Introduction to Robotics

Manipulation and Programming

Unit 4: Motion Control

ROBOT CONTROL: PART 1 INTRODUCTION TO CONTROL

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Objectives

- Explain the theory behind modeling of control.
- Example 1: Building Temperature Control
- Example 2: Automatic Speed Control
- Design Schematic
- Block Diagram

Introduction

SECTION 1

Feedback Controller

There are examples of feedback controllers everywhere. There are 3 essential elements of a feedback control system.

1. Actuator that manipulates and causes an action
2. Sensor that measures the response
3. Controller that adjusts the actuator in response to the measurement

Feedback Controller

- The controller receives the sensor measurement and compares it to the target (set point) to determine what adjustment is needed to the actuator. Some actuators are binary such as ON/OFF while others are continuous such as percent open (0-100%). Below are a couple examples of feedback controllers.

Case Study 1: Building a Temperature Control

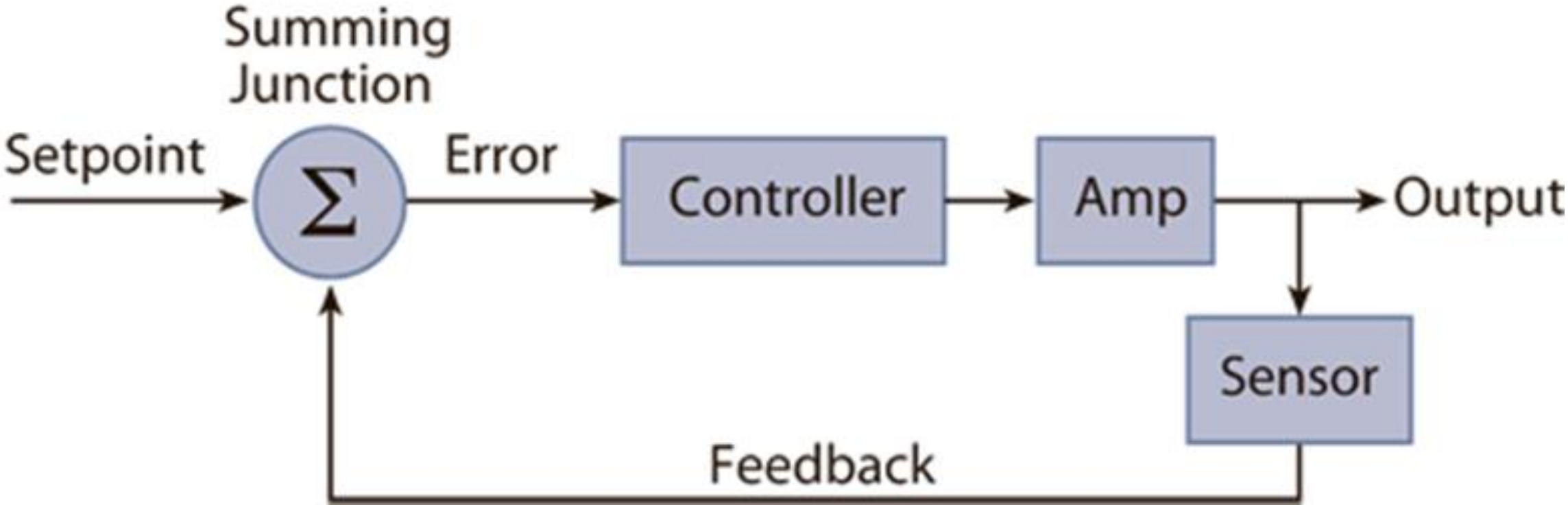
SECTION 2

Example 1: Building Temperature Control

- One well-known example of a controller is the **temperature control** of a building in winter includes a heater (actuator), sensor (temperature thermistor), and controller (thermostat). The controller switches the heater on when the temperature drops below a certain level and switches the heater off when the temperature rises above a certain level. A disturbance variable may be changes in the outside air temperature or a change in indoor temperature due to a door opening.

Example 1: Building Temperature Control

Element	Temperature Control
Actuator	Valve or switch in heater, Fuel to the furnace
Controller Set Point	Desired temperature indoors
Sensor	Temperature sensor such as a thermocouple or thermistor
Disturbance	Doors opening, wind, temperature outside


Summing
Junction
Setpoint
Σ
Error
Controller
Amp
Output
Sensor
Feedback

Case Study 2: Automobile Speed Control

SECTION 3

Example 2: Automobile Speed Control

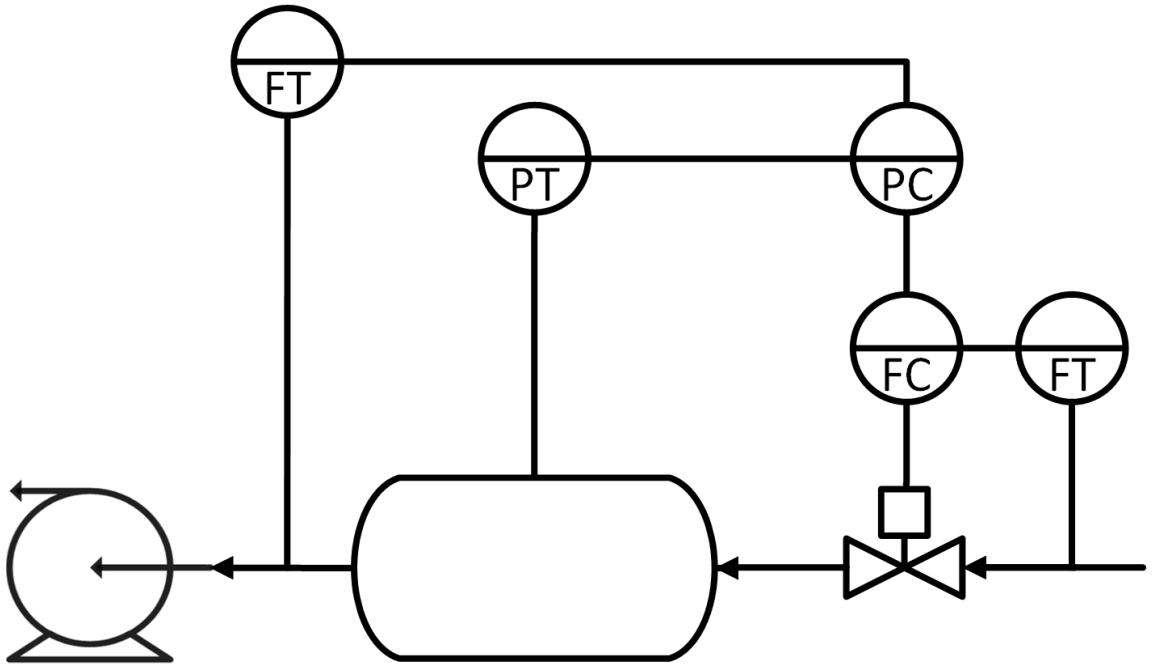
- Consider an automobile with an automatic cruise control. The driver may adjust the velocity set point for the controller. The controller adjusts the gas pedal position (actuator) in response to changes in the speedometer reading (sensor).
- A disturbance variable may be an approaching hill or wind that would cause a deviation of the speed from the desired set point.

Example 2: Automobile Speed Control

Element	**Cruise Control**
Actuator	Gas Pedal Position, Fuel to the Engine
Controller Set Point	Desired Speed (mph or km/sec)
Sensor	Speedometer, measured velocity
Disturbance	Hills, wind, other cars

Process Schematic

SECTION 4



Process Schematic

- A process schematic can be augmented with circles that reveal the type of transmitter or controller.
- Two letters in the circle name indicate the quantity being measured and whether it is a transmitter or a controller.

Measurement (Letter 1)	Description
A	Analyzer (mole or mass fraction)
C	Concentration
F	Flow
I	Current
L	Level
P	Pressure
R	Resistance
S	Speed
T	Temperature
V	Vibration
X	Miscellaneous

Device (Letter 2)	Description
C	Controller
E	Element
I	Indicator
M	Motor
S	Switch
T	Transmitter/Transducer
V	Valve
X	Miscellaneous
Z	Safety Device

Process Schematic

The diagram above has a *FT=Flow Transmitter*, *PT=Pressure Transmitter*, *PC=Pressure Controller*, *FC=Flow Controller*, and *FT=Flow Transmitter*. The *FT/FC* and *PT/PC* both form feedback loops because they measure and control the same quantity. The *FC* receives a set point from the *PC* above to create a **cascade controller** of two feedback loops. The upper *FT* measures a pressure disturbance and provides a **feedforward element** to the pressure control. Feedforward and cascade controllers are added to reject additional disturbances and are more advanced than common feedback control.

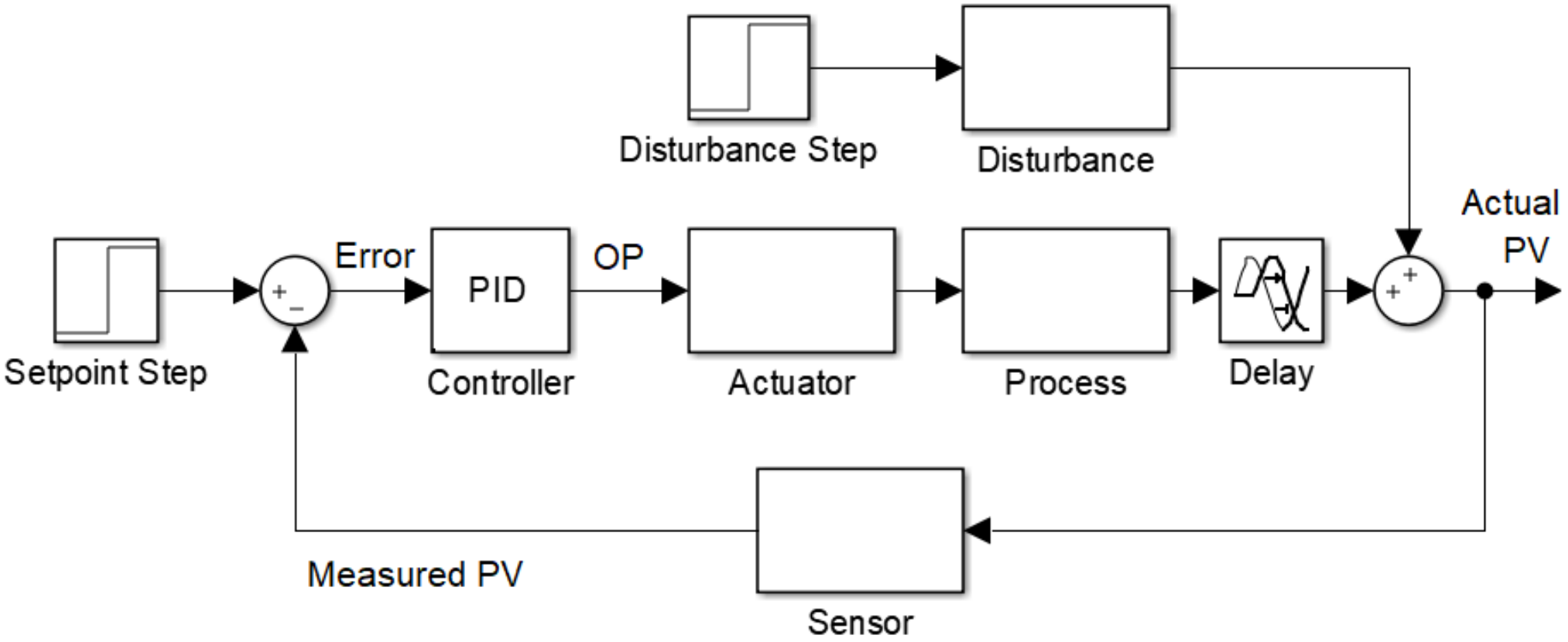
Block Diagram

SECTION 5

Block Diagrams

- Block diagrams show the blocks of a control system with the interconnections that determine the direction and connections of inputs and outputs. A feedback control system consists of a sensor, actuator and controller that are connected with information flowing in a loop.
- The loop is created with the sensor providing information to the controller. The controller changes the controller output that then changes the process. The process is measured again and the cycle repeats.

Block Diagram



Block Diagram

- Block diagrams are different than a process diagram in that it is a diagram of the flow of information, not necessarily how the pieces of equipment are physically placed.

Control Terminology

SECTION 6

Control Terminology

- There is different terminology when talking about common controllers such as Proportional Integral Derivative (PID) or advanced controllers such as Model Predictive Control (MPC).
- Below is a table of some of the terminology and associated abbreviations.

Control Terminology

Element	Common Control (PID)	Advanced Control (MPC)
Actuator	Controller Output (CO) or Output (OP)	Manipulated Variable (MV)
Controller	Set Point (SP)	Set Point (SP) or Range (SPHI/SPLO)
Sensor	Process Variable (PV)	Controlled Variable (CV)
Disturbance	Disturbance Variable (DV)	Disturbance Variable (DV)