Intelligent Controlling Water Dispersal: Comparison between Mamdani and Conventional Approach

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Abstract: - Adequacy of water supply plays a vital role in maintaining lawn health. Water need to be dispersed intelligently to provide a sufficient amount of moisture to the soil. Conventional system was investigated and it is found that the system used excessive amount of water and the amount dispersed may not be suitable for the moisture level of the lawn since it does not consider soil moisture based on weather condition. This research demonstrates the capability of fuzzy logic by developing a prototype namely, Fuzzy Water Dispersal Controller (FuziWDC). Rules were developed in Mamdani-style with normal fuzzy subsets using ranges suggested by the experts and later applied to a set of common Bermuda turfgrass. It is found that FuziWDC was particularly successful in controlling the water dispersal. Results were simulated in a graphical form and user would be notified about the dispersal time and day, the amount of water to use, and duration of dispersal. The prototype has performed better than the conventional irrigation system 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

As water scarcity remains a problem, an effort should be made to irrigate effectively. This is to avoid an excessive amount of water and to control the amount of water according to the moisture level of the lawn. In addition, it is vital to ensure that the lawn has enough water and irrigates only when it is needed to be watered [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 grass species and cultivars, the soil type, the frequency and number of inches of rain and weather condition such as humidity and temperature [2]. Thus, a reliable controller that can measure the soil moisture is needed.

Much work has been done in the area of controlling by using the capability of fuzzy logic. Such researches include planning and scheduling for autonomous small satellite [3], policing the task to select in real-time traffic controller [4], and golf cart navigation controller to automatically navigate the obstacles towards a selected destination in a golf course [5]. These systems deal with vague, imprecise, and uncertain knowledge and data [6]. Fuzzy set and fuzzy subset were determined to calibrate vagueness that describes linguistic variable.

This research attempts to explore the use of fuzzy logic for water dispersal controller by improving the work of [7]. The aims are to improve the conventional controller by demonstrating 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.

The paper is organised into five sections. Section 2 discusses the involved factors in irrigation while section 3 addresses the methodology that was employed in this research. Subsequently, in section 4, the findings and results of the research were presented. Also the presentation of an improved method of Mamdani's inferencing for the water dispersed controller. Finally in Section 5 a few conclusions are drawn based on the presented results besides outlining future directions of research inspired by these results.

2 Irrigation

The adequacy of moisture in the lawn is the secret of a beautiful garden. This can be done by irrigation. According to [8], irrigation is simply the act of watering lawn, plants, flower or garden. Generally, there are two categories of irrigation; the manual irrigation and the automated irrigation system. The automated irrigation systems are a convenient and cost-effective solution compares to the manual irrigation in reducing the waste of water. However, the automatic system is quite troublesome as one need to reprogram the automated irrigation system every time the weather change.

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.

In 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 [9]. 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) [10].

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. Fig. 1 shows the cross section of a lawn that describes four levels of soil. 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 composes horizon C. The last section is horizon R which is bedrock.

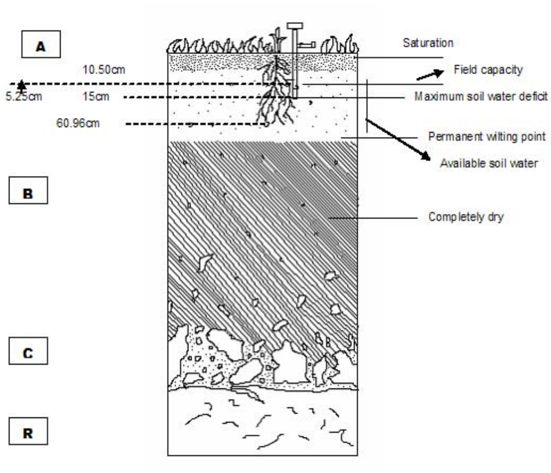

Fig. 1 Lawn Cross Section

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 [11]. Evaporation is the process by which water vaporizes and escapes from the surface, rising into the atmosphere [12]. Percolation is the downward movement of water through the soil. The combination of transpiration and evaporation process has created a term called Evapotranspiration or ET. It is a process that takes the loss of water from the soil by evaporation and by transpiration from the plant into consideration [11]. The ET is influenced by humidity, solar radiation, wind and, temperature [13]. It usually occurs from 10 am to 6 pm [12]. Thus, it is best to irrigate between 5 am to 10 am where the sun is low, winds are calm and temperature are cool [8].

2.4 Soil Moisture Level

According to [10], 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 [11]. 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 [11]. 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 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 Methodology

There are four major phases involved in this research and they are discussed in the following 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 ET 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's need. The ET 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 ET and bermuda turfgrass coefficient (Kc) data which was obtained from California Irrigation Management Information System CIMIS [18], which was based on the maximum and minimum value of the daily data series for the year 2004.

The second one is the creation of the dummy data for tensiometer reading. The value of tensiometer data have been constructed based on the total amount of soil moisture loss from the saturated level until the wilting point in the soil where the total amount of water in 1 foot depth of soil for loam soil is 5.8 inches per foot [14]. Assuming the root of the turf grass reaches the maximum growth, 2 feet deep. Thus, we assume that the amount of water in the soil is 11.6 inches per feet. From the initial amount of water, we deduct the ET rate using CIMIS data. Then, the ET will deduct this amount again for the next day. The process will be repeated until the end of that particular year.

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 [8, 15].

Evapotranspiration (ET) and Bermuda turfgrass coefficient (Kc) universe of discourse were built based on the maximum and minimum value of the data series (daily data for one year). A pilot testing was carried out on the identified fuzzy sets and fuzzy rules in order to ensure the rules and the subsets were applicable to be used or not. 108 rules was generated 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 standardisation, the representation of the value for each data in the subsets for all fuzzy inferences methods has been massaged using [6]. 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. 2a), Fig. 2b), and Fig. 2c) showed the representation of the inputs subsets while Fig. 2d) is the representation of the outputs subsets. After massaging process takes place, the initial rules have been reduced to 45 rules.

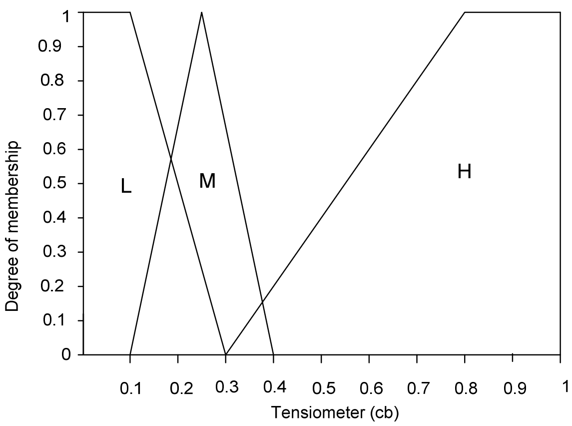

Fig. 2a) Tensiometer Reading Fuzzy Set

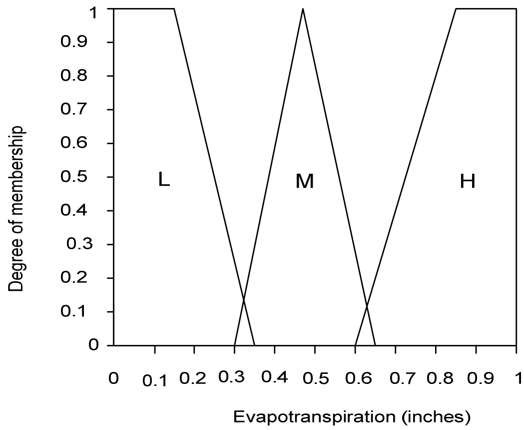

Fig. 2b) Evapotranspiration Fuzzy Sets

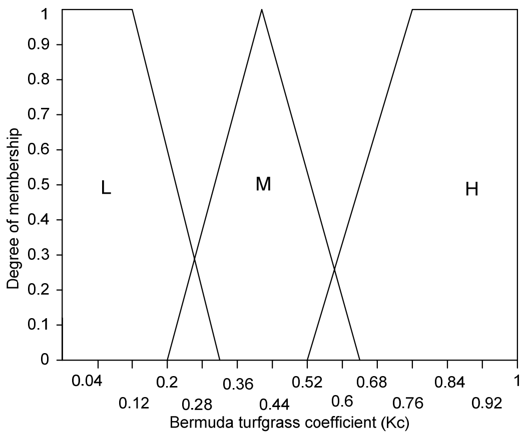

Fig. 2c) Turf Grass Coefficient Fuzzy Sets

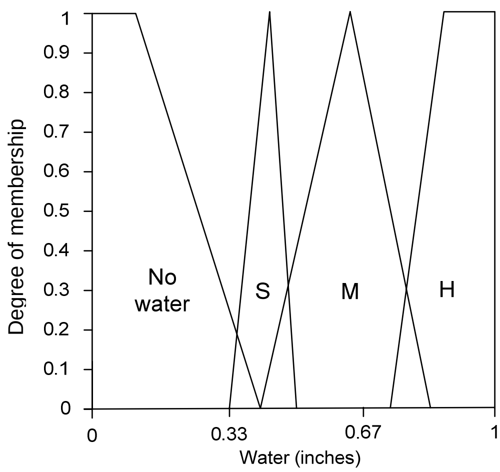

Fig. 2d) Water Fuzzy Sets

4 Findings and result

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

4.1 Mamdani and Conventional

FuziWDC model was experimented 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. Prior comparing these two approaches, a validation process was conducted whereby both results from the FuziWDC's simulation and MatLab were recorded and the annual average water usage was calculated. Subsequently, the results were visualized in the Microsoft Excel to produce the soil moisture percentage line graph for the whole year. The patterns were then analyzed. FuziWDC was expected to produce the same or similar result to the analysis that has been done in the MathLab Fuzzy Logic Toolbox.

4.2 The Prototype of FuziWDC

FuziWDC prototype was built 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. A Lawn Cross Section (LCS) was built to demonstrate the simulation processes. Fig. 3 shows a graphical interface of LCS. When the system decides it is time to irrigate, it will notify the user the day to irrigate, the amount of water to be used and the duration of the water to be dispersed. The next day, the user will see that the line increases.

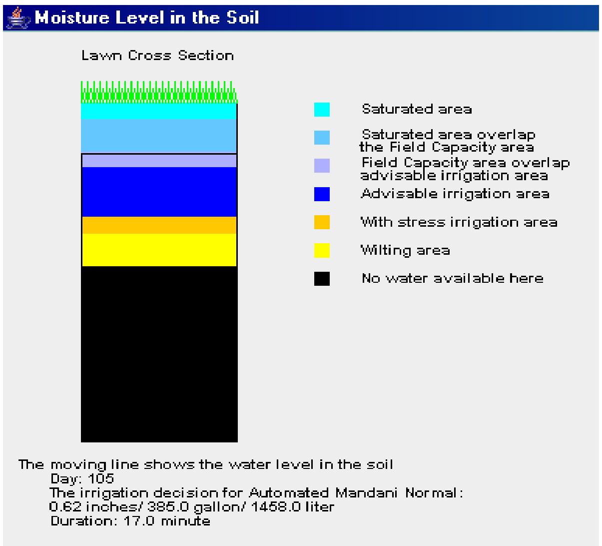

Fig. 3 A Graphical Outcome of Lawn Cross Section

4.3 The Comparison of the Conventional Irrigation System and FuziWDC

Normally, 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. 4 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.

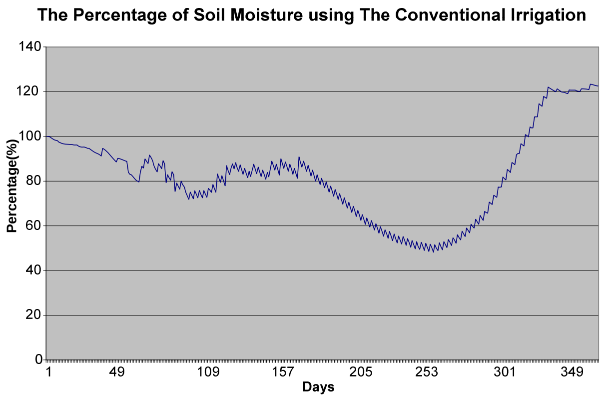

Fig. 4 The Percentage of Soil Moisture Using the Unadjusted Conventional Irrigation System

In the middle of Jun until in the middle of September, the water level in the soil dropped slowly approaching 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 increases 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 does not 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. 5 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 is 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 saving the water and meeting the plant needs.

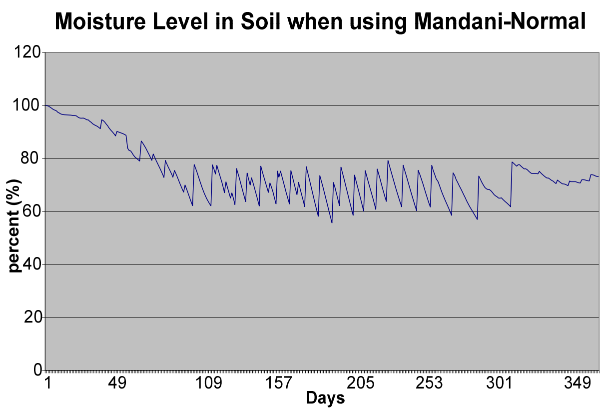

Fig. 5 The Percentage of Moisture Level in Soil Using Mamdani

5 Conclusion and future works

This research was carried out to demonstrate the application of fuzzy expert system in the area of irrigation by using Mamdani's inferencing. Parameters that involved are ET rate, bermuda coefficient rate and tensiometer reading. The FuziWDC prototype has successful in controlling the water dispersal. Results were simulated in a graphical form and users would be notified about the dispersal time and day, the amount of water to use, and duration of dispersal.

It is found that FuziWDC performed better than the conventional irrigation system as it reduced the amount of water used. In addition, soil moisture factor was taken into consideration in contrast with the conventional system. This make the FuziWDC need not to be adjusted several times per year as to meet the soil moisture condition. Furthermore, frequent adjustment of the system will be troublesome for the lawn owner.

There are still some needs of exploration. 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, and tapping the knowledge of the experts.

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