# DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR AUTOMATIC FERTILIZER APPLICATION USING ARTIFICIAL NEURAL NETWORK

BY



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# CERTIFICATION

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## DECLARATION

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## DEDICATION

This project is dedicated to Almighty God for His mercies upon my life and His everlasting grace He has bestowed on me since the beginning of my academic career till now. This project is also dedicated to my parents Mr. and Mrs. Ibraheem.

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# ABSTRACT

The development in science and technology has vital contribution towards improving the country's economy. One of the sectors that contribute to the country's economy is agriculture which needs the improvement of science and technology from time to time such as in its fertigation system. The manual applications of fertilizer that are commonly used are very stressful and consume enormous time especially when cultivating a large area of land and also do not ensure efficient management of fertilizer. Inefficient management of nutrient inputs has put a large constraint on the environment and human's health. Indiscriminate use of nitrogen and phosphorus fertilizers has led to ground water pollution. So farmers have to pay close attention to nutrient management and incorporate the concept of balanced plant nutrition into their farming techniques. So in this project, I am presenting a decision support system for an automatic Fertigation of tomato plant using artificial neural network.

The system was developed in a MATLAB environment using the MATLAB GUI toolbox and the MATLAB neural network toolbox. The system was designed in a way that user can input the image corresponding to the growth stage of the tomato plant and the system will be able to identify the name of the growth stage.

The system is able to automatically state when to dispense fertilizer to tomato plant at different stages of its development using the input image for the growth stages, the selected nitrogen content, phosphorous content, and potassium content of the soil.

For twelve test samples that were taken, an accuracy of 91.67% was achieved. Therefore, the decision of the system is said to be accurate.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to the study

Tomato (Lycopersicon esculentum Mill) is one of the most widely cultivated crops in the world and it is an important source of minerals, vitamins, dietary fibers and essential amino acids (Shankara *et al* 2005). The origin of tomato can be traced to the South American Andes (Shankara *et al* 2005). Tomato is an important global vegetable crop that required a nutrient potential for optimal vegetative and reproductive development (Sahu and Behera, 2015). Tomato contains much vitamin B and C, iron and they are an important cash crop for smallholders and medium-scale commercial farmers (Shankara, Vandam *et al* 2005). Tomato belongs to the Solanaceae family; this family also includes other well-known species, such as potato, tobacco, peppers and eggplant.

In getting high yield in tomato production, fertilizer application is very essential. Crop nutrients come from organic manures and chemical fertilizers (Shankara, Vandam et al 2005). Chemical fertilizers can be divided into two groups: compound fertilizers and simple fertilizers. Compound chemical fertilizers contain a mixture of nitrogen (N), phosphorus compounds (P2O5) and potash (K2O) in the ratio 1:2:1 while the simple fertilizer has only one nutrient and it is used when a crop has a specific deficiency. Tomato is usually given a combination of organic and chemical fertilizers (Shankara *et al* 2005). It is not necessary to apply this mixture at one time.

Fertigation is the process of injecting fertilizers to plants through irrigation system. Fertigation ensures delivery of water and nutrients to the root of the plant. Tomatoes take up nutrients best when the soil pH ranges from 6.2 to 6.8, and they need a constant supply of major and minor plant nutrients. To provide these major nutrients, mixture of a balance timed-release of appropriate fertilizer into the soil is required, following the rates given on the fertilizer label. The nutrients supplied by fertilizer is very significant in the growth of tomato crop, so there is need for the development of expert systems that can monitor the application of this fertilizer in case of large scale farming so as to reduce the stress of farmers. This will also encourage subsistence farmers who are not willing to practice large scale farming due to stress involved in fertilizer application and irrigation of plants. Subsequently, this will also give them the opportunity of achieving high productivity at the same time minimizes the use of fertilizer.

The intelligent control of Fertilizer application is the key technology of modern agriculture which can help improve the cultivation of plants most especially in Countries where the soil available for cultivation cannot provide the required nutrient needed by plants for their perfect growth. Hence, there is need for the development of intelligent fertilizer application systems to ensure maximum productivity.

## 1.2 Problem Statement

Tomato is vegetable crop that requires maximum nutrient potential for its optimal vegetative and reproductive development (Major *et al* 2005). But the available soils are not fertile enough to provide the adequate nutrient required by tomato plant for its maximum productivity. So there is need for farmers to apply fertilizer to these soils in order to provide the adequate nutrient required by the tomato plant for its maximum productivity. A lot of challenges are been faced by farmers with large plantation of the crop during manual application of fertilizer. Manual application of fertilizer can strenuous and time consuming for these farmers and this may serve as a source of discouragement to others who are willing to cultivate the crop in large quantity. Subsequently, the nutritive value of tomato in diet cannot be over-emphasized, so its cultivation in large quantity is required in order to increase their availability at cheaper and more affordable prices in markets. Therefore, there is need for development of intelligent systems that can automatically handles the application of fertilizer to tomato plants without needing the consent of the farmers. This will reduce the stress of farmers in the Fertigation of large area of tomato plantation and will also encourage others who are willing to largely cultivate tomato plant.

## 1.3 Aim and Objectives

The project is aimed at developing a decision support system for fertilizer application to tomato plant using artificial neural network (ANN).

The objectives of this project include:

i. To acquire dataset for the design of the proposed system.
ii. To design and implement a decision support system for automatic application of fertilizer to tomato plant in a GUI.
iii. To evaluate the performance of the designed system in (ii) above.

## 1.4 Significance of Study.

The increasing demand of the food supplies requires a rapid improvement in food production technology. In many countries where agriculture plays an important role in shaping up the economy and the climatic conditions are isotropic, but they are still yet to make full use of agricultural resources. One of the main reasons is the lack of fertile land for cultivation, but the available land can be made fertile through the application of fertilizer. However, there is need for the development of system that can supply the nutrient needed by plants (through the application of fertilizer) at every stages of their development. Also, the nutritive value of tomatoes cannot be over-emphasized, therefore there is need to attain maximum productivity in its cultivation. This will in turn helps to boost the availability of tomatoes in markets and also will be significant in the development of agriculture at large.

Moreover, the stress involved in manual application of fertilizers might be discouraging to some farmers who are willing to engage in large-scale farming, but invention of automatic fertilizer application systems will encourage these farmers to cultivate largely without stress.

### 1.5 Scope of Study

Crop nutrients come from organic manures and chemical fertilizers. Chemical fertilizers can be divided into two groups: compound fertilizers and simple fertilizers. Compound chemical fertilizers contain a mixture of nitrogen (N), phosphorus compounds (P2O5) and potash (K2O) in the ratio 1:2:1.The simple fertilizer has only one nutrient and it is used when a crop has a specific deficiency. Tomato can be given a combination of organic and chemical fertilizers. But the most important of all these nutrients to tomato plant is the nitrogen, phosphorous and potassium from the chemical compound fertilizer which are only aspect that are considered in this project. Also different classifiers have been used by researchers in the development of similar systems but this project is limited to only the use of ANN classifier.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Brief introduction

The literature review gives an overview about the tomato plant, its planting requirement, its growth stages, its irrigation and nutrient requirement, and symptoms of lack of each nutrient. The literature review also gives an overview about Image processing techniques, ANN classifier which include; different ANN architectures, learning laws and training algorithms. It also gives concise description of related works on intelligent Fertigation systems, Artificial Neural Networks and Image processing.

## 2.2 Tomato Plant

Cultivated tomato, Solanum lycopersicum, is a popular fleshy fruit and is known by different names worldwide like tomate (German), tomaatti (Finish), pomidoro (Italian), kamalis (Malay), jitomate (Spanish), pomidor (Russian) and tamatar (Hindi) (Govila *et al* 2003). Numerous varieties of tomato are widely grown in temperate climates across the world, with greenhouses allowing its production throughout the year and in cooler areas. The plants typically grow to 1–3 meters (3–10 ft.) in height and have a weak stem that often sprawls over the ground and vines over other plants. It is a perennial crop in its native habitat, and grown as an annual in temperate climates. An average common tomato weighs approximately 100 grams.

These growth periods also represent different nutritional needs of the plant. The duration of each stage may vary according to growing method, variety characteristics and climatic conditions. A typical example of a growth cycle of tomato plant by growth stages is described in table 2.1

Table 2.1: Growth cycle of tomato plant by growth stages (Haifa O.,2005)

| | | |
|---|---|---|
| Variety | VF121 | |
| Growing method | Greenhouse | |
| Number days to first flowering | 30 | |
| Number days to first harvesting | 65 | |
| Growth stage | Stage duration (days) | Crop age (days) |
| Planting | 1 | 1 |
| Vegetative | 14 | 15 |
| First flowering | 15 | 30 |
| First fruit set | 10 | 40 |
| Fruit growth | 20 | 60 |
| Starting harvest - until end of last harvest | 21-145 | 81-210 |

2.2.1 Planting Properties of Tomato

Tomato can be grown in an open field or as a protected crop in greenhouse or in a high plastic tunnel (Matt and Bussan, 2007). Tomatoes can be grown on soils with a wide range of textures, from light, sandy soils to heavy, clay soils. Sandy soils are preferable if early harvest is desired.

Favorable pH level of soil is 6.0-6.5. At higher or lower pH levels micronutrients become less available for plant uptake (Major *et al, 2005*).Temperature is the primary factor influencing all stages of development of the tomato plant. Generally, growing tomato plant requires temperatures between 10°C and 30°C. The temperature requirement at different growth stages is stated in the table 2.2.

Table 2.2: Temperature requirement at different growth stages (Haifa O., 2007)

| Growth stages | Temperature ($^0$C) | | |
|---|---|---|---|
| | Minimum | Maximum | Optimal |
| Germination | 11 | 34 | 16-29 |
| Vegetative growth | 18 | 32 | 21-24 |
| Fruit setting (night / day) | 10/18 | 20/30 | 13-18 / 19-24 |
| Formation of lycopene | 10 | 30 | 21-24 |
| Formation of carotene | 10 | 40 | 21-32 |

2.2.2 Irrigation Requirements

Tomato plants are fairly resistant to moderate drought. Proper management is essential to assure high yield and quality. The water requirement of outdoor grown tomatoes varies between 4000 - 6000 m³/ha. In greenhouses up to 10,000 $m^3$/ha of water are required (Matt and Bussan, 2007). 70% or more of the root system are in the upper 20 cm of the soil. Therefore, a drip system equipped with a fertigation device is often advisable. On light soils or when saline water is used, it is necessary to increase water quantities by 20% - 30%. Water requirement differs at various growth stages. The requirement increases from germination until beginning of fruit setting, reaching a peak during fruit development and then decreases during ripening. Mild water stress during fruit development and ripening has a positive effect on fruit quality: firmness, taste and shelf-life quality, but may result in smaller fruit (Matt and Bussan, 2007). Late irrigation, close to harvesting, may impair quality and induce rotting. Water shortage will lead to reduced growth in general and reduced uptake of calcium in particular. Calcium deficiency causes Blossom End Rot (BER). On the other hand, excessive irrigation will create anaerobic soil conditions and consequently cause root death, delayed flowering and fruit disorders. Tomatoes tolerate brackish water up to conductivity of about 2-3 mmho/cm. Acidic (low pH) irrigation water is undesirable, as it might lead to the dissolution of toxic elements in the soil (e.g. $Al^{3+}$).

### 2.2.3 Fruit development

After fruit setting, fruit ripens over a period of 45 - 70 days, depending upon the cultivar, climate and growth conditions. The fruit continues growing until the stage of green ripeness. Fruit development are in three stages: Ripening occurs as the fruit changes color from light green to off-white, pink, red, and finally dark red or orange. Depending on the distance and time to market, harvest may occur anytime between the pink to dark red stage, the later stages producing more flavorful fruit. The stages in the tomato fruit are described in the table 2.3.

Table 2.3: Stages of fruit ripening (Haifa O., 2007)

| Stage | Description |
| --- | --- |
| Breaker | Red stains appear on fruit skin |
| Pink | Tomato turns pink, not yet ready for consumption |
| Red | The tomato is red and completely ripe for consumption |

### 2.2.4 Fertilizer Requirement

Most fertilizers are a combination of the three nutrients commonly fed to plants: nitrogen, phosphorus, and potassium (referred to as the "N-P-K ratio"). A commercial fertilizer's analysis is listed on the label in a three-number series, such as 15-10-5. The three numbers represent those three nutrients. A 15-10-5 fertilizer contains 15% nitrogen, 10% phosphorus, and 5% potassium and the remainder of the fertilizer is filler material.

Nitrogen: Nitrogen encourages leaf growth, which is why fertilizers with higher ratio of nitrogen are an optimum choice for lawns and grasses. But in tomatoes, excess leaf growth discourages blossoms and fruit. A complete fertilizer with a balanced supply of the three major nutrients, such as 10-10-10 or 5-10-10, is a better choice for tomato plants at initial planting time. It is advisable to stay away from high-nitrogen fertilizers such as urea, ammonium sulfate or fresh manure, which will help produce dark green, tall tomato plants but fewer tomatoes.

Phosphorus: Phosphorus (the second number in the N-P-K ratio) encourages flowering and therefore fruiting and is required at a relatively constant rate, throughout the life cycle of the tomato plant. Other roles of potassium in tomato plant include:

- Regulating metabolic processes in cells
- Improves wilting resistance.
- Enhances resistance toward bacterial viral, nematodes and fungal pathogens.
- Reduces the occurrence of coloration disorders and blossom-end rot.
- Increases solids content in the fruit.
- Balancing of negative electrical charges in the plant.

Potassium: Once a tomato plant starts flowering, it needs a higher ratio of potassium (the third number in the N-P-K ratio). Good organic sources of potassium are granite dust and wood ash.

## 2.3 Symptoms of Deficiency of N-P-K in Tomato Plant

The main nutrients supplies by fertilizer are the nitrogen, phosphorous and potassium. Deficiency of these nutrients will affect the growth of tomato plant. The symptoms shown by the deficiency of these nutrients are described below.

### 2.3.1 Nitrogen

The chlorosis symptoms shown by the leaves in Figure 2.1 are the direct result of nitrogen deficiency. A light red cast can also be seen on the veins and petioles. Under nitrogen deficiency, the older mature leaves gradually change from their normal characteristic green appearance to a much paler green. As the deficiency progresses these older leaves become uniformly yellow (chlorotic). Leaves become yellowish-white under extreme deficiency. The young leaves at the top of the plant maintain a green but paler color and tend to become smaller in size. Branching is reduced in nitrogen deficient plants resulting in short, spindly plants. The yellowing in nitrogen deficiency is uniform over the entire leaf including the veins. As the deficiency progresses, the older leaves also show more of a tendency to wilt under mild water stress and senesce much earlier than usual. Recovery of deficient plants to applied nitrogen is immediate (days) and spectacular.

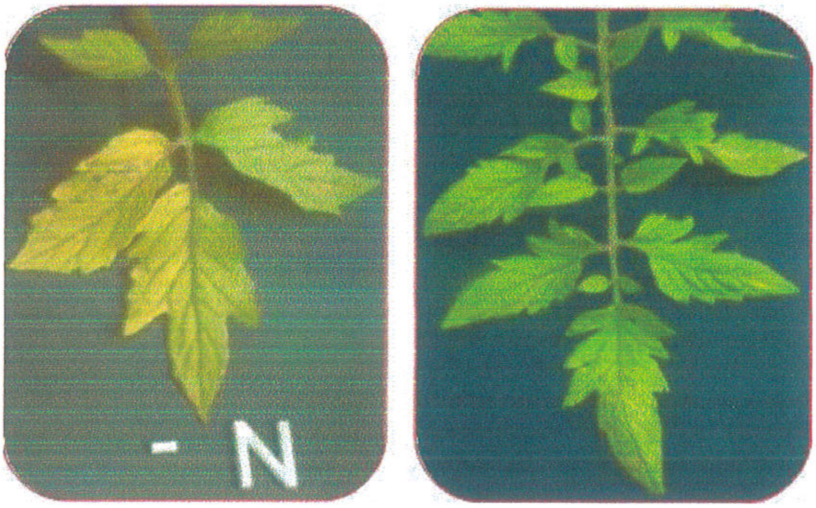



Figure 2.1: Characteristic nitrogen (N) deficiency symptom (Haifa O., 2007)

2.3.2 Phosphorus

The necrotic spots on the leaves in Fig. 2.2 are a typical symptom of phosphorus (P) deficiency. As a rule, P deficiency symptoms are not very distinct and thus difficult to identify. A major visual symptom is that the plants are dwarfed or stunted. Phosphorus deficient plants develop very slowly in relation to other plants growing under similar environmental conditions but with ample phosphorus supply. Phosphorus deficient plants are often mistaken for unstressed but much younger plants developing a distinct purpling of the stem, petiole and the lower sides of the leaves. Under severe deficiency conditions there is also a tendency for leaves to develop a blue-gray luster. In older leaves under very severe deficiency conditions a brown netted veining of the leaves may develop.


Figure 2.2: Characteristic Phosphorous (P) deficiency symptom (Haifa O., 2007)

2.3.3 Potassium

The leaves on the right-hand photo in figure 2.3 show marginal necrosis (tip burn). The leaves on the left-hand photo show more advanced deficiency status, with necrosis in the interveinal spaces between the main veins along with interveinal chlorosis. This group of symptoms is very characteristic of K deficiency symptoms. The onset of potassium deficiency is generally characterized by a marginal chlorosis, progressing into a dry leathery tan scorch on recently matured leaves. This is followed by increasing interveinal scorching and/or necrosis progressing from the leaf edge to the midrib as the stress increases. As the deficiency progresses, most of the interveinal area becomes necrotic, the veins remain green and the leaves tend to curl and crinkle. In contrast to nitrogen deficiency, chlorosis is irreversible in potassium deficiency. Because potassium is very mobile within the plant, symptoms only develop on young leaves in the case of extreme deficiency. Typical potassium (K) deficiency of fruit is characterized by color development disorders, including greenback, blotch ripening and boxy fruit.


Figure 2.3: Characteristic Potassium (K) deficiency symptom (Haifa O., 2007)

## 2. 4 Artificial Neural Networks

Artificial Neural Networks are systems that are purposely constructed to make use of some organizational principles resembling those of human brain (Snehal *et al, 2015*). Neural network have seen an explosion of interest over the last few years and are being successfully applied across an extraordinary range of problem domains, in areas as diverse as finance, geology, physics and biology (Grish, 2005). They represent the promising new generation of information processing system. A single artificial neuron, which is the unit or building block of ANNs, comprises four core elements: input(s), net function, transfer function and one output. The input(s) supplied to a node are multiplied by synaptic weights before getting processed by the transfer function. Synaptic or coefficient weights are the random values that define the strength or amplitude of individual input connected to the neuron. The learning part of ANN comes through continuous adjustment of these weight values. The resultant value of the net function passes through the activation function and thereby an ending output value is calculated and delivered by the corresponding node. The general expression of net function is expressed in equation 1.

$$u = b + \sum_{j=1}^{N} w_j \, x_j \qquad \text{.... ... ........................(1)}$$

Where, u = output of the net function; b = bias weight; N = number of inputs; x = input; and w = weight value for corresponding input ($w_j$: $1 \leq j \leq N$) (Sazzad, Chao *et' al 2016*)

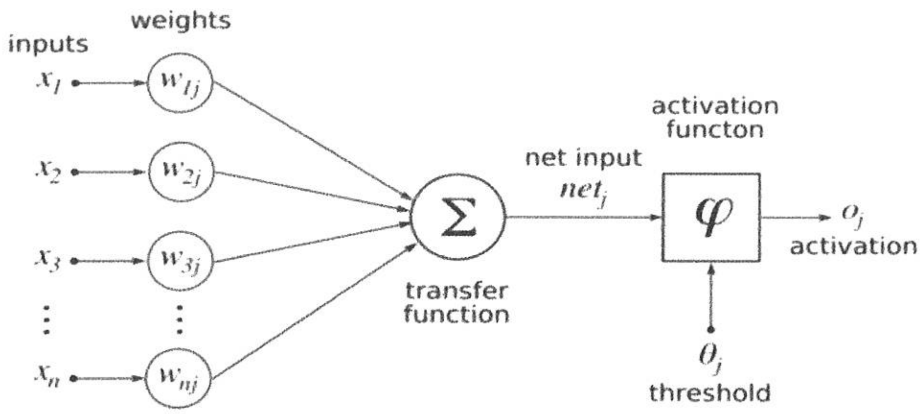



Figure 2.4: A simple Artificial Neural Network (Dominique, 2011)

A single artificial neuron can perform certain information processing, but for more complex tasks and more powerful computations, multiple neurons are needed to be connected with one another to make a complex network known as Artificial Neural Networks. They can be used to solve a wide range of problems such as pattern recognition, pattern generation, function approximation, memory association and so on. The interconnected neurons of a characteristic ANN system can be divided into three main layers: input layer, hidden layer(s) and output layer. Input layer neurons intake the input values from the environment and output layer neurons delivers the eventual outputs. Hidden layer neurons stay in between the input and output layer. They receive the outputs from other neurons as their inputs and deliver outputs to their successive layer neurons. Neural networks have been classified into several kinds which follow different architectures and different input-output mapping procedures and they have been used in different situations. Some architecture of neural networks includes:

Feed Forward Neural Networks: A simple neural network type where connections are made from an input layer to zero or more hidden layers and finally to an output layer. The feed forward neural network type is one of the most common neural networks in use (Dominique, 2007). It is suitable for many types of applications. The feed forward neural network is of two types, the single layered field forward neural network and the multi-layered feed forward neural network.

Single-layered feed-forward neural network: This artificial neural network has just one input layer and a single neural layer, which is also the output layer. The information always flows in a single direction, which is from the input layer to the output layer (Kriesel, 2005). In this architecture, the number of network outputs always matches with the amount of neurons. These networks are normally employed in pattern classification and linear filtering problems. Examples of neural network types that belong to this architecture are perceptron and ADALINE. The learning algorithms used in their training processes are based on Hebb's rule and Delta rule respectively (Da Silva *et al.*, 2017). The diagram in figure 2.5 describes a single-layered feed-forward neural network.

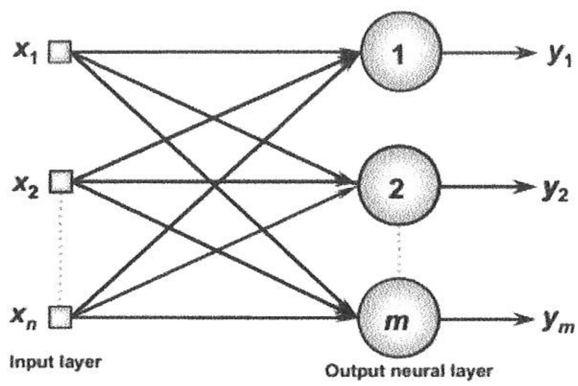



Figure 2.5: Example of a Single-layered feed-forward neural network (Da Silva, 2017)

Multi-layered feed forward neural network: feed-forward networks with multiple layers are composed of one or more hidden neural layers. They are employed in the solution of diverse problems, like those related to function approximation, pattern classification, system identification, process control, optimization, robotics, and so on (Da Silva et al., 2017). Among the main networks using multiple-layer feed-forward architectures are the Multilayer Perceptron (MLP) and the Radial Basis Function (RBF). The Learning algorithms used in their training processes are respectively based on the generalized delta rule and the competitive/delta rule (Simon, 2015). The diagram in figure 2.6 describes a multi-layered feed-forward neural network.

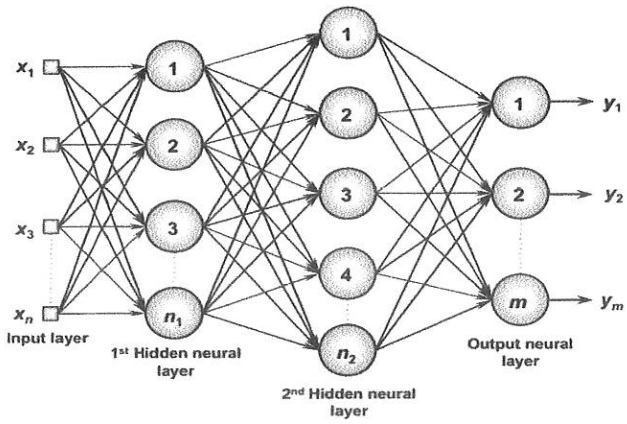



Figure 2.6: Example of a Multi-layered feed-forward neural network (Da Silva, 2017)

Recurrent or Feedback architecture: In these networks, the outputs of the neurons serve as the feedback inputs for other neurons. The feedback feature makes these networks to be suitable for dynamic information processing, meaning that they can be employed on time-variant systems, such as time series prediction, system identification and optimization, process control, and so forth (Da Silva *et al.*, 2017). Example of feedback network is the Hopfield network, whose learning algorithms used in its training process is based on energy function minimization. The diagram in figure 2.7 describes a recurrent or feedback neural network.

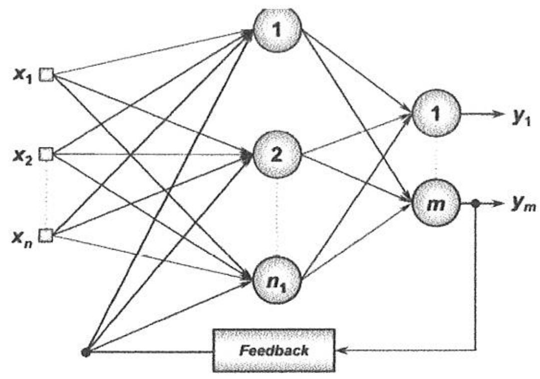



Figure 2.7: Example of a Recurrent or feedback neural network (Da Silva, 2017)

Mesh Architectures: In mesh architecture, the neurons are spatially arranged for pattern extraction purposes, and the spatial localization of the neurons is directly related to the process of adjusting their synaptic weights and thresholds. These networks serve a wide range of applications and are mostly used in problems involving data clustering, pattern recognition, system optimization, graphs. The Kohonen network is an example of mesh architecture neural network. The diagram in figure 2.8 describes a mesh architecture neural network.

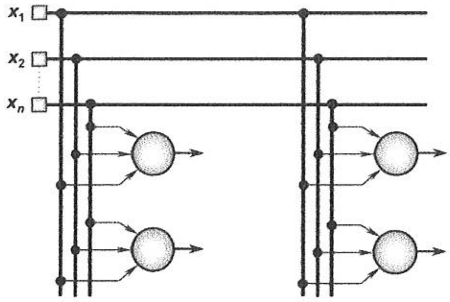



Fig 2.8: Example of a mesh architecture neural network (Da Silva, 2017)

### 2.4.1 Learning/Training Methods in ANN

Learning in ANN can be classified into three types:

Supervised learning: In this learning type, the input pattern that is used for the training are associated with the corresponding output pattern and presence of a teacher is assumed during the learning process. This teacher presents the desired output pattern of the network, and comparison between the computed outputs and the expected outputs is used to determine error. This error can be used to change the network parameters in order to improve the performance of the network (Hashimoto, 2004).

Unsupervised learning: In unsupervised learning, there is no teacher to present the desired output pattern to the network. The system learns on its own by adapting to the structural features of the input pattern.

Reinforced learning: In this learning type, a teacher is present but does not present the targeted output. It only indicates if the computed output is correct or incorrect. The information provided by this teacher helps the network in its learning process.

### 2.4.2 Training Algorithms

Most frequently used training algorithms for ANNs are Levenberg-Marquardt, Quasi-Newton, Conjugate Gradient, Resilient Back propagation and Orthogonal Least Squares algorithm and so on. The training method is chosen based on the available dataset and category of the application.

Batch gradient descent training: In the batch method, weights and biases are updated after applying all members of the training set. The gradients calculated for each input are summed up until the weights and biases are updated. In this method, weights and biases are updated in the reverse direction of the gradient of performance function. Its training function is Traingd.

Batch gradient descent training with momentum: Momentum allows the network to react to error level changes in addition to gradient changes. It also makes the algorithm trajectory softer by ignoring minor errors. Its training function is Traingdm.

Resilient Back propagation training function: This algorithm removes the harmful effects of the size of partial derivatives. Only the derivative sign is used for weight updates, and the derivative size has no effect on the weight updates. This algorithm has a much higher performance than the standard gradient descent algorithm. In addition, this method requires less memory. The back-propagation training takes place using the training function Trainrp.

Conjugated gradient algorithm: This is a balanced algorithm. It does not require the calculation of second derivatives and ensures convergence to the minimum quadratic function (Kriesel, 2005). In most conjugated algorithms, learning speed is used to determine the step size in updates. In most conjugated algorithms, the size of each step is set for each iteration. For this purpose, a search operation is done among all conjugated gradients to select the most appropriate one to minimize the performance function. The conjugated gradient comes in different types, including: The Fletcher-Reeves conjugated gradient algorithm with the training function Traincgf, the Pollack-Ribier conjugated gradient algorithm with the training function Traincgp, and the Paul-Bill conjugated gradient algorithm with the training function Traincgb.

Scaled conjugated gradient algorithm: This algorithm was designed to stay away from the time-consuming linear search. It is very complex and is based on the combination of the two methods of conjugated gradient and Levenberg-Marquardt. Its training algorithm needs more iterations to converge compared to the rest of conjugated gradient algorithms, but the amount of computation per iteration is markedly reduced because linear search is not performed in this method. Its training function is Trainscg.

Quasi-Newton algorithms: Newton methods usually have a better and more rapid convergence than conjugated gradient algorithms. But they are very complex and computationally expensive. Two quasi-Newton algorithms are: The BFGS algorithm which is located in the Trainbfg training function and the one-step secant algorithm which is located in the Trainoss training function. The latter requires less space and computation than the former.

Levenberg-Marquardt algorithms: This method usually have more rapid convergence than other algorithms. But this algorithm needs to maintain large matrixes in memory. This requires a lot of space. Its training function is Trainlm.

### 2.4.3 How to select ANN architectures for different application

i. Number of network inputs =number of problem inputs
ii. Number of neurons in output layer = number of problem outputs
iii. Output layer transfer function choice is partly determined by problem specification of the outputs

#### 2.4.4 Other Alternatives to ANN

**Fuzzy Logic**

Fuzzy logic is an extension of Boolean logic by Lot Zadeh in 1965 based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory (Dernoncourt, 2013). By introducing the notion of degree in the verification of a condition, thus enabling a condition to be in a state other than true or false, fuzzy logic provides a very valuable flexibility for reasoning, which makes it possible to take into account inaccuracies and uncertainties. One advantage of fuzzy logic in order to formalize human reasoning is that the rules are set in natural language. For example, here are some rules of conduct that a driver follows, assuming that he does not want to lose his driver's license

If the light is red... if my speed is high... and if the light is close... then I brake hard.

If the light is red... if my speed is low... and if the light is far... then I maintain my speed.

If the light is orange... if my speed is average... and if the light is far... then I brake gently.

If the light is green... if my speed is low... and if the light is close... then I accelerate.

Intuitively, the input variables like in this example are approximately appreciated by the brain, such as the degree of verification of a condition in fuzzy logic.

## 2.5 Image Processing

Image Processing is a technique used to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-today life for various applications. Various techniques have been developed in Image Processing during the last four to five decades. Most of the techniques are developed for enhancing images obtained from unmanned space crafts, space probes and military reconnaissance flights. Image Processing systems are becoming popular due to easy availability of powerful personnel computers, large size memory devices, graphics, software etc. Image Processing is used in various applications such as: Remote Sensing, Medical Imaging, Non-destructive Evaluation, Forensic Studies, Textiles, Material Science, Military, Film industry, Document processing, Graphic arts, Printing Industry and so on.

### 2.5.1 Methods of Image Processing

There are two methods available in Image Processing. Analog Image Processing and Digital Image processing.

Analog Image Processing refers to the alteration of image through electrical means. The most common example is the television image. The television signal is a voltage level which varies in amplitude to represent brightness through the image. By electrically varying the signal, the displayed image appearance is altered. The brightness and contrast controls on a TV set serve to adjust the amplitude and reference of the video signal, resulting in the brightening, darkening and alteration of the brightness range of the displayed image.

Digital Image Processing

In this case, digital computers are used to process the image. The image will be converted to digital form using a scanner – digitizer and then process it. It is defined as the subjecting numerical representations of objects to a series of operations in order to obtain a desired result. It starts with one image and produces a modified version of the same. It is therefore a process that takes an image into another. The term digital image processing generally refers to processing of a two-dimensional picture by a digital computer. In a broader context, it implies digital processing of any two-dimensional data. A digital image is an array of real numbers represented by a finite number of bits. The principle advantage of Digital Image Processing methods is its versatility, repeatability and the preservation of original data precision.

The various Image Processing techniques are:

i. Image representation
ii. Image preprocessing
iii. Image enhancement
iv. Image restoration
v. Image analysis
vi. Image reconstruction
vii. Image data compression

### 2.5.2 Image Representation

An image defined in the "real world" is considered to be a function of two real variables, for example, f(x,y) with f as the amplitude (e.g. brightness) of the image at the real coordinate position(x,y). The effect of digitization is shown in Figure 2.9.

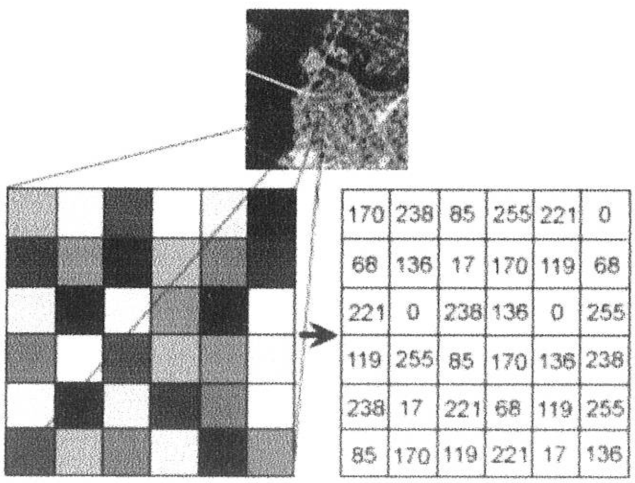



Figure 2.9: Image Digitization ( Rao KMM, Ramanjanyulu M, 2003)

The 2D continuous image f(x,y)is divided into N rows and M columns. The intersection of a row and a column is called as pixel. The value assigned to the integer coordinates [m,n] with {m=0,1, 2,...,M-1} and{n=0,1,2,...,N-1} is f[m,n]. Typically an image file such as BMP, JPEG, TIFF etc., has some header and picture information. A header usually includes details like format identifier (typically first information), resolution, number of bits/pixel, compression type, and so on.

### 2.5.3 Image Preprocessing

The following processes are involved in image preprocessing;

Magnification

The theme of magnification is to have a closer view by magnifying or zooming the interested part in the imagery. By reduction, we can bring the unmanageable size of data to a manageable limit ( Rao KMM, Ramanjanyulu M, 2003). For resampling an image nearest neighborhood, Linear, or cubic convolution techniques can be used. Magnification is usually done to improve the scale of display for visual interpretation or sometimes to match the scale of one image to another. To magnify an image by a factor of 2, each pixel of the original image is replaced by a block of 2x2 pixels, all with the same brightness value as the original pixel. An example of a magnified image is shown in figure 2.10

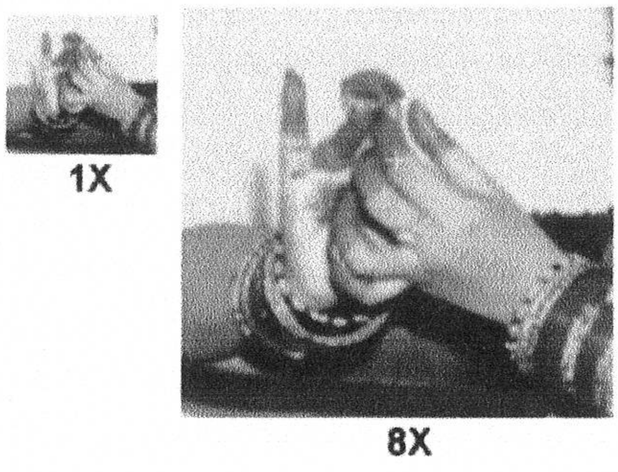



Figure 2.10: Image Magnification (Ramanjaneyulu M, KMM Rao, 2003)

Reduction

To reduce a digital image to the original data, every $n^{th}$ row and $n^{th}$ column of the original imagery is selected and displayed. Another way of accomplishing the same is by taking the average in 'n x n' block and displaying this average after proper rounding of the resultant value. An illustration of Image reduction is described in figure 2.11

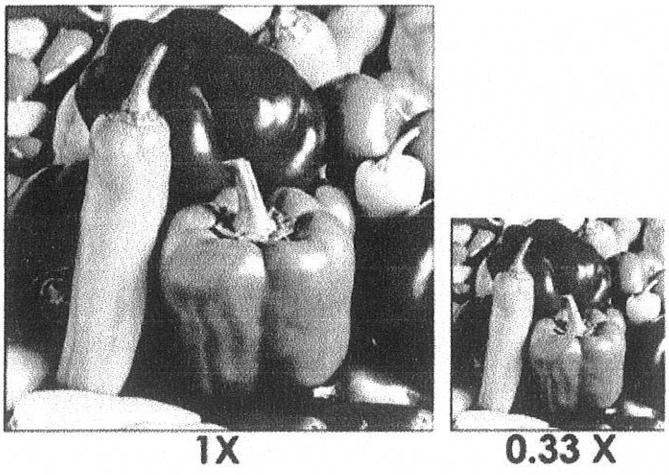



Figure 2.11: Image Reduction (Ramanjaneyulu M, KMM Rao, 2003)

Rotation

Rotation is used in image mosaic, image registration and so on. One of the techniques of rotation is 3-pass shear rotation, where rotation matrix can be decomposed into three separable matrices. Figure 2.12 described the 3-shear rotation;

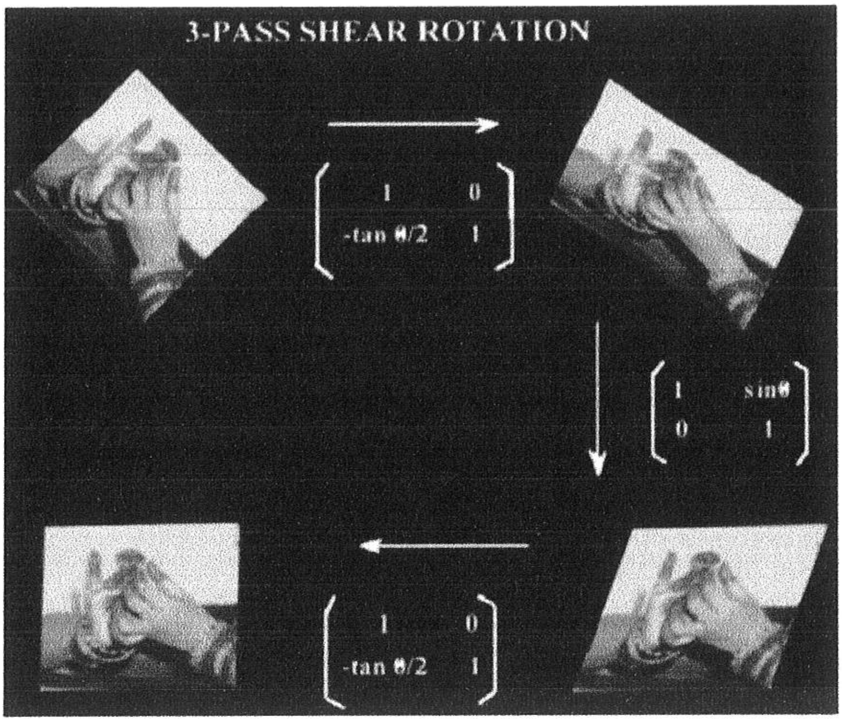



Figure 2.12: The 3-Shear Rotation ( Rao KMM, Ramanjanyulu M, 2003)

Mosaic

Mosaic is a process of combining two or more images to form a single large image without radiometric imbalance. Mosaic is required to get the synoptic view of the entire area, otherwise capture as small images. Figure 2.13 gives the illustration of the operation of image mosaic.

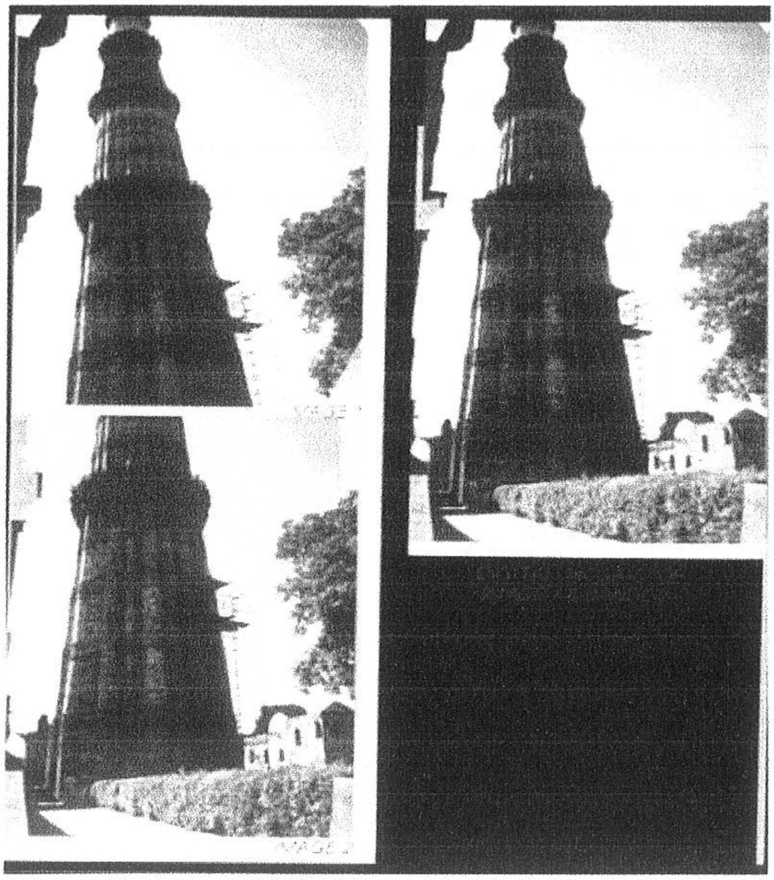


Figure 2.13: Image Mosaic ( Rao KMM, Ramanjanyulu M, 2003)

Image Enhancement Techniques

Sometimes images obtained from satellites and conventional and digital cameras lack in contrast and brightness because of the limitations of imaging sub systems and Illumination conditions while capturing image. Images may have different types of noise. In image enhancement, the goal is to accentuate certain image features for subsequent analysis or for image display. Examples include contrast and edge enhancement, pseudo-coloring, noise filtering, sharpening, and magnifying. Image enhancement is useful in feature extraction, image analysis and an image display. The enhancement process itself does not increase the inherent information content in the data. It simply emphasizes certain specified image characteristics. Enhancement algorithms are generally interactive and application dependent.

Some of the enhancement techniques are:

i. Contrast stretching
ii. Noise filtering
iii. Histogram modification

Contrast Stretching

Some images (e.g. over water bodies, deserts, dense forests, snow, clouds and under hazy conditions over heterogeneous regions) are homogeneous i.e., they do not have much change in their levels. In terms of histogram representation, they are characterized as the occurrence of very narrow peaks. The homogeneity can also be due to the incorrect illumination of the scene. Ultimately, image obtained are not easily interpretable due to poor human perceptibility. This is because there exists only a narrow range of gray-levels in the image having provision for wider range of gray-levels. The contrast stretching methods are designed exclusively for frequently encountered situations. Different stretching techniques have been developed to stretch the narrow range to the whole of the available dynamic range. The operation of contrast stretching is described in figure 2.14.

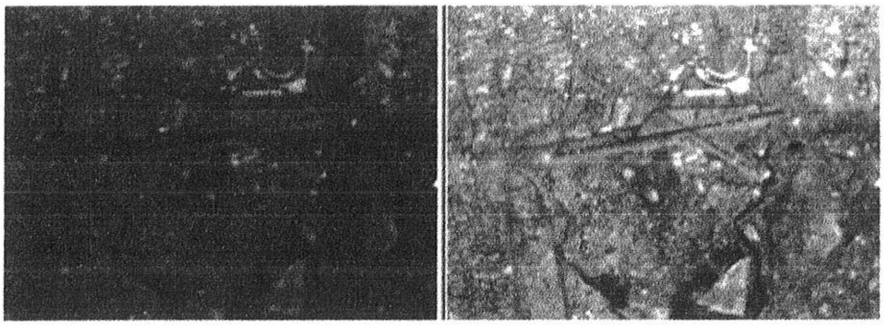


Figure 2.14: Contrast Stretching ( Rao KMM, Ramanjanyulu M, 2003)

Noise Filtering

Noise filtering is used to filter the unnecessary information from an image. It is also use to remove various types of noises from the images. Mostly this feature is interactive. Various filters like low pass, high pass, mean, median etc., are available. The operation of noise filtering is described in the figure below.

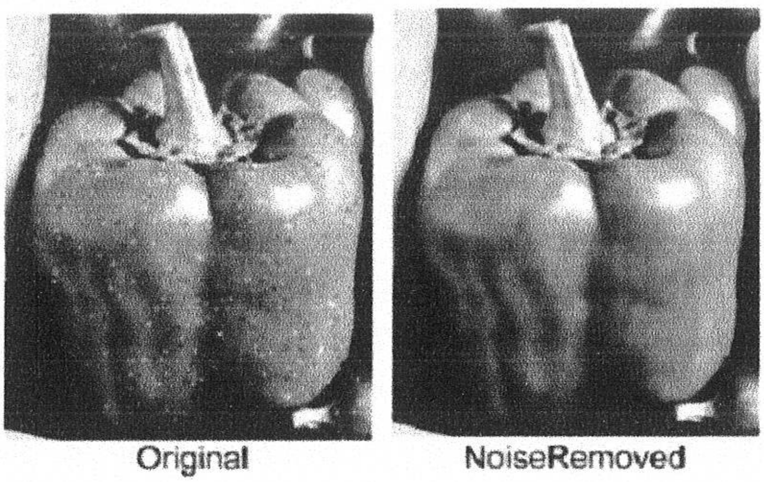



Figure 2.15: Noise Filtering

Histogram Modification

Histogram has a lot of importance in image enhancement. It reflects the characteristics of image. By modifying the histogram, image characteristics can be modified. One such example is Histogram Equalization. Histogram equalization is a nonlinear stretch that redistributes pixel values so that there is approximately the same number of pixels with each value within a range. The result approximates a flat histogram. Therefore, contrast is increased at the peaks and lessened at the tails. The operation of histogram equalization is shown in the figure below;

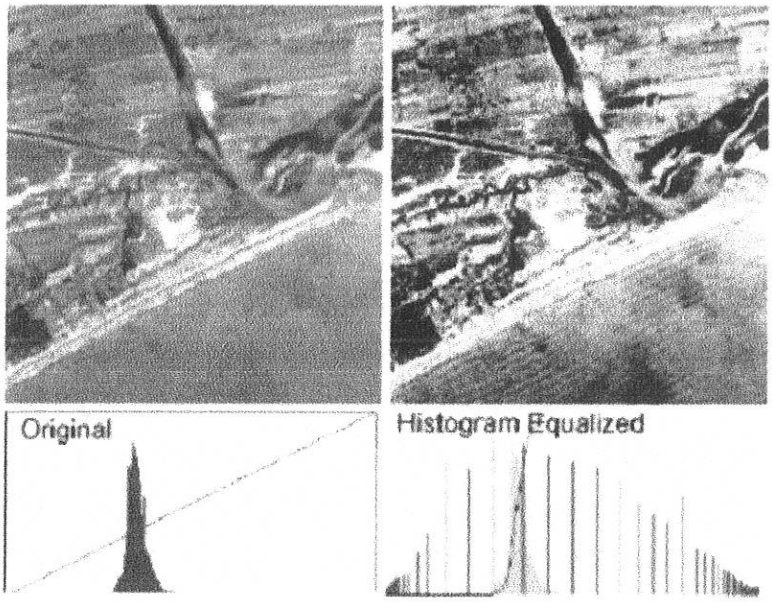



Figure 2.16: Histogram Equalization ( Rao KMM, Ramanjanyulu M, 2003)

### 2.5.4 Image Analysis

Image analysis is concerned with making quantitative measurements from an image to produce a description of it. In the simplest form, this task could be reading a label on a grocery item, sorting different parts on an assembly line, or measuring the size and orientation of blood cells in a medical image. More advanced image analysis systems measure quantitative information and use it to make a sophisticated decision, such as controlling the arm of a robot to move an object after identifying it or navigating an aircraft with the aid of images acquired along its trajectory. Image analysis techniques require extraction of certain features that aid in the identification of the object. Segmentation techniques are used to isolate the desired object from the scene so that measurements can be made on it subsequently. Quantitative measurements of object features allow classification and description of the image.

### 2.5.5 Image Segmentation

Image segmentation is the process that sub-divides an image into its constituent parts or objects. The level to which this subdivision is carried out depends on the problem being solved, i.e., the segmentation should stop when the objects of interest in an application have been isolated e.g., in autonomous air-to ground target acquisition, suppose our interest lies in identifying vehicles on a road, the first step is to segment the road from the image and then to segment the contents of the road down to potential vehicles. Image thresholding techniques are used for image segmentation.

### 2.5.6 Image Classification

Classification is the labeling of a pixel or a group of pixels based on its grey value. Classification is one of the most often used methods of information extraction. In classification, usually multiple features are used for a set of pixels i.e., many images of a particular object are needed. In remote sensing area, this procedure assumes that the imagery of a specific geographic area is collected in multiple regions of the electromagnetic spectrum and that the images are in good registration. Most of the information extraction techniques rely on analysis of the spectral reflectance properties of such imagery and employ special algorithms designed to perform various types of 'spectral analysis'. The process of multispectral classification can be performed using either of the two methods: Supervised or Unsupervised. In supervised classification, the identity and location of some of the land cover types such as urban, wetland, forest etc., are known as priori through a combination of field works and topo sheets. The analyst attempts to locate specific sites in the remotely sensed data that represents homogeneous examples of these land cover types. These areas are commonly referred as TRAINING SITES because the spectral characteristics of these known areas are used to 'train' the classification algorithm for eventual land cover mapping of reminder of the image. Multivariate statistical parameters are calculated for each training site. Every pixel both within and outside these training sites is then evaluated and assigned to a class of which it has the highest likelihood of being a member. The figure below describes the operation of image classification.

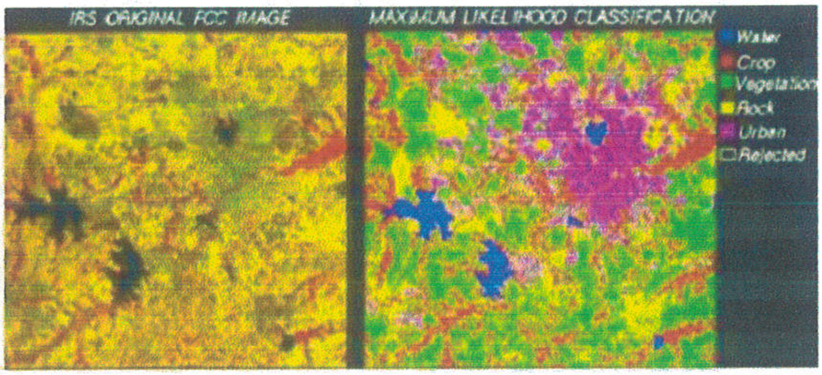



Figure 2.17: Image Classification ( Rao KMM, Ramanjanyulu M, 2003)

In an unsupervised classification, the identities of land cover types has to be specified as classes within a scene are not generally known as priori because ground truth is lacking or surface features within the scene are not well defined. The computer is required to group pixel data into different spectral classes according to some statistically determined criteria. The comparison in medical area is the labeling of cells based on their shape, size, color and texture, which act as features. This method is also useful for MRI images.

### 2.5.7 Image Restoration

Image restoration refers to removal or minimization of degradations in an image. This includes de-blurring of images degraded by the limitations of a sensor or its environment, noise filtering, and correction of geometric distortion or non-linearity due to sensors. Image is restored to its original quality by inverting the physical degradation phenomenon such as defocus, linear motion, atmospheric degradation and additive noise. The action of image restoration is described in the figure below.

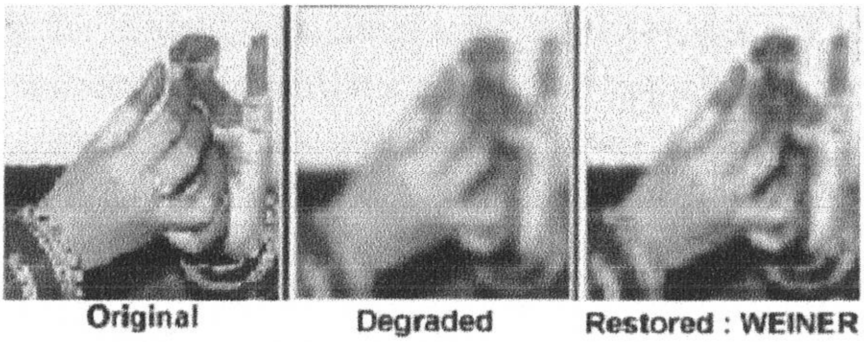



Figure2.18: Image Restoration ( Rao KMM, Ramanjanyulu M, 2003)

### 2.5.8 Image Reconstruction from Projections

Image reconstruction from projections is a special class of image restoration problems where a two-(or higher) dimensional object is reconstructed from several one-dimensional projections. Each projection is obtained by projecting a parallel X-ray (or other penetrating radiation) beam through the object. Planar projections are thus obtained by viewing the object from many different angles. Reconstruction algorithms derive an image of a thin axial slice of the object, giving an inside view otherwise unobtainable without performing extensive surgery. Such techniques are important in medical imaging (CT scanners), astronomy, radar imaging, geological exploration, and nondestructive testing of assemblies.

### 2.5.9 Image Compression

Compression is a very essential tool for archiving image data, image data transfer on the network etc. They are various techniques available for lossy and lossless compressions. One of most popular compression techniques, JPEG (Joint Photographic Experts Group) uses Discrete Cosine Transformation (DCT) based compression technique. Currently wavelet based compression techniques are used for higher compression ratios with minimal loss of data.

## 2.6 RELATED WORKS

A number of works have been proposed on artificial neural network and intelligent fertilizer application management systems. Saiful *et' al* (2010) developed an intelligent system for automatic control of water and fertilizer application. Soluble fertilizers are required for the direct delivery of fertilizers through drip irrigation and pumping and injection systems to introduce the fertilizers directly into the irrigation. Accurate and uniform application of nutrients to the wet area was provided by fertigation, where the active roots were concentrated. The design provides control of fertilizer mixing process using precise proportional pump injector flow rate with control time based injection at pre decided electrical conductivity (EC) value followed by plant nutrient uptake rate on time-based irrigation system for fertigation. The Planning of the irrigation system and nutrient supply to the crops according to their physiological stage of development, and consideration of the soil and climate characteristics brings good result in high yields and high quality crops. The limitation of the project is that it only ensure accurate mixing of the fertilizer in the tank but does not ensure the supply of exact amount of fertilizer needed at different stages of plant growth.

Jianloi *et' al* (2010) developed an intelligent system to automatically control the varying rate of applying fertilizer to plant. Four inputs which are feedback from sensors, tractor speed, fertilizer applicator volume and parameter, and GPS/ GIS/ PC was analyzed by the controller. After this analysis by the controller, the controller controlled the hydraulic valve and sends the serial data towards LCD screen. The limitation of this system is that it can only apply fertilizer to the soil when needed but without prior determination of the exact amount of fertilizer needed by the plant.

Mohd Salih *et' al* (2012) developed a solar powered automated fertigation control system for melon (Cucumis Melo) cultivation in green house. The system was powered with a solar system and tested on its effectiveness to control the nutrient mixing process and injecting nutrient solutions according to plants growth rate and also monitor all key parameters in fertigation system at the same time. The quality of nutrients solution level was manually checked using Electrical Conductivity (EC) meter. A predefined EC value was used as single input that control all automated processes in cucumis melo L. cultivation that was using the fertigation system. The system was developed using three cylindrical polyethylene tanks. The stocks of fertilizers were placed in two 30 litres tanks, and another 60 litres tank was used for mixing. Two fertilizer injectors were used in development of the system, three units of 12 V solenoid valve was used in the system to control water flow to the mixing tank and to control nutrient flow to the irrigation piping system. An ultrasonic sensor used as level sensor to monitor nutrient level in the mixing tank. The project was developed and tested to present a low cost solution for precise control of fertilizer mixing and irrigation to local farmers. The limitation of the project is that it only ensure accurate mixing of the fertilizer in the tank but does not ensure the supply of exact amount of fertilizer needed at different stages of plant growth.

Kaur (2013) developed an automated nutrient composition control Fertigation system with the help of a programmable microcontroller PIC16F877A. The pH readings were used to control availability of nutrients in the fertilizer solutions and the EC value was used to give information about the quantity of fertilizer being injected into the solution, if the EC readings of the solution is higher than the require amount, it can be understood that higher amounts of fertilizer has been injected in the fertilizer solution. Fertilizer tanks to deliver fertilizers and mixing tanks to mix fertilizers were used in this system. The control units like solenoid flow valves operated by relays circuits were available that allow fertilizer tanks to be turned open at pre -set times to deliver fertilizer in mixing tank. Solenoid valve was set to be turned ON and OFF according to a pre -determined program that controls the valve according to the pH and EC signal of solution. . The limitation of the project is that it only ensure accurate mixing of the fertilizer in the tank but does not ensure accurate supply of fertilizer needed at different stages of plant growth

Boopathy *et' al* (2014) developed a system that monitors the basic parameters in horticulture field such as pH level, temperature, soil moisture, water flow and soil characteristics. This system was used to automatically apply fertilizers based on the measured parameters in the soil in order to yield effective growth. PH sensor, level sensor, moisture sensor, temperature sensor and humidity sensor were used to measure the different basic parameters of the soil. The fertigation was automated using the information derived from these sensors. The system also consisted of an inlet water tank for the mixing of the fertilizer with water and a fertilizer outlet valve control for controlling the release of the mixed fertilizer to the soil. The whole system was integrated using a microcontroller MSP430. The limitation of this system is that it can only apply fertilizer to the soil when needed but without prior determination of the exact amount of fertilizer needed by the plant.

Hamidreza and Rasool (2015) developed an Artificial Neural Network (ANN) for Predicting Soil Type Classification. The study was carried out on the soil of Shahrekord in Iran using a database consists of 120 soil samples. Several training functions and algorithms were used in the ANN modeling in order to evaluate and compare the performance of each training method. The neural network used in this study had an input layer, an output layer and a hidden layer. The input layer includes 7 variables (MC, LL PL, SPT, X, Y, Z) and the output layer has only one parameter (soil type classification) while the hidden layer has 15 neurons. The number of nodes in the hidden layer was determined by trial and error. Relations of coefficient of residual mass (CRM), coefficient of determination (COD) and root mean square error (RMSE) were used to evaluate the performance of the ANN model and the result shows that the Levenberg-Marquardt training function with very high accuracy in network training is the best training function suitable for the prediction of geotechnical parameters of soil, including soil type.

Odílio *et' al.* (2015) developed an artificial neural network to serve as an alternative to volumetric water balance in drip irrigation management in watermelon crop. The volumetric water balance was taken as the standard for comparing the management carried out with the implementation of ANN. Multilayer Perceptron (MLP) network was used, the network had an input layer, a hidden layer and an output layer. At the input layer of the network, values for soil moisture obtained with capacitive sensors in land cultivated with irrigated watermelon was used. The intermediate or hidden layer was made of neurons, their amount was defined by tests carried out to meet the demands of the desired application, receiving as stimuli the responses obtained with the previous layer (input layer). The output layer consisted of one neuron that represent the irrigation time and back- propagation algorithm was used for training the network. This algorithm consists of two stages: the first feed- forward, where the outputs for each layer are calculated; the next step is known as back propagation, where the weights for all layers of the network are updated. The mean squared error and linear regression were used for the evaluation of the network. The limitation of the work is that quick learning cannot be achieved because its convergence speed in training is smaller compare to other ANN architectures.

Yin and Zhang (2015) developed a Fertigation control system based on embedded platform and self-adaptive control strategy. The system was made of open-tank mixing equipment with automatic control system based on embedded platform. The open-tank mixing equipment consisted of different tanks in which different fertilizers needed were stored and mixed with water appropriately. In the embedded platform, STM32, and ARM processor, was used as MCU (micro controller unit), LCD with touch screen was used as HMI (human-machine interface), µC/OS-IIis used for multi-task scheduling. On the basis of embedded platform, ANN-PID self-adaptive control strategy was proposed to control the water-fertilizer process and EC (electrical conductivity) sensor was used for indirect measurement of the concentration of nutrient solution in the soil before fertilizer application.

Ghorban and Yaser (2015) developed an artificial neural network model for the prediction of milk price for five month time horizon in Iran. The model was developed along with an Auto-regressive integrated moving average (ARIMA) model; Data from February 2006 to March 2013 were collected from Bureau of Animal Husbandry and Agriculture Support of Iran for the development of the model. Multi-layered perceptron neural network was used and the data collected serve as the input to the network, logistic functions (hyperbolic tangent and Sigmoid tangent) was used in the hidden layer and linear activity function was used in the output layer and back-propagation learning algorithm was used for training the network. Mean square error (MSE) was used to evaluate the performance of the two models and the results demonstrated that artificial neural network presents more accurate prediction compared to ARIMA. The summary of all the aforementioned related works is described in table 2.1

**Table 2.4: Summary table for the related works**

| Title of the Work | Work Done | Methodology | Limitation of the work |
|---|---|---|---|
| Saiful *et' al* (2010) | Intelligent system for automatic control of water and fertilizer application | The design provides control of fertilizer mixing process using precise proportional pump injector flow rate with control time based injection at pre decided electrical conductivity (EC) value followed by plant nutrient uptake rate on time-based irrigation system for fertigation. | The limitation of the project is that it only ensure accurate mixing of the fertilizer in the tank but does not ensure the supply of exact amount of fertilizer needed at different stages of plant growth. |
| Jianloi *et' al* (2010) | Intelligent system to automatically control the varying rate of applying fertilizer to plant | Four inputs which are feedback from sensors, tractor speed, fertilizer applicator volume and parameter, and GPS/ GIS/ PC was analyzed by the controller | The limitation of this system is that it can only apply fertilizer to the soil when needed but without prior determination of the exact amount of fertilizer needed by the plant. |
| Mohd Salih *et' al* (2012) | solar powered automated fertigation control system for melon (Cucumis Melo) cultivation in green house | The quality of nutrients solution level was manually checked using Electrical Conductivity (EC) meter. A predefined EC value was used as single input that control all automated processes in cucumis melo L. cultivation that was using the fertigation system | It only ensures accurate mixing of the fertilizer in the tank but does not ensure the supply of exact amount of fertilizer needed at different stages of plant growth. |

| | | | |
|---|---|---|---|
| Kaur (2013) | Automated nutrient composition control Fertigation system | The pH readings were used to control availability of nutrients in the fertilizer solutions and the EC value was used to give information about the quantity of fertilizer being injected into the solution | The limitation of the project is that it only ensure accurate mixing of the fertilizer in the tank but does not ensure accurate supply of fertilizer needed at different stages of plant growth |
| Boopathy *et' al* (2014) | Intelligent system that monitors the basic parameters in horticulture field and automatically apply fertilizer based on the measured parameter. | The fertigation was automated using the information derived from the PH sensor, level sensor, moisture sensor, temperature sensor and humidity sensor were used to measure the different basic parameters of the soil. | The system can only apply fertilizer to the soil when needed but without prior determination of the exact amount of fertilizer needed by the plant. |
| Odílio *et' al.* (2015) | artificial neural network to serve as an alternative to volumetric water balance in drip irrigation management in watermelon crop | Multilayer Perceptron (MLP) network with back propagation training algorithm | The limitation of the work is that quick learning cannot be achieved because its convergence speed in training is smaller compare to other ANN architectures. |

| | | | |
|---|---|---|---|
| Hamidreza and Rasool (2015) | Artificial Neural Network (ANN) for Predicting Soil Type Classification | Several training functions and algorithms were used in the ANN modeling in order to evaluate and compare the performance of each training method | |
| Ghorban and Yaser (2015) | Artificial neural network model for the prediction of milk price for five month time horizon in Iran | The model was developed and compared along with an Auto-regressive integrated moving average (ARIMA) model | |
| Hamidreza and Rasool (2015) | Artificial Neural Network (ANN) for Predicting Soil Type Classification | Several training functions and algorithms were used in the ANN modeling in order to evaluate and compare the performance of each training method | |

# CHAPTER 3

## METHODOLOGY

### 3.1 DESIGN OVERVIEW

The execution of this project started with the acquisition of image data for every stages of the growth of tomato plant. Follow by dataset based on the fertilizer requirement at these different growth stages of the tomato plant. Some preprocessing actions were performed on the acquired images before they were trained to be recognized by the developed model. An artificial neural network system was developed and trained using the established dataset, after the development and training of the model, a GUI was developed in order to establish an easy-to-use and user friendly model for the tomato farmers. Figure 3.1 describes the block diagram for all the operations that were performed during the development of the system.

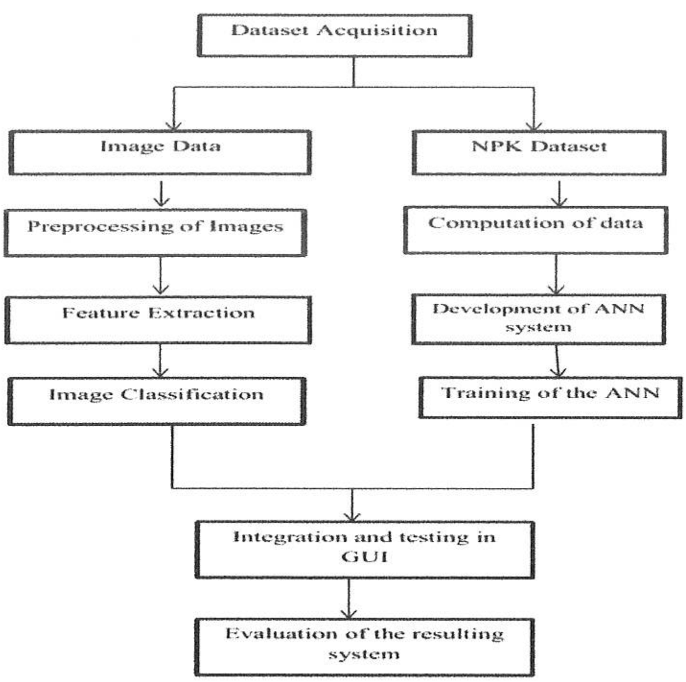



Figure 3.1: Block diagram for the development of the DSS system.

### 3.2.1 Data acquisition

The data acquired for the development of the system was in two places. The first data which was image data for the different growth stages of the tomato plant. The data was trained to be recognized by the developed system. The figure 3.3 below shows the set of images acquired for the system.

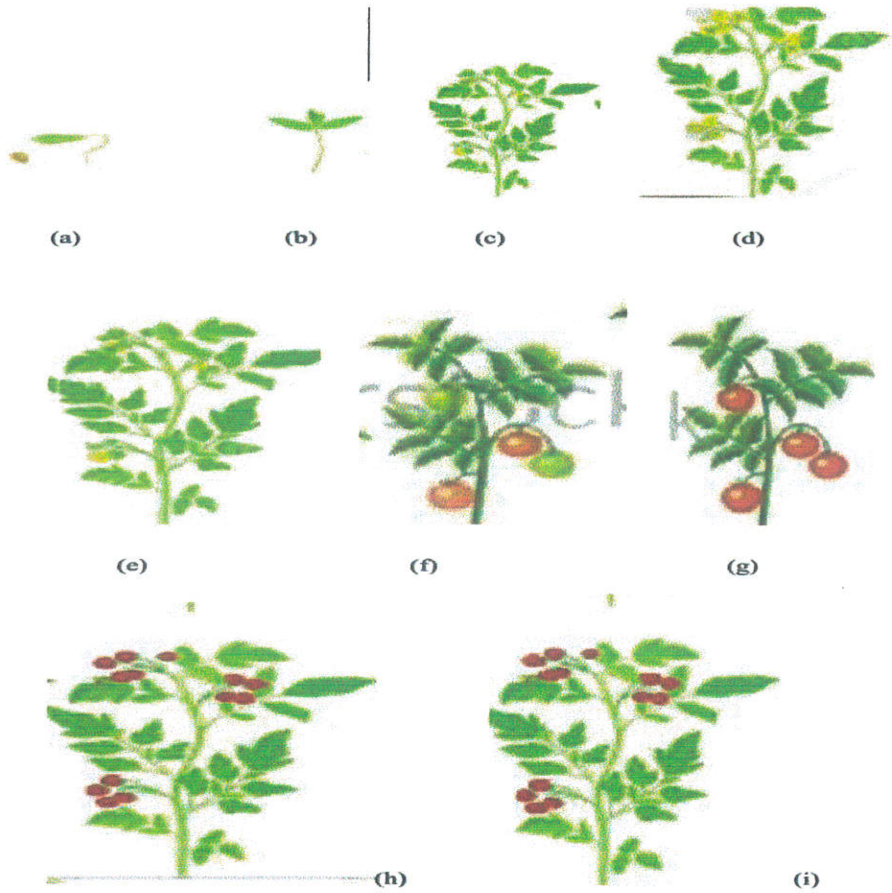


Figure 3.3.: Set of Tomato Images for the different growth stages

(a) Is the planting stage (b) is the Vegetative stage (c) is the Flowering stage (d) is the Fruit set stage (e) is the Fruit growth stage (f) is the First harvest stage (g) is the Second harvest stage (h) is the Third harvest stage (i) Last harvest stage

The second data acquired was the dataset that was used in the development, training and testing of the artificial neural network model. For this project, the data needed for the development of the model was formulated using the fertilizer requirement of tomato at every stage of their growth. The figure 3.4 below is the diagram of the dataset used for the development of the system.

| 1 | Planting stages | Nitrogen | Phosphorous | Potassium | Output |
|---|---|---|---|---|---|
| 2 | 1 | 1 | 0 | 1 | nodispensing |
| 3 | 2 | 8 | 2 | 13 | nodispensing |
| 4 | 3 | 9 | 2 | 4 | nodispensing |
| 5 | 4 | 6 | 2 | 9 | nodispensing |
| 6 | 5 | 24 | 6 | 38 | nodispensing |
| 7 | 6 | 6 | 2 | 9 | nodispensing |
| 8 | 7 | 3 | 1 | 4 | nodispensing |
| 9 | 8 | 2 | 1 | 2 | nodispensing |
| 10 | 9 | 2 | 1 | 3 | nodispensing |
| 11 | 1 | 1 | 0 | 0 | dispense |
| 12 | 3 | 1 | 1 | 0 | dispense |
| 13 | 4 | 0 | 0 | 1 | dispense |
| 14 | 2 | 6 | 1 | 10 | dispense |
| 15 | 3 | 10 | 3 | 4 | nodispensing |
| 16 | 5 | 0 | 1 | 1 | dispense |
| 17 | 6 | 7 | 3 | 7 | nodispensing |
| 18 | 7 | 4 | 1 | 4 | nodispensing |
| 19 | 8 | 2 | 1 | 0 | dispense |
| 20 | 9 | 3 | 1 | 3 | nodispensing |
| 21 | 1 | 0 | 0 | 0 | dispense |
| 22 | 3 | 8 | 2 | 3 | dispense |
| 23 | 4 | 0 | 1 | 1 | dispense |
| 24 | 5 | 1 | 1 | 3 | dispense |
| 25 | 2 | 9 | 3 | 5 | nodispensing |
| 26 | 6 | 5 | 2 | 3 | dispense |
| 27 | 1 | 0 | 1 | 0 | dispense |
| 28 | 7 | 2 | 0 | 1 | dispense |
| 29 | 8 | 2 | 0 | 0 | dispense |
| 30 | 9 | 2 | 0 | 3 | dispense |

Figure 3.4: Sample NPK Dataset used for training the ANN system.

The dataset used has 231 samples of data consisting of two sections, the input and output sections, the input section consist of the; the planting stage, the nitrogen content, the phosphorous content and the potassium content while the output states whether to dispense or not to dispense.

### 3.2.2 Preprocessing of Acquired Images

The acquired images were passed through three preprocessing stages in other enhance them for feature extraction. The figure 3.5 below describes the preprocessing actions that were performed on the acquired images.

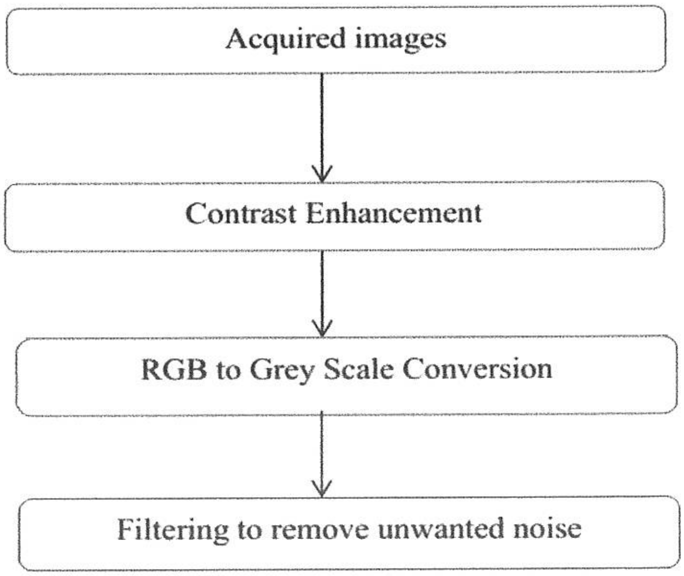
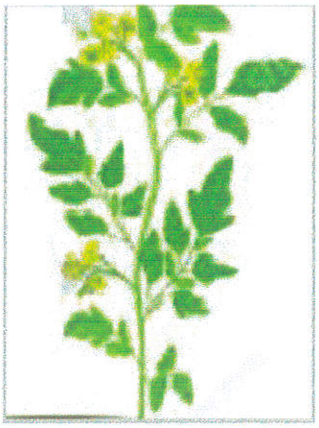



Figure 3.5: Image Preprocessing Stages

#### 3.2.2.1 Contrast Enhancement

The contrast enhancement of the images was the first preprocessing action that was carried out in order to improve the quality of the images. Figure 3.6 shows the contrast enhanced image (b) from the original image (a)



(a)

(b)

Figure 3.6: original image (a) and (b)Contrast Enhancement

#### 3.2.2.2 RGB to Grey scale Conversion

The second preprocessing stage involves the conversion of resulting image from stage one to grey scale image. This is done to ensure a more accurate extraction of features from the images. The figure 3.7 shows the conversion of the contrast enhanced image (a) to grey scale (b).

(a) (b)

Figure 3.7: (a) RGB image (b) Grey scale conversion

#### 3.2.2.3 Application of Filter

The third stage involved the application of median filter to the grey level image; this is done to remove the unwanted noise in the images. The figure 3.8 shows the grey level image (a) and the filtered image (b)

(a) (b)

Figure 3.8: (a) Grey Scale Image (b) Filtered Image

### 3.2.3 Feature Extraction

After the preprocessing of the acquired images, a feature extraction process was performed on the images in order to enable the system to be able to differentiate from each image. The number of connected regions in the images was determined, the perimeter of these regions was determined, also the area of the regions was determined, the minor axis length and the major axis length of the connected regions was determined. These parameters differs for the all the images and was used to differentiate between the images for each stage of growth of the tomato plant. The features extracted from the images are described in the table 3.1 below.

| Images for the growth stages | n | Mean of Area | Mean of perimeter | Mean of Minor Axis Length | Mean of Major Axis Length |
|---|---|---|---|---|---|
| Planting stage | 2 | 918 | 138.1445 | 35.7321 | 26.6207 |
| Vegetative stage | 1 | 4157 | 441.3690 | 99.5434 | 72.2392 |
| Flowering stage | 6 | 5.4067e+03 | 214.8757 | 47.1202 | 30.9415 |
| Fruit set stage | 9 | 3.7727e+03 | 148.4619 | 36.0364 | 22.7619 |
| Fruit growth stage | 2 | 16125 | 488.1415 | 133.7536 | 83.7441 |
| First harvest stage | 4 | 7.9385e+03 | 274.2033 | 63.0926 | 51.6553 |
| Second harvest stage | 1 | 13939 | 628.4080 | 157.3839 | 121.3396 |
| Third harvest stage | 6 | 5.3063e+03 | 217.7000 | 55.6484 | 32.7885 |
| Last harvest stage | 12 | 2.4372e+03 | 95.5554 | 28.6572 | 17.4129 |

### 3.2.4 Designing the ANN

At this stage, the number of hidden layers, the neurons in each layer, transfer function in each layer, training function, weight/bias learning function, and performance function was specified. The multilayer perceptron MLP neural network was used since it follows feed-forward architecture and supervised training. The perceptron network that was developed has a layer of input, a layer of output and ten hidden layers in between. The input layer consists of raw data which include the planting stage, the nitrogen, potassium, and phosphorous contents of the soil. In addition, the hidden layers have weights and generate output layer. MLP uses back propagation as its training algorithm. This algorithm repeats presentation of the input data to the neural network. In each iteration, the output data is compared with the desired one, error is computed and fed back (back propagated) to the network. This feedback is used to modify the weights of neurons. Finally, the desired output was generated based on iterations. The diagram of the developed ANN network is described in the figure 3.9;

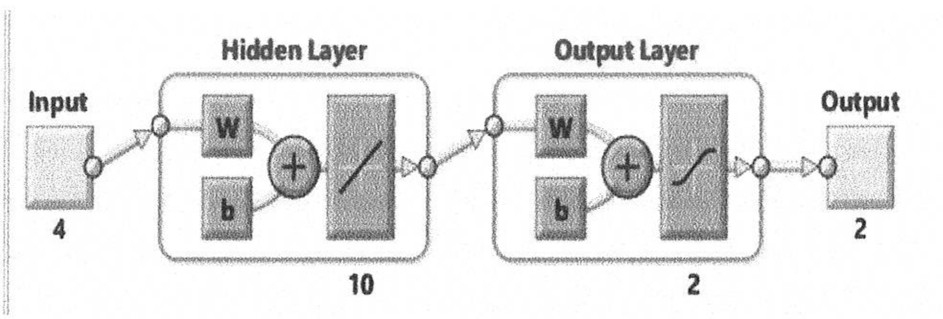



Figure 3.9: The developed ANN system.

From the diagram, it is seen that the developed ANN model has four neurons and in the input layer, ten neurons in the hidden layer, and two neurons in the output layer. In the building of the model, the dataset acquired was imported in to the MATLAB workspace. After the importation of the dataset into the workspace, the target output for the dataset is also imported in to the same workspace. After the importation of the input and the target data of the dataset, the ANN model was developed in the command window of the MATLAB using the neural network tool.

### 3.2.5 Training the network

The acquired dataset was divided in to three parts, the first part consists of 70% of the dataset which was used for training, the second part consists of 15% of the dataset which was used for testing, the third part consist of 15% of the dataset which was used for the validation of the system. During the training process, the name of the input data to be trained is specified and also the name of the target output of the data. Also the training parameters which include the goal, the no of epochs, the minimum gradient were set. After all the parameters were set, the training process was initiated.

## 3.3 Developing the graphical user interface (GUI) for integrating components and testing of the system.

A graphical user interface was developed for the system. The GUI comprises of two sections, the first section handles the image processing aspect of the system. In this first section, the loading of the images is done, the three preprocessing action is done on the selected image, and the extraction of features is done on the preprocessed images. The images acquired are for each stage in the growth of the tomato plant. After the preprocessing of these images and the features are extracted, the system was able to determine the stage for every input image. The second section of the GUI is for the selection of the nitrogen content, phosphorous content and potassium content of the soil. The GUI is developed such that after it identifies the stage of growth of the tomato from the input image, and the nitrogen, potassium and phosphorous contents are selected, it will state whether to dispense or not to dispense the fertilizer. This GUI will aid easy decision making by tomato farmers in the Fertigation of tomato plant. The GUI was designed from the GUI workspace in MATLAB. The figure below shows the developed GUI for the system.

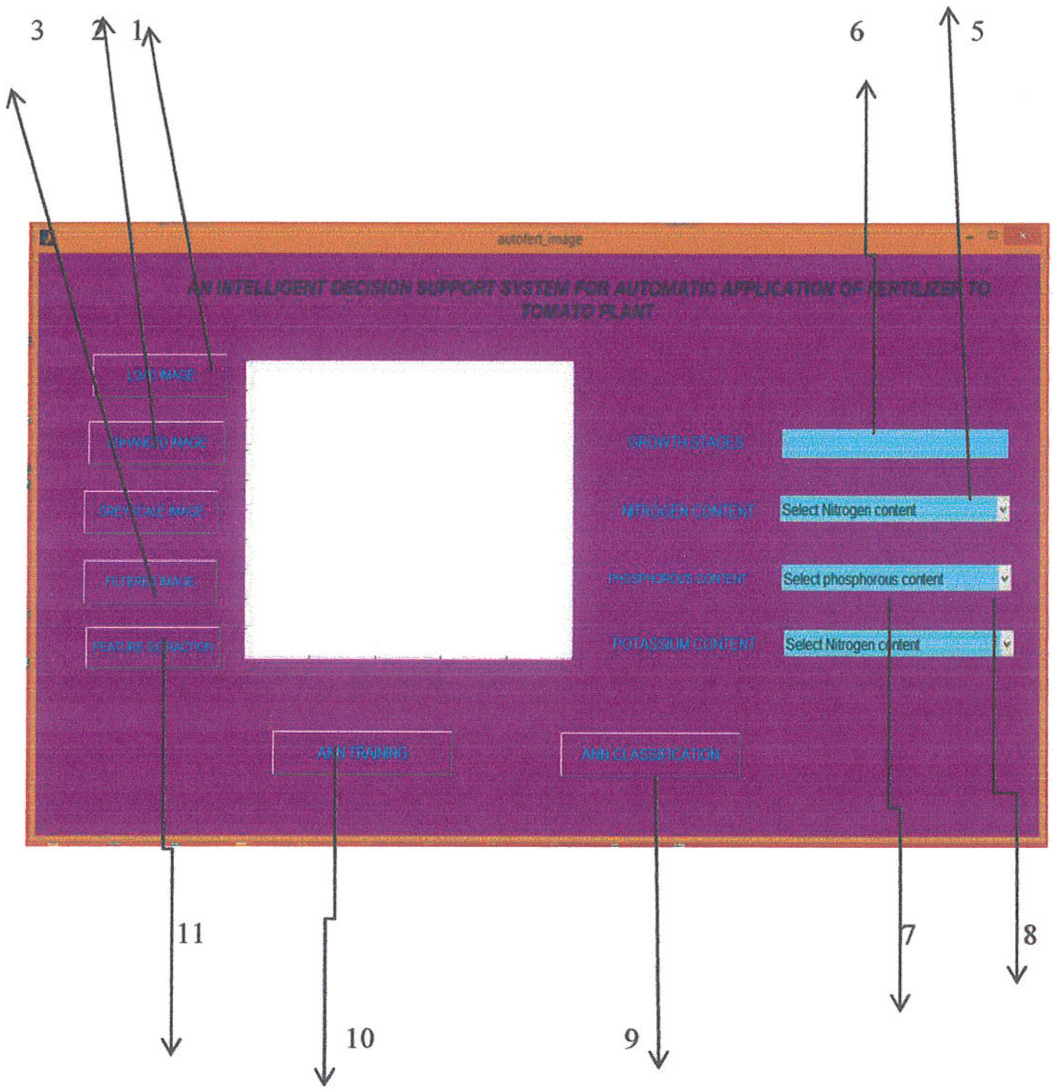



Figure 3.3: The developed User Interface for the system.

From the figure 3.3 above, it is seen that the GUI is developed in a way that the planting stages and the NPK (nitrogen, phosphorous and potassium) content of the soil are used to determine the need to dispense or not to dispense fertilizer to the plant. The GUI has seven buttons and three pop menus. The first button indicated with arrow named 1 is for loading the image. The second button indicated with arrow 2 is for enhancing the selected image. The third button indicated with arrow 3 is for converting the enhanced image in to a grey level image. The fourth button indicated with arrow 4 is for removing the unwanted noise from the image. The fifth button indicated with arrow 5 is for performing the feature extraction on the selected image. The sixth button indicated with arrow 8 is for the training of the ANN. The first pop menu is for selecting the nitrogen content, the second is for selecting the phosphorous content and the third is for selecting the potassium content.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Brief Introduction

This chapter gives the overview of the results of the GUI implantation of the developed system. These results are tested with the acquired dataset that was used in the training of the ANN. Also the result of the trained ANN is discussed in this chapter. The evaluation of the trained ANN is also done in this chapter.

## 4.2 Evaluation of the developed ANN using the number of hidden layers

Table 4.1 shows the accuracy results for different number of hidden layers being used for developing the ANN. When one hidden layers was used in training the network, the accuracy (the closeness of the actual output to the target output) that was arrived at was 48.13%. When the number of hidden layers was increased to two, the accuracy increased to 63.22%. When the hidden layers were increased to four, the accuracy was 79.9%. As the number of hidden layers was increased, the accuracy of the network increases and vice versa. Therefore, in order to ensure a more accurate system, an increased number of hidden layers should be used in the training of the network.

Table 4.1: Accuracy results for different number of hidden neurons

| Number of Hidden Layers | Accuracy (%) |
|---|---|
| 1 | 48.13% |
| 2 | 63.22% |
| 3 | 71.49% |
| 4 | 79.90% |
| 5 | 83.12% |
| 6 | 83.89% |
| 7 | 85.69% |
| 8 | 87.83% |
| 9 | 90.08% |
| 10 | 91.9% |

**4.3 Testing the results of the GUI implementation of the system with the acquired data**

In this section, some instances were taken from the result of the GUI implementation of the system, and they were verified with the dataset used in training the ANN. From the dataset, the stages in the growth of tomato plant that requires application of fertilizer are nine(planting stage, vegetative stage, flowering stage, fruit set stage, fruit growth stage, first harvest stage, second harvest stage, third harvest stage, last harvest stage), the fertilizer nutrient considered are three(Nitrogen, Phosphorous and Potassium) and the output are "dispense" and "no dispense".

The table 4.2 below shows the result of the GUI implementation of the system with the acquired data.

Table 4.2: The result of the test samples and their correctness with the dataset used for training the system

| Samples | Soil Parameters (Kg/ha) | | | | Output from the designed system | Correctness of the decision made |
|---|---|---|---|---|---|---|
| | Stages | N | P | K | | |
| 1 | Planting | 1 | 0 | 1 | dispense | Not Correct |
| 2 | Vegetative | 8 | 2 | 13 | No dispense | Correct |
| 3 | Flowering | 9 | 2 | 4 | No dispensing | Correct |
| 4 | Fruit set | 6 | 2 | 9 | No dispensing | Correct |
| 5 | Fruit growth | 24 | 6 | 38 | No dispensing | Correct |
| 6 | First harvest | 6 | 2 | 9 | No dispensing | Correct |
| 7 | Second harvest | 1 | 1 | 4 | Dispense | Correct |
| 8 | Third harvest | 2 | 0 | 1 | Dispense | Correct |
| 9 | Last harvest | 2 | 1 | 3 | Dispense | Not Correct |
| 10 | Planting | 0 | 0 | 1 | Dispense | Correct |
| 11 | Vegetative | 1 | 1 | 2 | Dispense | Correct |
| 12 | Flowering | 2 | 4 | 3 | Dispense | Correct |

From the test samples taken, the accuracy of the designed system can be calculated as 10/12 which is equal to 91.67%.

### 4.4 Validation of the developed system with another system

The figure 4.1 below describes the GUI of a DSS system for automatic fertilizer application to tomato plant using ANN. In this system, the user can select the current growth stage of the tomato plant, the nitrogen, phosphorous and potassium content of the soil, after selecting all these parameters, the system will tell whether to dispense fertilizer or not. But for a user that cannot identify the identify the current growth stage of the tomato by mere looking at the plant, the system may not be efficient for the person because he may not be able to select the right growth stage for the plant. But for the developed system in this project, such user will only select the picture similar to the current growth stage of his plant, the system will tell him the name of the stage, and he will select the nitrogen, phosphorous and potassium content of the soil and the system will tell him whether to apply fertilizer or not.

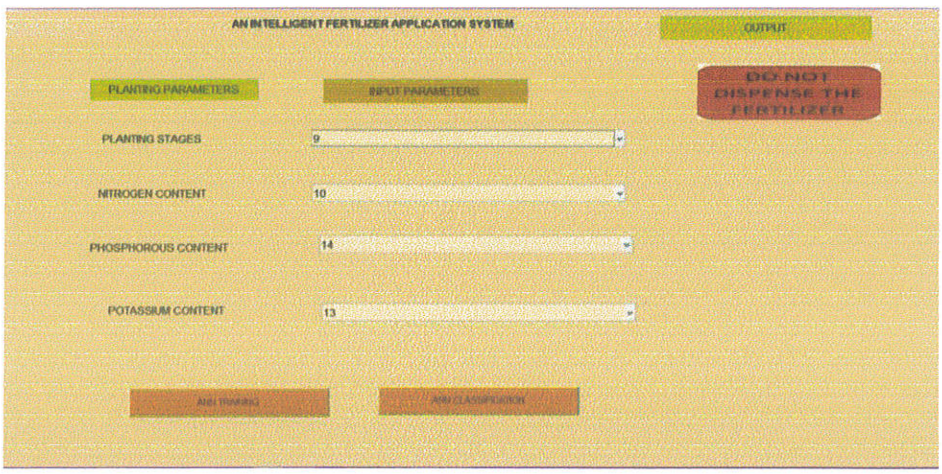



Figure 4.1: The GUI of a DSS system for automatic fertilizer application to tomato plant using ANN

# CHAPTER FIVE

## CONCLUSION AND RECOMMENDATION

### 5.1 Conclusion

In this project, MATLAB GUI tools have been used to develop a graphical user interface through which the user can select any image corresponding to the current growth stage of the tomato plant, and then select the contents of nitrogen phosphorous and potassium in the soil. With the 91.67% accuracy of the designed DSS system, a hardware implementation of this system can ensure efficient and automatic application of fertilizer to tomato plant.

### 5.2 Recommendation

Future works directions are suggested to be towards developing decision support systems for other cash crops and other crops that require high and timed application of fertilizer in order achieve their maximum productivity. Also hardware implantations of these systems are suggested in other future works.

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# APPENDIX

## Dataset Used For the Training of the System

| 1 | Planting stages | Nitrogen | Phosphorous | Potassium | Output |
|---|---|---|---|---|---|
| 2 | Planting | 1 | 0 | 1 | nodispensing |
| 3 | Vegetative | 8 | 2 | 13 | nodispensing |
| 4 | Flowering | 9 | 2 | 4 | nodispensing |
| 5 | Fruit set | 6 | 2 | 9 | nodispensing |
| 6 | Fruit growth | 24 | 6 | 38 | nodispensing |
| 7 | First harvest | 6 | 2 | 9 | nodispensing |
| 8 | Second harvest | 3 | 1 | 4 | nodispensing |
| 9 | Third harvest | 2 | 1 | 2 | nodispensing |
| 10 | Last harvest | 2 | 1 | 3 | nodispensing |
| 11 | Planting | 1 | 0 | 0 | dispense |
| 12 | Flowering | 1 | 1 | 0 | dispense |
| 13 | Fruit set | 0 | 0 | 1 | dispense |
| 14 | Vegetative | 6 | 1 | 10 | dispense |
| 15 | Flowering | 10 | 3 | 4 | nodispensing |
| 16 | Fruit growth | 0 | 1 | 1 | dispense |
| 17 | First harvest | 7 | 3 | 7 | nodispensing |
| 18 | Second harvest | 4 | 1 | 4 | nodispensing |
| 19 | Third harvest | 2 | 1 | 0 | dispense |
| 20 | Last harvest | 3 | 1 | 3 | nodispensing |
| 21 | Planting | 0 | 0 | 0 | dispense |
| 22 | Flowering | 8 | 2 | 3 | dispense |
| 23 | Fruit set | 0 | 1 | 1 | dispense |
| 24 | Fruit growth | 1 | 1 | 3 | dispense |
| 25 | Vegetative | 9 | 3 | 5 | nodispensing |
| 26 | First harvest | 5 | 2 | 3 | dispense |
| 27 | Planting | 0 | 1 | 0 | dispense |
| 28 | Second harvest | 2 | 0 | 1 | dispense |
| 29 | Third harvest | 2 | 0 | 0 | dispense |
| 30 | Last harvest | 2 | 0 | 3 | dispense |
| 31 | Fruit growth | 20 | 1 | 21 | dispense |
| 32 | Vegetative | 7 | 1 | 11 | dispense |
| 33 | Flowering | 6 | 1 | 3 | dispense |
| 34 | Fruit set | 1 | 1 | 1 | dispense |
| 35 | Second harvest | 4 | 2 | 5 | nodispensing |
| 36 | Third harvest | 1 | 1 | 2 | dispense |
| 37 | First harvest | 0 | 1 | 1 | dispense |
| 38 | Planting | 0 | 1 | 1 | dispense |
| 39 | Fruit growth | 2 | 2 | 3 | dispense |
| 40 | Third harvest | 0 | 1 | 2 | dispense |
| 41 | Vegetative | 5 | 0 | 9 | dispense |
| 42 | Fruit set | 2 | 2 | 1 | dispense |
| 43 | Second harvest | 4 | 1 | 7 | nodispensing |
| 44 | Third harvest | 2 | 2 | 2 | nodispensing |
| 45 | Last harvest | 0 | 0 | 2 | dispense |
| 46 | Planting | 0 | 0 | 0 | dispense |
| 47 | Third harvest | 2 | 3 | 2 | nodispensing |
| 48 | Flowering | 5 | 2 | 4 | dispense |
| 49 | Vegetative | 11 | 4 | 13 | nodispensing |
| 50 | Fruit growth | 2 | 0 | 2 | dispense |
| 51 | First harvest | 6 | 1 | 2 | dispense |
| 52 | Planting | 0 | 1 | 0 | dispense |
| 53 | Vegetative | 7 | 2 | 7 | dispense |
| 54 | Fruit set | 3 | 1 | 6 | dispense |
| 55 | Second harvest | 5 | 4 | 5 | nodispensing |
| 56 | Third harvest | 3 | 2 | 2 | nodispensing |
| 57 | Last harvest | 0 | 0 | 3 | dispense |
| 58 | First harvest | 10 | 3 | 9 | nodispensing |
| 59 | Second harvest | 3 | 3 | 5 | nodispensing |
| 60 | Third harvest | 3 | 3 | 2 | nodispensing |

| | | | | |
|---|---|---|---|---|
| 61 | 10 | 5 | 5 | dispense |
| 62 | 4 | 4 | 4 | nodispensing |
| 63 | 1 | 1 | 3 | dispense |
| 64 | 4 | 1 | 0 | dispense |
| 65 | 3 | 1 | 3 | dispense |
| 66 | 4 | 3 | 5 | dispense |
| 67 | 1 | 1 | 1 | dispense |
| 68 | 4 | 4 | 4 | nodispensing |
| 69 | 1 | 0 | 2 | dispense |
| 70 | 2 | 3 | 4 | dispense |
| 71 | 2 | 1 | 1 | dispense |
| 72 | 0 | 0 | 0 | dispense |
| 73 | 0 | 0 | 0 | dispense |
| 74 | 5 | 5 | 8 | dispense |
| 75 | 7 | 1 | 3 | dispense |
| 76 | 3 | 2 | 3 | dispense |
| 77 | 10 | 3 | 14 | dispense |
| 78 | 3 | 3 | 2 | dispense |
| 79 | 0 | 1 | 3 | dispense |
| 80 | 4 | 4 | 3 | nodispensing |
| 81 | 10 | 5 | 13 | dispense |
| 82 | 2 | 1 | 2 | dispense |
| 83 | 21 | 4 | 8 | dispense |
| 84 | 5 | 1 | 6 | dispense |
| 85 | 3 | 1 | 3 | nodispensing |
| 86 | 2 | 0 | 2 | dispense |
| 87 | 0 | 0 | 0 | dispense |
| 88 | 9 | 2 | 3 | dispense |
| 89 | 4 | 2 | 3 | dispense |
| 90 | 6 | 3 | 5 | dispense |
| 91 | 0 | 0 | 2 | dispense |
| 92 | 3 | 4 | 3 | nodispensing |
| 93 | 20 | 4 | 30 | dispense |
| 94 | 2 | 2 | 4 | nodispensing |
| 95 | 1 | 2 | 0 | dispense |
| 96 | 11 | 2 | 11 | dispense |
| 97 | 0 | 2 | 1 | dispense |
| 98 | 4 | 3 | 3 | dispense |
| 99 | 1 | 2 | 4 | dispense |
| 100 | 7 | 4 | 11 | dispense |
| 101 | 6 | 1 | 2 | dispense |
| 102 | 1 | 0 | 4 | dispense |
| 103 | 5 | 4 | 5 | nodispensing |
| 104 | 15 | 4 | 19 | dispense |
| 105 | 2 | 1 | 5 | nodispensing |
| 106 | 9 | 3 | 6 | nodispensing |
| 107 | 1 | 1 | 4 | dispense |
| 108 | 4 | 5 | 5 | nodispensing |
| 109 | 1 | 0 | 3 | dispense |
| 110 | 5 | 1 | 7 | dispense |
| 111 | 5 | 4 | 4 | nodispensing |
| 112 | 1 | 1 | 3 | dispense |
| 113 | 9 | 2 | 9 | nodispensing |
| 114 | 25 | 6 | 39 | nodispensing |
| 115 | 5 | 5 | 5 | nodispensing |
| 116 | 5 | 5 | 3 | nodispensing |
| 117 | 12 | 6 | 20 | dispense |
| 118 | 2 | 0 | 3 | dispense |
| 119 | 2 | 1 | 3 | dispense |
| 120 | 3 | 1 | 4 | dispense |

| | | | | |
|---|---|---|---|---|
| 121 | 9 | 2 | 9 | nodispensing |
| 122 | 0 | 2 | 4 | dispense |
| 123 | 0 | 1 | 2 | dispense |
| 124 | 6 | 6 | 6 | nodispensing |
| 125 | 7 | 2 | 3 | dispense |
| 126 | 17 | 2 | 13 | dispense |
| 127 | 3 | 3 | 3 | nodispensing |
| 128 | 1 | 1 | 4 | dispense |
| 129 | 5 | 1 | 2 | dispense |
| 130 | 5 | 1 | 2 | dispense |
| 131 | 5 | 1 | 6 | dispense |
| 132 | 11 | 1 | 12 | dispense |
| 133 | 4 | 5 | 6 | nodispensing |
| 134 | 3 | 1 | 3 | nodispensing |
| 135 | 2 | 2 | 4 | nodispensing |
| 136 | 0 | 0 | 0 | dispense |
| 137 | 6 | 1 | 4 | dispense |
| 138 | 4 | 2 | 4 | dispense |
| 139 | 3 | 1 | 5 | nodispensing |
| 140 | 3 | 1 | 4 | nodispensing |
| 141 | 2 | 0 | 1 | dispense |
| 142 | 0 | 0 | 2 | dispense |
| 143 | 2 | 1 | 4 | nodispensing |
| 144 | 16 | 3 | 17 | dispense |
| 145 | 0 | 1 | 1 | dispense |
| 146 | 0 | 0 | 0 | dispense |
| 147 | 5 | 2 | 3 | dispense |
| 148 | 3 | 2 | 6 | dispense |
| 149 | 4 | 2 | 7 | nodispensing |
| 150 | 2 | 1 | 4 | nodispensing |
| 151 | 10 | 2 | 20 | dispense |
| 152 | 2 | 0 | 0 | dispense |
| 153 | 1 | 0 | 6 | dispense |
| 154 | 2 | 4 | 3 | dispense |
| 155 | 1 | 1 | 1 | dispense |
| 156 | 0 | 1 | 1 | dispense |
| 157 | 5 | 1 | 5 | dispense |
| 158 | 17 | 2 | 11 | dispense |
| 159 | 6 | 2 | 6 | dispense |
| 160 | 4 | 3 | 4 | nodispensing |
| 161 | 2 | 2 | 2 | nodispensing |
| 162 | 6 | 6 | 6 | nodispensing |
| 163 | 1 | 1 | 1 | dispense |
| 164 | 0 | 1 | 5 | dispense |
| 165 | 2 | 1 | 2 | dispense |
| 166 | 1 | 1 | 1 | dispense |
| 167 | 7 | 3 | 7 | nodispensing |
| 168 | 2 | 2 | 1 | dispense |
| 169 | 3 | 4 | 5 | nodispensing |
| 170 | 5 | 5 | 5 | dispense |
| 171 | 1 | 0 | 1 | dispense |
| 172 | 0 | 0 | 0 | dispense |
| 173 | 4 | 5 | 6 | nodispensing |
| 174 | 1 | 6 | 2 | dispense |
| 175 | 3 | 2 | 2 | dispense |
| 176 | 8 | 7 | 9 | nodispensing |
| 177 | 30 | 7 | 40 | nodispensing |
| 178 | 1 | 1 | 1 | dispense |
| 179 | 5 | 5 | 5 | nodispensing |
| 180 | 4 | 2 | 4 | dispense |

| | | | | |
|---|---|---|---|---|
| 181 | 2 | 5 | 3 | dispense |
| 182 | 5 | 6 | 7 | nodispensing |
| 183 | 0 | 2 | 7 | dispense |
| 184 | 4 | 1 | 3 | dispense |
| 185 | 1 | 0 | 1 | dispense |
| 186 | 0 | 1 | 3 | dispense |
| 187 | 5 | 2 | 4 | dispense |
| 188 | 2 | 1 | 1 | dispense |
| 189 | 1 | 1 | 0 | dispense |
| 190 | 1 | 1 | 0 | dispense |
| 191 | 0 | 0 | 0 | dispense |
| 192 | 4 | 3 | 6 | dispense |
| 193 | 0 | 0 | 2 | dispense |
| 194 | 8 | 6 | 12 | dispense |
| 195 | 3 | 0 | 3 | dispense |
| 196 | 23 | 4 | 20 | dispense |
| 197 | 1 | 2 | 1 | dispense |
| 198 | 5 | 6 | 7 | nodispensing |
| 199 | 2 | 2 | 3 | nodispensing |
| 200 | 10 | 4 | 4 | nodispensing |
| 201 | 7 | 7 | 9 | nodispensing |
| 202 | 1 | 1 | 2 | dispense |
| 203 | 0 | 1 | 0 | dispense |
| 204 | 1 | 0 | 0 | dispense |
| 205 | 2 | 5 | 1 | dispense |
| 206 | 1 | 2 | 1 | dispense |
| 207 | 6 | 6 | 6 | dispense |
| 208 | 1 | 1 | 1 | dispense |
| 209 | 0 | 1 | 1 | dispense |
| 210 | 0 | 1 | 1 | dispense |
| 211 | 0 | 0 | 0 | dispense |
| 212 | 9 | 6 | 7 | dispense |
| 213 | 2 | 1 | 1 | dispense |
| 214 | 7 | 3 | 10 | nodispensing |
| 215 | 25 | 7 | 39 | nodispensing |
| 216 | 0 | 2 | 7 | dispense |
| 217 | 0 | 1 | 1 | dispense |
| 218 | 1 | 0 | 0 | dispense |
| 219 | 0 | 0 | 1 | dispense |
| 220 | 1 | 0 | 4 | dispense |
| 221 | 10 | 6 | 10 | nodispensing |
| 222 | 2 | 2 | 3 | dispense |
| 223 | 5 | 2 | 2 | dispense |
| 224 | 19 | 6 | 20 | dispense |
| 225 | 1 | 2 | 4 | dispense |
| 226 | 0 | 0 | 0 | dispense |
| 227 | 0 | 0 | 0 | dispense |
| 228 | 11 | 1 | 14 | dispense |
| 229 | 0 | 0 | 1 | dispense |
| 230 | 3 | 0 | 1 | dispense |