Original Article

# Enhancing the Stability of Light-Responsive Automatic Door Systems Against Sudden Light Changes

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## Abstract

In this study, a low-cost and light-responsive automatic chicken coop door system was developed. The system was designed to operate stably under sudden changes in ambient light conditions. The system was designed to address instability issues commonly encountered in coop doors that are required to open and close based on daylight conditions. For this purpose, a light testing cabinet was constructed and various illumination levels were tested using LDR and BH1750 light sensors along with optical diffusers. Regression models were developed to convert the analog data from the LDR circuit into lux values. Moreover, statistical filtering methods such as the Interquartile Range (IQR) and Z-Score were applied to prevent system instability caused by sudden changes in lighting (e.g., vehicle headlights, passing clouds). The effectiveness of the filtering methods was analyzed using both artificially generated data from the light test cabinet and real minute-based solar irradiance data collected from a meteorological station. The developed system achieved enhanced sensor accuracy and operational stability through the use of low-cost components and the integration of an outlier detection module. Test results showed that the regression model used for lux estimation based on LDR readings achieved an $R^2$ value of 0.97, and the application of IQR and Z-Score filtering methods successfully removed outliers, resulting in improved operational stability under variable lighting conditions. The proposed approach offers a versatile solution for various sensor-driven control systems, including automatic doors and smart home applications.

**Keywords**: Automatic Door Systems, BH1750, IQR and Z-Score Filtering, Outlier Detection, Stability Enhancement.

## 1. Introduction

Automatic door systems are commonly utilized across a wide range of applications, including industrial, commercial, and public buildings, as well as in transportation hubs like airports and metro stations, residential facilities, and agricultural or livestock environments. Various types of sensors—such as motion, pressure, ultrasonic, magnetic, photocell, and light sensors—are used to trigger the opening and closing of doors automatically, depending on the specific purpose. When the signals received from these sensors exceed predefined thresholds, the door systems either open or close. Automatic door systems eliminate the need for manual intervention, offering ease of use for people while also providing benefits such as energy efficiency, hygiene, comfort, and security for buildings (Gandhimathi et al., 2024).

Automatic opening and closing systems are also used in smart home automation to control windows and curtains. Windows can open automatically during the day for ventilation and close in response to environmental conditions such as rain and wind to protect the indoor environment (Abdulkareem et al., 2021). Similarly, curtains may remain open during the day

and close automatically at night for privacy. In these systems, various sensors such as temperature, light intensity, wind, and water sensors are employed (Islam et al., 2014).

Automatic door systems have also found increasing application in the livestock sector, particularly in poultry farming. In recent years, their use in chicken coops has grown significantly. The global market for outdoor automatic chicken coop doors was valued at USD 45.2 million in 2024 and is projected to reach USD 74.7 million by 2031, reflecting an annual growth rate of approximately 7.5% (2025). During daylight hours, chickens typically roam in outdoor areas where they can access fresh air and feed. In contrast, they require enclosed shelters to rest during the evening. Ensuring that the coop door remains closed at night is critical for both thermal insulation and protection against predators. Animals such as foxes, dogs, weasels, and raccoons commonly attack coops at night, often resulting in the loss of entire flocks (Sasirekha et al., 2023). To mitigate such risks, chicken coop doors must be opened in the morning and securely closed at night. Manually opening and closing these doors requires the physical presence of the coop owners during both morning and evening hours. This situation may lead to disruptions in daily routines, increased fuel consumption, and time inefficiencies (Chigwada et al., 2022). Furthermore, failure to open the coop during the day can induce stress in poultry and negatively affect egg production. In this context, light-sensitive automatic door systems offer a significant advantage by improving animal welfare and enhancing the convenience and operational efficiency of poultry farmers.

Unstable operation in automatic opening and closing systems may lead to issues such as security risks, energy inefficiency, or system malfunctions. Moreover, frequent and unnecessary activation due to misinterpretation of sensor data may result in hardware wear and user dissatisfaction. To prevent these adverse outcomes, automatic control systems must maintain stable operation even under irregular or extreme environmental conditions. Ensuring such robustness remains a significant challenge in the design of reliable automated systems.

Instability in automatic chicken coop door systems may arise due to two primary sources: natural and artificial factors. The first type of instability is caused by sudden decreases in ambient light levels due to changing weather conditions, which can lead to the door closing during the day or oscillating between open and closed states. The second source involves artificial light interference affecting the light sensor. Artificial lighting can occur in both short-term and long-term forms. For instance, short-term interference may be caused by car headlights passing near the coop, while long-term exposure may result from street lighting or external illumination from nearby residences.

Despite advancements in commercial automatic coop doors, users still experience issues such as inconsistent triggering due to ambient light fluctuations and the need for manual adjustments in certain conditions. For example, some models rely solely on raw sensor data, which can cause unintended operations during overcast weather or when exposed to artificial lighting. These limitations highlight the need for more stable and adaptive light-responsive control systems. To mitigate such instability, advanced solutions such as the integration of multiple sensor types or the use of image processing techniques could be considered. However, these approaches are often costly and may not be feasible for low-budget automatic coop door systems.

In this study, an automatic door system was developed, and a five-stage process was implemented to ensure its stable operation using different sensors and optical diffusers. First, a vertically sliding chicken coop door that operates automatically based on ambient light conditions was designed and constructed. To maintain low production costs, a Light Dependent Resistor (LDR) was selected as the primary light sensor. Second, a sensor testing

cabinet was built to evaluate the system's performance under controlled conditions. Third, the impact of two different optical diffusers on the measured light values from the sensors was examined within the test cabinet. An adjustable 30W LED flash and an industrial lux meter were used to determine the corresponding voltage outputs of the LDR circuit at specific lux levels. Fourth, based on the collected data, regression models of various degrees were developed to convert the analog voltage readings from the LDR into lux units. Finally, to ensure the stability of the door system, outlier filtering techniques—namely Interquartile Range (IQR) and Z-Score methods—were applied to both artificially generated data within the test cabinet and real-time minute-based solar irradiance data.

Our approach integrates calibrated light measurements and outlier filtering techniques, offering improved stability under fluctuating lighting conditions—unlike many existing systems that rely solely on unfiltered sensor data.

## 2. Literature Review

Numerous studies in the literature have addressed the design and development of automatic door systems. In one such study, a solar-powered automatic chicken coop door system was developed (Gandhimathi et al., 2024). The door was operated using a stepper motor controlled by an ESP32 microcontroller, with limit switches employed to define the movement boundaries. Ambient light intensity was measured every 10 minutes, and if the light exceeded 30,000 W/m², it was considered daytime; if it dropped below 2,000 W/m², it was considered nighttime. A variable named Prom1 (1 = day, 0 = night) was defined to distinguish between day and night. In addition, another variable (Prom2) served as a counter to ensure system stability; the door would only respond after three consecutive readings confirmed a state. In another study, an automatic opening and closing system for windows and doors in a home automation context was implemented using the STC89C52 microcontroller (Zhang, 2024). Environmental data such as rain, light, and wind were collected using relevant sensors. Four different scenarios were simulated: (1) windows and doors open during the day with no rain or wind, (2) windows and doors close at night under rainy and windy conditions, (3) real-time control based on rain and light intensity, and (4) temporary closure due to wind followed by reopening.

A separate study focused on preventing false openings in automatic door systems by developing a smart sensor that only activates when a person approaches the door directly rather than walking parallel to it (Nishida et al., 2014). A 3D-scanning door sensor was designed and tested with various approach angles (0°, 22.5°, and 45°) and walking speeds ranging from 500 to 2000 mm/s. The system effectively detected individuals approaching from up to 240 cm when the sensor was mounted at a 21° angle. In another work, the control of a sliding door and lighting system was achieved remotely via a NodeMCU microcontroller and the Blynk mobile application (Pandini et al., 2024). Instead of entering a password, users could access the home by activating the door through the mobile app. A magnetic contact switch was also used to notify the user if unauthorized attempts to open the door occurred.

In another application, a system for controlling windows and zebra blinds was developed using the TS 12SM-LF ambient light sensor, WS10 series water sensor, and the Atmel ATmega328p microcontroller (Islam et al., 2014). The blinds closed when the ambient light fell below 300 lux, and the windows automatically shut upon detection of rain. Tests showed that the window and blind responded 3−5 seconds after receiving sensor input. Another study employed a temperature sensor, water sensor, and Arduino Uno to control a window system (Abdulkareem et al., 2021). The window opened if the temperature exceeded 36°C and no rain

was detected. Conversely, it closed if the temperature dropped below 36ºC or if rain was sensed.

Additionally, several studies have focused on eliminating outliers from sensor data. One study evaluated surface water temperature as a critical ecological and climatic variable and compared the performance of three statistical algorithms for outlier detection (Jamshidi et al., 2022). The modified Z-score combined with exponential moving average and decomposition techniques yielded the highest F-score (0.83), demonstrating its effectiveness for large-scale datasets. Another study addressed outlier detection in mixed-type sales data from a pharmacy (Nur Rokhman, 2016). It found that combining attribute value frequency (AVF) with the Z-score algorithm effectively identified outliers. A separate investigation focused on outlier detection in blood glucose data obtained from continuous glucose monitoring (CGM) sensors (Nurhaliza et al., 2024). Both 3-sigma and Interquartile Range (IQR) methods were applied, with IQR shown to detect a more significant number of outliers.

While many studies in the literature have addressed the control of automatic chicken coop door systems using microcontrollers and various sensors, only a limited number have focused explicitly on system stability. The methods used in this study have also been actively employed in the literature for filtering outlier data. By ensuring accurate sensor readings and applying robust filtering techniques, the present work contributes to the literature on improving the stability of automatic chicken coop door systems.

## 3. Hardware Design of the Door System

This section presents the hardware components of the developed automatic door system and the light testing setup, described separately.
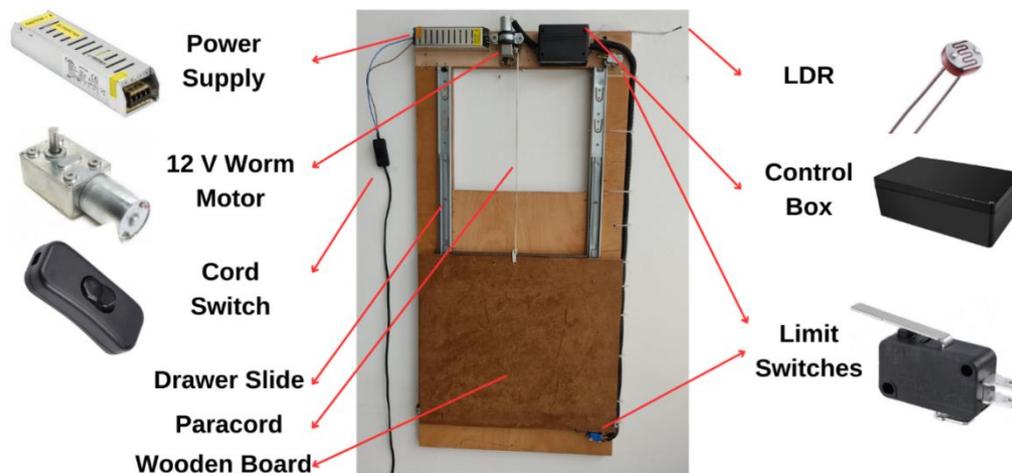


**Figure 1. Overview of the Developed Automatic Chicken Coop Door System**

### 3.1. Door Mechanism

A vertically sliding automatic chicken coop door was designed and constructed to operate according to ambient light conditions. An overview of the developed system is provided in Figure 1. The door frame was built using wooden panels, with dimensions of 45 × 95 cm, while the opening size was 30 × 40 cm to allow the passage of poultry. Drawer slides were installed to enable vertical movement of the wooden door. To actuate the door, a 12V 66 rpm worm gear motor was selected. The system was powered by a 12V 5A power supply. An LDR (Light Dependent Resistor) was used to measure ambient light intensity. Limit switches were mounted at the upper and lower ends of the drawer slides to constrain the door's motion

during opening and closing. A cord switch was included to enable manual control of the power supply when needed. A pulley system was employed to convert the motor's rotational motion into linear motion, and a paracord was used to pull the door. The control unit included a microcontroller, a motor driver module, and passive electronic components to manage system operations.

## 3.2. Sensor Testing Cabinet

To evaluate the performance of the light sensor used in the door system, a dedicated testing cabinet was constructed. The cabinet was built using aluminum T-slot profiles and thin wooden boards with dimensions of 50 × 55 × 55 cm. The interior of the cabinet, shown in Figure 2, was painted white to ensure uniform light diffusion. The top of the cabinet was enclosed to prevent external light interference during testing. A brightness-adjustable 30W LED flash was used as the internal light source. To measure the illumination level inside the cabinet, a Unit UT383BT lux meter was employed. This device can measure up to 100,000 lux at intervals of 500 milliseconds, and its readings were used as reference values during testing.

A custom circuit was designed to record sensor outputs at various lux levels. This circuit incorporated two types of light sensors: a BH1750 digital light sensor and an analog LDR. Sensor readings were displayed on an LCD screen and logged to a computer. The effect of using different optical diffusers on sensor readings was also evaluated. Two distinct types of optical diffusers were placed over each sensor, as shown in Figure 3, and measurements were recorded accordingly.



**Figure 2. Light Testing Cabinet**



**Figure 3. Optical Diffusers Used in the Test**

```
FUNCTION setup():
        Start serial communication (Serial.begin)
        Initialize the LCD screen (lcd.init)
        Initialize the light sensor (lightMeter.begin)

FUNCTION loop():
        bh1750Lux = Read lux value from BH1750
        ldrReading = Read analog value from LDR (analogRead)

        estimatedLux                                                    =
CALCULATE_LUX_WITH_REGRESSION(ldrReading)

        Display BH1750 and LDR lux values on LCD
        Log the values via serial port
        Wait for 1 second (delay)

FUNCTION CALCULATE_LUX_WITH_REGRESSION(LDR_reading):
        If LDR_reading < minimum_LDR_value:
            Return luxValues[0]
        If LDR_reading > maximum_LDR_value:
            Return luxValues[3]

        estimatedLux = a * (LDR_reading)^2 + b * (LDR_reading) + c
        Return estimatedLux
```

**Figure 4. Pseudo Code for main control software**

## 4. Software Architecture for Stable Door Operation

Unstable operation of the door system may lead to issues such as compromised poultry safety and unnecessary energy consumption. Therefore, accurate reading and interpretation of sensor data — a critical component of system control — is essential. This section first presents the system's main control software, followed by the regression models developed based on data obtained from the sensor testing cabinet.

### 4.1. Data Acquisition Software

The control software, implemented on an ATmega328p microcontroller, manages the opening and closing of the door based on predefined lux threshold values. To design a low-cost system with acceptable performance, two different sensors were employed within the same circuit. The first sensor used is the BH1750 digital light sensor, which directly measures light intensity and communicates via the I2C protocol, providing output in lux. The second sensor is a standard 5 mm LDR. To measure the resistance variation of the LDR due to light, it was connected in series with an LM334 constant current source configured to supply 1 mA. This method applies minimal current to the resistor, preventing self-heating, and the current source's built-in temperature compensation minimizes thermal drift. Sensor readings were both transmitted to a computer via a serial interface and displayed on a 2×16 character LCD screen. The core algorithm of the system is presented as a pseudo-code in Figure 4.

**Table 1. Effect of Diffuser Use on Sensor Reading**

| Measured Lux (Ref) | BH1750 [Lux] | | | LDR [Volt] | | |
|---|---|---|---|---|---|---|
| | No Diffuser | Small Diffuser | Large Diffuser | No Diffuser | Small Diffuser | Large Diffuser |
| 50 | 31 | 22 | 23 | 0,714 | 0,938 | 0,934 |
| 105 | 65 | 48 | 47,9 | 0,45 | 0,587 | 0,562 |
| 200 | 123 | 86 | 87 | 0,288 | 0,362 | 0,371 |
| 300 | 182 | 126 | 128 | 0,23 | 0,298 | 0,298 |
| 400 | 242 | 165 | 169 | 0,186 | 0,23 | 0,235 |
| 500 | 303 | 213 | 221 | 0,161 | 0,21 | 0,205 |
| 600 | 365 | 244 | 269 | 0,142 | 0,186 | 0,186 |
| 700 | 429 | 292 | 309 | 0,127 | 0,171 | 0,161 |

## 4.2. Regression Model for Lux Conversion

The LDR and BH1750 sensors used for light intensity measurements are widely known for their affordability and accessibility. In this study, the performance of the BH1750 sensor was also evaluated as a reference for calibrating the LDR. Both sensors respond to incident light intensity, and optical diffusers are often employed to ensure uniform light distribution over the sensor surface. Experiments were conducted to assess the effect of different diffuser configurations on sensor performance. Measurements were taken under three conditions: without a diffuser, with a small diffuser, and with a large diffuser. Illumination levels in the test environment were measured using a UT383BT lux meter, which provided reference values. The sensor and lux meter readings across various light levels are summarized in Table 1.

Analysis of the BH1750 data showed a direct correlation between sensor output and ambient lux levels. When diffusers were used, the output decreased by approximately 30% on average compared to readings taken without a diffuser. The output values for the small and large diffusers were found to be nearly identical, likely due to the similar dome-shaped geometry of both diffusers. Calibration coefficients were determined to convert BH1750 readings to actual lux values: 1.63 (no diffuser), 2.35 (small diffuser), and 2.26 (large diffuser).

LDR data in Table 1 revealed that voltage readings were higher without a diffuser. Similar to the BH1750, the readings for different diffusers were close to another. However, a nonlinear relationship was observed between the LDR voltage and lux values, necessitating the use of polynomial regression for accurate conversion. Analog readings from the LDR were converted to lux using regression models developed for each diffuser condition. The resulting polynomial equations and their corresponding R² values are provided in Table 2.

**Table 2. Regression Equations and R² Values for Different Light Diffuser Configurations**

| | No Diffuser | Small Diffuser | Large Diffuser |
|---|---|---|---|
| Linear | $y = -988.4x + 640.8$ | $y = -740.7x + 632.9$ | $y = -752.2x + 634.4$ |
| | $R^2 = 0.7235$ | $R^2 = 0.7039$ | $R^2 = 0.7106$ |
| Quadratic | $y = 3432x^2 - 3823x + 1049$ | $y = 2029x^2 - 2944x + 1047$ | $y = 2044x^2 - 2959x + 1047$ |
| | $R^2 = 0.9208$ | $R^2 = 0.9165$ | $R^2 = 0.9088$ |
| Cubic | $y = -13291x^3 + 19724x^2 - 9459x + 1586$ | $y = -6753x^3 + 12936x^2 - 7922x + 1672$ | $y = -6155x^3 + 11809x^2 - 7294x + 1575$ |
| | $R^2 = 0.9779$ | $R^2 = 0.9770$ | $R^2 = 0.9704$ |

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Precise. Resilience. Felicitous.
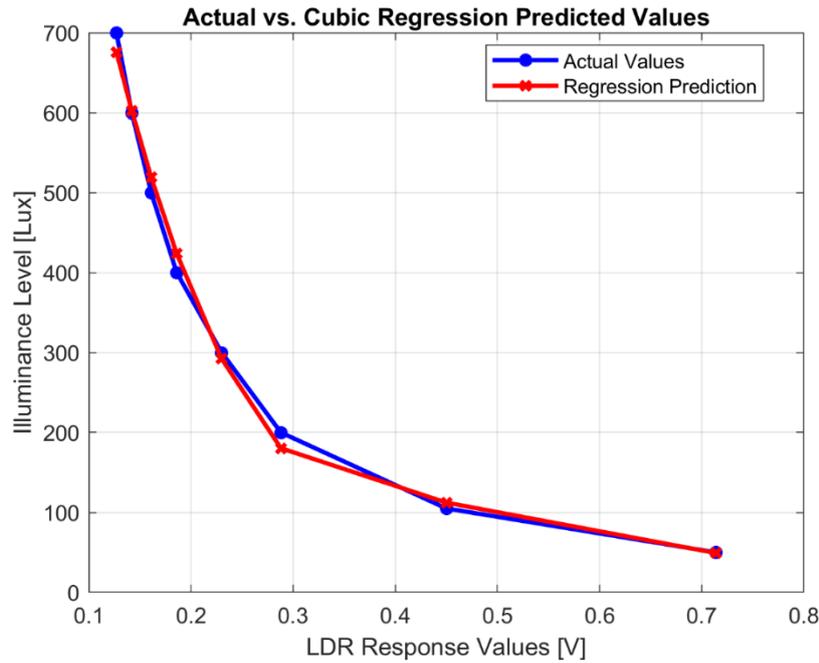
**Figure 5. Regression results for LDR to Lux Conversions**

Analysis of Table 2 shows that third-degree polynomial models yielded the highest accuracy in all diffuser conditions, with $R^2$ values averaging around 0.97. The regression curve derived from the best-fitting model for the LDR without a diffuser is illustrated in Figure 5, which shows a close agreement between estimated and actual lux values.

# 5. Outlier Filtering Module

In environments where ambient light is measured, factors such as vehicle headlights, street lamps, and sudden cloud movements can introduce outliers. These outliers represent one of the most critical causes of instability in automatic door systems. Such disturbances are categorized as either artificial or natural, and both types were analyzed independently in this study. Artificial light sources were simulated using a light testing cabinet, while real minute-based solar irradiance data from the year 2022 were utilized to represent natural factors. This section focuses on filtering these outliers using Interquartile Range (IQR) and Z-Score methods to enhance the system's stability.

In this study, the Z-Score and IQR filters were selected as statistical techniques to detect and eliminate outliers. The Z-Score method evaluates how many standard deviations each data point deviates from the mean, with a common threshold of $|Z|>3$, identifying those values as outliers (Benallal et al., 2022). This approach is particularly effective for datasets that approximate a normal distribution.

The IQR filter identifies outliers based on the interquartile range, defined as the difference between the third (Q3) and first (Q1) quartiles. Values falling outside the range of Q1 – 1.5×IQR and Q3 + 1.5×IQR are considered outliers (Kwak & Kim, 2017). This method is exceptionally robust in handling skewed or non-symmetrical data distributions. However, the filtering parameters were calibrated under specific conditions, and their performance may vary across different geographical regions or seasonal light patterns.

## 5.1. Filtering of Artificial Outliers

Artificial outliers were generated in the light testing cabinet using a brightness-adjustable LED flash. A total of 3300 data points were collected in the range of 0−3700 lux, containing random and abrupt spikes representative of typical outlier behavior. These peak values were then subjected to filtering.

Initially, the data were processed through the IQR filter, followed by the application of the Z-Score filter. This cascaded filtering strategy allowed for a more aggressive and sensitive detection of anomalies. The raw and filtered values obtained from the test environment are illustrated in Figure 6. The figure shows that the IQR filter effectively identified most outliers; however, it was less sensitive to values in the 100−150 data range. Applying the Z-Score filter to the remaining dataset further eliminated undetected outliers, which can be attributed to the standard deviation-based structure of the Z-Score method. The results demonstrate that these combined filtering techniques successfully removed statistically insignificant extreme values. Consequently, the overall system stability was significantly improved through this sequential outlier elimination approach.
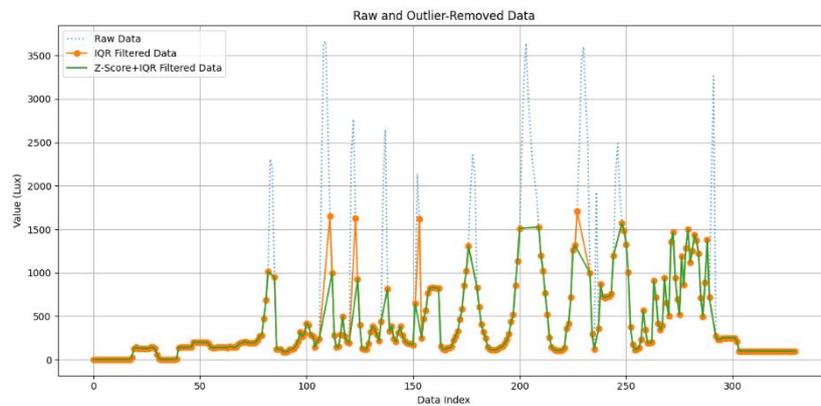


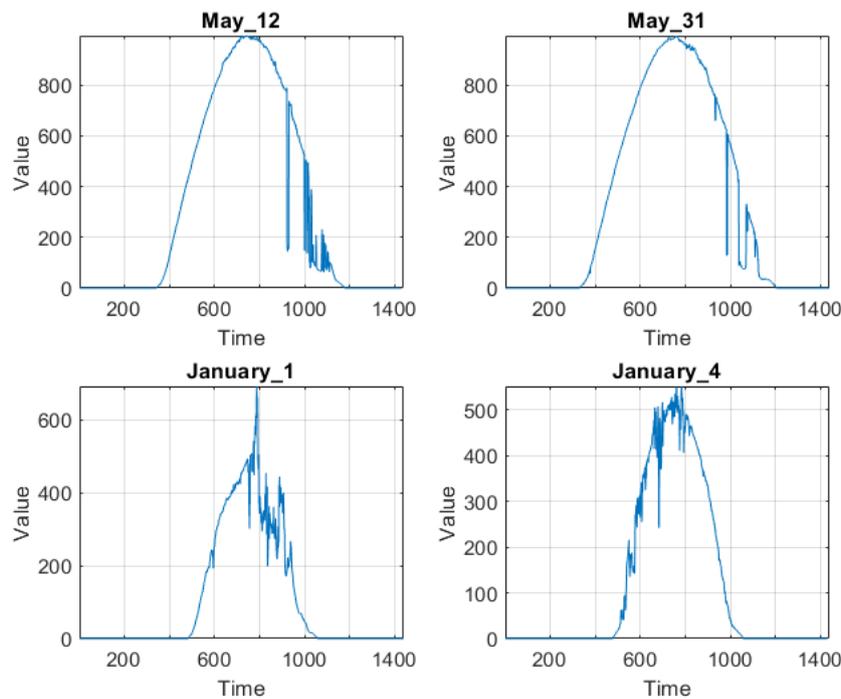**Figure 6. Filtering outliers in test data obtained in the test chamber**



**Figure 7. Solar radiation sample values**

## 5.2. Filtering of Natural Outliers

Natural outliers are typically of meteorological origin and are mostly caused by sudden cloud movements. To evaluate the effectiveness of the filtering approach described in the previous section on larger-scale, minute-based solar irradiance data from the year 2022 were used. These data were obtained from the meteorological measurement station located at Selçuk University (Basciftci et al., 2022). To exemplify sudden fluctuations in annual radiation levels, four days with the highest variance in solar irradiance during 2022 were selected. The irradiance profiles of these days are illustrated in Figure 7.

Minute-based solar irradiance data from June 19, a day with pronounced fluctuations, were selected for detailed filtering analysis. The time interval between 15:00 and 19:00, characterized by significant fluctuations, is presented in Figure 8. To enhance the visibility of oscillatory behavior within the time series, the graph was truncated after 19:00. All values beyond this time point were zero and thus excluded from the visualization. Although the graph includes only a subset of the data, the filtering process was applied to the entire dataset covering the time period from 15:00 to 23:59.

Upon examining the graph of the solar irradiance data, short-duration but high-amplitude spikes can be observed in the raw dataset. These abrupt fluctuations are most likely caused by environmental factors such as passing clouds, reflection effects, and temporary deviations. Particularly between 15:00 and 17:00, the sudden rises and drops visible in the raw data are significantly smoothed out in the filtered dataset, ensuring continuity of the time series. This effect is especially apparent between 16:39 and 16:58. Additionally, the measurements recorded between 15:00 and 15:30 were statistically identified as outliers based on IQR thresholds calculated from the full-day dataset, and were completely excluded by the filter. The primary reason for this is that irradiance values throughout the rest of the day—especially towards the evening—were relatively low, causing the midday peaks (>700 W/m²) to be perceived as extreme values by the filtering algorithm.

The parameters, descriptions, and results of the applied filtering methods are summarized in Table 3. The tests of these filtering strategies were conducted using both the previously recorded solar irradiance data and the sensor readings collected from the light testing cabinet. The "Values" column in the table reflects outcomes based on these datasets. The embedded system implementing the discussed filters operates in real-time in the field, recording minute-based data, dynamically calculating relevant parameters, and performing filtering operations accordingly.
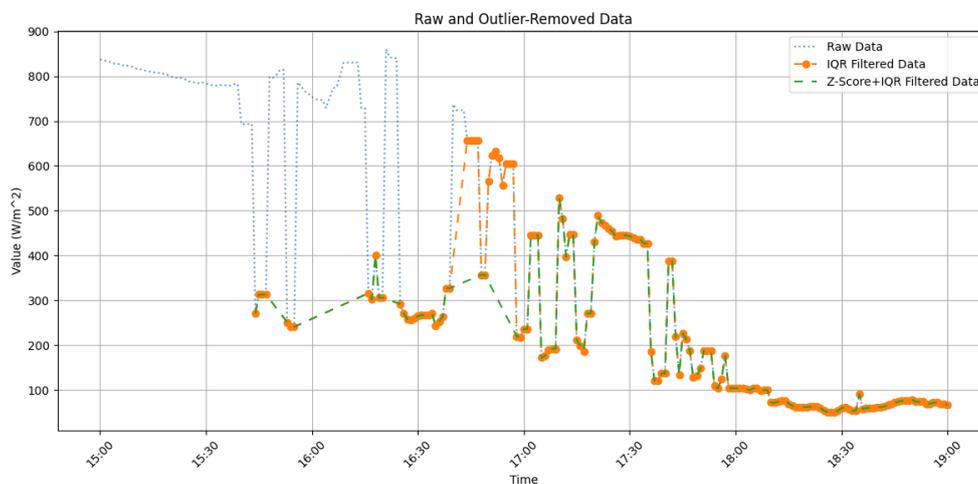


**Figure 8. Filtering outliers in radiation data**

**Table 3. Parameters of IQR and Z-Score Filters**

| IQR Filter Parameters | | |
| --- | --- | --- |
| Parameter | Description | Values |
| Q1 | The lower 25% of the data | 0.0 |
| Q3 | The upper 75% of the data | 267.0 |
| IQR | Q3 - Q1 | 267.0 |
| Lower bound | Q1 - 1.5 × IQR | -400.5 |
| Upper bound | Q3 + 1.5 × IQR | 667.5 |

| Z-Score Filter Parameters | | |
| --- | --- | --- |
| Parameter | Description | Values |
| Mean | Average of data | 187.98 |
| Standart Deviation | Standard deviation of data | 281.92 |
| Z Threshold | [(x - mean) / std] Z score value | 3 |

## 6. Conclusion

In this study, a light-sensitive automatic chicken coop door system was developed. To ensure cost-effectiveness, the system was designed using an LDR sensor. A dedicated light testing cabinet was constructed to evaluate the sensor's performance under varying lighting conditions. The impact of different optical diffusers on sensor readings was investigated, and regression models were developed to convert the analog voltage output of the LDR into illuminance values in lux.

Analysis of the collected data indicated that the third-degree polynomial regression model provided the highest accuracy for the LDR sensor, achieving an average $R^2$ value of approximately 0.97. This allowed for a more precise conversion of analog sensor data into meaningful light intensity values.

To eliminate instability caused by outliers, IQR and Z-Score filtering methods were applied. Experimental results showed that these statistical techniques effectively removed anomalous values and significantly improved the overall stability of the system.

As a result, a low-cost and stable automatic coop door system was successfully developed. Future work may explore supervised learning methods such as decision trees or support vector machines to classify light conditions and improve decision-making under varying illumination. Additionally, the system could be extended to detect the presence of a passing object during door closure and reopen accordingly. The use of alternative sensors and hardware components may further improve the reliability and robustness of the system. This study contributes to the field by combining sensor calibration with statistical filtering techniques to improve stability in light-responsive systems, an area that has received limited attention in previous studies.

### 6.1. Acknowledgments

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