

Smart Umbrella Reminder Using AI and IoT: A Comprehensive Review of Enabling Technologies, Rain-Prediction Models, Existing Designs, and Deployment Challenges

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Abstract- Forgetting an umbrella is a small problem, but it happens to almost everyone, and ordinary weather apps do little about it because they cannot tell whether you are actually carrying one. Smart umbrellas try to close that gap with sensors, a microcontroller and a phone connection. This paper presents a focused narrative review that synthesises twelve sources: five foundational works on IoT architectures and protocols, Random Forests, LSTM networks and TinyML [1]–[5], four research prototypes of IoT umbrellas [6]–[9] and three commercial or hobbyist designs [10]–[12]. The review examines three connected themes: the technologies and design elements on which a rain-aware umbrella rests, the strength of the evidence for existing designs, and the conditions that matter for deployment. Existing designs mostly detect rain, track location or guide navigation. In the sources we could access, none documents a system that joins a learned rain-probability estimate, on-device inference and carry detection to decide when a reminder is really worth sending, and none reports a head-to-head accuracy test of prediction models on umbrella hardware. The review contributes two comparative tables, a conceptual ESP32-based hybrid edge–cloud architecture and a prioritised agenda of research gaps and future directions. The architecture is a proposal only; it has not been built or tested, and no accuracy figures are claimed for it.

Keywords— Smart Umbrella, Internet of Things, Rain Prediction, TinyML, Edge AI, MQTT, Random Forest, LSTM

I. INTRODUCTION

Anyone who commutes in a monsoon climate knows the routine: the sky looks fine in the morning, the umbrella stays by the door, and by the evening you are soaked. The forecast was available all along. What was missing was a nudge at the right moment. Weather apps report the weather but they are passive, and they have no idea whether the umbrella is in your hand or still at home.

A smart umbrella tries to supply that nudge. In its simplest form it is an ordinary umbrella with a few sensors and a microcontroller, connected to a phone. Machine learning can estimate the chance of rain, and IoT communication carries that estimate to the person. Three developments make this practical now. Low-cost boards such as the ESP32 bring Wi-Fi and Bluetooth for a few dollars. Lightweight IoT protocols make it cheap to move small sensor

readings around [1], [2]. And TinyML frameworks can run trained models in only kilobytes of memory [5]. The idea is not new in spirit, since hobbyists were wiring forecasts to umbrella stands as early as 2015 [12], but it is still thinly covered in the research literature.

This paper reviews twelve sources that together span foundational technology papers [1]–[5], research prototypes [6]–[9] and commercial or hobbyist designs [10]–[12]. Three questions guide the review. RQ1: Which technologies and design elements underpin a rain-aware smart umbrella? RQ2: How strong is the evidence for existing smart-umbrella designs? RQ3: What does the evidence imply for a reminder that fires only when rain is likely and the umbrella is being left behind? Likely users include daily commuters, students on campuses, elderly or visually impaired people who would benefit from voice alerts, and smart-city planners who could use umbrellas as sources of local rain data.

The contributions of this paper are: (i) a structured narrative review of twelve sources; (ii) comparative tables of umbrella designs and prediction-model families; (iii) identification of research gaps; and (iv) a conceptual ESP32-based architecture with a research agenda. Section II describes the methodology, Section III reviews the literature, Section IV compares the designs and models, Section V discusses challenges and gaps, Section VI proposes research directions and Section VII concludes.

II. REVIEW METHODOLOGY AND LITERATURE SELECTION CRITERIA

1. Search Strategy

This is a narrative review of a purposively chosen set of sources, not a systematic one. We searched IEEE Xplore, ResearchGate, publisher pages and general web search using combinations of the terms smart umbrella, IoT, rain prediction, weather forecasting, TinyML, edge computing and MQTT.

2. Inclusion and Exclusion Criteria

We kept sources that described a sensing, communication or prediction method relevant to a rain-aware reminder device and that gave enough detail to say what the method does. Commercial products and hobbyist projects were treated as grey literature: we used them only to describe what features exist, never as evidence of accuracy. The foundational works [1]–[5] were included because they define the components any smart umbrella is built from.

3. Screening Outcome and Limitations

Twelve sources were retained: five foundational works [1]–[5], four research prototypes [6]–[9] and three commercial or hobbyist designs [10]–[12]. Three limits should be stated plainly. Scopus and Web of Science were not queried directly, so coverage is not exhaustive and we report no study counts. The foundational works on IoT, Random Forests, LSTM and TinyML [1]–[5] predate 2022. For some of the umbrella papers [7]–[9] we could read only the abstract, so our descriptions of them stay at that level. Finally, none of the sources reports a head-to-head accuracy test of rain-prediction

models on umbrella hardware, so we do not pool or rank numerical results. Because most umbrella sources are prototypes or products, conclusions about performance are inferences and are labelled as such.

III. LITERATURE REVIEW

1. Reminder versus Weather Report

A weather app reports conditions; a reminder device makes a decision about when to speak. The difference matters for umbrellas, because the useful moment is the one when rain is likely and the umbrella is not with the person. This requires two inputs that a phone app lacks: a local reading of the weather and a signal showing whether the umbrella is carried.

2. IoT Foundations

Gubbi et al. [1] set out a layered view of the Internet of Things in which sensing, networking and cloud analytics are separate concerns that can be combined for different applications. It remains the standard reference for how a device like a smart umbrella fits into a larger system, although it says nothing about rain. Al-Fuqaha et al. [2] surveyed the protocols and technologies that connect such devices and compared options such as MQTT and CoAP with the available wireless links. For a battery-powered umbrella, the practical lesson is that a lightweight publish-subscribe protocol such as MQTT keeps radio time, and therefore energy use, low. Neither survey covers AI-based prediction, so they supply the plumbing and not the intelligence.

3. Rain-Prediction Models

The simplest approach is a threshold rule: warn when humidity is above one limit or pressure has fallen past another. These rules are fast, cheap and easy to explain, but they miss slow trends and tend to raise false alarms. Breiman's Random Forest [3] combines many decision trees and is known to work well on tabular data of the kind weather stations produce, such as temperature, humidity and pressure. Its drawback here is size, since a large forest can be heavy for a small chip. Hochreiter and Schmidhuber's LSTM network [4] is designed for sequences and can learn how conditions change over hours, which suits

rain forecasting. It demands more data and more compute, so it usually lives in the cloud.

4. TinyML on Microcontrollers

David et al. [5] describe TensorFlow Lite Micro, a framework for running machine-learning models on devices with very little memory and no operating system. This is what makes on-device rain prediction conceivable: the umbrella could reach a decision without waiting for a round trip to a server. The price is that models must be small and are often quantised, which can cost some accuracy.

5. Features and Design Elements of Smart Umbrellas

Across the research prototypes and products, six functional building blocks recur: (i) environmental sensing of temperature, pressure, humidity or light [7], [10]; (ii) location sensing or GPS to prevent loss [7], [11]; (iii) direction guidance using LEDs and a compass [6]; (iv) automatic opening and closing driven by a motor [7], [11]; (v) solar charging to extend battery life [7]; and (vi) a smartphone app that delivers alerts [7], [10], [11]. Oombrella [10] additionally shares readings among nearby users and sends a Bluetooth notification when the owner walks away from the umbrella.

Han et al. [6] augmented an umbrella with LEDs on the ribs, a three-axis electronic compass and Bluetooth so that it could point the way to a destination in the rain; weather prediction was not their goal. Akshitha et al. [7] describe an IoT umbrella with weather sensors, GPS, solar charging, automatic opening and closing, a flashlight and a smartphone app that sends alerts. Karthik [9] and Jayamani et al. [8] also present sensor-based IoT umbrellas, although we could read only abstract-level information for these. The common pattern is a reactive device that senses present conditions rather than forecasting.

6. Reminder-Type Designs in Practice

The designs closest to a rain reminder are commercial or hobbyist, so they are described here as grey literature. Oombrella [10] carries temperature, pressure, humidity and light sensors, shares readings among nearby users, warns of likely

rain and sends a Bluetooth notification if you walk away from it. The HAZ umbrella [11] adds a motorised canopy, location sensing to prevent loss and an app that works as a weather reminder. A 2015 hobby project [12] used an online forecast and the IFTTT service to light up an umbrella stand and suggested adding a pressure sensor to detect whether the umbrella was present.

These examples show that the market has recognised both needs, rain warning and loss prevention. What the public descriptions do not reveal is how the rain estimate is made or how well it works, and claims from products were not independently verified. The pressure-sensor idea in [12] and the Bluetooth left-behind alert in [10] come closest to carry awareness, but both are rule-based or unpublished. Whether any of these designs would perform well on a real monsoon commute is untested in the sources reviewed.

7. Strength of the Evidence

No source in the review reports a head-to-head accuracy test of threshold rules, Random Forest, LSTM and TinyML models on umbrella hardware. What is known about each family comes from its foundational paper [3]–[5] and describes general characteristics such as suitability for tabular data, sequence learning or small memory, not performance in this application. The research papers on umbrellas [6]–[9] report prototypes, not measured prediction accuracy, and for [7]–[9] we could read only the abstract. We also found no shared dataset or benchmark for umbrella-level rain prediction. The evidence base is therefore best described as a set of design demonstrations rather than validated results.

The sources span 2015 to 2025 for umbrella designs and reach back to 1997 for LSTM [4]. The foundational papers cover components well but not their combination, and the umbrella papers cover combinations of sensors and actuators but not prediction. The two bodies of work have barely met.

IV. COMPARATIVE ANALYSIS OF EXISTING DESIGNS

Table I summarises the smart-umbrella designs discussed above and Table II compares the model families a rain-aware umbrella could use. Because

purposes, hardware and reporting differ, the studies are compared qualitatively rather than numerically. The ratings in Table II are qualitative judgements drawn from the characteristics reported in [3]–[5]; they are not measured results, and the final row describes an expected profile of the proposed design, which has not been built.

Table 1: Comparison of Smart-Umbrella Designs

Work / product	Type / objective	Technologies	Main contribution	Scope limitation
IFTTT stand, 2015 [12]	Hobby project; rain-aware umbrella stand	Online forecast, IFTTT, optional pressure sensor	Light turns on when rain is forecast	Rule-based; depends on an internet forecast
Han et al., 2017 [6]	Prototype; safety directions in rain	LEDs on ribs, 3-axis compass, Bluetooth	Direction guidance to a destination through a phone link	Navigation focus; no rain prediction
Karthik, 2021 [9]	Prototype; automatic umbrella	Sensors, IoT	Sensor-triggered operation for different weather conditions	Reactive; no forecast; abstract only
Jayamani et al., 2022 [8]	Prototype; IoT umbrella design	Sensor-based IoT	Design and development of a sensor-based IoT umbrella	Abstract only; details not assessed
Akshitha et al., 2025 [7]	Prototype; IoT umbrella	Weather sensors, GPS, solar panel, auto open/close, flashlight, app	Alerts delivered to a smartphone app	Prediction method not described in abstract
Oombrella [10]	Commercial product; weather and left-behind alerts	Temperature, pressure, humidity and light sensors; Bluetooth	Rain-likely alert, Bluetooth left-behind alert, shared user data	Commercial; model and accuracy not published
HAZ umbrella [11]	Commercial product; IoT umbrella	Motorised canopy, location sensing, app	Weather reminder; phone-disconnect alert	No evidence of a learned prediction model

Table 2: Qualitative Comparison of Rain-Prediction Approaches

Approach	Technique	Typical data	Accuracy	Latency	Scalability	Main limitation
Threshold rules	Fixed humidity / pressure limits	Local sensors	Low	Very low	High	Misses trends; false alarms
Random Forest [3]	Tree ensemble	Weather history	Medium–High	Low	Medium	Larger memory use
LSTM [4]	Recurrent time-series network	Weather history	High	Medium	Medium	Needs data and compute
TinyML [5]	Quantised model on the MCU	Local sensors	Medium	Very low	High	Small model, lower accuracy

Approach	Technique	Typical data	Accuracy	Latency	Scalability	Main limitation
Proposed hybrid (expected)	Edge ML plus cloud forecast	Sensors + forecast	High (expected)	Low	High	Needs Wi-Fi for forecast

Three patterns emerge. First, smart-umbrella designs concentrate on convenience features such as automatic opening, location tracking and navigation rather than on prediction [6]–[11]. Second, rule-based and TinyML approaches win on speed and power but give up accuracy, while LSTM models lead among single models on accuracy but need data and compute. Third, a hybrid that keeps a compact model on the device and uses a cloud forecast as an extra input looks like a reasonable compromise, but that remains a hypothesis until it is measured. Since purposes, hardware and reporting differ, no single approach can be declared best on the evidence reviewed.

V. RESEARCH CHALLENGES AND IDENTIFIED GAPS

The following gaps are drawn from the reviewed literature and from reasoning about the system design. (i) Missing integration. The umbrellas either detect rain, track location or guide navigation [6]–[11], and none documents a design that combines a forecast, a learned prediction and carry detection in one decision. (ii) Cloud dependence. Heavier models such as LSTM are rarely run on low-power chips [4], [5], so most designs depend on the cloud, and the reminder can arrive late or not at all when the network is poor. (iii) Context-blind alerts. A reminder that fires whenever rain is possible, regardless of whether the umbrella is already in hand, risks alert fatigue and may lead people to mute the app; this is a design argument, as none of the sources we read reports a user study of alert annoyance. (iv) Thin evidence. Prototypes lack measured prediction accuracy, there is no shared dataset or benchmark, and small local datasets limit how far any model trained on them can be trusted elsewhere. (v) Deployment. A real umbrella gets wet, folded, dropped and left in bags, so waterproofing, battery life and cost matter as much as the model, and every added feature (motor, GPS, solar panel) adds cost,

weight and power demand. (vi) Privacy and fairness. A device that records where a person goes and whether they carry an umbrella holds location and habit data, which should be stored minimally, protected in transit and never shared without consent; predictions should also work as reliably in different localities as where training data was plentiful. (vii) Sustainability and access. Costly devices could widen the gap between those who can afford them and those who cannot, while low-power chips, reusable parts and recyclable casings reduce e-waste.

VI. PROPOSED RESEARCH DIRECTIONS

1. Proposed Conceptual Architecture

Fig. 1 gathers the design implications of the reviewed sources into a layered architecture for a smart umbrella reminder. It is a conceptual proposal derived from the literature and has not been tested experimentally. Layer 1 captures the usage context: commuters in monsoon-type weather who may or may not carry the umbrella [1]. Layer 2 reads temperature, humidity, pressure and a carry-status signal such as touch or grip [10], [12]. Layer 3 is an ESP32 that filters and normalises the readings, runs a light model and provides Wi-Fi and Bluetooth [5]. Layer 4 sends data by MQTT [2] to a cloud service that combines them with a weather-forecast API and a heavier Random Forest or LSTM model [3], [4]. Layer 5 weighs the result against whether the umbrella is carried. Layer 6 delivers the reminder through the app, buzzer, LED or voice. If the network is down, the on-device model can still raise a local alert; this offline fallback is the authors' inference from the cloud dependence of heavier models, and none of the reviewed sources tested it. Layer 7 closes the loop with evaluation, with results fed back into the earlier layers.

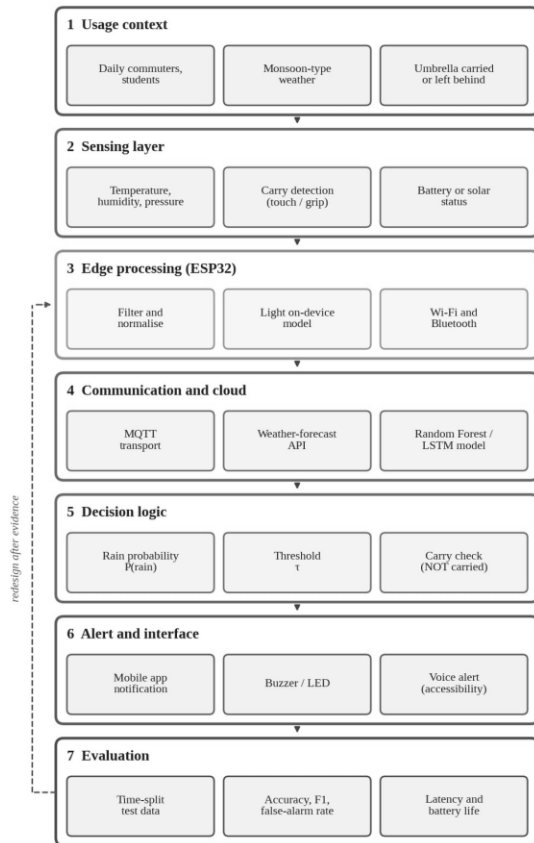


Fig.1. Proposed conceptual architecture of the smart umbrella reminder (conceptual, not experimentally validated)

2. Working Principle

The proposed working principle has four steps. (1) The sensing layer reads temperature, humidity and pressure together with a carry-status signal, and the ESP32 filters and normalises the readings. (2) The model turns the feature vector x (temperature, humidity, pressure, forecast and short time-window features) into a rain probability. In the simplest case this is a logistic output stage, which is also how the final layer of a neural network or the vote share of a forest can be read:

$$P(\text{rain}) = \sigma(w^T x + b), \quad \sigma(z) = 1 / (1 + e^{-z}) \quad (1)$$

where w holds the weights and b is the bias. (3) A reminder is sent only when the probability reaches a threshold τ and the umbrella is not being carried:

$$\text{alert} = [P(\text{rain}) \geq \tau] \text{ AND NOT carried} \quad (2)$$

Choosing τ is a trade-off between missed rain and false alarms, and it is the natural place for personalisation. (4) The alert is delivered through the app, buzzer, LED or voice, and the outcome is evaluated and fed back into the design.

3. Directions Requiring Investigation

Priorities include (i) an ESP32 prototype with a mobile app tested on real commutes; (ii) multi-season, multi-city datasets with ground-truth rain labels; (iii) solar or energy-harvesting charging for longer battery life; (iv) alerts personalised from a user's habits while keeping data on the device; (v) voice alerts for elderly and visually impaired users; and (vi) explainable alerts that say why a reminder was sent.

A prototype should be judged on accuracy and F1-score, because rainy days are usually the minority class, and on alert latency, false-alarm rate and battery life. Test data should be split by time or by day, not at random, since neighbouring readings are highly correlated and random splits can inflate results. Results should be reported against the threshold-rule baseline so that any gain from machine learning is visible.

VII. CONCLUSION AND FUTURE SCOPE

Across the twelve reviewed sources, smart umbrellas have moved from hobby projects to commercial products, yet the literature we examined still treats rain detection, location tracking and prediction as separate features. The components needed to join them already exist: lightweight IoT protocols [1], [2], proven rain-prediction models [3], [4] and TinyML [5]. What is missing is an integrated, tested design that sends a reminder only when rain is likely and the umbrella is left behind, along with open data to measure it. For a practical device this points to a compact on-device model, a cloud forecast as an extra input, carry detection, and careful handling of privacy, battery life and cost.

Future work should build the proposed architecture as a prototype, test it on real commutes and publish the measured accuracy, latency and false-alarm rate.

The architecture proposed here is a starting point, not a validated result.

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