Control Optimization of Water System for Aeroponics

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Abstract

We have created a model to mimic the behavour of aeroponic water system. Using search algorithms we found optimal or sub optimal control scheme for such systems. The aeroponic water system of investigation uses air compressor to spray fine mists onto free roots of various plants. Optimazation occures for both correct moisture percent in roots as well as compressor active time. We propose our model be used to optimize Clarkson Universities Greenhouse project.

1 Introduction

In aeroponics nutrient ritch water is spraid onto the free hanging root system of plants. This method of cultivation has many benifits including maximal oxygen intake and high nutrient uptake. The main drawback is the methods need for mist production. It is common that compressors are used to store air preasure and release mists at periodic intervals. This system is used by Clarkson Universities Greenhouse project and has prompted our interest in modeling it.

The model consist of a compressor, preasure tank, mist pipe and root system. The compressor is activated when the preasure tank drops to a threshold preasure. This causes the compressor to be activated for a precalculated amount of time. The mist pipe switches on and off at a particular frequency and period. The root system is modeld as a drying system with a given max moisture content and linear evaporation rate. ***.

1.1 Mathematics of Model

Several assumptions are made about each aspect of the model. There is an assumed linear drying rate of the roots. The mist spray rate is linear dependent on preasure of the tank. The compressor is assumed to increase preasure at a constant rate. Modeling this with equation we get the system

Table 1: Constants of Interest

Variable	explination
P_m	air loss rate from mister
W_m	water spray rate from mister
E_r	evaporation rate of roots
M_m	max moister content of roots
V_t	volume of tank
C_r	compression rate of compressor
$M_c(t)$	mist control function with values 0 or 1
$P_c(t)$	pump control function with values 0 or 1
$M(t)$	moister content of roots in percent
$V(t)$	volume of air compressed in tank

$$V(t+1) = V(t) + C_r P_c(t) - P_m \frac{V(t)}{V_t} M_c(t) \tag{1}$$

$$M(t+1) = M(t) + W_m \frac{V(t)}{V_t} M_c(t) - E_r \tag{2}$$

1.2 Optimization

We wish to optimize both the power usage of the compressor as well as maintaining ideal moister content in the roots. We have included a cost function for the number of times the compressor is activated. This is because starting the compressor often takes several times as much energy as running it. Putting this together gives the following optimization problem.

Table 2: Optimization constants

Variable	explination
I_m	Ideal moister content of root
C_s	Cost for turning the compressor on
λ_r	importance factor of root moisture
λ_m	importance factor of motor usage

$$O = \lambda_r ||I_m - M(t)|| + \lambda_m ||P_c(t) + C_s|| \tag{3}$$

Because this optimization takes into account both moisture exprestions and cost of running the compressor we have included constants λ_r and λ_m to control the importance of each componet.

1.3 Search Space

The hope for optimizing these equations was to use calculus of variations however there are several real world constrants that make this difficult. Both the mist and pump control must be discrete 0, 1 for relevance to the Clarkson greenhouse project. I believe that the problem can still be solved analyticaly however in the interest of time we have coded the model and simply searched for the optimal solution. Our search space is inspired by the system currently used at Clarkson.

Table 3: Search Space

Variable	explination
F_m	frequency of mister activation
M_t	mist activation time
T_p	threshold presure to activate compressor
C_t	compressor activation time

By randomly trying combinations of these values and running our model on them we could discover the optimal or sub optimal solutions.

1.4 Appling to Clarkson's Greenhouse project

Our proposed model is highly dependent on many unknown constants. These values can be found by performing simple experiments and calculations. To illustrate this we have included several instructions on obtaining various constants

2 Data and Results

We have coded our model and run several simulations. The following data is the result of the following realistic constant values.

By searching on the space described above we obtained and optimal configuration seen bellow. The time period examed was 24 hours.

These results in them selves are not interesting however they prove that this method works and demonstrates its power.

Table 4: Constants cook book

Variable	method
P_m	Measure preasure decrease of tank vs time and do a linear interpilation. Calculated volume change from preasure change
W_m	Weight weight increase of root vs time with mist on and do linear interpilation.
E_r	Weight root system while drying and do linear interpilation. It should follow a negative exponential.
M_m	Compare weight of soaked roat and completely dry root.

Table 5: Test Model

Variable	value
P_m	.3 units per second
W_m	.01 percent per second
E_r	.0002 percent per second
M_m	.16 percent
V_t	10 units
C_r	2 units
I_m	.08
C_s	3.0
λ_r	3.0
λ_m	1.0

3 Produced Data

If we plot the volume compressed and root moisture content several interesting aspects can be seen. A

3.1 Temperature readings over time

4 Discussion

Table 6: Optimal Solution

Variable	value
F_m	150 seconds
M_t	5 seconds
T_p	3.69
C_t	2 seconds

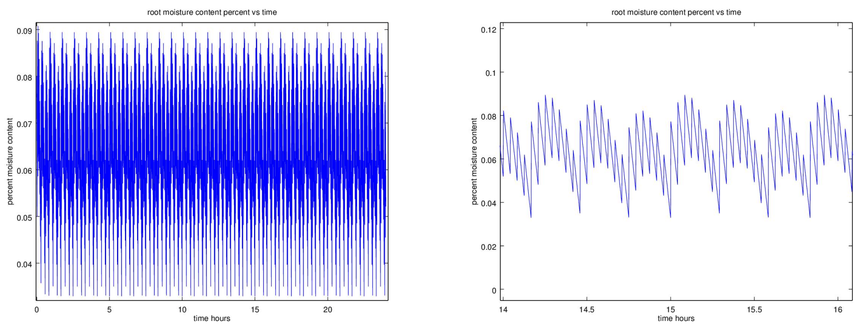

Figure 1: root moisture content

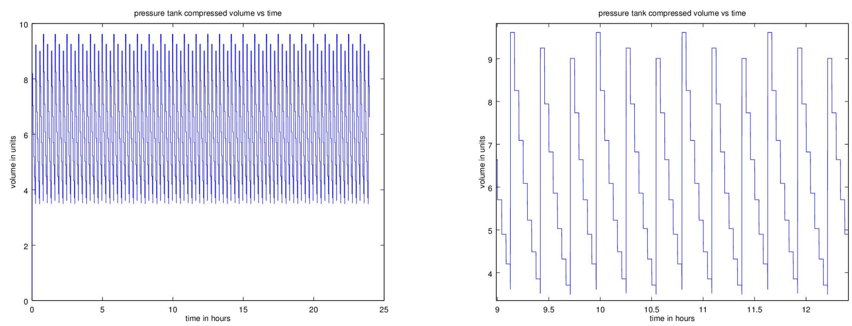

Figure 2: pressure tank compressed