

**DEVELOPMENT OF SOFTWARE FOR WATER
PUMPING(IRRIGATION)SYSTEM**

BY

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PG/M.ENGR/14/69574

**BEING A THESIS SUBMITTED TO THE
DEPARTMENT OF ELECTRONIC ENGINEERING
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**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF
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APPROVAL PAGE

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**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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ELECTRONICS AND COMPUTERS OPTION)
IN THE DEPARTMENT OF ELECTRONIC ENGINEERING, UNIVERSITY OF
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DECLARATION

I, IBOKETTE, BASSEY OKON, a postgraduate student of Department of Electronic Engineering, University of Nigeria, Nsukka declare that the work embodied in this thesis is original and has not been submitted by me in part or in full for any other diploma or degree of this or any other University.

.....

IBOKETTE, BASSEY OKON

.....

DATE

DEDICATION

I dedicate this thesis work to those that made it happen. God Almighty for giving me the strength to stand the storm and the wisdom to accomplish the task.

Electronic and Computer Engineers, the experienced and the newly ordained. I stood on their shoulders to be who I am. Bassey ñIsaò Edet for working my shift without complaint and my beloved wife - Imoh who endured my absence and reduced money for upkeep. I am indebted to your enthusiasm and support

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ABSTRACT

This research work undertakes the development of water pumping system (with emphasis on Irrigation) that is capable of automatically managing water budgets from a reservoir through a microcontroller subsystem. The water pumping for irrigation system can be used in gardens, farms, urban/rural water supply systems, and in fact, general water management systems for both domestic and industrial applications. The key objective of this research is to develop a user-friendly and efficient water management system that has the capability to irrigate farms based on automated algorithm, logic and electronic circuitry. The entire water pumping system is comprised water of store/reservoir, water-level sensor,(micro)controller, filter, pump, valves, soil-moisture-content sensor and software system. In this study, most of these were implemented but filters and valves were not implemented because of the scope of this study. The Object Oriented System Analysis and Design (OOSAD) methodology was used for the analysis and development of the system under consideration. The software application communicates directly with a microcontroller unit and uses manual over-ride approach in some cases to manage water budgets. The water-level sensor checks the level of water storage in a reservoir and reports to an electronic controller; the soil-moisture-content sensor checks the soil moisture content and also reports to the controller. The water pumping software for irrigation system was developed using the following languages: C# for Windows application development, for establishing routines and relationships; Embedded C was used in defining status and processes in the Aduino Uno microcontroller; PHPMyAdmin as a database management system and MYSQL relational database server version 5.5 as the backend for storing user inputs from the frontend. The water-pumping software for irrigation system provides the user interface providing irrigation in gardens or farms. The system was able to perform as expected; pumping water from reservoir which can be used to irrigate farms or gardens.

TABLE OF CONTENTS									PAGES
Preliminary Pages									
Title Page	..	..	..	..	..	..	..	..	i
Approval Page..	..	..	..	..	..	..	..	..	ii
Certification Page	..	..	..	..	..	..	..	..	iii
Declaration	..	..	..	..	..	..	..	..	iv
Dedication	..	..	..	..	..	..	..	..	v
Acknowledgement	..	..	..	..	..	..	..	..	vi
Abstract	..	..	..	..	..	..	..	..	vii
Table of Contents	..	..	..	..	..	..	..	..	viii
List of Figures..	..	..	..	..	..	..	..	..	xi
List of Tables	..	..	..	..	..	..	..	..	xii
List of Abbreviations (Acronyms)	..	..	..	..	..	..	..	..	xiii
CHAPTER ONE: INTRODUCTION									
1.0 Introduction	..	..	..	..	é	..	..	..	1
1.1 Statement of Problem	..	..	..	..	..	..	..	..	2
1.2 Objective of Study	..	..	..	..	..	..	..	..	3
1.3 Significance of study	..	..	..	..	..	..	..	..	3
1.4 Scope of the study	..	..	..	..	..	..	..	..	4
1.5 Organisation of the Thesis	..	..	..	..	..	..	..	..	5
CHAPTER TWO: LITERATURE REVIEW									
2.0 Introduction	..	..	..	..	..	..	..	..	6
2.1 Historical Background of Water/Irrigation works in Nigeria	..	..	..	..	..	..	..	..	6
2.1.2 National Water Policy..	..	..	..	..	..	..	..	..	7
2.1.3 Features of Water Pumping for irrigation system	..	..	..	..	..	..	..	..	12

2.2	Irrigation	..	..	..	..	..	..	..	15
2.2.1	Irrigation Methods	..	..	..	..	..	..	..	15
2.3	Theoretic background of the proposed software	..	..	..	..	..	..	..	18
2.3.1	C# (C- Sharp)	..	..	..	..	..	..	..	18
2.3.2	Embedded C	..	..	..	..	..	..	..	18
2.3.3	MySQL	..	..	..	..	..	..	..	19
2.3.4	PHP MyAdmin	..	..	..	..	..	..	..	19
2.4	Analysis of Existing Systems	..	..	..	..	..	..	..	21
2.5	Research Gap	..	..	..	..	..	..	..	22

CHAPTER THREE: SYSTEM ANALYSIS AND DESIGN

3.0	Introduction	..	..	..	..	..	..	..	25
3.1	Drawbacks of Reviewed Systems	..	..	..	..	..	..	..	25
3.2	System Analysis (of Proposed system)	..	..	..	..	..	..	..	26
3.2.1	Software Components	..	..	..	..	..	..	..	26
3.2.1.1	Embedded C	..	..	..	..	..	..	..	26
3.2.1.2	Funtional Requirements	..	..	..	..	..	..	..	26
3.2.1.3	Non-Functional Requirements	..	..	..	..	..	..	..	27
3.2.2	Hardware Components	..	..	..	..	..	..	..	28
3.2.2.1	Arduino Uno Microcontroller	..	..	..	..	..	..	..	28
3.2.2.2	Solenoid Valve	..	..	..	..	..	..	..	30
3.2.2.3	Soil Moisture Sensor	..	..	..	..	..	..	..	31
3.2.2.4	Water Level Sensor	..	..	..	..	..	..	..	33
3.3	System Design	..	..	..	..	..	..	..	35
3.3.1	Design Goals	..	..	..	..	..	..	..	36
3.3.1.1	Performace Criteria	..	..	..	..	..	..	..	36

3.3.1.2 Dependability	36
3.3.1.3 Maintenance	36
3.3.1.4 End-User Criteria	37
3.3.2 Architecture of the System	37
3.3.3 Subsystem Decomposition	38
3.3.4 Hardware/Software Mapping	39
3.3.5 Persistent Data Management	39
3.3.5.1 Mapping	40
3.3.5.2 Relationship Among tables	41

CHAPTER FOUR: SYSTEM IMPLEMENTATION

4.0 Introduction	42
4.1 Development Environment/Programming Tools	42
4.2 Sytem Implementation	42
4.2.1 Hardware Implementation	43
4.2.2 Software Implementation	44
4.3 Software Testing	45
4.4 System Documentation	47
4.4.1 User Manual	47
4.4.2 Cost estimates	50
4.4.3 Source code listing(as appendix)	50

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion	51
5.2 Suggestions for Further work(Recommendation)	51
References	53

Appendices

LIST OF FIGURES

Figure 3.1	Schematic of the Computerised Irrigation System	..	27
Figure 3.2	Picture of the Arduino Uno Microcontroller	..	29
Figure 3.3	Arduino Uno board with components layout	..	30
Figure 3.4	Picture of Soil Moisture sensor	..	32
Figure 3.5	Picture of the Water Level Sensor (HC-SR04)	..	33
Figure 3.6A	System Flowchart	..	35
Figure 3.6B	Layered Representation of the system	..	39
Figure 3.7	Mapping Diagram	..	40
Figure 3.8	Relationship between Tables	..	41
Figure 4.1	System Block Diagram	..	42
Figure 4.2	Hardware Schematic Diagram	..	43
Figure 4.3	Login Screen	..	45
Figure 4.4	Software Splash Screen	..	45
Figure 4.5	The Main Window of the software	..	46
Figure 4.6	The Data Log screen /Result	..	46
Figure 4.7	Picture of the system setup with software running	..	49

LIST OF TABLE

Table 3.1:	Soil Moisture Content Parameters	..	..	..	..	32
Table 3.2:	Crop Water Requirement	..	..	..	..	33
Table 4.1:	Bill of Engineering Measurement and Evaluation	..	..			50

LIST OF ABBREVIATIONS (ACRONYMS)

AC	Alternating Current
BEME	Bill of Engineering Measurements and Evaluation
CBO	Community-Based Organisation(s)
CRBRDA	Cross River Basin and Rural Development Authority
DC	Direct Current
EEPROM	Electrically Erasable Programmable Read Only Memory
EU	European Union
FIWA	Federal Inland Waterways Authority(Nigeria)
FME	Federal Ministry of Environment
FMWR	Federal Ministry of Water Resources
GND	Ground
GUI	Graphical User Interface
IEG	Independent Evaluation Group
MB	Megabyte(s)
MDG	Millennium Development Goal
NC	Normally Closed(relay)
NEPA	National Electric Power Authority
NEPAD	New Development Partnership for Africa
NGO	Non Governmental Organisation(s)
NIWA	National Inland Waterways Authority
NO	Normally Open
NWP	National Water Policy (Nigeria)
NWRI	National Water Resource Institute
NWRP	National Water Rehabilitation Project
OOSAD	Object Oriented System Analysis and Design
RAM	Random Access Memory
RBDA	River Basins Development Authority
RDBMS	Relational Database Management System
REALM	Resource Allocation Model
ROI	Return On Investment
RX	Receiver
SIDES	Surface Irrigation Systems Design and Evaluation Software
SRAM	Static Random Access Memory
SQL	Structured Query Language
SWPIS	Software for Water Pumping(Irrigation) System
TTL	Transistor-Transistor Logic
TX	Transmitter
UART	Universal Asynchronous Receiver/Transmitter
UNICEF	United Nations International Children Emergency Fund
USB	Universal Serial Bus
V	Volt/Voltage
WMO	World Meteorological Organisation
XSS	Cross Scripting

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

Over 70% of planet earth, as well as over 70% of the human body, is water. Water supply is critical to sustainable development and economic competitiveness of any nation. Population surge, industrialisation and rising standards of living, have put water demand on the rise; though without corresponding increase in the quantity of the resource[1].

Water pumping is required in situations where site conditions do not favour the use of gravity supply. This may occur in irrigation or water supply projects. In either case, gravity systems tend to involve high capital cost but low operating cost. On the other hand, pumping systems tend to require lower capital cost but high operating cost. The choice between gravity supply, and pump fed supply is therefore, an economic one. When the economic case is not obvious, then the economic viability of each alternative must be established, and the economically superior alternative chosen[2].

Water demand is determined by segregating the total demand into categories such as:

- 1) Irrigation demand;
- 2) Domestic demand;
- 3) Industrial demand;
- 4) Commercial demand;
- 5) Institutional demand.

For irrigation, the water demand is derived from the total area to be irrigated and the water

required per unit of area irrigated. The water demand required per unit area irrigated depends on the crop, the climatic conditions, and the soil conditions.

For categories of demand except irrigation, the population to be served and its per capita water consumption is estimated, and from these data, the aggregated water demand is computed. The water quality for categories of demand other than irrigation will generally be to human health standards[3].

In practice, demand for irrigation will usually be isolated and designed for separately, because the location where it occurs and the water quality demanded is often different[4].

Computer software/simulation models are widely used by water authorities around the world for planning and management of water supply systems. These water supply systems consist of "nodes" such as reservoirs, demand centres, stream junctions and pipe junctions, and "carriers" such as rivers and pipes. They supply irrigation and urban water demands, meet environmental flows, and provide releases for hydropower generation and other uses.

This water pumping/irrigation software is about the use of computer and supporting technology to provide effective, efficient and economically viable alternative to the current manual/semi-automated systems and leveraging positively on water budget.

It is a system that is vast, adaptable and scalable making it suitable for domestic and commercial water budget planning/management.

1.1 STATEMENT OF PROBLEM

Water is inarguably considered one of the most important components in sustaining life, both of plants and animals. Some organizations/farmers use irrigation(artificial application of water to farm) to improve plant growth and crop yield. The cost and convenience of using

traditional or conventional irrigation methods vis-à-vis modern technology driven method will show a marked difference.

Besides, there are many challenges from the old manual system of water pumping and irrigation ranging from system concerns such as managing different and diverse areas with their peculiar requirements, to theoretical questions such as revisiting evolving needs of the system. Some fundamental challenges are stated below:

1. Inability to properly plan for water budgets and schedule water pumping action(s) remotely
2. Due to the inefficiency of the current manual system, the need arises to automate water pumping for irrigation system in order to efficiently handle water budgets in homes, farms and towns/cities for irrigation purpose.
3. The inconvenience of going to each section of the area/farm will be eliminated with the use of an automated system.

1.2 OBJECTIVES OF THE STUDY

The aim of this study is to design water pumping software for Irrigation system that will proffer solutions to some basic challenges confronting most contemporary water pumping/irrigation systems. The objectives include:

1. To develop and implement an efficient water pumping software system that has the capability of mitigating against water wastage in an irrigation system.
- 2 To create a friendly Graphic User Interface for the irrigation system.

1.3 SIGNIFICANCE OF STUDY

This research promises to make important contribution in the quest to developing software for water pumping for irrigation system. It will help individuals, government(s) and

organizations to make reasonable and informed choices on cost effective, convenient and efficient alternative in choosing water pumping software for irrigation.

The software will create an interface for the user thereby increasing patronage/acceptability.

The convenience and cost effectiveness the developed software will offer will positively change the mindset/attitude of users thereby leading to fast application/acceptance of the system by individuals and organizations.

For the past few years computer has been used increasingly for water pumping and irrigation systems management. This is because computer, in general and computer software, in particular have been recognized as key measure for improvement of water use in water pumping and irrigation systems[5].

Besides commercial software made by international authors, use of Nigerian made software show several advantages: simple and easy to understand and use because of common language interface; more adaptable to Nigerian conditions because the software is made based on experience and practice of Nigerians.

1.4 SCOPE OF THE STUDY

This work covers the design and implementation of a water pumping software for irrigation system. It will enable the farmer to automate one of the essential farming operation(which is irrigation) thereby saving money, time and energy.

This application is developed as a desktop application. It is not a web application software. It can not be used for simulations of plant growth or crop yields.

1.5 ORGANISATION OF THESIS

This work is arranged such that Chapter One contains the background information on the study along with problem statement, objectives, research questions, among others. In Chapter Two, literature review of relevant works is presented. Chapter Three contains the materials and method used in the research. Specifically, the system analysis, design goals and system components. In Chapter Four, the results and discussion of the results are presented. Conclusion and recommendation for further work are presented in Chapter Five followed by References and Appendices.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

In this chapter, the review of related literature was carried out, historical background of Water/Irrigation works in Nigeria, National Water Policy, features of water pumping/irrigation system, types, advantages and disadvantages. Cogent contributions of other authors were considered, the extent of scholarly work they have covered and discoveries made will guide in choosing the methodology for the research work. Since the objective of Water Pumping for irrigation system is to effectively manage water resources and provide information to the user, together with the link structure that interconnects them, the remaining part of this chapter describes the theoretical framework of the study, which deals with the software development technologies that are needed to design the new Water Pumping software for irrigation.

2.1 HISTORICAL BACKGROUND OF WATER/IRRIGATION WORKS IN NIGERIA

According to *Water Supply in Nigeria Status Report [1]* Operation of public water supply systems commenced only early in the twentieth century in Lagos and a few towns like Calabar, Kano, Ibadan, Abeokuta, Ijebu Ode and Enugu.

The government's major intervention came during the first National Development Plan period(1962-1968) through the establishment of the River Niger and Lake Chad Basin Commissions.

The first water corporation was formed in the western region in 1966 with the staff of the Water Division of the Ministry of Works constituting the nucleus. The next sets of corporations were formed in the 1970s. The Federal Government elevated its level of involvement in the management of water resources in 1976 when the Federal Ministry of Water Resources and the eleven River Basin Development Authorities(RBDAs) were created. The purpose of the RBDAs was to provide bulk water, primarily for irrigation.

Today, all the thirty six states and the Federal Capital Territory have Water Boards/Corporations or Public Utilities Boards managing their public water supplies.[1]

2.1.2 National Water Policy

Nigeria, with a land area of about 924,000sq.km, is located within the tropics where its climate is semi-arid in the North and gradually becoming humid in the South. The annual rainfall varies from over 4,000mm in the South-East to below 250mm in the extreme North-East and is subject to significant temporal variation. The surface water resources potential of the country is estimated at 267.3 billion cubic metres while the groundwater potential is 51.9 billion cubic metres.

For the water resources assessment of the country, 163 automated hydrometric stations were established in 8 hydrological areas of the country while 26 existing primary stations were existing, primary stations upgraded to meet WMO (World Metrological Organization standards). The Ministry's National Hydrological Program has the objective of having 486 hydrological stations to constitute the basic primary network.

The total irrigation potential is about 3.14 million ha comprising of:

- À 2.04 million ha for formal farmer owned and managed schemes based on conjunctive rise of surface/water and shallow Fadama aquifers; and

À 1.1 million ha for formal public irrigation projects, which are under government control.

Government constructed 200 dams storing up to 31 billion cubic metres. Out of these, 11 billion cubic metres are meant to command up to 340,000 hectares of irrigated land. So far, about 100,000 hectares of land have been equipped with the infrastructure whilst currently only about 60,000 hectares can actually be irrigated; thus the remaining 40,000 of the equipped field need some major rehabilitation. The balance of 240,000 hectares of land that can be commanded by the water stored so far, need to have the full complement of irrigation facilities in order for the country to derive the benefits fully.

A large percentage of the country's population which is estimated to be in the neighbourhood of 170 million does not have access to potable water. It is estimated, according to Multi-indicator Cluster Survey of 1999 by the Federal Office of Statistics, that only 52% of the urban (48% if peri-urban areas are included) and 39% of rural dwellers have access to potable water.

The Ministry has been collaborating with other sectors that are associated with water resources activities such as Federal Ministry of Agriculture, Environment, Power and Steel, Federal Department of Inland Waterways Authority and Nigerian Meteorological Services Agency.

The institutional arrangement for water resources development and management is such that all tiers of government, that is Federal, States and Local Government are involved.

To boost manpower supply for the water resources sector, the National Water Resource Institute(NWRI), Kaduna was established in 1979.

It runs certificate, remedial and National Diploma and Higher National Diploma and professional post graduate courses in water resources. Under the National Water Rehabilitation Training Programme, the Institute has trained a total number of 805 officers of State Water Agencies.

The Institute also runs a Data Bank with data from the eight (8) hydrological areas of the country. The Data Bank has meteorological data from about 222 stations nationwide.

Legal Framework Presently, only the following Statutory laws: Decree 101, 1993; Minerals Act of 1990; National Inland Waterways Authority(NIWA) Decree 13 of 1997; RBDA Act of 1990 and State Water Edicts are relevant in the development and management of the nation's water resources. Other Decrees associated with water resources are those of National Electric Power Authority(NEPA), Federal Ministry of Environment(FME) and the Land Use Decree.

Overview of the Policy Development Process

Consequent upon the enactment of Water Act 101 of 1993 and the preparation of the National Water Resources Master Plan in 1995, the Water Resources Management Reform Programme commenced in 1997. This programme carried out a Water Sector review in Legal and Regulatory Framework, Institutional Framework and Participatory Approach, Information and Water Resources Data base, Water Resources Economics and Financing, Environment and Resource Sustainability, Water Resources Infrastructure, Assets and Assets Management and International Waters. The report of these reviews provided inputs in the formulation for a Water Resources policy, principles and strategies as presented in the draft policy[6].

Overview of Urban Water Management Policies in Nigeria

The Federal Ministry of Water Resources (FMWR) is the main national coordinating body in the water sector. Water resource management is a complex function which include regulatory, support and operational activities.

The responsibilities for water resources development in Nigeria are vested on government agencies including the Federal Ministry of Water Resources, State Water Agencies and non-governmental or donor agencies such as Community-Based Organisations(CBO), Non-Governmental Organisations(NGO), Water AID, European Union(EU), World Bank and United Nations International Children Emergency Fund(UNICEF) etc. Other government agencies not directly concerned with water resource development but carry out water resource developments include the Federal and State Ministries of Agricultures and Environment.

The policies include the following:

Water Policy Reform in Nigeria

The World Bank has been providing assistance to Nigeria in the water supply sector since 1979. The first generation of assistance was directed at investments and strengthening institutions at the state level, especially since urban water supply is constitutionally a responsibility under Nigeria's constitution. The second generation of assistance was in the form of a loan of US\$256 million for the National Water Rehabilitation Project (1991-2001), which targeted the entire country.

Concurrently also, the World Bank supported the First Multi-State Water Supply Project (1992-2000) with a loan of US\$101 million, which was targeted at Kaduna and Katsina

States. The third generation of assistance (2000-2004) was the provision of US\$5 Million under the Small Towns Water and Sanitation Pilot Project aimed at satisfying the needs of 16 towns. However it is sad to note that the Independent Evaluation Group (IEG) of the World Bank considers its intervention between 1979-2005 to have failed because the seven selected case studies were rated as unsatisfactory with unlikely sustainability and with negligible or modest institutional development impact [6].

National Water Supply and Sanitation Policy of 2000

This policy spelt out the Institutional Framework for Water Supply and Development thus;

The Federal Ministry of Water Resources: It is charged with the responsibilities of policy advice and formulation, data collection, monitoring and co-ordination of water resources development (of which water supply is a component) at the National level.

The River Basin Development Authorities (RBDAs): This came into existence following the promulgation of Decree 25 of 1976. The current law on RBDAs is the RBDA Act; cap 396 Laws of the Federation of Nigeria, 1990.

The authorities are charged with the development, operation and management of reservoirs for the supply of bulk water for water supply amongst other uses in their areas of jurisdiction.

The National Water Resources Institute: It is be responsible for manpower training, research, development and studies under the National Water Supply Training Network in the water supply sector.

The State Water Agencies: These agencies are responsible mainly for urban, semi-urban and rural water supplies. In some States separate agencies exist for rural water supplies and urban and semi-urban water supplies.

The Local Government Authorities: Are responsible for the provision of potable water to rural communities.

The National Water Policy (NWP) Document of 2004

Water abstraction for public water supply is guided by the National Water Policy. In order to meet Nigeria's water supply demand, the following policy objectives had been drawn and the guiding principles for implementation.

The formulation of the water resources policy was guided by; The Millennium Development Goals (MDGs), New Partner for African Development (NEPAD) Objectives and the resolutions of various conferences, conventions and meetings based on the International trends and agreements in water Policy. The International trends and agreements in water policy highlighted the fact that water management and development should be conducted on a participatory basis with decision making occurring at the lowest appropriate level [7].

2.1.3 Features of Water Pumping Software for Irrigation System

A safe supply of potable water is the basic necessity of mankind in the industrialized society, therefore water supply systems are the most important public utility. A colossal amount of money is spent every year around the world for providing or upgrading drinking water facilities. The major share of capital investment in a water supply system goes to the water conveyance and water distribution network. Nearly 80% to 85% of the cost of a water supply project is used in the distribution system; therefore, using rational methods for designing a water distribution system will result in considerable savings.

The water supply infrastructure varies in its complexity from a simple, rural town gravity system to a computerized, remote-controlled, multisource system of a large city; however, the aim and objective of all the water systems are to supply safe water at the cheapest cost. These systems are designed based on least-cost and enhanced reliability considerations.

In general, water distribution systems can be divided into four main components: (1) water sources and intake works, (2) treatment works and storage, (3) transmission mains, and (4) distribution network. The common sources for the untreated or raw water are surface water sources such as rivers, lakes, springs, and man-made reservoirs[8].

Components of a Water Distribution System

Some components of a water distribution system are:

- A *source* supplies water to the system. This could be a spring, well, or reservoir
- A *sink* is a user of water. It represents a house, factory, or farm, or a group of such water consumers. A sink absorbs water from the system at a fixed rate.
- A *pipe* carries water over a distance. A pipe has a characteristic resistance that limits the amount of water that can flow through it. The water flowing into a pipe equals that flowing out.
- A *tank* stores water. It also decouples the input/output flows: The rate at which water flows into the tank can be different from the rate at which it flows out. For example, if the input flow is greater than the output, the contents of the tank increases. A tank has a characteristic maximum output flow rate, determined by the size of the outlet in the tank.
- A *valve* regulates the flow of water. It can be ON, causing no resistance to the flow, or OFF, which stops the flow entirely. A valve is assumed to be operated by some sort of servo-mechanism, and is typically controlled by switches associated with a tank.

Flow, Pressure and Back Pressure

Every component in the system has three important aspects: flow, pressure and back pressure.

When we connect one component to another, we're connecting these three aspects.

Flow:

The bottom-line characteristic of components in the water system is flow. This is the amount of water passing through the component per unit time. It's usually what we're interested in measuring when we model a system.

Often the flow into a component is the same as the flow out. This is true of pipes and of valves. However, as noted above, it is not true of tanks.

Pressure:

When a valve is turned off, the flow both into it and out of it stops, but water may still be trying to flow through the valve. This potential for flow is pressure. A source or a tank provides water at a certain pressure. If the rest of the system permits, this pressure will cause a proportional flow: the greater the pressure, the greater the flow but if a valve is turned off, the flow will stop, regardless of what the water the pressure is. Pressure, like flow, is transmitted downstream from one component to another.

A tank decouples pressure as well as flow. The pressure downstream from a tank is determined by the tank, not by the upstream pressure.

Back Pressure:

In opposite to pressure is back pressure. This is caused by the resistance to flow by some components. A small-diameter pipe, for instance, will slow the flow of water, so that no matter how much pressure is supplied, the flow will still be small. This back pressure will slow the flow not only into the component causing the back pressure but into all components upstream.

Back pressure goes the opposite way from flow and pressure. It's transmitted from the downstream component to the upstream component. Tanks decouple back pressure as they do pressure and flow.

2.2 IRRIGATION

Irrigation is the artificial application of water to the land or soil. Irrigation can be described as the application of water to the soil to make available essential moisture for plant growth. It also serves as insurance against drought and to provide a cooling effect on the soil environment for plant growth and development. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and revegetation of disturbed soils in dry areas and during the period of inadequate rainfall. Additionally, irrigation has a few other uses in crop production, which include protecting plants against frost, suppressing weed growth in grain fields and preventing soil consolidation[4].

Irrigation is also used for dust suppression, disposal of sewage and in mining. It is often studied together with drainage, which is the natural or artificial removal of surface and sub-surface water from a given area. So, irrigation is aimed at improving and raising the productivity of soil resources. Principally, the irrigation system is aimed at increasing and improving agricultural yield, particularly in moisture-deficient environments[9].

A crop requires a certain amount of water at some fixed time interval of its period of growth. Irrigation methods differ, depending on some factors such as topography, water resources, crop type, land tenure system, available power source, the growing season and the rain and water regime[10].

2.2.1 Irrigation Methods

Irrigation methods can come under broad classification as surface and sub-surface irrigation. Surface irrigation refers to water application above the ground level, while sub-surface irrigation means water application below the ground surface.

Irrigation method can also be classified based on the system of water application to the field; this includes flood irrigation-this technique imitates flooding in its implementation, and methods such as check basin irrigation, border irrigation, furrow irrigation, etc. are included. Flood method allows sheet of water to be distributed to the field.

There is also the microcontroller-based irrigation system and often the microcontroller of choice is the Aduino due to its compactness. Most microcontroller-based irrigation systems are open loop and are mostly used in gardens and experimental farms with rather limited application in large farms.[10]

Other irrigation types include the sprinkler and trickle (i.e. drip) irrigation; these are irrigation methods that allow water application to the field under pressure. Sprinkler irrigation imitates rain in its application and the pressure is obtained through pumping with careful selection of nozzles, operating pressures and sprinkler spacing. A sprinkler head should discharge water at a rate which could be simultaneously absorbed by the soil, therefore the infiltration rate of the soil should not be lower than the water application rate.[10]

The maximum rate at which water enters the soil is known as its infiltration capacity. Infiltration rate is affected by factors such as initial moisture content, elapsed time during wetting, soil surface conditions and rate of application. It is important to determine the application rate of water when designing an irrigation project so as to ensure maximum infiltration and minimum wastage in form of runoff. This can be done by making the application rate less than or equal to the infiltration rate[10]

The way forward for all this is **Economic /End Use Efficiency**: Economic efficiency is a key objective of water demand management and needs to be viewed from the broader

perspectives of the society. End use efficiency means doing more in economic terms with less water. Water saving strategies and technologies can be adopted in all economic sectors to achieve end use efficiency. A lot more water can be saved through end use efficiency by application of smart technologies and metering. This is where the development of this software will come in.

Crop Water Requirement

This is the amount of water required by a crop in its whole production period for a normal growth in a field and it varies considerably. Crop water requirements are normally expressed by the rate of evapotranspiration(ET) i which is the difference between evaporation and transpiration of water in plants/field.[11]

For a given climate, crop and crop development stage, the maximum evapotranspiration(ET_m) in mm/day(millimeters of water/day) of the period considered is:

$$ET_m = K_c * ET_o$$

Where:

- ET_m i Refers to conditions when water is adequate for unrestricted growth and development under optimum agronomic and irrigation management
- ET_o - Reference Crop evapotranspiration.
- K_c i Empirically-determined crop co-efficient and it varies with crop development stage.

$$Irrigation\ water\ need = Crop\ Water\ Need - Available\ rainfall$$

The total water demand for irrigation and crops in a particular field is determined by:

- Infiltration (percolation loss) through the soil
- Seepage (conveyance loss) through the channel
- Maximum evapotranspiration of the crop [12]

2.3 THEORETICAL BACKGROUND

The study undertakes the development of a Water Pumping Software for irrigation system using the following technologies: C# (C-Sharp), MYSQL Relational Database Server, MySql Admin database management system. The Model-View-Controller programming concept was used in the study as well as Object-Oriented System Analysis and Design methodology. A brief explanation of each software development technology employed in this research work is given below:

2.3.1 C# (C- SHARP)

C# is one of the programming languages designed for the Common Language Infrastructure. It is intended to be a simple, modern, general-purpose, object-oriented programming language. The language, and implementations thereof, provide support for software engineering principles such as software robustness, durability, and programmer productivity[12].

This study employed C# in the development of this piece of software application and large collections of functions, routines and procedures that constitute the water pumping(Irrigation System) software components or architecture

2.3.2 Embedded C

Embedded C is a set of language extensions for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems. Historically, embedded C programming requires nonstandard extensions to the C language in order to support exotic features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/O operations[13].

Embedded C is the most widely used programming language for embedded processors/controllers as it enjoys a huge library and uses very few lines of codes to accomplish great tasks. Assembly is also used but mainly to implement those portions of the code where very high timing accuracy, code size efficiency, etc. are prime requirements. It is also very portable between different platforms, small in size, reliable and scalable. Hence high level languages are preferred for embedded systems programming. It was used in developing the microcontroller side of the project.

2.3.3 MYSQL

MYSQL relational database server is a backend software that is responsible for storing data in database objects such as tables, records, queries, reports, etc. and therefore becomes a de facto repository for some Universe of Discourse (UoD);

2.3.4 PHP MYADMIN

This is a database management system used for administering MYSQL database server mainly through its frontend.

In terms of the Model-View-Controller (MVC) programming concept employed in the development of this Water Pumping software for irrigation application, it is pertinent to explain how it will be used in the research project. The definitive MVC programming concept allows a programmer to arrange the software components of an application in orderly and hierarchical pattern that promotes secured, hack-proof and user-friendly system in the codebase. Software components of this Water Pumping application responsible for database connectivity and manipulation are located within the model logic layer; software components responsible for establishing communication between the view logic layer and the model logic

layer are located within the controller logic layer; those software components responsible for handling user request in the Graphical User Interface (GUI) of the application are located within the view logic layer of the MVC architecture.

Apart from considerations involved in orderly arrangement of the source code of this software, the study also used the MVC programming concept to enhance stability, extensibility, maintainability and predictability of the Water Pumping software for Irrigation application. The standard Model-View-Controller design architecture primarily supports the separation of concerns i namely, data access layer, business rule logic layer and user interface layer. As pointed out earlier, the MVC programming concept includes a wide range of considerations for building high-performing, scalable and secure applications, which ensures that software components (i.e. program modules) are structured professionally to provide adequate security through separation of concerns in the codebase[14].

The concept of separation of concerns in the codebase pertains a standard programming effort that entails structuring of the Graphical User Interface (GUI), called the View Logic, in a manner that it is independent of MYSQL relational database engine (the Model Logic) through an intermediary structure (the Controller Logic). The application contains numerous software components or modules that are structured in an orderly and hierarchical pattern to promote ease of use and to prevent cross site scripting (XSS) as well as similar malicious attempts by hackers.

This research work takes security questions very seriously by imbibing the concept of Model-View- Controller (MVC) programming technology as a recommended international standard for the design and development of information systems of this nature. The research project encapsulates all the logical structures that communicate with MYSQL relational database

engine in the model logic as a separate business entity. The system allows the view logic to render the model logic into a form of interaction that generates an appropriate interface for a user. All the requests made by a user through the view logic such as, making a login attempt, clicking on a button, etc., are coordinated by the controller logic and updated by the model intelligence that results a change in the model's state in a way appropriate to the user's action. To ensure a deeper security implementation of this software application, the controller logic interface is further sub-divided into the front controller and the action controller. The front controller sub-logic is responsible for directly interacting with the user through the view or presentation logic interface whereas the action controller sub-logic is responsible for updating the model with user requests. Furthermore, the front controller is also responsible for rendering the feedback from the model logic to the appropriate page[14].

In summary, C# is used for designing the view logic or Graphical User Interface, presenting the layout of the pages of the application, rendering user requests and inter-modular communications; MYSQL relational database is used for storing records posted from the C# forms. MS Visual Studio 2008 was used to develop this application.

2.4 ANALYSIS OF EXISTING SYSTEMS

In the late 1970s, the Federal Government of Nigeria established the Rivers Basin Development Authorities and Cross River Basin and Rural Development Authority (CRBRDA) was one of them. The main purpose of this agency of government is the development, operation and management of reservoirs for the supply of bulk water for water supply, irrigation amongst other uses in their areas of jurisdiction. CRBRDA developed some irrigation schemes in Ibiaku Isiet-Uruan LGA, Uyanga-Akampka LGA, Oku-Iboku-Itu LGA, Oku Abak-Abak LGA, etc ï some pilot(experimental) and few operational schemes. Almost

all of them were manually operated (where water was manually pumped into trenches/channels/furrows to irrigate the fields depending on the type of crops on that field).

The system that was operational was not computerized or automated. The few pilot schemes, especially in their nurseries were automated (using sprinkler system). As the system was not fully automated, it does not support efficient resource management and utilization, generating reports, reporting errors or audit trail of activities.

Due to lack of follow up by government, changes in policy thrusts, the project was stalled. The agency, currently, is unable to use the partially developed irrigation system because of lack of trained personnel and policy thrust of government.

There are also automatic sprinkler systems mostly employed by experimental/research farms, wealthy individual in their homes and gardens but they rarely deployed in large farms in Nigeria due to high cost, selectivity (not suitable for all kinds of crops), inability to adapt to changes such as soil moisture content, water level in the reservoir, etc, which can lead to running the pump dry, resulting in damage to supporting systems.

2.5 RESEARCH GAP

Recently, software and different simulation tools have been employed in Irrigation systems. Oladipo, I. and Adewumi, J.K. [15] designed a Computer Aided Drip Irrigation system for Nigerian agricultural environment using ClimWAT package. The package considered four (4) agricultural zones in the country on the basis of climatic condition; i.e South, Lower Middle Belt, Upper Middle Belt and North. The crops covered in the work were arable and perennial commercial crops popularly grown in the country. The design models that formed the background of the algorithm of the software were Crop Water Requirement Model,

Hydrologic Design Model, Hydrologic Design Model and Irrigation Water Requirement Model.

It was a very good system, a step in the right direction and a system developed with Nigeria as primary area of application, but it was plagued with challenges such as having to depend on ClimWAT(an online weather/climate updating database) which the developer could be denied access if prompt subscription is not made. The cost of developing and running this system is high considering that periodic subscription to the ClimWAT database will be needed for efficiency of the system. ClimWAT is foreign-based and the fluctuating and exorbitant foreign exchange rate adds greatly to the cost of the software.

Sirisha Adamala, et al [16] developed Surface Irrigation Systems Design and Evaluation Software (SIDES). A software for the design and evaluation of surface irrigation systems (furrow, border and basin) along with the design of water conveyance systems (open channel and pipe line) is developed to assist users in educational and research organizations. The software named as 'SIDES' was developed using Visual Basic 6 programming language. The developed software for the design of surface irrigation systems was based on the volume balance approach and tested using the available published datasets. SIDES also provided detailed tabular and step wise design results. It was basically for research purpose and lacked facilities(modules) for field application and also not very suitable for everyday user.

B.J.C. Perera, et al [2] discussed the REALM (REsource ALlocation Model) which is a generalized computer simulation software package that models the harvesting and bulk distribution of water resources within a water supply system. It is a modeling tool, which can be applied to develop specific water allocation models. REALM simulation models were developed in Australia. Attractive features of REALM include generality in modeling a wide

range of water supply systems with diverse forms of operating rules, flexibility in terms of analysing 'what if' scenarios, and high reliability. It is used in comprehensive tool for water supply planning and management.

Other available water pumping/irrigation systems are the traditional methods and using micro-controllers (timers) for water pumping and irrigation system.

This study develops user friendly software that provides an adaptable interface for water pumping and irrigation purpose in Nigeria. The software could also be used to compare cost and volume of water used for domestic, industrial, commercial or irrigation purpose.

Features of the proposed software are:

• Professional- Total management for water systems of any scale and type

• Accurate- Detailed and customized reports

• Flexible- Accommodating a range for different crop water requirements.

• Efficient - Real-time scheduling for multiple irrigation tasks

• Cost Effective - Significant savings on water and energy with rapid Return-On-Investment(ROI) through effective water budgets and resource management.

- Reports

- Custom-formatted reports for easy sorting and viewing
- Generating reports according to saved definitions
- Show water pumping programs by pumping dates, farms, activity etc.

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN

3.0 INTRODUCTION

Nigeria is among nations that are at the moment technically unable to meet its food needs from rain-fed production at low level of inputs and appears likely to remain so even at intermediate levels of rain in the mid-term before 2025. Water is still a limiting factor in much of the country but most especially in the northern semi-arid and dry sub-humid zones in the north.

A computerized irrigation system plays a great role in simplifying the job of a farmer and satisfying the needs of stakeholders in a farm. It consists of a combination of hardware and software that act as a supervisor with the purpose of managing irrigation and its related practices such as fertigation(mixing fertilizer with irrigation water) and maintenance. Few documentations are found in Nigeria especially in Akwa Ibom State to be reviewed.

3.1 DRAWBACK OF THE REVIEWED SYSTEMS

- Could not generate reports which could be used for planning
- Could not produce reports which could sufficiently be used for fault tracing and system auditing
- Some were expensive to operate and maintain
- Most led to wastage of water instead of conserving the resource.

This work tried to fill the gap by automating/computerizing irrigation. It tries to satisfy the works of administrators, engineers and farmers. With an automated irrigation software

system, farmers and stakeholders can easily interact with system, manage their water budget, improve their crop yield and ultimately their profitability.

3.2 SYSTEM ANALYSIS(OF PROPOSED SYSTEM)

The functional and non functional requirements of the (proposed) system are discussed in this section including the software and hardware components.

3.2.1. Software Components

Software components include embedded software written for the controller and the User Interface Application which is written using C#. There are varieties of programming languages that can be used to instruct the controller viz Assembly Language, Embedded C, Java, Python etc. Embedded C is the most commonly used programming language and hence it is used for this particular project.

3.2.1.1 Embedded C

Embedded C is small and reasonably simpler and C compilers are available for all embedded devices existing. Unlike assembly, C has advantage of processor independence and offers more flexibility. It also supports low level bit wise data manipulation. Considering all these benefits, Embedded C is used as programming language for the microcontroller.

The functional and non-functional requirements of the system are described and modeled.

3.2.1.2 Functional Requirements

The functional requirements of the system are:

- Select a farm/field
- Activate the external controller
- Irrigate the farm
- Generate report

3.2.1.3 Non-Functional Requirements

Security requirements are important factors in this system as important data will be stored in the database. User validation will be done during Login to ensure that the user is valid and that the user has access to the software. There is no provision for general user.

The system will have consistent interface formats and button sets for all forms in the application. Application will have a form-based interface for data entry and viewing formats, and will generate reports that are formatted in a table and that should look like the existing manual report formats for user friendliness.

The system will be easily maintained by the developer or other authorized trained person and it quickly generates reports and activate the irrigation system.

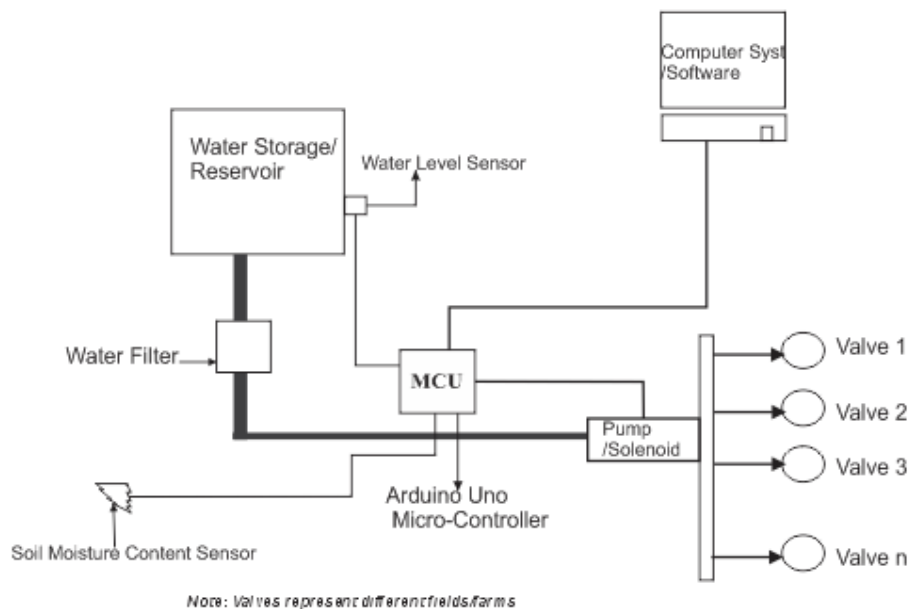


Figure 3.1: Schematic of the Computerised Irrigation system

3.2.2. Hardware Components

The hardware components used for this project are introduced below.

3.2.2.1 Microcontroller Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; it simply connects to a computer with a USB cable or can be powered with a AC-to-DC adapter or battery to get it started. It features the Atmega8U2 programmed as a USB-to-serial converter.

Power

The power source is selected automatically. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. The board can operate on an external supply of 6 to 20 volts. The recommended range is 7 to 12 volts.

Memory:

The Atmega328 has 32 KB of flash memory for storing code (of which 0,5 KB is used for the bootloader); It has also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the [EEPROM library](#)).

Input/Output

The Uno has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values).

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an *.inf file is required.

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board.

Programming

The Arduino Uno can be programmed with the Arduino software. The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

The bootloader can also be bypassed and the microcontroller programmed through the ICSP (In-Circuit Serial Programming) header. Figures 3.2 and 3.3 show the pictures of the Arduino Uno Microcontroller and the board components layout.

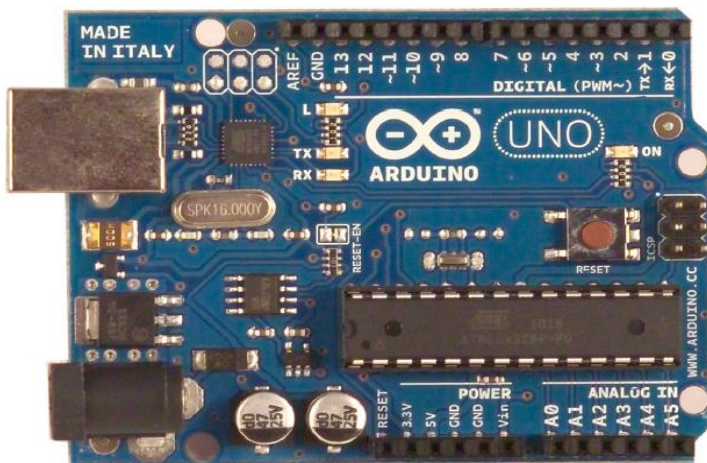


Figure 3.2: Picture of the Arduino Uno Microcontroller

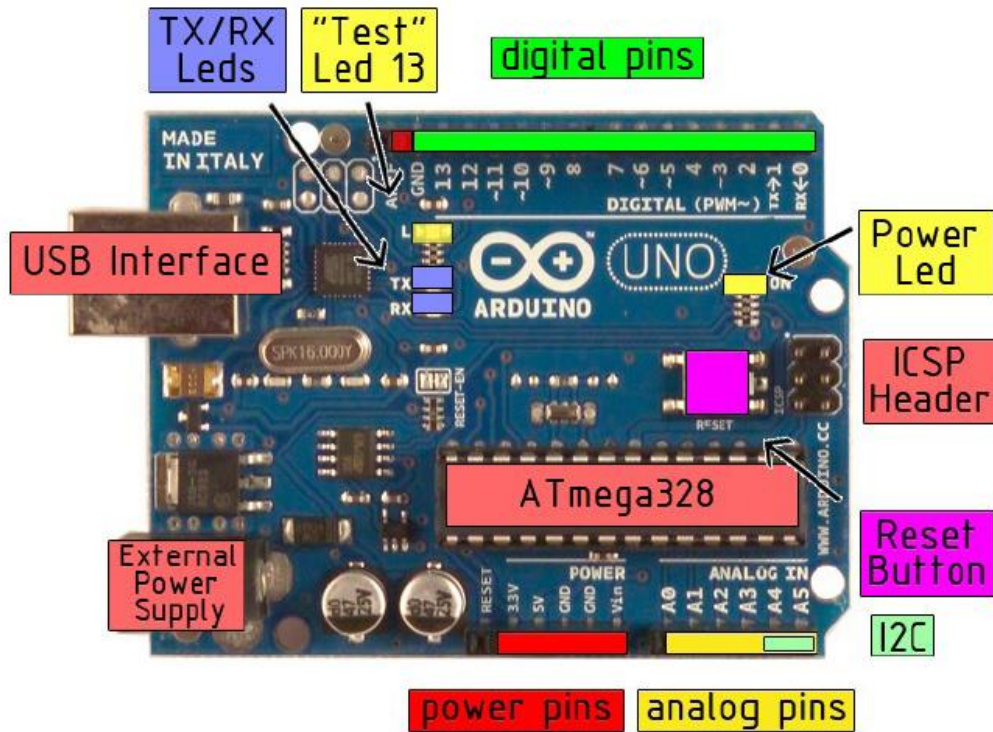


Figure 3. 3: Arduino Uno board with component layout

The serial interface is programmable for three duplex UART modes for serial I/O. The first port is used to interface the Water Level Sensor module to receive and send the information; second port interfaces to the DC motor operated solenoid to send the actuation signal while third port connects to the Moisture Content sensor to receive the monitored signal[17].

3.2.2.2 Solenoid Valve

Installed DC motor operated valve serves the purpose of operating the Actuator Node. Incorporated DC motor is compatible with 12V DC supply. DC motor operated valves are interfaced with the controller node to control the flow of water. The Solenoid valve has an orifice of 16mm; pipe size of $\frac{1}{2}$ "ø; operates within temperature range of -5°C to 100°C and a Pressure of between $0\text{Kg}/\text{cm}^2$ and $10\text{Kg}/\text{cm}^2$ [18].

A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

A 2-way valve, with 2 ports was used; if the valve is **open**, then the two ports are connected and fluid may flow between the ports; if the valve is **closed**, then ports are isolated. If the valve is open when the solenoid is not energized, then the valve is termed **normally open** (N.O.). Similarly, if the valve is closed when the solenoid is not energized, then the valve is termed **normally closed**.

A small solenoid can generate a limited force. An approximate relationship between the required solenoid force F_s , the fluid pressure P , d is the diameter of the solenoid and the orifice area A for a direct acting solenoid valve is:

$$F_s = PA + P\pi d^2/4$$

3.2.2.3 Soil Moisture Sensor

Soil moisture sensors typically refer to sensors that estimate volumetric water content. The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, temperature, or electric conductivity[19].

Measuring soil moisture is important for agricultural applications to help farmers manage their irrigation systems more efficiently. Knowing the exact soil moisture conditions on their fields, not only are farmers able to generally use less water to grow a crop, they are also able

to increase yields and the quality of the crop by improved management of soil moisture during critical plant growth stages[20].

For this project, Grove Moisture Sensor Eagle V1.3 was used. It measures soil moisture content based on soil resistivity and it has the following parameters[20]:

Dimension: 2.0cm x 6.0cm

Supported Platforms: Arduino

Raspberry Pi

TI LaunchPad

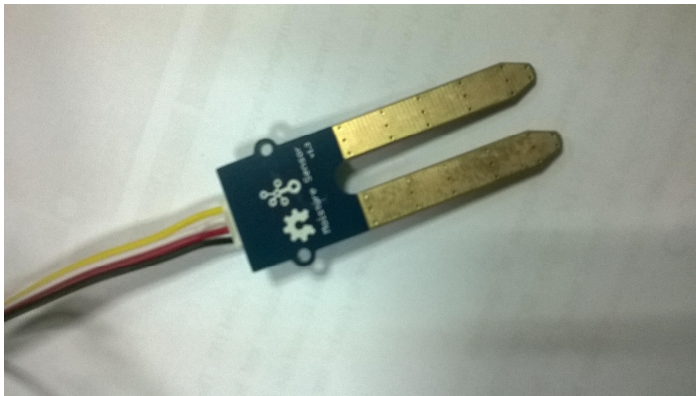


Figure 3.4 Picture of Soil Moisture Sensor

Table 3.1: Soil Moisture Content Parameters

Item	Parameter	Minimum	Typical	Maximum	Unit
Voltage	-	3.3	-	5	V
Current	-	0	-	35	mA
Outputs	Sensor in Dry soil	0	-	200	Nil
	Sensor in humid soil	300	-	700	Nil
	Sensor in water	700	-	950	nil

Table 3.2: Crop Water Requirement

Crop	Water Requirement(mm/day)
Maize	500 i 800mm
Cassava	500 i 700mm
Plantain	1200 i 2200mm

The data for the crop water requirement is a published[11]

3.2.2.4 Water Level Sensor

An ultra sound distant measurement system was used to sense the water level in the reservoir.

The particular component used was HC-SR04 as shown in Figure 3.4.



Figure 3.5: Picture of the Water Level Sensor(HC-SR04)

HC-SR04 Specifications

Type	Pin Symbol	Pin Function Description
HC i SR04	1. Vcc	5V Power supply
	2. Trig	Trigger pin
	3. Echo	Receive Pin
	4. GND	Power ground

Electrical Parameters	Electrical Parameters	HC-SR04 Ultrasonic Module
	Operating Voltage	Dc-5V
	Operating Current	15mA
	Operating Frequency	40KHz
	Highest Range	4M
	Nearest Range	2cm
	Measuring Angle	15 ⁰
	Input Trigger Signal	10us TTL pulse

The power pins are VCC and GND. The ultrasonic range finder works on 5V of power. This is connected to VCC. GND is connected to ground.

The trigger (trig) pin is the pin needed to trigger or start the sensor into ranging mode. A 10-microsecond pulse needs to be sent to the trigger pulse in order for the sensor to be triggered on. Without this pulse and the sensor will never go into ranging mode to detect objects. Therefore, this is a crucial pin for that reason. When it receives this pulse, it sends out 8 40KHz pulses to detect an object and waits to listen back for these sound pulses.

The echo pin is the pin that sends the result of the sent out pulses. If the pulses have been received back, this means that the pulses bounced off of an object and came back to the sensor, which means an object has been detected. The echo pin then returns the pulse representing the amount of time it took for the pulses to be received back. With this time, we can compute the distance the object is from the sensor. If no object has been detected, the pulses are not received back, so the echo pin returns no pulse or a 0.

Test distance = (high level time $\times$ velocity of sound (340M/S) / 2 [21].

3.3 SYSTEM DESIGN

In the previous section we have identified the functional and non-functional requirements of the system. The following are discussed in this section: design goals, system architecture, system decomposition, deployment and database design.

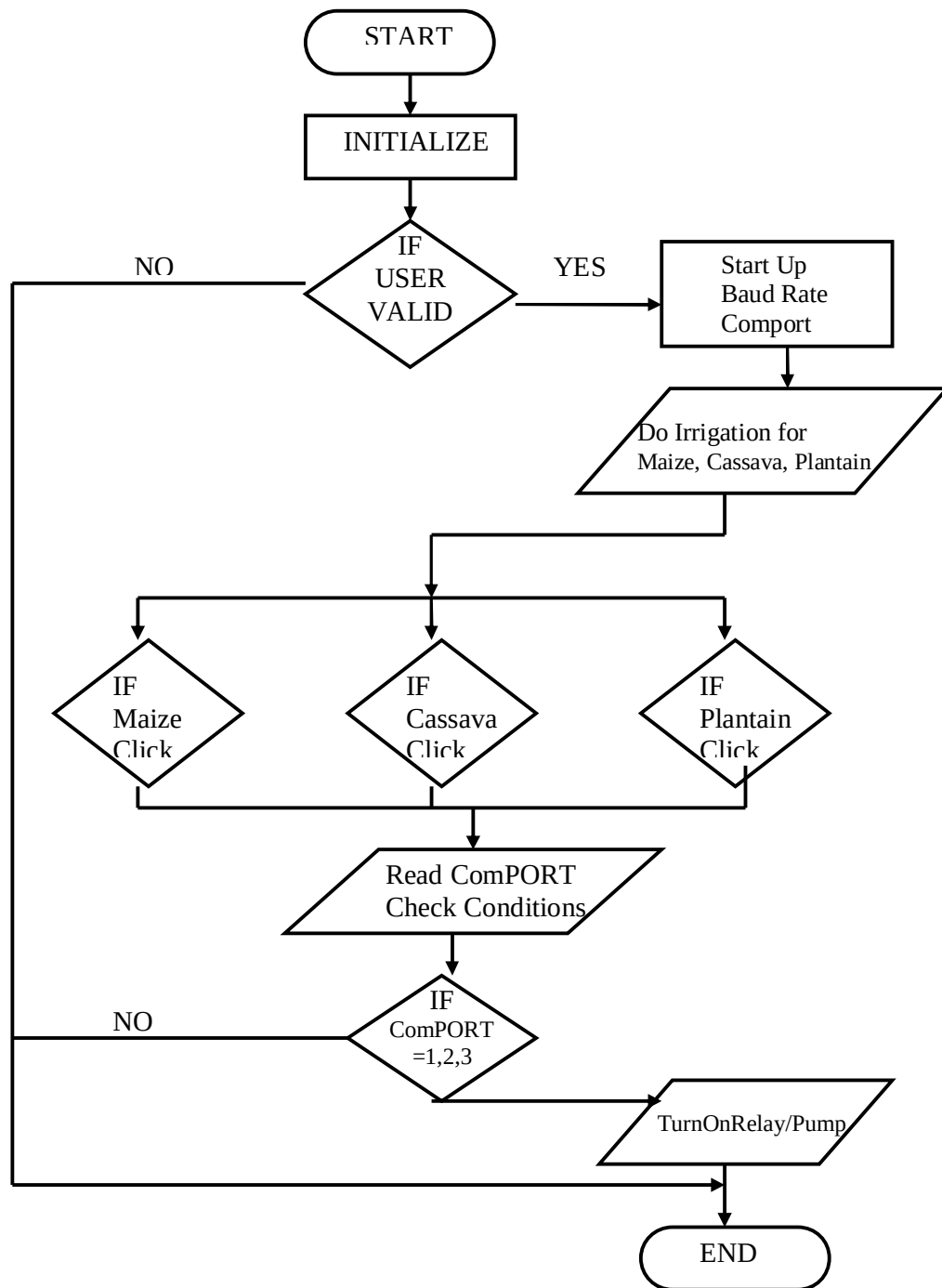


Figure 3.6A: System Flowchart

3.3.1 Design Goals

Design goals describe the qualities of the system that developers should optimize. Such goals are normally derived from the non-functional requirements of the system.

Design goals are grouped into five categories. These are

- Performance

- Dependability

- Maintenance

- End User Criteria

3.3.1.1 Performance Criteria

The part of the system to be used for the irrigating the farm should have a fast response time (real time) with maximum throughput. Furthermore, the system should not be taking up too much space in memory. The developer has chosen fast response time over throughput and hence the system should try to be more interactive. In the case of the logging subsystem, the system should be more reliable in order to satisfy the constraints than fast response time.

3.3.1.2 Dependability

The farm needs the system to be highly dependable as it is expected to be used by non-IT professionals. The system should be robust and fault tolerant. Furthermore, as the system is handling sensitive data (irrigation activity log) of the farm, reasonable emphasis should be given to security.

3.3.1.3 Maintenance

The system should be easily extensible to add new functionalities at a later stage. It should also be easily modifiable to make changes to the features and functionalities.

3.3.1.4 End User Criteria

Usability: Usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. From the end users' perspective the system should be designed in such a way that it is easy to learn and use, efficient and having few errors if any.

Trade-off is inevitable in trying to achieve a particular design goal. One best case is the issue of security versus response time. Checking User-Id and Password before a member can enter to the Software for Irrigation creates response time problem/overhead. The other case is the issue of response time versus quality. There is some amount of time taken by the system to generate the log showing the correctness of parameters before pumping/irrigating a particular field. So the user has to wait a little after telling the system to irrigate a particular field and getting the result to get the farm irrigated.

3.3.2 Architecture of the System

The proposed automated system is expected to replace the existing manual system. The architecture used for the system is a 2-tier Client/Server Architecture.

The data tier maintains the applications data such as error logs, duration of irrigation, date of irrigation data etc. It stores these data in a relational database management system (RDBMS).

The first tier implements the business logic, controller logic and presentation logic to control the interaction between the application's clients(user) and data. The controller logic processes client requests such as requests to view error log, irrigate farm or to retrieve data from the database. Business rules enforced by the business logic dictate how client (user) can and cannot access application data and how applications process data.

The client tier is the applications user interface containing data entry forms and client side applications. It displays data to the user. Users interact directly with the application through user interface. The client tier interacts with the database/application server to make requests and to retrieve data from the database. It then displays to the user the data retrieved from the server.

3.3.3 Subsystem Decomposition

Subsystem decompositions will help reduce the complexity of the system. The subsystems can be considered as packages holding related classes/objects[22]. The Software for Water Pumping(Irrigation) System (SWPIS) under consideration is decomposed into subsystems as shown in Figure 3.6. These subsystems may be further decomposed into other subsystems. The major subsystems identified are "Settings(Hardware/Controller)", "Login", "DataReader" and "FarmOutlook" subsystems.

The "Login" subsystem authenticates a user to grant access. The "Settings" subsystem establishes the Hardware connection(s). It allows the choosing of the communication port used(though chosen by the system automatically) and the connection/authentication is established and acknowledged. "DataReader" subsystems is used to generate the log data from the database and also reset the data reader window to default. The "FarmOutlook" subsystem is made up of the different farms (cassava farm, Maize farm and Plantain farm) and establishes the irrigation process, activates the pumping and irrigates the specified farm.

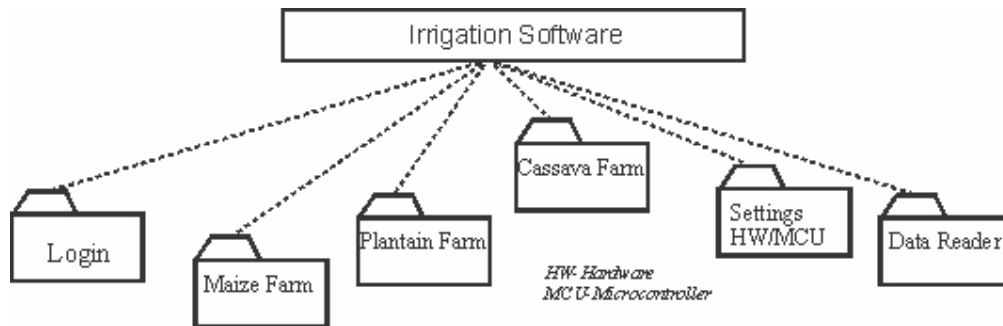


Figure 3.6B: Layered Representation of the system

3.3.4 Hardware/Software Mapping

One of the major tasks in system design deals with hardware/software mapping which deals with which components would be part in which hardware and so on. The Software for Water Pumping(Irrigation) system is a broad system that performs many functions as described earlier in this chapter. It consists of the Micro-controller based hardware which activates the solenoid for irrigating the farm. The application software system also assists in a user friendly interface in controlling the hardware. The system assists the user to pump water (irrigate farm, generate reports/log of events including errors. The applications of the system will run on the workstation connected to the database server by ado.net.

3.3.5 Persistent Data Management

Persistent data management deals with how the persistent data (file, database, etc) are stored and managed and it outlives a single execution of the system. Information related to irrigation basic information, user and error logs, the date of irrigation and other related information are persistent data and hence stored on a database management system. This allows all the programs that operate on the Software for Water Pumping (Irrigation) System data to do consistently. Moreover, storing data in a database enables the system to perform complex queries on a large data set.

Irrigation is done periodically. For complex queries over attributes and large dataset Microsoft SQL Server is implemented, which is a Relational Database Management System.

3.3.5.1 Mapping

In order to store information persistently we map objects into tables and the attributes into fields to the specific table based on the objects found on the system. Therefore, we identified the major tables that will be implemented on the selected DBMS.

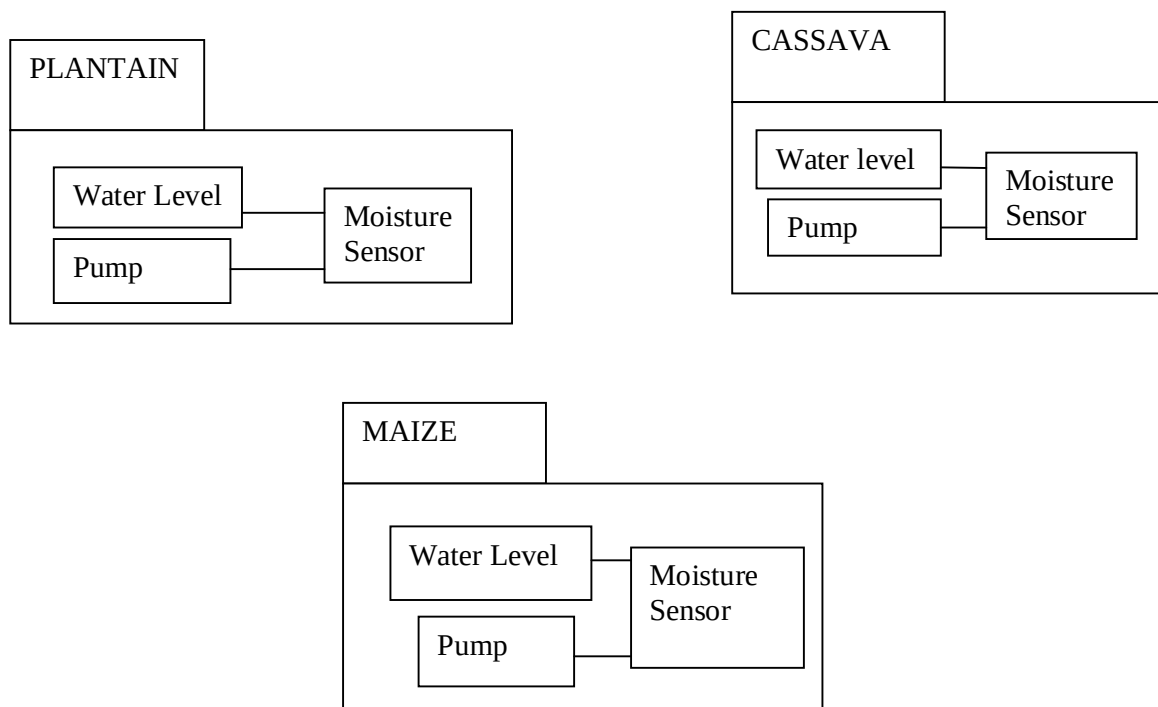


Figure 3.7: Mapping Diagram

3.3.5.2 Relationships among Tables

This part is to describe and show the necessary relationships among the tables, which are selected to store the data persistently in the system. Generally there are three types of relationships in a relational database system. These are one-to-one, one-to-many and many-to-many relationships. The system under consideration has one-to-many and many-to-many relationships. One of the aims in a database system is to reduce redundancy and for that purpose many-to-many relationship has to be reduced to one-to-one relationship.

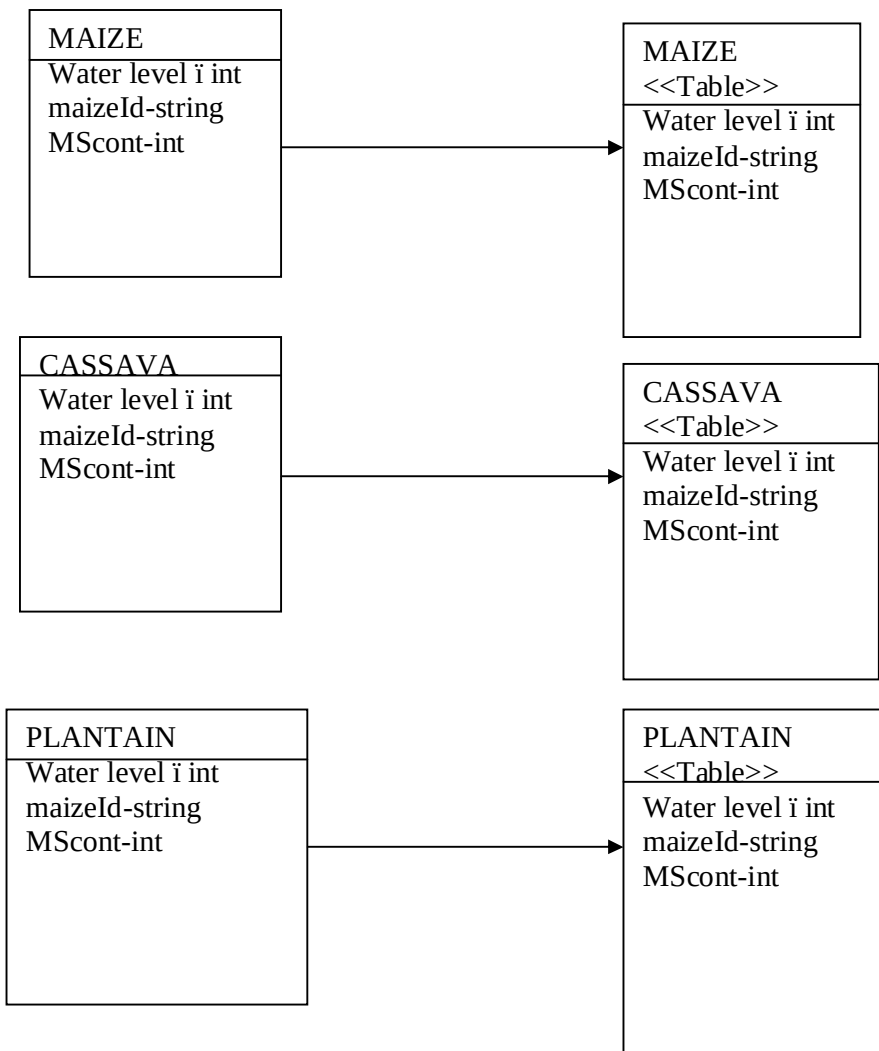


Figure 3.8: Relationship between Tables

CHAPTER FOUR

SYSTEM IMPLEMENTATION

4.0 INTRODUCTION

In this chapter, the tools used in developing the prototype and the developed systems are described.

4.1 DEVELOPMENT ENVIRONMENT/PROGRAMMING TOOLS

The system has one application using the database; the Windows application which is the Frontend application for user interaction. The Windows application is developed using C#, which is one of the development languages in .NET and is object oriented. Embedded C is also used to program the Arduino Uno Micro controller.

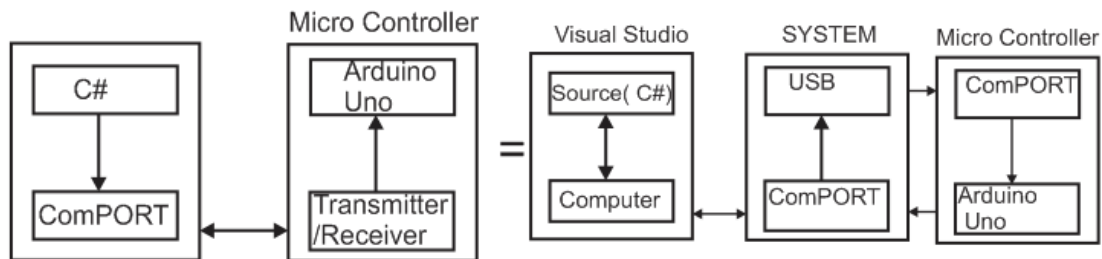


Figure 4.1 System Block Diagram

4.2 SYSTEM IMPLEMENTATION

The is actual putting together of all it takes for the designed system to perform the function which it was designed foré to solve the research problem in this case to perform irrigation using a computer software and accompanied hardware.

4.2.1 Hardware Implementation

Here the hardware implementation is described. It is basically the relationship between components/systems used in the design of the entire system. This is represented succinctly with the use of a circuit diagram.

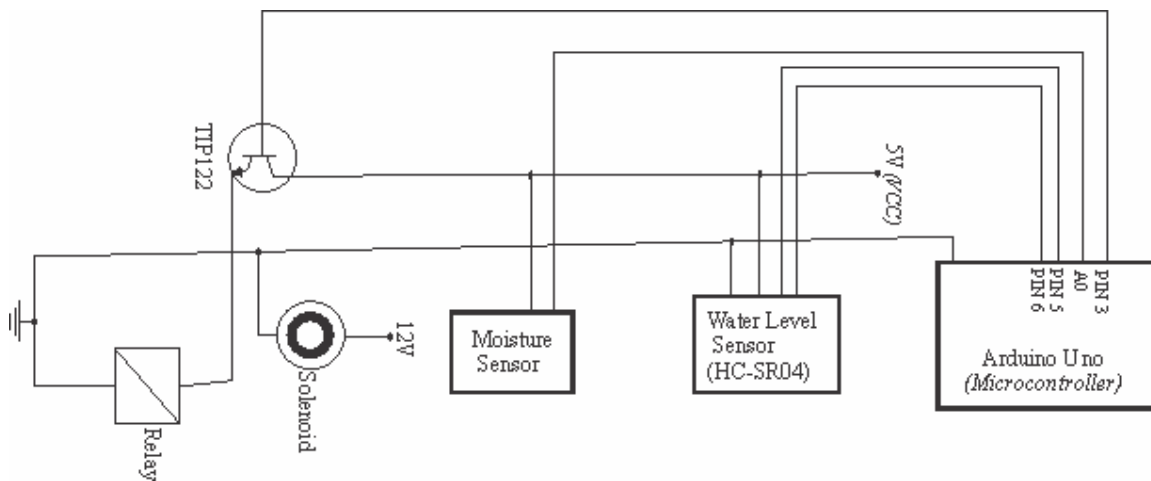


Figure 4.2: Hardware Schematic Diagram

The source code of the C#-based Software for Water Pumping(Irrigation) System is given in Appendix A, while the source code for the Embedded C-based program for Arduino Micro-controller system is given in Appendix B. The results obtained from the software are presented in form of screenshot, as presented in the sections that follow. The system requirements for the development of the C#-based software include the following:

A Hardware:

A computer system with the following minimum specifications:

Hard disk free space: 3-4 GB for a typical installation

RAM: 1024MB (at least 2048 MB recommended)

Processor: Any Intel® or AMD x86 processor supporting the SSE2 instruction set

An Arduino Uno Microcontroller with specification as stated in 3.3.3.1 with associated internal components such as a relay, resistor, etc

Solenoid valve

Centre-Positive 12VDC power adapter

USB cable

Water Level Sensor(HC-SR04)

Probe-type Soil moisture content sensor

Wiring cables

Â Software:

Operating System: Windows OS

Windows supported are:

Windows XP Service Pack 3

Windows Server 2003 R2 with Service Pack 2

Windows Vista® Service Pack 1 or 2

Windows Server 2008 Service Pack 2 or R2

Windows 7

Windows 8

Application: Microsoft Visual Studio 2008

Arduino Microcontroller Programmer.

4.2.1 Software Implementation

Here, the implemented system is described. How the user interacts with the system and some of the results of interaction with the system along with the screen shots are described.

When a user starts the application, a login screen is displayed as shown in Figure 4.3 to authenticate the user. If the user has typed the correct user id and password to the login screen, the system displays a splash screen for 6 seconds and then a window containing the main menus of the system as shown

in Figure 4.5 The main window displays menus of the software. The system log which serves a reporting platform is also shown as Figure 4.6

4.3 SYSTEM TESTING

System testing of software or hardware is a process conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements and it fall within the scope of the project. It helps to detect any inconsistencies between the software/hardware units that are integrated together. The Login, Software splash screen, the Main window and Data Reader(Data Log Viewer) are shown in Figures 4.4, 4.5, 4.6 and 4.7 respectively.

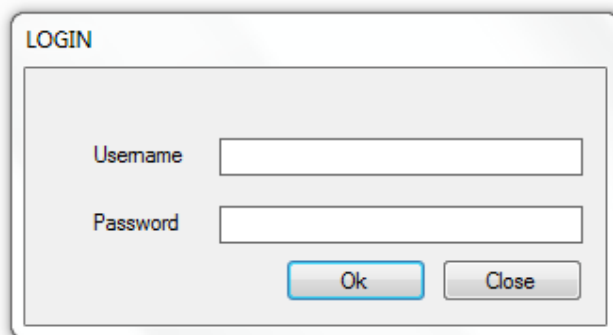


Figure 4.3: Login Screen

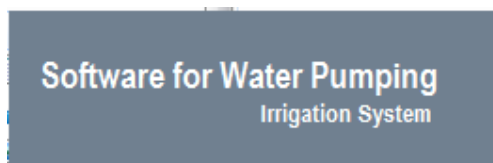


Figure 4.4: Software Splash Screen



Figure 4.5: The main window displays menus of the software

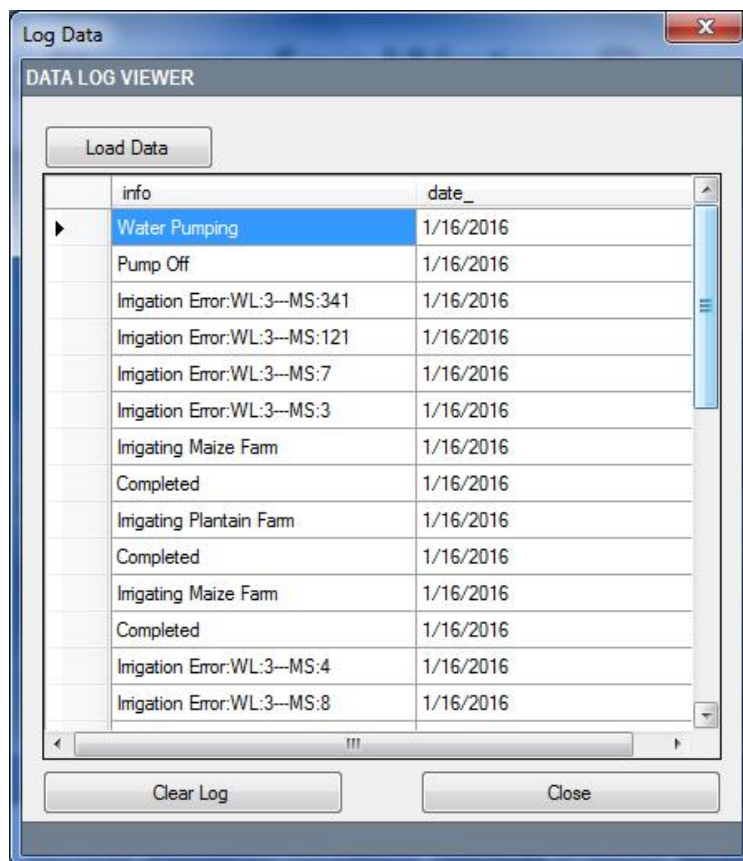


Figure 4.6: The Data Log Viewer/Result

4.4 SYSTEM DOCUMENTATION

System documentation is written text that accompanies systems which could be computer software, hardware or both. It either explains how it operates or how to use it, and may mean different things to people in different roles.

4.4.1 User Manual

This is a brief of the operation of the developed system. Its features functions and usage.

The ñboxò which contains the Microcontroller and it associated electronic is connected to a computer system which has finished booting the Software for Water Pumping (Irrigation) System [SWPIS] loaded through any of the computer's USB ports. This is done after making sure the associated sensors are connected (attached) to where they should be ñ Soil moisture Content sensor probe to any soil/soil sample, Water level sensor to the storage tank/water reservoir(the Water level sensor should be at the top of the tank/reservoir NOT in contact with water but at least 5cm from the water surface). The solenoid should also be connected to the preferred distribution system(pipe network for irrigating a particular farm or field) through a 1/2" pipe. The 12V-centre positive power supply should also be connected to any electrical socket outlet.

When the ñboxò is connected to the computer system through its USB interface, the computer automatically detects the external hardware and assigns it a ComPort. The User does not need to choose the Baud rate, the system automatically chooses 9600. The user then clicks on START to enable/establish/authenticate the connection between the microcontroller and the computer system. The User now choose the farm to be irrigated by clicking on the appropriate button- Maize, Cassava or Plantainé the name NOT the picture of the farm.

When the User clicks on any of these, the system checks the conditions which are basically two(2).

1. Is there water in the reservoir (above the set threshold)?
2. Is the soil moisture content to the selected field as indicated in Table 3.1?

If these conditions are met, the farm will be irrigated for a pre-set period. The timing is pre-set to avoid user entering wrong values which may lead to under/over supply of water to the farm.

Error Reporting:

If there is any abnormality i.e. that is any of the above condition or any other abnormality that may affect the system adversely, the system will not pump/irrigate the farm/field. It will display such error in the DATA READER field of the software. WL error indicates Water level below threshold while MS error indicates soil Moisture Sensor indicating that the soil water content for a particular field or crop is already above the threshold i.e. the crop(s) is already well watered and does not need irrigation at the moment. This was done to eliminate the use of RAIN Sensor which would have added to the cost of this project. It helps prevent the field from being watered after or during rain thereby saving water budget and protecting crops from being over-watered through water logging which can lead to wilting of the crops.

The DATA READER window also acts as a report display screen for the system log which shows errors, irrigation dates, etc. The Load Data Button loads the irrigation log while the Reset List clears the Data Reader workspace/window.

After the field(s) are irrigated, the user clicks the STOP button to terminate the port communication, may disconnect the USB cord/external hardware box and continue to use the computer system for other purposes. At any other time irrigation is needed, the above processes ensue but the computer will remember the ComPort that was used previously and reassigns it and the process continues.

The Data Log viewer/Result is a window that shows the working of the system(simulation to check of the system will perform as designed). It is used for system auditing and evaluation. WL- Water Level, MS-Moisture Sensor. Values MS3,MS7,MS121 and MS 341 indicate soil moisture content for different crops.

MS3 means the soil is dry

MS7 indicates the threshold for irrigating maize farm

MS121 indicates the minimum for irrigating cassava farm

MS 341 indicates the minimum for irrigating plantain farm.

COMPLETED-indicates that the pumping or irrigation process was successfully done(the soil moisture content reads above the threshold).

IRRIGATING MAIZE or PLANTAIN FARM indicates the farm being irrigated while 1/16/2016(date) provides the timestamp which is used to know when which activity took place.

For the pump(irrigate any farm) ALL parameters must be okay. (it will irrigate maize farm if WL is above threshold, MS reads below MS121; cassava farm if WL is above threshold, MS is below 341; Plantain farm if WL is above threshold and MS above 341, ELSE it will report Error).

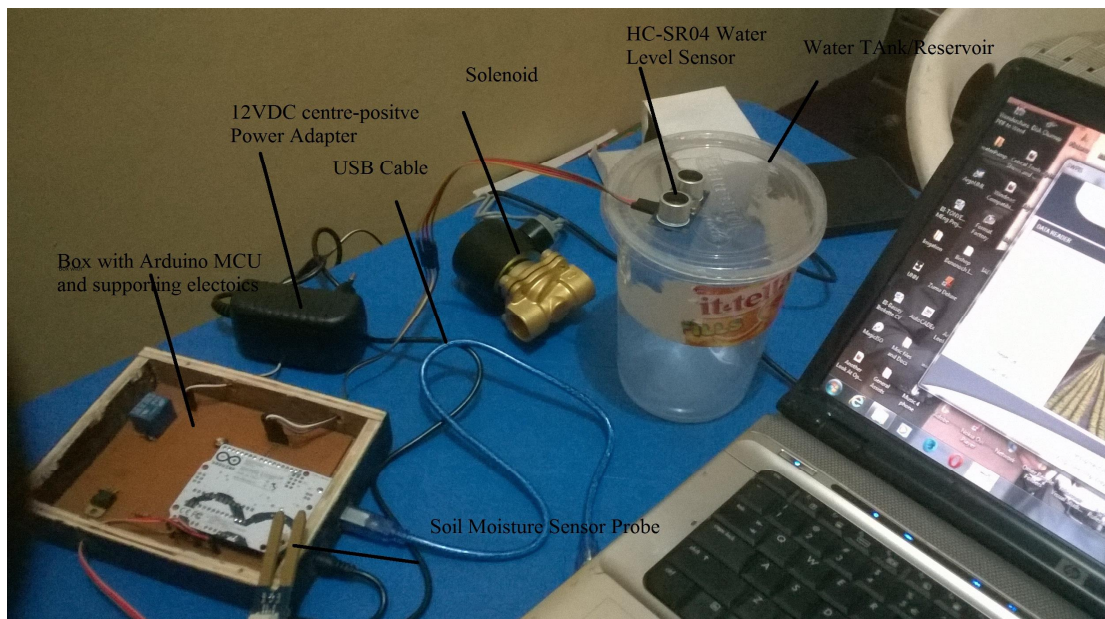


Figure 4.7: Picture of the system setup with the software running.

4.4.2 Cost of the System

Table 4.1: Bill of Engineering Measurement and Evaluation

S/N	Item Description	Quantity	Unit Price(₦)	Amount(₦)
1	USB Cable	1	300	300
2	Water Level Sensor(HC-SR04)	1	5,000	5,000
3	Arduino Uno Microcontroller and kit	1	25,000	25,000
4	Solenoid valve	1	10,000	10,000
5	Centre-Positive Power supply	1	1,000	1,000
6	Soil Moisture sensor	1	5,000	5,000
7	Connecting cables(wires)	20	Varied	1,000
8	Software i free download for Embedded C(from Arduino site) and a token for MYPHP Admin, MS-Visual Studio 2008			5,000
				52,300

From the table above, it can be seen that the software with accompanying hardware system is quite affordable to even small scale farmers.

It should be NOTED that cost of the computer system and operating system was not included in the above.

4.4.3 Source Code Listing

Windows (Irrigation) Software Source code listing (C#) i Appendix A

Arduino Uno source code (Embedded C) Appendix B

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In this project, we developed an automated irrigation system that facilitates the various activities taking place in farms.

The system developed in the project consists of windows and hardware(micro controller) applications. These are two different applications on the same database. The windows application takes most of the activities such as logging, timing, error reporting and activating the pumps. The Micro controller application facilitates the communication between the field sensors and the Windows software and the activation of the solenoid(pumping).

The solution to the Irrigation Software is simple. The Water Level Sensor senses the level of water in the reservoir, the soil moisture content sensor senses the moisture content levels in the field these are compared with set values, if all set conditions are met, the pump(solenoid) is triggered through a relay. If there is discrepancies the error are logged so also are the time and field the irrigation took place. They are all stored in the database.

The prototype has been tested. It has been shown that the system effectively irrigate farms(fields), easily retrieves information about farms irrigated and generates the required reports such as error logs, date and time of irrigation.

5.2 RECOMMENDATIONS

To enhance the efficiency of the system, some recommendations are made for future works.

As agriculture/food sufficiency is central to development, there should be a good policy to make stakeholders participate in farm improvement programs and decision making. Farmers and Agricultural agencies in Nigeria are among the stakeholders. To facilitate easy

information access to such bodies the Windows application could be further enhanced by incorporating web application for online access and additional reports required by agricultural agencies and farmers. Such facilities will increase participants in decision making at agricultural activities especially irrigation and farm/crop improvement.

There is also need to bring in "quasi-stakeholders" like meteorological services to provide online, real-time weather information free for farmers. This can be integrated into the Windows software so developed.

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