Intelligent Water Dispersal Controller Using Mamdani Approach

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Abstract: - Controlling the amount of water in maintaining lawn health and beauty is a main topic in horticulture. A reliable controller is needed to control the amount of water to be dispersed as to ensure the soil has adequate moisture level. The use of fuzzy logic for controlling water dispersal is discussed in this paper. The performances of fuzzy water dispersal controller (FuziWDC) were measured on a significant set of common Bermuda turfgrass. The improved Mamdani inferencing for the task of water dispersal controller that considered both evapotranspiration (ET), tensiometer variable was presented as opposed to the earlier research. The comparison results between the Mandani and the conventional approach was shown. As the result, FuziWDC has performed better than the conventional approaches based on the lower annual average water usage for the whole year recorded.

Key-Words: - Dispersal Controller, Evapotranspiration, Fuzzy logic, Lawn, Mamdani Inferencing, and Tensiometer

1 Introduction

From the 17th century till now, maintaining lawn health and beauty has become one of the top considerations for every lawn owner. In maintaining the beauty and the health of the lawn, it is important to ensure that the lawn has enough water and is water only when it is needed to be water [1]. In lawn management, intelligent used of water can be done by controlling the amount of water to be dispersed after considering aspects such as a) grass species and cultivars, b) the soil type, c) the frequency and number of inches of rain and d) weather condition such as humidity and temperature [2]. Realizing the scarcity of water resources, there is a need to develop a reliable controller that can measure the soil moisture that will help to decide when to water and how much water is needed for watering.

Fuzzy Expert System has been successfully used in many type of controller. Some of the applications include motor controls and navigation [3, 4], and paper mill automation [5]. It is also been used in real-time traffic controller in asynchronous transfer mode (ATM) network. In controlling the task, fuzzy expert system is used in 'policing' which task to select as to ensure that each user source complies with the traffic parameter negotiated in the call setup to avoid traffic congestion [6].

Given the work of [7], we decided to explore the use of fuzzy logic for water dispersal controller. We aim to improve the simulation controller that can demonstrate the moisture level of the garden soil, the amount of water dispersed and watering day by simulating the environment parameter for moisture, climatology and the plant water scarce resistance.

In section 2 we discuss the involved factors in irrigation. In Section 3, we explain the approach and method that were employed in this research. In section 4, we discuss the findings and results of the research and we present an improved method of Mamdani's inferencing for the water dispersed controller. Finally in Section 5, we draw some conclusions about the results presented in this research. We also outline future directions of research inspired by these results.

2 Irrigation

There are many attempts to implement soft computing technique in irrigation. Most of the attempt is for the irrigation process for the commercial plantation. An attempt by [7] is for melon cultivation in greenhouse using Fuzzy Expert

System. In this attempt, the fuzzy control system was developed for the on-off control irrigation system. The fuzzy control system was programmed to take the soil moisture content from various climate sensors. The aims were to save water resources and preserve the melon quality.

For the purpose of this research, several factors had been considered before irrigating. These factors are bermuda grass characteristic, soil characteristic, water lost factor and advisable time of the day for irrigation, the moisture level in the soil and the amount of water needed.

2.1 Bermuda Turfgrass Characteristic

Common bermuda turfgrass is a warm season turfgrass with an optimum of 80^0F (26.67^0C) to 95^0F (35^0C). It is also excellent in heat adaptation but poor adaptation in cold weather [8]. That is why Common Bermuda Turfgrass is suitable to be planted in Malaysia. Usually the maximum root depth of a turfgrass is 2 feet under (60.96cm), the effective root depth (ft) for Water Management in Deep, Well-Drained Soil is between 1.5 to 2 feet (45.72cm to 60.96cm) and the turf grass allows 50% of water to deplete from its soil, where it is called Management Allowable Soil Water Depletion (MAD) [9].

2.2 Soil Characteristics

There are 4 levels of soil profile typically found under a lawn that composed of 4 horizons, that are A, B C and R. The A horizon is dark in color as a result of profuse root growth throughout the horizon. It is rarely more than one to two feet deep, often much less and is most conductive to plant growth because it is high in nutrient from decomposing organic matter. The B horizon is often where clay, organic matter, iron and aluminium accumulate. Parent material or unweathered material composes horizon C. The last section is horizon R which is bedrock.

2.3 Water Lost Factor and Advisable Time of the Day for Irrigation

Water is lost through the process of transpiration, evaporation, runoff and percolation. Transpiration is a process of water loss through the leaves although some may occur through any part exposed to the atmosphere [10]. Evaporation is the process by which water vaporizes and escapes from the surface, rising into the atmosphere [11]. Percolation is the downward movement of water through the soil. The combination of transpiration and evaporation process has created a term called Evapotranspiration. It is a process that takes the loss of water from the soil by evaporation and by transpiration from the plant into consideration [10]. The evapotranspiration is influenced by a) humidity, b) solar radiation, c) wind and, d) temperature [12]. It usually occurs from 10 am to 6 pm [11]. Thus, it is best to irrigate between 5 am to 10 am where the sun is low, winds are calm and temperature are cool [13].

2.4 Soil Moisture Level

According to [9], irrigation must be applied prior to permanent wilting in order to avoid serious injuries or permanent damage to the turf. One way to determine when the grass needs to be water is by using the knife or soil probe (core sampler) [2]. This method is not really suitable for a home garden owner because it requires a lot of time and energy. Another method to determine when the grass needs to be water is by using soil moisture sensor called tensiometer. Tensiometer has been used for many years to measure water tension in the field [14]. Its reading may be used as indicators of soil water and the need for irrigation [10]. As the soil dries out, water is pulled through the porous tip, causing the gauge to indicate higher soil moisture tension [2].

When the instrument installed at shallower depths of the root zone reaches a certain readings, they can be used to determine when to irrigate, based on soil texture and plant type [10]. The placement of tensiometer with depth is critical. It should be centered in the crop root zone, but at least 4-6 inches below the surface [15]. The idea is to irrigate after the plant or turf grass has reach its Management Allowable Depletion (MAD) point. That is when the tensiometer reading fell in the area of available water with stress.

2.5 The Amount of Water

According to [2], the most common method of determining when and how much to irrigate is by using evapotranspiration (ET) data. The amount of water that is applied to replace ET losses also depends on which grass species is being grown because different species have different needs, and these needs can vary throughout the year, depending on growth rate. The ET value shows the maximum amount of soil water loss, but most landscape can maintain a healthy condition with much less water.

Hence, a multiplying factor called "crop coefficient" is used [16].

Crop coefficient is not only vary by species but also within a species over the growing seasons, with warm grass ranging from 0.63 to 0.78 and cool seasons grass ranging from 0.79 to 0.82 [17]. Therefore, it can be concluded that the crop coefficient is the ability of the crop to stay healthy with less amount of water. In getting the amount of water needed for irrigation in a certain period of time, the ET value and the crop coefficient is multiplied.

3 Approach and Method

There are four major phases involved in this phase. The discussion of each phase would be described in the next sections.

3.1 Knowledge Acquisition

Considering all the opinion and present research, the parameter that should be considered in the domain problem is the tensiometer reading, the evapotranspiration rate and the turf grass coefficient. This is because the tensiometer acts like the detector of the soil moisture content in the soil. The grass should be irrigated based on the moisture content in the soil because the soil moisture content shows the grass need. The evapotranspiration rate shows the amount of water loss from the soil by the process of evaporation and transpiration. The turf grass coefficient shows the grass ability of water resistance. The external moisture received by the soil was considered because it gives the added moisture content to the soil while the depth of grass root was considered because it shows the ability of the grass to extract water from certain depth of the soil.

3.2 Data Acquisition

In this phase, the aim is to get dummy data for the system to process. The used of dummy data in this project is due to the difficulties of obtaining the actual data from experts in Malaysia. Therefore, the data were extracted from overseas resources. There are two methods of data acquisition. The first one is the data for Evapotranspiration (ET) and bermuda turfgrass coefficient (Kc) data which was taken from [18]. The second one is the creation of the dummy data for tensiometer reading. The creation of tensiometer dummy data was based on the total amount of soil moisture loss from saturated level until the wilting point in the soil [14].

3.3. Fuzzification and Rules Development

In this phase the rules were developed in Mamdani-style with normal fuzzy subsets. The set of range for the tensiometer reading and the water usage were developed based on earlier work [12, 15]. Evapotranspiration (ET) and Bermuda turfgrass coefficient (Kc) universe of discourse were built based on the maximum and the minimum value of the data series (daily data for one year). We run pilot testing on the identified fuzzy sets and fuzzy rules in order to ensure the rules and the subsets were applicable to be used or not. We generated 108 rules using decision tree representation.

The testing was done using MatLab Fuzzy Tool Box. Our testing showed that some of the rules and the presentation of the subset were unacceptable. This is due to the inclusion of the negative value in the applied water subsets. The level of moisture did show unfavorable result. This is because the soil received moisture from the irrigation activity in December where it is winter and the irrigation pattern is rapid in autumn even though the humidity is high at that season.

3.4 Preprocessing

For standardization, the representation of the value for each data in the subsets for all fuzzy inferences methods has been massaged using [19]. Then, the massaged subsets for all the inputs and the output were entered in the MatLab software for the preparation of the FuziWDC comparison. Fig. 1a), Fig. 1b), and Fig. 1c), show the representation of the inputs subsets while Fig. 1d) is the representation of the outputs subsets that has been massaged. After massaging process takes place, we have reduced the rules to 45 rules.

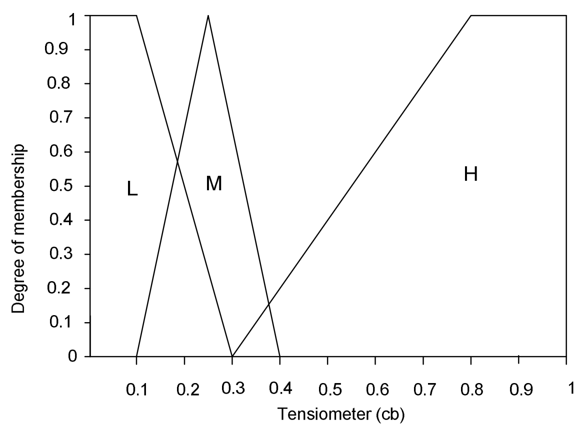

Fig. 1a) Tensiometer Reading Fuzzy Set

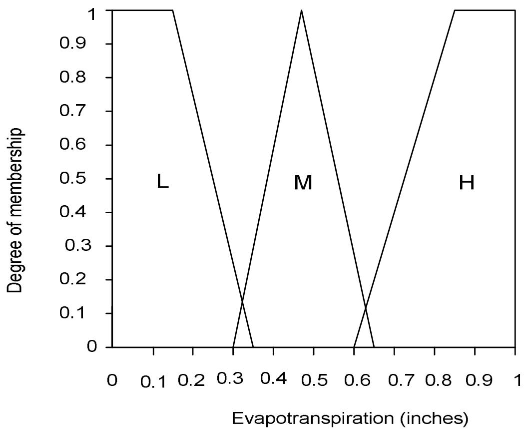

Fig. 1b) Evapotranspiration Fuzzy Sets

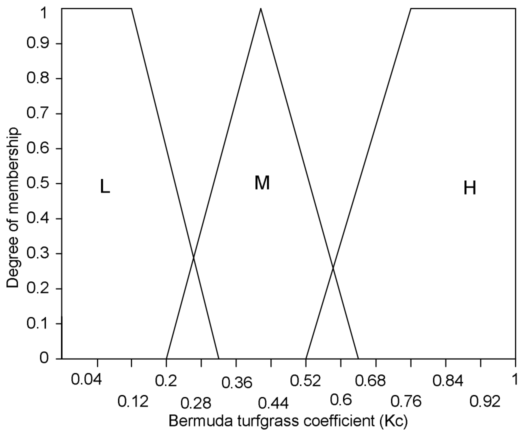

Fig. 1c) Turf Grass Coefficient Fuzzy Sets

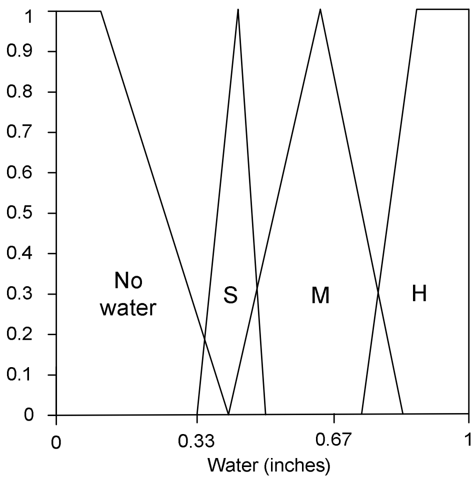

Fig. 1d) Water Fuzzy Sets

4 Findings and result

Several experiments have been conducted in order to achieve the desired and targeted results.

4.1 Mamdani and Conventional

We experiment the model of FuziWDC with the conventional irrigation system. The comparison was based on the annual average amount of water used for the whole year. The intention is to see the pattern of the soil moisture percentage for a year. To obtain the amount of water used for each fuzzy inference method, MatLab software was used and results were recorded. The annual average water usage was calculated from these results. Then, the percentages of moisture level were added in the Microsoft Excel to produce the soil moisture percentage line graph for the whole year. The patterns were then analyzed. This activity is conducted for guideline of the simulation system. FuziWDC was expected to produce the same or similar result to the analysis that has been done in the MathLab Fuzzy Logic Toolbox and Microsoft Excel.

4.2 The Prototype of FuziWDC

We built a FuziWDC prototype using JAVA programming language. The inputs are evapotranspiration rate, bermuda coefficient rate and tensiometer dummy data. The FuziWDC simulates the result in a graphical form either it is time to water or not, the amount of water used, duration of dispersal and the day of dispersal. For this purpose we used data set from year 2005. We built a Lawn Cross Section (LCS) to demonstrate the simulation processes. Fig. 2 shows a graphical interface of LCS. When the system decides it is time to irrigate, it will notify the user the day it irrigate, the amount of water used and the duration of the water dispersed. The next day, the user will see that the line increased.

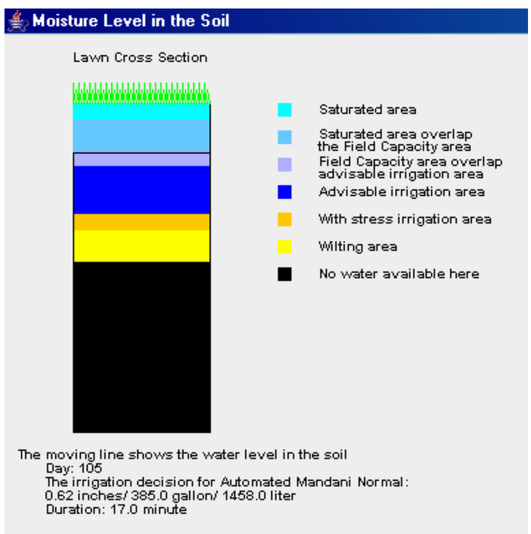

Fig. 2 A Graphical Outcome of Lawn Cross Section

4.3 The Comparison of the Conventional Irrigation System and FuziWDC

The conventional irrigation system was set by the owner according to the owner institution and some irrigation experience. FuziWDC was set only once and was expected to work automatically. Our results show that the conventional system used 299.589 liter of water a year while FuziWDC only used 223.616 liter of water per year. This shows that the conventional irrigation system used higher amount of water if compared to FuziWDC.

Fig. 3 shows the percentage of soil moisture when using the unadjusted conventional irrigation system. This system was set to start the irrigation activity on the second month of spring and stop at the end of autumn. From January until in the middle of April, the system showed favorable result. However, approaching at the end of April, the system showed that the lawn was irrigated when the water level is in the saturated area. This means that the water supplied to the soil was excessive.

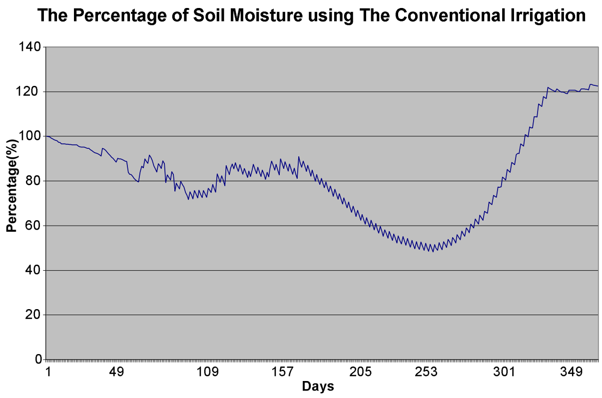

Fig. 3 The Percentage of Soil Moisture Using the Unadjusted Conventional Irrigation System

In the middle of Jun until in the middle of September, the water level in the soil dropped slowly below the Management Allowable Depletion level which is 50% of the soil content. This shows that the amount of water supplied to the soil was not enough to meet the plant requirement and is not efficient in coping with the water loss for that period. When the year is approaching end of September, the water level increase slowly. However, it kept on increased until at the end of the year. This time the amount of water received by the soil was more excessive compare to the amount of water received in the second quarter of the year. This analysis allowed us to conclude that, the unadjusted conventional irrigation system is ineffective in meeting the plant water requirement. This is the reason why in the real world situation, the system needs to be adjusted several times according to the season of the year.

However, when fuzzy logic is applied in the irrigation activity, the system doesn't have to be adjusted several times in a year. Instead, the system is acquired to be installed once and it can work on its own. Fig. 4 shows the moisture percentage pattern when fuzzy expert system was employed. The pattern showed that the moisture level never goes below 50% of the soil moisture content and never exceed 100% of the moisture content. The most maximum water that is allowed to be loss is 50% of the soil moisture content. However, allowing 50% of water content made the water level in the area of the advisable irrigation area with stress. If the irrigation starts at this level, and attempted to fill up the soil moisture until the field capacity, the system might end up using more water. That is why to be at the safe side, the system will only allowed 40% of water loss in the soil. This condition gives some advantages to the lawn owner and the plant.

When irrigation at 40% of water loss, less water needed to be applied for irrigation and less electricity needed to be used for the system to irrigate. Since the water level is maintained at the advisable irrigation area without stress, it is easier for the plant to absorb the water. Therefore, the plant can stay healthy no matter what the season is. These findings have demonstrated that fuzzy expert irrigation system performed better than the conventional irrigation system in water saving and meeting the plant needs.

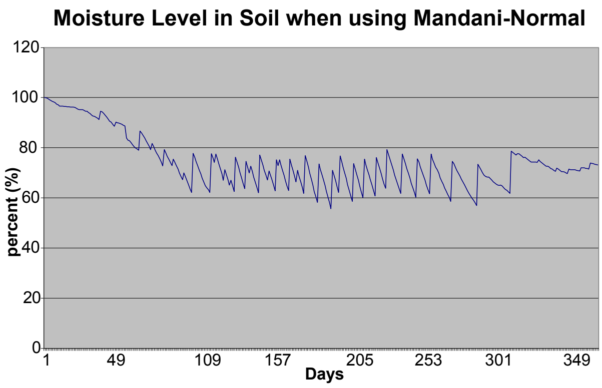

Fig. 4 The Percentage of Moisture Level in Soil Using Mamdani

5 Conclusion and future works

FuziWDC has demonstrated its capability to display the moisture level of the garden soil, the amount of water dispersed and watering day by simulating the environment parameter. The prototype performed better than the conventional irrigation system due to less amount of water used in average liter. It is also showed that the conventional irrigation system used greater amount of water than the fuzzy expert system as it failed to consider soil moisture based on weather condition. That is why in the real world, the conventional irrigation system is been adjusted several times per year to meet the soil moisture condition. However, frequent adjustment of the system will be troublesome for the lawn owner.

There are a lot of areas that can be explored to improve the irrigation that we had today. The intelligent irrigation system can be developed using soft computing method such as the hybrid of fuzzy expert and neural network to determine when to water the lawn based on the condition of the grass. Perhaps, when irrigation area is matured enough, more irrigation product will be built based on the intelligent system method. Some constraints include difficulties in getting the data, time limitation and to capture the knowledge of the experts.

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