MECH 420 SENSORS AND ACTUATORS

Solutions to Assignment 1

Sol-Problem 1 (Problem 1.2 from Textbook)

Lights On-off System for an Art Gallery

There are two essential measurements in this system

(a) Light intensity detection

(b) People count.

We should not measure the light intensity inside the gallery because there will be ambiguity as to the control action. Specifically, when the lights are on at night, the sensor would probably instruct the lights to be turned off thinking it is the day time because it could not differentiate between daylight and artificial light. To avoid this, a simple timer to indicate a rational time interval as the night time (e.g., 7:00 p.m. - 12:00 midnight) could be used. Alternatively a photo-voltaic sensor could be installed outside the windows of the gallery or on top of a sunroof.

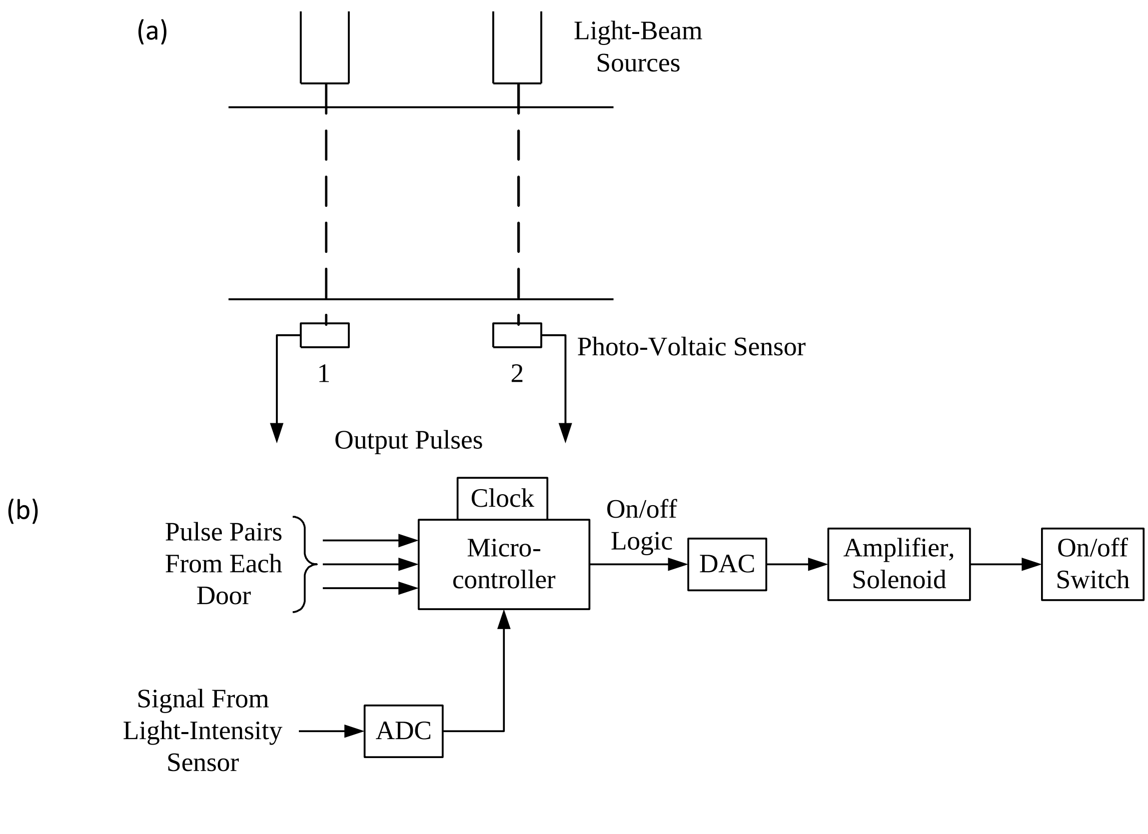

Figure S1.2: (a) People counting device; (b) Control system.

People count has to be made directionally (i.e., entering or leaving) at each door. Hence a pair of probes is needed. Force sensors on the floor, turnstile counters, or light-pulse sensors may be used for this purpose. For example, consider the following arrangement:

The light beams are generated by laser or LED visible-light sources. They are received by a pair of photo-voltaic cells. When the beam is intercepted for a short period of time, an output pulse is generated at the corresponding photo cell (see Figure S1.2(a). The order of the pulses determines the direction (entrance or exit) of travel.

Even though measurements are made in the system, this is essentially an "open-loop" control system, as clear from the system schematic diagram shown in Figure S1.2(b).
The system output is the on/off status of the switch controlling the gallery lights. Even though the number of people in the gallery is counted and the light intensity is measured to control the switch, the status of the switch is not used to control the number of people in the gallery, or the day-light intensity. Hence there is no feedback path.

The operation of the control system is straightforward. The pulse signals from each door are detected and timed. This determines the people entering and leaving. A count (COUNT) is kept. Furthermore, the light intensity (INT) is measured and compared with a desired level (INTD). A logic circuit can be developed to realize the following logic:

$$LOGIC \ = \ \left(COUNT.GT.0\right).AND.\left(INT.LT.INTD\right)$$

If this function is TRUE, the lights are turned on using a suitable actuator (e.g., a solenoid actuated by a current). Otherwise the lights are turned off.

Sol-Problem 2 (Problem 1.3 from Textbook)

Component	Component Type
Stepper Motor	Actuator
PID Circuit	Controller
Power Amp	Signal Modifier
ADC	Signal Modifier
DAC	Signal Modifier
Optical Encoder	Sensor/transducer
Process Computer	Controller
FFT Analyzer	Signal Modifier
DSP	Signal Modifier/Controller

Sol-Problem 3 (Problem 1.6 from Textbook)

The schematic diagram of an automated bottle-filling system is shown in Figure S1.6.

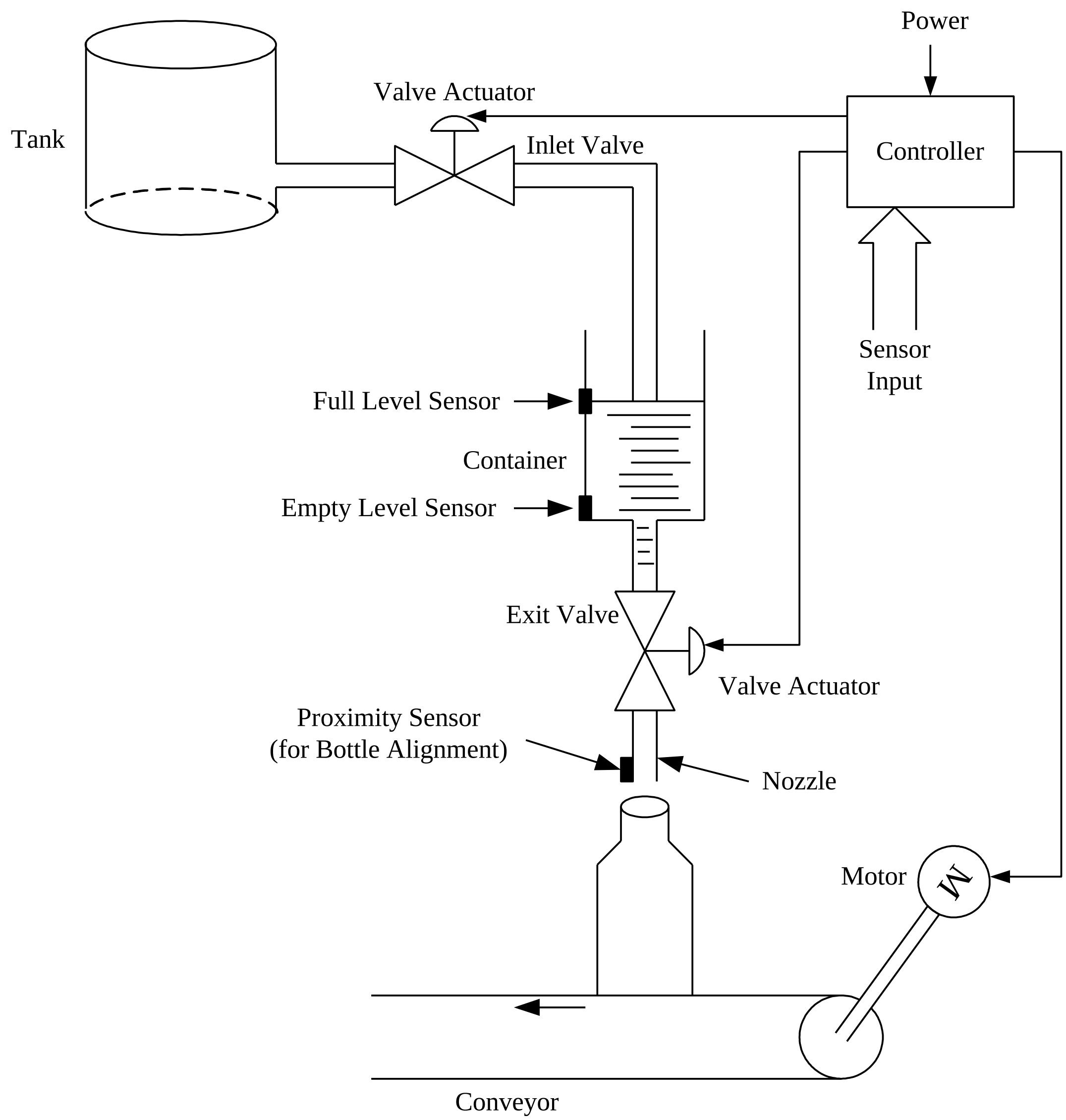

Figure S1.6: Schematic diagram of an automated bottle-filling system.

The operation of the automated bottle-filling system can be described by the following series of steps:

1. When the power is on, the controller checks the sensor input to see (1) is the filling container full, and (2) is there an empty bottle under the nozzle?
2. If the first condition is not satisfied, the inlet valve is opened to fill the container until "full container" signal from the corresponding sensor is received.
3. If only the first condition is satisfied, the motor is activated to move an empty bottle under the nozzle.

4. The motor is stopped when “bottle in position” is detected (from the proximity sensor).
5. The exit valve is opened to fill the bottle.
6. When “container is empty” signal is received (from empty level sensor) the exit valve is closed. The motor is turned on again and the conveyor moves away the filled bottle.
7. Go to Step 1. The whole process is repeated again and again until either power is off or the “process stop” command is received by the controller.

Sol-Problem 4 (Problem 1.7 from Textbook)

Note that one component may perform several functions.
Controller: Thermostat
Actuator: Valve actuator
Sensor: Thermocouple, pilot flame detector
Signal Modification: Transmitters and signal conditioning devices for thermostat signal to the valve, thermocouple signal, and pilot flame detector signal.

Operation: The thermocouple measures the room temperature, compares it with the set point, and determines the error (= set point - actual temperature). If the error is positive, a signal is transmitted to turn on the natural gas valve. If negative, the valve is turned off. The pilot flame detector checks if the pilot flame is off. If so it overrides the actuator signal and turns off the valve.

For better performance, measure the water flow rate, the inlet water temperature, and the outside temperature and incorporate a feedforward control as well as the original feedback scheme. In particular, the time delay in the process reaction can be considerably reduced by this method. Also a more sophisticated control scheme may be able to produce an improved temperature regulation, but it is not necessary in typical situations.

Sol-Problem 5 (Problem 1.8 from Textbook)

(a) Load torque (using a dynamometer), or armature current of the dc motor
(b) Input temperature of the liquid (using a hot-wire device)
(c) Flow rate of the liquid (using a flow meter); Temperature outside the room (using a thermocouple); Temperature of steam at radiator input
(d) Tactile forces at the gripper (using piezoelectric, capacitive or strain gauge sensors); Weight of the part to be picked up
(e) Torque transmitted at manipulator joints (using strain gauge torque sensor); Curvature of the seam contour (using image processing).

Sol-Problem 6 (Problem 1.9 from Textbook)

a. Muscle contraction, body movements, body temperature, heart rate
b. Decisions, profits, finished products
c. Electric power, pollution rate.
d. Front wheel turn, direction of heading, noise level, pollution level.
e. Joint motions, position, velocity, acceleration, torque, end-effector motion.