

Arduino-Based Automated Birdcage with Integrated Mass and Thermal Control

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Abstract—Manual bird care is highly vulnerable to neglect during prolonged owner absence, while fluctuating ambient temperatures can compromise avian health and well-being. This study designs, implements, and evaluates a standalone, Arduino-based automated birdcage that integrates mass-based feed dispensing, water refilling, thermal management, and fault detection without relying on continuous internet connectivity. Two independent load cells with HX711 modules measure feed and water mass directly, driving a servo motor and a DC water pump, while an n-point moving-average filter mitigates mechanical vibration and bird-movement noise. A DHT22 sensor monitors ambient temperature and humidity to control an incandescent heating lamp via a hysteresis algorithm that eliminates rapid actuator chattering near switching thresholds. User interaction and monitoring are supported through a 16x2 LCD, input buttons, and a buzzer. Experimental evaluations under controlled laboratory conditions, with no live birds present, demonstrated high precision: the feed-dispensing system achieved an average accuracy of 99.38% (0.62% relative error) and the water-refilling subsystem reached 99.78% accuracy (0.22% relative error). The heating subsystem-maintained actuator states within the targeted 28.0–30.0°C hysteresis band at a single measurement point, and fault-detection mechanisms properly halted actuators and triggered visual-auditory alerts during simulated sensor anomalies and zero-mass-gain events. These results confirm the functional feasibility and robustness of the standalone automated birdcage, providing a reliable engineering baseline for maintaining optimal avian environmental conditions and basic dietary needs during owner absence.

Keywords—automated birdcage, hysteresis control, temperature control

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I. INTRODUCTION

Birdkeeping is a popular activity in Indonesia and carries emotional and social value, with human–pet interactions contributing to physical and psychological well-being [1], [2], [3]. It is practiced across age groups [4] and, in Javanese culture, is associated with socio-economic status [5], thereby strengthening concern for avian welfare [6]. Captive birds consequently require consistent access to food and drinking water as well as species-appropriate nutrition, housing, and hygiene to support longevity and reduce stress and disease susceptibility [7], [8], [9].

Reliance on manual feeding, watering, and temperature management increases the risk of neglect, particularly when owners are absent or multiple cages must be managed. Cage

conditions substantially influence bird health and productivity [10], [11]. In poultry, poorly controlled temperature and humidity are associated with lower productivity and higher mortality [15], while heat stress can impair growth, body weight, reproductive performance, and product quality [12], [13], [14]. Microcontroller- and IoT-based systems have therefore been developed to automate the monitoring and control of temperature, humidity, air quality, and feed or water availability, reducing continuous manual supervision and supporting more stable cage conditions [18], [19].

Previous studies have developed IoT-based feeding and watering systems using Wi-Fi-connected microcontrollers, servo-driven feeders, pumps, and web or mobile interfaces [17], [18]. Some systems also use ultrasonic sensors to monitor feed availability and regulate scheduled feeding, whereas more comprehensive smart-poultry architectures integrate environmental sensors, actuators, feeders, and water dispensers to reduce labor and support sustainable poultry management [19]. However, these systems commonly emphasize remote connectivity or scheduled operation rather than integrated, stand-alone control based on direct feed and water mass measurements.

This study therefore designs, implements, and evaluates an Arduino-based stand-alone birdcage system that extends previous automatic-feeding and smart-cage designs [20]. Unlike [20], which reported an IoT-based automatic feeding system for caged rabbits using a single mass sensor and scheduled dispensing, the present system adds a second independent load-cell channel for simultaneous feed and water mass control, hysteresis-based actuator switching to prevent unstable operation under fluctuating sensor readings, and integrated warning/error fault detection, while operating without continuous internet connectivity [21], [22]. The evaluation examines subsystem integration, functional responses, and measurement performance relative to reference weighing and dispensing procedures [23]. By combining automatic feeding, water refilling, temperature control, and fault detection, the study provides an integrated design reference for automated bird-care systems during prolonged owner absence.

II. METHODS

The automated birdcage relies on a foundational Input-Process-Output structure. The overall structural integration is depicted in the system block diagram below (Figure 1):

- a) Input Block: The input block comprises two load cells for measuring feed and water mass and a

- DHT22 sensor for monitoring cage temperature and humidity.
- Process Block:** The Arduino Nano acts as the centralized computation unit, executing calibration algorithms, digital filtration, and real-time control validations.
 - Output Block:** Directs mechanical and thermal actions via the motor servo, DC water pump, and heating lamp. Visual reporting is handled by the 16x2 LCD, while immediate auditory warnings are managed via the passive buzzer.

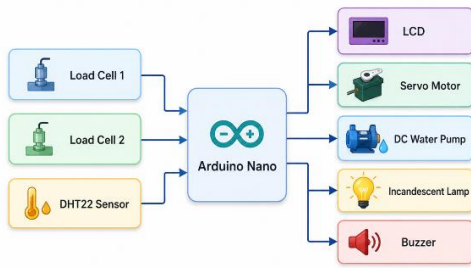


Figure 1. System Block Diagram

The control software operates continuously through six stages. First, the system initializes the sensors, actuators, buzzer, and LCD, and loads the calibration coefficients and control thresholds. Second, sensor fluctuations caused by bird movement or mechanical vibration are reduced using an n-point moving-average filter:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (1)$$

where $\bar{x}$ is the filtered value, x_i is the i -th sensor reading, and n is the filter-window size. Third, readings outside the sensor-specific validity limits for 10 consecutive cycles trigger an Error State and disable the corresponding actuator. Fourth, valid readings are processed using hysteresis control to prevent actuator chattering near the switching thresholds:

$$Y = \begin{cases} 1 & \text{if } S \leq S_{min} \\ Y_{prev} & \text{if } S_{min} < S < S_{max} \\ 0 & \text{if } S \geq S_{max} \end{cases} \quad (2)$$

where S is the filtered sensor value, S_{min} and S_{max} are the lower and upper thresholds, and Y_{prev} is the previous actuator state retained within the hysteresis band. Fifth, a Warning State is activated when an actuator operates for 30 s without producing a load-cell increase of at least 3.0 g, indicating possible blockage or resource depletion. These threshold values were set empirically from preliminary bench trials to balance responsiveness against normal sensor noise; their effect on detection sensitivity and false-warning rate was not systematically evaluated (see Results and Discussion). Finally, the LCD displays the filtered measurements, operating parameters, and fault notifications, while the buzzer provides an audible warning during error or warning conditions.

In the physical design phase, all components were assembled according to the automated birdcage blueprint (Figure 2). The

Arduino Nano served as the central controller due to its compact size and sufficient I/O capacity. Load cells with HX711 modules were placed beneath the feed and water containers to measure mass, while a DHT22 sensor monitored temperature and humidity inside the cage. A servo motor controlled the feed valve, opening when mass dropped below the minimum threshold and closing at maximum capacity. The DC water pump supplied drinking water based on load-cell readings. For heating, an incandescent lamp was installed, with both lamp and pump driven through a relay module to handle higher voltage/current requirements. The system was powered by a 12V DC adapter, stepped down via a buck converter to provide stable 5V for the microcontroller, sensors, and servo. All components were integrated into a compact enclosure (14.5 × 9.5 × 5 cm) attached to the birdcage (45 × 30 × 32 cm).

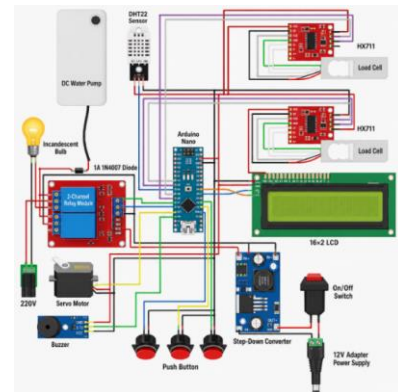


Figure 2. Schematic Wiring Diagram of the Arduino-Based Automatic Bird Cage with Feeding, Drinking, and Cage Heating Features

III. RESULTS AND DISCUSSION

A. Prototype Implementation

The automated birdcage prototype integrated feed and water measurement, servo- and pump-based refilling, environmental monitoring, heating control, user-interface, and fault-notification functions. The electronic components were installed in a 14.5 cm × 9.5 cm × 5 cm enclosure attached to a 45 cm × 30 cm × 32 cm birdcage. The feed and water containers were placed on separate load cells, allowing both quantities to be measured and controlled independently. The completed prototype is shown in Figure 3.

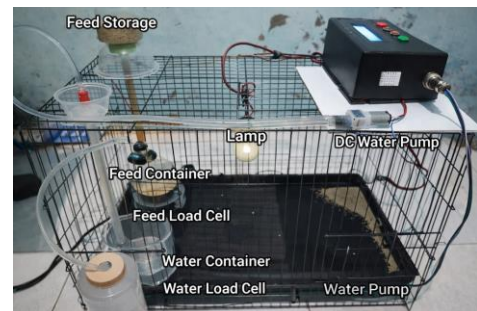


Figure 3. Prototype of the Arduino-Based Automatic Birdcage System

B. Automatic Feed-Filling and Water-Filling Performance

The feed-filling subsystem was tested using minimum and maximum thresholds of approximately 20 g and 50 g, respectively. The servo opened at 19.9 g, remained open while the measured mass increased from 20.0 g to 49.6 g, and closed at 49.7 g after a brief fluctuation near the upper threshold. The response indicates that the actuator retained its previous state within the hysteresis region rather than switching repeatedly near the threshold, as summarized in Table 1.

Table 1. Feed-filling Functional Test

<i>Measured Feed Mass</i>	<i>Servo Response</i>	<i>Interpretation</i>
19.9 g	Valve opened	Feed mass was below the minimum threshold
20.0–49.6 g	Valve remained open	Feed was being added
49.7 g	Valve closed	Feed mass approached the maximum threshold

Feed-measurement performance was evaluated at ten target masses between 10 g and 100 g using an external digital scale as the reference. The relative error ranged from 0.12% to 2.00%, with an average of 0.62% and a corresponding average accuracy of 99.38%. The largest error occurred at the 20-g target, whereas the smallest occurred at 80 g. The proportionally higher error at low masses was likely influenced by sensor fluctuations, servo-response delay, and residual feed movement after valve closure. Unlike scheduled feeders [17], [24], the developed subsystem used direct mass feedback to determine feed availability and terminate dispensing at the specified threshold [23], [24]. It also combined weight-based dispensing with hysteresis control and fault-state detection [23], [25].

The water-filling subsystem used the second load cell to control the DC pump. The pump was activated at 19.9 g, remained active from 20.9 g to 99.9 g, and stopped at approximately 100.1 g, as presented in Table 2.

Table 2. Water-filling Functional Test

<i>Measured Water Mass</i>	<i>Pump Response</i>	<i>Interpretation</i>
19.9 g	Pump activated	Water mass was below the minimum threshold
20.9–99.9 g	Pump remained activated	The container was being filled
100.1 g	Pump stopped	Water mass reached the maximum threshold

Ten target masses between 20 g and 200 g were tested, producing relative errors of 0.00–0.67%. The average relative error was 0.22%, corresponding to an average accuracy of 99.78%. Zero relative error was obtained at the 40-g and 100-g targets, while the largest error of 0.67% occurred at 60 g. Although the water-filling error was lower than that of the feed subsystem, this difference does not necessarily indicate greater sensor accuracy. Feed dispensing was affected by residual particle movement, whereas water measurement was influenced by pump pressure, residual tube flow, and container oscillation.

The reported errors therefore represent the combined response of the sensor, actuator, mechanical structure, and dispensed material. Direct mass measurement also enabled the system to determine the remaining water quantity without relying solely on schedules, remote commands, or continuous Wi-Fi connectivity.

C. Temperature-Control Performance

The temperature-control test evaluated the response of the heating lamp at lower and upper thresholds of 28.0°C and 30.0°C. The lamp was activated below 28.0°C, remained on while the temperature increased through the hysteresis region, and switched off at 30.0°C. The switching response is presented in Table 3.

Table 3. Temperature-control Test

<i>Measured Temperature</i>	<i>Lamp Condition</i>	<i>Interpretation</i>
27.0°C	On	Below the lower threshold
27.9°C	On	Below the lower threshold
28.0°C	Remained on	Within the hysteresis region
29.0°C	Remained on	Within the hysteresis region
30.0°C	Off	Upper threshold reached
31.0°C	Off	Above the upper threshold

The controller retained the previous lamp state between 28.0°C and 29.9°C, preventing rapid relay switching near the threshold. This confirms the functional operation of the hysteresis logic but does not demonstrate uniform temperature regulation throughout the cage. Only one DHT22 measurement point was used, and heating rate, cooling rate, overshoot, settling time, and spatial temperature distribution were not evaluated. The result should therefore be interpreted as validation of the lamp-switching logic at the specified thresholds, rather than proof of biologically ideal cage conditions.

D. Interface and Fault-Handling Performance

The LCD, control buttons, and fault-notification functions were evaluated through operational and deliberately induced abnormal conditions. The LCD displayed the measured parameters and threshold settings, while the buttons supported page navigation, parameter adjustment, and notification reset. Invalid sensor readings and the absence of a required mass increase during actuator operation caused the corresponding actuator to stop and activated the LCD and buzzer notifications. The functional results are summarized in Table 4.

These functions provide limited fault detection by verifying whether an actuator command produces the expected physical response, thereby preventing continued operation when a feed channel is empty, a hose is blocked, or a sensor is disconnected. However, the tests did not evaluate repeated fault events, false-warning rates, detection-time variation, long-duration operation, or recovery under repeated disturbances.

The results therefore demonstrate functional fault response under controlled laboratory conditions, not comprehensive system reliability.

Overall, the prototype integrated two mass-measurement channels, automatic feed and water refilling, temperature-based heating, local parameter configuration, and fault notification on a single Arduino Nano platform. Its main contribution is not a new sensing or control principle, but the integration of direct feed and water mass feedback, hysteresis-based heating, and basic fault detection in a stand-alone system. Compared with internet-dependent systems [10], [23], [24], and feeder-focused embedded platforms, the prototype can perform its core control functions without continuous connectivity. It should also be noted that each of the ten target masses in the feed- and water-filling tests was measured only once rather than through repeated trials, so the reported errors reflect single-measurement deviations rather than a statistically characterized variability (e.g., standard deviation) of the load-cell readings. Nevertheless, long-term repeatability, sensor drift, power-failure response, bird-induced vibration, load-cell contamination, spatial temperature distribution, and direct welfare outcomes in live birds remain outside the scope of the present evaluation.

Table 4. Interface and Fault-handling Functional Test

Tested Function	Expected Response	Result
LCD operational-information pages	Relevant parameters displayed	Successful
Minimum- and maximum-threshold pages	Configuration values displayed	Successful
Navigation button	LCD page changed	Successful
Increment and decrement buttons	Parameter value changed	Successful
Invalid sensor reading	Actuator stopped, buzzer activated, LCD error displayed	Successful
No mass change during actuator operation	Actuator stopped, buzzer activated, LCD warning displayed	Successful

IV. CONCLUSION

This study developed and functionally evaluated an Arduino-based automated birdcage integrating mass-based feed dispensing and water refilling, DHT22-based heating control, a local user interface, and fault notifications. The feed- and water-filling tests produced average relative errors of 0.62% and 0.22%, respectively, while the heating subsystem maintained the programmed actuator states within the 28.0–30.0°C hysteresis band. The interface and fault-handling functions also responded as intended during laboratory testing. These findings demonstrate the feasibility of integrating the subsystems into a stand-alone platform that operates without continuous internet connectivity. However, the conclusions are limited to engineering functionality under controlled conditions. Further

studies should evaluate repeated and long-duration operation, sensor drift, power-failure response, spatial temperature distribution, realistic cage disturbances, and species-specific environmental requirements before the system is applied to live birds.

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