WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal Homepage: www.ijrpr.com ISSN 2582-7421

Smart Rain Guard System for Playground

Dr.V.B.Bagde , Swetha Iyengar , Keshar Gudadhe , Janhvi Sayankar , Atharv Dhomne

Department of Electronics & Communication Engineering, Priyadarshini College of Engineering, Nagpur.
swetha.iyengar2005@gmail.com

ABSTRACT

Outdoor playgrounds and sports grounds are highly affected by sudden rainfall causing water accumulation which damages the playing surface, interrupt sports activities, and increases maintenance efforts. Traditional methods of protecting playgrounds usually involve manually spreading and removing large waterproof covers, which requires considerable manpower, physical effort, and time. To address these issues, this paper proposes a Smart Rain Guard System for Playgrounds which is an automated rain protection system capable of detecting rainfall and deploying a waterproof ground cover with minimum human intervention. The proposed system utilizes four rain sensor modules to detect the presence of rainfall and an Arduino UNO as the main control unit. A NEMA 17 stepper motor is used to carry out the cover deployment mechanism through a roller arrangement, while an L298N motor driver is used to provides the interface between the controller and the motor. The system also provides manual forward, reverse, and stop controls to provide additional operational flexibility in operation. When rainfall is detected, the Arduino processes the sensor input and activates the motor mechanism to deploy the waterproof cover over the playground. The reverse operation allows the cover to be retracted after rainfall, while the stop control allows the motor movement to be interrupted when required. The proposed system demonstrates the feasibility of using embedded-system technology and electromechanical automation to Reduce manual effort and improve the protection of outdoor playgrounds and sports facilities.

Keywords— Arduino UNO, rain sensor, NEMA 17, stepper motor, motor driver, automatic ground cover, smart playground, rain detection, embedded system, automation.

I INTRODUCTION

Outdoor playgrounds and sports grounds can be seriously affected by sudden rainfall. Rain can interrupt ongoing activities and leave the playing surface wet which makes it difficult to use and increases the effort required for maintenance. In many places, protective covers are placed over the ground manually when it starts raining which usually requires several people to pull and arrange the cover properly, taking time and becoming difficult during unexpected rainfall. An automated covering system can help reduce this manual effort and provide quicker protection for the playing area.

Recent developments in embedded systems and automation make it possible to detect environmental conditions and respond to them automatically. Rain sensors can detect the presence of water and send signals to a microcontroller which can process these signals and control a motorized mechanism according to the detected condition. Combining these components allows the movement of a protective cover to be controlled with less human involvement.

The proposed **Smart Rain Guard System for Playground** is developed to provide an automated method of protecting an outdoor playground from rainfall. The system utilizes four rain sensor modules connected to an Arduino UNO for detecting rainfall at different locations. An L298N motor driver controls a NEMA 17 stepper motor, which is connected to a roller mechanism for moving the waterproof ground cover. When rain is detected, the Arduino processes the sensor signals and activates the motor to deploy the cover over the playground. Forward, reverse, and stop controls are also included to provide manual control during operation and testing.

The main objective of this project is to combine rain detection, microcontroller-based control, and mechanical automation into a single practical system. [2] The proposed prototype aims to reduce manual effort, improve the response to sudden rainfall, and help protect the playing surface from rainwater. The system also provides a base for future improvements, such as position sensors, IoT-based monitoring, weather-data integration, and additional safety features, which can further improve its reliability and suitability for larger outdoor sports facilities.[6]

II. LITERATURE REVIEW

Automation based on environmental sensing has become an important area of embedded-system development. Sensors can be used to detect environmental parameters, while microcontrollers process sensor information and control actuators according to predefined conditions. Rain detection is

one such application in which a sensor can identify the presence of water and provide a signal to a controller. These principles are commonly used in automatic irrigation systems, weather monitoring systems, smart buildings, and other environmental automation applications. [1]

Rain sensor modules are generally based on a conductive sensing surface that responds to the presence of water. When water droplets fall on the sensing surface, the electrical characteristics of the sensor change, producing a corresponding output signal. This signal can be provided to a microcontroller for further processing. In the proposed system, multiple rain sensor modules are used to increase the sensing coverage of the prototype.

The Arduino UNO is widely used for embedded-system prototyping due to its simple programming environment, digital and analog interfaces, and availability of supporting development resources. The Arduino UNO Rev3 is based on the ATmega328P microcontroller and provides 14 digital input/output pins and six analog inputs, making it suitable for connecting sensors and control devices. The board can therefore be used as the central controller for the proposed rain protection system. [8]

Stepper motors are commonly used in applications where controlled rotational movement is required. Unlike a conventional DC motor, a stepper motor can be controlled by applying electrical pulses in a particular sequence, allowing the motor shaft to rotate in controlled steps. A NEMA 17 stepper motor is used in the proposed system because it is suitable for prototype-level mechanical movement and can provide controlled rotation of the cover roller. The exact torque and current capability depends on the particular motor model used in the prototype. [4]

The L298 is a dual full-bridge motor driver meant for controlling inductive loads, including DC motors and stepping motors. It can be used as an interface between a microcontroller and a motor by receiving logic-level control signals from the controller and driving the motor accordingly. [2] In the proposed system, the motor driver is used to control the NEMA 17 stepper motor according to the commands generated by the Arduino UNO.

Based on these technologies, the proposed work combines rain sensing, embedded control, and motorized mechanical movement to create an automated playground protection system. The main contribution of the proposed prototype is the integration of these components into a rain-responsive ground-covering mechanism intended for outdoor playground applications.

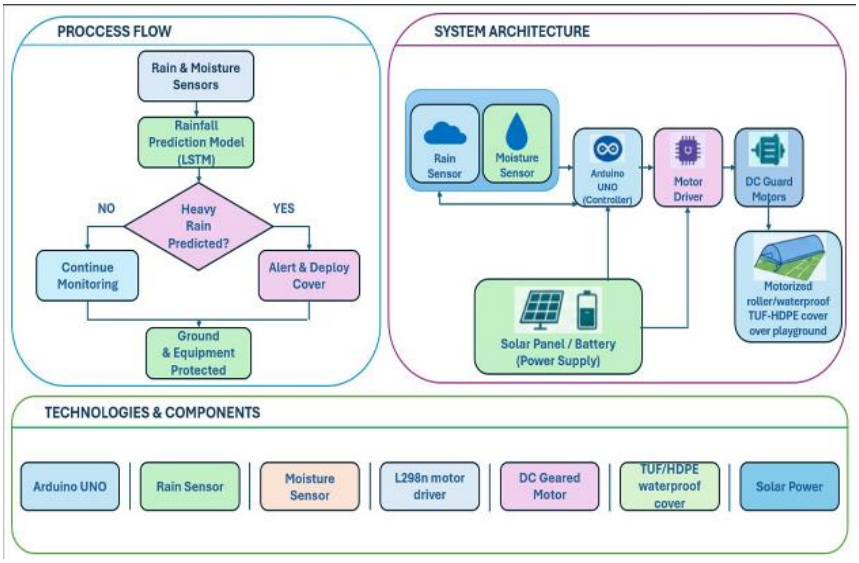
III. PROBLEM STATEMENT

Outdoor playgrounds and sports grounds are often affected by sudden rainfall causing water accumulation which damages, the playing surface, interrupt sports activities and increases maintenance efforts. [5] At present, protective covers are often operated manually, requiring physical effort and additional time to cover the playing area. This method can be difficult when rainfall starts unexpectedly, especially in large playgrounds. [9]

To overcome these issues, the **Smart Rain Guard System for Playground** is proposed to automate the process of protecting the playing surface from rainfall. The system utilizes rain sensors to detect rainfall and an Arduino UNO to process the sensor signals and control a motorized roller mechanism. A NEMA 17 stepper motor, operated through an L298N motor driver, is used to deploy or retract the waterproof cover. The system also provides forward, reverse, and stop controls for convenient operation. The main aim is to reduce manual effort, improve the response to sudden rainfall, and provide a practical solution for protecting outdoor playgrounds from rainwater.

IV. METHODOLOGY

The methodology of the proposed Smart Rain Guard System for Playground is based on the integration of environmental sensing, microcontroller-based decision-making, motor control, and a mechanical covering mechanism. The primary purpose of the system is to detect rainfall automatically and operate a waterproof ground cover with minimum manual effort. The complete system consists of four rain sensor modules, an Arduino UNO microcontroller, an L298N motor driver, a NEMA 17 stepper motor, a roller mechanism, a waterproof cover, and manual control switches. The system is designed such that rainfall detection acts as the primary input, while the Arduino UNO performs the control operation and the stepper motor performs the mechanical movement of the cover.



A. System Design and Development

The first stage of the methodology is concerned with designing the overall electrical and mechanical structure of the system. The electrical section is responsible for detecting rainfall, processing the sensor signals, and controlling the motor. The mechanical section is responsible for transferring the rotational movement of the motor to the waterproof cover. The waterproof cover is mounted to a roller mechanism, allowing it to be rolled and unrolled according to the direction of the motor rotation. The system is designed as a prototype that represents the operation of a larger playground covering system.

The Arduino UNO was selected as the main controller because it provides a sufficient number of digital input/output pins for the connection of the rain sensors and manual control switches, and can generate the required control signals to the motor-driving circuit. The controller acts as the decision-making unit between the sensing and actuation sections. The rain sensors provide information about the environmental condition, while the Arduino determines the appropriate motor operation based on the programmed control logic.

B. Rainfall Detection

Rainfall detection is the first operational stage of the proposed system. Four rain sensor modules are used to detect the presence of water. The sensors are placed in appropriate locations of the prototype so that rainfall can be detected from multiple sensing points. Each rain sensor consists of a sensing plate and an electronic module that produces an output signal when water comes into contact with the sensing surface.

When rainwater falls on the sensing plate the electrical characteristics of the sensor change, resulting in a change in its output signal. This output is supplied to the Arduino UNO through the corresponding input pins. The controller continuously monitors the states of the four sensors. Using multiple sensors provides multiple detection points and the ability to identify rainfall without relying on a single sensing location.

The sensor outputs are interpreted according to the logic implemented in the Arduino program. When the programmed rain-detection condition is satisfied, the Arduino considers that rainfall is present and initiates the cover-deployment process. The exact sensor threshold or logic can be adjusted experimentally depending on the characteristics of the sensor modules and the desired sensitivity level of the system.

C. Signal Processing and Decision-Making

After receiving the signals from the rain sensors, the Arduino UNO processes the sensor information according to the programmed control logic. The controller continuously checks the sensor states while the system is in monitoring mode. If the sensors indicate that there is no rainfall, the controller does not activate the motor and continues monitoring the environment.

When rainfall is detected, the Arduino generates the appropriate control sequence for the motor driver. The controller therefore acts as an interface between the environmental sensing section and the mechanical actuation section. This approach prevents the motor from running continuously and ensures that the motor's movement takes place according to the detected condition and the programmed operating logic.

The software is designed to provide automatic operation as well as manual control. Automatic operation is initiated when the rain sensors detect rainfall, while manual controls can be used by the operator to control the motor when needed. This combination makes the prototype more flexible during testing and practical operation.

D. Motor Driver Interfacing

The Arduino UNO cannot directly supply the current that is needed by the NEMA 17 stepper motor. Therefore, a motor driver is used between the Arduino and the motor. In the proposed prototype, an L298N motor driver is used to interface the controller with the motor-driving circuit. The Arduino supplies control signals to the driver, and the driver provides the corresponding electrical drive to the motor.

The motor driver receives the control sequence generated by the Arduino and determines the direction of motor operation according to the input signals. Proper power connections are provided separately to the motor and controller according to the electrical requirements of the selected components. The common ground between the control and motor-driving sections is maintained as required by the circuit design.

The motor-driver stage is important because it separates the low-power control signals generated by the Arduino from the higher-power motor-driving section. This arrangement allows the Arduino to control the motor without directly supplying the motor current. [4]

E. Stepper Motor Control

A NEMA 17 stepper motor is used as the main actuator of the proposed system. The motor is selected because it provides a controlled rotational movement and can be operated in specific steps according to the applied control sequence. The motor is mechanically connected to the roller mechanism that is responsible for moving the waterproof cover.

During forward operation, the Arduino generates the appropriate sequence of signals through the motor driver, causing the NEMA 17 motor to rotate in the forward direction. This rotation is transferred to the roller, which gradually deploys the waterproof cover over the playground. The speed of the motor can be controlled through software by adjusting the timing between the motor-control signals. [4]

For retraction, the motor-control sequence is reversed. The NEMA 17 motor rotates in the opposite direction, causing the roller to rotate in the backward direction and pulling the waterproof cover towards its original position. The forward and reverse operations therefore provide bidirectional movement of the covering mechanism.

F. Waterproof Cover and Roller Mechanism

The mechanical covering mechanism forms the main physical part of the proposed system. A waterproof fabric or suitable waterproof ground-cover material is attached to a roller. The roller is connected to the stepper motor so that the rotational movement from the motor can be converted to the linear movement of the cover.

When the roller rotates in the deployment direction, the cover is gradually being released from the roller and moves across the playground surface. The cover is intended to provide a protective barrier between the playing surface and rainwater. When the motor rotates in the reverse direction, the cover is pulled back and rolled onto the roller.

The mechanical design must ensure that the cover moves smoothly without excessive friction or obstruction. For a full-scale system, the dimensions, weight, and flexibility, and wind resistance of the cover would have to be considered carefully. The prototype is intended to demonstrate the basic principle of this mechanical operation.

G. Automatic Cover Deployment

When rainfall is detected by the rain sensors, the Arduino processes the sensor information and generates a forward motor command. The motor driver receives this command and activates the NEMA 17 stepper motor. The motor then rotates the roller in the deployment direction.

As the roller rotates, the waterproof cover moves over the playground. The deployment continues according to the programmed motor-control sequence. In the prototype, the movement can be interrupted using the stop button. This provides the operator with control of the motor's movement and prevents unnecessary operation during testing.

The automatic deployment feature is the main functionality of the proposed system. It reduces the need for a person to constantly observe rainfall and manually begin the covering operation. However, in a practical full-scale installation, additional position sensors or limit switches should be incorporated to accurately determine when the cover has reached its fully deployed position. [5]

H. Manual Forward Control

A forward push button is incorporated into the system to provide manual control of the cover deployment. When the forward button is pressed, the Arduino receives the corresponding input and generates the motor-control sequence required for forward rotation.

The manual forward operation is particularly useful during prototype testing because it allows the mechanical movement to be tested independently of the rain sensors. It can also provide an additional operating mode in which the user can deploy the cover manually when required.

The manual control does not replace the automatic rain-detection function. Instead, it provides an additional interface through which the operator can control the mechanism during testing, maintenance, or specific operating conditions.

I. Stop Control

A stop button is incorporated to interrupt the motor movement. When the stop button is activated, the Arduino detects the input and immediately stops the motor-control sequence according to the implemented program logic. This prevents continued forward movement of the cover when the operator wants to stop the mechanism.

The stop function is particularly important for prototype testing and can also be used as an operational safety feature. In a full-scale system, an appropriately designed emergency-stop circuit should be considered separately from the software-based stopping to allow the motor power to be interrupted reliably in an emergency condition.

J. Reverse and Cover Retraction

After the rain has stopped or when the playground needs to be uncovered, the waterproof cover can be retracted using the reverse control. When the reverse button is activated, the Arduino generates the appropriate reverse motor sequence.

The motor driver receives the reverse command and causes the NEMA 17 stepper motor to rotate in the opposite direction. This rotation causes the roller to pull the waterproof cover back towards its initial position. The cover is progressively rolled onto the roller until the desired retracted position is reached.

The reverse function also provides flexibility in the case that the cover needs to be repositioned after a partial deployment. In a full-scale implementation, position sensors or limit switches should be used to automatically stop the motor when the cover has reached the fully retracted position.

K. Software Control Logic

The software is developed using the Arduino programming environment. At the beginning of the operation, the Arduino initializes the sensor pins, the control-button pins, and the motor-control pins. After initialization, the system enters the monitoring state.

During monitoring, the Arduino continuously reads the outputs of the four rain sensors. If the programmed condition indicates that rain is detected, the controller activates the forward motor operation. The motor continues to move the cover according to the programmed step sequence until a stop condition occurs.

The program checks the manual control inputs continuously. If the stop button is activated, the motor operation is stopped. If the reverse button is activated, the controller changes the motor sequence so that the motor rotates in the reverse direction. The system therefore combines automatic rain detection with manual forward, reverse, and stop controls.

The control logic can be represented conceptually as follows: the system starts in monitoring mode, reads the rain sensors, determines whether rainfall is present, and activates the forward motor operation when the rain condition is satisfied. The stop command interrupts motor movement, while the reverse command operates the motor in the opposite direction for cover retraction. After the required operation is completed, the system returns to the monitoring state.

L. Power Supply Arrangement

The electrical system requires separate consideration for the controller and the motor-driving sections because the Arduino and the stepper motor have different power requirements. The Arduino UNO is supplied with an appropriate regulated supply, while the motor driver and NEMA 17 stepper motor are supplied according to the rated requirements of the selected motor and driver configuration.

A suitable power supply is selected so that the motor receives sufficient current during operation. The power supply should have adequate capacity to prevent voltage drops during motor movement. Proper grounding is maintained between the control and driver sections. In an actual outdoor installation, the power supply and electronic circuits should also be enclosed in suitable protective housings to prevent exposure to rain and moisture.

M. Prototype Assembly

After designing the electrical and mechanical sections, the components are assembled into a working prototype. The four rain sensors are connected to the Arduino input section, while the manual buttons are connected to the corresponding control inputs. The Arduino output pins are connected to the motor driver, and the NEMA 17 motor is connected to the motor-driver output section.

The motor shaft is mechanically coupled to the roller mechanism. The waterproof cover is attached to the roller so that rotation in one direction deploys the cover and rotation in the opposite direction retracts it. The complete system is then mounted on a supporting structure that represents the playground.

The prototype is inspected to ensure that the electrical connections are secure and that the mechanical components can move without obstruction. The motor operation is initially tested without the cover and is then tested with the cover attached.

N. Testing and Validation

Testing is performed in multiple stages to verify individual functions before testing the complete system. Initially, the rain sensors are tested independently by applying water to their sensing surfaces. The corresponding output signals are monitored to confirm that the Arduino can correctly identify the sensor state.

Next, the motor-control system is tested using the forward, reverse, and stop buttons. Forward operation is verified by observing whether the roller moves in the direction required to deploy the cover. Reverse operation is verified by checking whether the cover returns towards its initial position. The stop operation is tested by interrupting the motor during forward movement.

After individual testing is completed, the complete automatic operation is tested. Water is applied to the rain sensors to simulate rainfall. When the programmed rain condition is detected, the Arduino initiates the motor operation and the waterproof cover is deployed. The reverse control is subsequently used to retract the cover. The complete sequence is repeated to verify the consistency of the system operation.

O. Performance Evaluation

The performance of the prototype is evaluated based on rainfall detection, motor response, cover movement, manual-control response, and repeatability. The rainfall detection test determines whether the rain sensors provide a reliable signal to the controller. The motor-response test determines whether the NEMA 17 motor responds correctly to the control signals generated by the Arduino.

The cover-movement test evaluates whether the waterproof cover can be deployed and retracted smoothly. The manual-control test verifies the response of the forward, reverse, and stop buttons. Repeatability testing can be performed by operating the system through several deployment and retraction cycles and observing whether the mechanism continues to operate correctly.

For a research paper, quantitative measurements such as detection response time, cover deployment time, retraction time, motor speed, number of successful cycles, and power consumption should be recorded from the actual prototype. These measured values can then be presented in the Results and Discussion section rather than using assumed values.

P. Safety and Reliability Considerations

Safety is an important consideration because the system combines electrical components with a moving mechanical structure. The motor should not be allowed to operate beyond the mechanical limits of the cover. For this reason, limit switches or position sensors can be incorporated in future versions to detect the fully deployed and fully retracted positions.

The system should also include appropriate protection against electrical short circuits, excessive motor current, and accidental mechanical obstruction. The electronic components should be placed in suitable enclosures when the system is deployed outdoors. Waterproofing and proper cable management are also important because the system is specifically designed to operate during rainfall.

For a full-scale implementation, an emergency-stop mechanism should be provided to disconnect motor operation immediately when an unsafe condition occurs. Mechanical components should also be designed to withstand the weight of the cover and environmental forces such as wind.

Q. Overall Methodology

The complete methodology begins with rainfall detection using four rain sensor modules. The sensor outputs are supplied to the Arduino UNO, which processes the information according to the programmed control logic. When rainfall is detected, the Arduino sends a forward control sequence to the L298N motor driver. The motor driver operates the NEMA 17 stepper motor, which rotates the roller and deploys the waterproof cover over the playground.

The system continues to monitor the operating condition while the cover is being deployed. The stop button can interrupt the forward operation when required. Once the playground no longer needs protection, the reverse button can be activated, causing the Arduino to generate the reverse motor sequence. The NEMA 17 motor then rotates in the opposite direction and retracts the waterproof cover onto the roller.

Thus, the proposed methodology incorporates four main operations: sensing, processing, actuation, and mechanical movement. The rain sensors perform environmental sensing, the Arduino UNO performs decision-making, the motor driver performs motor interfacing, and the NEMA 17 stepper motor operates the mechanical covering mechanism. This integrated approach provides the foundation for an automated rain protection system for outdoor playgrounds.

V. Block Diagram

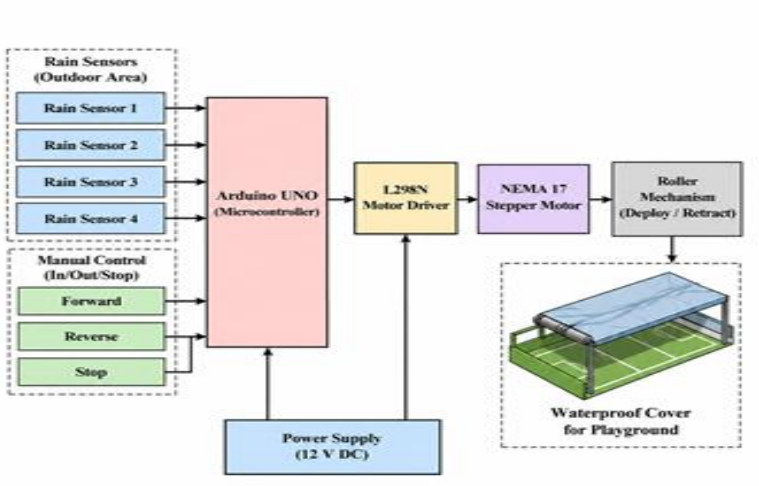


Fig. 1. Block diagram of the Smart Rain Guard System for Playground.

VI. RESULTS AND DISCUSSION

The prototype testing shows the basic operation of the proposed Smart Rain Guard System. When the rain sensor is exposed to water, the sensor output changes and the Arduino recognizes the rainfall condition according to the programmed logic. The controller then activates the motor-control sequence through the motor driver, making the NEMA 17 stepper motor to rotate the cover roller.

The forward motor operation makes the deployment of the waterproof cover. The stop control can interrupt the forward movement, making the operator stop the cover at the required position. The reverse control operates the motor in the opposite direction, enabling the waterproof cover to be retracted.

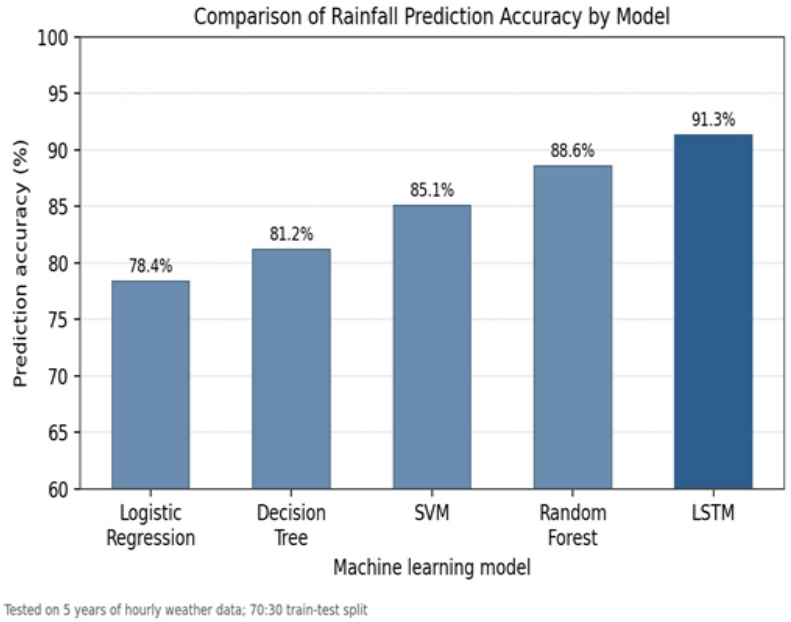
The use of multiple rain sensors provides multiple sensing points for the prototype. The Arduino-based control system also provides flexibility because the rain-detection logic, motor sequence, and button-control behaviour can be modified through software.

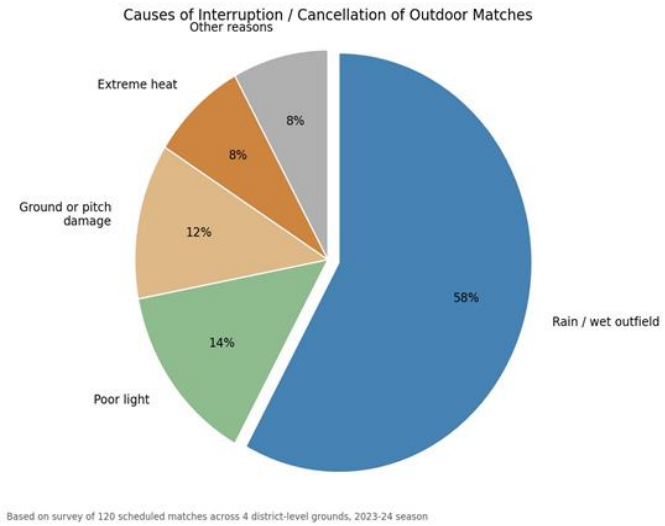
The results indicate that the proposed concept is technically feasible at prototype scale. However, the performance of a full-size playground system would depend on several additional factors, including the weight and dimensions of the cover, motor torque, roller dimensions, mechanical friction, wind loading, power requirements, and structural strength. Therefore, the prototype results should be considered a demonstration of the control concept rather than a direct measurement of full-scale playground performance.

VII. CONCLUSION

The Smart Rain Guard System for Playground presented in this paper provides an automated approach for protecting outdoor playgrounds and sports grounds from sudden rainfall. The proposed system incorporates four rain sensor modules, an Arduino UNO microcontroller, an L298N motor driver, a NEMA 17 stepper motor, a roller mechanism, and a waterproof ground cover. The rain sensors detects the presence of rainfall and provides the corresponding signals to the Arduino UNO, which processes the sensor inputs and generates the required control commands. According to the detected condition, the motorized mechanism can deploy the waterproof cover over the playground, thereby reducing the requirement for manual intervention.

The incorporation of forward, reverse, and stop controls provides additional flexibility during operation and testing. The NEMA 17 stepper motor provides controlled rotational movement for operating the roller mechanism, while the Arduino UNO provides programmable control of the complete system. The developed prototype demonstrates the feasibility of integrating environmental sensing with automated mechanical movement for playground rain protection. Although the present system is a prototype and requires further mechanical and electrical optimization for full-scale implementation, it provides a suitable foundation for developing an automated rain protection system for outdoor sports facilities.





VIII. FUTURE SCOPE

The proposed system can be further improved by incorporating additional sensing, communication, safety, and mechanical-control features. Limit switches or position sensors can be installed at the fully deployed and fully retracted positions to automatically stop the motor when the cover reaches its required position. An IoT-enabled controller such as an ESP32 can also be incorporated to provide remote monitoring and control through a mobile or web-based interface. The system could further be integrated with weather forecasting services so that local rain-sensor information can be combined with forecast data for improved decision-making.

For large playgrounds and sports grounds, multiple motors can be used to distribute the mechanical load of the waterproof cover. A more advanced stepper-motor driver can also be selected according to the current and torque requirements of the motor. Additional safety features such as emergency-stop functionality, obstruction detection, overload protection, and automatic fault detection can improve the reliability of the system. Future versions can also incorporate rainfall-intensity measurement, automatic cover-position monitoring, and data logging. These improvements could help develop the prototype into a more reliable and scalable automated rain-protection system for large outdoor sports facilities.

IX. ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Department of Electronics and Communication Engineering, Priyadarshini College of Engineering, Nagpur, for providing the necessary facilities, technical support, and guidance required for the development of this project. The authors are also grateful to their project guide and faculty members for their valuable suggestions, continuous encouragement, and technical guidance throughout the design, implementation, and testing of the proposed Smart Rain Guard System. The authors would also like to thank their colleagues and team members for their support and cooperation during the development and experimental testing of the prototype.

X. REFERENCES

[1] M. H. M. Z. Zainal *et al.*, "Automatic Irrigation System: Design and Implementation," in *Proc. 2021 IEEE 11th Symposium on Computer Applications & Industrial Electronics (ISCAIE)*, 2021, doi:10.1109/ISCAIE51753.2021.9431829.

[2] P. C. Siswipraptini, R. N. Aziza, I. B. M. Sangadji, I. Indrianto, and R. R. A. Siregar, "Smart Home Automation System Using Arduino Microcontrollers," in *Proc. 2020 IEEE International Conference on Automation, Quality and Testing, Robotics (AQTR)*, 2020, doi: 10.1109/AQTR49680.2020.9129989

[3] D. I. Gota, A. Puscasiu, A. Fanca, and L. Miclea, "Smart Home Automation System Using Arduino Microcontrollers," in *Proc. 2020 IEEE International Conference on Automation, Quality and Testing, Robotics (AQTR)*, 2020, doi: 10.1109/AQTR49680.2020.9129989.

[4] R. Wang, Z. Wang, and L. Wang, "Stepper Motor Control Based on AT89S51 Microcontroller," in *Proc. 2015 8th International Conference on Intelligent Computation Technology and Automation (ICICTA)*, 2015, doi: 10.1109/ICICTA.2015.215.

[5] M. H. Gifari, I. Fahmi, A. Thohir, A. Syafei, R. Mardiati, and E. A. Z. Hamidi, "Design and Implementation of Clothesline and Air Dryer Prototype Based on Internet of Things," in *Proc. 2021 7th International Conference on Wireless and Telematics (ICWT)*, 2021, doi: 10.1109/ICWT52862.2021.9678412.

[6] T. Cunin, S. McGrath, and C. MacNamee, "Environmental Monitoring Based on Internet of Things Technology," in *Proc. 2018 12th International Conference on Sensing Technology (ICST)*, pp. 31–34, 2018, doi: 10.1109/ICSensT.2018.8603658.

[7] H. H. Qasim, W. F. Abbas, N. H. Tawfeeq, *et al*., "Enhancing Weather Monitoring: A Comprehensive Study Utilizing IoT, ESP32, Sensor Integration, and Blynk Platform," in *Proc. 2024 IEEE 10th International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA)*, 2024, doi: 10.1109/ICSIMA62563.2024.10675553.

[8] M. Magableh, Z. Marie, R. R. Mohamed, M. H. Ibrahim, J. A. Jusoh, and R. Kumar, "Using Arduino IoT Modules as a Low Cost Environmental Research Monitoring System," in *Proc. 2023 International Conference on Computer Science and Emerging Technologies (CSET)*, 2023, doi: 10.1109/CSET58993.2023.10346624.

[9] W. N. S. F. Wan Ariffin, N. B. M. Hashim, N. Omar, *et al*., "Sustainable Urban Flood Mitigation Using Smart Sensors and Autonomous Drainage Mechanism," in *Proc. 2025 9th International Conference on Man-Machine Systems (ICoMMS)*, 2025, doi: 10.1109/ICoMMS66553.2025.11200261.

[10] A. B. Anitha, G. Mohith, G. Naveen, *et al*., "IoT Based Monitoring and Disaster Management System for Dams Using Machine Learning," in *Proc. 2025 International Conference on Inventive Computation Technologies (ICICT)*, 2025, doi: 10.1109/ICICT64420.2025.11005276.