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Irrigation Expert System for Trees

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Abstract— ***Management water usage becomes an important issue in Egypt, as a result of the continuous increase in Egypt's population and its Nile waters share stabled. Optimum cultivate water usage will lead to reduce the wasted water. This work aids optimizing crop water usage by developing a generic design for irrigation expert system for trees. The irrigation expert system aims to provide the farmers by the irrigation expertise to determine the exact water needed at exact time according to the crop requirements and the environmental factors which effect factors like the temperature, soil type, source of water, etc. It was experimented on developing irrigation expert system for Mango.***

Index Terms— **Expert systems, Knowledge based systems, Irrigation, Irrigation management.**

I. INTRODUCTION

Egypt faces the water scarcity with the fact that its share in the Nile waters is predetermined. Also, its water-use efficiency is low, due to high water losses. So, enhancing water-use efficiency in irrigated agriculture is one of the main objectives of Egyptian agricultural ministry [1].

Management of irrigation is one of the most important aspects of cultivation production. Farmers do not have the needed information to minimize water usage without reducing plant productivity [2]. Optimize the irrigation water usage need an expert to provide farmers by the exact needed water at exact time to irrigate their crops. These experts are rare to found when farmers needed. Also, it doesn't easy to found them in all Egypt villages. Using information and communication technology to develop systems that manage water usage will help in enhancing the irrigation water usage efficiency. Expert systems technology can be used to transfer knowledge from irrigation experts to both agricultural engineers/officers and farmers which lead to enhance water usage in Egypt. Expert system also known as knowledge based system which is a branch of artificial intelligence and was developed by the AI community in the mind-1960s [3]. It is a computer program that includes the knowledge and analytical skills of one or more human experts in a particular problem domain [4]. The idea of expert system building is to code knowledge into a computer program so it can be consulted in much the same way that one consults a human expert. Well-designed expert systems mimic the human experts reasoning process to solve specific problems and can be used by non-experts to improve their problem-solving capabilities. Also, experts can use it as knowledgeable assistants [5].

The use of expert systems technology has many benefits. It was explained through experiments where the fields which are managed by the expert system have used less resource in terms of pesticides, fertilizers and water than the control fields and preserve environment [6]. Also, the expert systems training courses increase the knowledge base of extension agents and speed the introduction of new technologies and agronomic practices [7].

The goal of the work described here is to optimize crop water usage by using expert system technology. This goal can be achieved by helping framers to irrigate their crops by the exact needed amount of water at the exact needed time. The work presents a generic design for irrigation expert system for trees which provides the farmers by the irrigation expertise to determine the exact water needed at exact time according to their environments. The used knowledge based for developing this a generic design is acquired from previous desktop irrigation systems which developed by the Central Laboratory for Agricultural Experts Systems (CLAES) for irrigate citrus, mango, and grape trees in Egypt [8]-[10]. This generic is built dependent on Common-KADS knowledge engineering methodology. The development of an expert system is seen in Common-KADS as the construction of three knowledge layers domain, inference, and task knowledge [11].The proposed irrigation task consists of three basic sub-tasks ("Expand", "Propose" and "Adjust") and two transfer tasks (Get input, Display schedule). These sub-tasks control six inferences namely: expand case, compute Et0, compute Etcrop, compute SWHC, compute water requirement, and adjust schedule.

The structure of the paper in the following section, a brief overview of related work is presented in section2. Section 3, describes the structure of the irrigation expert system for trees, while section 4 presents its inference knowledge layer. Section 5 presents how the inference steps are controlled by the irrigation task. Case study for mango expert system is presented in section 6. The final section presents the conclusion.

II. RELATED WORK

Expert systems began to appear as a branch of Artificial Intelligence In the late 1960's to early 1970's. The basic idea of developing expert systems can be found in the goal of Artificial Intelligence to develop "thinking computers" [12]. The expert system is defined by Bunchanan as computer system in which an attempt is made to capture and render operable human knowledge about specific domain [13]. Expert system is different from traditional computer program since it solves problems by mimicking human reasoning processes, relying on belief, logic, rules of thumb opinion and experience [14]. So, it deals with challenging real world problems through the application process which reflect human judgment and intuition. Expert systems provide powerful and flexible means for obtaining solutions to a variety of problems that often cannot be dealt with by traditional methods [15].

The Expert System mimics the experience of an expert who is consulted for a specific problem in his/her specialty.

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The user usually uses this system by answering some inquiries. The expert system uses the user's responses to reach a conclusion and provide one or more solutions to the problem at hand [16].

Irrigation practices rely on many parameters which should be taken into consideration in order to make a decision. These parameters are used by mathematical models to compute the crop water requirements. However, irrigation practice is not only computing crop water requirements but it contains other issues that need human judgment. So, irrigation experts combine their experience with these models to calculate the crop water requirements [17]. The main goal of an irrigation expert system is to construct an irrigation schedule for a particular crop in a particular farm. The output is a plan of water quantities to be applied and the time of application. This plan is calculated according to the plant requirements and the affecting factors like the soil type, climate, source of water, etc [18].

Since the early 1980s, expert system technology has been applied to a variety of agricultural problems. Many agricultural expert systems were developed to aid farmers in activities that are done on the farm before and during cultivation [19]. It provides them by advice about land preparation, planting, irrigating, fertilizing, and identify and treat disorders.

CUPTEX [20], CITEX [21], NEPER [22] and PADDY [23] expert systems for cucumber, citrus, wheat, paddy production management respectively were developed for handling most of agricultural practices including irrigation. Mahmoud and his colleges present integrate the Geographical Information System (GIS) with expert system to develop system for agriculture production management including irrigation. They use the geographical information system to decrease the need for human deployment in the farms to collect such data [2].

Other examples of irrigation expert systems include IRRIGATE was developed to help water managers and agricultural advisors to manage water for gravity irrigation of hay cropping systems. Reference [24] shows IRRINET is an expert system for irrigation scheduling developed with the aim to progressively reduce water use for irrigation. IRRINET nor only provides farmers by irrigation advice for the main water demanding crops, but it provides them also by a day-by-day information on how much and when to irrigate farm crops [24].

III. IRRIGATION EXPERT SYSTEM FOR TREES

The main goal of these systems is to obtain the optimal quantity of water taking into consideration all the parameters which affect the needed water like: the soil, water, climate, crop, and farm data. The proposed generic design is designed based on the knowledge based existing in the previous desktop irrigation systems for irrigate citrus, mango, and grape trees which developed [8] - [10]. This Common-KADS methodology is used to develop the proposed irrigation design. As say before, Common-KADS constructs the three knowledge layers domain, inference, and task knowledge for developing expert system. The domain knowledge contains of domain models and its ontology and. Domain ontology is the terminologies which are used in a specific domain models. The domain model is a group of expressions about a domain which represents specific relations between ontology items. Inference knowledge represents all inference steps which are used in solving the problem. While the control sequence of these inference steps to achieve system objective is including in the task knowledge which is actually the algorithm of the expert system [11], [25].

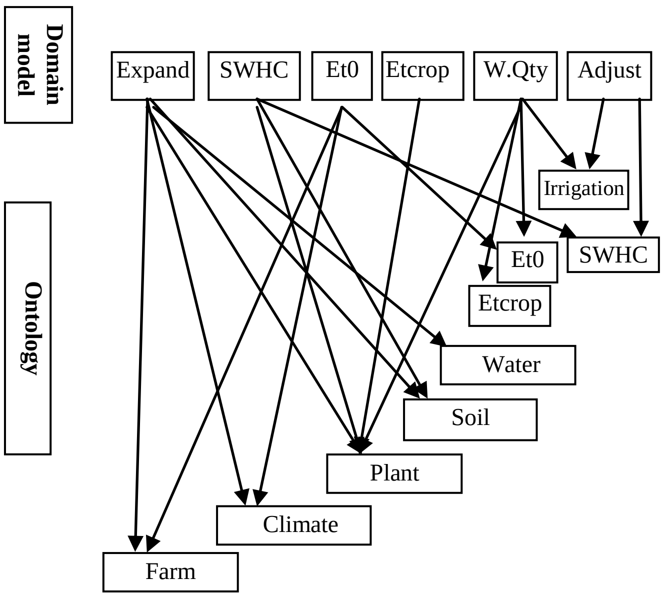

Fig. 1: Domain Knowledge schema

The proposed irrigation knowledge base includes six domain models namely: expand, compute Et0, Etcrop, SWHC, W.Qty, and adjust. These modules represent the relations between the ontology. Fig. 1 shows the domain knowledge schema. The following sections describe the inference, and task knowledge used for developing irrigation expert system for trees.

IV. INFERENCE KNOWLEDGE

The irrigation inference layer consists of six inference steps which are shown in Fig. 2. The following is a brief description of these inferences:

A. Expand case

It is responsible for completing the needed parameters which effect in calculating the needed water quantity.

B. Compute ET0

Its goal is to compute the crop evapotranspiration (ET0) which measures the effect of climate on crop water requirements, Penman method [26].

$$et0 = Adj_{fact} \times Wieg_{fact} \times Net\_rad + [(1 - Wieg_{fact}) \times Win_{fact} \times (Ea - Ed) \quad (1)$$

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Equation (1) is used to compute ET0, where Adj_{fact} is the adjustment factor for the effect of weather conditions, $Wieg_{fact}$ is the weight factor between temperatures and Altitudes, Net_rad is the net radiation balance between incoming solar radiation and outgoing terrestrial radiation, Win_{fact} the wind factor, Ea is the saturation vapor pressure at mean air temperature, Ed is the mean actual vapor pressure of the air.

C. Compute Etcrop,

Its goal is to compute the crop evapotranspiration (Etcrop) at different crop growth stage to calculate the effect on the crop characteristics on crop water requirements. Equation (2) is used to compute the Etcrop, where $Farm_A$ is the farm area, Kc is the crop coefficients, Gc is the green cover area.

$$Etcrop = farm_A \div 1000 \times et0 \times Kc \times Gc \qquad (2)$$

D. Compute SWHC

Its goal is to compute the effect of soil type on the depth of water that can be stored within the crop root depth.

$$SWHC = farm_A \times Rd \times Sbd \times (Sp \div 0.03) \times Ad \times (1 \div Irr\_eff) \times Drang_{fact} \times Wsr \times (Eciw \div Ece + 1) \qquad (3)$$

Equation (3) is used to compute the soil's SWHC, Where Farm_A is the farm area, Rd is the rooting depth, Sbd is the soil bulk density, SP is the soil saturated percentage, Ad is the required water percentage, Irr_eff is the efficiency of the irrigation system, $Drang_{fact}$ is the factor for the used draining system, Wsr is the Flat rate of wetting, Eciw is the salinity of irrigation water, Ece is the degree carry the crop to salinity.

E. Compute water requirement

Its goal is to compute water requirement based on the user situation and give the optimal water to minimize crop water stress and maximize yields. It computes for each 10 day.

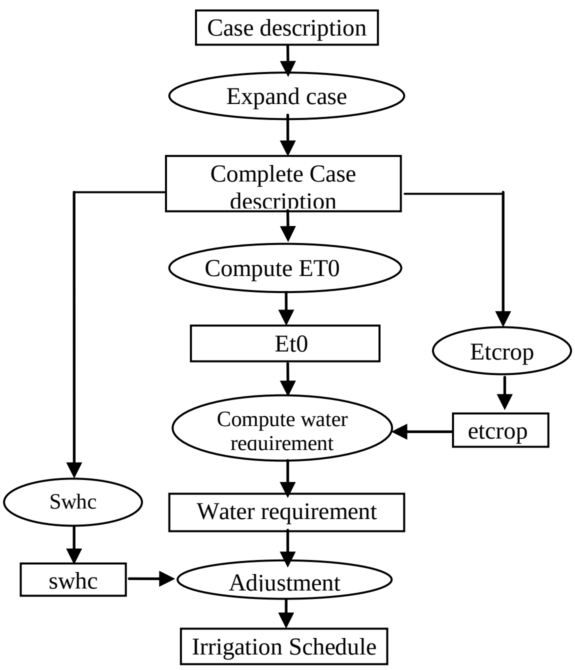

Fig. 2: Inference Structure for Irrigation

Equation (4) is used to computed water quantity, where $Drang_{fact}$ is the factor for the used draining system, irr_{LR} is the irrigation leaching requirement, Irr_eff is the efficiency of the irrigation system.

$$WaterQ = Etcrop \times Drang_{Fact} \times (1 + Irr_{LR}) \div Irr\_eff \qquad (4)$$

F. Adjust schedule

Its goal is to adjust the proposed irrigation schedule to generate the quantity and time for each irrigation operation.

V. TASK KNOWLEDGE

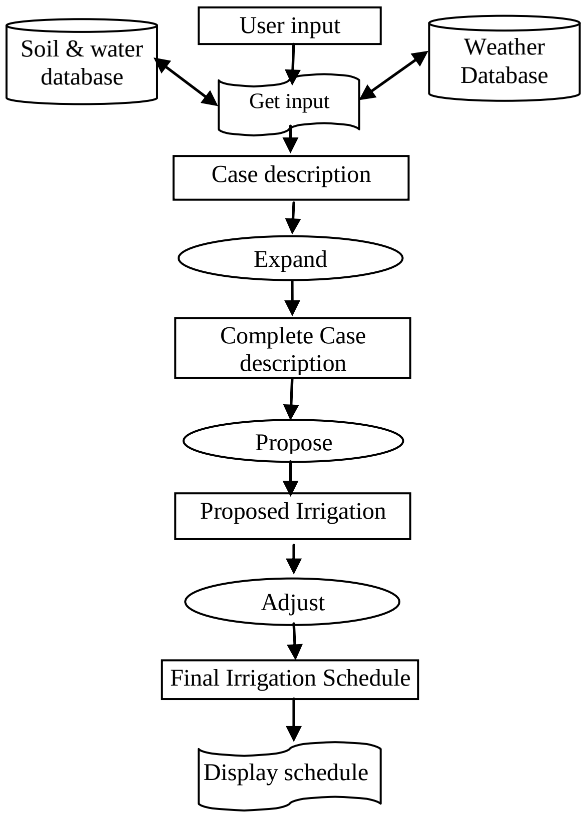

Fig. 3: Task Structure for Irrigation

Fig. 3 represents the irrigation task which consists of three basic sub-tasks for handling knowledge namely: "Expand", "propose" and "Adjust" and two transfer tasks (Get input, Display schedule). A brief description of each of these subtasks is given below:-

A. Get input display schedule sub-task

This task is responsible for handling the interaction with the user. Its interface asks the users questions which showing according to the user situation. These questions enquiry about farm, soil, climate, and crop parameters which effect in computing the water required for irrigate the crop.

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month	avg tc	avg rh	actual sun	mws	
1	12.400	86	7.170	69	Edit
10	22.700	80	9.540	69	Edit
11	19.300	81	8.160	60	Edit
12	15.100	85	6.730	69	Edit
2	13.100	85	7.880	103	Edit
3	15.300	82	8.760	78	Edit
4	19.000	76	9.670	78	Edit
5	23.000	70	10.600	69	Edit
6	25.600	70	11.900	69	Edit
7	27.000	75	11.670	69	Edit
8	27.000	78	11.350	60	Edit
9	25.000	80	10.540	0	Edit

Fig. 4: Climate input screen

B. Expand sub-task

Expand task is responsible for completing the needed parameters to calculate the needed water quantity. It utilizes the user data input to derive the needed parameters. It uses expand case inference step to archive this goal.

C. Propose sub-task

Propose task aims to compute the proposed irrigation schedule. The needed water in each plant stage is calculated according to the user specific situation which determined in the previous subtask. It uses three inference steps namely: compute ET0, compute Etcrop, compute water requirement.

D. Adjust sub-task

Adjust task is responsible to generate the final irrigation schedule. It uses the compute SWHC, adjustment inference steps to determine the right time of irrigation operations.

E. Display schedule sub-task

Display schedule task is responsible for displaying the final irrigation schedule.

VI. CASE STUDY

The generic irrigation expert system design for trees is experiment on developing irrigation expert system for Mango which is built as web application. Its knowledge based is developed using the Mini Knowledge Share and Reuse tool (MiniKSR) [27]. While the interface tasks are developed using the visual basis.net.

The following steps show the execution process sequence of the system to generate the final irrigation schedule:

- First, Get input sub-task collects the input from users about plant and environmental information. The system enquiries about the farm are region, area, irrigation type, soil type, plant crop verity and plantation date…etc. According to the input region, the system displays the weather data (show Fig. 4). The user can customize the weather data according to its current date.
- After that, the complete case description is generated from the user input data. Then the propose subtask calculates the crop evapotranspiration (ET0) and the crop evapotranspiration (Etcrop) to determine the water required which is compute for each 10 days. Fig. 5 shows the generated proposed irrigation schedule from the propose subtask.
- Adjust sub-task calculates SWHC and uses it to generate the water quantity for each irrigation operation and its date as shown in Fig. 6.

If the farm contains multi varieties or multi plant ages, the system calculate the optimum quantity of water for each variety in this farm.

VII. CONCLUSION

Expert systems can offer a good solution for management irrigation water due to the rare in irrigation experts and difficulties in finding them. It transfers expertise to farmers helping them to irrigate their crop in the same way the irrigation experts done. The goal of the irrigation expert system is to determine the exact amount of needed water and the exact timing for applying it. The amount of water applied is determined dependent on each user situation.

The proposed irrigation

Month	Range Day	Water requirement m^3/Faddan
3	1_10	189.61
3	11_20	189.61
3	21_31	150.29
4	1_10	201.21
4	11_20	201.21
4	21_30	201.21
5	1_10	252.31
5	11_20	252.31
5	21_31	277.54

Fig. 5: Proposed irrigation schedule

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date	each time m3/faddan
15/3	19
16/3	19
17/3	19
18/3	19
19/3	19
20/3	19
22/3	30
24/3	30
26/3	30
28/3	30
30/3	30

Fig. 6: Final irrigation schedule

The proposed a generic design was developed using the knowledge based for citrus, mango, and grape [8]-[10]. It was designed to apply on flooding and dripping irrigation system. It was experimented on developing irrigation expert system for Mango. It calculate optimum water quantity according to the crop requirements and the affecting factors like the temperature, soil type, source of water, etc. Also, it takes into consideration the different variety and age of plant in the same farm when determine the water amount

Computing the exact amount of water needs weather and soil parameters which could be not available for farmers, so the system used a historical data for weather. Link the system by weather website will supply it by the newer weather data. The availability of the day by day data can enhance the irrigation to be generated day by day.

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