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Guttermate: A Gutter Cleaning Device Suitable for K-Style, Box-Type, and Spanish Gutters with a Water Flush Out System

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***Abstract* -** This study developed and assessed an Automatic Roof Gutter Cleaner, a robotic apparatus designed to autonomously clean roof gutters with the aim of improving safety and operational efficiency. The prototype incorporates a 3D-printed enclosure, a microcontroller for system control, distinct motors dedicated to locomotion and brush rotation, as well as a water spray mechanism. It was engineered to be compatible with three prevalent gutter profiles: K-style, Box-type, and Spanish-style gutters. Empirical evaluation revealed that the device operates effectively but exhibits notable limitations in performance. Specifically, field testing demonstrated a cleaning efficiency of ~91% with a rate of ~1.80 in^2/s over a 150-second cleaning cycle on Box-type gutters; however, efficiency markedly declined during shorter cleaning intervals and when applied to Spanish-style gutters. And a user acceptance survey, grounded in the Technology Acceptance Model, indicated that while the device was perceived as user-friendly, its perceived usefulness was diminished primarily due to prolonged cleaning durations. Consequently, user's willingness to adopt or recommend the device was moderate. These findings suggest that although the prototype is functional, its potential for commercial viability is contingent upon future design enhancements that significantly accelerate cleaning speed, thereby meeting user expectations as a replacement for a manual roof gutter cleaning.

***Keywords* -** *Gutter Cleaner, Efficiency, Cleaning rate, User Acceptance*

I. INTRODUCTION

Roof problems, including debris accumulation, manual cleaning inefficiency, and safety concerns, pose significant challenges in building construction and maintenance, affecting home structural integrity and value. Neglecting it and its maintenance can result in a number of serious problems that jeopardize the integrity and longevity of a roof (Yuhang et al., 2020). It involves water damage that seeps into the foundation, leading to structural instability and cracks that are expensive to fix. Clogged gutters can cause roof leaks, deterioration of roofing materials, and mold growth (Admin, 2025).

Manual gutter cleaning can be hazardous, prone to falls, and falls from ladders are linked to high morbidity and mortality rates, especially among the elderly (Liasidis et al., 2022). On a blog *"Pros and Cons of Different Roof Cleaning Methods,"* manual cleaning of rain gutters is an environmentally friendly method that uses hand tools and brushes to remove dirt, debris, and stains from roofing surfaces. Nevertheless, this method is characterized by its labor-intensive and time-consuming nature, and it may prove less effective in addressing persistent stains, as well as the removal of moss or algae.

Shifting towards autonomous roof gutter cleaner systems remains imperative for escalating the efficiency and safety of gutter maintenance procedures. This system lessens the householders' need to use ladders which decreases the chances of accidents and falls (Cleaning, 2024).

Therefore, in this project, the researchers will develop a roof gutter cleaning device that can be placed on the roof gutters of homeowners during cleaning and removed when done. This innovation also increases the efficiency of the cleaning process by guaranteeing complete debris removal without the need for extensive manual labor.

II. STATEMENT OF THE PROBLEM

The main objective of this study was to develop an application and web app-based GIS smart mapping system for electrical needs called Bantay Kuryente.

Specifically, the study will address the following:

1. Identify existing roof gutter cleaner products in terms of specifications, gutter design, problems, and possible improvements.
2. Design and integrate innovations into an automated gutter cleaner that auto-reverses when done cleaning and sprays water on its path, to soften the dirt or rotten leaves and flush the remaining dirt.
3. Evaluate the performance of the system by conducting system testing in terms of:
   3.1. Area Clean
   3.2. Cleaning Time

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4. Evaluate the system's performance utilizing users' acceptance in terms of:
   4.1. Perceived Ease of Use
   4.2. Perceived Usefulness
   4.3. Behavioral Intention to Use

II. METHODOLOGY

A. Research Design

This study will employ a quantitative approach to designing and evaluating an automated gutter cleaning device that prioritizes effectiveness and practicality. Quantitative design is defined as the collection and analysis of numerical data. It can also identify patterns and averages, formulate forecasts, examine causal linkages, and extrapolate findings to broader populations (Bhandari, 2023). The first phase focuses on identifying user requirements and the analysis of existing products related to gutter design and maintenance. Direct observations of common maintenance practices will further clarify essential design criteria.

B. Research Environment

The researchers conducted this study at the Telecom Compound located in Barangay Subangdaku, Mandaue City, which provided an optimal setting for the project.

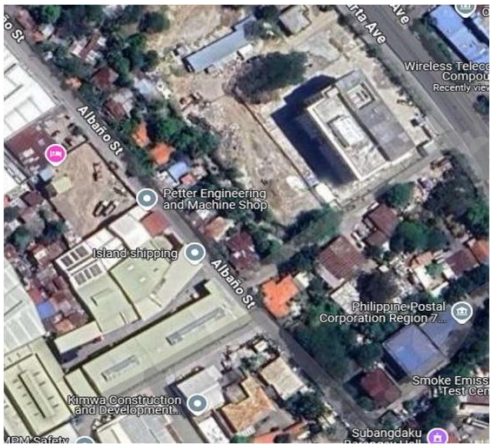

Figure 1. Research environment map

C. Research Respondents

The research study focused on residences that met the primary criteria established by the researchers. Specifically, the selected houses were required to be situated beneath a tree, equipped with a roof gutter, and have leaves or debris present directly on the gutter.

D. Research Instrument

The researchers will conduct a post-evaluation survey to determine user acceptability based on the user's Perceived Ease of Use, Perceived Usefulness, and Behavioral Intention with the device. Perceived Ease of Use determines how users can operate the device with no difficulty. Perceived Usefulness determines how useful the device is in solving their gutter cleaning problems efficiently and conveniently. The respondents will have the option to indicate their level of satisfaction by selecting from the following choices: Not Satisfied, Less Satisfied, Satisfied, or Very Satisfied. This approach will enable the researchers to assess the satisfaction levels of the respondents concerning the project design.

E. Research Procedure

The research focused on developing an automated roof gutter cleaning system, employing a systematic approach to achieve this goal. Initially, the researchers reviewed all relevant studies, theories, and existing designs related to the project to establish a solid foundation for the design process. Subsequently, they created a questionnaire based on other pertinent surveys and distributed it to collect essential data from respondents.

F. Treatment of Data

A weighted average is a statistical computation that allocates different significance levels to the values within a specific data set. This method can yield more precise results compared to a simple average, where each value in the data set is treated with equal weight (Ganti, 2024). A Likert scale is a measurement tool to assess survey respondents' opinions, attitudes, motivations, and other related constructs. This scale presents a continuum of response options that span from one extreme viewpoint to its opposite. This study used a 4-point Likert scale to extract accurate and precise results.

IV. RESULTS AND DISCUSSION

The device was tested on three different gutter styles as specified in the scope and limitations; the length of each gutter is approximately 8 feet with a width of 1/3 feet.

A. Controlled Test

Table 1. Summary of Results for K-Style gutter

Cleaning Time (seconds)	Area Cleaned (ft^2)	Cleaning Rate (ft^2/s)	Efficiency (%)
150	2.29	0.0153	93.09

It is found that the cleaning time of the device is 150 seconds, while cleaning 2.29 ft^2 at a rate of 0.0153 ft2/s. These results amount to the device's average cleaning efficiency of 93.09% for this type of gutter. However, the objectively measured slow speed represents a significant performance constraint that, although it does not compromise the cleaning effectiveness of the device, is likely to adversely affect practical user acceptance and commercial feasibility due to the prolonged time necessary to complete a full cleaning operation.

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Table 2. Summary of Results for Box-type gutter

Cleaning Time (seconds)	Area Cleaned (ft^2)	Cleaning Rate (ft^2/s)	Efficiency (%)
150	2.18	0.0145	93.58

The findings for the box-type gutter replicate the performance trend identified with the K-style gutter, attaining a marginally superior efficiency of 93.58%. This consistency substantiates the prototype's dependable cleaning performance across varying gutter configurations. However, the cleaning rate of 0.0145 ft²/s remains notably low and closely comparable to the prior measurement, underscoring a significant limitation related to the slow operational speed. This constraint substantially restricts the system's practical utility and applicability for large-scale operations.

Table 2. Summary of Results for Spanish gutter

Cleaning Time (seconds)	Area Cleaned (ft^2)	Cleaning Rate (ft^2/s)	Efficiency (%)
225	2.16	0.0061	87.40

The data pertaining to the Spanish-style gutter demonstrates a marked decrease in performance, characterized by a reduced efficiency of 87.40% and a considerably slower cleaning rate of 0.0061 ft²/s relative to other gutter configurations. This performance necessitated 225 seconds to clean an equivalent surface area, suggesting that the prototype's design is suboptimal for this specific gutter profile. Accordingly, these findings substantiate the conclusion that the device's effectiveness is significantly diminished when applied to Spanish-style gutters, thereby exacerbating its overall constraints in terms of operational speed and commercial viability.

Table 4. Summary of Results for the Device's Overall Performance

Gutter Type	Cleaning Time (seconds)	Area Cleaned (ft^2)	Cleaning Rate (ft^2/s)	Efficiency (%)
K-Style	150	2.29	0.0153	93.09
Box-Type	150	2.18	0.0145	93.58
Spanish	225	2.16	0.0061	87.40

The aggregated data indicate that the prototype exhibits a high level of cleaning efficiency for conventional gutter profiles, particularly K-style and box-type gutters, achieving efficiency rates exceeding 93%. Conversely, its performance is significantly diminished when applied to Spanish-style gutters, with efficiency declining to 87.40% and a cleaning rate less than half that observed for the other gutter types. This pronounced disparity underscores a fundamental design limitation concerning non-standard gutter configurations. Furthermore, the consistently low cleaning rates, all below 0.0153 ft²/s, quantitatively substantiate the primary commercial limitation, namely insufficient operational speed.

B. Controlled vs. Field Test

Table 5. Comparison of Performance: Controlled vs. Field

Gutter Type	Cleaning Time (seconds)	Controlled		Field Test	
		Cleaning Rate (ft^2/s)	Efficiency (%)	Cleaning Rate (ft^2/s)	Efficiency (%)
Box	150	0.0145	93.58	0.0125	91.44

During field tests, the device's efficiency reached 91.44% with a cleaning rate of 0.0125 ft^2/s, removing 185.9 grams of debris while the remaining debris amount to 17.4 grams. The device's performance in the actual environment is behind 0.002 ft2/s compared to the tested 0.0145 ft2/s of cleaning rate. This result differential is suspected to be caused by the state of the gutter and the type of leaves or debris that are in the environment/field, which requires the device more time to be able to achieve a higher efficiency.

C. Post-Evaluation Survey Results

This section presents the data gathered from the survey conducted after the respondents were shown the capability of the device to be able to determine the device's Ease of Use, Usefulness, and the user's Behavioral Intention to Use.

Table 6. User Acceptance in terms of Ease of Use

Question	Mean	Interpretation
1. How would you rate the device's easy operation?	3.2	Satisfied
2. How would you rate your navigation with the device?	3	Satisfied
3. How would you rate the user-friendliness of controls and features of the device?	2.9	Satisfied
4. How would you rate the functionality of the device?	2.9	Satisfied
5. How would you rate the ease of installation and removal of the device?	3	Satisfied

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Overall Mean	**3**	**Satisfied**

According to the table, the data shows a unanimous but basic level of acceptance for the Automatic Roof Gutter Cleaner regarding Perceived Ease of Use (PEOU). Out of 10 respondents, all five criteria; operation, navigation, user-friendliness, functionality, and installation were rated as "Satisfied". The overall average score of 3 indicates that, from the user's viewpoint, the device does not present major usability challenges; it works well and is not difficult to use. Although the data confirms that PEOU is positively perceived by the respondents, it cannot be applied to a larger population. The lack of any "Very Satisfied" ratings suggests there is a potential to improve aspects like intuitiveness, ease of control, or installation to make the device not just acceptable but exceptionally easy to use.

Table 7. User Acceptance in terms of Usefulness

Question	Mean	Interpretation
1. How would you rate the cleaning time of the device?	2.8	Satisfied
2. How would you rate the device's cleaning result?	2.9	Satisfied
3. How would you rate the time and effort saved during gutter maintenance?	3	Satisfied
4. How would you rate your overall roof gutter cleaning experience using the device?	2.9	Satisfied
5. How would you rate the overall performance of the Automatic Roof Gutter Cleaner?	3	Satisfied
Overall Mean	**2.92**	**Satisfied**

The table present a more detailed and critical perspective compared to the Ease of Use findings. The average score of 2.92, although still considered "Satisfied," is noticeably lower than the 3.0 score for Ease of Use, indicating that respondents value the device's usefulness less than its ease of use. This is an important observation. The data highlights a particular concern: Question 1, which addresses the device's cleaning time, received a 2.8 mean but still a "Satisfied" rating. This implies that users feel the device is slower than expected, undermining its key promise of efficiency. Although aspects like cleaning results, effort saved, overall experience, and performance were rated as "Satisfied," the dissatisfaction with speed acts as a negative factor that reduces the overall usefulness rating.

Table 8. User Acceptance in terms of Behavioral Intention to Use

Questions	Mean	Interpretation
1. How satisfied are you with your intention to use the Automatic Roof Gutter Cleaner for future cleaning tasks?	2.9	Satisfied
2. How satisfied are you with the Likelihood of recommending the Automatic Roof Gutter Cleaner to a neighbor or friend?	3	Satisfied
3. How satisfied are you with your willingness to purchasethe Automatic Roof Gutter Cleaner if it becomes available?	2.8	Satisfied
Overall Mean	**2.9**	**Satisfied**

According to the table, the respondents show a consistent but unenthusiastic Behavioral Intention to Use (BI), with an average rating of 2.9 ("Satisfied") across the three questions about future use, recommendation, and purchase. This outcome aligns well with the other two factors: the user found the device reasonably easy to use (PEOU = 3.0) and somewhat useful (PU = 2.92). The "Satisfied" rating reflects this moderate, lukewarm attitude; there are no strong negative reasons to avoid using the device, but the absence of "Very Satisfied" responses, especially due to the noted slow cleaning speed that lowered perceived usefulness means there is also no strong motivation to enthusiastically recommend or buy it.

Table 9. Aggregate Mean for User Acceptance

Category	Mean	Interpretation
Ease of Use	3	Satisfied
Usefulness	2.92	Satisfied
Behavioral Intention to Use	2.9	Satisfied
Aggregate Mean	**2.91**	**Satisfied**

The aggregate mean score of 2.91 signifies a satisfactory

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degree of user acceptance for the system, as presented in Table 22. This score reflects consistently positive evaluations across all assessed categories, including Ease of Use (3.00), Perceived Usefulness (2.92), and Behavioral Intention to Use (2.90). Although these results indicate general satisfaction, the slight gradual decrease from ease of use to behavioral intention suggests that, despite recognizing the system's usability and utility, participants demonstrate a marginally reduced willingness to adopt the system in the future.

V. CONCLUSION

The findings indicate that the Automatic Roof Gutter Cleaner functions effectively as a prototype, demonstrating high cleaning efficiency, especially on K-style and box-type gutters, where it achieves debris removal rates exceeding 93%. Nonetheless, its efficacy is significantly reduced when applied to Spanish-style gutters. Furthermore, the device's commercial potential is constrained by its slow cleaning speed (0.0061 ft^2/s – 0.0153 in^2/s), which adversely affects users' perceived utility and their willingness to adopt the technology.

The assertion that a product's slow operational speed adversely affects perceived utility and the intention to adopt is robustly substantiated by Davis's Technology Acceptance Model (TAM). Central to TAM is the construct of Perceived Usefulness, which refers to the extent to which an individual believes that utilizing a system will improve their job performance, serving as a critical predictor of user acceptance. A reduction in system speed directly diminishes this perception by impairing task efficiency and the potential for time savings, both of which are fundamental aspects of usefulness. As a result, decreased Perceived Usefulness corresponds with a reduced Behavioral Intention to Use, a relationship that has been empirically confirmed in numerous TAM-based investigations across diverse technological contexts (Davis, 1989).

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization, Methodology; Author 2: Data curation, Writing-Original draft preparation, Writing-Reviewing; Author 3: Investigation, Validation, Visualization, Writing- Reviewing; Author 4: Methodology, Data Visualization

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GENERATIVE AI STATEMENT

The authors used ChatGPT solely as a language-support tool to improve the clarity, coherence, and grammatical accuracy of the manuscript. All AI-assisted outputs were critically reviewed, revised, and validated by the authors to ensure the accuracy, integrity, and originality of the content. The authors accept full responsibility for the final version of the manuscript and its published content.

ETHICAL CONSIDERATIONS

Prior to the data gathering, ethical approval was obtained from the University of Cebu Academic Research Ethics Committee (UCAREC). The approved protocol ensured adherence to the principles of respect for persons, beneficence, justice, voluntary participation, informed consent, confidentiality, and anonymity, and compliance with the Data Privacy Act throughout the research process.

DECLARATION OF INTEREST

The authors declare that they have no competing financial, professional, or personal interests that could have influenced the conduct, findings, or publication of this study.

DATA AVAILABILITY

Data will be made available by the corresponding author on request.

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