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Design and Development of an Early Warning System for Potato Disease- Late Blight

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ABSTRACT
Pest attack and plant diseases are the major cause of the economic losses faced by farmers. Pest management is the fruitful method to control pests. Due to lack of knowledge in farmers, the excessive use of the harmful chemicals in their crop makes the soil infertile degrading the quality of soil as well as causing a great threat to the agro ecosystem. The prime objective of this paper work is an early forecasting of disease. Potato is one of the world's most produced and consumed crop. Thus, an early warning system is developed to forecast a disease in potato, named Late Blight, which is caused by the fungus Phytophthora Infestans. For the forecast, necessary environmental parameter which affects the growth of fungus was studied and those parameters are temperature, humidity and carbon dioxide concentration. Sensors were interfaced with the Arduino comprising of AT mega 328 microcontroller and the severity index has been calculated with the help of the standard equation of Beta Regression Model.

Keywords
Late Blight, Phytophthora Infestans, Arduino, Beta Regression Model.

1. INTRODUCTION
Agriculture is considered as one of the most ancient activities of man in which innovation and new advancements in the technology are merely accepted. The changes are accepted only with the improved results in production and quality. According to one of the surveys conducted in 2013-2014, India contributed 13.7% of GDP as a part of the agriculture. Around 45% [1] population is working in fields and is entirely dependent on the agricultural activities. Also if we consider in a very close aspect than 70% of the country side population earns its occupation from agriculture [1].

As major portion of the population is dependent on agriculture, the manufacturers are promoting the use of the insecticides and pesticides and the farmers are using them for their benefits. Ingestion of these chemical pesticides and insecticides adversely affect the entire agro ecosystem along with the human health leading to the diseases such as liver disorder, asthma, cancer etc. The prior prediction of the risk to crop will be beneficial to farmers and also it will be helpful to them in limiting the use of the harmful chemicals [2]. Thus, in order to protect the agro-eco system, it is necessary to forecast the diseases in plants with the help of the management system known as plant disease forecasting. The main objective of the plant disease forecasting is to accurately predict the disease in the plant when the three factors - host, environment, and pathogen - all interact in such a fashion that disease can occur and cause economic losses.

The crop which is undertaken is potato and the disease is known as potato Late Blight caused due to the fungus like organism oomycete and the name of that fungus like organism is Phytophthora Infestans [3]. The most produced as well as consumed crop, potato is a starchy, tuberous crop with a high nutritive value. The binomial word of the potato tuber is Solanum Tuberosum. [4]. In the Andes, where the species is indigenous, there are some other closely related cultivated potato species. Potatoes were introduced outside the Andes region approximately four centuries ago, and have since become an integral part of much of the world's food supply. With an annual global production of about 300 million tonnes, potato is an economically important staple crop in both developed and developing countries. India ranks fourth in terms of area and is the third largest country in world in terms of production of potato after China. The potato production and its cultivation is affected by many of the climatic conditions and the environmental parameters like temperature, humidity [5], concentration of carbon dioxide and impacts of excess pests.

Potato late blight is considered as one of the most devastated disease in potato. It was also regarded as the epidemics that destroyed the potato crops in Europe in the 1840's and this destruction finally resulted into mass starvation. The fungus is dispersed by wind-borne sporangia, which are produced on branched hyphae (sporangiophores) that emerge from the stomata of infected leaves in humid conditions. When Phytophthora Infestans sporangia's were studied in laboratory conditions, they were found to germinate either by releasing zoospores or by producing a hyphal outgrowth. The type of germination is governed by environmental conditions, especially temperature. The sporangia release zoospores [6] at low temperatures (4 – 12) ° C but by hyphal outgrowth at higher temperatures (20 – 27) °C [7].

The disease appears as water- soaked irregular pale green lesions mostly near tip and margins of leaves. The pathogen causes purplish-brown lesions on the surface of tubers. Often secondary invaders such as bacteria may enter rotted tubers making observations of symptoms difficult. A white mildew, which consists of sporangia and spores of the pathogen, can be seen on lower surface of the infected leaves especially around the edges of the necrotic lesions. Light to dark brown lesions encircle the stems. The affected stems and petioles become weak at such locations and it may collapse eventually. Entire crop gives blackened blighted appearance especially under disease favourable conditions and may be destroyed within a week.

A.K. Srivastava, T.K.Bagh, B.P. Singh [4] properly explained regarding the potato tuber and helped to understand the different late blight resistant with the help of the AUDPC (Area Under Disease Progress Curve). For the better understanding, V.K.Gupta, S.K.Kaushik, B.P Singh [8] used the same method of AUDPC but performed with the different method for commercial cultivars in the North-Eastern Hill region in order to explain the late blight resistants. Sandika Biswas, Bhushan Jagyasi, Bir Pal Singh and Mehi Lal [9], explained the disease potato late blight with the help of Fuzzy C-Mean clustering in which the images of the infected stems and leaves were considered in order to study the disease.

The main objective of the work showed here predicts the risk of occurrence of the Late Blight disease in potatoes on the basis of the calculation of the severity/ infection index. Thus, for the purpose of the evaluation of the severity index value, the three of the sensors that is temperature, humidity and CO2 [10] concentration is studied and then interfaced with the Arduino and the corresponding values is observed. Based on the standard equation of the Beta Regression Model, the severity index is calculated which indicates the risk level to the crop. This method poses a greater importance as compared to the other methods used, because it has low cost, low power consumption and most importantly it is eco-friendly, and there is no need to wait for the results, as the sensor after interfacing with the Arduino produces immediate calibrated results.

2. THEORETICAL BACKGROUND

Disease Forecasting Using Prediction Model

By making the use of Beta regression model as prediction model, disease forecasting has been done for the potato disease, Late Blight. This model was very much helpful in the calculation of the severity index in order to describe the risk of occurrence of the disease. The Beta Regression Models are commonly used by practitioners or users to model variables that assume the values in the standard unit interval (0, 1) [11, 12]. In general the Beta regression model is a prediction model that gives analytic values. It employs a parameterization of the beta distribution in terms of its mean and a precision parameter. Simple beta regression models are similar to generalized linear models. As mentioned that it takes the values in terms of the standard unit interval, the data is measured in a continuous scale and is restricted to the unit interval, i.e. $0 < y < 1$.

In this paper the generalized equation of beta regression model is used for the disease forecasting of potato, and the equation for the generalized beta model is as described below:

$$Y = pt^q (1-t)^r H^s \quad (1)$$

where Y is the severity index, H is the humidity and p, q, r, s are the unknown parameters that are estimated from data; t equals (T –Tmin) / (Tmax – Tmin), which is a scaled version of temperature defined with the minimum and maximum temperatures for the fungus to cause the infection (Tmin and Tmax). The parameter q describes that how steeply Y increases with increasing T up to the optimum temperature; the parameter r describes how steeply Y decreases with increasing T till the optimum. The above equation can be linearized to:

$$\log(Y) = \log(p) + q\log(t) + r\log(1-t) + s\log(H) \quad (2)$$

Three environmental parameters such as, temperature, humidity, and carbon dioxide concentration are considered so as to calculate the severity index. Thus, the above logarithmic equation can be further modified and re-written as:

$$Y = 1 \Big/ 1 + e^{-\left(B_0 + B_1 * cel + B_2 + RH + B_3 * CO_2\right)} \quad (3)$$

Where *B0*, *B1*, *B2*, *B3* are unknown parameters which was calculated from past experimental data; *cel* is temperature value in ºCelsius, *RH* is Relative Humidity value, CO_2 is carbon dioxide concentration in ppm and *Y* is severity index, which is main parameter in disease forecasting of potato.

3. PROPOSED METHODOLOGY

For making a system which fulfills all the objective of project requires a proper methodology. The fungus causing the disease Late Blight, is mostly affected by the temperature, humidity and the concentration of the carbon dioxide. Thus, after proper review the optimized range is found out and based on which the amount of power supply and the sensors is selected. LM35 is used for temperature, HIH-4000 for humidity and CM1101 CO_2 module sensor for the carbon dioxide concentration. These sensors are interfaced with Arduino which comprises of AT mega 328 microcontroller.

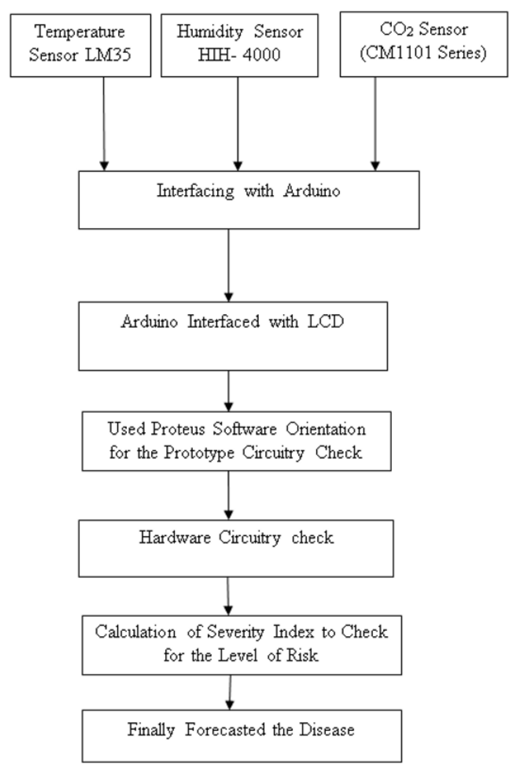

Figure 1: Flow Chart of the System

Analog interfacing has been done as all the three sensors are of analog type. The data obtained from sensors are to be displaced on the 16*2 JHD alphanumeric LCD screen. Thus sensors, along with the Arduino interfacing are then interfaced with LCD. After completing all the interfacing, the prototype circuitry is checked on the software tool, Proteus. This tool helps to properly examine the wire connections and also helps to prevent the circuit from damage. Once the prototype circuitry is properly examined, hardware connections are carried out and the system is developed. After we are available with the temperature and humidity values, the severity index is being calculated with the help of the standard equation of Beta Regression Model and the disease will be forecasted. Figure 1 shows the flow chart which describes the step by step procedure carried out in the project work to develop the proposed system

4. RESULTS AND DISCUSSION

The hardware circuit is checked on the proteus software first so that the prototype can be properly checked and the connections can be verified to prevent the damage. The circuitry of the prototype module in which all the three sensors are interfaced with the arduino is shown below in Figure 2. The results are displayed on the LCD screen along with the serial monitored values.

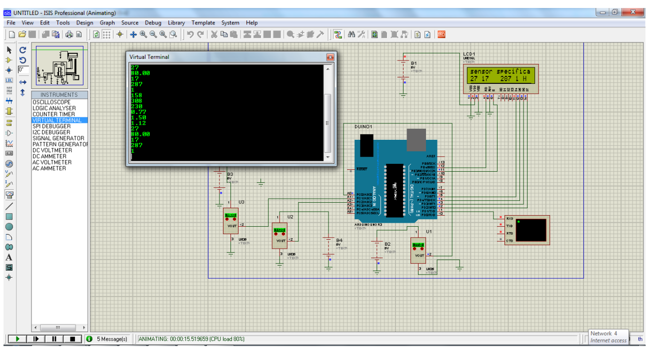

Figure 2: Prototype Circuitry of the Complete Hardware in the Proteus Software

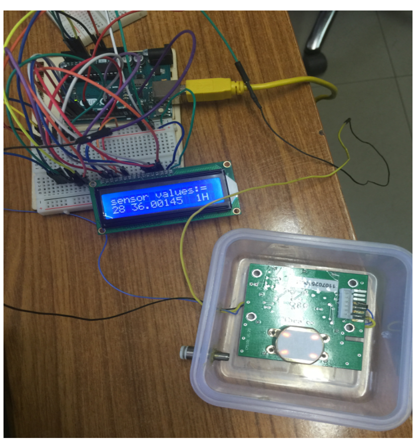

Figure 3: The Complete Hardware Circuit Along with Interfacing of All the Sensors

The prototype circuitry was checked and verified first and the actual hardware interfacing was done with the Arduino. Arduino was then interfaced with the LCD and the corresponding calibrated values of the temperature, humidity and CO_2 concentration is displayed on the 16x2 JHD 162A alphanumeric LCD. The complete hardware circuitry along with the results displayed is shown in Figure 3:

4.1 Disease Analysis Using the Environmental Parameter as Temperature

The optimum temperature for the fungal growth of the Phytophthora Infestans is in between the temperature range of (16-24) °C. This indicates that within this temperature range, the fungus will have a minimum threat to the crop, and as the temperature decreases below or even increases above, the fungus may cause severe threat to the crop. Thus it can be concluded that for the temperature below 16° C and above 24 ° C, it poses a great threat to the crop as below 16 °C the crop is destroyed due to the frost and the crop above the temperature range of 24 °C is at the high risk of damage [13]. The crop is under high risk is known based on the value of severity index for this temperature. Figure 4 shows the response of potato disease severity with change in temperature. This graph describes that above 24 °C there is a steep increase in the severity index as calculated with the help of the standard Beta Model equation, and there is not much loss to the crop within the optimized temperature range between (16-24) °C. Also the graph clearly states that above 24°C of the temperature value the infection/severity index increases up to 0.81, which is very close to 1 indicating the high risk to the crop, thus concluding that chances of infection above the 24°C is very high.

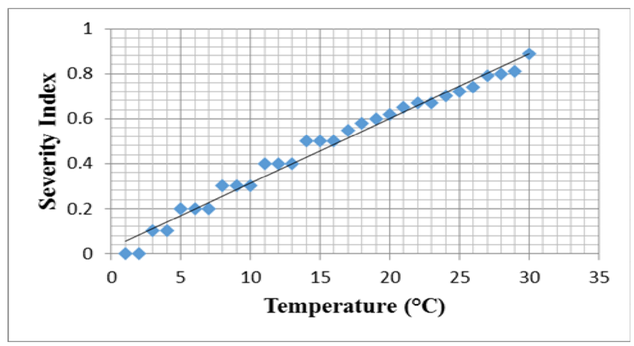

Figure 4: Response of Potato Disease Severity with Change in Temperature

4.2 Disease Analysis Using the Environmental Parameter as Humidity

When the relative humidity of the air is less than 50% there are very less chances of the disease infection which are only 0.2% of the total. The danger of the infection increase as the relative humidity crosses the limit of (85-90)%, [13, 14] the disease severity gradually increase beyond this point to almost 0.85 of the value. The Figure 5 below shows the response of potato disease severity with change in humidity. It explains that beyond the limit of the 90% of the Relative Humidity, the severity index gradually increases to 1, which is the steepest value.

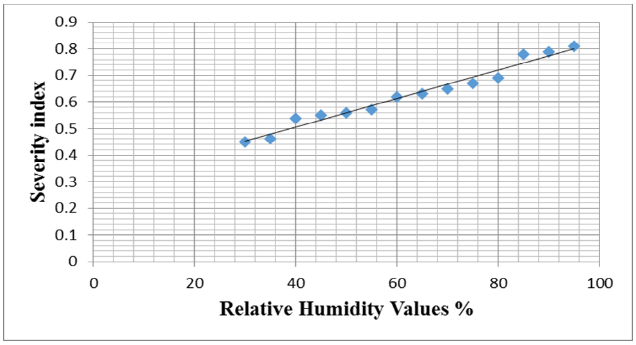

Figure 5: Response of Potato Disease Severity with Change in Humidity

4.3 Disease Analysis Using the Environmental Parameter as Carbon dioxide

When the concentration of carbon dioxide [14] in the surrounding atmosphere increases; the growth of the fungus causing the disease Late Blight also rises resulting in the steep increase in the severity index. The range of the carbon dioxide in ppm is (0-2000) or (0-5000), thus the Figure 6 explains the relation between the ppm concentration and the voltage. It can be concluded that the relation between the concentration and voltage is linear, that means with increase in voltage the concentration of carbon dioxide also increases, and as soon as the voltage decreases the concentration also decreases and vice-versa. In order to increase the concentration of the carbon dioxide, air was blowed from mouth in the closed box containing the sensor.

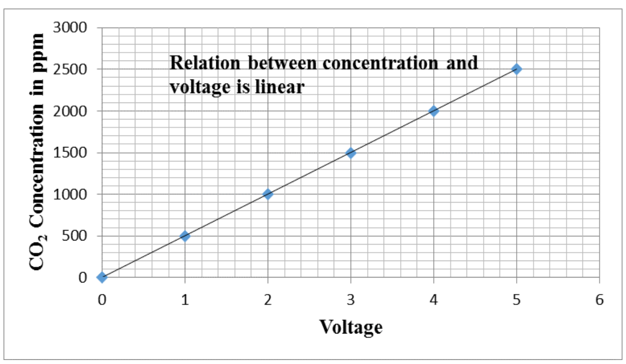

Figure 6: Response of Change in CO2 Concentration with Voltage

5. CONCLUSION

In this work, a simple Arduino platform based hardware system has been developed with the help of interfacing of various sensors. The programming software tool Proteus is used, which measured the various parameters involved for the purpose of pest management. A relation between various parameters to find out the optimum conditions for pest growth has been established. The developed system firstly measures the different parameters of environment like air temperature, air humidity, and carbon dioxide concentration. After the environmental parameter measurement, a relation between the various parameters and the severity index of disease of crop has been established. The developed system acquires all the information which will affect crop growth and provides capability of controlling the growth of pest. The calculation of severity index has helped with the prediction and control of growth of pest, but still this system can be further very easily upgraded. The developed system can be upgraded with the help of the Remote connectivity by the help of which information about severity can be sent directly to farmers on their mobiles.

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