**Sudan University of Sciences and Technology**
**College of Engineering**
**School of Electrical and Nuclear Engineering**

# Aflatoxin Detection in Sudanese Peanuts Using Machine Vision

# الكشف عن الأفلاتوكسين في الفول السوداني باستخدام الرؤية الآلية

**A Project Submitted In Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) In Electrical Engineering**

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# الآية

قال تعالى:

"اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ (5)"

[سورة العلق 1-5]

# DEDICATION

As well as everything that we do, we would be honored to dedicate this work to our parents for their emotional and financial support, our brothers, our sisters and our friends, especially our friend **Mohammed Hafiz**, whose has been a constant source of inspiration for us. They have given us the drive and discipline to tackle any task with enthusiasm and determination. Without their love and support this project would not have been made possible.

# ACKNOWLEDGEMENT

First and above all, we praise God, the almighty for providing us this opportunity, and granting us the capability to proceed successfully. Grateful for this opportunity, we would like to give our sincere thanks to our supervisor, **Mr. Gaafer Babiker** for his valuable guidance continues encouragement, suggestions, constructive ideas and advice in assisting us to complete this work.

# ABSTRACT

Aflatoxins are the toxic metabolites produced by certain kinds of Aspergillus molds that are found naturally all over the world; they can contaminate food crops and pose a serious health threat to humans and livestock. They have been studied extensively because of being associated with various chronic and acute diseases especially immunosuppression and cancer. Aflatoxin occurrence is influenced by certain environmental conditions such as drought seasons and agronomic practices. Peanuts is highly Susceptible for aflatoxin contamination during harvesting, production and storage. Aflatoxin detection based on chemical methods is fairly accurate. However, they are time consuming, expensive and destructive. hyperspectral imaging can be used as an alternative for detection of such contaminants in a rapid and nondestructive manner. In order to classify aflatoxin contaminated peanuts from uncontaminated ones, a compact machine vision system based on hyperspectral imaging is proposed. In the proposed system both UV and Halogen excitations are used. Under ultraviolet 365 nm illumination, aflatoxin contaminated samples exhibit bright green yellowish fluorescence (BGYF). This phenomenon is used as a base for detecting aflatoxin contaminated peanuts.

# المستخلص

الأفلاتوكسينات هي مستقلّبات سامة تنتجها أنواع معينة من فطريات ال ( Aspergillus Flavus) , والتي توجد بشكل طبيعي في جميع أنحاء العالم , وبإمكانها تلويث المحاصيل الغذائية و تشكل تهديداً صحياً خطيراً للإنسان و الماشية . تمت دراستها على نطاق واسع بسبب إرتباطها بأمراض مزمنة و حادة خاصةً ضعف المناعة و السرطان . تواجد الأفلاتوكسين يعتمد على ظروف بيئية معينة .

الفول السوداني أحد المحاصيل شديدة الحساسية للتلوث بالأفلاتوكسين أثناء الحصاد و الإنتاج و التخزين . يعتبر الكشف عن الأفلاتوكسين بالطرق الكيميائية دقيقاً إلى حد ما . و مع ذلك , فهي تعتبر طريقة تستهلك كثيراً من الوقت و مكلفة و مدمرة للعينة . يمكن إستخدام التصوير الطيفي كبديل للكشف عن تلوثات الأفلاتوكسين بطريقة سريعة غير مدمرة . من أجل فرز الفول السوداني الملوث من غير الملوث بالأفلاتوكسين ؛ تم إقتراح نظام مدمج يستعمل رؤية الآلة و معالجة الصور يعتمد على التصوير الطيفي . في النظام المقترح تم إستخدام إشعاع فوق البنفسجي و إشعاع الهالوجين . تحت إضاءة الأشعة فوق البنفسجية بطول موجي 365 نانومتر؛ تظهر العينات الملوثة بالأفلاتوكسين إشعاع أخضر مصفر ساطع . تم إستخدام هذه الظاهرة كأساس للكشف عن الفول السوداني الملوث بالأفلاتوكسين .

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| WHO | World Health Organization |
| FAO | Food Agricultural Organization |
| AFB1 | Aflatoxin B1 |
| AFB2 | Aflatoxin B2 |
| AFG2 | Aflatoxin G2 |
| PPB | Parts Per Billion |
| HPLC | High-Performance Liquid Chromatography |
| GMP | General Manufacturing Practice |
| HACCP | Hazard Analysis And Critical Control Point |
| QC | Quality Control |
| NP-HPLC | Normal Phase HPLC |
| RP-HPLC | Reversed Phase HPLC |
| RPC | Reversed Phase HPLC |
| SEC | Size Exclusion Chromatography |
| ID | Internal Diameter |
| UV | Ultraviolet |
| PLCs | Programmable Logic Controllers |
| CPU | Central Processing Unit |
| I/O | Input And Output |
| NO | Normally Open |
| VDC | Volt Direct Current |
| LAD | Ladder Diagram |
| STL | Statement List |
| FBD | Function Block Diagrams |

| | |
|---|---|
| RAM | Random Access Memory |
| ROM | Read Only Memory |
| EPROM | Erasable Programmable Read-Only Memory |
| UVEPROM | Ultraviolet Erasable Programmable Read Only Memory |
| ODE | Ordinary Differential Equation |
| FFT | Fast Fourier Transform |
| BGYF | bright green yellowish fluorescence |
| HS | Hyperspectral |
| HSI | Hyperspectral imaging |
| MHSI | Medical hyperspectral imaging |
| CMOS | Complementary Metal Oxide Semiconductor |
| CCD | Charge-Coupled Device |
| HIAT | Hyperspectral Image Analysis Toolbox |
| CenSSI | Subsurface Sensing and Imaging |
| LARSIP | Laboratory of Remote Sensing and Image Processing |
| USB | Universal Serial Bus |
| IDE | Integrated Development Environment |
| CNC | computer numerical control |
| RGB | red, green, blue |

# CHAPTER ONE
# INTRODUCTION

## 1.1 General Concepts

Aflatoxins are naturally occurring mycotoxins found on foods such as corn, peanuts, various other nuts and cottonseed. Since their discovery in the 1960s A few months after the death of more than 100.000 young Turkeys in poultry farms in England, an apparently new disease that was termed "Turkey X disease" appeared. Speculations made during 1960 regarding the nature of the toxin suggested that it might be of fungal origin. In fact, the toxin-producing fungus was identified as Aspergillus flavus in 1961 and the toxin was given the name Aflatoxins by virtue of its origin (A. flavus → Afla) [1].

The chemical structure of aflatoxin is coumarin nucleus linked to a bifuran and either a pentanone, as in AFB1 and the dihydro derivative AFB2, or a six – member lactone, as in AFG1 and its corresponding derivative AFG2 [2].In an attempt to harmonize the current tolerances to aflatoxin which exist in different countries, the working group on mycotoxins of the World Health Organization (WHO) and Food Agricultural Organization (FAO) proposed maximum limits of 15μg/Kg for total aflatoxins in raw groundnuts based on a sample size of 20 Kg.

## 1.2 Reseaech Problem

Sudan used to be one of the world's top exporters of peanuts it proudly boasts 14% of the world total peanut's production and is one of the top five producers worldwide providing much needed foreign exchange. In fact, peanut cultivated area represents about 35% of total cash crop area. Traditional, small-scale farming in Sudan's western states produces 70% of the country's peanut supply.

But in the recent years the ranking of Sudan has fallen back dramatically due to the lack of oversight and poor management and quality control.

In Sudan, aflatoxin has been detected from a wide range of feeds, foods, crops, air, soil and patients. It is one of the most dangerous contaminants of high toxicity and carcinogenic potency to both man and his domestic animals .It has serious impacts on both Economic and health.

### 1.2.1 Aflatoxin Impacts on Agriculture and Food Security, Trade, and Health

- **Agriculture and Food Security**

Aflatoxin contamination of key staples can affect the agricultural sector output, generally, and each of the four pillars of food security (availability, access, utilization, and stability), specifically. Contamination in staples such as maize, sorghum and peanuts can directly reduce availability of food. Producers of the affected crop may also earn less

because of product rejection, reduced market value, or inability to gain access to the higher-value international trade and the formal market. Lower farmer income in turn limits ability to purchase food for the family, which translates into reduced access to food. Contamination reduces use options for the affected produce through complete rejection or need to put it to other safe uses. Given the link between aflatoxin and adverse human health impact—particularly the confirmed linkages to liver cancer, synergistic effects with Hepatitis B, and potential association with stunting and immunosuppression contaminated food presents a clear food security threat.

– **Trade**

Many countries have established regulations to limit exposure to aflatoxin, typically expressed in parts per billion (ppb). Some countries have different limits depending on the intended use, the tightest applying to human consumption and exports, and the highest to industrial products. These regulations can result in foregone trade revenues arising from increased cost of meeting the standards – including cost of testing, rejection of shipments and even eventual loss of admissibility into foreign markets. The direct economic impact of aflatoxin contamination in crops results mainly from a reduction in marketable volume, loss in value in the national markets, inadmissibility or rejection of products by the international market, and losses incurred from livestock disease, consequential morbidity and mortality. Specifically, in the international market, products that do not meet the aflatoxin standards are either rejected at the border, rejected in channels of distribution, assigned a reduced price, or diverted to non-human or even non-fee uses. Similar economic losses may occur in domestic markets if consumer awareness about the problem rises, if leaders in marketing

channels begin to pay more attention, and/or if regulations are either tightened or more strictly enforced. Under any of these circumstances, premiums for aflatoxin-free commodities may be realized for a limited period of time. In the long run, the premium will eventually vanish as compliance becomes a threshold condition for being accepted as a supplier. While it may seem that tighter phytosanitary standards imply more costs than benefits, in fact once suppliers internalize the economic costs of non-compliance and bear them as a financial cost, greater economic benefits for society will arise in several forms, including larger and more stable markets and reduced burden of disease.

- **Health :**

If aflatoxin-contaminated crops are consumed by humans, aflatoxin poisoning (i.e. aflatoxicosis) can occur. Chronic exposure to even low levels of contamination in crops consumed regularly increases liver cancer risk and can suppress the immune system. Aflatoxin can also enter the human diet through livestock products if the livestock are given contaminated feed. High levels can be fatal. Children can also be affected through breast milk or direct consumption of weaning foods. Some experts suspect association of aflatoxin exposure with child growth stunting.

## 1.3 Research Objectives:

- To create more sufficient method to detect aflatoxin in peanuts.
- To apply scientific control methods.
- To achieve high detection accuracy, in rapid way.
- Testing a simple model of aflatoxin detection machine.

## 1.4 Methodology:

- Study all previous studies in the same field.
- Research about aflatoxin.
- Drawing the proposed machine structure.
- Design a simple model of the machine.
- Testing simple model detection range.
- Testing simple model reject operation.

## 1.5 Project outlines

This project consist of five chapters: chapter one gives an introduction about the principles of the project, in additions its reasons, motivation and objectives.

Chapter two discusses the food quality control and the commonly used methods for detecting aflatoxin (HPLC). Chapter three describes the software and hardware of the proposed machine. Chapter four shows the structure & process of the proposed machine, the system implementation of the simple model and testing, finally chapter Five provides the conclusion and recommendation.

# CHAPTER TWO

# BASICS FOOD QUALITY CONTROL

## 2.1 Introduction

Food is any substance which when consumed provides nutritional support for the body. It may be of plant or animal origin, containing the known five essential nutrients namely, carbohydrates, fats, proteins, vitamins and minerals. Usually after consumption, food undergoes different metabolic processes that eventually lead to the production of energy, maintenance of life, and/or stimulation of growth [3]. The history of early man shows that, people obtained food substances through hunting, gathering, and agriculture.

The assurance and protection of food quality has always been important to humans. This is evident from the fact that, one of the earliest laws known to man was that of Food. Right from the Garden of Eden, there was a law guiding the consumption of food. In our time too, governments over many centuries have endeavored to provide for the safety and wholesomeness of man's food by legal provisions, [4] [5]. In spite of these provisions, adulteration of foods has increased and the detection of these adulterants has proved more difficult, essentially because of the sophisticated methods being used in the adulteration. The birth of modern chemistry in the early nineteenth century made possible the production of materials possessing properties similar to normal foods which, when

fraudulently used, did not readily attract the attention of the unsuspecting consumer. However, modern analytical techniques are now available to detect adulterants in foods.

## 2.2 Food Quality Control

Quality control is the maintenance of quality at levels and tolerance limits acceptable to the buyer while minimizing the cost for the vendor. Scientifically, quality control of food refers to the utilization of technological, physical, chemical, microbiological, nutritional and sensory parameters to achieve the wholesome food. These quality factors depend on specific attributes such as sensory properties, based on flavor, color, aroma, taste, texture and quantitative properties namely; percentage of sugar, protein, fiber etc. as well as hidden attributes likes peroxides, free fatty acids, enzyme [6] [7] [8].

Although, quality attributes are many, not all need to be considered at every point in time for every particular product. It is important to always determine how far relatively a factor is in relation to the total quality of the product. The quality attribute of a particular product is based on the composition of the product, expected deteriorative reactions, packaging used, shelf life required and the type of consumers. The most important element and ultimate goal in food quality control is protecting the consumer.

To ensure standardization of these procedures, food laws and regulations cover the related acts affecting the marketing, production, labeling, food additive used, dietary supplements, and enforcement of General Manufacturing Practice (GMP), Hazard Analysis and Critical

Control Point (HACCP), federal laws and regulations, factory inspections and import/export inspections [9].

### 2.2.1 Importance of Food Quality Control (QC)

The most important quality factor of processed food is safety and reliability followed by “deliciousness” and “appropriate price” [8]. The colossal loss a food industry will record if defective products were rejected or recalled.

### 2.2.2 History of Food Quality Control

Many years ago, about 2500 years BC Mosaic and Egyptian laws had provisions to prevent the contamination of meat. Also, more than 2000 years ago, India already had regulations prohibiting the adulteration of grains and edible fats. In the actual sense, the laws of Moses contained decrees on food that are quite similar to certain aspects of modern food laws. Books of the Old Testament prohibited the consumption of meat from animals that died other than those intentionally slaughtered, perhaps consciously or otherwise, this was to ensure that contaminated meats were not consumed.

### 2.2.3 Food Contamination

Contamination of food can occur at any of the phases of the food supply chain and these will be expounded under the following broad categories:

- Physical
- Chemical

- Microbiological
- Other contaminants

- **Physical Contamination**

One of the major physical contaminations is adulteration. It is the mixing of inferior quality material with the superior product, thereby reducing the nature, quality and originality in taste, color, odor and nutritional value and ultimately causing ill effects on the health of the consumer [10].The main motive of adulteration and of course the "adultratee" is to gain undue advantage and most often profits. Almost all the food stuffs being sold in the market are prone to adulteration, but main food products that are often heavily adulterated are spices, milk products, edible oil, beverages drinks, sweets, pulses, sugar, processed foods, rice and cereal products like flour.

- **Chemical Contamination**

Chemicals, which elicit harmful effects when consumed by animals or humans, are said to be toxic. The use of chemicals in the production and processing of food and food products not only affects the quality, but also disguises the deterioration and constitutes deliberate adulteration which is potentially very harmful to the health [11]. It is advised that food additives like coloring matter, preservatives, artificial sweetening agents, antioxidants, emulsifiers/stabilizer, flavors/flavoring enhancers etc., if used should be of approved quality and processed under good manufacturing practices.

- **Microbiological Contamination**

Microbiological contamination of food is perhaps the most prevalent health problem in the contemporary world [11] [10]. To ensure good quality and safe food therefore, microbiological criteria should be established and freedom from pathogenic microorganisms must be ensured, including the raw materials, ingredients and finished products at any stage of production/processing. Accordingly, the microbiological examination of the foods products has to be adopted widely. The microbiological criteria must be applied to define the distinction between acceptable and unacceptable foods [10]. Food poisoning often results from the consumption of old, used, residual, fermented or spoiled food, as these may be contaminated with bacteria or other microorganisms, hence toxic. Infants and children are more susceptible to food poisoning and care should always be taken when giving them food. Gastroenteritis is caused by food contaminated with the enterococcus, streptococcus faecalis, which is frequently found in the human intestinal tract [10].

- **Other Contaminants**

Metals are one of the many unintentional contaminants of food. When present beyond trace amounts, they are toxic. They find their way into food through air, water, soil, industrial pollution and other routes including food utensils.

## 2.3 High Performance Liquid Chromatography

High-performance liquid chromatography (or High-pressure liquid chromatography, HPLC) is a specific form of column chromatography generally used in biochemistry and analysis to separate, identify, and

quantify the active compounds. HPLC mainly utilizes a column that holds packing material (stationary phase), a pump that moves the mobile phase(s) through the column, and a detector that shows the retention times of the molecules. Retention time varies depending on the interactions between the stationary phase, the molecules being analyzed, and the solvent(s) used. The sample to be analyzed is introduced in small volume to the stream of mobile phase and is retarded by specific chemical or physical interactions with the stationary phase. The amount of retardation depends on the nature of the analyte and composition of both stationary and mobile phase. The time at which a specific analyte elutes (comes out of the end of the column) is called the retention time. Common solvents used include any miscible combinations of water or organic liquids (the most common are methanol and acetonitrile). Separation has been done to vary the mobile phase composition during the analysis; this is known as gradient elution. The gradient separates the analyte mixtures as a function of the affinity of the analyte for the current mobile phase. The choice of solvents, additives and gradient depend on the nature of the stationary phase and the analyte [12].

### 2.3.1 Types of HPLC

Types of HPLC generally depend on phase system used in the process. Following types of HPLC generally used in analysis:

- **Normal phase chromatography**

Also known Normal phase HPLC (NP-HPLC), this method separates analytes based on polarity. NP-HPLC uses a polar stationary phase and a non-polar mobile phase. The polar analyte interacted with and is retained by the polar stationary phase. Adsorption strengths increase with increased

analyte polarity, and the interaction between the polar analyte and the polar stationary phase increases the elution time.

- **Reversed phase chromatography**

Reversed phase HPLC (RP-HPLC or RPC) has a non-polar stationary phase and an aqueous, moderately polar mobile phase. RPC operates on the principle of hydrophobic interactions, which result from repulsive forces between a polar eluent, the relatively non-polar analyte, and the non-polar stationary phase. The binding of the analyte to the stationary phase is proportional to the contact surface area around the non-polar segment of the analyte molecule upon association with the ligand in the aqueous eluent.

- **Size exclusion chromatography**

Size exclusion chromatography (SEC), also called as gel permeation chromatography or gel filtration chromatography mainly separates particles on the basis of size. It is also useful for determining the tertiary structure and quaternary structure of proteins and amino acids. This technique is widely used for the molecular weight determination of polysaccharides.

- **Ion exchange chromatography**

In Ion-exchange chromatography, retention is based on the attraction between solute ions and charged sites bound to the stationary phase. Ions of the same charge are excluded. This form of chromatography is widely used in purifying water, Ligand-exchange chromatography, Ion-exchange chromatography of proteins, High-pH anion-exchange chromatography of carbohydrates and oligosaccharides, etc.

- **Bio-affinity chromatography**

Separation based on specific reversible interaction of proteins with ligands. Ligands are covalently attached to solid support on a bio-affinity

matrix, retains proteins with interaction to the column-bound ligands. Proteins bound to a bio affinity column can be eluted in two ways:

- Bio Specifics elution: inclusion of free ligand in elution buffer which competes with column bound ligand.
- A specific elution: change in pH, salt, etc. which weakens interaction protein with column-bound substrate. Because of specificity of the interaction, bio affinity chromatography can result in very high purification in a single step (10 - 1000-fold).

### 2.3.2 Parameters

For the accurate analysis of a compound, there are some parameters which are used as a standard for a particular compound. If there is a change occurs in the parameters the result may be affected greatly. The most commonly used parameters are internal diameter, particle size, pore size, pump pressure. For different compounds the parameters can be changed according to their nature and chemical properties.

- **Internal diameter**

The internal diameter (ID) of an HPLC column is a critical aspect that determines quantity of analyte that can be loaded onto the column and also influences sensitivity. Larger columns are usually seen in industrial applications such as the purification of a drug product for later use. Low ID columns have improved sensitivity and lower solvent consumption at the expense of loading capacity.

- **Particle size**

Most traditional HPLC is performed with the stationary phase attached to the outside of small spherical silica particles (very small beads). Smaller particles generally provide more surface area and better separations, but the

pressure required for optimum linear velocity increases by the inverse of the particle diameter squared.

- **Pore size**

Many stationary phases are porous to provide greater surface area. Small pores provide greater surface area while larger pore size has better kinetics especially for larger analytes. Pore size defines an ability of the analyte molecules to penetrate inside the particle and interact with its inner surface. This is especially important because the ratio of the outer particle surface to its inner one is about 1:1000. The surface molecular interaction mainly occurs on the inner particle surface.

- **Pump pressure**

Pumps vary in pressure capacity, but their performance is measured on their ability to yield a consistent and reproducible flow rate. Modern HPLC systems have been improved to work at much higher pressures, and therefore be able to use much smaller particle sizes in the columns (< 2 micrometers).

### 2.3.3 Instrumentation

Figure (2.1) shows the instrumentation of the HPLC:

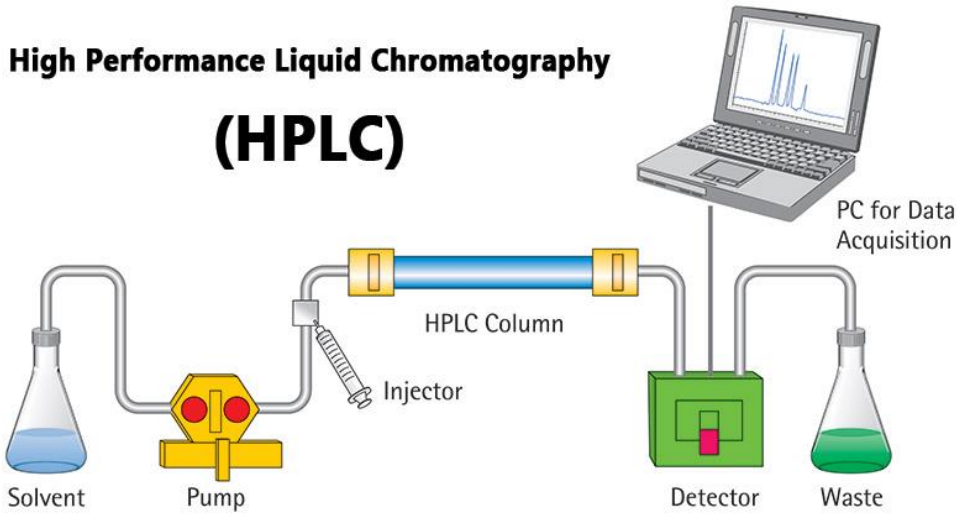


Figure (2.1): instrumentation of the HPLC

- **Injection of the sample**

Septum injectors are available; using which sample solution is injected. Sample can be injected when the mobile phase is flowing or it is stopped. A new advanced rotary valve and loop injector can be used to produce reproducible results.

- **The detector**

There are several ways of detecting when a substance has passed through the column. Generally, ultraviolet light spectroscopy is attached, which detect the specific compounds. Many organic compounds absorb UV light of various wavelengths. The amount of light absorbed will depend on the amount of a particular compound that is passing through the beam at the time.

- **Interpreting the output from the detector**

The output is recorded as a series of peaks, each one representing a compound in the mixture passing through the detector and absorbing UV light. The area under the peak is proportional to the amount of substance,

which is passed through detector, and this area can be calculated automatically by the computer linked to the display.

### 2.3.4 Application

The information that can be obtained using HPLC includes identification, quantification, and resolution of a compound. Preparative HPLC refers to the process of isolation and purification of compounds. This differs from analytical HPLC, where the focus is to obtain information about the sample compound.

- **Chemical Separations**

It is based on the fact that certain compounds have different migration rates given a particular column and mobile phase, the extent or degree of separation is mostly determined by the choice of stationary phase and mobile phase.

- **Purification**

Purification is defined as the process of separating or extracting the target compound from a mixture of compounds or contaminants. Each compound showed a characteristic peak under certain chromatographic conditions. The migration of the compounds and contaminants through the column need to differ enough so that the pure desired compound can be collected or extracted without incurring any other undesired compound.

- **Identification**

Generally, assay of compounds is carried using HPLC. The parameters of this assay should be such that a clean peak of the known sample is observed from the chromatograph. The identifying peak should have a reasonable retention time and should be well separated from extraneous peaks at the detection levels which the assay will be performed.

# CHAPTER THREE
# SYSTEM HARDWARE AND SOFTWARE CONSIDERATIONS

## 3.1 Introduction

This chapter deals with the type of hardware that is used and the software to support the same. Selection and identification of suitable software is also taken into account. Connectivity between various technologies used is established. The designing of interfaces and identification of all functional requirements is carried out. In this chapter we discussed three main subjects: programmable logic controller, MATLAB and image processing.

## 3.2 Programmable Logic Controller

Programmable Logic Controllers (PLCs), also referred to as programmable controllers, are in the computer family. They are used in commercial and industrial applications. A PLC monitors inputs, makes decisions based on its program, and controls outputs to automate a process or machine as shown in Figure (3.1).

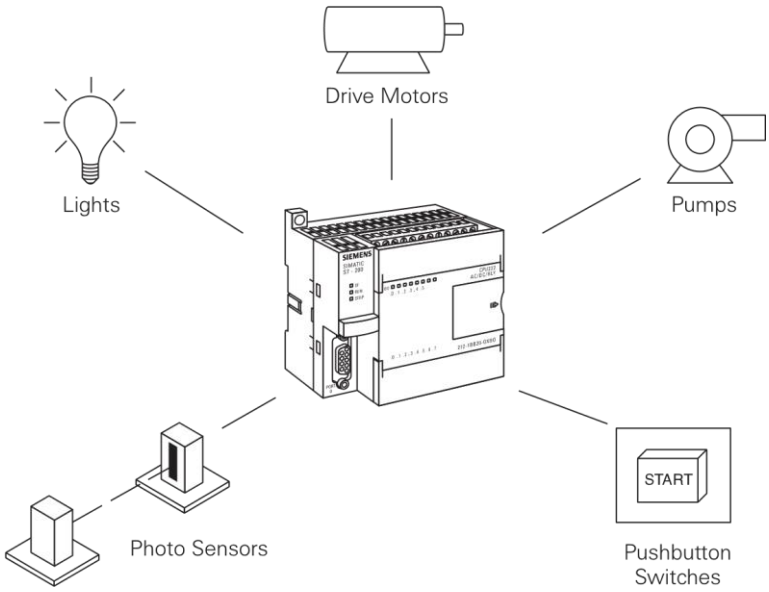


Figure (3.1): PLC

### 3.2.1 Basic PLC Operation

PLCs consist of input modules or points, a Central Processing Unit (CPU), and output modules or points. An input accepts a variety of digital or analog signals from various field devices (sensors) and converts them into a logic signal that can be used by the CPU. The CPU makes decisions and executes control instructions based on program instructions in memory. Output modules convert control instructions from the CPU into a digital or analog signal that can be used to control various field devices (actuators). A programming device is used to input the desired instructions. These instructions determine what the PLC will do for a specific input. An operator interface device allows process information to be displayed and new control parameters to be entered. Pushbuttons (sensors), in this simple example,

connected to PLC inputs, can be used to start and stop a motor connected to a PLC through a motor starter (actuator) as shown in Figure (3.2).

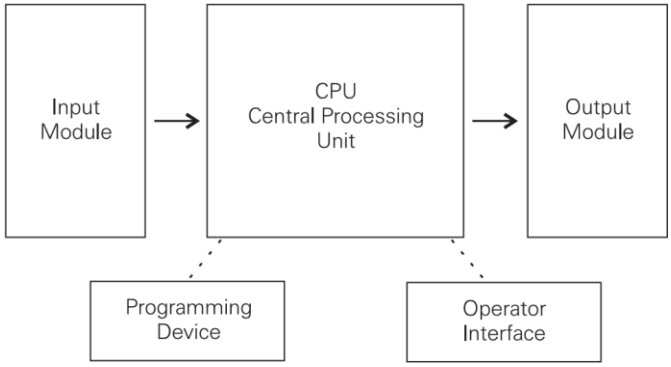


Figure (3.2): Basic PLC Operation

### 3.2.2 Hard-Wired Control

Prior to PLCs, many of these control tasks were solved with contactor or relay controls. This is often referred to as hardwired control. Circuit diagrams had to be designed, electrical components specified and installed, and wiring lists created. Electricians would then wire the components necessary to perform a specific task. If an error was made the wires had to be reconnected correctly. A change in function or system expansion required extensive component changes and rewiring.

### 3.1.3 Advantages of PLCs

The same, as well as more complex tasks, can be done with a PLC. Wiring between devices and relay contacts is done in the PLC program. Hard-wiring, though still required to connect field devices, is less intensive.

Modifying the application and correcting errors are easier to handle. It is easier to create and change a program in a PLC than it is to wire and rewire a circuit. Following are just a few of the advantages of PLCs:

- Smaller physical size than hard-wire solutions.
- Easier and faster to make changes.
- PLCs have integrated diagnostics and override functions.
- Diagnostics are centrally available.
- Applications can be immediately documented.
- Applications can be duplicated faster and less expensively.

### 3.1.4 Siemens PLCs

Siemens makes several PLC products lines in the SIMATIC® S7 family. They are: S7-200, S7-300, and S7-400.

- **S7-200**

The S7-200 is referred to as a micro PLC because of its small size. The S7-200 has a brick design which means that the power supply and I/O are on-board. The S7-200 can be used on smaller, stand-alone applications such as elevators, car washes, or mixing machines. It can also be used on more complex industrial applications such as bottling and packaging machines.

- **S7-300 and S7-400**

The S7-300 and S7-400 PLCs are used in more complex applications that support a greater number of I/O points. Both PLCs are modular and expandable. The power supply and I/O consist of separate modules

connected to the CPU. Choosing either the S7-300 or S7-400 depends on the complexity of the task and possible future expansion. Your Siemens sales representative can provide you with additional information on any of the Siemens PLCs.

### 3.2.5 Terminology

The language of PLCs consists of a commonly used set of terms; many of which are unique to PLCs. In order to understand the ideas and concepts of PLCs, an understanding of these terms is necessary.

- **Sensor**

A sensor is a device that converts a physical condition into an electrical signal for use by the PLC. Sensors are connected to the input of a PLC. A pushbutton is one example of a sensor that is connected to the PLC input. An electrical signal is sent from the pushbutton to the PLC indicating the condition (open/ closed) of the pushbutton contacts as shown in Figure (3.3).

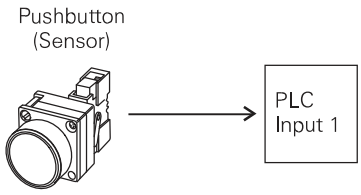


Figure (3.3): Sensor

- **Actuators**

Actuators convert an electrical signal from the PLC into a physical condition. Actuators are connected to the PLC output. A motor starter is one

example of an actuator that is connected to the PLC output. Depending on the output PLC signal the motor starter will either start or stop the motor as shown in Figure (3.4).

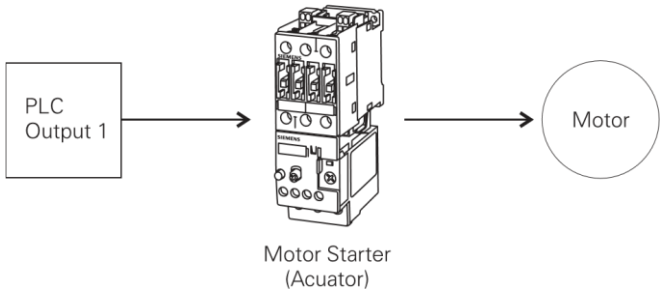


Figure (3.4): Actuators

- **Discrete Input**

A discrete input, also referred to as a digital input, is an input that is either in an ON or OFF condition. Pushbuttons, toggle switches, limit switches, proximity switches, and contact closures are examples of discrete sensors which are connected to the PLCs discrete or digital inputs. In the ON condition a discrete input may be referred to as a logic 1 or a logic high. In the OFF condition a discrete input may be referred to as a logic 0 or a logic low. A Normally Open (NO) pushbutton is used in the following example. One side of the pushbutton is connected to the first PLC input. The other side of the pushbutton is connected to an internal 24 VDC power supply. Many PLCs require a separate power supply to power the inputs. In the open state, no voltage is present at the PLC input. This is the OFF condition. When the pushbutton is depressed, 24 VDC is applied to the PLC input. This is the ON condition as shown in Figure (3.5).

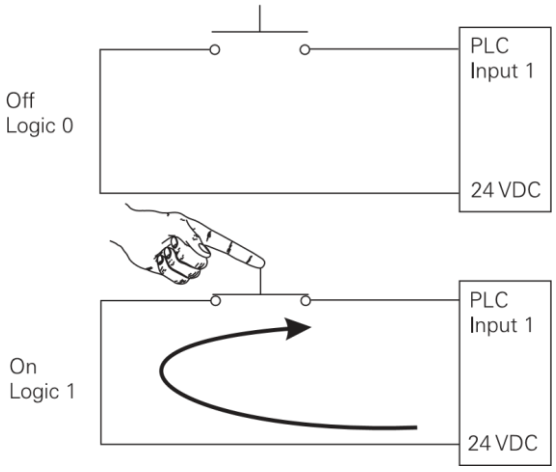


Figure (3.5): Discrete Input

– **Analog Inputs**

An analog input is an input signal that has a continuous signal. Typical analog inputs may vary from 0 to 20 milliamps, 4 to 20 milliamps, or 0 to 10 volts. In the following example, a level transmitter monitors the level of liquid in a tank. Depending on the level transmitter, the signal to the PLC can either increase or decrease as the level increases or decreases as shown in Figure (3.6).

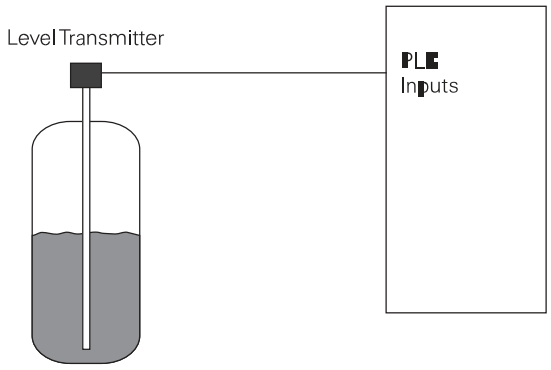


Figure (3.6): Analog Inputs

– **Discrete Outputs**

A discrete output is an output that is either in an ON or OFF condition. Solenoids, contactor coils, and lamps are examples of actuator devices connected to discrete outputs. Discrete outputs may also be referred to as digital outputs. In the following example, a lamp can be turned on or off by the PLC output it is connected to as shown in Figure (3.7).

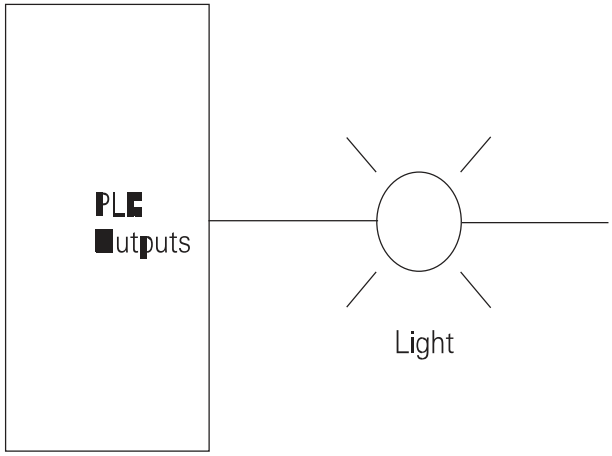


Figure (3.7): Discrete Outputs

– **Analog Outputs**

An analog output is an output signal that has a continuous signal. The output may be as simple as a 0-10 VDC level that drives an analog meter. Examples of analog meter outputs are speed, weight, and temperature. The output signal may also be used on more complex applications such as a current-to pneumatic transducer that controls an air-operated flow-control valve as shown in Figure (3.8).

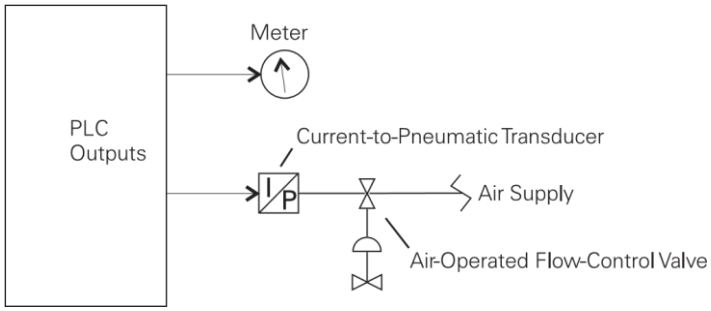


Figure (3.8): Analog Outputs

- **Central Processor Unit**

The central processor unit (CPU) is a microprocessor system that contains the system memory and is the PLC decision making unit. The CPU monitors the inputs and makes decisions based on instructions held in the program memory. The CPU performs relay, counting, timing, data comparison, and sequential operations as shown in Figure (3.9).

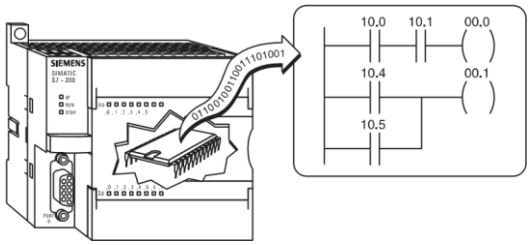


Figure (3.9): CPU

### 3.2.6 Programming

A program consists of one or more instructions that accomplish a task. Programming a PLC is simply constructing a set of instructions. There are

several ways to look at a program such as ladder logic, statement lists, or function block diagrams.

- **Ladder Logic Diagram**

Ladder logic (LAD) is one programming language used with PLCs. Ladder logic uses components that resemble elements used in a line diagram format to describe hard-wired control.

The left vertical line of a ladder logic diagram represents the power or energized conductor. The output element or instruction represents the neutral or return path of the circuit. The right vertical line, which represents the return path on a hard-wired control line diagram, is omitted. Ladder logic diagrams are read from left-to-right, top-to-bottom. Rungs are sometimes referred to as networks. A network may have several control elements, but only one output coil.

- **Statement List**

A statement list (STL) provides another view of a set of instructions. The operation, what is to be done, is shown on the left. The operand, the item to be operated on by the operation, is shown on the right. A comparison between the statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure. The set of instructions in this statement list perform the same task as the ladder diagram.

- **Function Block Diagrams**

Function Block Diagrams (FBD) provide another view of a set of instructions. Each function has a name to designate its specific task.

Functions are indicated by a rectangle. Inputs are shown on the left-hand side of the rectangle and outputs are shown on the right-hand side. The function block diagram shown below performs the same function as shown by the ladder diagram and statement list.

### 3.2.7 PLC Scan

The PLC program is executed as part of a repetitive process referred to as a scan. A PLC scan starts with the CPU reading the status of inputs. The application program is executed using the status of the inputs. Once the program is completed, the CPU performs internal diagnostics and communication tasks. The scan cycle ends by updating the outputs, then starts over. The cycle time depends on the size of the program, the number of I/Os, and the amount of communication required.

### 3.2.8 Software

Software is any information in a form that a computer or PLC can use. Software includes the instructions or programs that direct hardware.

### 3.2.9 Hardware

Hardware is the actual equipment. The PLC, the programming device, and the connecting cable are examples of hardware.

### 3.2.10 Memory Size

Kilo, abbreviated K, normally refers to 1000 units. When talking about computer or PLC memory, however, 1K means 1024. This is because

of the binary number system (210=1024). This can be 1024 bits, 1024 bytes, or 1024 words, depending on memory type.

- **Random Access Memory**

Random Access Memory (RAM) is memory where data can be directly accessed at any address. Data can be written to and read from RAM. RAM is used as a temporary storage area. RAM is volatile, meaning that the data stored in RAM will be lost if power is lost. A battery backup is required to avoid losing data in the event of a power loss.

- **Read Only Memory**

Read Only Memory (ROM) is a type of memory that data can be read from but not written to. This type of memory is used to protect data or programs from accidental erasure. ROM memory is nonvolatile. This means a user program will not lose data during a loss of electrical power. ROM is normally used to store the programs that define the capabilities of the PLC. EPROM Erasable Programmable Read Only Memory (EPROM) provides some level of security against unauthorized or unwanted changes in a program. EPROMs are designed so that data stored in them can be read, but not easily altered. Changing EPROM data requires a special effort. UVEPROMs (ultraviolet erasable programmable read only memory) can only be erased with an ultraviolet light. EEPROM (electronically erasable programmable read only memory), can only be erased electronically.

- **Firmware**

Firmware is user or application specific software burned into Erasable Programmable Read-Only Memory EPROM and delivered as part of the hardware. Firmware gives the PLC its basic functionality.

### 3.2.11 Putting It Together

The memory of the S7-200 is divided into three areas: program space, data space, and configurable parameter space.

- Program space stores the ladder logic (LAD) or statement list (STL) program instructions. This area of memory controls the way data space and I/O points are used. LAD or STL instructions are written using a programming device such as a PC, then loaded into program memory of the PLC.
- Data space is used as a working area, and includes memory locations for calculations, temporary storage of intermediate results and constants. Data space includes memory locations for devices such as timers, counters, high-speed counters, and analog inputs and outputs. Data space can be accessed under program control.
- Configurable parameter space, or memory, stores either the default or modified configuration parameters.

### 3.2.12 Basic Requirements

In order to create or change a program, the following items are needed:

- PLC: Throughout this course we will be using the S7-200 because of its ease of use.
- Programming Devices: The program is created in a programming device (PG) and then transferred to the PLC. The program for the S7-200 can be created using a dedicated Siemens SIMATIC S7 programming device, such as a PG 720 (not shown) or PG 740, if STEP 7 Micro/WIN software is installed.
- A personal computer (PC), with STEP 7 Micro/WIN installed, can also be used as a programming device with the S7-200.
- Software: A software program is required in order to tell the PLC what instructions it must follow. Programming software is typically PLC specific. A software package for one PLC, or one family of PLCs, such as the S7 family, would not be useful on other PLCs. The S7-200 uses a Windows based software program called STEP 7-Micro/WIN32. The PG 720 and PG 740 have STEP 7 software pre-installed. Micro/WIN32 is installed on a personal computer in a similar manner to any other computer software.
- Connector Cables PPI (Point-to-Point Interface): Connector cables are required to transfer data from the programming device to the PLC. Communication can only take place when the two devices speak the same language or protocol. Communication between a Siemens programming device and the S7-200 is referred to as PPI protocol (point to- point interface). An appropriate cable is required for a programming device such as a PG 720 or PG 740. The S7-200 uses a 9-pin, D-connector. This is a straight-through serial device that is

compatible with Siemens programming devices (MPI port) and is a standard connector for other serial interfaces.

A special cable, referred to as a PC/PPI cable, is needed when a personal computer is used as a programming device. This cable allows the serial interface of the PLC to communicate with the RS-232 serial interface of a personal computer. DIP switches on the PC/PPI cable are used to select an appropriate speed (baud rate) at which information is passed between the PLC and the computer [13].

All Basic Requirements is shown in figure (3.10).

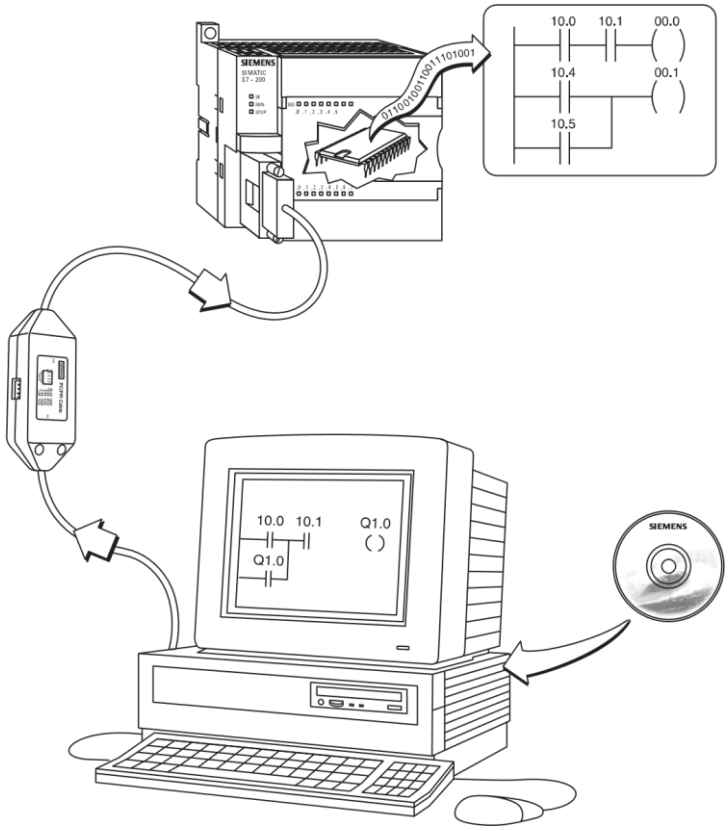


Figure (3.10): Basic Requirements of PLC

## 3.3 MATLAB

### 3.3.1 Mathematical Origins

For his entire career, Moler has taken great interest in systems of linear equations, which are often represented in matrix form. After completing his doctorate at Stanford University in 1965, Moler continued to work with his PhD thesis supervisor (and founder of the Stanford University Computer Science Department) George Forsythe on improved computational methods for solving systems of linear equations, and they wrote a book together

The mathematical and computational basis for the first version of MATLAB begins with a series of papers by J. H. Wilkinson and 18 of his colleagues published between 1965 and 1970 in the journal Numerische Mathematic. The papers were collected in a volume edited by Wilkinson and C. Reinsch, Handbook for Automatic Computation, Volume II: Linear Algebra, published in 1971. The papers present algorithms, implemented in Algol 60, for solving matrix linear equation and eigenvalue problems. These were research papers presenting results about numerical stability, details of implementation, and, in some cases, new methods. The importance of using orthogonal transformations wherever possible was emphasized by Wilkinson and the other authors. Part I of the Handbook, with 40 Algol procedures, is about the linear equation problem; part II, with 43 procedures, is about the eigenvalue problem. A list of the individual procedures is provided in.

### 3.3.2 Classic MATLAB

This first MATLAB was not a programming language; it was just a simple interactive matrix calculator. There were no user-defined functions, no toolboxes, no graphics and no ODEs or FFTs.

The snapshot of the start-up screen shown in Figure 4 lists all the functions and reserved words.

There are only 71 of them. If you wanted to add another function, you could request the source code from Moler, write a FORTRAN subroutine, add your new name to the parse table, and recompile MATLAB.

- **Toolboxes**

MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others [14].

Much of the power of today's MATLAB derives from the toolboxes available for specialized applications. In release 2018a there are 63 of them. Here are the categories:

- Parallel Computing.
- Math, Statistics, and Optimization.

- Control Systems.
- Signal Processing and Wireless Communications.
- Image Processing and Computer Vision.
- Test and Measurement.
- Computational Finance.
- Computational Biology.
- Code Generation.
- Application Deployment.
- Database Access and Reporting.

## 3.4 Image Processing:

Image processing is a branch of computer which is interested in conducting operations on the images in order to improve them according to specific criteria or extract some information from them. The traditional image processing system consists of six consecutive phases, respectively:

- Image acquisition by optical sensor (for example a camera, laser sensor, etc.).
- Initial processing (pre-processing) image distortion or converted to a binary image.
- Cutting the image (segmentation) to separate the important information (for example, any object in the image) from the background.
- Features extraction or features.

- Classification, linking to the pattern you come back to and learning about patterns.
- Image understanding.
- Image processing systems are used in many applications, especially applications of automatic control, robots, computer vision, etc.

Some people can imagine that the digital processing of images means only the processes of adorning the images and inserting some of the decorations and drawings on them or removing them so that they appear in another appearance that differs from the original. However, digital image processing goes beyond that, and in fact it does not really care about this aspect of image processing at all. As the focus here is on the appropriate digital coding of images and finding ways to process this digital data so that these images or information carried by the images can be used by the machine, which can be a computer, a robot, or other machines. Digital image processing is of great importance in the field of image awareness, that is, when we try, for example, to make the computer or the robot understand the image or its meaning, and it is also very important in the field of pattern recognition or shapes. For example, you can visualize a robot that recognizes the shape of a person (for example, a human is equal to a large rectangle from which four small and circular rectangles branch out) and he salutes him while he does not revive a domestic cat, for example. Also, to recognize patterns is of great importance in the automatic processing of the photos taken by shuttles to the surface of the earth, and this is a military use, for example. It is also important in navigation depending on maps or images from the ground.

### 3.4.1 Image Processing Applications

Image processing has a huge array of applications. Almost every field of science and technology can benefit from image processing methods. The need to extract information from images and interpret their contents has been one of the driving factors in the development of image processing over the past decades. Image processing applications cover a wide range of human activities, such as the following:

- Medical Applications
- Astronomy applications
- Biology applications
- Meteorology applications
- Agricultural applications
- Entertainment applications
- Inspection applications industrial inspection Applications

- **Image Processing In Agriculture Industry**

Historians say if they need to pick two most important events in the history of human, first event happened around late 17th century until early 19th century, which is the Industrial Revolution. And the second event happened about 12,000 years ago in the human history. It's called the Neolithic Revolution or Neolithic Demographic Transition, sometimes called the Agricultural Revolution.

It has been proved that image processing is effective tool for analysis in various fields and applications. From the farmers' point of concern,

parameters like yield, canopy, and quality of product were important measurements. In order to analyze the parameters, the expertise were required most of time. And because of the geographical characteristic of farms, it was definitely time consuming and costlier issue. So often time, the process of decision making with expert advice may not be affordable, and complicated. For the most of time, feedback from experts and their services may consume long time. In evolution towards sustainable agriculture system it was clear that important contributions can be made by using emerging technologies. Image processing was one of the tools which can be applied to measure the parameters related to agronomy with accuracy and economy. In image processing, radiation such as Gamma ray, X-ray was important source. Imaging in UV band, visible band, Microwave band are also from source of radiation. Image processing along with availability of communication network can change the situation of getting the expert advice well within time and at affordable cost since image processing was the effective tool for analysis of the parameters. There are a lot of different areas in agriculture that image processing is very useful and effective such as image techniques, weed detection and fruit grading. Compare to tradition methods to analyze the parameters, it has been proved that using image processing for the analysis is more accurate and less time consuming and these applications can improve decision making for vegetation measurement, irrigation, fruit sorting, etc.

Two areas that image processing is useful in agriculture system were introduced earlier. First one is weed detection. Weeds were the plants growing in wrong place in farm which compete with crop for water, light, nutrients and space, causing reduction in yield and effective use of

machinery [15]. Because of these reasons, weed control was crucial in farming. Numerous methods based on image processing can potentially solve part of this problem by creating weed detection techniques using image processing algorithms based on edge detection, and color detection. The second area is fruit/ food grading. In the past decade, expectations in quality and quantity of food and safety standards have increased. This issue has caused need of more and faster accurate grading, sorting of fruits and foods or agriculture products which causes increased processing and labor work. Digital image processing is nondestructive, accurate and reliable method to achieve the needs. Potentially image processing in agriculture can be applied in areas of detection of defects, sorting, cracks and bruises on agricultural products, grading of fresh products, etc.

With the available functionalities based on image processing techniques, it has been proved that image processing is effective method for digital agricultural system.

A hyperspectral image is a wide collection of data, stored in pixels, each of them usually highly correlated to their neighbors. Therefore, they are composed by thousands or, sometimes, millions of data points.

Handling this amount of information and extracting the relevant information have been possible thanks to the adaptation of the classical multivariate data analysis techniques (such as Principal Component Analysis or Multivariate Curve Resolution) to the analysis of hyper spectral data cubes, showing a high utility and success in extracting the desired information.

### 3.4.2 Hyperspectral Image Processing

Hyperspectral Imaging is an essential technique to deep explore surfaces in which more detail than the one provided by the single point spectroscopy is needed. Many devices for acquiring hyperspectral images have been manufactured and there is an increasing interest for improving the data analysis techniques applied to such complex datasets as shown in Figure (3.11)

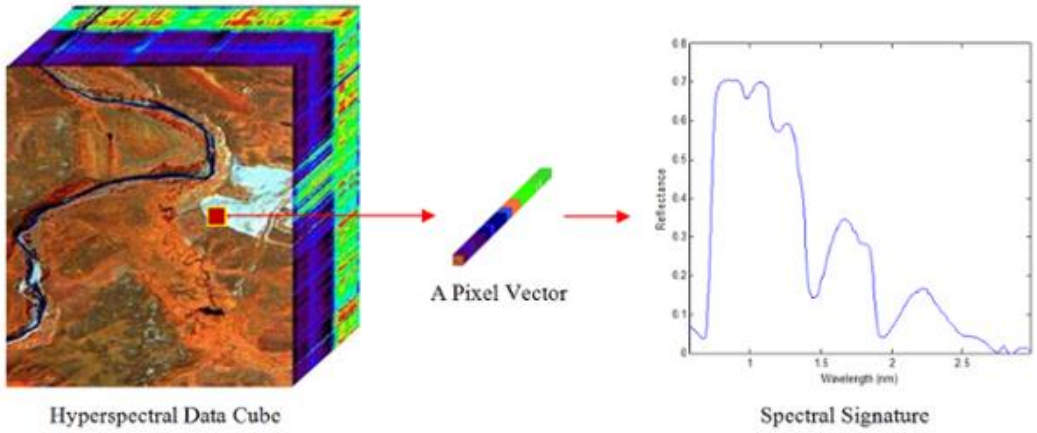


Figure (3.11): The Concept of Hyperspectral Imaging

### 3.4.3 Image Processing Operations

Image processing operations can be divided into two levels [16]:

- Low level image processing
- High level image processing

- **Low Level Image Processing**

The low level is also called image pre-processing that operates at the pixel level [17]. The input to low level image processing operators is an image whereas the output is either image or data. Few examples of low level image processing operators are contrast enhancement, noise reduction, and

noise removal in an image. They are also used for edge detection and various image transformations or calculate simple characteristics such as contours histograms. Low level image processing operators can be classified as point operators, neighborhood operators and global operators, with respect to the way the output pixels are determined from the input pixels [17].

– **High Level Image Processing**

The high level image processing operations operate in order to generate higher abstractions. They work on abstractions derived from intermediate-level image processing operators. They are used to interpret the image content such as classification and object recognition. These operations work on graphs, lists and relations among regions/objects to derive some decision. Image enhancement and image segmentation are situated in low level operation while image representation, feature selection and image interpretation are situated in high level operation. Most of image processing for agriculture application is a combination of low level and high level operations. This is because most of the system is made for object recognition purpose.

# CHAPTER FOUR
# SYSTEM APPLICATIONS

## 4.1 Introduction

According to the economic and health effects of the aflatoxin in Sudanese peanuts that has been mentioned in the last chapters A superior model has been proposed to build a machine that sprite the infected peanuts kernels from the normal ones This proposed Design will assure a clean products that will help the country to export the peanuts widely. It also improve the quality of the local products that use peanuts and contribute to healthy food oil.

## 4.2 System Main Components

The main components of the system is shown in figure (4.1).

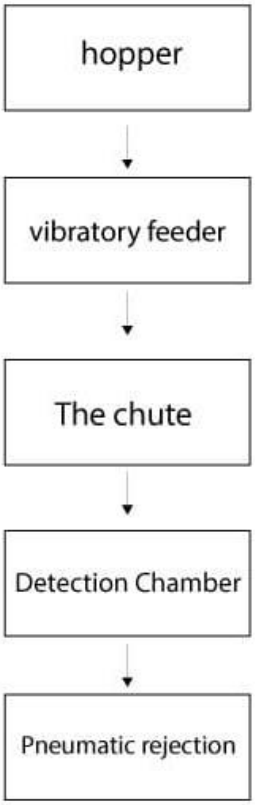


Figure (4.1): System main block diagram.

### 4.2.1 Hopper

A hopper is a large, pyramidal or cone shaped container used in industrial processes to hold particulate matter or flow-able material of any sort like dust, gravel, nuts, seeds etc. and can then dispense these from the bottom when needed.

Most hoppers are made of plastic, metal, or composite materials. The proposed hopper in this design is made from stainless steel as shown in figure (4.2).

Figure (4.2): Stainless Steel Hopper.

### 4.2.2 Vibratory Feeder

A vibratory feeder is an instrument that uses vibration to "feed" material to a process or machine. Vibratory feeders use both vibration and gravity to move material. Gravity is used to determine the direction, either down, or down and to a side, and then vibration is used to move the material. They are mainly used to transport a large number of smaller objects.

It can come out a variety of products arranged orderly, with automatic assembly equipment in various parts of the product assembled into a complete one product, or with automatic machinery to complete the processing of the work piece as shown in figure (4.3).

- **Advantages**

I. High quality, high efficiency, high performance

II. Easy & convenient operation

III. The machine can feeding, sending a variety of products and assembling

IV. Good quality & competitive price

V. Professional manufacture

VI. First class of service

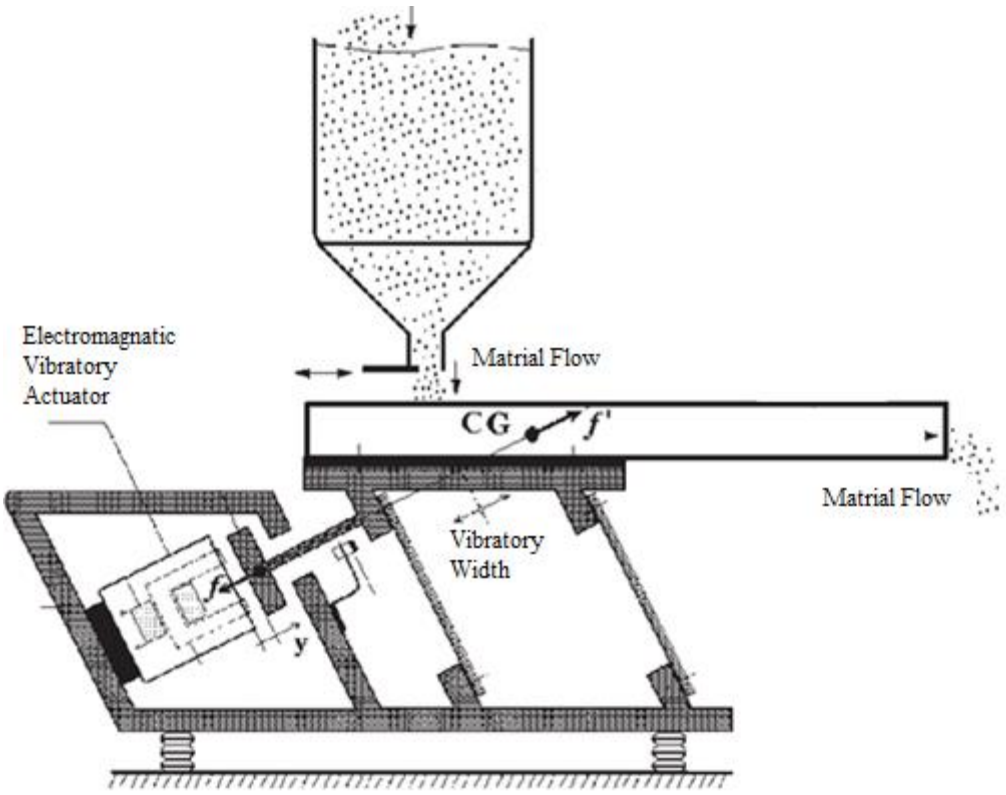


Figure (4.3): The Vibratory Feeder

### 4.2.3 The Chute

A chute is a vertical or inclined plane, channel, or passage through which objects are moved by means of gravity.

The proposed chute in our design is made from stainless steel and it’s shown in figure (4.4).

Figure (4.4): Stainless steel chute

### 4.2.4 Detection Chamber

- **Ultraviolet (UV)**

It's a form of electromagnetic radiation with wavelength from 10 to 400 nm, shorter than that of visible light, but longer than X-rays. UV radiation is present in sunlight, and constitutes about 10% of the total electromagnetic radiation output from the Sun. It is also produced by electric arcs and specialized lights, such as mercury-vapor lamps, tanning lamps, and black lights. Although long-wavelength ultraviolet is not considered an ionizing radiation because its photons lack the energy to ionize atoms, it can cause chemical reactions and causes many substances to glow or fluoresce. Consequently, the chemical and biological effects of UV are greater than simple heating effects, and many practical applications of UV radiation derive from its interactions with organic.

This BGYF is used to detect and reject contaminated peanuts in this proposed machine. Molecules. Under ultraviolet 365 nm illumination, aflatoxin contaminated samples exhibit bright green yellowish fluorescence (BGYF).

- **Halogen Lamp**

The halogen lamp is also known as a tungsten halogen, quartz-halogen or quartz iodine lamp, is an incandescent lamp consisting of a tungsten filament sealed into a compact transparent envelope that is filled with a mixture of an inert gas and a small amount of a halogen such as iodine or bromine as shown in figure (4.5).

Figure (4.5): Halogen lamp

The combination of the halogen gas and the tungsten filament produces a halogen cycle chemical reaction which redeposit evaporated tungsten to the filament, increasing its life and maintaining the clarity of the envelope. This allows the filament to operate at a higher temperature than a standard incandescent lamp of similar power and operating life; this also produces light with higher luminous efficacy and color temperature. In detection and classification applications halogen illumination was used by Hirano who used transmittance ratio (T700 nm/T1100 nm) bands for peanuts classification under halogen illumination and achieved 95% classification accuracy. Then in 2001 it has been achieved to 96.6% classification accuracy rate of corn samples illuminated by 100 W quartz–tungsten–halogen lamp by utilizing the spectral reflectance ratio (R735 nm/R1005 nm).

In this proposed machine design both UV and halogen excitation UV illumination are used for the fluorescence, halogen excitation is for reflectance phenomena.

- **Hyperspectral Camera**

The device which capture image is very important for this project, as the output of the system greatly depends on the input image quality. Normal

cameras cannot be used directly because aflatoxin can only be observed with HS cameras. Hyperspectral imaging (HSI) is a technique that analyzes a wide spectrum of light instead of just assigning primary colors (red, green, blue) to each pixel. The light striking each pixel is broken down into many different spectral bands in order to provide more information on what is imaged. The algorithms and the image processing methodologies associated with HSI are a product of military research, and were primarily used to identify targets and other objects against background clutter. In the past, HSI has seen civil applications, and has particularly been useful in satellite technology. It might become an inexpensive, promising, and quick tool for the assessment of tissue conditions at diagnosis and during surgery.

The medical applications include forensics, detection of colorectal and gastric cancer or ulcers. In HSI, the unique color signature of an individual object can be detected. Unlike other optical technologies that can only scan for a single color, HSI is able to distinguish the full color spectrum in each pixel. Therefore, it provides spectral information in addition to 2D spatial images. With a hyperspectral camera, the light is captured through a lens and split into different spectral lengths by a dispersive element such as a prism or a diffraction grating. Also possible is a recording of different wavelengths at different positions in the FOV. The heart of the MHSI camera is a CCD or CMOS detector array that reads out the information inherent to the captured light

The cameras can be customized to meet the wavelength or the application-specific performance needed.

## 4.3 Process & System Architecture

- The hopper feeds a bulk of in shell peanuts to the process through the vibratory feeder.
- The peanuts slides through a chute where the detection process happens for any signs of aflatoxin contamination.
- The detection process take place in a closed chamber with UV & halogen excitation and a sensor “hyperspectral camera “that records a UV hyperspectral images of the peanuts.
- The images is processed & analiezed in matlab using “hyperspectral tool box “. The MATLAB will detect any apperance of BGYF “aflatoxin” and then sends a signal to the plc to do the reject process.
- The reject process in done by using a pneumatic Ejector.

### 4.3.1 Hopper and Vibratory Feeder and Chute

The mechanical vibratory feeder feeds the peanuts from storing hopper to the chute. For equal distribution of peanuts & it maintains the flow of peanuts from hopper to chute.

### 4.3.2 Detection Chamber & Camera System

The detection chamber is a sealed dark room made from stainless steel. It contains the camera system which composes of the excitation sources and the huperspectral camera. Excitation Sources: UV & halogen.

### 4.3.3 Image Processing System

Image processing system as shown in the Figure “4.6” is very important part of the aflatoxin detection system. The system consisted of Computer/Laptop Controller as shown in figure (4.6).

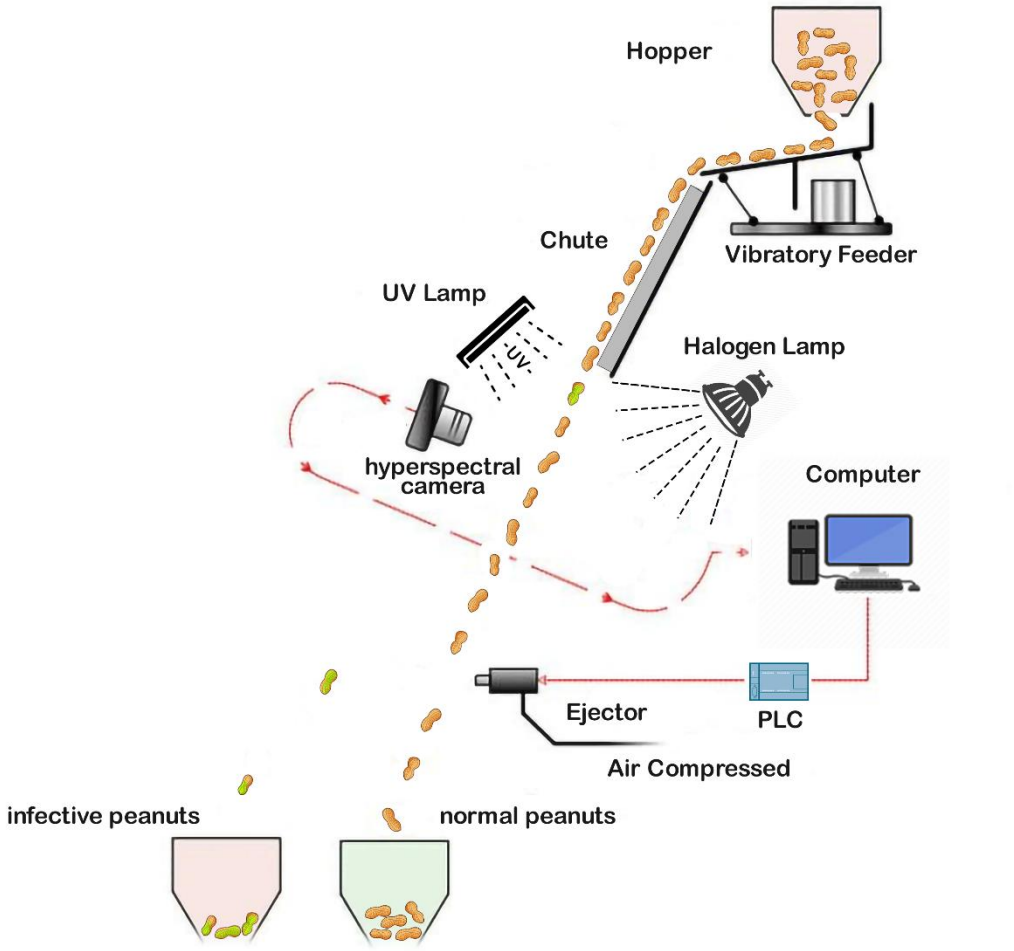


Figure (4.6): Image Processing System

- **Computer/Laptop**

Computer is equipped with NVIDA GeForce graphical processing unit. This help the system in fast processing of images and fast training on aflatoxin dataset. MATLAB is installed on the system. MATLAB hyperspectral tool box is used for hyperspectral image processing.

This computer also act as server which is responsible for all processing of aflatoxin detection system. The Image Processing system can only be controlled through this computer.

- **MATLAB Hyperspectral Tool Box**

The Hyperspectral Image Analysis Toolbox (HIAT) is a collection of algorithms that extend the capability of the MATLAB numerical computing environment for the processing of hyperspectral and multispectral imagery. The purpose of the HIAT Toolbox is to provide information extraction algorithms to users of hyperspectral and multispectral imagery in environmental and biomedical applications. HIAT has been developed as part of the NSF Center for Subsurface Sensing and Imaging (CenSSIS) Solution ware that seeks to develop a repository of reliable and reusable software tools that can be shared by researchers across research domains. HIAT provides easy access to supervised and unsupervised classification algorithms developed at Laboratory of Remote Sensing and Image Processing (LARSIP) over the last 10 years. The MATLAB Hyperspectral Image Analysis Toolbox as shown in figure (4.7).

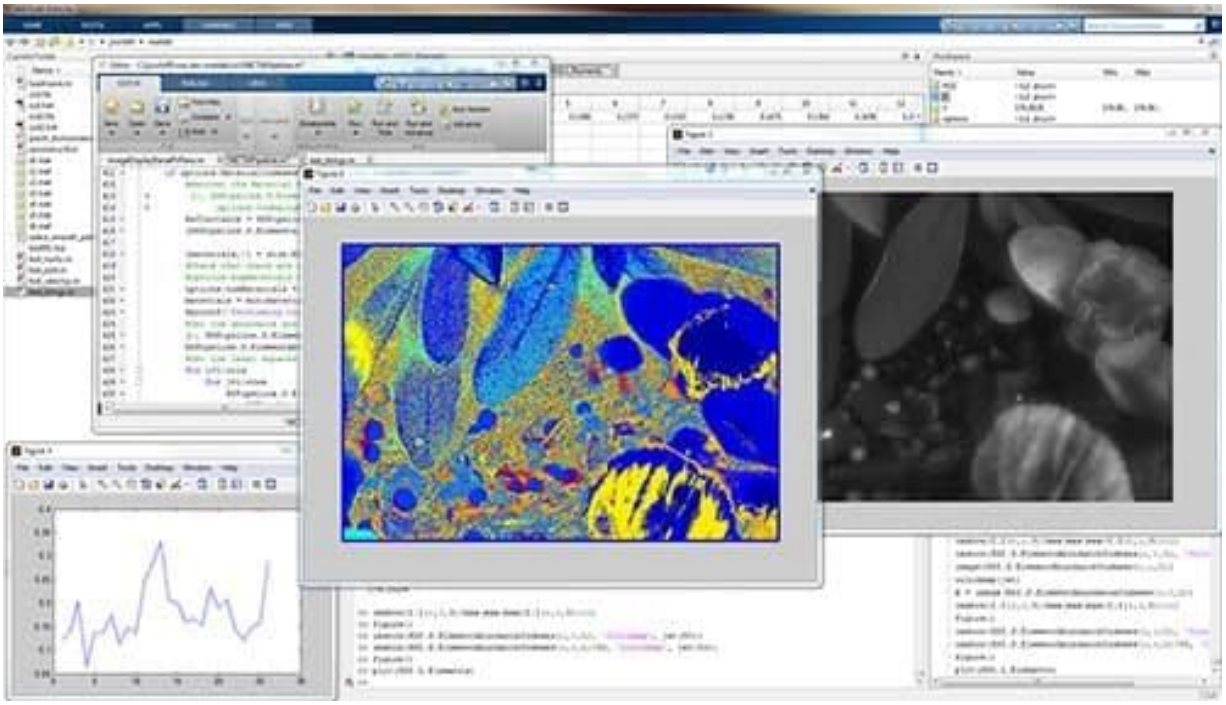

Figure (4.7): Hyperspectral Tool Box Interface

– **Controller**

The main part of any system is its processing unit, which controls whole processing of the system. For our proposed aflatoxin detection machine this device is Programmable logic controller (PLC). In our proposed the PLC is used only as an IO device and all computations and image processing are performed in the MATLAB. The connection between the matlab and plc is ensured via a general process visualization interface, which can transmit a data via different communication protocols: A simple model was made for better explaining the structure and principle of the proposed aflatoxin detection machine using Arduino - color sensor – motors.

### 4.3.4 Pneumatics System

Pneumatic rejection acts as important actuating part to apply pressure force to reject the infected peanut samples .The pneumatic system has signal receiving from The Plc Digital output Module.

The synchronization between falling peanut with image and signal processing system must be necessary. It can calculate by the time analysis starts from image taken by camera to pneumatic air generated. This time cannot always constant. To generate air pressure the air compressor can be used. The response time of pneumatics is practically high. The newest technology of pneumatics can give less than 5 ms of response.

## 4.4 System Implementation

The Aflatoxin detecting machine simple model contains a frame made of wood and cardboard, stand, color sensor and servo motor which are installed together.

### 4.4.1 Microcontroller-Arduino

Arduino is a small microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. Arduino can either be powered through the USB connection from the computer or from a 9V battery, Figure (4.8) describe all Arduino pins. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently.

The hardware consists of an open source hardware board that is designed around the Atmel AVR Microcontroller. The intention of Arduino was to make the application of interactive components or environments more accessible. Arduino is programmed via an Integrated Development Environment (IDE). An Arduino program is written in either C or C++ and is programmed using its own IDE.

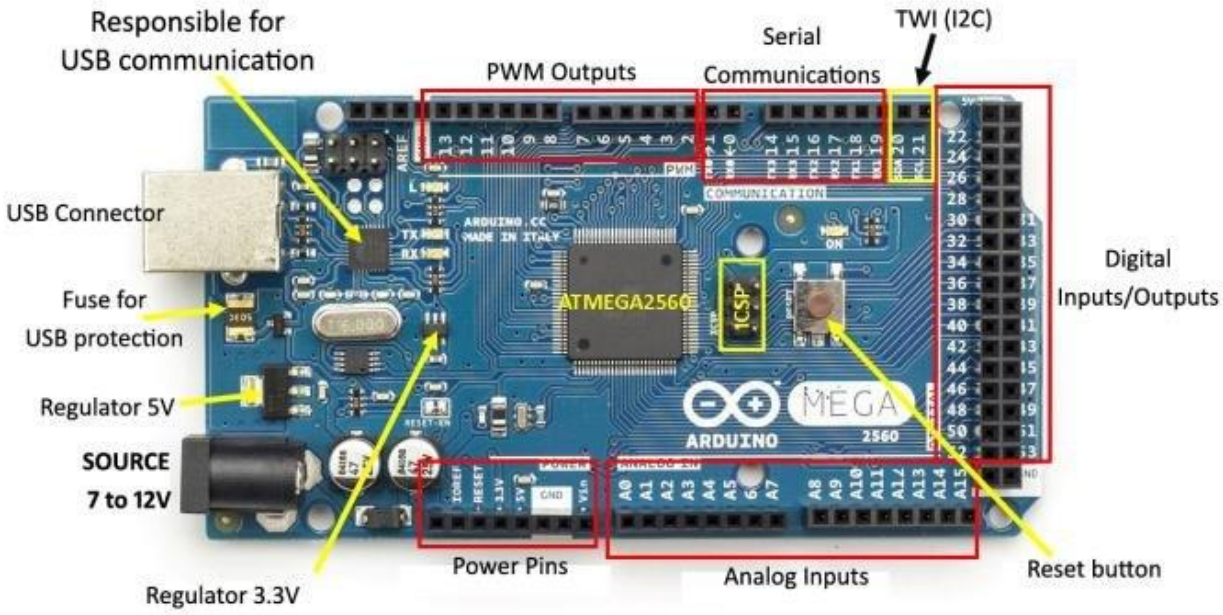


Figure (4.8): Arduino Mega Components

### 4.4.2 Servo Motor

Servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servomotors are not a specific class of motor, although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system.

Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

A Blue Tower Pro SG90 9g Micro Servo Motor is used in the model which shown in figure (4.9).


Figure (4.9): Blue Tower Pro SG90 9g Micro Servo Motor

- **Specifications**
  - Metal gears
  - Operating Voltage: 4.8 - 6VDC
  - Speed: 0.1 sec/60° at
  - Torque: 2.5 kg.cm
  - Size: 32 x23x12mm
  - Weight: 14.7g
  - Rotation angle: 180 degree

### 4.4.3 Color sensor

The TCS3200 color sensor can detect a wide variety of colors based on their wavelength. This sensor is specially useful for color recognition projects such as color matching, color sorting, test strip reading and much more.

The TCS3200 color sensor uses a TAOS TCS3200 RGB sensor chip to detect color. It also contains four white LEDs that light up the object in front of it as shown in figure (4.10).


Figure (4.10): color sensor

- **Specifications**

Here's the sensor specifications:

- Power: 2.7V to 5.5V
- Size: 28.4 x 28.4mm (1.12 x 1.12″)
- Interface: digital TTL
- High-resolution conversion of light intensity to frequency

- Programmable color and full-scale output frequency
- Communicates directly to microcontroller

### 4.4.4 Design and instructor of the simple model

A simple model has been designed to demonstrate the detection process according to this steps:

- First, the frame made of a (45*45cm) piece of wood, a piece of cardboard (59*80cm) mounted on the frame to cover the gape this frame work as a holder which all the project components are installed on its surface. Figure (4.11) is showing the frame carrying the cardboard.

Figure (4.11): The frame

- The second step, a stand was made of three (6*2cm, 6*2cm and 9*2cm) wood pieces , this stand works as a holder for the color sensor as shown in figure (4.12) this combination works as detection chamber as we mention above in the proposed design of the machine.

Figure (4.12): Color Sensor Installed To Wooden Arm

- The third step, a servo motor added to the base of the wooden arm .An arm is attached to the servo motor to work as rejecting system forcing the peanuts to move to the precised location.
- Finally, all the components were intalled to the wooden frame, control components are installed behind the cardboard only the color sensor, servo motor and the Demonstration drawing are in the front view of the cardboard.

## 4.5 Control unit and wiring

The color sensor and the servo motor are connected to the arduino using jumper wires, a code written in the arduino software 1.8.13 is used to control the color sensor and servo motor.

**- Color sensor wiring**

- The color sensor has 4 controlling pins (s0, s1, s2 and s3) those pins were connected to the arduino pins (4, 5, 6 and 7) a jumper wires used in this process as shown in figure (4.13).
- Two more pins were connected to the Arduino from the color sensor the first pin was the ground to ground and the other one is the power pin to supply the color sensor with +5v as shown in figure (4.13).
- The last pin was the output pin and it’s connected to the slot number 8 on the Arduino as shown in figure (4.13).

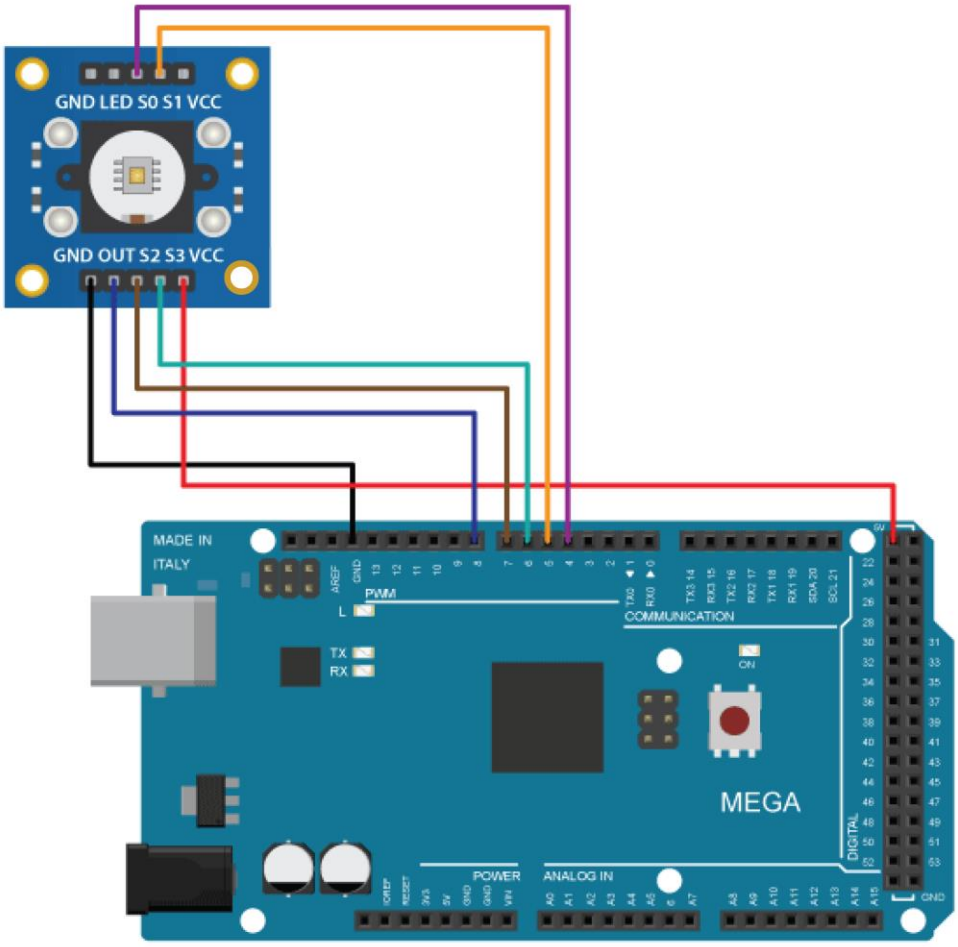


Figure (4.13): Color sensor wiring

– S0 and S1 are used for scaling the output frequency. The frequency can be scaled to three different preset values of 100 %, 20 % or 2%. This frequency-scaling function allows the output of the sensor to be optimized for various frequency counters or microcontrollers.

| S0 | S1 | Output frequency scaling |
|---|---|---|
| L | L | Power down |
| L | H | 2% |
| H | L | 20% |
| H | H | 100% |

Table (4.1): frequency scaling

– The TCS230 senses color light with the help of an 8 x 8 array of photodiodes. The photodiodes have three different color filters .S2 and s3are used to specify the color according to this table.

| S2 | S3 | Photodiode type |
|---|---|---|
| L | L | red |
| L | H | green |
| H | L | Clear (no filter) |
| H | H | Blue |

Table (4.2): Color defining table

- **Servo motor wiring**

Servo motor has only 3 pines the ground one is connected to the arduino ground.

The second one is connected from the arduino to supply the servo motor with +5 volte.

The third pin of the servo motor is connected to the arduino's pin number 9 this pin is used to control the angle of the servo motor.

- **Simple model testes**

The model has been tested to get the proper functionality for each element as the following:

  - First the peanut infection test, when a yellow colored peanut exposed to the color sensor for the first time the sensor gave the results as shown in figure (4.14).

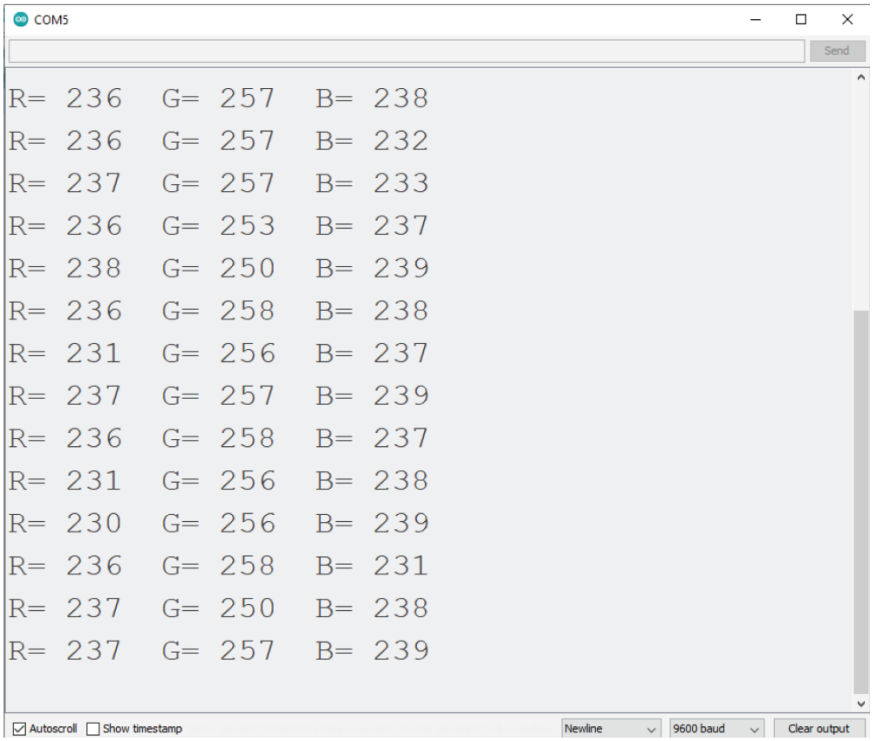


Figure (4.14): The sensor results of the yellow colored peanut

– According to this results a color range was set for the yellow colored peanut, this range is given in the table (4.3).

| | |
|---|---|
| R | The range is between 220 and 240 |
| G | The Range between 250 and 270 |
| B | The Range between 230 and 250 |

Table (4.3): Range of the yellow colored peanuts

– Secondly no infection test, in this test a normal peanut is exposed to the color sensor for the first time the sensor gave the results as shown in figure (4.15)

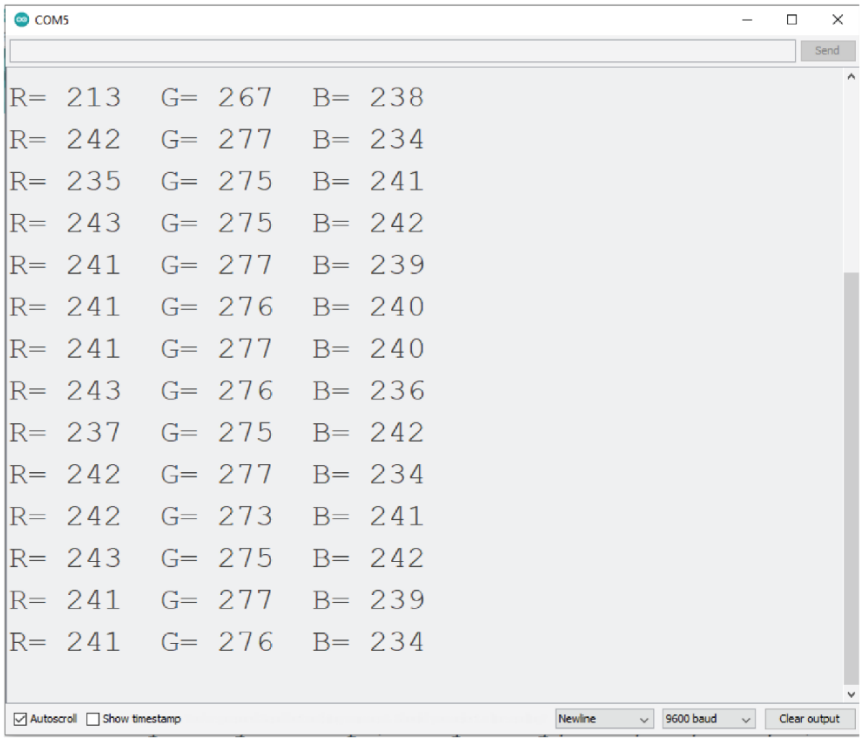

Figure (4.15): The sensor results of the normal peanut

- After studying the results a range has been decided for the normal peanuts this range is shown in table (4.4).

| | |
|---|---|
| R | The range is between 240 and 260 |
| G | The Range between 270 and 290 |
| B | The Range between 235 and 260 |

Table (4.4): Range of the normal peanuts

# CHAPTER FIVE
# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

The main goal of this project is to create a new method to detect aflatoxin contamination in Sudanese peanut crop, using image processing and control science. This project is chosen due to disadvantages of laboratory common methods that are time consuming and destructive. Furthermore, the results we get from these methods are not reliable and not accurate.in Sudan those methods can not be applied efficiently due to lack of equipments.

To solve this problem a design for aflatoxin detection machine is proposed based on machine vision and hyperspectral image processing, this detection system uses communication between hyperspectral camera, MATLAB and PLC. A block diagram has been developed for the proposed machine and a simple model has been designed to test the principle of the detection using pre prepared peanut samples to demonstrate the machine mechanism.

## 5.2 recommendation

- Another detection chamber can be added to the design to increase the accuracy of the detection.
- A matlab program can be added to calculate aflatoxin. Concentration in ppb.
- The machine elements can be upgraded to the latest versions.

-Finally, another feature can be added to the machine is human machine interface screen to monitor the machine statues.

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# APPENDIX

The arduino main code for the simple model

```
#include <Servo.h>

Servo servo;



#define S0 4

#define S1 5

#define S2 6

#define S3 7

#define sensorOut 8



int redfrequency = 0;

int greenfrequency = 0;

int bluefrequency = 0;



void setup() {
```

```
  pinMode(S0, OUTPUT);
  pinMode(S1, OUTPUT);
  pinMode(S2, OUTPUT);
  pinMode(S3, OUTPUT);
  pinMode(sensorOut, INPUT);

  // Setting frequency-scaling to 20%
  digitalWrite(S0,HIGH);
  digitalWrite(S1,LOW);
  servo.attach(9);
  servo.write(90);

  Serial.begin(9600);
}

void loop() {
```

```
delay(1000);

// Setting red filtered photodiodes to be read

digitalWrite(S2,LOW);

digitalWrite(S3,LOW);

// Reading the output frequency

redfrequency = pulseIn(sensorOut, LOW);

//Remaping the value of the frequency to the RGB Model of 0 to 255

//frequency = map(frequency, 20,72,255,0);

// Printing the value on the serial monitor

//Serial.print("R= ");//printing name

//Serial.print(redfrequency);//printing RED color frequency

//Serial.print("  ");

delay(50);



// Setting Green filtered photodiodes to be read

digitalWrite(S2,HIGH);
```

```
digitalWrite(S3,HIGH);

// Reading the output frequency

greenfrequency = pulseIn(sensorOut, LOW);

//Remaping the value of the frequency to the RGB Model of 0 to 255

//frequency = map(frequency, 30,90,255,0);

// Printing the value on the serial monitor

//Serial.print("G= ");//printing name

//Serial.print(greenfrequency);//printing RED color frequency

//Serial.print("  ");

delay(50);


// Setting Blue filtered photodiodes to be read

digitalWrite(S2,LOW);

digitalWrite(S3,HIGH);

// Reading the output frequency

bluefrequency = pulseIn(sensorOut, LOW);
```

```
 //Remaping the value of the frequency to the RGB Model of 0 to 255
 //frequency = map(frequency, 25,70,255,0);
 // Printing the value on the serial monitor
// Serial.print("B= ");//printing name
 //Serial.print(bluefrequency);//printing RED color frequency
// Serial.println("  ");
 delay(50);


  if ((redfrequency >= 220 && redfrequency <= 240)&&(greenfrequency >= 250 && greenfrequency <= 270)&&(bluefrequency >= 230 && bluefrequency <= 250))
  {
   Serial.println("Peanut is infected!");
   servo.write(180);
   delay(1000);
   servo.write(90);
   }
```

```
  if ((redfrequency >= 240 && redfrequency <= 260)&&(greenfrequency >= 270 && greenfrequency <= 290)&&(bluefrequency >= 240 && bluefrequency <= 260))
  {
   Serial.println("Peanut is Good :) ");
   servo.write(0);
   delay(1000);
   servo.write(90);
   }
}
```