DESIGN AND FABRICATION OF AUTONOMOUS IRRIGATION SYSTEM FOR AGRICULTURE

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Abstract - *Agriculture is the leading sector in water usage and wastage at the same time, due to inefficient irrigation techniques. Agriculture accounts for around 70% of all water withdrawals globally and approximately 60% of that is wasted, largely due to inefficient techniques. While trying to improve the frequency and effectiveness using existing methods like drip irrigation, furrowing etc., it becomes impossible for essential activities. Improper scheduling can lead to water logging of the soil. This project aims to propose an autonomous irrigation system that works at improving the frequency of irrigation and using solar powered electronic control. The moisture sensor detects the moisture content in the soil and the robot sends the water through the slave pipes. The slave pipes are connected to the master pipe, which in turn gets the water with a sufficient pressure head. The slave pipes are rewound after watering so that there is no formation of pests and fungus. The implementation of this robot in field results in the quality of irrigation and effective use of water resources.*

Key Words: **furrowing, water logging, autonomous irrigation system, robot car, master and slave pipes, solenoid valve.**

1. INTRODUCTION

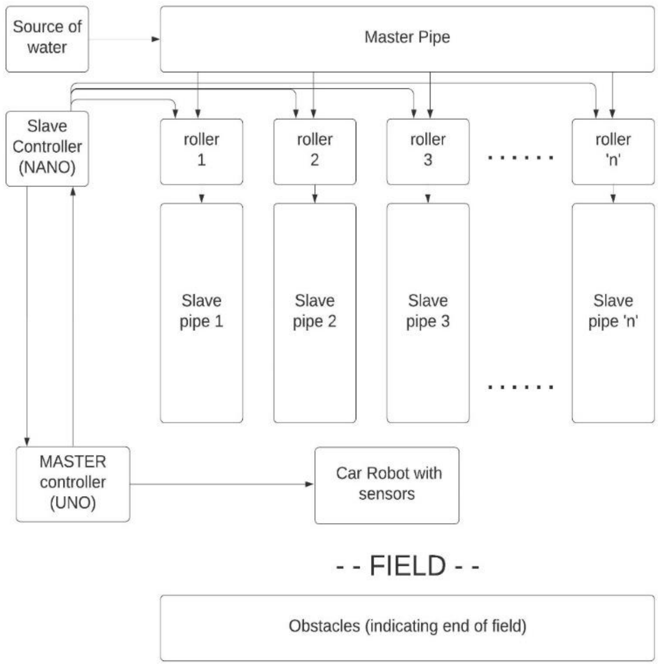
The farmers involve in a lot of physical work for effectively managing and planning the water supply to the entire field, by applying various methods and techniques. But even after implementation of many practices, there is no guarantee that crops are not getting adequate and equal amount of water.

The need for obtaining equal amount of water for every crop is to minimize the wastage and improve the productivity of farming by maintaining a constant Infiltration velocity for each crop.

Infiltration Velocity or Intake Rate is the rate of water entry into the soil expressed in terms of depth of water per unit area according to flow in the soil. This sophistication of new type of irrigation has a lot of benefits like prevention of water logging and enhancement of supply of water to individual crops.

we have designed a model which involves simple components that work hand in hand and ultimately irrigates as per the crop's Irrigation Requirement.

1.1 SCHEMATIC ARRANGEMENT OF MODEL



1.2 OUR APPROACH

This model is a sophistication of drip irrigation where the crop receives water when the moisture content is low. Initially the pipes are wound to a roller across the field. The pipes are extended to cover the crops column by column across the field. Irrigation takes place with the help of pipes placed equidistant across the field. After the irrigation process, the pipes are wound automatically onto a roller and keeps the field free of pipes.

This project consists of subsystems that work hand in hand. The first mechatronic subsystem is a robot car which houses three operations viz. providing motion to moisture sensor arm, gripper, and path guidance. The motion to the robot car is provided with the help of DC motors driven by a motor driver. The master pipe gets water with sufficient pressure head. The slave pipes have a solenoid valve at the master slave junction. The valves are actuated with the signals from the robot car. After watering for some set time, the valves are closed, and the roller motor winds back the slave pipe onto the roller. The robot car comes back to the specific position and resumes back the moisture monitoring.

The frequency of irrigation is dependent on the Infiltration Rate of the soil and the output from the moisture sensor. Infiltration Rate is defined as the maximum rate at
which a soil under given condition and at given time can absorb water when there is no divergent flow at borders.

The frequency of irrigation can also be manually fed by the farmer is he wants to limit the usage of the device. For this, we implement a Boolean OR logic at the beginning of the process to the controller program.

2. MATHEMATICAL EXPLANATION

Consider the field as a linear path. In traditional irrigation system, a single water outlet is placed at the starting point i.e., left most side of the field. As we know, factors like soil friction and uneven surface, the water happens to stagnate in course of length making the farthest crops to receive less amount of water as compared to the crops at the starting point.
Mathematically,
Amount of water received by a single crop of a field is inversely proportional to the position of that crop from the water outlet point.

i.e., $V \propto 1/x$

Or

$(V \times x) = K$

Where, V = amount of water in individual crop in milliliters

x = linear distance from the starting point in meters

K= constant of proportionality

Finally, we can express it as,

Amount of water to individual crop = K/x

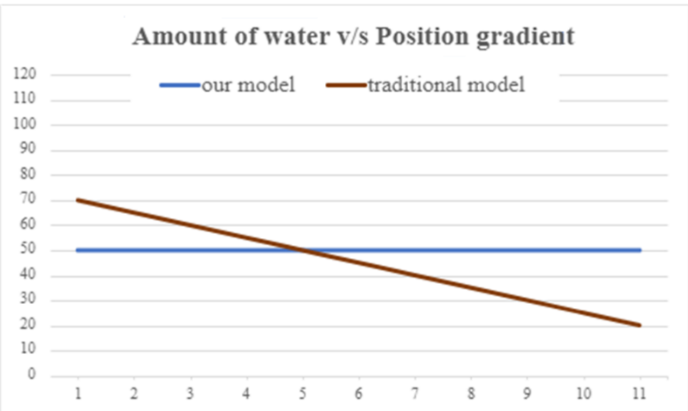


Fig: Graph on theoretical assumption of traditional versus our model

Amount of discharge of water for crop: $Q = v \times A \times x_i$ (m^3/sec)

where, v is the velocity in m/s, which is assumed to be uniform throughout the flow.

And $x_i = (L - d_i) / L$ (the length gradient)

L – length of field in meters

D_i – distance from master pipe to i^{th} crop in meters

In the theoretical calculation, let us assume that there are no frictional losses in the pipes, the pipes have a uniform

diameter through-out the length i.e., The pipe is assumed to be prismatic.

So, the effective area $A = (\pi/4) \times (x)^2$

Where, x is the diameter of the outlet at individual crop.

The quantity of water at crop i = Qi = $Q \times x_i$

where $x_i = (L-d_i)/L$ (length gradient)

d_i - distance from master pipe to ith crop in metres

L – length of field in metres

In the traditional method one can observe that the quantity of water decreases with the increase of length of field in traditional method of irrigation.

Observing our model,

The quantity of water at crop i = $Q_i = V \times A_i \times x_i$

where xi = $(L-t_i)/L$ (length gradient)

t_i - distance from master pipe to i^{th} crop in metres

L – length of field in metres

A_i – area of outlet for i^{th} crop = $(\pi/4) \times d_i^2$ in m^2

d_i – diameter of outlet at crop i in meters

V – velocity in meter / sec

3. COMPONENTS USED

1. Arduino Uno R3
2. Soil moisture sensor module (EC-1258)
3. Ultrasonic sensor (HC-SR04)
4. Motor drivers (LM298)
5. DC motors (100rpm and 30rpm)
6. Jumper wires and bread board
7. Batteries (12V and 9V)
8. Arduino nano
9. Bluetooth module (HC-05)
10. Solenoid valve
11. Solar panel (5W)

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4. CONSTRUCTION AND WORKING

The Project is aimed in supplying water to the field with the help of a master-slave pipe arrangement, and an autonomous car robot that traces its path and acts accordingly. The project is composed of four stages.

- Development of a firm chassis and assembly of car robot.
- Design of a master and slave configuration.
- Attaching sensors and actuators.
- Co-ordination of car robot with the master-slave section.

Moisture level measurement

The car motor is placed at the initial position near slave pipe1. The motor is actuated over the signal and the arm attached to it, which is made of a plastic scale is used to insert the moisture sensor into the soil. The moisture sensor will be fed an input value in the code, a limiting value, the sensor gives an analog output in terms of the percentage of moisture content present in the field. If the reading of the moisture content exceeds the limiting value, the moisture sensor passes a signal to the controller and triggers a signal which pulls up the motor that is connected to the moisture sensor arm.

Fig: Moisture sensor penetrated into the soil

Fig: Moisture sensor moved out of the soil

Gripper actuation

The gripper is connected to Arduino uno. It is a 1 degree of freedom gripper used to grab the slave pipe. Initially, the gripper actuates automatically and grabs the slave pipe. When the robot car reaches the other end of the field, the signal is sent from robot car path guidance system to open the gripper and finally the gripper releases the slave pipe.

Car robot movement

The data transfer takes place between the Arduino Uno and the motor driver, which makes the motors to actuate, and the car robot moves.

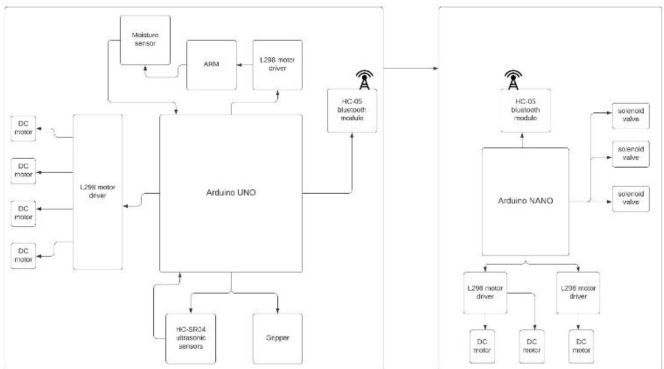

Fig: Block diagram

Obstacle avoidance

The motion of the wheels causes the entire car robot to move, there are three ultrasonic sensors placed on the chassis, the purpose of them is to calculate the distance between the obstacle in front of the car robot and return the sensed value to the controller. The distance between the car robot and the obstacle is calculated by converting the returned analog value into centimeters. The controller then uses a comparison operation between the distance calculated and the limiting distance set. If the distance calculated is more than the limiting value specified in the code, the controller does nothing, and carries out the next cycle. If the distance calculated is less than the limiting value, the microcontroller will send a signal to the motor driver to stop the motor. The main purpose of ultrasonic sensor is to ensure that car robot will not get hit to any obstacles in between the field.

Intercommunication of microcontrollers

After reaching the other end of the field, the ultrasonic sensor triggers a stop command, which stops the movement of the wheels of car robot. Then the actuation signal is sent to the gripper to stop holding the slave motor. The slave motor is held down, and the car robot moves a few inches away from the pipe. Here are now where two devices intercommunicate between each other, Arduino Uno, and Arduino Nano.

Fig: Robot car following the specified path

Irrigation of field

Here, the solenoid valve is opened and allows the water to flow through the slave pipe. The water gets equally distributed to the field, since equidistant holes are fabricated on the slave pipe, which are in such a way that the hole which is near to the master pipe has lesser diameter compared to the hole which is placed far from the master.

This type of arrangement is done to ensure that all crops get equal amount of water. We know that, for a fluid travelling with an initial velocity, the area of cross section (A) is directly proportional to the discharge (Q). We also know that, according to pascal's law, the force exerted is the product of the pressure available and area.

Fig: Water coming from slave pipe

Here we are decreasing the area of cross section to decrease the flow rate and increase the pressure. Even though there will be pressure gradient across the slave pipe, decreasing the area will limit this pressure gradient and ensure that all the crops get equal amount of water.

The irrigation from the slave pipe takes place for around 15 to 30 minutes depending on the moisture content checked by the moisture sensor at the beginning. There is no need to monitor the speed, distance, or time of watering because, the aim of the project is to provide frequent watering cycles to the crop in a less interval of time, so that no crop remains completely nourished or completely dry.

After irrigation of the slave1 the car robot moves to slave 2, with the help of ultrasonic sensors. The same process is repeated for all the slave pipes and the robot returns to the initial position after watering the entire field.

Fig: Master slave pipe assembly

Movement of pipes

Once the watering time is completed at slave1, the Arduino Nano sends a signal to solenoid valve to close and the watering will be stopped. Then, the roller rolls back with the help of 30rpm DC motors.

Fig: Motor shaft connection to a roller

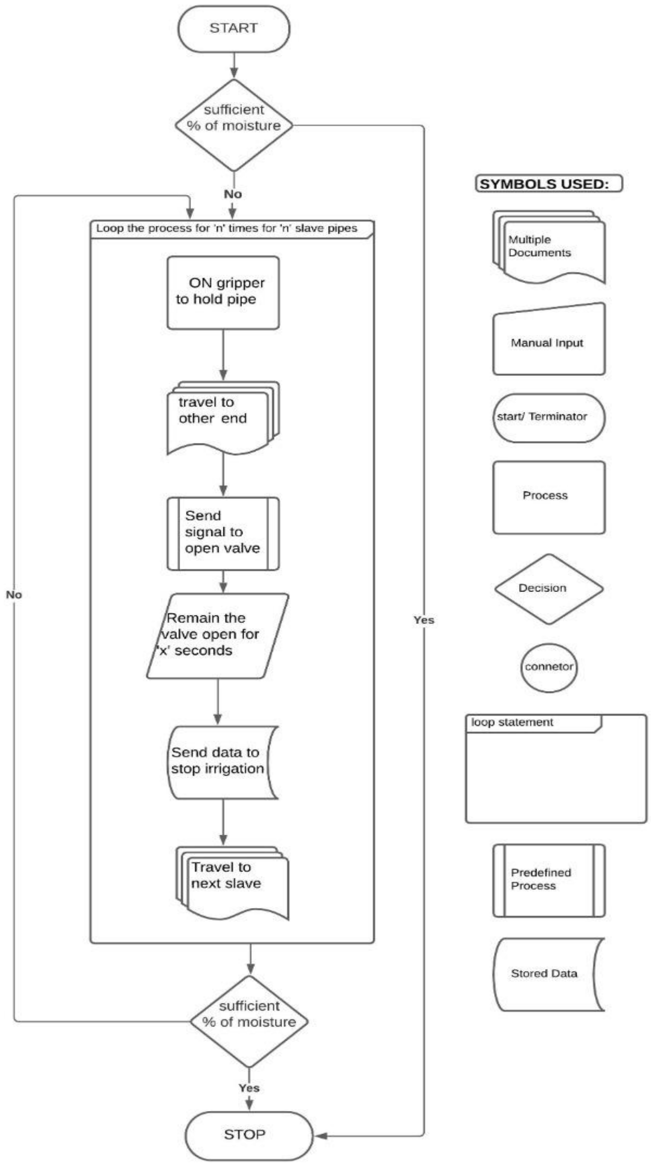

Fig: Flow chart

5. RESULTS AND DISCUSSIONS

After performing the necessary experimentation on the prototype, it has been concluded that

• The quantity of the water changes with the position gradient of the field. The change of water level with respect to position gradient depends on the factors like inlet position of water and viscosity of the water. Among the two factors, the inlet position plays a key role in water logging. Here the proposed model has resolved this problem by increasing the number of inlets and distributed water supply in the field instead of a single inlet. So, we conclude that the proposed model has ironed out the problem of water logging.

• The frequency of irrigation increases the growth of crops evenly.
• The amount of time solenoid valve remains open is inversely proportional to the percentage of moisture content measured with the moisture sensor.
• By incorporating the autonomous irrigation system, the human intervention has been reduced to almost zero. The problem with human intervention is not only the consumption of precious time of humans but also the crops had to compromise as the watering is done according to the clock of human but not to the clock of crops. So, we can conclude that the proposed model aims at eliminating the human intervention and the crops are watered with zero compromise.

Fig: Prototype setup

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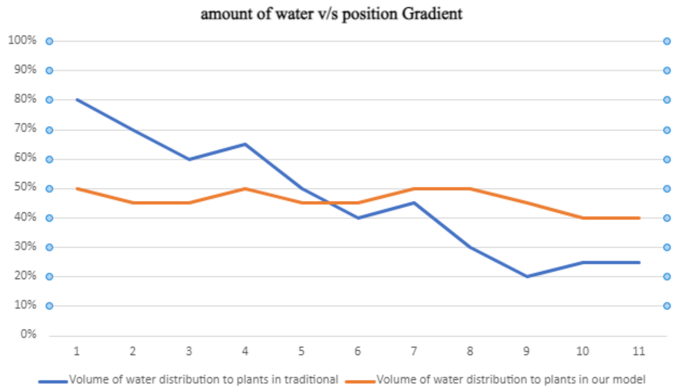

Fig: Graph based on practical valves

The graph is comparison of distribution of water to the crops between the traditional irrigation method and the proposed model. Traditionally the water reachability at the other end is lower than the crops present at the portion of field near to the water inlet. This causes imbalance in water received to the crops.

So, the proposed model plot concludes that the water reachability is increased drastically throughout the field and reduces the imbalance of water received by the crops of a field.

Generally, Sprinkler irrigation, drip irrigation and subsurface drip irrigation systems require high tech-components, but they cannot be incorporated in agriculture. Extremely high-tech solutions exist using Geographic Information System and satellites to automatically measure the water content of each crop to optimize the irrigation system. But automation of irrigation can sometimes also be done with simple design like the model proposed and the sophistication done with surgical dexterity is not less than a fine piece of engineering art.

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