BRADLEY University

TeeJet TECHNOLOGIES

TeeJet Adaptive Controls Research Project – 2020
Project Statement

Model-Free Adaptive Flow Rate Control of Heterogeneous Agricultural Spraying Machines

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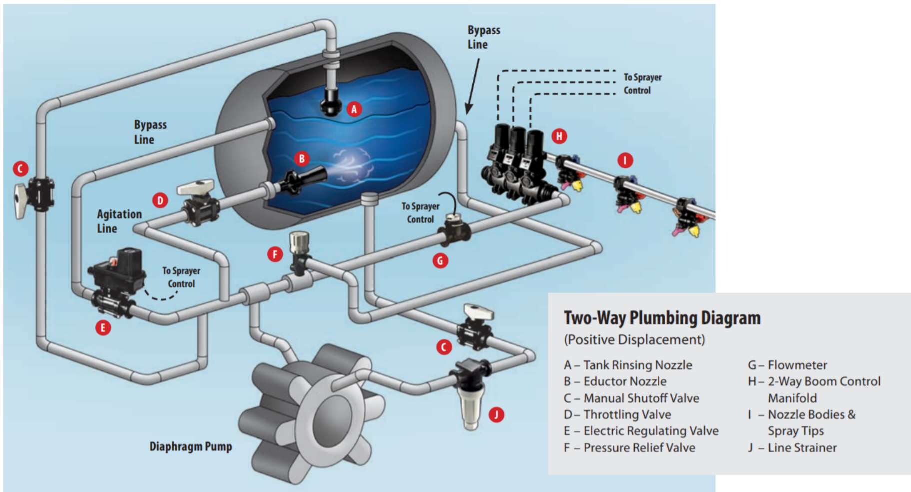

Figure 1: Two-way plumbing diagram of an agricultural srayping machine [Courtesy of TeeJet Technologies].

List of Abbreviations

PWM Pulse Width Modulation

1 Background

Agricultural Spraying machines are used to apply chemicals to farmland to increase the productivity of the plants. Fertilizer increases yield by 40% to 60%. If pesticides are not used, yield decreases by 50% to 90%. To maximize these yields, the correct amount of chemical must be applied to the correct area of the plant or directly to the soil.

Dr. Miah, Do we need a reference here?

A two-way plumbing diagram of an agricultural spraying machine is shown in Figure 1. Chemical is added to water to the tank of the sprayer to dilute the chemical to the proper concentration. When the pump is engaged, fluid flows from the bottom of the tank to the pump through **Maunual Shutoff Valve C**, **Line Strainer J** and into the pump. In some sprayers, the speed of the pump can be changed. Here, fluid can flow in a number of directions depending on the configuration of the Sprayer.

Fluid can flow back to the tank to agitate or mix the chemical into the water so that sediment does not form at the bottom of the tank. This is manually changes by moving the position of **Throttling Valve D**. If too much pressure builds up in the system, **Pressure Relief Valve F** opens to prevent system damage. The amount of fluid pumped out to the boom can be changed by opening or closing **Electric Regulating Valve E**. This is typically controlled by an embedded system. The amount of fluid pumped out to the boom is measured by the **Flowmeter G**. The flow rate measured by **Flowmeter G** indicates how much fluid is being applied to the farmland.

The boom is split into sections containing consecutive groups of nozzles. Boom sections can be turned on and off by **Boom Control Manifold H**. Fluid exits the boom from the **Nozzle Bodies and Spray Tips I**. The mechanics of the nozzles create a spray when exiting the boom. Droplet size if a function of the pressure across the boom. **Nozzle Bodies and Spray Tips I** have a

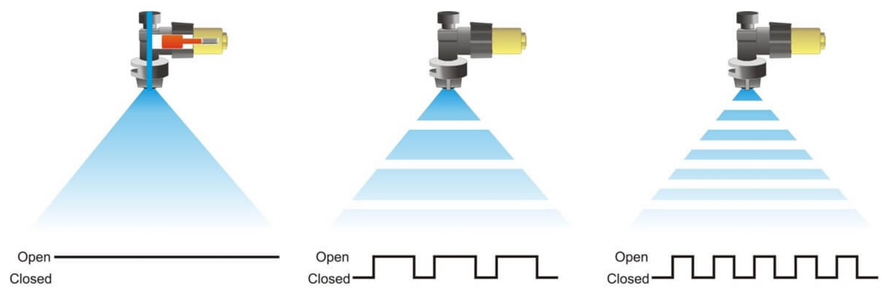

Figure 2: Nozzle Body Spray Pattern when Applied a PWM Signal.

solenoid attach that opens or closes the valve as shown in Figure 2 . By applying a PWM signal, we can control the pressure across the boom without impacting the flow rate.

Image take from web - needs to be re-made

2 Problem Statement and Objectives

Farming chemicals are regulated by the government which certifies the chemical for certain droplet sizes. This limits the farmer to how fast the vehicle can drive and apply the correct amount of chemical without an increase in pressure to achieve the same flow rate [L/ha]. In a sprayer application, we have two separate discrete-time feedback control systems to solve these problems:

1. **Rate Controller**: this system controls to a desired flow rate [L/ha]. This system ensures the correct amount of fluid is applied to the field. Target flow is calculated by the prescription for the field, the speed of the vehicle, and the length of the boom.

2. **Droplet Size Controller**: this system controls to a constant pressure across the boom of a sprayer. Droplet size directly correlates to the pressure across the boom. This can be determined from the nozzle's datasheet (see TeeJet product catalog). This ensures proper application of the fluid and prevents drift due to atmospheric conditions.

Flow rate controllers and sprayers can all be manufactured by different companies. This makes it very difficult to come up with a Droplet Size Controller design that will perform on all machines without developing a unique system for every configuration.

Figure 3 shows the block diagram of a two-input two-output discrete-time control system block diagram, where $D_2(z)$, $G(z)$, $x_2^{[d]}$, and x_2 are assumed to be unknown.

Problem statement: Develop a control system for the Droplet Size (Pressure) Controller ($D_1(z)$) that can adapt to different plant models and rate controllers.

Outcomes:

TeeJet expects design of a control system that can:

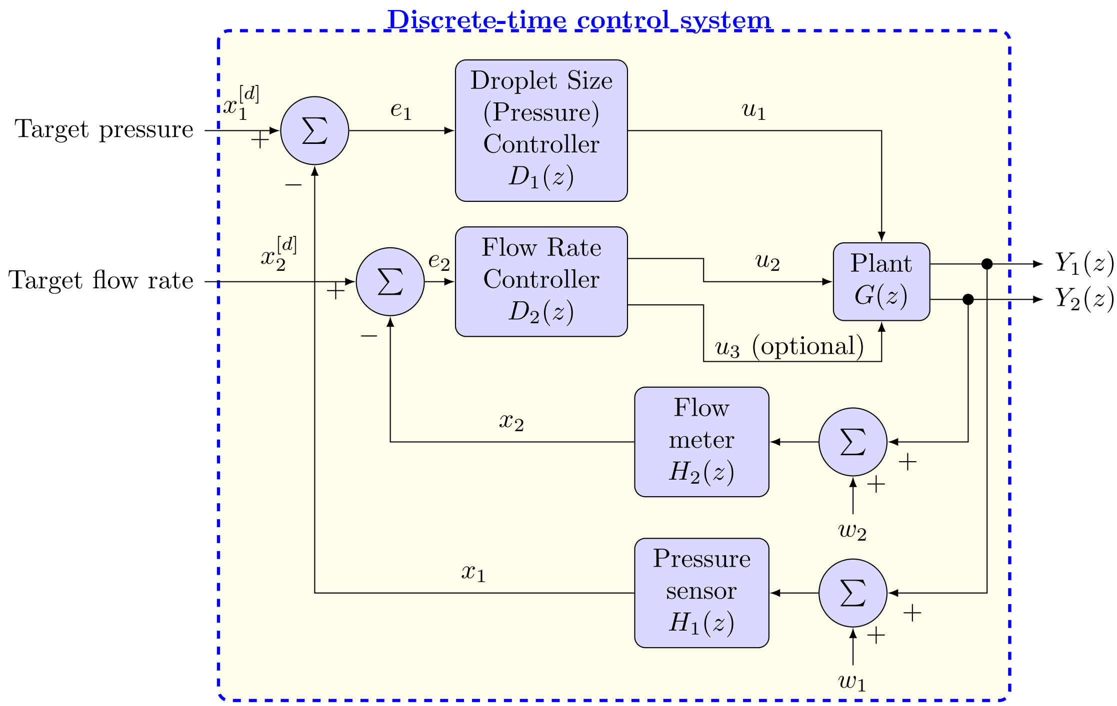

Figure 3: Two-input, two-output discrete-time control system block diagram.

Table 1: Description of signals used in the control system block diagram shown in Figure 3.

Signal	Description	Unit
$x_1^{[d]}$	Target pressure	[psi]
$x_2^{[d]}$	Target flow rate	[GPA]
x_1	Actual pressure	[psi]
x_2	Actual flow rate	[GPA]
u_1	Duty cycle to solenoids (limited between 0 and 100)	[%]
u_2	Open/close signal for regulating valve	[V]
u_3	Pump speed (optional)	[rev/min]
w_1	Pressure sensor noise	[V]
w_2	Flow meter noise	[V]

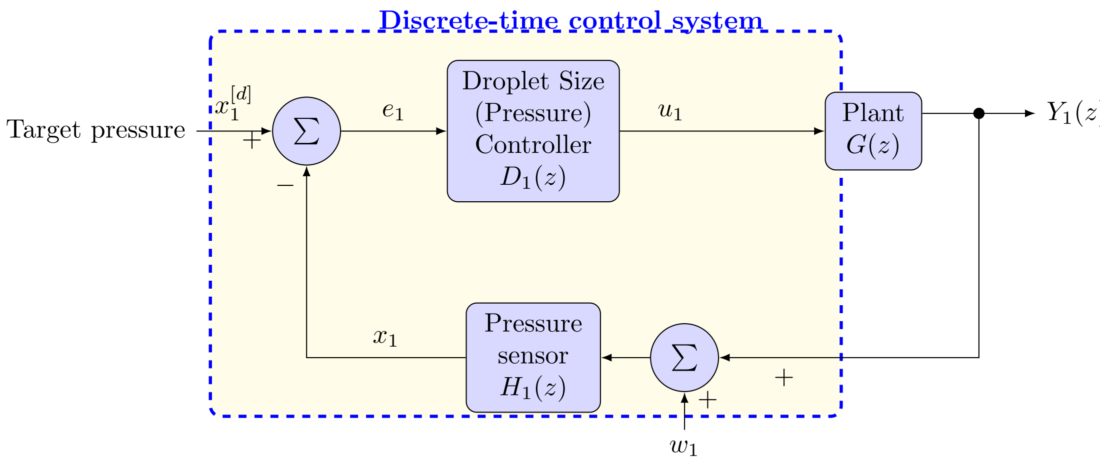

Figure 4: One-input, One-output discrete-time control system block diagram.

1. adapt to different plant models
2. adapt to different rate controllers

Student experience are expected to learn the following items that pertain to proposed solution:

1. Design the control system that is ready for implementation
2. Conduct computer simulations using MATLAB and Simulink
3. Validation and testing using real-time embedded system

3 Solution Approach

Model-Free Reinforcement Learning Control Approach

The control system of the Droplet Size controller can be simplified as in Figure 4.

Plant will be modeled using a state-space approach:

$x[k+1] = Ax[k] + Bu[k]$

$y = Cx[k] + Du[k]$

$$\begin{bmatrix} x_1[k+1] \\ x_2[k+1] \\ x_3[k+1] \\ x_4[k+1] \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} b_{11} \\ b_{21} \\ b_{31} \\ b_{41} \end{bmatrix} u_1$$

where the coeffiecients of A and B are unknown.

Approximate values for A and B have been identified using MATLAB's System Identification toolbox:

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -0.5724 & 1.551 & -2.193 & 2.106 \end{bmatrix} B = \begin{bmatrix} -2.4988 * 10^{-4} \\ -3.6800 * 10^{-4} \\ -0.0025 \\ -0.0031 \end{bmatrix}$$

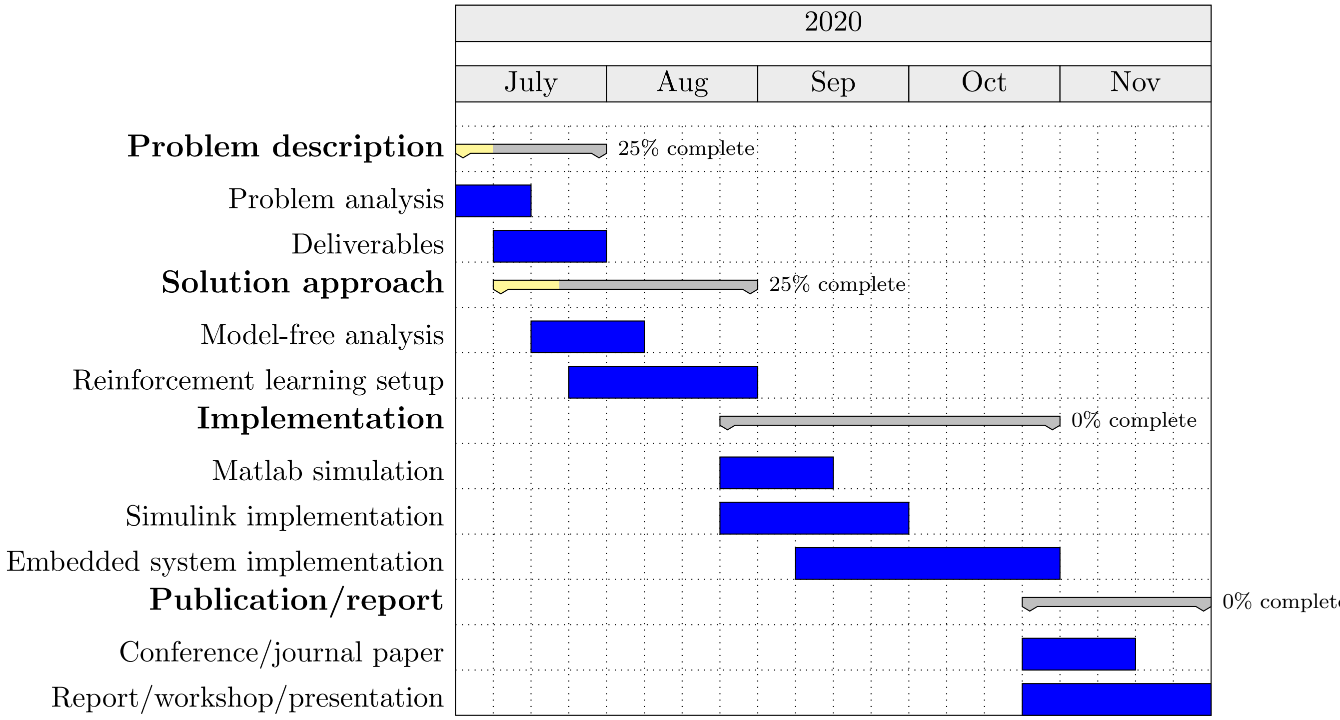

Figure 5: Gantt chart showing the project activities from July 2020 to November 2020.

where the sampling time is 50ms.

A typical pressure range is around 55 to 80psi. A typical flow rate range is around 5 to 15 Gal/ i.

OPTIONAL: description of x_1, x_2, . . .

u_1 is our control signal which will be converted to a PWM signal when sent to the nozzle drivers over the local CAN bus. Let the PWM frequency = 20Hz.

The solution will be implemented on an embedded system.

4 Deliverables

TBD

5 Timeline and Milestones