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# 이동평균 알고리즘을 적용한 스마트 그린하우스 자동제어 시스템

## An Smart Greenhouse Automation System Applying Moving Average Algorithm

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**Abstract** - Automation of greenhouses has proved to be extremely helpful in maximizing crop yields and minimizing labor costs. The optimum conditions for cultivating plants are regularly maintained by the use of programmed sensors and actuators with constant monitoring of the system. In this paper, we have designed a prototype of a smart greenhouse using Arduino microcontroller, simple yet improved in feedbacks and algorithms. Only three important microclimatic parameters namely moisture level, temperature and light are taken into consideration for the design of the system. Signals acquired from the sensors are first isolated and filtered to reduce noise before it is processed by Arduino. With the help of LabVIEW program, Time domain analysis and Fast Fourier Transform (FFT) of the acquired signals are done to analyze the waveform. Especially, for smoothing the outlying data digitally, Moving average algorithm is designed. With the implement of this algorithm, variations in the sensed data which could occur from rapidly changing environment or imprecise sensors, could be largely smoothed and stable output could be created. Also, actuators are controlled with constant feedbacks to ensure desired conditions are always met. Lastly, data is constantly acquired by the use of Data Acquisition Hardware and can be viewed through PC or Smart devices for monitoring purposes.

**Key Words** : Greenhouse, Automation, Moving average, Sensors, Actuators

### 1. Introduction

Greenhouse automation systems are designed to control and monitor various microclimatic parameters such as moisture level, temperature, light, humidity, Co2 gas level and provide an optimum condition for the growth of plants inside a greenhouse. Greenhouse technology has improved a lot, and cost of electronic components associated with it are constantly decreasing. The rise of open-source electronics and software platforms like Arduino, Raspberry Pi etc. are contributing a lot in making hardcore electronics and programming easy and accessible[1-4].

Many type of research are in progress to fully automate agricultural systems such as animal farms and greenhouses for achieving optimum results. It is more like E-agriculture, or ICTs in agriculture, which is about designing, developing and applying innovative ways to use ICTS in agriculture. In the work by S. V. Devika et al (2014), Arduino based automatic plant watering system is designed where it uses a moisture sensor and water pump to irrigate plants. It is only focused on the automating irrigation system in a greenhouse. Another similar work by S.P Jena et al (2015) is about data acquisition in a greenhouse using Arduino and LabVIEW. This work is more focused on acquiring data from different sensors for monitoring purposes rather than controlling actuators associated with it. Likewise, in the work presented by H. Singh et al (2015), technical details of sensors is more focused while the paper is about remote sensing in greenhouse monitoring system. Also, testing of designed prototypes is missing. J.A. Enokela and T.O. Othoigbe (2015) developed two stations: Sensors/Actuators stations and Remote monitoring station where they communicate through XBEE radio modem for the control and monitoring of greenhouse systems. Prototype building process including flowcharts and circuit diagram are shown, but no any results relating to the testing of the prototype were shown.

In this paper, a simple yet improved prototype of a smart greenhouse using Arduino platform is designed focusing on feedbacks and algorithms. Once the command is executed, an actuator operates for a specified time but again the system checks the environment and compares with the threshold, and if the condition is met the actuator operates else stops. Through this, the creation of optimum environment inside the greenhouse for the growth of plants is ensured. Especially,

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Moving average algorithm is designed to smooth out short-term fluctuations which can cause actuators to turn on and off repeatedly. Chapter 2 gives detailed development of the algorithm. Data are constantly acquired by Data Acquisition Hardware (DAQ) and can be viewed from PC or Smart devices. For further analysis of the acquired signal waveform, Time domain analysis and Fast Fourier Transform (FFT) were done with the help of LabVIEW program. Overall, the whole system can be divided into five steps:

(1) Sensing, where sensors create signals from surrounding environment,

(2) Signal Conditioning, where sensed signals are isolated and filtered,

(3) Processing, where the micro-controller receives the signal and performs the specified task,

(4) Actuating, where actuators like water pump, heater, light bulbs operate after receiving signals from the micro-controller and

(5) Monitoring, where all the tasks can be monitored from PC or Smart devices.

## 2. Smart Greenhouse

### 2.1 System Architecture Concept

The automated greenhouse consists of a soil moisture sensor (J3Y), a temperature sensor (LM35) and a photo resistor for sensing microclimatic environment inside the greenhouse and a water pump (DC motor), a heat sinker fan or heater, and light bulbs as actuators. The sensed data are compared with the given thresholds and microcontroller (Arduino UNO) sends signals to actuators to operate or not. Fig. 1 shows the conceptual picture of the automated greenhouse.

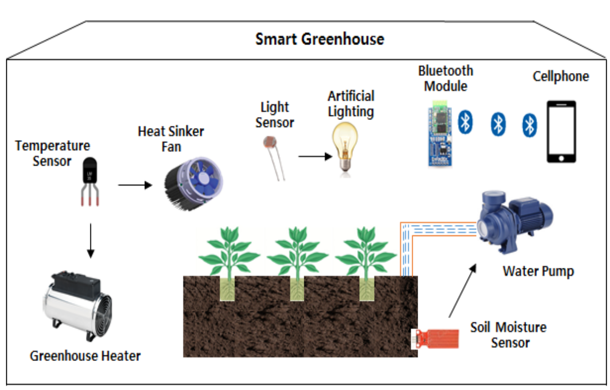


그림 1 스마트 그린하우스 자동제어 시스템의 개념도

Fig. 1 Conceptual picture of Smart Greenhouse Automation

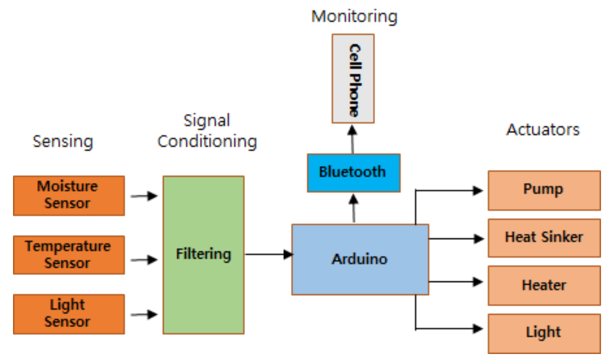


그림 2 스마트 그린하우스 자동제어 시스템의 블록도

Fig. 2 Block Diagram of Smart Greenhouse Control System

As mentioned in the introduction part, the whole system consists of five steps; sensing, signal conditioning, processing, actuating and monitoring. Fig. 2 shows the block diagram of the system including all these five steps.

## 3. Hardware Design

This work only uses a moisture, temperature and a light sensor for sensing the environment in a greenhouse but additional sensors can be added to the system easily. For signal conditioning, an Ultraprecision Operational Amplifier (OP177GP) is used for buffering the signal, and a 220Ω resistor and a 220$\mu$F capacitor is used for filtering purpose. A general purpose diode (IN4007), Bipolar Junction Transistors

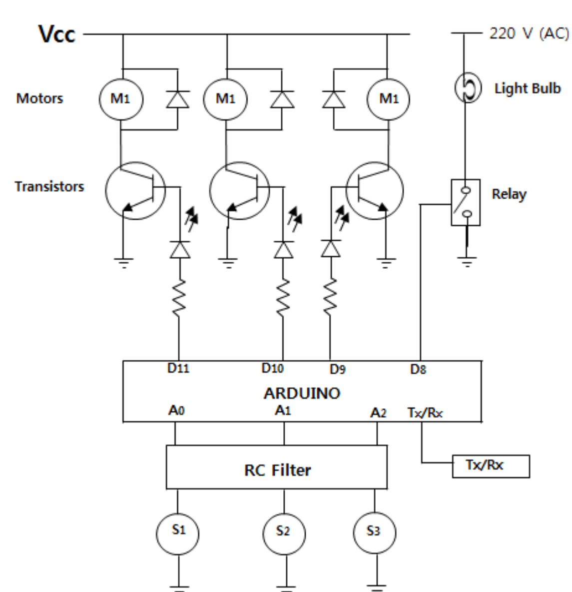


그림 3 자동제어 시스템의 회로 구성도

Fig. 3 Circuit Schematic of the automated system

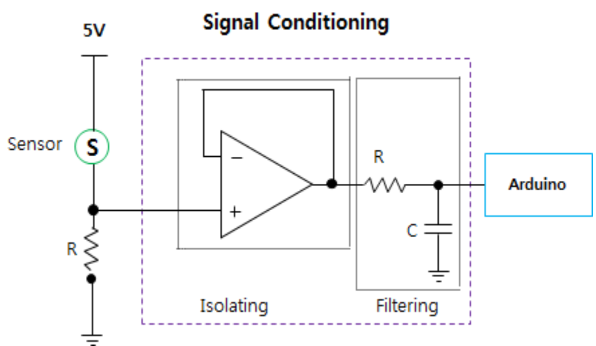


그림 4 하드웨어의 신호조정회로도

Fig. 4 Schematic signal conditioning circuit

(2222A), 1 KΩresistors, LEDs, DC motors, a Relay module were used for actuator circuit. Likewise, Arduino UNO and NI USB-6008 are used as a micro-controller and data acquisition respectively.

Fig. 3 represents the circuit schematic of the automated system. Every electronic component has their own role in the system. The diode is connected parallel to the motor to provide a safe path for the short term current that might be created if the current is suddenly cut off. LEDs are connected to the base of transistors to check if the current has been supplied by the Arduino or not. Signal is sent to relay through the micro-controller which makes the path for the current to flow for artificial lighting in the greenhouse.

Fig. 4 shows the signal conditioning circuit schematic for the hardware where sensed signals are first buffered using an op-amp and then filtered to remove noise. The filter is a simple first order RC-type low pass filter. The order of the filter can be increased as per requirements.

## 4. Software Design

The software is developed using Arduino Integrated Development Environment (IDE) which is a free open source software. Fig. 5 shows a part of the program developed for the entire system.

Fig. 6 shows the main program flowchart of the automated system. The main strategy of this system is to compare the sensed signals of the individual micro-climatic parameters to the predefined thresholds and execute the specified task. Once the command is executed, an actuator operates for a specified time but again the system checks the environment and compares with the threshold and if the condition is met the actuator operates else stops. This feedback system ensures the desired condition in the greenhouse is always

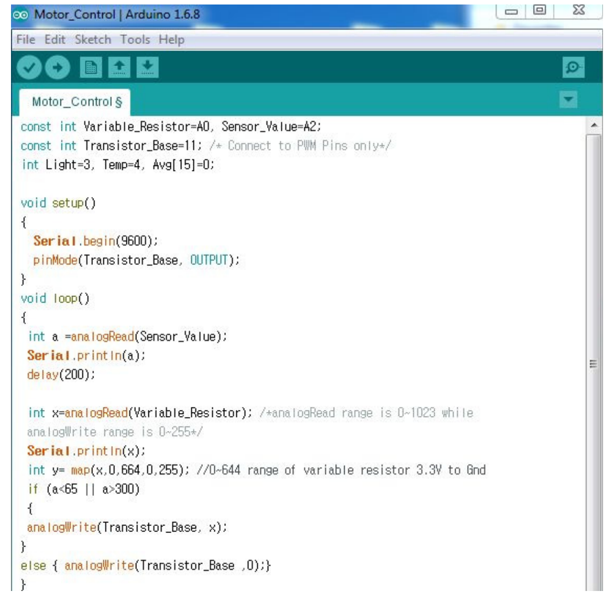


그림 5 아두이노 IDE에 제작된 프로그램

Fig. 5 Main program developed in Arduino IDE

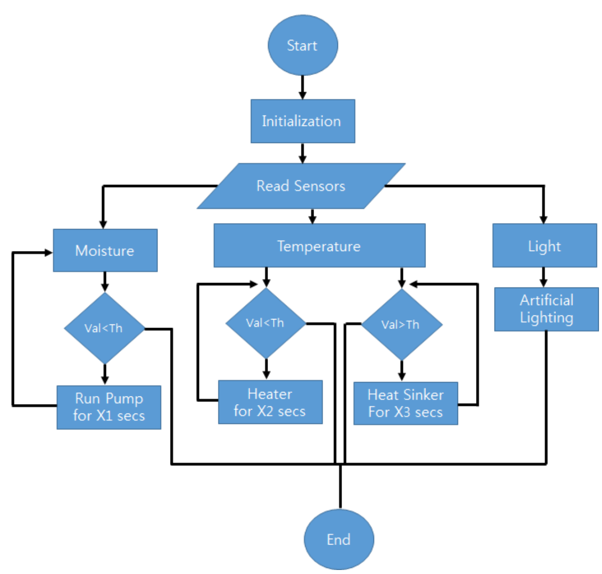


그림 6 자동제어 시스템의 신호흐름 선도

Fig. 6 Main program flowchart of the automated system

met. Most automated systems just check the environment and operate actuators once or twice a day. Especially during very hot or cold days, actuators might need to run more often in order to maintain an optimum environment in the greenhouse. In this work we have developed an algorithm which regularly checks the environment inside the green-house in small intervals and constantly feedbacks the system so as to meet the optimum conditions.

$$Avg_{t1} = [x_0^{t1} + x_1^{t1} + x_2^{t1} + ....... + x_{n-1}^{t1}]/(n-1) \tag{1}$$

$$Avg_{t2} = [x_1^{t1} + x_2^{t1} + x_3^{t1} ...... + x_{n-1}^{t2}]/(n) \tag{2}$$

Here, equation (1) and (2) represents the mathematical expression of the Moving average algorithm. $Avg_{t1}$ represents the total average value and $x_0^{t1}$, $x_1^{t1}$, $x_2^{t1}$ represents each different sensor reading taken in time $t_1$ with total $n$ number of samples. $Avg_{t2}$ represents the total average value at time $t_2$ that immediately comes after $Avg_{t1}$ with the recent reading $x_{n-1}^{t2}$ included and $x_0^{t1}$ being deleted from the array.

Fig. 7 shows the working concept of the algorithm. Fig.8 shows calculated Moving average from the acquired data where blue line represents signal sensed by photo sensor and red line represents its moving average. Often times because of rapidly changing environment, use of imprecise sensors or any inaccuracies in the system may cause a lot of variations in the acquired data. This may cause actuators to frequently turn on or off which is not desired. In order to smooth out these variations Moving algorithm is developed where the code sequentially stores specified amount of readings (15 in this work) from the sensor and stores them into an array. When an additional new value is sensed it is added to the array and the last value is subtracted and the average is immediately calculated. This greatly helps in smoothing the outlying data and creates more stable output.

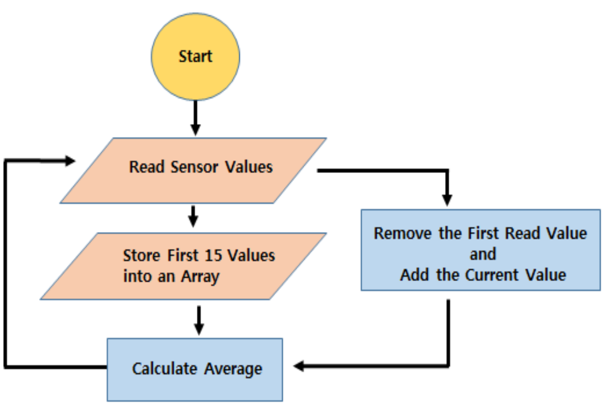


그림 7 스마트 그린하우스를 위한 이동평균 알고리즘

Fig. 7 Moving average algorithm for the smart greenhouse

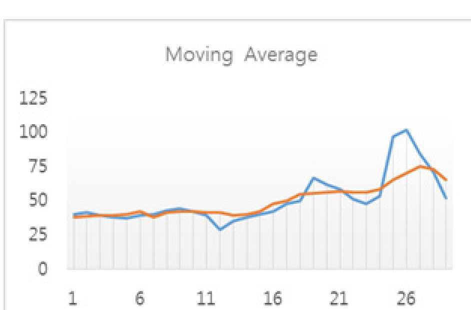


그림 8 수집된 데이터의 이동평균값

Fig. 8 Moving average of the acquired data

## 4. Results and Discussions

### 4.1 Results

A simple laboratory prototype was built using the hardware parts mentioned in Chapter 3. With the help of DAQ, time domain and frequency domain analysis was done of the filtered signals.

Fig. 9 and Fig. 10 represents the block diagram of time and frequency domain analysis, and time and frequency domain analysis of the filtered signal respectively. Continuous data was sampled by DAQ with the sample rate of 10 KHz.

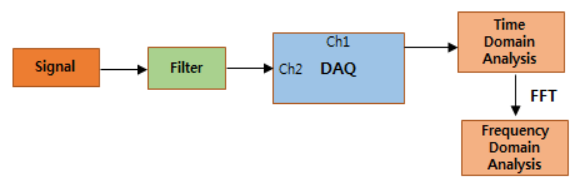


그림 9 수집된 데이터의 시간과 주파수 분석 블록

Fig. 9 Block diagram of time and frequency domain analysis of the acquired system

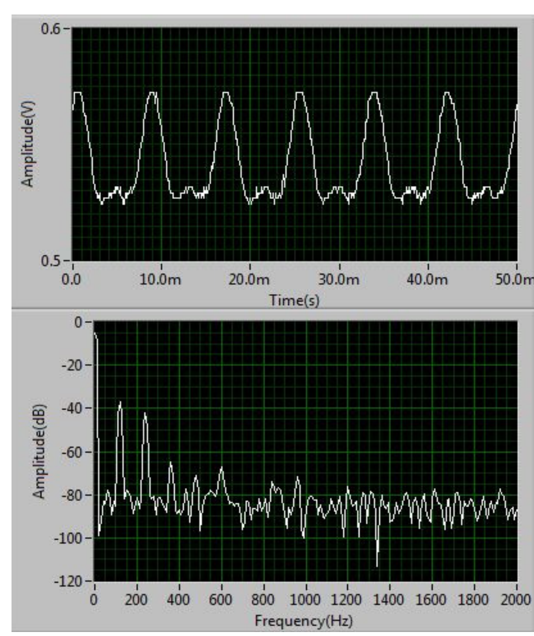


그림 10 필터링 과정 거친 뒤 신호의 시간과 주파수 분석

Fig. 10 Time and frequency domain analysis after filtering

Sensors generally have low frequency signals and addition of high frequency noises can corrupt its original signal. It can be seen that high frequency components above 600 Hz is eliminated through the use of the filter.

### 4.1 Discussions

The built prototype operated well in the laboratory after hardware was set up and code were burned to the micro-controller.

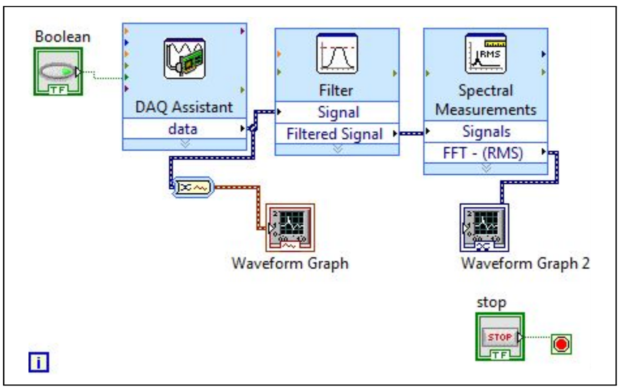


그림 11 LabVIEW에서 설계된 5차 바타워스 저역통과 필터
Fig. 11 Design of a fifth order Buttorworth low pass filter in LabVIEW

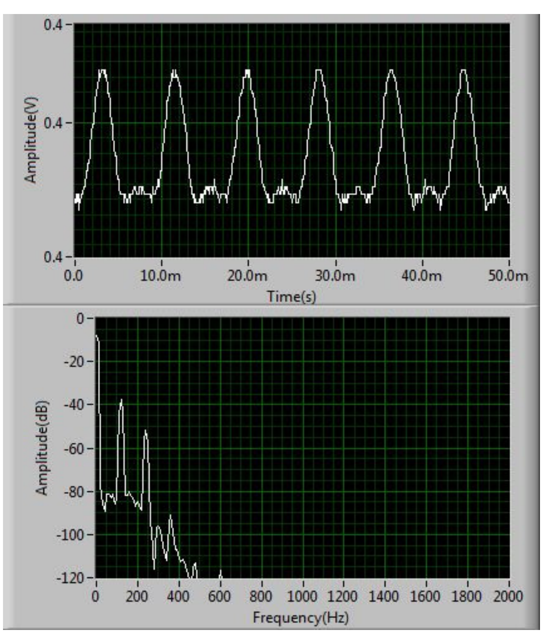


그림 12 디지털 필터링 과정 거친 뒤 신호의 시간과 주파수 분석
Fig. 12 Time and frequency domain analysis after digital filtering process

The source of noise and its nature (high or low frequency) could not be correctly observed from the environment so with the hit and trial method the value of the capacitor was taken. Actually, noise can be filtered digitally also without any inconvenience. We built a fifth order Butterworth low pass filter with 5 KHz cutoff frequency with LabVIEW program as given in Fig.11.

Here, as shown in Fig.12 with the increase in the order of the filter there is a sharp cutoff in the frequency. For the improvement of the overall system to be used in a real greenhouse, high precision sensors can be used for acquiring more accurate data. Likewise, high- performance micro-controllers like Arduino Due (84 MHz) can be used for used for faster data processing. For long range connectivity and low power operation LoRa (Low Power Wide Area Network) communication technology can be utilized. Lastly, with the increase in automation, utility and maintenance cost also increases. Therefore, requirement analysis should thoroughly be done before the design of such automated systems.

## 4. Conclusion

A simple yet improved prototype for a greenhouse automated system is designed using Arduino UNO micro-controller. The system focuses on feedbacks and algorithms to ensure optimum condition for the cultivation of plants are always met. A separate signal conditioning circuit for buffering and filtering, and especially, Moving average algorithm are designed for the noiseless and smooth data acquisition. With the use of this algorithm variations in the output because of rapidly changing environment or use of imprecise sensors can be greatly smoothed out. The addition of sensors or other hardware can easily be done to sense or process other micro-climatic parameters in the greenhouse. The designed system could be further improved and implemented to the real systems as per the need of the user.

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