

Access provided by:
**Universidad Nacional de Colombia
 (UNAL)**
 Sign Out

[Browse](#)[My Settings](#)[Get Help](#)[Browse Conferences > 2015 International Conference...](#)[Back to Results](#)

ZigBee-based irrigation system for home gardens

<< Results

[View Document](#)

6
 Paper
 Citations

674
 Full
 Text Views

5

Author(s)

[A. R. Al-Ali](#) [Murad Qasaimeh](#) [Mamoun Al-Mardini](#) [A. R. Al-Ali](#) ; [Murad Qasaimeh](#) ; [Mamoun Al-Mard](#) [View All Authors](#)
Abstract[Authors](#)[Figures](#)[References](#)[Citations](#)[Keywords](#)

Abstract: Single-chip microcontrollers equipped with wireless transceivers are gaining popularity in smart home automation because of their built-in resources, low power consumption, size, affordability and durability. Research and development professionals are seizing the opportunity to design and integrate more functions and services for smart home monitoring and control systems utilizing such microcontrollers. This paper presents a wireless irrigation system for a smart home garden that can be integrat... **View more**

Notes: As originally published there is an error in this document. The author name "Mamoun Al-Mardinia" should instead have been "Mamoun Al-Mardini" as noted here. The metadata has been updated but the article PDF remains unchanged as originally published.

Metadata

Abstract:

Single-chip microcontrollers equipped with wireless transceivers are gaining popularity in smart home automation because of their built-in resources, low power consumption, size, affordability and durability. Research and development professionals are seizing the opportunity to design and integrate more functions and services for smart home monitoring and control systems utilizing such microcontrollers. This paper presents a wireless irrigation system for a smart home garden that can be integrated with existing smart home control systems. The system consists of slave nodes and a master station each of which is equipped with a wireless microcontroller. Each slave node is equipped with a temperature sensor, a soil-moister sensor, a water valve, a microcontroller and a zigbee transceiver. The slave microcontroller reads and frames the surrounding temperature of the garden's grass and trees along with soil moisture. Then, the frame is forwarded to the master station via a zigbee ad-hoc network. The master station has an embedded fuzzy logic irrigation algorithm to water the grass and trees based on a set of rules. A home web-server is interfaced with the master station for remote access monitoring and operation. The proposed system can be operated as a stand-alone unit or can be integrated with existing home automation systems.

Notes: As originally published there is an error in this document. The author name "Mamoun Al-Mardinia" should instead have been "Mamoun Al-Mardini" as noted here. The metadata has been updated but the article PDF remains unchanged as originally published.

Published in: 2015 International Conference on Communications, Signal Processing, and their Applications (ICCSPA'15)

Date of Conference: 17-19 Feb. 2015

INSPEC Accession Number: 15040755

Date Added to IEEE Xplore: 09 April 2015

DOI: 10.1109/ICCSPA.2015.7081305

Electronic ISBN: 978-1-4799-6532-8

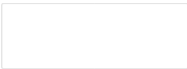
Publisher: IEEE

Loading web-font TeX/Main/Regular

Conference Location: Sharjah, United Arab Emirates

 Contents

 Contents



Full Text

Authors

References

Citations

Keywords

Back to Top

Download
PDF

Download PDF

Download Citation

Download Citation

View References

View References

Email

Email

Print

Print

Request Permissions

Request
Permissions

Export to Collabratec

Export to
Collabratec

Alerts

Alerts

SECTION I.

Introduction

Single chip based embedded systems, smart sensors and wireless networks are gaining ground in irrigation systems of large farmlands, greenhouses, pastures and fruit orchards [1]–[2][3][4][5][6][7][8][9][10][11][12]. A wireless sensor network that monitors soil humidity and temperature, and solar radiation was designed [1]. The collected data from these sensors is transmitted to a web service via a coordinator. Farmers can access, monitor and manage the system via the World Wide Web. Another wireless sensor network with irrigation valve control system was developed [2]; the valve actuation is based on a single chip microcontroller with an embedded customized firmware, a power deriver circuit, a communication protocol and a web interface. The wireless access range reached 1610 meters under the line-of-sight condition and 170 meters under obstructed conditions. A zigbee-based data acquisition was designed for street forestation trees, bonsai plants and greenhouse [3]. The weather condition is collected and transmitted to a Java based control algorithm that makes the makes the irrigation scheduled based the plant type and predefined scenarios.

A low-cost RFID-based system to monitor the soil moisture status in crops field and surrounding air temperature was designed [4]. The system can use up to three soil moisture sensors and up to four thermocouple temperature to control the irrigation schedule. A wireless irrigation system consists of weather station that is equipped with Bluetooth and global position system (GPS) was designed [5]. The weather station transmits the status of the soil moisture and temperature and surrounding air temperature through Bluetooth to a computerized base station which can be access the internet. Some has utilized the mobile phone short messaging service (SMS), GPS and Camera to collect farm fields' photos and broadcast it for remote inspection [6]–[7][8]. Some of the reported irrigation systems use soft computing tools such as fuzzy logic and neural networks to control the irrigation schedules and better manage the water resources [9]–[10][11][12]. It was also reported that some systems may save

20%-30% of water consumption in comparison to conventional methods [11]. Utilizing such systems increases crop yield per square meter and optimizes energy requirement based on particular timing operation [12].

On the other hand, smart homes are equipped with smart appliances that are fully automated using wired and/or wireless embedded controllers. Several standby power reduction and energy management systems have been reported [13]–[14][15][16]. Smart energy meters have also been implemented in millions of residential premises to better manage and save power [17]–[18][19][20]. Smart home appliances are monitored and controlled remotely as well as locally using wired and wireless stand-alone embedded systems that utilized single chip microcontrollers [21]–[22][23][24][25].

From the aforementioned studies, one can conclude that smart homes that are equipped with controllers provide multiple integrated functions and services but lack irrigation functions to water garden grass and trees.

This paper proposes an outdoor garden automatic irrigation system for smart homes. This added service can be a standalone or integrated within the existing smart home automation systems as a sub-module. The proposed system is based on Web Server-Master-Slaves architecture; each slave consists of a set of sensors, water valve actuators, single chip microcontroller and wireless transceiver. The master receives the garden temperature and soil moisture from the slave nodes. The water valves are operated according to predefined irrigation modes. The system is interfaced with a PC-server to enable access through the Internet to manage the irrigation scenarios remotely.

The rest of the paper is organized as follows: Section II specifies the system requirements. Section III describes the proposed system hardware architecture. Section IV details the embedded software operation scenarios. Implementation and testing are discussed in section V followed by a conclusion in section VI.

SECTION II.

The Proposed System Requirements

To design an effective and efficient system, the functional and non-functional requirements should be specified. The following requirements must be satisfied for the proposed system:

- Made from off-the-shelf complements and Easy to install and configure.
- Easy to operate and switch between manual and automatic operation modes.
- Supports two way wireless communications between server, master and slave,
- Displays periodic and historic sensor array data of each slave.

- Allows operation through the Internet and smart phone.
- Should be mobile, cost effective, reliable and secure

To fulfill the above mentioned requirements, the proposed irrigation system must have hardware and software architectures. Both architectures are described in the following sections.

SECTION III.

Proposed System Hardware Architecture

To satisfy the hardware architecture requirements, the proposed system consists of three basic modules: slave, master and server modules. These modules are developed in a modular fashion and thus allowing master-slaves or server-master-slaves to operate as standalone modules.

A. Slave Module

This module consists of several off-the-shelf components namely; temperature and soil moisture sensors, a signal conditioning circuit, single-chip microcontroller with ZigBee transceiver [26], driver circuit and a water valve. The microcontroller has built-in digital input/output ports, analog-to-digital-converter and programmable memory. Figure 1 shows the slave-module basic building blocks. In this module, the microcontroller gathers the temperature and soil moisture and operates the water valves based on an embedded irrigation algorithm that will be described in section IV. The microcontroller sends the collected data to the master using a low-power wireless Zigbee network.

B. Master Module

This module consists of several add-on slave-modules and one master that coordinates with the slave modules as described in section II-A. The master is a single-chip microcontroller that is also used in the slave-module integrated with wireless Zigbee transceiver. Figure 2 shows the master-slaves hardware layout. Through wireless transceiver, the master module gathers the sensors array data from each slave node and commands the water valve of each slave-module based on embedded irrigation algorithms that will be described in section IV.

C. Server Module

This module integrates the master and slave modules described earlier with a home web server. The server is a high-end personal computer that is equipped with wireless interface for communicating with the master-module. Adding the server allows web access for a remote operation. Figure 3 depicts the system slave-master-server hardware building blocks.

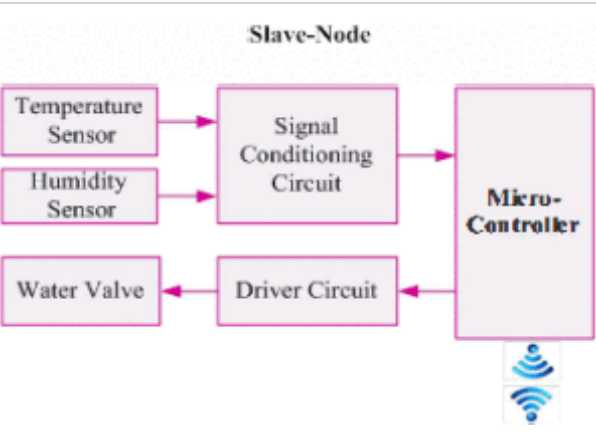


Fig. 1.
Building blocks for the slave-node

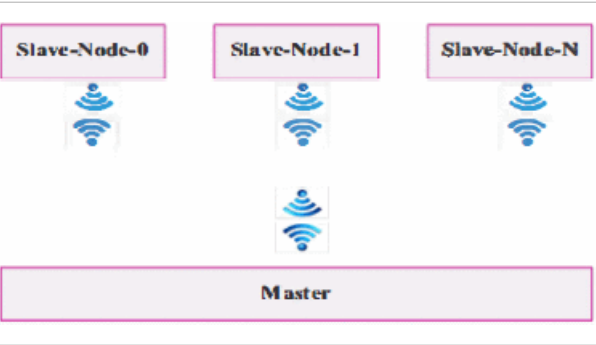


Fig. 2.
Master-slaves hardware layout

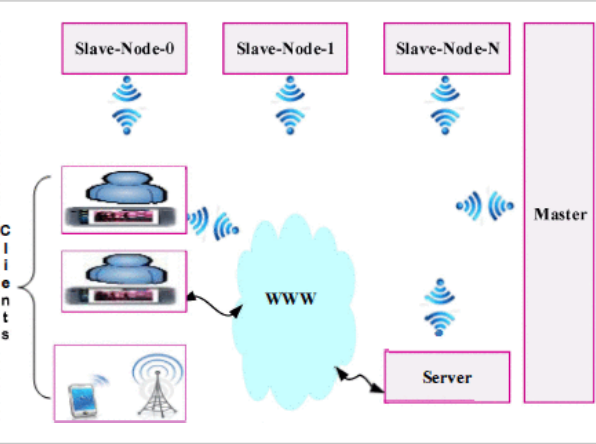


Fig. 3.
Proposed system overall hardware building blocks

SECTION IV. System Software Architecture

To satisfy the system software requirements, the irrigation system algorithm is divided into two modes of operation; manual and fuzzy operation modes:

A. Manual Operation Mode

In this mode, two slaves are used. One monitors and irrigates the garden trees through one valve while the other monitors and irrigates the garden grass through another valve. The system is scalable. Additional slave nodes can be added as desired. Each slave is essentially stand-alone. The microcontroller in the slave reads the temperature and moisture sensors and water the trees and grass manually. Home owner turns ON/OFF the watering valve manually whenever required.

B. Fuzzy Operation Mode

In this mode, the master node communicates with slave nodes using the Zigbee protocol to form a wireless sensor network [26]. The operation of slave nodes is automatically coordinated via the master node. The master receives each slave sensor's readings and coordinates the watering process based on a fuzzy logic algorithm. For each slave, the fuzzy logic algorithm has two attributes for the inputs and one attribute for the output. The input attributes are the temperature (Temp) and soil moisture (S-Moist), and the output attribute is the water valve (W-Valve).

There are three steps that are involved in the fuzzy logic algorithm namely; fuzzification, rules-based inference engine and defuzzification:

- Fuzzification The fuzzification process converts the crisp input variable values into linguistics terms and maps them with a set of membership functions. Each slave-node has two crisp input values namely; temperature and soil moisture. It is assumed that the temperature linguistic terms are cold, warm and hot. The soil moisture linguistic terms are dry, normal and wet. Figure 4 and 5 show the proposed membership functions along with their ranges.
- Rules-Based Inference Engine A set of fuzzy rules is assembled using: “If < premises> Then < conclusion >” structure The number of rules is obtained using the following formula [28]: $N= P_1 \times P_2 \times \dots \times P_N$.

Where: N is the total number of possible rules for the fuzzy system and PN is the number of linguistic terms for the input linguistic variables N.

Since there are three membership functions for the temperature and three membership functions for the soil moisture, the total number of rules is: $N = 3 \times 3 = 9$. Table I shows the rules and weight calculations.

- Defuzzification: The defuzzification process is the method of converting the rule-based engine decision into a single quantifiable output. The water valve for each slave node has two linguistic terms namely; ON and OFF. Table I shows output membership functions for the water valve. Once a rule is decided based on the inputs from the fuzzifier, the output valve is turned ON or OFF accordingly. The root-sum-square (RSS) and fuzzy centroid algorithm methods are used to calculate the crisp value for the valve status [27]. For example, the temperature was set at 13°C and soil moisture was set at 37%. The corresponding weights for the 13°C

temperature are; Cold=R1=0.4, Warm=0.6 and Hot=0.0 and for 37% soil moisture are; Dry=0.8, Normal=0.2, Wet=0.0). For this case, four rules attributes to the “ON” status (R1, R4, R7 and R8) and five rules attributes for the OFF status. (R2, R3, R5, R6 and R9). Using the RSS method, the output valve status is calculated as shown in the equations 7–8. Equation 9 combines both “ON” and “OFF” weights to calculate the actual valve weight.

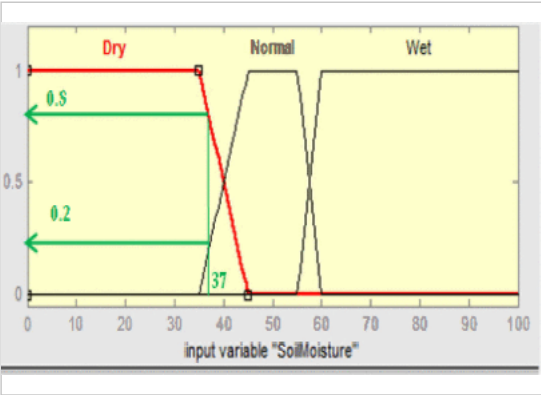


Fig. 4. Temperature membership functions

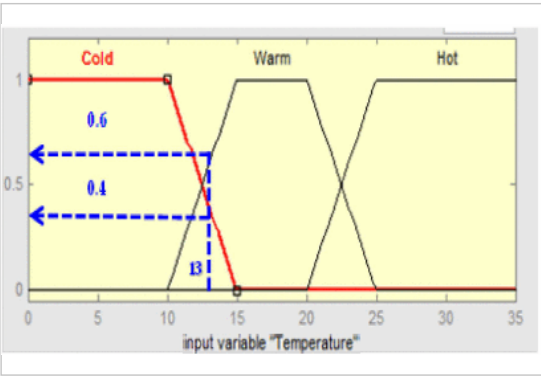


Fig. 5. Soil moisture membership functions

Table I. Fuzzy rules

Rule #	IF	Temp.	AND	Soil Moist.	THEN	Water Valve
1	if	cold	and	dry	then	on
2	if	cold	and	norm.	then	off
3	if	cold	and	wet	then	off
4	if	warm	and	dry	then	on
5	if	warm	and	norm.	then	off
6	if	warm	and	wet	then	off
7	if	hot	and	dry	then	on
8	if	hot	and	norm.	then	on
9	if	hot	and	wet	then	off

$$\begin{aligned} \text{Temperatur}_{\text{cold}}(x) &= \begin{cases} 1 & 1 \leq x \leq 10 \\ \frac{15-x}{5} & 10 < x < 15 \\ 0 & \text{otherwise} \end{cases} \\ \text{Temperatur}_{\text{warm}}(x) &= \begin{cases} \frac{15-x}{5} & 10 < x \leq 15 \\ 1 & 15 < x < 20 \\ \frac{30-x}{10} & 20 \leq x < 30 \\ 0 & \text{otherwise} \end{cases} \end{aligned}$$

[View Source](#)

```

\begin{gather*} \text{Temperatur}_{\text{Hot}}(x)=\begin{cases} \frac{x-20}{5} & 20 \leq x < 25 \\ 1 & x \geq 25 \end{cases} \\ \text{SiolMoisture}_{\text{Dry}}(x)=\begin{cases} 1 & x \leq 35 \\ \frac{45-x}{10} & 35 < x \leq 45 \\ 0 & x > 45 \end{cases} \\ \text{SiolMoisture}_{\text{Normal}}(x)=\begin{cases} \frac{x-35}{10} & 35 < x \leq 45 \\ 1 & 45 < x < 55 \\ \frac{60-x}{5} & 55 \leq x < 60 \end{cases} \\ \text{SiolMoisture}_{\text{Wet}}(x)=\begin{cases} \frac{x-55}{5} & 55 \leq x \leq 60 \\ 1 & x \geq 60 \end{cases} \\ \text{ON}=\sqrt{R_1^2+R_4^2+R_7^2+R_8^2} \\ \text{OFF}=\sqrt{R_2^2+R_3^2+R_5^2+R_6^2+R_8^2} \\ \text{Water}_{\text{value}}=\sum_{n=1}^n \text{Strength}_{\text{i}} \\ \text{Water}_{\text{value}}=(0.283 \ast 0.25) + \frac{0.721 \ast 0.75}{0.283+0.721}=0.609
\end{gather*}

```

[View Source](#)

SECTION V.

Simulation, Implementation and Testing

To verify the proposed software, the fuzzy logic algorithm was simulated using the MATLAB fuzzy logic toolbox. Nine different inputs were used to trigger nine rules. As shown in Figure 6. For an input temperature of 13° C and input soil moisture of 37%, the simulation gave water valve weight of 0.6, which turned the water valve ON. This simulation result outputs a weight of 0.60 matches and conforms to the calculated weight of 0.609 (see section V) with a small error of $0.6 - 0.609 = 0.009$. Figure 7 shows another case where the simulated inputs values turn OFF the water valve.

A hardware prototype of the proposed system was built using an off-the-shelf microcontroller [26]. Figure 8 shows the hardware experimental setup for one slave node. The simulated fuzzy logic algorithm is implemented using the microcontroller fuzzy logic library based on C program [27].

Fifteen different input sets are selected to test the nine rules. As shown in table II, the experimental results conform to the simulation results. However the little water valve output weight differences between the experimental and simulations do not change any of the water value status (ON to OFF or vice-verse).

Home owners can access the system using the World Wide Web to monitor and turn on the fuzzy logic control system.

The details of the web server, database and user privileges software development are not reported because it is standard which do not add any new idea rather than it is common and easy to develop. Similar web access arrangements were reported by the first author [28].

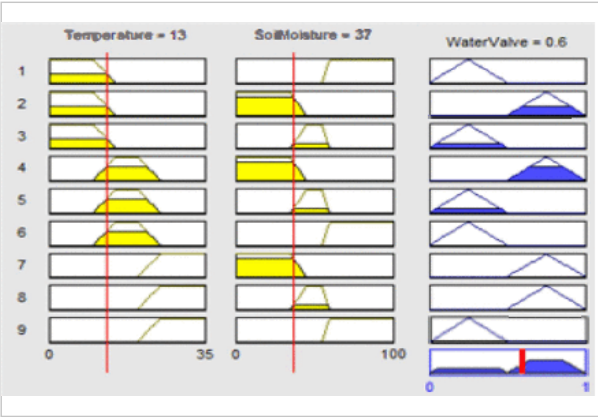


Fig. 6. Simulation example "water valve ON"

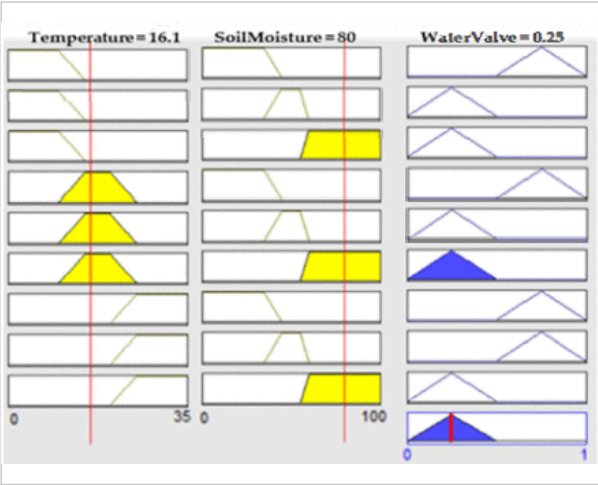


Fig. 7. Simulation example "water valve OFF"

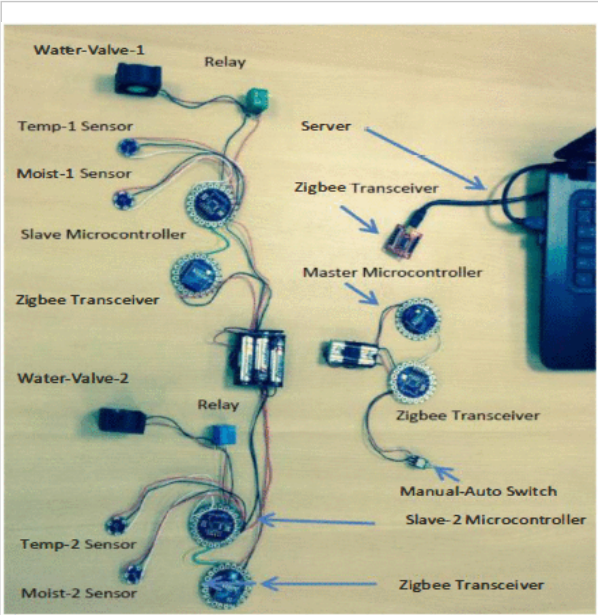


Fig. 8.
Prototype experimental setup

Table II Simulation and experimental results

Test #	Temp. Input	Soil Moisture Input	Water Valve Output	
			Simulation Results/ Valve Status	Experimental Results/ Valve Status
01	05	10	0.750 /ON	0.730/ON
02	12	50	0.250/OFF	0.250/OFF
03	29	50	0.750/ON	0.750/ON
04	13	37	0.609/ON	0.630/ON
05	17	40	0.510/ON	0.520/ON
06	26	70	0.250/OFF	0.230/OFF
07	09	40	0.510/ON	0.520/ON
08	05	70	0.250/OFF	0.000/OFF
09	15	40	0.530/ON	0.520/ON
10	12	30	0.750/ON	0.730/ON

SECTION VI.
Conclusion

An automatic fuzzy logic based smart home irrigation system was proposed, developed, simulated and tested. The system used off-the-shelf components. Home owners can irrigate their garden grass and trees manually or automatically via local control or remote control using the Internet. The system was tested using software simulation tools and an experimental hardware system. The simulation results and the experimental setup performance were as expected and satisfactory. The system can be integrated with other home automation systems with little modifications.

ACKNOWLEDGMENT

The authors would like to thank the Computer Science and Engineering Department, American University of Sharjah, UAE, for providing the resources. Special thanks go to Ms. Jumanah Aldmour and Ms. Lalitha Murugan for their contribution in fuzzy logic simulation and testing.

- Authors
- Keywords
- Related Articles



References

Citations

Keywords

Back to Top

IEEE Account

- » Change Username/Password
- » Update Address

Purchase Details

- » Payment Options
- » Order History
- » View Purchased Documents

Profile Information

- » Communications Preferences
- » Profession and Education
- » Technical Interests

Need Help?

- » **US & Canada:** +1 800 678 4333
- » **Worldwide:** +1 732 981 0060
- » Contact & Support

| About IEEE Xplore | Contact Us | Help | Accessibility | Terms of Use | Nondiscrimination Policy | Sitemap | Privacy & Opting Out of Cookies

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.
© Copyright 2018 IEEE - All rights reserved. Use of this web site signifies your agreement to the terms and conditions.

IEEE Account

Profile Information

Purchase Details

Need Help?

Other

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.
© Copyright 2018 IEEE - All rights reserved. Use of this web site signifies your agreement to the terms and conditions.

US & Canada: +1 800 678 4333
Worldwide: +1 732 981 0060