Design of a Helmet Visor Cleaning Device Using a Rain Sensor Based on an Arduino Uno

Singgah Khairun Okba[1], Nur Sultan Salahuddin[2], Aldi Julian Prakoso[3]

[1]Mechanical Engineering, Gunadarma University, singgahkhairun@staff.gunadarma.ac.id, Indonesia
[2]Computer System, Gunadarma University, sultan@staff.gunadarma.ac.id, Indonesia
[3]Computer System, Gunadarma University, aldin@student.gunadarma.ac.id, Indonesia

Abstract. This study designed and functionally tested a helmet visor (kaca helm) cleaning device that automatically responds to rain conditions using an Arduino Uno–based control system. The device was intended to help maintain rider visibility by removing rainwater and reducing moisture on the visor through a small wiper mechanism. The hardware design integrated a rain sensor as the input, an Arduino Uno as the controller, and a servo motor to drive the wiper, supported by an LED indicator for status feedback. The control logic was implemented in Arduino C to read the rain sensor condition and activate outputs accordingly. Functional testing was conducted by applying water to the rain sensor and observing system responses under wet and dry conditions. The results showed consistent state changes: when the sensor surface was wet, the LED indicator turned on, and the servo output moved through the reported 0–70° range to drive wiper motion; when the sensor was dry, the LED turned off, and the servo returned to 0° with no wiper movement. The device also stopped detecting once the rain condition ended, returning the system to its idle state. These findings demonstrate a basic rain-triggered actuator mechanism for visor cleaning that may support safer riding behavior by reducing the need for manual wiping during rainfall.

Keywords Arduino Uno, Rain sensor, Servo motor, Helmet visor, Wiper mechanism

INTRODUCTION

Rain and spray can rapidly degrade a motorcyclist's visual field by forming droplets and water films on the helmet visor, which distort contrast and increase visual workload during hazard perception. Such weather-related degradation is a recognized contributor to elevated crash risk for two-wheeler traffic, especially in regions with frequent rainfall and mixed roadway conditions (Garg et al., 2025; Miao et al., 2025). At the surface level, droplet adhesion, coalescence, and gravity-driven motion on curved transparent visors produce nonuniform optical distortion that can persist without active removal (Barwari et al., 2019). Therefore, a compact, low-cost mechanical cleaning aid attached to a helmet visor is relevant as an engineering intervention to support visibility during rain events, while still respecting constraints unique to helmets such as limited mounting space, mass distribution, and user ergonomics.

Common practical responses include manual wiping with a glove or cloth, which is simple but interrupts control inputs and is inconsistent under continuous precipitation. Surface-engineering approaches such as hydrophobic and self-cleaning coatings can reduce droplet residence time and promote roll-off, yet performance depends strongly on

coating durability, abrasion resistance, and long-term stability under wiping and environmental exposure (Yilbas et al., 2021). Anti-fog/anti-condensation strategies are also widely studied because condensed microdroplets scatter light and reduce transparency, and coating-based solutions must balance transparency, adhesion, and wear resistance (Wahab et al., 2023). In practice, coatings may be sensitive to contamination, repeated cleaning, and mechanical abrasion, so their effect can degrade with use (Yilbas et al., 2021).

Miniature wiper mechanisms represent a direct mechanical approach that can actively remove water from a transparent surface when rain occurs. Prior open-access prototypes in related contexts commonly combine a rain/moisture sensor with a microcontroller and a motor/servo to actuate a wiping arm, demonstrating feasibility and low component cost (Adeniran et al., 2021; Devi et al., 2022). Helmet-focused implementations have also been reported using embedded control and servo actuation, indicating that visor-scale wiping is mechanically achievable, but design details and verification practices vary and are not always documented in a way that is easily reproducible for mechanical–mechatronic development (Fadlan & Thamrin, 2020). Additionally, rain-sensing modules are often threshold-based, so sensitivity drift or false triggering due to splashes, humidity, or contamination can affect reliability unless sensor handling and calibration are addressed (Christakis, 2025).

Despite the availability of low-cost microcontrollers and sensors, there remains a practical gap for a replicable, visor-scale mechatronic design that (i) triggers automatically from a rain sensor state, (ii) actuates a compact wiper mechanism suitable for a helmet visor, and (iii) documents a clear engineering workflow and functional verification procedure that can be reproduced and extended in mechanical–mechatronic product development. Existing automatic wiper studies often target automotive windshields or small test rigs rather than the specific constraints of helmet-mounted mechanisms (Adeniran et al., 2021; Khaladkar, 2025). Helmet-oriented work exists, but the integration of sensing control actuation and the reporting of verification steps can be strengthened to support reproducibility and iterative improvement (Fadlan & Thamrin, 2020).

At the system level, the functional architecture follows the common mechatronic chain of sensor to controller to actuator to mechanical output, where the primary input is

the rain sensor condition (wet vs. dry) and the primary output is the resulting wiper motion over the visor area.

The novelty is intentionally positioned as practical and application-specific rather than claiming a new sensing principle or new actuation physics. The contribution lies in adapting low-cost, widely available components to a helmet-visor context and reporting the engineering rationale, integration concept, and functional verification logic in a form aligned with replicable mechanical–mechatronic prototyping. Sensor-threshold behavior is a known factor in rain-detection modules, and sensitivity handling can materially affect robustness, so recommended practices from open-access work are considered when discussing reliability and calibration needs (Christakis, 2025).

The objectives are: (1) to realize a visor-cleaning prototype integrating a rain sensor, Arduino Uno control, and a servo-actuated wiper mechanism; (2) to describe the mechanical and mechatronic integration in a way that supports replication and modification; and (3) to verify core functional behavior under wet versus dry sensor conditions using observable system responses (Prakoso, 2018). The expected contributions are: an application-focused system architecture, a documented prototype integration concept for visor wiping, and a clearly stated functional evaluation intent that can be extended to repeatability and reliability testing in future work (Gwosch & Matthiesen, 2023). The remainder of this article is organized as follows: the Methods section details the design–build–test workflow, components, integration, and test procedure; the Results and Discussion section summarizes observed functional behavior and practical limitations; and the Conclusion section outlines applicability and improvement opportunities.

METHODS

Research Design

This work adopted an engineering design build test approach in which a rain-triggered mechatronic prototype for helmet-visor cleaning was designed, assembled, programmed, and then verified through functional testing. The verification focus was binary functional correctness under two environmental input states dry versus wet rain-sensor conditions because this type of embedded mechatronic demonstrator is commonly

validated first through repeatable scenario tests and observable acceptance criteria before deeper reliability qualification is attempted (Gwosch & Matthiesen, 2023).

Functional verification was performed by operating the system while alternating the sensor between dry and wet states and observing (i) indicator status (LED) and (ii) actuation response (servo-driven wiper motion). Similar rain-sensing wiper demonstrations typically use threshold-based state decisions combined with repeatable wetting/drying trials to confirm correct actuation and prevent false triggering (Adeniran et al., 2021; Devi et al., 2022).

System Overview and Architecture

The system architecture follows a simple signal path: rain sensor to Arduino Uno controller to servo actuator to visor wiper, with an LED indicator used to communicate detected rain/activation status. The uploaded document provides a block-level depiction of this end-to-end architecture, which is used here as the baseline for the replication description .
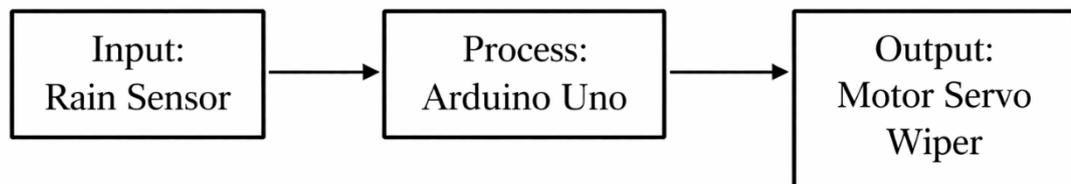

Figure 1. System block diagram: rain sensor condition is processed by Arduino Uno to command a servo-driven wiper and LED status indication.

In typical rain-sensing wiper control, the rain sensor produces either an analog voltage proportional to wetness or a comparator-based digital state, and the microcontroller maps that input to a discrete wiping command and indicator output (Devi et al., 2022; Jayasudha & Fathima, 2024).

Materials, Components, and Tools

Table 1 summarizes the components used in the prototype implementation as evidenced by the wiring figures in the uploaded document, together with replication-oriented notes.

Table 1. Key materials and components

Item	Role in system	Interface/connection used
Arduino Uno	Main controller	Reads sensor; drives servo + LED
Rain sensor module (AO/DO)	Wet/dry detection	AO→A0 and DO→D12; VCC→5 V; GND→GND
Servo motor	Rotary actuation of wiper arm	PWM control on D9
LED indicator	Status feedback	Arduino digital output (indicator LED)
Wiper arm + blade	Clears visor surface	Mechanically linked to servo horn
Mounting/bracket & fasteners	Attach mechanism to helmet/visor	Mechanical

Recommended lab tools include a multimeter for continuity checks, a regulated bench supply (or equivalent), basic hand tools for assembly, and a stopwatch/video capture for response-time observation (Gwosch & Matthiesen, 2023).

Mechanical Design and Fabrication

The prototype integrates a compact wiping mechanism mounted to a helmet visor assembly (see Figure 4). The servo provides rotary motion that is transmitted through the servo horn to a wiper arm, producing a wiping sweep across the visor surface. The mechanical objective is to achieve (i) sufficient blade contact for water removal, (ii) minimal added mass and protrusion, and (iii) safe placement that does not interfere with rider vision or helmet operation.

Figure 2. Prototype of the helmet visor cleaning device (front view) showing the visor-mounted wiper concept and actuator placement.

For small wiper linkages, stroke limits should be set to prevent overtravel and mechanical binding, and the wiper blade should be mounted with mild compliance to accommodate visor curvature and reduce scratching (Fadlan & Thamrin, 2020; Khaladkar, 2025). Assembly should include alignment checks at the extreme commanded angles, ensuring clearance from visor edges and helmet vents, and fastening methods should resist vibration loosening (Gwosch & Matthiesen, 2023).

Electronics and Wiring

Electrical interconnection is defined by the uploaded wiring figures. The rain sensor module is connected using both its analog and digital outputs: AO is routed to Arduino A0, and DO is routed to Arduino digital pin 12. Power is supplied from Arduino 5 V to sensor VCC, with a shared GND reference. Servo control is provided via PWM on Arduino digital pin 9, as indicated in the Arduino connection summary figure 4.
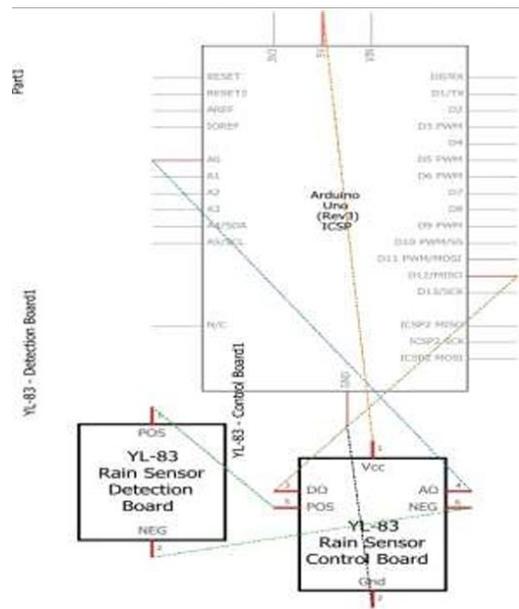
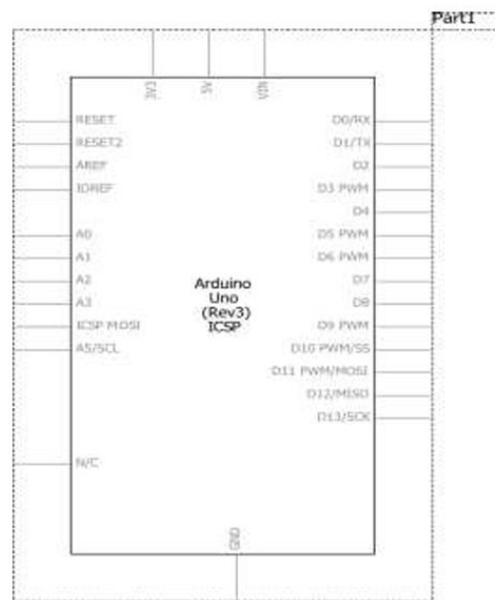Figure 3. Rain sensor module wiring to Arduino (AO/DO, VCC, GND).

Figure 4. Arduino Uno pin usage summary for sensor and servo connections.

Because servos can draw transient currents, it is common to power the servo from a supply capable of higher peak current and to keep grounds common to maintain signal reference integrity (Adeniran et al., 2021; Devi et al., 2022). Place local decoupling near the servo supply and route sensor wiring away from high-current paths to reduce false triggers and improve stability (Gwosch & Matthiesen, 2023).

Control Algorithm and Software Implementation

The embedded control behavior is a two-state decision: when rain is detected (wet sensor), the system asserts the LED indicator and commands the servo to a wiping position; when rain is not detected (dry sensor), it deasserts the indicator and returns the servo to its home position. This binary mapping is consistent with many Arduino-based rain-wiper prototypes that prioritize robust on/off behavior before implementing intensity-adaptive wiping (Devi et al., 2022; Das et al., 2021).

Based on the uploaded wiring, the implementation reads the sensor's digital output on D12, while the sensor's analog line is also available on A0 for optional logging or threshold characterization. The servo is driven from D9 using standard Arduino servo PWM generation.

A replication-oriented pseudocode representation is:

Initialize I/O:
  set LED pin as OUTPUT
  attach servo to PWM pin
Loop:
  read rain_state from sensor digital pin
  if rain_state indicates WET:
    LED = ON
    servo = WIPE_ANGLE
  else:
    LED = OFF
    servo = HOME_ANGLE
  wait short interval (debounce / stability)

Use debounce / time filtering to avoid chatter at the wet/dry threshold, for example a short moving window or minimum-on/minimum-off time, since raindrop sensors can fluctuate during partial wetting and evaporation (Christakis, 2025; Jayasudha & Fathima, 2024).

Experimental Setup and Test Procedure

Functional testing was performed by placing the assembled prototype in a stable condition and then alternating the rain sensor between dry and wet conditions by applying water to the sensing surface. Each test cycle consisted of:

1. Power the system and allow initialization.
2. Confirm dry baseline: sensor not wetted to indicator off to actuator at home.
3. Apply water to the sensor surface to create a wet condition.
4. Observe indicator transition and servo-driven wiping motion.
5. Remove water / allow drying and confirm return to home behavior.

To strengthen repeatability, conduct multiple trials per condition, standardize the wetting method (e.g., consistent droplet volume or spray duration), and keep sensor orientation consistent across trials (Gwosch & Matthiesen, 2023). Document failures such as false triggers, delayed activation, incomplete wiping sweep, or mechanical sticking, as commonly reported in prototype wiper demonstrations (Adeniran et al., 2021; Khaladkar, 2025).

Data Collection and Performance Metrics

The primary recorded outcomes for functional verification are:

- Rain input state: dry vs wet (by controlled wetting).
- Indicator state: LED on/off corresponding to detection and actuation status.
- Actuation response: servo movement present/absent and qualitative wiping sweep completion.

Quantitative metrics where feasible, including (i) response time from wetting to first servo motion, (ii) return time from drying to stop/home, (iii) false-trigger rate during dry trials, and (iv) success rate across repeated cycles (Gwosch & Matthiesen, 2023). using the analog output (A0), log analog readings to characterize wetness dynamics and help set comparator sensitivity in a reproducible way (Christakis, 2025; Jayasudha & Fathima, 2024).

Reliability, Repeatability, and Safety Considerations

Mechatronic prototypes exposed to water require attention to sensor durability, wiring insulation, and mechanical wear. Rain sensor plates can exhibit oxidation and sensitivity drift over time; simple physical overlays or protective measures can be used to improve practical sensitivity and robustness, provided they do not prevent droplet

contact (Christakis, 2025). Electrical safety practices include insulating exposed conductors, strain-relieving wires near moving parts, and keeping electronics away from direct splash paths while preserving sensor exposure. Mechanical safety practices include limiting protrusions, ensuring the wiper does not obstruct the rider's field of view, and verifying that the mechanism cannot detach under vibration (Fadlan & Thamrin, 2020; Gwosch & Matthiesen, 2023).

Data Analysis

Given the verification objective, analysis is primarily descriptive: each dry/wet trial is classified as pass/fail based on whether the indicator and actuation responses match the intended state mapping. Pass/fail counts can be summarized per scenario and used to identify failure modes for iteration, which aligns with common early-stage mechatronic validation workflows (Gwosch & Matthiesen, 2023).

RESULTS

Prototype Realization

A complete helmet-visor cleaning prototype was realized by integrating a rain-sensing input, an Arduino-based controller, an LED indicator, and a servo-driven wiper mechanism. The assembled unit was documented from multiple views to show the placement of the wiper on the visor and the mounting of the electronics on the helmet body (see Figures 6–8). The front view shows the wiper blade positioned to sweep across the visor surface, indicating that the mechanical linkage and blade alignment were implemented to produce a visible wiping path. The side and top views further indicate how the assembly was packaged on the helmet, including the relative placement of the wiping mechanism and the rain-sensor plate (Figures 5–6). The rear view documents the placement of the controller board and wiring, confirming that the electronic subsystem was physically integrated with the wearable prototype (Figure 7).

Figure 5. Helmet-visor cleaner prototype (side view) showing packaging of the wiping assembly.

Figure 6. Helmet-visor cleaner prototype (top view) showing placement of the rain-sensor plate and wiring.
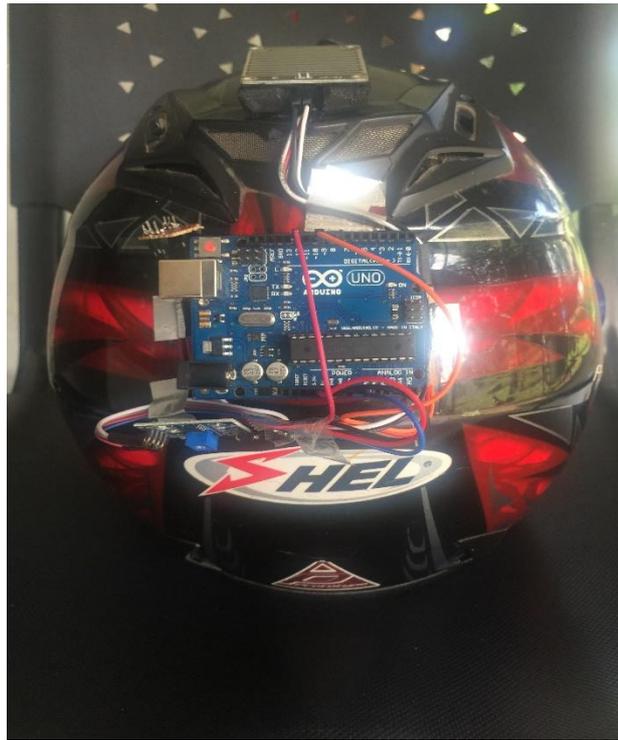
Figure 7. Helmet-visor cleaner prototype (rear view) showing controller board placement and wiring integration.

Sensor Response and Detection Outcomes

The rain-sensor subsystem was evaluated using wet versus dry conditions applied to the sensor plate, and the observed output was reported using the LED indicator as the primary detection outcome. Under wet sensor conditions, the LED was observed to turn on, while under dry sensor conditions the LED was observed to turn off. These outcomes were summarized in the uploaded document as a two-condition functional table, which is reproduced in journal format in Table 2.

Table 1. Rain-sensor detection outcome using LED indicator

Sensor condition	Observed indicator outcome
Wet	LED ON
Dry	LED OFF

Photographic documentation supports the same wet/dry outcomes. When the sensor plate was wetted, the sensor condition was shown visually (Figure 8) and the LED indicator state was shown as ON (Figure 9). When the sensor plate was dry, the sensor condition was shown visually (Figure 10) and the LED indicator state was shown as OFF

(Figure 11). The reported interpretation was that the LED state tracked whether the rain sensor was detecting water present on the sensing surface.

Figure 8. Wet rain-sensor plate condition during functional test.
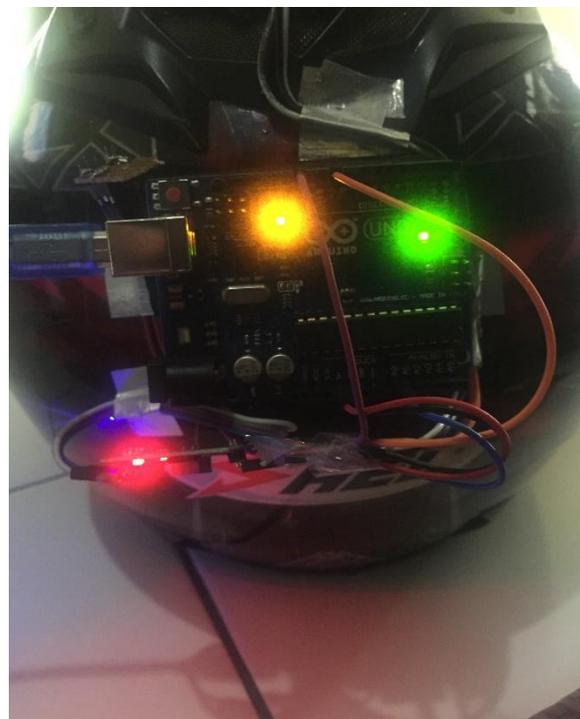

Figure 9. LED indicator observed ON under wet sensor condition.

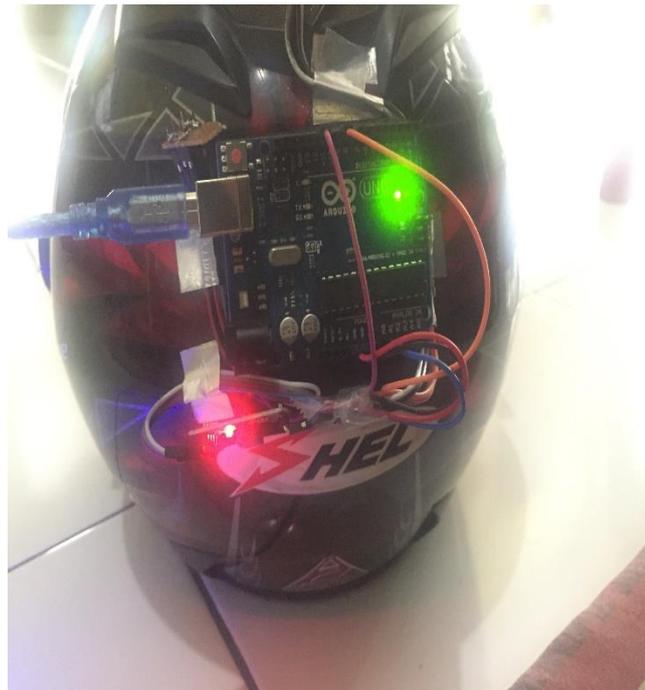Figure 10. Dry rain-sensor plate condition during functional test.

Figure 11. LED indicator observed OFF under dry sensor condition.

Controller and Indicator Behavior

The controller behavior was reported through the digital indicator state and its consistency with the applied sensor condition. The LED used for indication was documented as connected to Arduino pin 13 in the results narrative, and the observed behavior was that the LED was ON when the system detected rain (wet sensor condition)

and OFF when the sensor was dry. The outcome description emphasized that the detection state changed when the water on the sensor dried, at which point the LED turned OFF and detection was considered to stop. No intermediate indicator states or partial-detection modes were reported, so the controller behavior is best characterized as a binary state response aligned with wet/dry sensor conditions.

Actuator and Wiper Motion Results

The actuator subsystem was evaluated by observing servo rotation and its association with the rain detection state. The uploaded document reported that, when rain was detected (LED ON), the servo rotated over a commanded movement range from 0° to 70°, and the servo was described as rotating to drive the wiper motion. When rain was not detected (LED OFF), the servo output was reported at 0°, and the servo was described as not rotating. These outcomes were summarized in the uploaded document as a functional table, which is reproduced in Table 3.

Table 2. Servo actuation outcome under rain/no-rain conditions

Condition	LED state	Servo output	Observed actuator outcome
Rain detected	LED ON	0°–70°	Servo rotates
No rain detected	LED OFF	0°	Servo does not rotate

Photographic documentation was also provided for the actuator states. The servo was shown during the reported 0°–70° condition (Figure 12), and the servo was shown at 0° as a return-to-home condition (Figure 13). Together, these figures support the reported mapping between detection state and servo motion.

Figure 12. Servo condition reported as 0°–70° during rain-detected state.

Figure 13. Servo condition reported as 0° (return to initial position) during no-rain state.

System level functional testing was reported as an end-to-end sequence: applying water to the rain sensor produced an "active" state in which the LED turned ON and the servo rotated to drive wiping, while removing water and allowing the sensor to become dry produced an "inactive" state in which the LED turned OFF and the servo returned to

0°. The functional success condition was therefore demonstrated through consistency across the sensor–indicator–actuator chain: wet sensor to LED ON to servo rotates (0°–70°), and dry sensor to LED OFF to servo stops/returns (0°). The results were summarized using pass/fail-style condition mapping tables to support early-stage functional validation reporting (Gwosch & Matthiesen, 2023). No numeric response times, repeated-trial counts, or statistical summaries were reported in the uploaded results section. Accordingly, the results are presented as deterministic functional outcomes tied to the tested conditions, supported by tables and photographic evidence of each state.

DISCUSSION

The prototype achieved the intended closed loop behavior for a helmet-visor cleaning concept: rain presence at the sensing surface triggered a status indication and actuator motion, while a dry condition led to an idle state. The reported functional outcomes show a clear wet–dry discrimination using a rain-sensor module interfaced to an Arduino Uno, with an LED used as an immediate state indicator and a servo driving the wiper motion. In the reported configuration, the servo command range was expressed as a return to zero behavior in dry conditions and an active motion command up to a defined angle when rain was detected, indicating a simple two-state control strategy suitable for low-cost mechatronic prototyping.

Rain-sensor modules commonly used in Arduino prototypes rely on a change in conductivity across interdigitated traces when a water film bridges electrodes, which can produce a strong contrast between dry and wet states but can also be sensitive to droplet distribution and contamination. The reported wet dry switching behavior is therefore consistent with the expected physics of surface-wetting detection and a comparator/threshold decision in the controller. In similar rain-sensing wiper prototypes, a thresholded sensor signal is used to drive a discrete actuator command, reflecting the same "event-triggered" control pattern. (Devi et al., 2022; Adeniran et al., 2021).

A key implication of threshold-based rain detection is that the stability of "wet" versus "dry" decisions depends on how the threshold is defined and whether hysteresis or filtering is applied. Even without changing hardware, literature shows practical methods to improve sensitivity and reduce ambiguous transitions by modifying how water accumulates on the sensing surface, for example using overlays that influence wetting and drainage. (Christakis, 2025).

In measurement-focused rain sensing, calibration and signal-processing steps (e.g., smoothing, robust event detection, and well defined mapping from raw signal to "rain/no-rain") are central to reducing noise-driven toggling and to improving repeatability across environments. (Clemens et al., 2024).

The reported use of both analog and digital interfacing paths (typical for many sensor modules that provide AO/DO outputs) can be interpreted as a design option: analog signals enable richer characterization and diagnostics, while digital outputs can simplify the final on/off decision. Prior Arduino based wiper studies frequently adopt one of these approaches depending on whether the goal is basic automation or more detailed sensing characterization. (Khaladkar, 2025; Das et al., 2021).

the visor-wiper problem differs from automotive windshield wiping because it is strongly constrained by mass, packaging, mounting rigidity, and user ergonomics. A small wiper must maintain sufficient contact with a curved transparent surface while avoiding excessive friction, chatter, or scratching risks. Compliant wiper mechanisms and linkage designs in the wiper literature emphasize controlling contact forces and reducing sensitivity to geometric tolerances, which becomes even more important at small scales where mounting flex and alignment errors can dominate. (Karakuş & Tanık, 2018).

The reported servo-driven actuation reflects a common choice for compact prototypes because servos provide position control with simple PWM interfacing. However, servo-driven wiping introduces design tradeoffs between commanded angle, linkage geometry, and effective swept area. Wiper dynamics studies show that blade–surface interaction and contact conditions can influence wiping stability, particularly under changing wetness and friction states. (Fujii & Yamaguchi, 2007). Similarly, research on wiper-blade dynamics and compliance indicates that vibration and stick–slip behaviors can emerge when friction and normal force are not well controlled, suggesting that blade material and compliance are not merely "materials choices" but functional design variables. (Kim et al., 2022).

The architecture reported here aligns with a broad pattern in open-access Arduino wiper literature: a low-cost rain sensor triggers an embedded controller that drives an actuator (servo or motor) and optionally a status indicator. (Devi et al., 2022; Adeniran et al., 2021). Some prior implementations focus on automotive-scale wiping and may use different actuators or mechanisms, but the core logic detect rain and actuate wiping

remains similar. (Khaladkar, 2025; Das et al., 2021). A contribution of the present visor-focused concept is the mechanical integration challenge: translating a wiper principle into a helmet-mounted, compact form factor with simplified assembly and functional verification.

Although the reported outcomes emphasize correct wet dry triggering and wiper actuation, broader robustness concerns are typical for rain-sensor and wiper mechanisms. Surface-wetting sensors can drift due to residue, oxidation, or changes in surface energy, which can shift sensitivity and affect decision thresholds over time. Practical sensitivity-enhancement methods in the literature also highlight that small mechanical or surface modifications can materially change detection outcomes. (Christakis, 2025).

For the actuation side, compact wiper systems are susceptible to misalignment, variable friction, and vibration-driven chatter, especially when the mounting structure is lightweight. Wiper research shows that friction variation with wetness and the dynamic coupling between blade, linkage, and surface can influence noise and stability. (Liu et al., 2025). reliability-oriented testing frameworks recommend combining functional verification with repeatability checks and boundary-condition testing to reveal latent failure modes, even in early prototypes. (Gwosch & Matthiesen, 2023).

several practical constraints become central: visibility must not be obstructed by the wiper hardware, added mass should be minimized, and the system should tolerate outdoor moisture exposure. The reported use of an LED as a state indicator can support rapid functional checks during development, but for practical deployment the indicator would need to be evaluated for glare, user distraction, and placement. Power delivery and electrical protection are also critical, since moisture ingress can cause corrosion and short-circuit risks in exposed wiring and connectors.

Rain sensing itself can be approached in multiple ways (surface wetting sensors, capacitive/inductive sensing structures, or other transduction concepts), and open-access sensor research emphasizes calibration and design choices that influence measurement repeatability. (Clemens et al., 2024; He et al., 2024).

While the reported implementation uses a direct wet/dry decision suitable for functional demonstration, future visor-focused systems may benefit from more robust sensing and packaging strategies that better match the outdoor mechanical environment.

The following recommendations are framed as future work and typical best practice, rather than as already-verified outcomes:

1. Signal conditioning and decision stability. Add hysteresis and/or time-based filtering to reduce chatter near the wet dry boundary, and consider calibrating the wet/dry threshold under multiple droplet patterns and environmental conditions. (Clemens et al., 2024).

2. Sensor surface management. Explore low-cost overlays or surface treatments that improve repeatable wetting and drainage on the sensor, while keeping the sensing principle unchanged. (Christakis, 2025).

3. Mechanical compliance and contact control. Introduce controlled compliance in the wiper blade or linkage to manage contact force on a curved visor and reduce sensitivity to mounting tolerances. (Karakuş & Tanık, 2018; Kim et al., 2022).

4. Robustness-oriented testing. Extend functional tests with repeatability trials and boundary-condition checks (e.g., different water application angles, partial wetting, vibration), following validation-oriented mechatronic testing principles. (Gwosch & Matthiesen, 2023).

The reported evaluation primarily demonstrates correct functional switching and actuator response under wet versus dry sensing conditions, which is appropriate for early-stage design–build–test verification. However, visor wiping performance in realistic riding conditions may depend on additional factors not addressed by basic wet/dry tests, such as airflow, droplet size distributions, vibration, and long-term exposure effects. The broader wiper and sensor literature indicates that friction dynamics, contact force management, and sensor calibration can meaningfully affect stability and repeatability, motivating expanded testing and refinement in future iterations. (Fujii & Yamaguchi, 2007; Gwosch & Matthiesen, 2023).

CONCLUSION

This study aimed to realize a compact helmet-visor cleaning prototype that automatically responds to rain detection using a rain sensor, an Arduino Uno controller, an LED status indicator, and a servo-driven wiper mechanism. The system was

implemented as an integrated wearable demonstrator and evaluated through wet versus dry functional trials.

The prototype operated as an end to end sensor controller actuator chain, enabling automatic wiping behavior when rain was present at the sensor surface. The rain-sensor detection outcome was binary: wet condition to LED ON, and dry condition to LED OFF. The actuator behavior followed the same binary mapping: under rain-detected conditions the servo was reported to move across 0°–70°, while under no-rain conditions the servo was reported at 0° and did not rotate. Photographic documentation of wet/dry sensor states and corresponding indicator/actuator states supported the observed functional transitions.

The work contributes a simple and replicable mechatronic integration concept for visor cleaning that combines low-cost sensing, embedded control, and compact actuation for a helmet application. The demonstrated on/off automation suggests potential practical value for maintaining visor clarity during rain, while remaining within a lightweight prototyping approach.

The reported evaluation focused on wet/dry functional correctness and did not include quantified response-time measurements, repeated-trial statistics, or durability and field testing. Failure modes such as false triggering under splashes, long-term sensor drift, or mechanical wear were not characterized in the reported results.

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