THE USAGE OF SMART SPRINKLER SYSTEM IN SMART HOME

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Purpose: The purpose of this publication is to present the usage of smart sprinkler system in smart homes.

Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

Findings: The integration of a Smart Sprinkler System within the context of a Smart Home represents a groundbreaking convergence of technology and water management, reshaping conventional approaches to lawn care and irrigation. This innovative system epitomizes a seamless fusion of convenience, efficiency, and sustainability in the modern landscape of home automation. Operating on real-time data and intelligent algorithms, the Smart Sprinkler System ensures precise water usage by dynamically adapting to environmental changes, avoiding over-watering or under-watering, and aligning with conservation efforts. The publication emphasizes the system's connectivity, leveraging the Internet of Things (IoT) for remote control and integration into smart home ecosystems. Notable features include energy efficiency, aesthetics enhancement, and integration with other devices. While the advantages are evident, the accompanying tables comprehensively detail key features, advantages, and potential challenges, providing a nuanced perspective for homeowners and highlighting the ongoing evolution of these systems in advancing sustainable, efficient, and connected living experiences.

Originality/Value: Detailed analysis of all subjects related to the problems connected with the usage of smart sprinkler system in smart home.

Keywords: Smart City, energy efficiency, smart home, smart house, digitalization, smart sprinkler system.

Category of the paper: literature review.

1. Introduction

A Smart Sprinkler System in the context of a Smart Home represents a pioneering integration of technology and water management, revolutionizing the traditional approach to lawn care and irrigation. In the contemporary era of home automation, this system stands out

as a testament to the seamless fusion of convenience, efficiency, and sustainability (Wu et al., 2023).

At its core, the Smart Sprinkler System is designed to cater to the specific needs of a lawn or garden by leveraging real-time data and intelligent algorithms. This level of precision ensures that water is utilized judiciously, avoiding over-watering or under-watering, thereby contributing to water conservation efforts. Through the integration of weather data, soil moisture levels, and even local watering restrictions, the system adapts dynamically to the ever-changing environmental conditions (Chaudhari et al., 2023).

The purpose of this publication is to present the usage of smart sprinkler system in smart home.

2. Smart sprinkler system in smart home

One of the standout features of this innovative system lies in its connectivity. Harnessing the power of the Internet of Things (IoT), the Smart Sprinkler System can be controlled remotely through dedicated smartphone applications or integrated into existing smart home ecosystems (Patheja et al., 2023). This connectivity not only provides homeowners with the flexibility to manage their irrigation system from anywhere in the world but also facilitates real-time monitoring and adjustment. Moreover, the system often incorporates advanced sensors and moisture detectors strategically placed throughout the landscape (Douha et al., 2023). These sensors continuously gather data, enabling the Smart Sprinkler System to make informed decisions about when and where to water. The ability to create custom watering schedules based on specific plant types or landscaping zones further enhances the system's adaptability and efficiency (Alsaedi et al., 2023).

Energy efficiency is another critical aspect of the Smart Sprinkler System (Afroz et al., 2024). With the integration of smart sensors, the system optimizes water distribution, minimizing wastage and promoting a sustainable approach to lawn care. This not only aligns with the broader environmental goals of smart home technologies but also translates into cost savings for homeowners over the long term (Raff et al., 2024).

In addition to the environmental and economic benefits, the Smart Sprinkler System contributes to the overall aesthetics of the smart home landscape. The automation of the irrigation process eliminates the need for manual intervention, reducing the burden on homeowners and allowing them to enjoy a well-maintained and lush garden effortlessly (Sobhani et al., 2023).

As technology continues to evolve, the Smart Sprinkler System represents a glimpse into the future of smart home landscaping (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022). Its ability to seamlessly integrate with other smart devices, learn from user behaviors, and adapt to environmental variables positions it as a cornerstone of modern, connected living (Ramanujam et al., 2024). Ultimately, this innovation not only elevates the efficiency of traditional irrigation methods but also underscores the potential of smart home technology to enhance the quality of life for homeowners (Ameur et al., 2023).

Table 1 contains descriptions of key features of smart sprinkler system usage.

Table 1.
Key features of smart sprinkler system usage

Key Features of System Sprinkler	Description
Precision Watering	The smart sprinkler system utilizes real-time data, including weather conditions and soil moisture levels, to deliver precise and efficient watering. This minimizes water wastage by avoiding over-watering or under-watering, promoting water conservation.
Remote Control	Through the integration of IoT technology, users can control and monitor the sprinkler system remotely using dedicated smartphone applications. This feature provides homeowners with the flexibility to manage their irrigation system from anywhere, enhancing convenience and adaptability.
Dynamic Adaptation	The system dynamically adapts to changing environmental conditions, adjusting watering schedules based on factors such as temperature, humidity, and local watering restrictions. This ensures that the irrigation process remains responsive and optimized for the specific needs of the lawn or garden.
Customized Watering Schedules	Homeowners can create customized watering schedules tailored to the unique requirements of different plant types or landscaping zones. This feature allows for a personalized approach to lawn care, optimizing water distribution based on specific characteristics and preferences.
Sensor Integration	Advanced sensors and moisture detectors strategically placed throughout the landscape continuously collect data. This data informs the system's decision-making process, enabling it to make informed choices about when and where to water. Sensor integration enhances the overall efficiency of the sprinkler system.
Energy Efficiency	The smart sprinkler system optimizes water distribution, reducing energy consumption and promoting sustainable lawn care practices. By minimizing water wastage, homeowners not only contribute to environmental conservation efforts but also benefit from long-term cost savings associated with efficient water usage.
Integration with Smart Home	The system seamlessly integrates with other smart home devices and ecosystems, allowing for a cohesive and interconnected home automation experience. Integration capabilities enable users to manage the sprinkler system alongside other smart technologies, streamlining overall home maintenance and control.
Automated Operation	Automation eliminates the need for manual intervention in the irrigation process. The system operates autonomously based on predefined schedules, environmental data, and user preferences. This automated operation reduces the workload on homeowners, providing them with a hands-free and effortlessly maintained garden or lawn.

Cont. table 1.

Learning Capabilities	Some smart sprinkler systems incorporate machine learning algorithms to analyze user behavior and adapt the watering patterns accordingly. Over time, the system learns from usage patterns, optimizing its performance to align with the specific needs and preferences of the homeowner and the landscape.
Enhanced Aesthetics	Beyond functionality, the smart sprinkler system contributes to the overall aesthetics of the smart home landscape. The automation of irrigation processes ensures a consistently well-maintained and lush garden, enhancing the visual appeal of the outdoor space and complementing the modern, connected living experience.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

3. The advantages and problems of using smart sprinkler system

Implementing a smart sprinkler system offers a myriad of advantages, revolutionizing the conventional approach to lawn care and irrigation. One significant benefit lies in water conservation, as these systems employ precision watering based on real-time data, mitigating over-watering and under-watering (Valencia-Arias et al., 2023). This not only contributes to environmental sustainability but also results in cost savings for homeowners by optimizing water usage and minimizing energy consumption (Jonek-Kowalska, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł, Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). The convenience and flexibility afforded by smart sprinkler systems are unparalleled. With remote control capabilities through dedicated smartphone applications, users can effortlessly manage and monitor their sprinkler systems from anywhere. This adaptability allows for real-time adjustments to settings, schedules, and responses to changing weather conditions without requiring physical presence (Dhaou, 2023).

Efficient lawn care is another notable advantage. Customized watering schedules, dynamic adaptation to environmental changes, and sensor integration ensure that each part of the landscape receives the appropriate amount of water (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023). This promotes healthy plant growth and maintains an aesthetically pleasing lawn without the need for constant manual intervention. The integration of smart sprinkler systems with other devices and ecosystems within a smart home further enhances their utility. This interconnectedness enables users to coordinate and control their sprinkler system alongside other smart technologies, fostering a unified and efficient smart home experience (Hussain et al., 2023; Chen et al., 2023).

The automated operation of smart sprinkler systems eliminates the need for manual intervention, making lawn care a hands-free experience. Operating autonomously based on predefined schedules, weather data, and user preferences, these systems reduce the time and effort homeowners need to dedicate to maintaining their outdoor spaces (Hussain et al., 2023). Beyond the immediate benefits, smart sprinkler systems contribute to environmental conservation by promoting responsible water usage and reducing the ecological footprint associated with traditional irrigation methods (Tong et al., 2023; Rhode et al., 2023). Additionally, a well-maintained, lush lawn enhances the curb appeal of a property, potentially increasing its value (Gajdzik et al., 2023; Jonek-Kowalska, Wolniak, 2021; Jonek-Kowalska, Wolniak, 2022).

Some smart sprinkler systems go a step further with learning capabilities, analyzing user behavior to adapt watering patterns over time. This adaptive learning optimizes the system's efficiency by tailoring watering schedules to the specific needs and preferences of the homeowner and the unique characteristics of the lawn or garden (Bsarir-Ozel et al., 2023; Olabode et al., 2023).

Smart sprinkler systems provide a time-saving, cost-effective, and environmentally conscious solution to lawn care, offering homeowners an effortless way to maintain a beautiful and sustainable outdoor space.

Table 2 highlighting the advantages of using smart sprinkler system in smart home.

Table 2.
Advantages of using smart sprinkler system

Advantage	Description
Water Conservation	Smart sprinkler systems employ precision watering based on real-time data, reducing water wastage by avoiding over-watering or under-watering. This contributes to water conservation efforts and aligns with sustainable practices, promoting responsible use of this valuable resource.
Cost Savings	By optimizing water usage and minimizing energy consumption, smart sprinkler systems lead to long-term cost savings for homeowners. Efficient irrigation reduces water bills and lowers energy costs, providing an economic benefit alongside environmental conservation.
Convenience and Flexibility	Remote control capabilities via smartphone applications offer unparalleled convenience. Homeowners can manage and monitor their sprinkler system from anywhere, providing flexibility in adjusting settings, creating schedules, and responding to changing weather conditions without the need for physical presence.
Efficient Lawn Care	Customized watering schedules, dynamic adaptation to environmental changes, and sensor integration contribute to efficient lawn care. The system ensures that each part of the landscape receives the appropriate amount of water, promoting healthy plant growth and maintaining an aesthetically pleasing lawn without manual intervention.
Integration with Smart Homes	Smart sprinkler systems seamlessly integrate with other smart home devices and ecosystems. This integration allows users to control and coordinate their sprinkler system alongside other smart technologies, fostering a unified and interconnected smart home experience that enhances overall efficiency and management.

Cont. table 2.

Automated Operation	Automation eliminates the need for manual intervention, making lawn care a hands-free experience. The system operates autonomously based on predefined schedules, weather data, and user preferences, reducing the time and effort homeowners need to dedicate to maintaining their outdoor spaces.
Environmental Impact	Smart sprinkler systems contribute to environmental conservation by promoting responsible water usage. Precision watering and efficient irrigation practices align with eco-friendly principles, reducing the ecological footprint associated with traditional, less controlled irrigation methods.
Enhanced Property Value	A well-maintained, lush lawn enhances the curb appeal of a property. Smart sprinkler systems contribute to the overall aesthetic appeal of the landscape, potentially increasing property value. A beautifully manicured lawn adds to the visual attractiveness of the home, making it more appealing to potential buyers or tenants.
Learning and Adaptation	Systems with learning capabilities analyze user behavior and adapt watering patterns over time. This adaptive learning enhances the system's efficiency by tailoring watering schedules to the specific needs and preferences of the homeowner and the unique characteristics of the lawn or garden, further optimizing water usage.
Time-Saving and Effortless	The combination of automation, remote control, and efficient operation reduces the time and effort homeowners need to invest in lawn care. Smart sprinkler systems streamline the irrigation process, allowing users to enjoy a beautifully maintained garden without the manual labor traditionally associated with watering and maintaining outdoor spaces.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

Table 3 highlighting some of the common problems and challenges associated with the problems of using smart sprinkler system in smart homes.

Table 3.
Problems of using smart sprinkler system

Problem	Description	Methods of Overcoming
Initial Cost	The upfront cost of installing a smart sprinkler system, including the purchase of devices, sensors, and controllers, can be a barrier for some homeowners. This initial investment may discourage adoption, especially for those on a tight budget.	**Research and Comparison:** Conduct thorough research to identify cost-effective options and compare different smart sprinkler systems. **DIY Installation:** Some systems offer straightforward DIY installation, reducing installation costs. **Government Rebates:** Explore potential rebates or incentives offered by local governments for the installation of water-saving devices, which may offset initial costs.
Technical Complexity	The technical complexity of smart sprinkler systems may pose a challenge for users who are not tech-savvy. Setting up the system, configuring settings, and troubleshooting technical issues may be intimidating for some homeowners.	**User-Friendly Interfaces:** Choose a system with a user-friendly interface and clear instructions for installation and configuration. **Professional Installation:** Opt for professional installation services if available, ensuring that the system is set up correctly. **Customer Support:** Select a system with robust customer support to assist users with any technical challenges they may encounter.

Cont. table 3.

Dependency on Connectivity	Smart sprinkler systems heavily rely on a stable internet connection and may face challenges if connectivity issues arise. Interruptions in connectivity can hinder remote control functionality and the ability to receive real-time weather updates, impacting the system's performance.	**Backup Systems:** Some smart sprinkler systems come with backup options, such as offline schedules or local control via Bluetooth. **Stable Internet:** Ensure a reliable internet connection, and consider implementing redundancies such as a secondary internet service provider or a backup power source for routers. **Offline Operation:** Choose a system that can operate offline based on pre-set schedules without constant reliance on internet connectivity.
Compatibility with Existing Setup	Compatibility issues may arise when integrating a smart sprinkler system with an existing irrigation setup. Incompatibility with current wiring, valves, or irrigation infrastructure may require additional modifications, adding complexity to the installation process.	**Compatibility Checks:** Before purchasing, verify compatibility with existing irrigation components. **Professional Assessment:** Seek advice from irrigation professionals to assess compatibility and identify necessary modifications. **Consult Manufacturer Support:** Contact the manufacturer's support for guidance on integration and potential challenges with existing setups.
Power Source Dependency	Smart sprinkler systems rely on a stable power source to operate efficiently. Power outages or disruptions may affect the system's functionality, leading to missed watering schedules and potential issues with the automated operation.	**Battery Backup:** Choose a system with battery backup capabilities to ensure continued operation during power outages. **Uninterruptible Power Supply (UPS):** Consider using a UPS to provide temporary power during outages. **Solar-Powered Options:** Explore solar-powered smart sprinkler systems that reduce dependency on traditional power sources and enhance resilience during power interruptions.
Limited Compatibility with Landscaping Features	Some smart sprinkler systems may not be compatible with certain landscaping features such as drip irrigation systems, specialized plants, or complex garden layouts. This limitation can hinder the system's ability to cater to the diverse needs of different landscapes.	1. **Compatibility Research:** Prior to installation, research the system's compatibility with various irrigation methods and landscaping features. 2. **Customization Options:** Choose systems that offer customization features to adapt to different landscaping needs. 3. **Consultation with Experts:** Seek advice from landscaping professionals to assess compatibility and explore workarounds for specialized features.
Weather Prediction Inaccuracy	Smart sprinkler systems rely on weather data for efficient watering schedules. However, inaccuracies in weather predictions can lead to suboptimal watering, with the system either over-watering or under-watering based on inaccurate forecasts.	1. **Multiple Data Sources:** Integrate the system with multiple weather data sources to improve accuracy. 2. **Sensor-Based Adjustment:** Utilize soil moisture sensors to supplement weather data, allowing the system to adapt in real-time based on current conditions. 3. **Regular Calibration:** Periodically calibrate the system and adjust settings based on observed weather patterns rather than solely relying on predictive data.
Security and Privacy Concerns	The connectivity of smart sprinkler systems to the internet raises security and privacy concerns. Unauthorized access to the system could lead to tampering with watering schedules or the potential exposure of personal data.	**Secure Network Configuration:** Ensure that the network used by the smart sprinkler system is secure, with strong passwords and encryption. **Regular Software Updates:** Keep the system's firmware and software up to date to address potential security vulnerabilities. **Privacy Settings:** Review and adjust privacy settings within the system's application to limit data sharing and access permissions.

Cont. table 3.

Dependency on External Services	Some smart sprinkler systems rely on external cloud services for functionality. If these services experience downtime or discontinuation, it may impact the system's ability to receive updates, operate remotely, or access certain features.	**Offline Functionality:** Choose systems that offer offline functionality for essential features, allowing the system to operate independently of external services. **Vendor Reliability:** Select reputable vendors with a history of reliable service and a commitment to maintaining infrastructure. **Data Backup:** Regularly back up system settings and configurations to mitigate potential data loss in the event of service disruptions.
Maintenance and Upkeep	Regular maintenance is crucial for the optimal performance of smart sprinkler systems. Issues such as clogged nozzles, sensor malfunctions, or wear and tear on components can arise over time, requiring attention and potential replacements.	**Scheduled Maintenance:** Implement a routine maintenance schedule to inspect and clean nozzles, sensors, and other components. **System Health Monitoring:** Choose systems with built-in diagnostic features that alert users to potential issues, facilitating proactive maintenance. **Professional Services:** Consider professional maintenance services to ensure thorough inspections and address potential problems before they escalate.
Limited Local Watering Regulations Integration	Smart sprinkler systems may not seamlessly integrate with local watering regulations, leading to unintentional violations. This lack of synchronization can result in penalties or restrictions imposed by local authorities.	**Manual Schedule Adjustments:** Regularly check and adjust watering schedules to align with local regulations, even if not directly integrated. **Regular Updates:** Keep the system's software up to date to ensure compatibility with any changes or updates to local watering regulations. **Communication with Authorities:** Stay informed about local watering regulations and proactively communicate with local water authorities to address any concerns or seek guidance on compliance.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

4. Conclusion

The integration of a Smart Sprinkler System within the framework of a Smart Home signifies a groundbreaking fusion of technology and water management, reshaping traditional approaches to lawn care and irrigation. This system epitomizes a harmonious blend of convenience, efficiency, and sustainability in the contemporary landscape of home automation. At its essence, the Smart Sprinkler System operates on real-time data and intelligent algorithms, meticulously tailored to the specific requirements of a lawn or garden. The precision in watering ensures judicious use of water, aligning with conservation efforts by avoiding over-watering or under-watering. By dynamically adapting to environmental changes through the integration of weather data, soil moisture levels, and local watering restrictions, the system stands as an innovative solution for modern landscape management.

The publication aims to shed light on the utilization of smart sprinkler systems in smart homes. Noteworthy is the system's connectivity, leveraging the Internet of Things (IoT) to enable remote control through dedicated smartphone applications and integration into existing smart home ecosystems. This connectivity, coupled with advanced sensors and moisture detectors, empowers the system to make informed decisions, creating custom watering schedules tailored to specific plant types or landscaping zones. Energy efficiency is a pivotal aspect, with smart sensors optimizing water distribution, minimizing waste, and fostering sustainable lawn care. The resulting cost savings align with environmental goals while enhancing economic viability for homeowners. Beyond functionality, the system's automation contributes to the aesthetic appeal of the smart home landscape, eliminating the need for manual intervention and providing homeowners with a consistently well-maintained garden.

As a beacon of future smart home landscaping, the Smart Sprinkler System exemplifies seamless integration with other devices, learning capabilities, and adaptability to environmental variables. Its role extends beyond improving traditional irrigation methods, showcasing the potential of smart home technology to elevate homeowners' quality of life. With advancements continuing to unfold, the system promises a glimpse into the evolving landscape of modern, connected living. Table 1 details key features of smart sprinkler system usage, highlighting its precision watering, remote control capabilities, dynamic adaptation, customized schedules, sensor integration, energy efficiency, integration with smart homes, automated operation, learning capabilities, and its contribution to enhanced aesthetics.

Table 2 outlines the advantages of using a smart sprinkler system, emphasizing water conservation, cost savings, convenience, efficient lawn care, integration with smart homes, automated operation, environmental impact, enhanced property value, learning capabilities, and the time-saving, effortless nature of its operation. However, Table 3 delves into the potential challenges and problems associated with smart sprinkler systems, offering detailed descriptions of each issue and suggesting methods for overcoming or mitigating these challenges. These include considerations such as initial costs, technical complexity, dependency on connectivity, compatibility with existing setups, power source dependency, landscaping feature compatibility, weather prediction inaccuracies, security and privacy concerns, reliance on external services, maintenance and upkeep, and integration with local watering regulations.

While smart sprinkler systems present unparalleled advantages, acknowledging and addressing potential challenges ensures a holistic understanding of their implementation in smart homes. The ongoing evolution of these systems reflects a commitment to advancing sustainable, efficient, and connected living experiences for homeowners.

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