An LED and Spectroscopy System for Detecting Aflatoxin in Corn

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1 Introduction

1.1 Objective

Aflatoxins are produced by the fungus Aspergillus flavus. It can invade corn kernels, especially if the plant has undergone some stress[1]. The toxin can bring harmful effects on human body, especially the liver. Aflatoxicosis, having harmful effects on livestock, domestic animals and humans, is the poisoning that results from ingesting the toxin. The toxin can also cause damage to urinary system, digestive system, nervous system and reproductive system. Large doses can lead to acute illness and death [2]. Long-term consumption of foods containing aflatoxin can cause liver cancer, intestinal cancer, and gastric cancer.

We would like to create a low-cost Light Emitting Diodes (LEDs) spectroscopy system to let researchers from other places participate in this aflatoxin research. A group of researchers have built a device in the laboratory of Professor Matt Stasiewicz. We are interested in working with John M. Hart to build and improve the reflectance spectroscopy system based on these principles for detecting the presence of aflatoxins, which can be reproduced and distributed.

1.2 Background:

Aflatoxins can be detected by using reflectance spectroscopy method. According to the paper "Detection of Aflatoxin Contaminated Figs Using Near-Infrared (NIR) Reflectance Spectroscopy", NIR spectroscopy can provide spectral data from a specimen [3]. Based on aflatoxins' special physical property under ultraviolet (UV) light, for instance the B-group aflatoxins exhibit blue fluorescence (around 450nm); the G-group exhibits yellow-green fluorescence (approximately 550 nm) under ultraviolet (UV) light [4]. According to the research plan, a custom spectrometer were chosen to collect the reflected light from the kernel to check for the presence of the toxin. LED diodes with various wavelengths are mounted on the sealed metal alloy tube, which will shine at the corn kernel, and the reflection light from the kernel will project onto the sensors installed at the top and the bottom of the tube. Then, data will be passed to the software which designed by the spectrometer provider to reveal the magnitude of the reflection light signal at different frequencies. Based on the given data, researchers will be able to determine if the corn kernel carries aflatoxins.

The concurrent circuit setup used by the research group are on two pieces of breadboards. In order to adjust the brightness, it requires user to manually tune the resistance value without a reading of the impedance value. Therefore, it is inconvenient for researchers to adjust the resistors by hand and precisely jump to the desired brightness level for different diodes. Moreover, the only way they can change the duration of time for the pulse of the LEDs is to modify the code. In order to add convenience and functionality to the prototype, we would like to build a webpage-based graphical user interface (GUI), where users can adjust the brightness of the LEDs and duration of their pulses. The GUI is connected to a microcontroller which automates the sequence of the 3 tasks: 1) pulsing of LEDs, 2) indicating when one cycle is done, 3) prompting error messages when there is issue with the circuit setup.

1.3 High-Level Requirements

- The circuit connected to the LEDs will be able to balance the brightness of each LED so that these LEDs can be pulsed at the same brightness level.
- The set up will include a control module to enable the interaction between the webpage-based graphical user interface (GUI) and the LEDs using microcontrollers.
- The GUI will display a panel for user to adjust the brightness of the LEDs and to change the duration of time for the pulse of the LEDs.

2 Design:

2.1 Block Diagram

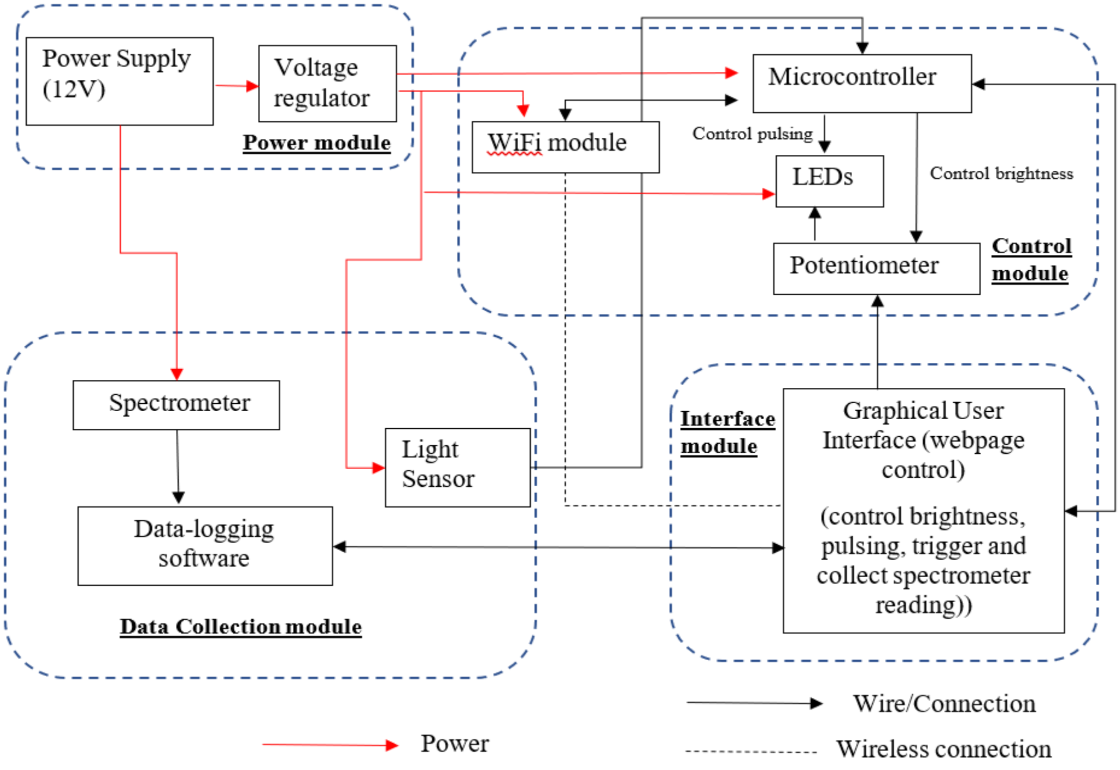

Figure 1: Block Diagram of our Project

2.2 Physical Design

We will be using an inclined light tube (similar to the original design in Agricultural Bioprocess Laboratory, University of Illinois, Urbana-Champaign) so that the kernel can move in moderate speed for data collection with the spectrometer. There are holes at each end of the light tube for the LEDs to be located. There are also 3 holes in the middle of the tube, where light sensors are located. If there are extra time, we would attempt adding an automated kernel sorting function to sort the good and bad kernels.

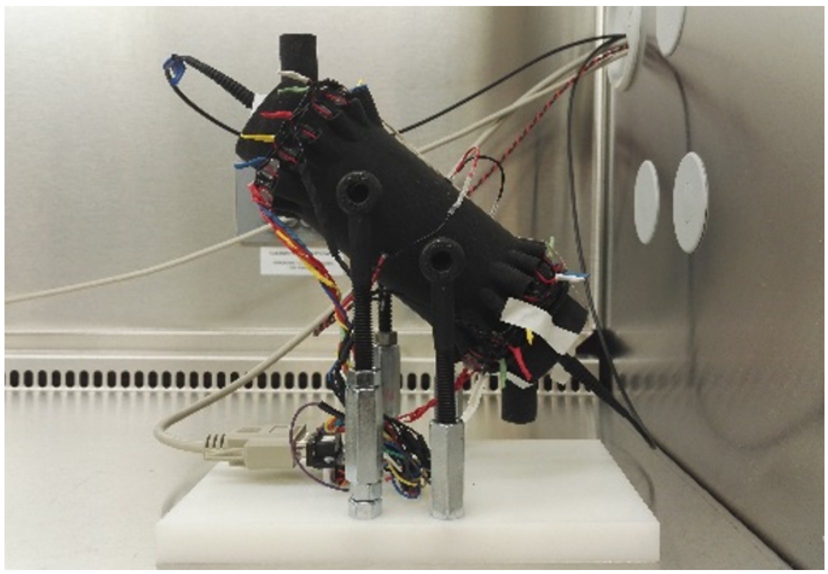

Figure 2: A prototype of the light tube [5]

2.3 Functional Overview

<u>**Power Module**</u>

Power supply: It supplies 12V to the voltage regulator.

Voltage regulator: The voltage regulator will be used to step down the voltage provided by the power supply from 12V to 5V.

<u>**Control Module**</u>

Microcontroller (ATMega328 chipset): The microcontroller interfaces with a web page to control the pulsing of the LEDs and the brightness of the LEDs. It needs to be programmed so that the LEDs are triggered to pulse (to be switched on and off for a short duration of time) when the user initiates it or when the sensor detects the presence of the kernel.

LEDs: Ultraviolet, infrared and visible-light LEDs are needed for this project. Five types will be used in this project. Each set of LEDs consists of 6 units, so that sufficient light intensity can be projected onto the kernel.
Potentiometers: They are connected at the emitter of transistor and are connected to the microcontroller. Pulse width modulation method will be used to control the brightness of the LEDs.
Wi-Fi Module: It provides wireless communication for signal transmitting in between the micro controller unit and the client controlling handset. It will occupy one band from the 2.4GHz cluster.

<u>**Interface Module**</u>
Graphical User Interface (web page): The microcontroller can run as a web server host. The webpage will be coded with C, JavaScript, or PHP depending on capability. It receives signal from light sensors to trigger the spectrometer for data collection.

<u>**Data Collection Module**</u>
Light Sensors: They detect the presence of kernel and send signal to the GUI when a kernel is detected.
Spectrometer: Before the experiment, the background light intensity needs to be collected so that the value can be used for the calculation of reflectance. Then spectrometer is triggered to collect data of the reflected light intensity from the corn kernel.

2.4 Block-level Requirement

Requirements
1.Voltage regulator (i) The voltage regulator needs to reduce the input voltage of 12V to between 4.75V and 5.25V, as a power supply for the microcontroller. (ii) The voltage regulator should be able to allow maximum of 5A current pass through.
2. Microcontroller (i) It is able to adjust the PWM to the potentiometer, which then changes the brightness of the LEDs. (ii) It is able to communicate with the WiFi module to enable data transfer from the web page to the LEDs. (iii) It can receive signal from 3 light sensors in the middle of the tube to trigger the pulsing of the LEDs, followed by data collection on the spectrometer.

3. LEDs (i) The LEDs need to be connected to bipolar junction transistor (BJTs) for current-balancing purpose. (ii) Their pulsing time is controlled by the microcontroller. The pulsing time is expected to be set to 10ms. (iii) The LEDs will be mounted to the 3D printed Light Tube.
4. Potentiometer (i) It is able to adjust the current flow across each LEDs digitally, to be within its permitted range. Examples of LEDs which might be used: (we might be using different models of LEDs, but with similar features) - For C513A-MSN-CV0Y0132, the range of forward current is 30-100mA. - For MTE3650L2-UV-HP, the range of forward current is 0-300mA. - For MTE5010-095-IR, the range of forward current is 0-100mA. - For TSHA5200, the range of forward current is 0-100mA. - For TSUS5400, the range of forward current is 0-150mA.
5. Webpage control (i) It can display a panel with 5 sliders, where users can adjust the brightness of each type of LEDs, based on the response shown on the spectrometer output. (ii) It can display warning message if there is
6. Spectrometer (i) The leads to the spectrometer should be able to be mounted properly onto the 3D-printed Light Tube.

2.5 Risk Analysis

2.5.1 Power Delivery Issue

As we mentioned above that our circuit is required to be able to power 30 LED diodes. In order to power 5 different types of LED diodes, along with other peripherals which are essential to our product, there will be 5 different voltage levels required for the circuit. Hence, in order to properly power each individual components correctly, a precise multilevel voltage divider circuit will be needed to meet these needs. Transistors and resistors will be used to control the voltage and current through each component in the circuit. Accurate calculation is significant in our design.

2.5.2 Thermal Issue

Along with the power issue we mentioned above, based on a draft calculation of the overall power consumption, in order to drive all the LED diodes and other peripherals, an estimate of 3.3A current is required. As for overall power consumption, we are looking for 25W as the maximum output from the voltage regulator. In addition, to step down the voltage to 5 additional outputs, the conversion circuits will emit a high level heat. Therefore, we need to take the thermal safety of the circuit into consideration. Carefully selecting and learning the features of the electronic components we will use is necessary before we design the circuit.

2.5.3 Wireless Band Selection Issue

As we know that, 2.4 GHz cluster is defined as industrial, scientific and medical radio band cluster ruled by FCC under Part 15 regulation [10]. As this range of frequency can be used without acquiring a license registration, there are a lot of devices which are running at this frequency range. In order to maintain stable wireless connection, we have to make sure that our device will transmit signal continuously at a fixed frequency. Moreover, we need to make sure that it will not overlap with any other wireless devices which operates in the lab environment. A proper band selection is required for our design. If there is interference, we should prompt to user to acknowledge this specific issue.

3 Ethics & Safety

The purpose of our project is to design a device which can help to detect Aflatoxin in grains. This project is related to solving the issue of food safety. This is an implementation of IEEE ethics code #1 -- holding paramount the health of the public [6]. The device we design will be used by the department of Food Science and Human Nutrition research team so that they can further study aflatoxin in grains. Their research results will help the public to improve the understanding of the emerging technologies for the detection of toxins in food. This is also the IEEE ethics code #5 required [6]. At the same time, contributing to society and human well-being is also the requirement in ACM code of ethics [7].

There are several potential safety hazards with our project. In our project, we will use 30 LEDs, including some UV LEDs. UV radiation may harm human's eyes. Exposure to ultraviolet (UV) radiation have acute harmful effects and chronic harmful effects. The acute harmful effects is short-lived and reversible. Sunburn (or erythema) and tanning (or pigment darkening) are examples of this. UV-A and UV-B may cause acute harmful effects. Besides acute effects, chronic effects are more serious. Premature aging of the skin, suppression of the immune system, damage to the eyes, and skin cancer are all possible chronic harmful effects of exposure to UV. So sometimes it's life threatening [8]. In order to avoid this from happening, we will mount the UV LEDs inside the Light Tube and make sure the lid is closed when the LEDs are on.

The current through the circuit we design may be high, transistors and LEDs are easily damaged, so circuit protection may be a big issue we need to consider when we design and connect the circuit. In this case, we need to read the datasheet and do the calculations very carefully when we design the circuit to ensure the current is in the appropriate range. In addition, we plan to connect these LEDs in parallel to decrease the effect if one of the component is damaged.

Moreover, the lab environment which our product will be placed at requires Biology Safety Level 2. It is essential for the researchers at the facilities to be able to perform maintenance easily for our design. So we need to know the proper way to isolate the circuit from the chemical compounds used to decontaminate the system, such that there won't be any toxic or chemical reaction which may take place with our product.

We need to address the Biology Safety Level 2. We will conduct final testing of our device in the biology lab, there are some rules we need to follow in the lab, including making sure our circuit box is easy to decontaminate. No food or drink is allowed in the lab. Since there are also other research groups working in that lab, it is important that we need to wash hands before entering and leaving the lab and avoid to touch any chemicals [9].

Security for the WiFi connection is another issue we need to consider. We will use a webpage-based interface software to control the circuit, the whole device will be working under the WiFi environment. Maintaining the WiFi operating on the proper bands without interferencing with other wireless devices which operates at the same 2.4 GHz unlicensed operation range is essential for the design.

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