Factory Automation and Control Methods
Lecture 5: Industrial Control Systems

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Outline

- Process industries versus discrete manufacturing Industries
  - Level of automation
  - Variables and parameters in the two industries
- Continuous Versus Discrete Control
  - Continuous control systems
  - Discrete control systems
- Computer Process Control
  - Control requirements
  - Capabilities of computer control
  - Forms of computer process control

What is industrial control?

"***Industrial control*** is defined here as the automatic regulation of unit operations and their associated equipment, as well as the integration and coordination of the unit operations in the larger production system."

Note: unit operations in this class refers to manufacturing processes.

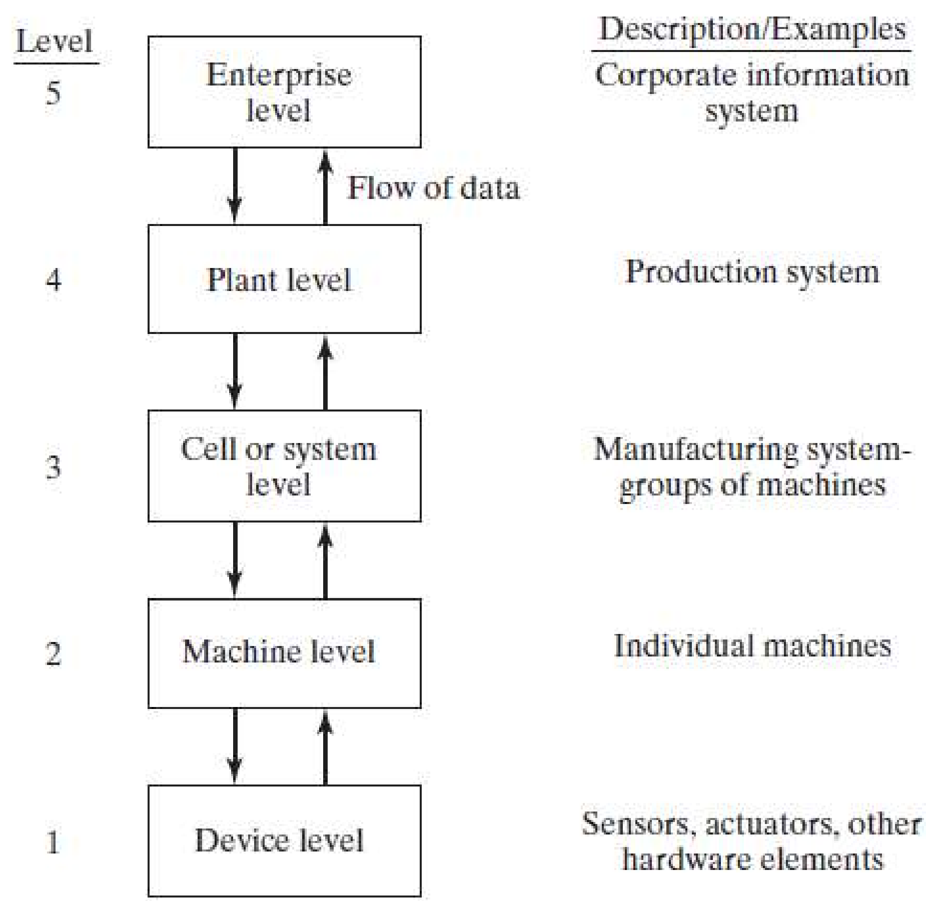
Process Industries Versus Discrete Manufacturing Industries

Industries and their production operations were divided into two basic categories:

- Process industries: perform their production operations on amounts of materials, because the materials tend to be liquids, gases, powders, etc.
- Discrete manufacturing industries: perform their operations on quantities of materials, because the materials tend to be discrete parts or productions.

Process Industries Versus Discrete Manufacturing Industry

Levels of Automation in the Two Industries



Process Industries Versus Discrete Manufacturing Industry

Levels of Automation in the Two Industries

Level	Process Industries	Discrete Manufacturing Industries
5	Enterprise level—management information system, strategic planning, high-level management of enterprise	Enterprise level—management information system, strategic planning, high-level management of enterprise
4	Plant level—scheduling, tracking materials, equipment monitoring	Plant or factory level—scheduling, tracking work-in-process, routing parts through machines, machine utilization
3	Supervisory control level—control and coordination of several interconnected unit operations that make up the total process	Manufacturing cell or system level—control and coordination of groups of machines and supporting equipment working in coordination, including material handling equipment
2	Regulatory control level—control of unit operations	Machine level—production machines and workstations for discrete product manufacture
1	Device level—sensors and actuators comprising the basic control loops for unit operations	Device level—sensors and actuators to accomplish control of machine actions

Process Industries Versus Discrete Manufacturing Industry

Variables and parameters in the two industries

In the process industries, the variables and parameters of interest tend to be continuous, whereas in discrete manufacturing, they tend to be discrete.

Process Industries	Discrete Manufacturing Industries
Chemical reactions	Casting
Comminution	Forging
Chemical vapor deposition	Extrusion
Distillation	Machining
Mixing and blending of ingredients	Plastic molding
Separation of ingredients	Sheet metal stamping

Process Industries Versus Discrete Manufacturing Industry

Variables and parameters in the two industries

A ***continuous variable*** (or parameter) is one that is uninterrupted as time proceeds, at least during the manufacturing operation.
Ex. force, temperature, flow rate, pressure, and velocity.

A ***discrete variable*** (or parameter) is one that can take on only certain values within a given range. Ex. limit switch open or closed, motor on or off, and work part present or not present in a fixture

Continuous Versus Discrete Control

- Process industries tend to emphasize the control of continuous variables and parameters.
- Manufacturing industries produce discrete parts and products, and their controllers tend to emphasize discrete variables and parameters.

There are also two basic types of control:

- Continuous control, in which the variables and parameters are continuous or analog
- Discrete control, in which the variables and parameters are discrete.

Continuous Versus Discrete Control

Comparison Factor	Continuous Control in Process Industries	Discrete Control in Discrete Manufacturing Industries
Typical measures of product output	Weight measures, liquid volume measures, solid volume measures	Number of parts, number of products
Typical quality measures	Consistency, concentration of solution, absence of contaminants, conformance to specification	Dimensions, surface finish, appearance, absence of defects, product reliability
Typical variables and parameters	Temperature, volume flow rate, pressure	Position, velocity, acceleration, force
Typical sensors	Flow meters, thermocouples, pressure sensors	Limit switches, photoelectric sensors, strain gages, piezoelectric sensors
Typical actuators	Valves, heaters, pumps	Switches, motors, pistons
Typical process time constants	Seconds, minutes, hours	Less than a second

Comparison between continuous and discrete control

Continuous Versus Discrete Control

Continuous control systems

In continuous control, the usual objective is to maintain the value of an output variable at a desired level.

There are several ways to achieve the control objective in continuous process control systems such as

- Regulatory control
- Feedforward control
- Steady-state optimization
- Adaptive control
- ……

Continuous Versus Discrete Control

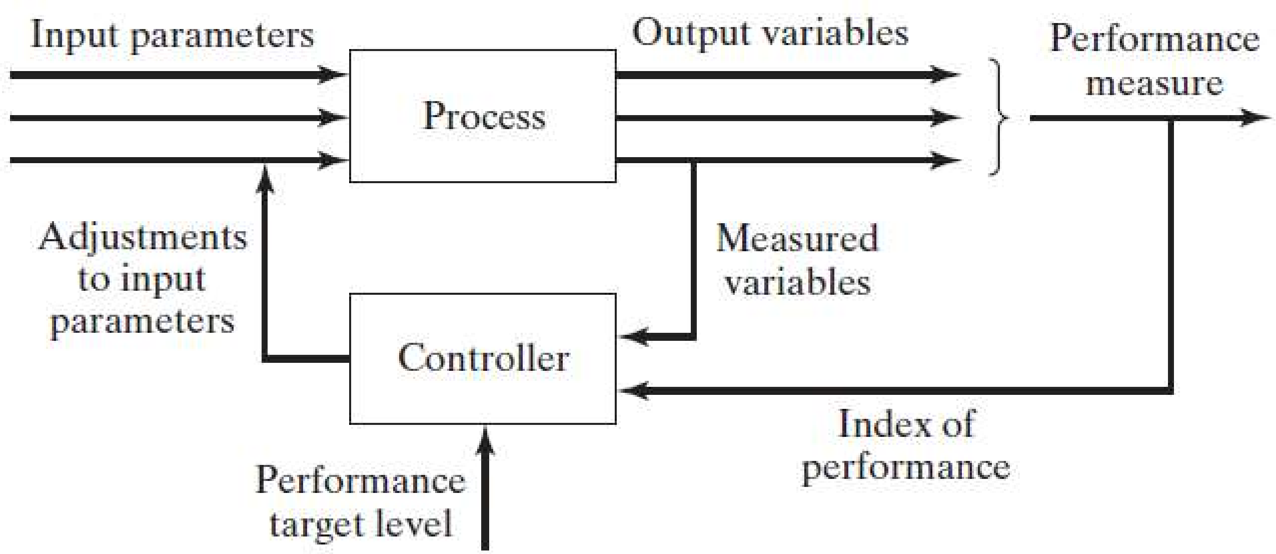
Continuous control systems

Regulatory Control: the objective is to maintain process performance at a certain level or within a given tolerance band of that level.

Applications: appropriate when the performance attribute is some measure of product quality, and it is important to keep the quality at the specified level or within a specified range.

Continuous Versus Discrete Control

Continuous control systems

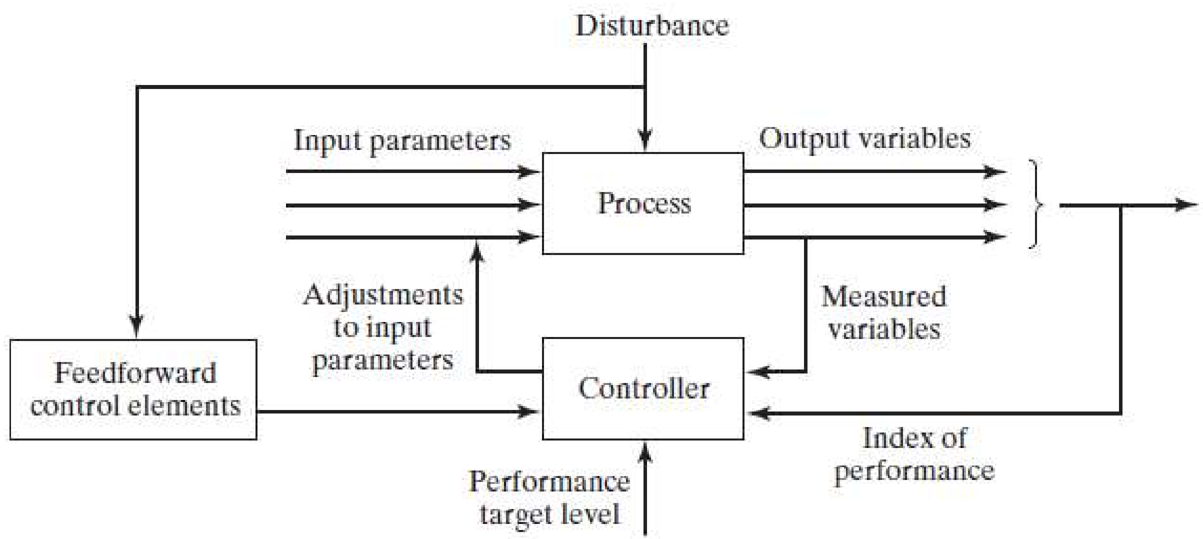


Note: The trouble with regulatory control (and also with a simple feedback control loop) is that compensating action is taken only after a disturbance has affected the process output. An error must be present for any control action to be taken.

Continuous Versus Discrete Control

Continuous control systems

Feedforward Control: anticipate the effect of disturbances that will upset the process by sensing them and compensating for them before they affect the process.



Note: In the ideal case, the compensation is completely effective. However, complete compensation is unlikely because of delays and/or imperfections in the feedback measurements, actuator operations,

Continuous Versus Discrete Control

Continuous control systems

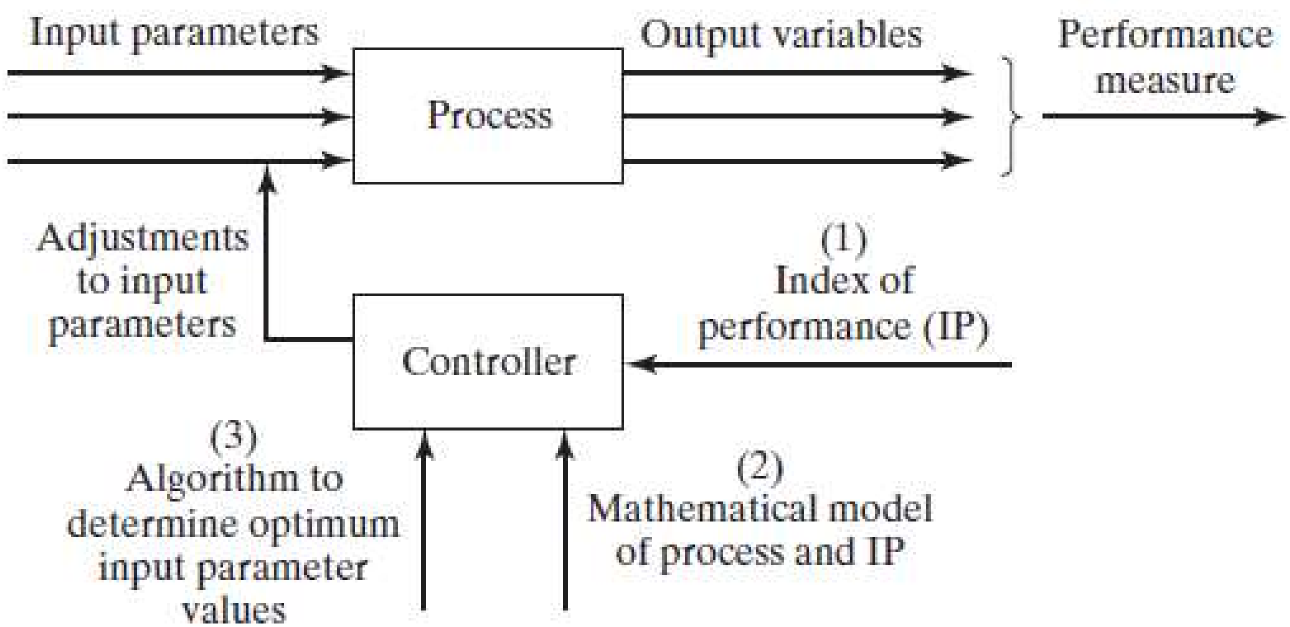
Steady-State Optimization. This term refers to a class of optimization techniques in which the process exhibits the following characteristics:

- there is a well-defined index of performance, such as product cost, production rate, or process yield.
- the relationship between the process variables and the index of performance is known
- the values of the system parameters that optimize the index of performance can be determined mathematically.

When these characteristics apply, the control algorithm is designed to make adjustments in the process parameters to drive the process toward the optimal state.

Continuous Versus Discrete Control

Continuous control systems



Steady-state (open loop) optimal control

Continuous Versus Discrete Control

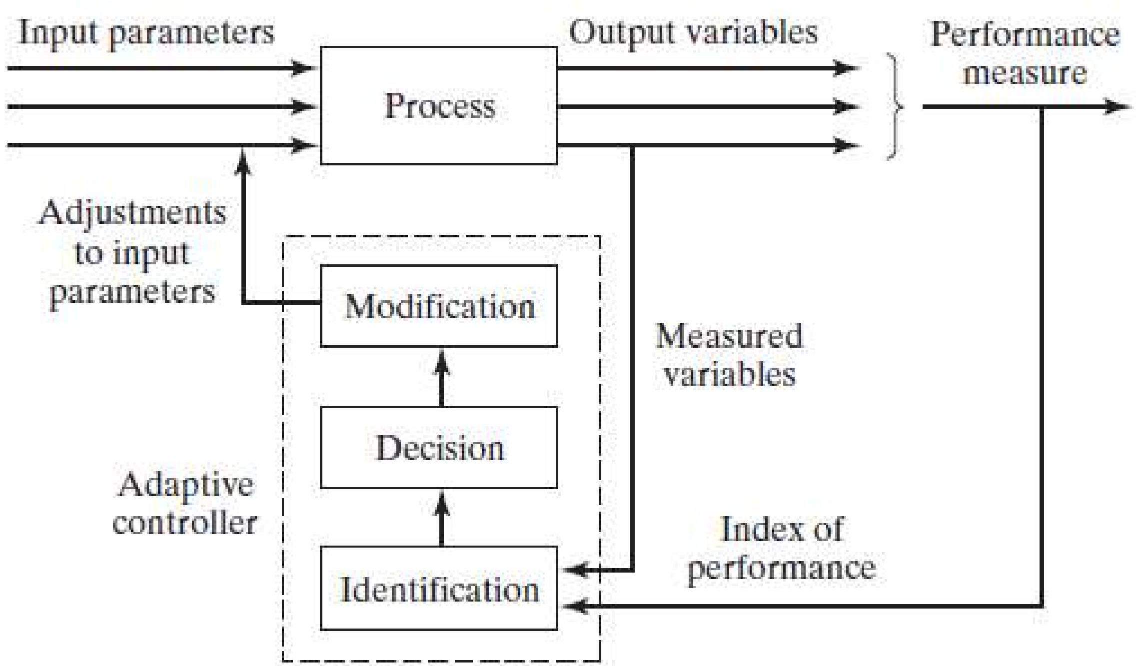
Continuous control systems

Steady-state optimal control operates as an open-loop system. It works successfully when there are no disturbances. When such disturbances are present in the application, a self-correcting form of optimal control can be used, called
adaptive control.

Continuous Versus Discrete Control

Continuous control systems

Adaptive Control



Continuous Versus Discrete Control

Discrete control systems

- In discrete control, the parameters and variables of the system are changed at discrete moments in time, and the changes involve variables and parameters that are also discrete, typically binary (ON/OFF).

- The changes are defined in advance by means of a program of instructions, for example, a work cycle program. The changes are executed either because the state of the system has changed or because a certain amount of time has elapsed.

Continuous Versus Discrete Control

Discrete control systems

These two cases can be distinguished as

- Event-driven changes: executed by the controller in response to some event that has caused the state of the system to be altered.

  Ex. Counting parts moving along a conveyor, A robot loads a work part into the fixture,…

- Time-driven changes: executed by the control system either at a specific point in time or after a certain time lapse has occurred.

  Ex. Heat-treating operations, operation of a washing machine,

References

Mikell P. Groover, “Automation, Production Systems and Computer-integrated Manufacturing” , 4th edition, Pearson, chapter 2