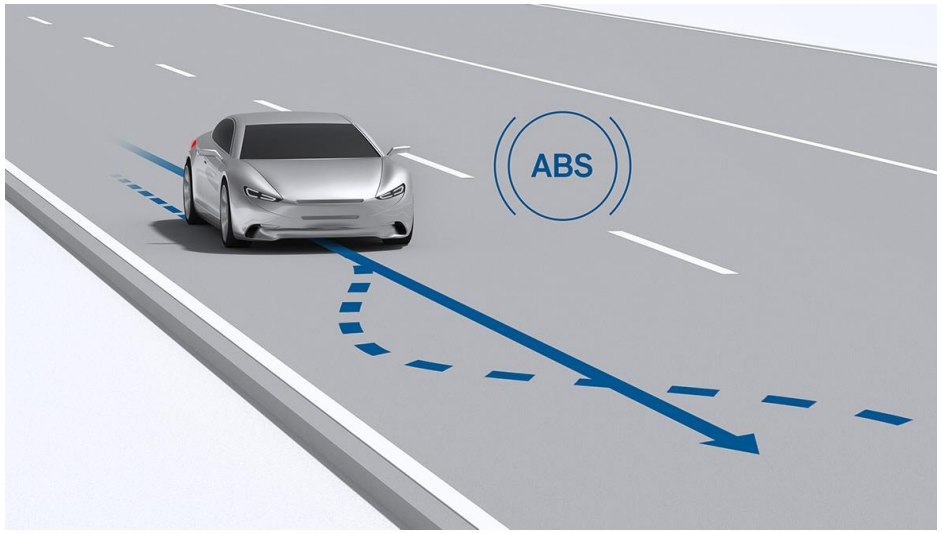
- Brake hydraulic pump

Information

- Wheel speed
- Brake hydraulic pump pressure

Cost Factor

- Passenger comfort
- Braking distance



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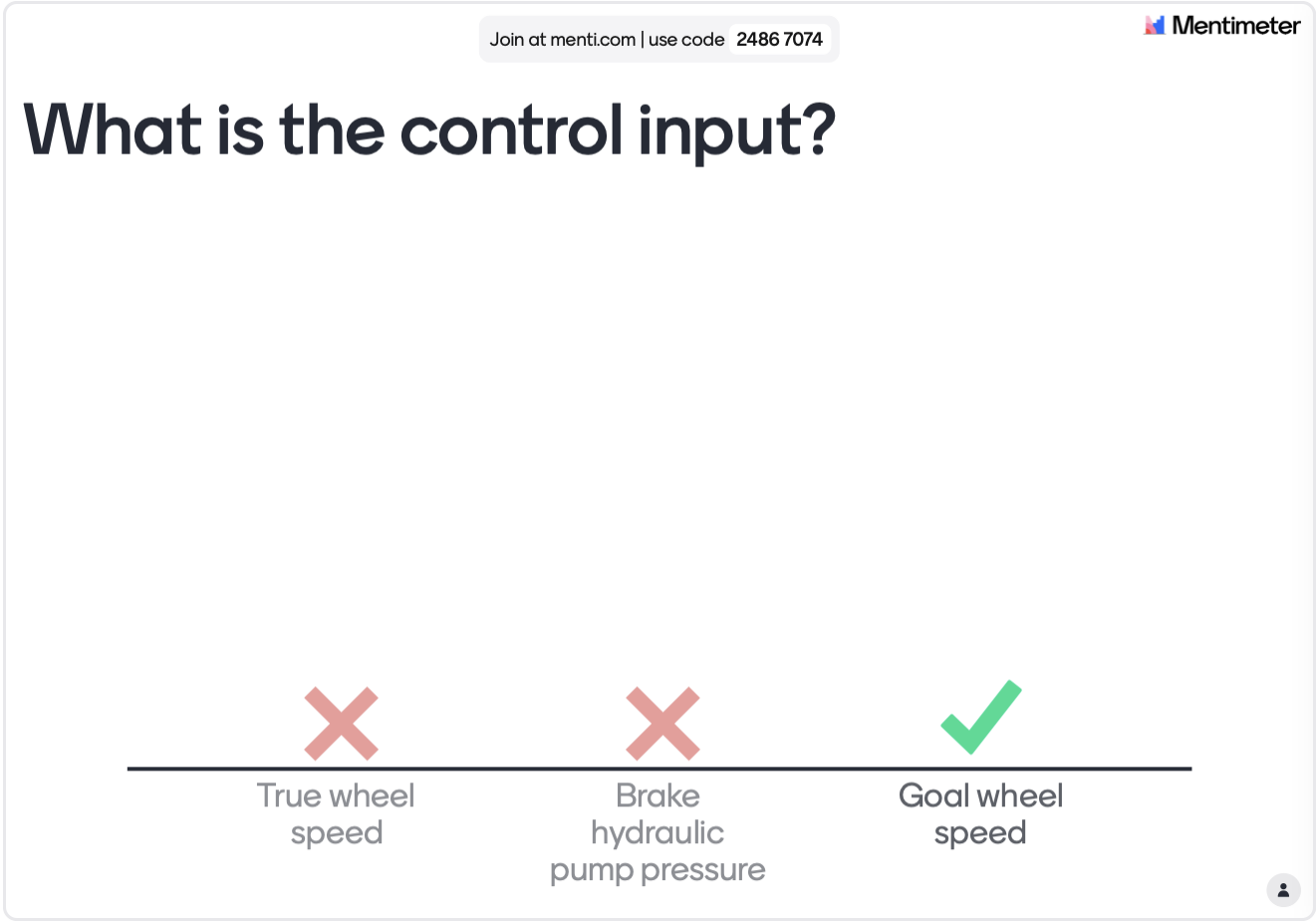

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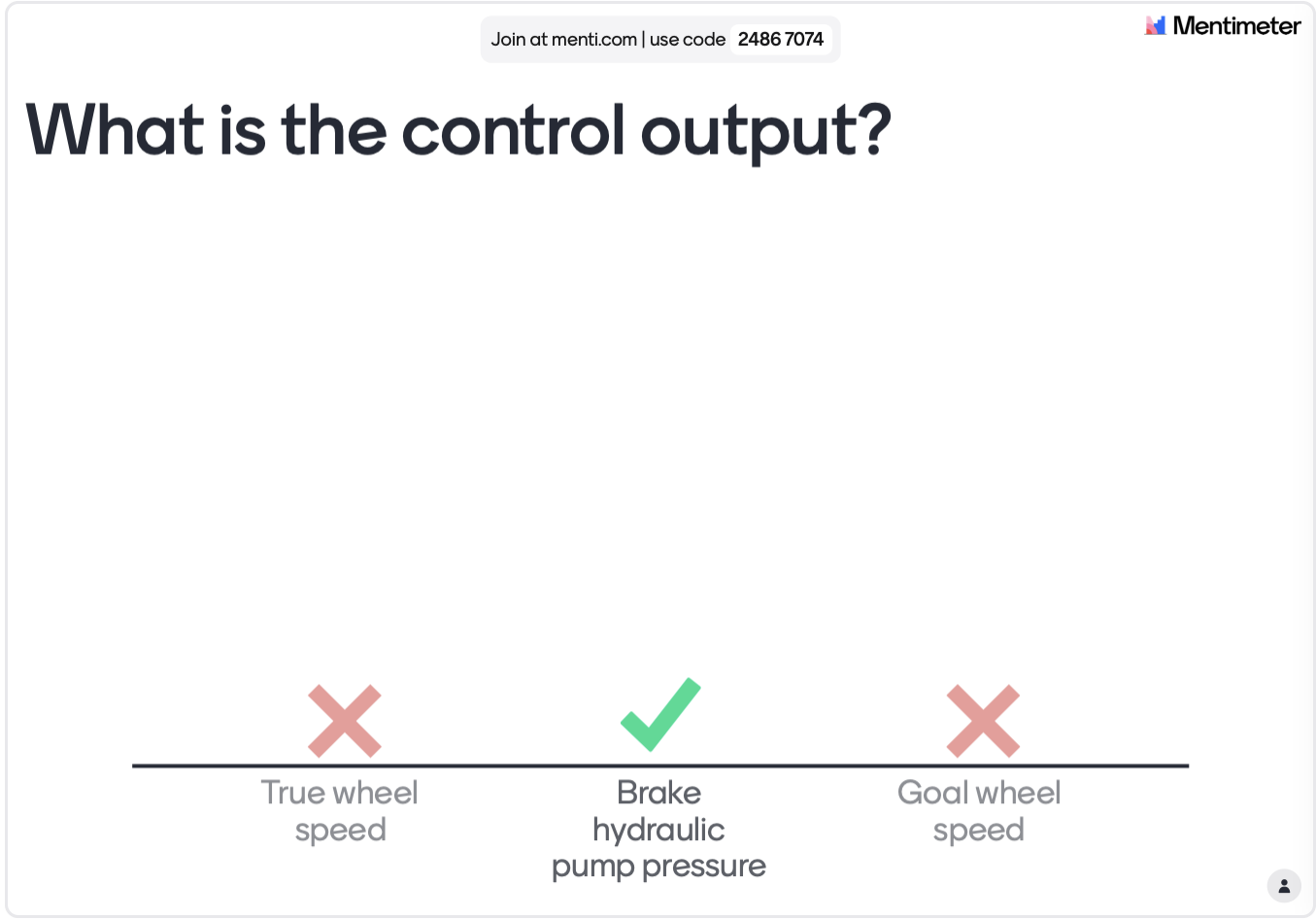

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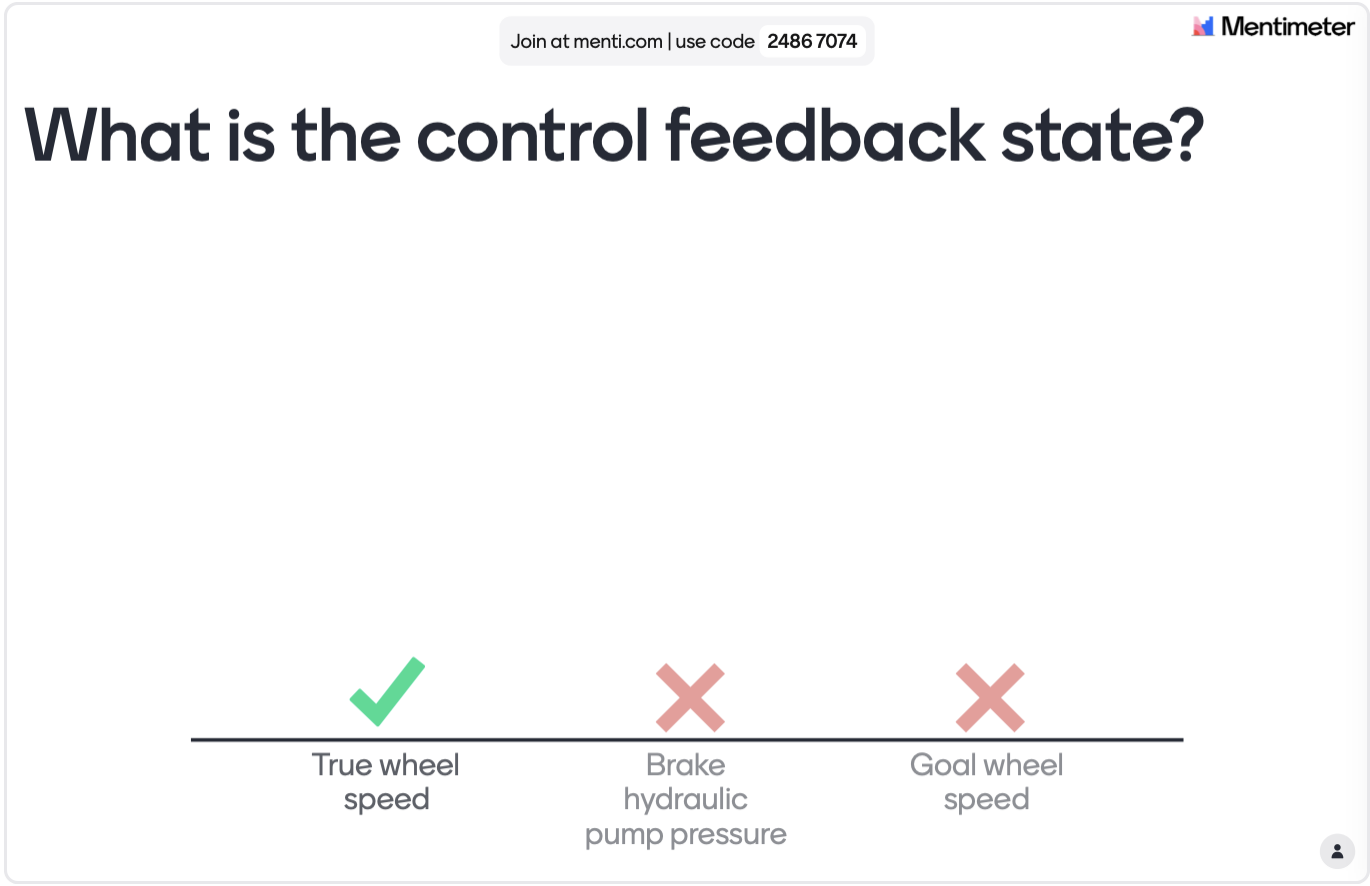

Next Week

- By next Wednesday:
  - Group up (5-6 ppl/group)
    - Register on Moodle;
  - 3 project ideas
    - Prepare a 3 min presentation for the ideas