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Multiple Sensor Data Fusion Based Top-Down Embedded System for Automatic Plant Pot Watering

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ABSTRACT
Most of the plants require just the right amount of water. Any quantity of water less or more than required for a given type of plant is not desirable. In this project, two sensors are used to spray the right quantity of water into the plant pot. A soil moisture measuring sensor and photoresistor sensor are employed to measure the water content in the pot's soil and the radiation level of the sun respectively. A simple linear proportionate formula is employed to calculate the amount of water to be sprayed into the plant pot using the input values of the two above mentioned sensors. A simple motor is actuated to compress the sprayer for the calculated duration of time based on the above mentioned formula.

Keywords: Top down approach, Sensors, Agriculture, Embedded

1. Introduction

Agriculture is the largest food producing sector globally followed by animal husbandry and fishing. Garden farming has gained much popularity and can be a stable source of medicinal plants supply for urban areas. Agricultural automation is a growing sector with a projected market value of USD 20.3 billion by 2025. A lot of plants grown in certain environmental conditions require the correct quantity of water at the correct time watered to them for best yield. This watering requirement depends mainly on two factors: the soil moisture content and the ambient temperature. The ambient temperature plays a vital role in deciding the quantity and the timing of irrigation since plants lose most of their water by transpiration. Transpiration is the process of evaporation of water from plant leaves. For different plant varieties different levels of transpiration are acceptable for best yield. In this proposed solution, we have the plant's soil moisture level assessed by soil moisture sensor and the ambient temperature measured by a temperature sensor. Based on the readings of the above two sensors, the correct quantity of water is irrigated at the correct timings of the day. The automaton for this is loaded in an embedded system and control input is given to the water spray pump installed above the plant's pot. The automaton for this will be developed by machine learning algorithms or direct top-down approach by observation and data collection.

2. Proposed System

The system consists of soil moisture sensor, LDR, ESP8266, relay and a water pump. The system mainly sense the moisture content in the soil and if necessary the command is sent to relay through ESP8266 and the water pump is turned on. The plant watering is automated with the help of soil moisture sensor and LDR. In a soil moisture sensor, A small charge is placed on the electrodes and electrical resistance through the sensor is measured. As water is used by plants or as the soil moisture decreases, water is drawn from the sensor and resistance increases. Conversely, as soil moisture increases, resistance decreases. A light dependent resistor is an electronic component that is sensitive to light. When light falls upon it, then the resistance changes. Values of the resistance of the LDR may change over many orders of magnitude the value of the resistance falling as the level of light increases. When the soil moisture level is low and light is present, the ESP: a low power Wi-Fi solution, micro controller, receives the data and is coded so the plant is watered with water pump.

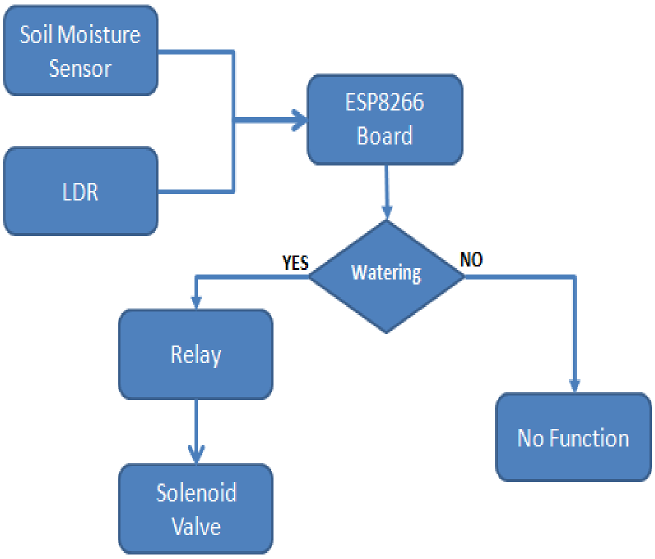

Figure 1. Block Diagram

3. Arduino Microcontroller

“The microcontroller used to implement this project and similar projects are Arduino boards. Presented below is an outline of Arduino family boards.”[2]

3.1 Introduction

“Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices. It’s hardware products are licensed under a CC-BY-SA license, while software is licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially from the official website or through authorized distributors”[2]

“Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ('shields') or breadboards (for prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs. The microcontrollers can be programmed using the C and C++ programming languages, using a standard API which is also known as the Arduino language. In addition to using traditional compiler tool chains, the Arduino project provides an integrated development environment (IDE) and a command line tool (arduino-cli) developed in Go”[2]

“The Arduino project began in 2005 as a tool for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, thermostats and motion detectors. The name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduin of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014”[2]

3.2 Hardware

“Arduino is open-source hardware. The hardware reference designs are distributed under a Creative Commons Attribution Share-Alike 2.5 license and are available on the Arduino website. Layout and production files for some versions of the hardware are also available”[2]

“Although the hardware and software designs are freely available under copy left licenses, the developers have requested the name Arduino to be exclusive to the official product and not be used for derived works without permission. The official policy document on use of the Arduino name emphasizes that the project is open to incorporating work by others into the official product. Several Arduino-compatible products commercially released have avoided the project name by using various names ending in –duino”[2]

“An early Arduino board with an RS-232 serial interface (upper left) and an Atmel ATmega8 microcontroller chip (black, lower right); the 14 digital I/O pins are at the top, the 6 analog input pins at the lower right, and the power connector at the lower left.”[2]

“Most Arduino boards consist of an Atmel 8-bit AVR microcontroller (ATmega8, ATmega168, ATmega328, ATmega1280, or ATmega2560) with varying amounts of flash memory, pins, and features. The 32-bit Arduino Due, based on the Atmel SAM3X8E was introduced in 2012. The boards use single or double-row pins or female headers that facilitate connections for programming and incorporation into other circuits. These may connect with add-on modules termed shields. Multiple and possibly stacked shields may be individually addressable via an I²C serial bus. Most boards include a 5 V linear regulator and a 16 MHz crystal oscillator or ceramic resonator. Some designs, such as the Lily Pad, run at 8 MHz and dispense with the onboard voltage regulator due to specific form-factor restrictions.”[2]

“Arduino microcontrollers are pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory. The default boot loader of the Arduino Uno is the Opti boot bootloader. Boards are loaded with program code via a serial connection to another computer. Some serial Arduino boards contain a level shifter circuit to convert between RS-232 logic levels and transistor–transistor logic (TTL) level signals. Current Arduino boards are programmed via Universal Serial Bus (USB), implemented using USB-to-serial adapter chips such as the FTDI FT232. Some boards, such as later-model Uno boards, substitute the FTDI chip with a separate AVR chip containing USB-to-serial firmware, which is reprogrammable via its own ICSP header. Other variants, such as the Arduino Mini and the unofficial Boarduino, use a detachable USB-to-serial adapter board or cable, Bluetooth or other methods. When used with traditional microcontroller tools, instead of the Arduino IDE, standard AVR in-system programming (ISP) programming is used. An official Arduino Uno R2 with descriptions of the I/O locations. The Arduino board exposes most of the microcontroller's I/O pins for use by other circuits. The Diecimila, Duemilanove, and current Uno provide 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs, which can also be used as six digital I/O pins. These pins are on the top of the board, via female 0.1-inch (2.54 mm) headers. Several plug-in application shields are also commercially available. The Arduino Nano, and Arduino-compatible Bare Bones Board and Boarduino boards may provide male header pins on the underside of the board that can plug into solderless breadboards.”[2]

“Many Arduino-compatible and Arduino-derived boards exist. Some are functionally equivalent to an Arduino and can be used interchangeably. Many enhance the basic Arduino by adding output drivers, often for use in school-level education, to simplify making buggies and small robots. Others are electrically equivalent, but change the form factor, sometimes retaining compatibility with shields, sometimes not. Some variants use different processors, of varying compatibility.”[2]

3.3 Software

“A program for Arduino hardware may be written in any programming language with compilers that produce binary machine code for the target processor. Atmel provides a development environment for their 8-bit AVR and 32-bit ARM Cortex-M based microcontrollers: AVR Studio (older) and Atmel Studio (newer).”[2]

IDE:

“The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, and Linux) that is written in the Java programming language. It originated from the IDE for the languages Processing and Wiring. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. The source code for the IDE is released under the GNU General Public License, version 2."[2]

"The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware."[2]

Pro IDE:

"On October 18, 2019, Arduino Pro IDE (alpha preview) was released. The system still uses Arduino CLI (Command Line Interface), but improvements include a more professional development environment, auto completion support, and Git integration. The application frontend is based on the Eclipse Theia Open Source IDE. The main features available in the alpha release are:"[2]

Sketch:

"A sketch is a program written with the Arduino IDE.[64] Sketches are saved on the development computer as text files with the file extension .ino. Arduino Software (IDE) pre-1.0 saved sketches with the extension."[2]

"A minimal Arduino C/C++ program consists of only two functions:

setup( ):

This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch. It is analogous to the function main ().

loop ( ):

After setup () function exits (ends), the loop() function is executed repeatedly in the main program. It controls the board until the board is powered off or is reset. It is analogous to the function while."[2]

4. Industry 4.0

"Wikipedia defines Industry 4.0 as thus: The Fourth Industrial Revolution (4IR or Industry 4.0) is the ongoing automation of traditional manufacturing and industrial practices, using modern smart technology. Large-scale machine-to-machine communication (M2M) and the internet of things (IoT) are integrated for increased automation, improved communication and self-monitoring, and production of smart machines that can analyze and diagnose issues without the need for human intervention."[3]

Automation under Industry 4.0 has a particular schema or pattern at its outset. Presented below is how automation in the mass production industry as well as consumer level products are built in today's technological era.

The schema presented in Figure 2 has a lot of other components involved but the generic outline of it stands justifiable for all kinds of automation today.

The software automaton of the conventional automation model, which is the status quo, was built by a human expert or a team of human experts till now. With the advent of machine learning technology, the software automaton was not fully directly designed by human experts. The human experts build the machine learning software and give the real world data set as training information. The machine learning software identifies the pattern between the input and the output parameters of the dataset in the form of a mathematical model. This mathematical model can be downloaded as a working software module to other electronic computing devices. This mathematical model is referred to as the 'trained machine learning module'. The software automaton of all the current digital embedded devices is a mathematical model that gives a numerical output for a numerical input based on arithmetic and logical conditions. This software automaton, as explained above can be either directly developed by a set of human experts by means of setting the boundary conditions themselves based on observation and requirement or can be downloaded as an executable module from machine learning training systems that are trained with relevant dataset. In whatever way the software automaton is developed, it can be loaded onto the relevant embedded computing module that can be used for either sensor based closed loop automation or open loop automation.

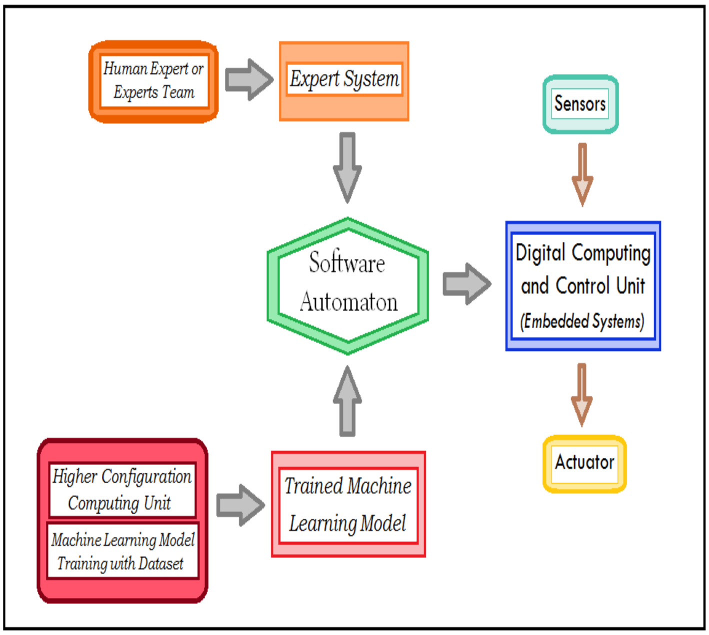
Human Expert or Experts Team
Expert System
Sensors
Software Automaton
Digital Computing and Control Unit (Embedded Systems)
Actuator
Higher Configuration Computing Unit
Machine Learning Model Training with Dataset
Trained Machine Learning Model

Figure 2. Schema of Automation

The technological components of Industry 4.0 includes IoT, augmented reality, virtual reality, cloud computing, 3D printing, big data analytics, networking, data security, human-machine interaction and others. IoT is a very effective way to collect real world data. Sensors integrated with data acquisition and transmission systems can be placed anywhere and the collected data can be pre-processed if required and used as datasets to train machine learning models.

Cloud computing is employed for optimized utilization of computing resources. There are many third party vendors like Google and Amazon which are very reliable in terms of data security and speed of computation. These services offer companies and organizations a cheap and reliable way to harness the power of artificial intelligence and machine learning.

Big data analytics is the set of technological components involved with collecting, collating and managing large quantities of data for analytics and decision making. When so much data is involved, especially with third party service providers, data security plays an important role.

One of the paramount concerns about Industry 4.0 is the unemployment it can create due to powerful automations. The field of human-machine interactions and co-working has been a very developing field now to mitigate the above mentioned problem.

5. Working

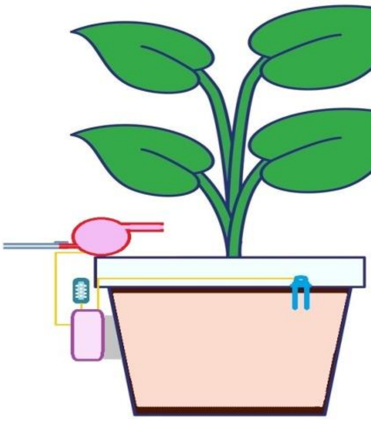

Figure 3. Schematic Diagram

Presented above is a schematic diagram (Figure 3) of a pot plant wherein a soil moisture sensor is carefully placed in the spoil of the pout and a temperature sensor that measures the ambient temperature is placed outside. Both the above mentioned sensors are connected to a microcontroller and battery unit. The microcontroller and battery unit controls the water pump that water the plant based on the sensor readings and the machine learning trained automaton module loaded.

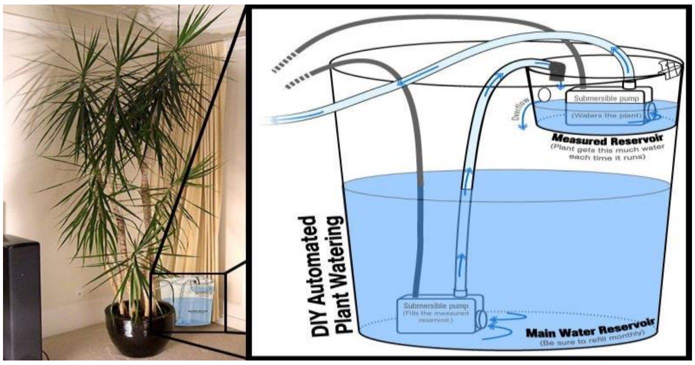
Submersible pump
(Waters the plant)
Overflow
Measured Reservoir
(Plant gets this much water each time it runs)
DIY Automated Plant Watering
Submersible pump
(Fills the measured reservoir.)
Main Water Reservoir
(Be sure to refill monthly)

Figure 4. Automated plant watering

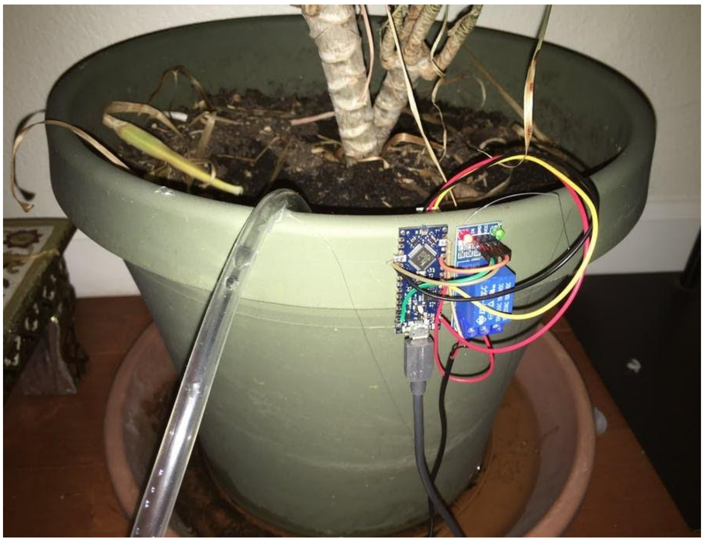

Figure 5. Soil moisture based plant watering

Presented above in Figure 4 and 5 are two images of a water reservoir schema and simple soil moisture based pot watering mechanisms respectively.

6. Results And Discussion

As shown in the Figure 6 and Figure 7, the circuit of the system consists of a soil moisture sensor, a temperature and humidity sensor, an Arduino Uno board and a water pump. This is an ideation level prototype of the product presented in this paper. The industrial grade prototype of this product will have a very similar setup as above. For larger shrubs and trees, an array of sensors can be used. Multiple sensor data fusion can be implemented for high level accuracy and reliability of the system. The difference will be that more industrial grade components will be used. This circuitry was tested and the performance was satisfactory in terms of validating the proposed method. In the industrial grade prototype this system can be integrated with an IoT module and the data will be transmitted to the cloud computing enabled server. Analytics can be performed on the collected, collated and pre-processed data for obtaining useful inferences of the system and the environment.

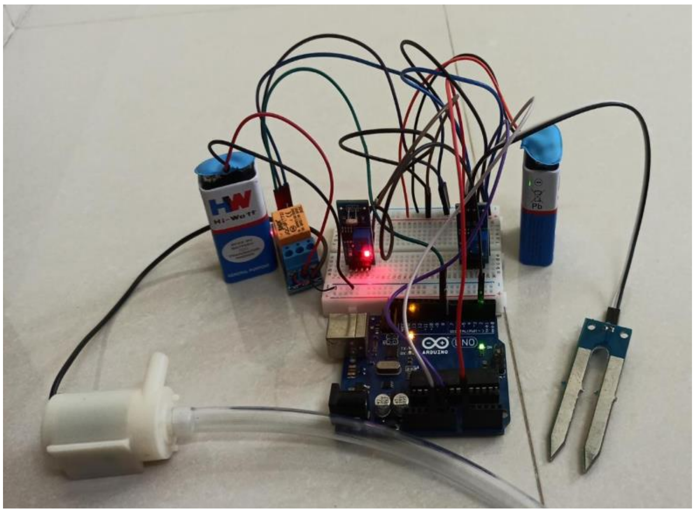

Figure 6. Arduino Setup

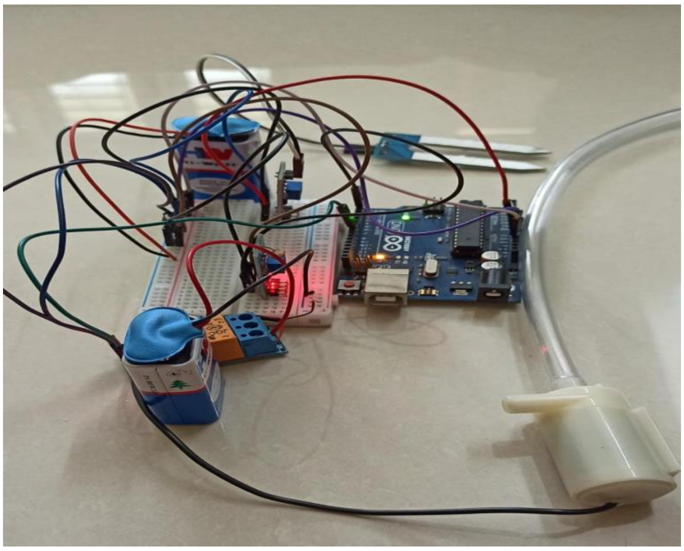

Figure 7. Output Image Top view

7. Conclusion And Future Work

This product idea presented in this paper is a top down automaton that takes two input data processes and gives two outputs. The inputs are the soil moisture content and the ambient temperature. This method alone has the potential to automate a great deal of irrigation. An auxiliary technology that can be used with this to improve accuracy of the yield is drone based or robotic vehicle based image processing. Periodic image processing of how the plant growth will ensure the reliability and the corrective measures required to alter the above mentioned top-down algorithm. This top-down algorithm in the first place will be developed by either a single reliable machine learning model or ensemble machine learning model. Therefore, the efficiency of this top-down approach can be perfected from plant species to species by continuous data collection, data processing and machine learning implementation. There are always outliers with respect to these real case scenarios like the presence of a plant disease or other such cases. Periodic manual observation and random checking of plants will ensure the monitoring of efficiency of this approach.

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