Implementation of Speech Recognition using MFCC for Plant Watering and Lighting System

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Abstract

Smart farming, in a sense, is the integration of technology to the activities that are to be done in farming. As said by the Food and Agriculture Organization (FAO), production must increase by 70% by 2050 to feed the 9.6 billion people and agriculturists eyes the Smart farming method in order to cope with such increasing demands. This paper presents a part of this technology. With that, the proponent will use that technology to make a system that will aid in the plant health and growth by means of providing proper light and water sources. The system will be applied in a greenhouse where plants can be grown indoors. The watering and lighting shall be automated in a way that it can be controlled by the Arduino microcontroller. Furthermore, the highlight of the project is voice control, which will make use of speech processing by using Matlab VOICEBOX with MFCC for feature extraction and ANN for training and testing of data.

Keywords: *Smart farming, Arduino, speech processing, Matlab VOICEBOX, MFCC, ANN*

1. Introduction

According to the Food and Agriculture Organization (FAO), by 2020 there shall be about 9.6 billion people inhabiting the planet and an increase of 70% in food production shall be necessary by that time. That is a very formidable challenge in the agriculture sector specially when availability of arable lands is quite limited, there is increasing necessity for fresh water, price and availability of energy, particularly from fossil fuels, are constantly changing and most importantly in climate change, since, according to a current article by the UN could lead to changes in seasonal events in the life cycle of plant and animals. That is why modern technologist started taking Smart farming as a recommendation to meet the growing needs in the agricultural field [1][2]. But that is the major concern. In this study, the problem to be addressed is in the inconvenience in the farming activity such as the time and effort it will take for farmers to come in the greenhouse and do the watering or the lighting. The system will resolve such problems with the functionality of voice control in a specified distance.

Smart farming has different types of technologies but in this study, only software applications (MATLAB), communications systems (WIFI shield for communication between laptop and Arduino), and hardware and software systems (Arduino as hardware and an MATLAB as software) are to be used and the area concerned will be in Indoor Farming since the research focuses mainly on the showering and lighting for the plants inside a greenhouse [2].

Further development of technology has paved way to the

introduction of automatic commands. One of the results of these developments is the processing of sound, particularly human voice, to be converted to that which will be understood by computers. Audio processing is the intentional alteration of sounds or audio signals by means of an audio effect or effects unit [3]. In this research, voice command shall be used as a medium of automation for the showering and lighting of the plants. Voice recognition shall be processed by means of Artificial Neural Network (ANN) and Mel Frequency Cepstral Coefficient (MFCC). Each received speech signals is to be segmented for processing of phonemes and sound variations and will be trained for distinct features of signals. The proponent sees this method as the most appropriate since ANN can actually learn from the observation of data sets, moreover, random function approximation tool can be used. To make a solution, ANN receives data samples instead of the entire data sets. Much similar to how human mind learns [4]. Since spoken words have their own distinct properties, training the program to identify certain signal features can be a great method in processing vocal features.

For the automation of the showering and lighting, the functionalities shall be made by the use of Arduino. Programming in Arduino is quite easy since it is based on easy-to-use hardware and software as compared to other microcontrollers. Furthermore, it is an open-source prototyping device [5] which can be cloned easily and be bought at a lower price if ever no original one can be bought nearby or a strict budget is to be followed. The Arduino board suitable for such research is the Arduino UNO since it is the most available in the market and it has complete functionalities and ports that will be usable in the system.

The system will be useful agricultural sector because not only does it lessen the workload and labor of farmers, it also makes maintenance of plant growth convenient since the farmer does not have to exert much effort in showering, much less lighting. The system can also provide the right amount of light and water to the plants by means of proper manipulation of the system by the use of uttering the right commands. The machine will do the work efficiently and accurately in terms of the amount of time and exertion of efforts for showering and lighting.

1.2. Objectives of the Study

The focal objective of the study is to implement smart farm technology to the actual care for the growth of the designated plants. The study focuses on the use of sound processing to give commands to the hardware and enable the system to function. Specifically, the study aims to:

1. Interpret voice speech as digital signals.
2. Process received signals using MFCC and convert to text.
3. Use ANN for testing and training of acquired signals.

4. Provide the accuracy of interpreting spoken signals whether the system sensed the words probably or not.

5. Connect to the Arduino device from a remote location in a conventional distance via WIFI connection.

6. Control the amount of intensity for lighting or watering.

7. Determine the effectiveness by means of time and effort consumption using automated farming compared to the traditional method.

1.3. Significance of the Study

Most of the farming and irrigation industry in the Philippines is still manually done and as discussed in the background of the study, the agricultural sectors need to adapt to modern technological farming in order to meet the required production rate increase of 70% by the year 2050 [1]. If the agriculture sector does not adapt to modernization, then dire results may occur. Therefore, smart farming will be significant in this modern era.

The research will be of use to farm owners because smart farming can enhance their traditional farming activities to the automated smart farming system. The system can augment the system and improve some workload that are otherwise tiresome for farmers to do. This system has the capability to increase the pace of work by having machines do all the work and the voice reading functionality can increase convenience by means of just uttering words to be done by the system instead of exerting effort in showering each and every plant and also lighting them. The system can also diminish cost by somehow lessening laborers since the machine will be doing the majority of the activities.

Moreover, the research will be significant to farmers because it will help in the work they are doing by having robot assistance. Hence, having the work efficiently done and easier compared to them doing manually.

And as for future researchers, the study can be further enhanced by adding more features in the voice function like more words to be accepted or voice recognition security functions. The future researchers can also add more features other than voice but also imaging. Moreover, the system can be integrated to be a part of a bigger project where the Internet of Things (IoT) can be used as medium of connection throughout the entire smart farm system.

1.4. Scope and Limitations

As discussed in the previous sub-chapters, smart farming has different types of technology and also multiple fields of application. In this research, the technology to be used are only software applications, communications systems, and hardware and software systems and the area concerned will be in Indoor Farming. Indoor Farming can either be for

greenhouses or stables, but only greenhouse is to be addressed for apprehension. Apart from those mentioned are of no concern and shall be address by other researchers. For now, the maintenance of plant health and growth shall be automated, which is the showering and lighting for the designated plants with a specified level.

The plants that are to be observed are tomatoes, chili and bell pepper. The system may also apply to other and every plants that can be placed in a greenhouse but for simplicity purposes, only the said three shall be observed.

Sound processing shall be the medium of control which is the recognition and processing of human voice to will the machinery to perform given actions. Since Filipino farmers are more used to the Filipino language and some are not articulately-inclined to the English language, the proponent specified the commands for both Filipino (Specifically, Tagalog) and English words. The words that will be recognized by the system are: "Buksan ang ilaw", Patayin ang ilaw", "Liwanag pa", "Bawasan ang liwanag", "Buksan ang pandilig", "Patayin ang pandilig", "Laksan", "Hinaan" for Tagalog, "Lights ON", "Lights OFF", "Brighter", "Dimmer", "Shower ON", "Shower OFF", "Intensify", "Weaken" for English. If any other commands are heard, the system will wave it off and will notify that there is no existing function for such command.

The showering and lighting controller and the specifications of the system shall be implemented through Arduino UNO.

2. Review of Related Literature

Past researches have proven that speech recognition is possible and is already being integrated on various fields. The proponent found out that there are multiple techniques and algorithms in the feature extraction and interpretation of speech signals which varies in effectiveness but the one method that caught the proponent's interest is the MFCC method in Artificial Neural Network. This method has been used intensively in speech processing over the past few decades and still proves to be one of the most convenient to use. With that, the voice processing shall be done by means of MFCC and be trained with multiple coefficients so as to come up with the desired results.

Smart farming has been around for a few years. It is still not that much implemented in the agricultural sector but there are some farms that make use of technology to further enhance irrigation and animal and plant care. The proponent will create a system that is purely categorized as Smart Farming because the system will be of great help in the maintenance and care of plants inside a greenhouse. Together with the desired speech processing methodology, the proponent shall invent a smart farm technology with voice command. There

are certain studies that cites voice command functionalities into certain systems but in this proposal, that functionality will be integrated to smart farming.

3. Conceptual and Theoretical Framework

This chapter cites the concept and theory on how the system works. Contained in this chapter are the proposed function and build of the system and other representations.

3.1. Conceptual Framework

This study aims to design a smart farm system wherein voice recognition is to be integrated in order to control the lighting and showering of plants within a greenhouse. In this part of the study, the proponent shall discuss the concept of the proposed system with consideration to the activities that needs to be done in order to complete the system in an organized method.
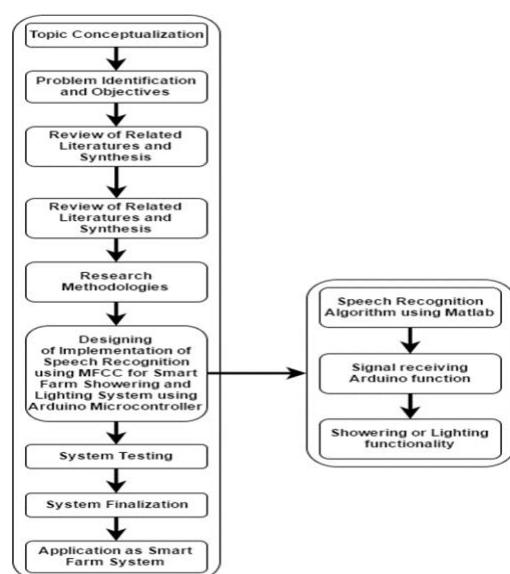

Figure 1. Method of Research

Figure 1 shows the methodology of the research which is represented by a waterfall model. Formulation of the topic is based on the current events and problems that needs to be undertaken. With the need to advance in technological terms for agriculture, the proponent came up with the idea of smart farming. To novelize the research, speech processing shall be integrated, and thus the title "Implementation of Speech Recognition using MFCC for Plant Watering and Lighting System". Every step needs to be addressed accordingly so as to efficiently create the system within time constraints.
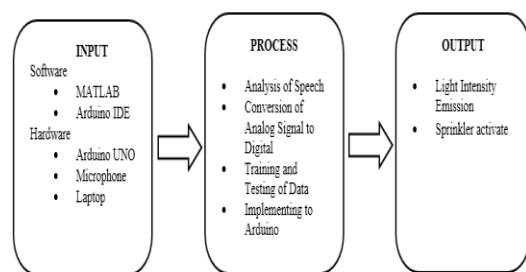

Figure 2. IPO Chart

Figure 2 shows the input, process and output chart of the system. The input part is categorized to two (2) parts namely hardware and software. The software used was MATLAB for speech processing via ANN and the Arduino IDE to control the lighting and watering mechanism of the system. For the hardware part, a microcontroller is used which is the Arduino UNO as the main circuitry on how the watering and lighting will function. A microphone is also used as the receiver for the speech. Lastly, a laptop to process the inputted signals. For the process part,

there will be the analysis for the inputted signal. The signal shall be segmented into milliseconds for more accurate training and testing. Of course, the signal shall be tried and tested and once the program finishes identifying the signal, it will be sent to the Arduino to implement the received user command. The output will be the implementation of watering or lighting inside the greenhouse.
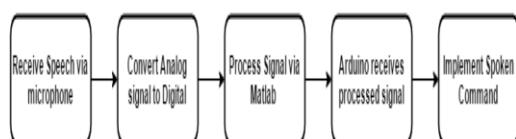

Figure 3. Block Diagram of the System

Figure 3 shows the simple block diagram of the system. There are only four (4) steps to be followed. First is the microphone which receives the spoken signal, then the signal will be processed in MATLAB. Once the signal is processed, it is sent to the Arduino via WIFI connectivity through a wireless router serial and the device will implement the command if it will be on the watering or lighting functionalities.
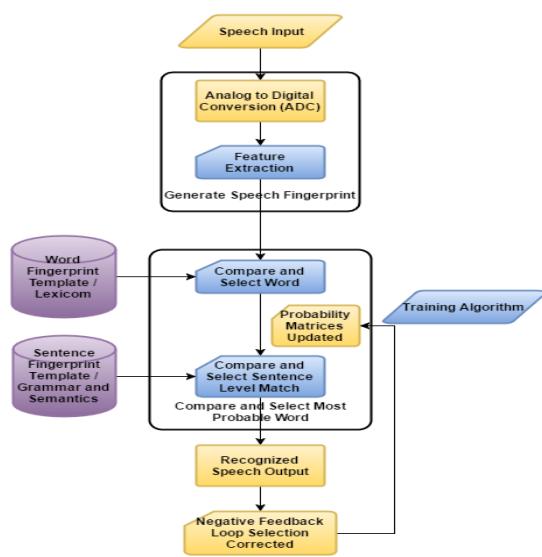

Figure 4. Basic Structure for Speech Recognition Systems

Figure 4 shows the basic structure of almost all speech recognition systems. There are two (2) main activities to be done, the first one is the generation of the speech fingerprint to determine the uniqueness of the acquired speech and the second is signal and the comparing and selecting of the closest probable word recognized. In the first activity, the inputted voice is converted from analog signal to digital signal. After that, an algorithm for feature extraction is to be applied to the digital signal, in this case it's Mel Frequency Cepstral Coefficient (MFCC). Once applied, the speech fingerprint shall be generated in a form of clustered dots. That fingerprint is then compared to an existing database of word fingerprints commonly known as Lexicom and chooses the closest possible signal. Once chosen, the word is then compared to sentence level matching to compare to the grammar and semantics database for a phrase or sentence recognition. After all those, the output shall then be given. If ever the output is incorrect, the system loops back and updates the probability matrices by means of training the data.

3.2. Theoretical Framework

In working with signals on computer, digital signal processing is the best choice for such work. Signal processing has a lot of algorithms that can be used in order to make real-time processing of signals either by time domain or frequency domain.

Matlab VOICEBOX

MATLAB is a multi-paradigm computing environment and is a great tool for processing signals since the software has multiple toolboxes that users can choose from, in addition, MATLAB algorithms can be easily interfaced to other languages such as C++, Fortran, etc. since Arduino IDE runs in the C/C++ language, the software can easily be interfaced to the Arduino board, which will be the microcontroller to be used in controlling the watering and lighting. The proponent will make use of the VOICEBOX toolbox in MATLAB in speech processing since it has multiple tools that can prove useful in the analysis of signal spectra and other recognition algorithms.

Speech Processing Technique

Spoken words have unique tract signals formed by filtering the shape of vocal tract of humans. The shape can be the basis for determining which word is heard and thus give accurate representation of the phoneme. The vocal tract shape will be shown in the envelope of the short time power spectrum. Using MFCC, the system will be able to accurately represent that envelope [6] [7] [8] [9]. Once the features of the signal are extracted, Artificial Neural Network (ANN) will be used for probability computation. With ANN, the vowel signals can be classified into their respective categories [10]. MATLAB has this toolbox that can

work for ANN called the Neural Network Toolbox which provides algorithms, functions, and applications for the visualization, training, creation and simulation of neural networks. The Neural Network Toolbox shall be used for the training and analyzing of the designated signal fingerprints [11].

Proper Lighting

For plants to grow in a greenhouse, usually a light intensity of 120-150 µmol/m2sec is enough. Intensities higher than that could result in death of seedlings, but older plants can withstand it. Meanwhile, a very low light intensity could outcome in chlorotic and weak plants [12]. Such lamps are called *grow lamps.* The light spectrum is usually in degrees Kelvin (K). For tomatoes, the best artificial light emission is about 6000 K which resembles the natural daylight [13]. For bell peppers and chili peppers, about 293.15 to 301.15 Kelvin is enough [14].

3.3. Proposed Design

The proponent made use of the Signal processing toolbox for MATLAB to work and generate with the accepted signals. For accepting of commands, the mic of a computer is to be used. Once the command is processed, it is then sent to the Arduino for the final implementation which is activating the lighting or watering of the system.
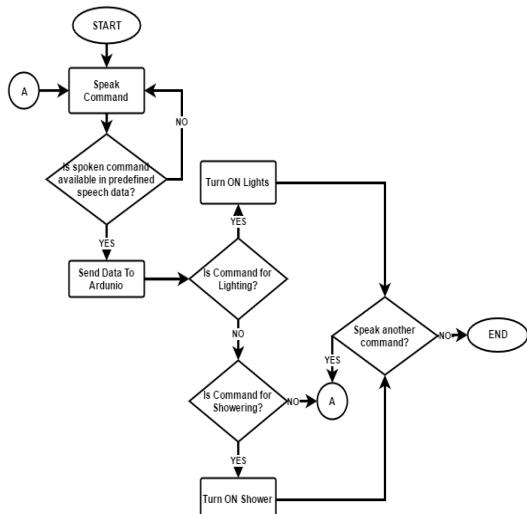
Figure 5. Flowchart of the System

Figure 5 shows the flow of the system. The first stage is to accept input from user and interpret the signal as spoken command which will be fetched from the database if command is available. It shall then send to Arduino the processed command. The last part of the system is the determination whether the spoken command is for lighting or watering.
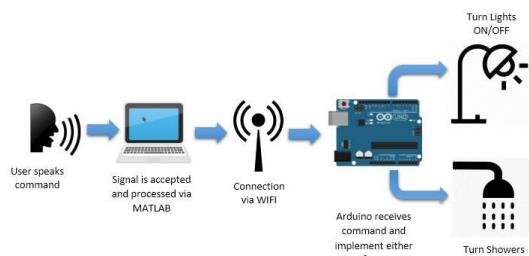

Figure 6. Relationship Diagram of the Project

Figure 6 shows how each components are interconnected with each other. With user input as speech into the laptop and is processed from speech to text and will be sent to the Arduino via WIFI connection. The output shall then be implemented to a lamp or sprinkler.

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