SPC-Based Decision Supporting System for Data Analysis of Tomato, Bell pepper and Chili

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Abstract

One of the big and possible roles of technology is the developing of new system for agricultural industry. Indeed, Philippines is rich in agricultural resources. However, the country needs improvement by implementing new systems, which will help farmers in lessening their works. In this work, the proponents will design and develop a system that is capable of reading a CSV file from the monitored plants (Tomato, Bell Pepper and Chili) with different used parameters such as Temperature and Humidity, Soil Moisture and Soil Acidity Level. Fuzzy logic, VB. Net and Statistical Process Control (SPC) are the tools and methodologies to be used in this study. Moreover, control charts will be used in showing data trends for analysis. There are different patterns which will be used in determining the abnormalities of the data, once one of the pattern is detected it is considered to be an abnormal. The design system will notify the user whenever an abnormality (OOC and OOS) is being encountered. The abnormality encountered by the system will be analysed in the Decision Support System which is made of Fuzzy Logic. The Fuzzy Logic contains the set of rules given by the proponents which will be the basis in determining the abnormalities encountered in the system. Thus, the abnormality which has given a solution will be sent through SMS for proper action to be undertaken by the farmers. With this, the module is able to help farmers in modelling an intelligent farm system such as SPC-Based and decision support system of plant health status. This system will help to replace the manual operation such as monitoring and analyzing of data as well as suggesting solutions to the problem.

Keywords: *Statistical Process Control, Decision Supporting System, Fuzzy Logic, Smart Farm, Control Charts*

1. Introduction

This section outlines the works and attainment of the study. It contains the research background and problem statement. The objectives and scopes are cited as well as the significance of the study. This chapter would serve as the foundation in showing the feasibility of the study.

1.1 Background of the Study

Technology has become part of one's lifestyle. It has been using so much, these days, in each, and in every domain of our lives, in education, business, agriculture, or in the regular household work and its uses are increasing day by day [1]. The enhancement in technology significantly affects different institutions, and the society in general, that created countless opportunities and challenges for millions of individuals and organizations. Like machines that are used to replace the work intended for humans primarily to reduce or lessen man power and also reduce human error [2]. Computers, gadgets and electronic equipment are used in daily basis, for example; researching in the earlier year is an arduous and time-consuming work. However, with the evolving technology, research literally can now be done with just a click and only in few minutes.

One of the big and possible roles of technology is the developing of new system for agricultural industry. Agriculture, such as farming is being generated in different countries in lessening farmers' work [3]. Philippines, indeed, is still mainly an agriculture country [4]. As a developing country, usually monitoring, gathering, analyzing of data and giving proper solutions to the vegetable crops are handled by the farmers manually, which give hassles to the farmers and results in the slow process [5]. It is very unlucky that technology is not even adequately perceived in the field of farm such as management system. As a simple and new farmer, it would be very hard to decide whether what solution would fit the best for a vegetable crop. And also, the time that it consumes for the farmers and users analyze the conditions of the plants. Thus, this study aims for the solution of problem. This system will help to replace the manual operation such as monitoring and analyzing of data as well as suggesting solutions to the problem of farmers as well as lessening their work.

The proponents deemed that it is necessary to implement database system for notifying the user with an effective solution to be undertaken by the farmers. The design system will help ease decision making for the farmer. Manual operation in the agriculture, such as roaming around the farm, deciding the proper solution and telling others what should be the action in maintaining healthy yield and productivity of the plants is greatly noticed by the developer, thus, the proponents decided to change the old way system by implementing new system. The development of new systems is important for determining the future agriculture.

In due course, the study relates on allowing today's farmers with different decision tools and measurement technologies aimed for incorporating items, information and administrations for better efficiency, quality and benefit. The system includes managing, storing, analyzing and decision making on what may be the possible causes that might affect the growth of vegetable crops with the used of different monitored parameters. It aims to help the farmers and users in lessening the time and effort that they needed to exert in the agriculture and farms. Additionally, it may help them to decide what should be the necessary solution and action for the vegetable crops to maintain its quality. It is convenient to use, time saving and labor reduction for the farmers. For this study, the proponents gives an approach by using Fuzzy Logic, Visual Basic.Net, Decision Support System and Statistical Process Control. This will help the user to analyze data, decision making and notify the user if there is an effective solution needed to be undertaken. Thus, this shows the difference of our system.

1.5 Objectives of the Study

This study aims to develop a database system that will help the users and farmers analyze data, decision

making and notify them with effective solutions needed by the plants.

Specifically, the study aims to:

1. Design a user-friendly system which allows real time notification (LCD monitor) needed for the plants;

2. Read Comma Separated Values (CSV) file containing a data from monitored vegetable crops (Tomato, Chinese cabbage and Bell Pepper) with different used parameters (Temperature and Humidity, Soil Moisture and pH Level) manage it effectively and use it to analyze its own activity;

3. Identify constraints with the use of Statistical Control Process and provide decision making based on the constraints;

4. Notify the user by sending a Short Message Service (SMS) with the possible solutions for maintaining the health of plants;

5. Test and evaluate the system and application in terms of functionality and accuracy;

6. Develop a user-manual for operational purposes;

7. Develop cost-benefit analysis for system implementation

1.6 Significance of the Study

Modernization is being able to adjust to the most recent and current trend in innovation to enhance the quality of plants in the farm. The implementation of the system will greatly affect farmers and users since it can be aid in the uplifting of technological capability of the agriculture system. Thus, the farmers will not exert much time and effort, and better than doing things manually to improve plants quality. System will provide the necessary features for the farming process such as decision making. It will automate the manual task that is being used in old process.

Additionally, the proponents will also be benefitted from this study because they will be able to acquire deep knowledge that will largely help them when they become professional. By conducting this study, it will give them an opportunity to strengthen and practice their creativity and ability.

The system differs from the other system, since the most of the study such as Decision Supporting System didn't include Statistical Process Control. What makes the proponents system unique is the utilization of Statistical Process Control with the Decision Support System for notification; it is integrated to come up with one system. It has the capability of reading text file such as Comma Separated Values (CSV) which contains data that is needed in analyze, and notifying the user by popping a message in the monitor and sending of SMS with a message that needed to be undertaken by the farmers. Thus, this study is to help farmers minimize their effort in analyzing data and give proper solution based on analyzed data. The system will be developed to speed up the analyzing, deciding and notifying the solutions

needed for vegetable crops. The system will be placed in a personal computers or laptops, because it will be used by the user, farmer or the administrator.

1.7 Scope and Limitation of the Study

This paper focused mainly on the development of SPC-Based Decision Supporting System for Data Analysis of Tomatoes, Bell Pepper and Chili that allows the farmers or the users to have a system that will help them decide what best solution should be given to vegetable crops using personal computers. The vegetable crops are planted on a garden with the size of 8X6ft.2 inside the Lyceum of the Philippines University – Laguna campus. The system is capable of accepting CSV files containing data that will be stored and be updated anytime the farmers receive new monitored data. Monitored data comes from the people who managed the monitoring system. The data will be plotted in a chart so that the user will see the trends of data over the time. LCD Monitor will be used in displaying the Control Charts. The system is also capable of analyzing the data that will help users in deciding the proper actions needed by a plant. When the system come up with a suggested proper solution based on the decision made by the system, it will notify the user via a screen pop-up which will show that a new message is send to the user, the sending of message will be done through a SMS containing the proper action needed by the plants.

With this, Fuzzy Logic, Visual Basic.Net and Statistical Process Control (SPC) used for developing the system. Fuzzy Logic works just like how human brains work. The utilization of the fuzzy logic is to make systems to think like a human. It plays an important role which will help the user to decide and to come up with an effective results [7]. Moreover, the Visual Basic.Net is a high-level programming language and has a capability to develop an executable file to make a system [8]. The used of VB.Net will help the proponent to develop a graphical user interface for the user. SPC is a group of tools and techniques used in measuring and controlling the quality of data. With this, it may help the users to maintain the quality of a product or process and improved it by showing trends of data needed to boost. The data is arranged and plotted in a graph with a given limits to show the trends of data, specifically the used of Controlled Charts for Variables [9]. The Decision Support System (DSS) is intended to help decision makers in compiling a variety of raw data and documents, to be analyze, solve problems and make decisions. It may show information graphically and include an Artificial Intelligence (AI). Intelligence is described as an exceptionally broad mental capability, ability to reason, solve problems, think intellectually, and plan complicated ideas. DSS has an objective of facilitating "what if analysis" and not replacement of someone's judgement [10]. In the decision support system, the program will know if the vegetable crops is lacking of water, or accepting huge

amount of sun light, and so on. It will help the user suggest some solutions just like vegetable crops needs water. Moreover, circumstances of Out-of-Specs (OOS) and Out-of-Control (OOC) limits will be monitored with regards to the limits of the parameters. The system could be run in a personal computer or laptop with an operating system of Windows (7, 8, 8.1). Additionally the system will use Notepad and Excel for storing the data. Thus, this tools will help the proponents to develop an effective system for Smart Farm. The system cannot supply beyond its rated value.

2. Review of Related Literatures

This chapter contains synthesis of the literature. The proponents collect information with different ideas, thoughts and information that may help them developing the study. With these study, the proponents came up with a tangible knowledge of developing the system. Based on the information gathered, the proponents establish conceptual and theoretical frameworks.

Based on the related literature, due to evolution of technology there are different systems developed to help the users lessen their work. According to the review of related literature, there are different methods and techniques in designing and implementing the system. Most of the study conducted and implemented used of sensors, GSM and smartphones in monitoring different parameters within the crops, plants,

vegetable and surroundings, the data sensed by the sensors will be analyze and will be sent via SMS text messages. Additionally, most of the study uses Web-based to view and access the information in through the use of internet. The used of .net platforms are also seen by the proponents to produce a graphical user interface. Thus, the used of different methods and technologies can be beneficial to provide an efficient and functional systems. Similarly, the used of smartphone and .net as well as the use of Fuzzy Logic Toolbox and MATLAB Toolbox will be used by the proponents in developing the system, but not the use of internet in viewing and accessing the data collected. Existing studies focuses more on monitoring and analyzing the data using internet, however their system is not capable of reading text file, with this, the proponents' system came up of doing a study that enables system to read CSV file containing the monitored.

3.   Conceptual   and   Theoretical Framework

This   section   presents   and discusses the steps and method that the proponents needed to follow in designing the system. It presents the conceptual and theoretical framework as well as the proposed design to be used in developing the system. Moreover, this includes, but not limited to processes, tools and equipment used in implementing and developing the software and hardware of the project.

3.1 Conceptual Framework

The study aimed to design and develop a SPC-based decision support system for notifying and sending SMS message containing the proper action needed by the vegetable crops. In this study, the proponents were able to create diagrams showing the comprehensive order procedure on how the system will be done. With the use of diagrams, the proponents were capable of determining the things and tools needed in doing the study. In addition, it helps the proponents in forming the idea of processing the whole system.
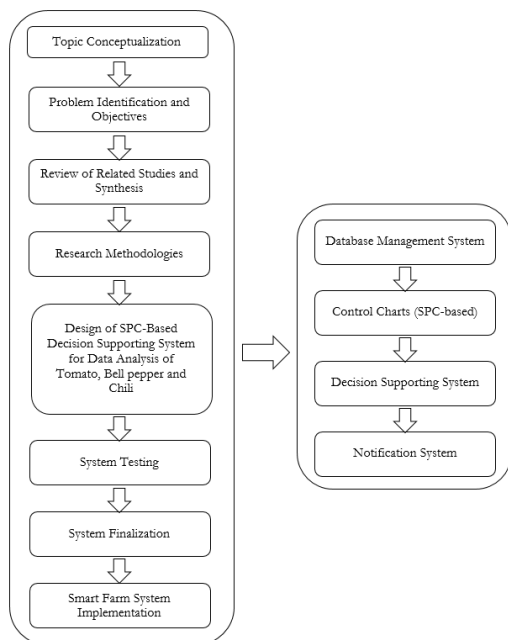
Figure 1. Method of Research

The Figure 1 shows the method of research needed to follow to finish the system. First is the Topic Conceptualization, the proponents formulated an idea to be studied, and that idea came up in developing the study which is "SPC-Based Decision Supporting

System for Data Analysis of Tomato, Bell pepper and Chili". Next is Problem Identification and Objective, this step is to identify the problem and specify the goals in making the system. As the proponents of this study, the observed problem is the manual operation in a Smart Farm. The third one is the Review of Related Literature and Synthesis, this means that the proponents needed to make research which is related to the study as well as summarizing the Related Literature to see the methods used in developing a system as well as to providing what makes the system unique by using different methods and enhancing some old systems. The fourth one is the Research Methodologies, in this step, the proponents must show the different framework of the system as well as the methods that they are going to use in designing the system. The fifth is the Design of SPC-Based Decision Supporting System for Data Analysis of Tomato, Bell Pepper and Chili, in the design; it will be composed of Database Management System, followed by Controlled Charts, then Decision Supporting System and the Notification System. For Decision-Making, Fuzzy Logic will be used. The System Testing comes next, the proponents needed to test the system to see if there's a defect and if the system is producing an accurate and reliable outputs. Then System Finalization comes, this is where the proponents need to finalize the system to be able to utilize by the user. Lastly is the Smart Farm System Implementation, the system must be implemented so that

farmers will be able to use it to lessen their work.

Table 1. IPO Chart of the System

INPUT	PROCESS	OUTPUT
• Temperature and Humidity, Soil Moisture and pH Level data from Monitored Vegetable Crops (Tomato, Bell Pepper and Chili)	• Get the monitored data • Plot the data in chart • Analyze the plotted data	• Visualization of Trend/Control Charts (LCD Monitor) • Recommended and Suggested Solutions to the Problems • Notification (SMS and Pop up)

The Table 1 shows the Input, Process and Output of the system. The input will be the monitored data from the vegetable crops. Then the Process is get the monitored data, plot it in the chart and analyze the data. The output will be shown in the monitor such as the controlled chart, pop up as well as the notification through SMS with the proper solution needed by the plants.
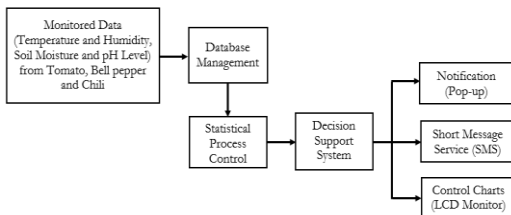
Figure 2. Block Diagram of the System

The Figure 2 shows the flow of data in the whole system. The diagram is composed of Monitored Data from vegetable crops, Database Management, Statistical Process Control, Decision Support System, Notification and Short Message Service.

The monitored data will be uploaded in the Database Management, which is made up of Visual Basic.Net. The monitored data will be plotted in the Statistical Process Control (Control Charts) to see the variation and trends of

the input data. The Control Charts has its corresponding limits, with this, the system were able to see the occurring problems from the data. The detected problems will be analyzed and sent in the Decision Support System where Fuzzy Logic will be used for setting rules, it will provide possible solutions to the detected problems. The solutions made by Decision Making will notify the users through Pop-up and Short Message Service (SMS) as well as displaying of Control Charts in LCD Monitor.
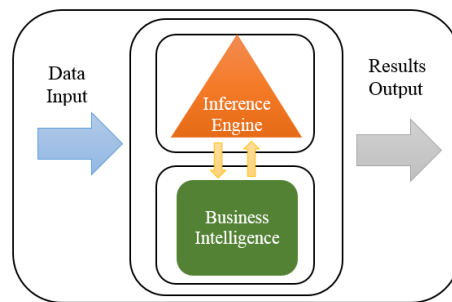

Figure 3. Architecture Component of Decision Support System

Figure 3 shows the components of Decision Support System, this includes the knowledge base and the inference engine. The Business Intelligence (BI) is a process for presenting data and analyzing information to help users in making more informed decisions. It allows to store, access, gather and analyze data to assist users in decision making. For the analytical to be accessible to corporate decision makers and operational workers, BI comprehensively includes various kinds of tools and approaches that permit organizations to accumulate data from internal and external sources, get it ready for execute, analysis and develop queries

against the data, and generate dashboards, data visualizations and reports [11]. Thus, this means that the results coming from the system will be based onto the rules given by the proponents.
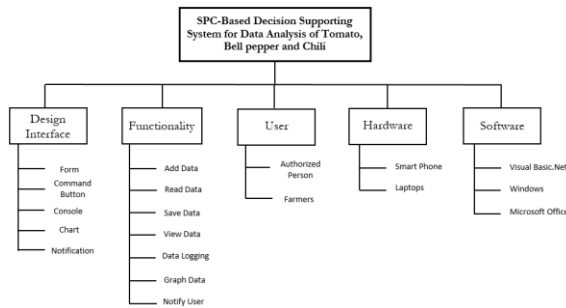

Figure 4. Work Breakdown Structure (Organizational Chart)

The Work Breakdown Structure which is Figure 4 is divided into 5 segments which are the Design Interface, Functionality, User, Hardware and Software. For the Design Interface, it includes all the tools needed to design the Graphical User Interface. The Functionality describes the functions of the system that the user can do. The user talks about the people who can use the system. For the hardware, it simply describes the hardware part of the system and the Software part will be the software that will be used to design and develop the system.

3.2 Theoretical Framework

3.2.1 Statistical Process Control

Dr. Walter Shewhart and Dr. W. Edwards Deming developed the concept and principle of Statistical Process Control [12]. Statistical Process Control produces Control Charts where it will show problems existing in the data. Out-of-Control conditions in the data will be shown using Control Charts [13]. It will be employ in the system to help farmers monitor and identify what should be the action need to be undertaken. The main objective of the SPC is to provide a real-time process to have a quality data and improve data constantly [14]. The collected data from the monitored vegetable crops will be uploaded in the system and the system will be plotting the data. With SPC concept, it will help users to maintain the quality of a product or process specifically vegetable crops that is being monitored and improved it by showing trends of data with the used of Control Charts for Variables. Charts are useful tool to monitor the data. Moreover, there are set limits and it is designed to recognize if a failure is occurring [15]. The data is arranged and plotted in a graph with a given limits to show the trends of data. Thus, the limits are used to recognize and correct the problems.

Equation used to show trends of data:

$$UCL = X_{bar} + R$$

-equation 1

$$LCL = X_{bar} - R$$

-equation 2

X – Historical average

R – Range of data
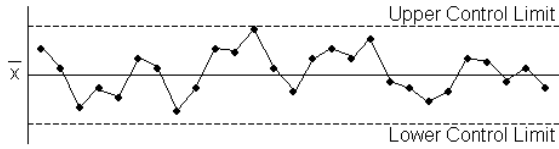
UCL – Upper Control Limit
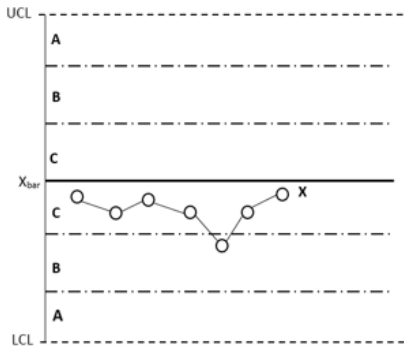
LCL – Lower Control Limit

Figure 5. Process in Control

In determining the occurrences in the Control Chart, the data or point which will fall outside its control limit is the Process out of Control [16]. To determine the occurrences, different figures will be shown

Figure 8. Two Out of Three Consecutive Points in a Row in Zone A

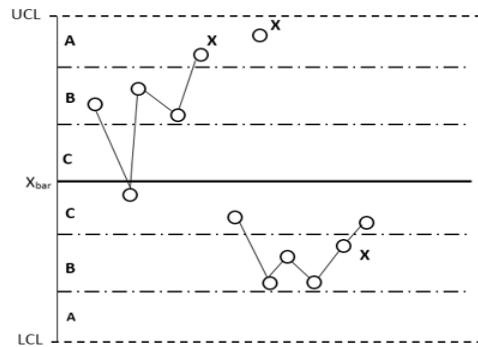Figure 6. Seven or More Points in a Row in Zone C or Beyond

Figure 9. Four Out of Six Points in a Row in Zone B or Beyond
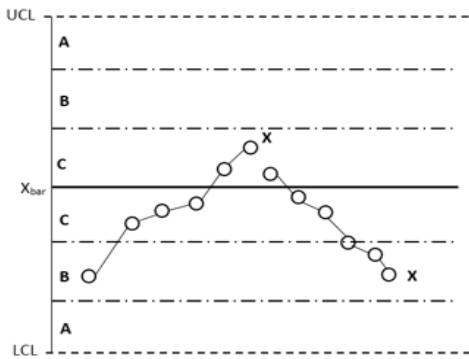
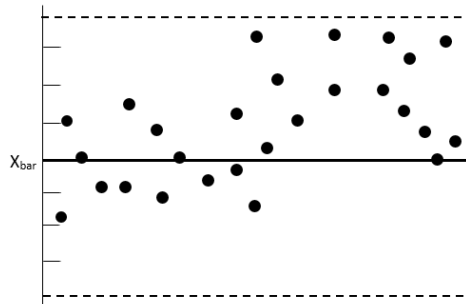Figure 7. Six or More Points in a Row Steadily Increasing or Decreasing

Figure 10. Out-of-Control Pattern: Change or Jump in Level
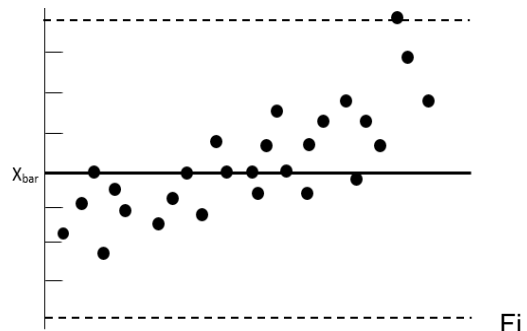

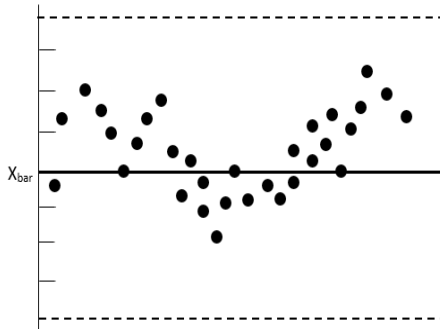Figure 11. Out-of-Control Pattern: Trend or Steady change in Level

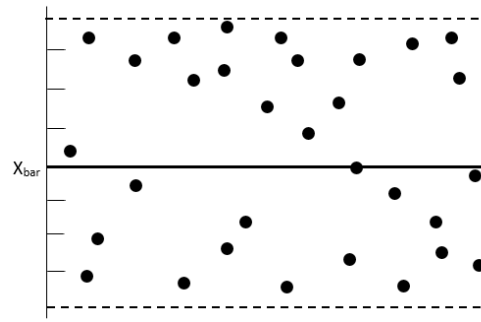Figure 12. Out-of-Control Pattern: Recurring Cycles

Figure 13. Out-of-Control Pattern: Two Populations

3.2.2 Decision Supporting System

The concept of Decision Support System (DSS) will be utilized by the system because of its capability to assist users is some decision-making activity. DSS helps users to resolve complicated problems, however, DSS can possibly use with computerized management information systems [10]. In order to apply the DSS concept, the proponents must know how to use it. First is the use of data collected by the user needed in the system. Then the data will be evaluated by the system and examine the data to see if there's a need of change in the data and will give an effective solution for data, same goes as the proponents' system. DSSs serve the organization, operations, and masterminding levels of an affiliation and settle on decisions, which may change quickly and not indicated ahead of time. A DSS is an intuitive software-based system expected to help users to make information into more information from a mix of unrefined data, files, singular learning, or plans of action to recognize and make consideration of issues and choose. The Fuzzy Logic will be utilized in decision making.

3.2.3 Short Message Service

Short Message Service (SMS) refer to as sending short messages which consists of up to 160 character [17]. Most of the study used Global System for Mobile communication (GSM) in sending text messages to the users but with the proponents' study, it will be with the use of Visual Basic.Net (VB.Net) to in notifying the users through text messaging. Through the use of VB.Net, proponents will be able to send text messages to the users.

3.2.4 Visual Basic.Net

Visual Basic.Net (VB.Net) was developed by Microsoft as an Object-Oriented programming language. Because of the word "basic", this means that the language is for the beginners. It has a simple syntax, but then using VB.Net, anyone can make and create a powerful applications and has a capability to develop an executable file to make a system [18]. With the use of VB.Net, the proponents will be able to make a Graphical User Interface (GUI) for the users.

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3.2.5 Fuzzy Logic Toolbox

Based on Fuzzy Logic, MATLAB functions is provided in Fuzzy Logic Toolbox for simulating, designing and analyzing different systems. It will help the proponents in designing the fuzzy logic inference. Using simple logic rules, the toolbox allows the user to model a composite system and then implement the rules into fuzzy inference system. Fuzzy Logic works just like how human brains work. The utilization of the fuzzy logic is to make systems to think like a human. It plays an important role which will help the user to decide and to come up with an effective results [7]. On the other hand, Fuzzy Logic deals with different probabilities, areas between 0 and 1, and area between true or false, which referred to the concepts of "degrees of truth".

The major use of Fuzzy Logic reclines in the Neural Networks (NN). NN work via connections establish in the information, and they works just how like human brains communicate with data. Neural Network is produced using an intricate arrangement of nodes, interconnected components that contain related bits of information. Neural network are hailed for their learning capacities and versatile qualities that permit them to react successfully to different situations and circumstances [7]. The proponents will be using the Sugeno style Fuzzy logic interface system for If-Else rules.
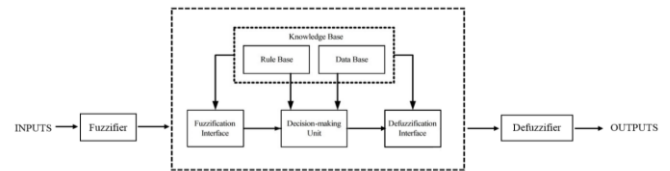

Figure 14. Architecture Component of Fuzzy Logic

3.2.6 MATLAB

MATLAB is one application that has high performance language for specialized processing. It can be utilized for computing, and programming a simple to-use environment where the user can solve the issues effectively, quick and intelligibly. It is likewise an imparting system whose basic information is an exhibit which does not require any dimensioning on the system. It is great in explaining matrices, vectors or even a portion to make the outcomes less complex and precise [19].

3.2.7 Plants and its Behavior

For this study, the proponents make use of three vegetable crops to be analyzed, these are the following:
•   Tomato – Basically, tomato is served and consider as a vegetable and most people doesn't consider it as a fruit. Tomato is a fruit and part of potatoes and eggplants family. It comes in a variety of shapes, sizes and colors [20]. The ideal temperature for the tomato plant to grow is at 20-30°C. For young plants to grow well in day and night, the temperature must be around 25°C, but when it grow older, it seems to have an advantage from lower night than day temperature. When

temperature increased over 32°C during the day and the temperature at night must be 10°C -20°C, when 21°C for the night then fruit setting will be reduced. Poor fruit set will also result when temperature is lower than 10°C. To maintain fruit setting for tomato, it requires minimum growth temperature from 13-14.5°C, for optimum growth it requires 15-20°C, and for maximum growth temperature 22°C, thus for marinating the fruit set tomato it requires 13-22°C. Lower temperatures are required for tomatoes that are about to produce fruit in order for the fruit to express a more vibrant red color once it ripens [21] [22]. When temperature above 25°C with high humidity and strong wind results decreased yield and for night temperatures above 20°C with high humidity and lack of sunshine result to poor fruit production and immoderate vegetative production [23].

With good drainage, tomatoes can bloom in different soil types but preferably in sandy to sandy loam soil. Optimum soil pH for tomato is 5.8-7.0. If soil pH is below 5.8 (soil is acidic), lime should be apply to the soil. New transplanted seedlings should water the plants regularly for 1-2 weeks and after seeding, when the soil gets dry, irrigation can be done usually 7-10 days interval according to soil type and weather conditions [22]. Tomato must irrigate by furrow method during dry season. Accordingly, tomato is very sensitive in flood, thus, irrigation is done only to moisten root during the flowering up to the harvest [24]. The water requirements for the newly planted tomato in a day (7-10 days) must be a quart of water, more water if wind is notable, temperatures are hot, and if it is sunny. When tomato is planted on the ground for 10-14 days, over 10 days water must be 1-3 inches or even 2 weeks. For main growing season, follow the 1-3 inches a week rule, for summer seasons, water the tomato from 2-3 times a week. When the soil type is sandy soil, water it consistently for 2-3 times a week and double the inch a week during growing season [25].

The ideal range of humidity for tomato ranges from 80%-90%. The tomato lose weight and low quality when humidity less than 80% while it is considerable at risk of rot and mold growth when humidity is greater than 90% [26]. Wind causes pollination for tomato, because of unusual structure of tomato flower, wind is mainly help to shaken the pollen and make it fall to another anthers causes reproduction of tomato [27]. High wind speed can result to high transpiration rates but it also depends on the available water in the soil. If soil moisture is very low, despite the high wind speed the plant leaves for some time will tend to withhold the water it has. In extreme cases such as long exposure to high wind speed drying of the leaves might occur.

• Chili – Chili is termed as "Sili" in the Philippines [28]. The ideal daytime temperature must be 20°C - 32°C, but it will not set fruit when temperature at night is greater than 24°C. If the temperature falls at 15°C or surpass to 32°C for long period, growth and production will reduced. The soil pH must range from 5.5 to 6.8 [29]. The optimal humidity for chili peppers must be 60%-70% [30]. For small

plant, the amount of water for the chili must be 500millilitres as it grows bigger, it needs 1.5L of water per day [31].

• Bell Pepper – Planting bell pepper in hot weather, and moist drained soil is best. Accordingly, to have a good germination, before planting the seeds it should be kept in warm and moist from 70°F-80°F [32]. For its temperature, it ranges for 18-27°C, when the temperature decreased from 18°C below and increased to 27°C for long period, yield and growth will decreased. Bell peppers can endure up to 30°C day time temperature, but the night temperature should be 21-24°C. Bell pepper is humidity insensitive, it means that humid doesn't affect its flowering or fruit set. The recommended soil type is sandy, loam or silty-loam because of its capability with water holding. Indeed, bell pepper can grow in different types of soil as long as its pH is 5.5-6.8 and the soil should well drained. If the bell pepper is planted during September-October, irrigations is not very necessary, but if it is planted during summer season, irrigation is needed; always water it especially the root and do not let the ground crack [33]. An approach for watering the Bell pepper is two to three times a week, with a water level of 1-2 inches [34].
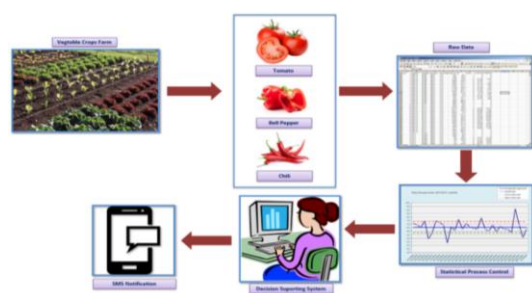
3.3 Proposed Design

Figure 15. Structural Design of the System

In this study, SPC-Based Decision Supporting for Data Analysis of Tomato, Chinese cabbage and Bell pepper is to be developed by the proponents. The user will be given a CSV file to be placed in the system. The file contains monitored data of the vegetable crops with respect to its observed parameter. The system will read the file and to be plotted in a chart with the given Upper Control Limit and Lower Control Limit to show trends and variations as well as the constraints data. The system will analyze the detected problem by the used of Statistical Process Control (Control Charts) and make decision using the set of rules in Fuzzy Logic based on the data. After analyzing data, the system will provide a notification to be sent through SMS containing the suggested solutions that is needed by the plant, as well as the system will be popping a notification message saying that message is sent.

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