Gutter Done

Loose Screw Design - Jahmar J, Hakim B, Raymond W, Hussain S

Objective

This project addresses critical safety concerns and inefficiencies in traditional gutter maintenance, which is essential for protecting residential structures from water damage, particularly for middle-aged homeowners in North America. Considering the significant risks associated with manual gutter cleaning—highlighted by the high incidence of ladder-related injuries among older adults [1] and environmental hazards in their residences [2]—a robotic solution is proposed to mitigate these risks. The initial phase involved extensive market research to identify gaps and confirm the viability of a robotic approach for this demographic. Findings led to the identification of seven key performance metrics and three secondary metrics, guiding the development of a prototype. This prototype demonstrates the potential functionalities of a user-friendly, affordable, and lightweight robotic device capable of autonomously navigating diverse gutter systems, ensuring efficient water channeling to protect structural integrity and prevent water damage. The poster outlines the process of leveraging these metrics to guide design and prototype development, aiming to enhance residential infrastructure protection and promote safer home maintenance practices.

Motivation

The critical need to enhance gutter maintenance practices stems from their current hazardous, inefficient, and labor-intensive nature. Ladder falls, for instance, represent 16% of all US workplace fall-related fatalities, highlighting the broad dangers associated with maintenance tasks such as gutter cleaning for individuals of all ages [3]. Additionally, blocked roof gutters are a frequent cause of property damage during rainstorms, highlighting the vital role gutters play in effectively channeling water away from structures to protect foundations and prevent water intrusion [4].

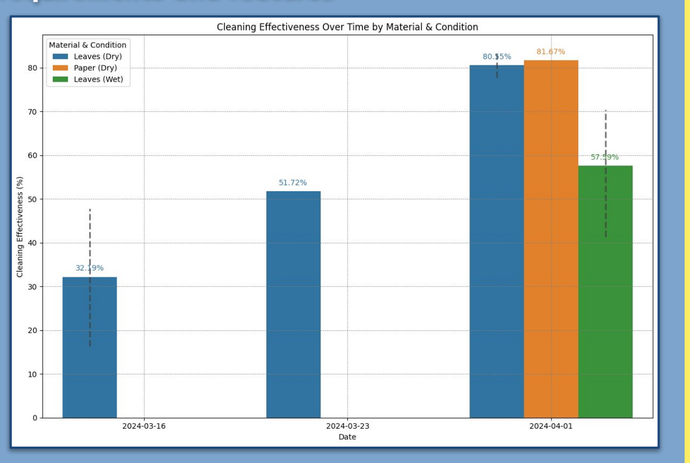
The development of an automated system aims to revolutionize gutter maintenance by making the process safer, quicker, and more accessible. This proposed solution enhances home safety and overall quality of life, addressing the challenges of traditional gutter maintenance and advancing technology in home care. Automating gutter cleaning significantly reduces the dangers posed by traditional methods, providing a safer and more efficient alternative.

Furthermore, the system protects residential structures by preventing water damage, typically caused by clogged gutters. This not only safeguards the home's foundation and exterior but also mitigates health risks associated with stagnant water, such as mold and bacteria growth, which can lead to respiratory illnesses [5] [6]. The project also addresses environmental concerns by ensuring cleaner runoff, by not allowing the accumulation of pollutants [7]. This innovative approach secures the immediate surroundings of the homeowner and contributes to broader environmental conservation efforts, demonstrating that practical improvements in home maintenance can yield extensive benefits.

Approach

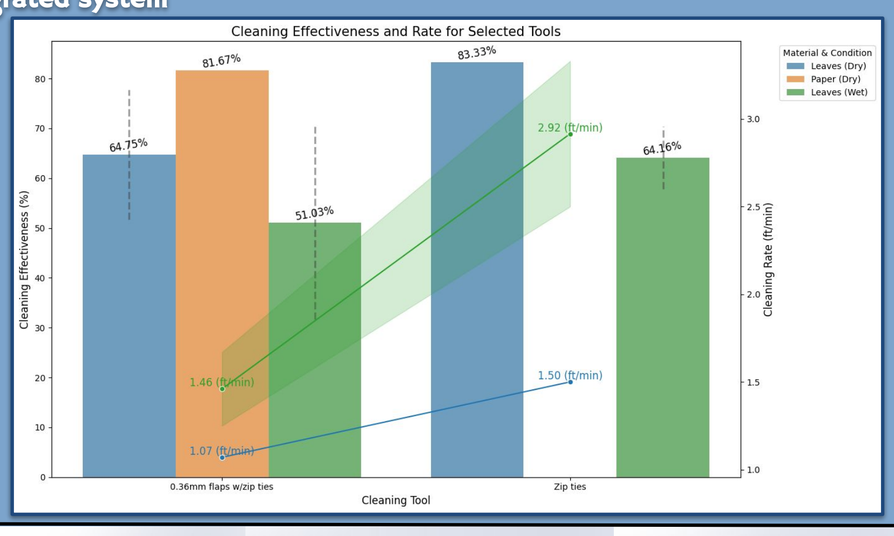
Market Research
- Compare various perseverative & maintenance solutions
- Identify User relevant product requirements and features

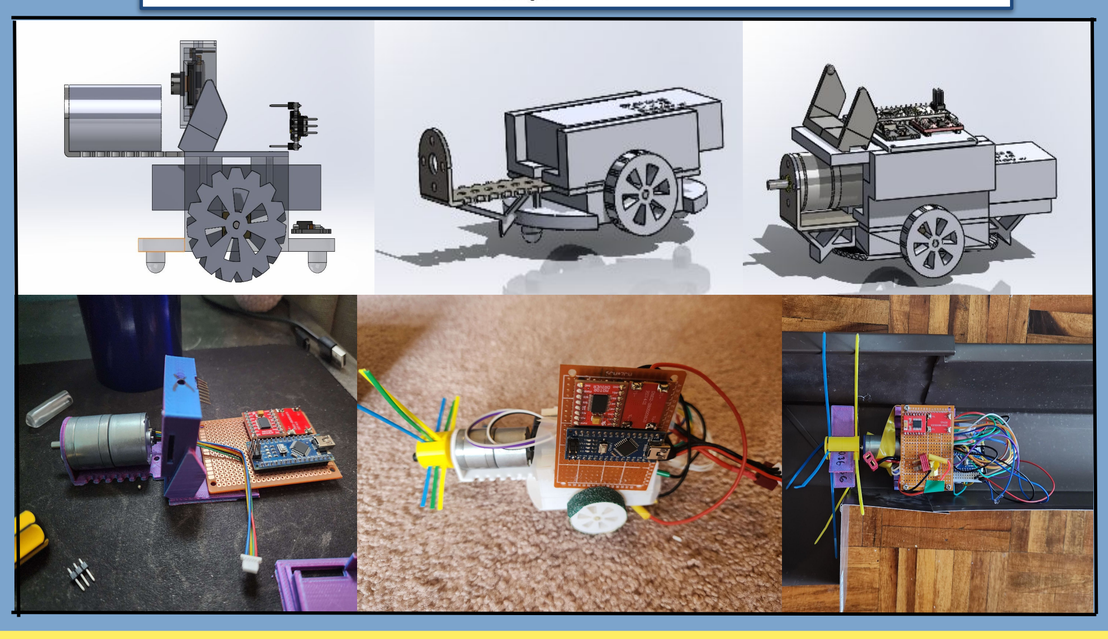
Challenges
- Mobile Robot
  - Hanger supports
  - Roof Placement
  - Inside of Gutter
    - Compactness
    - Turning
  - Outside of gutter
    - Balancing
- Preventive solution
  - Cost
- Nonlinearity of debris
  - Infeasible to model



Subsystems
- Debris removal system
- Movement/base system
- Electronics system
- Integrated system

Prototyping, Testing, and Benchmarking
- Rapid prototyping with 3D prints
- Benchmarking with 5" K-Style Gutters





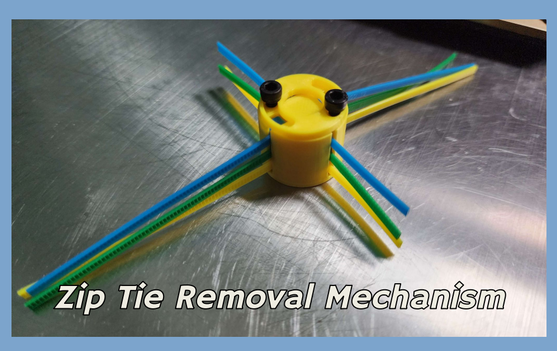
Final Design

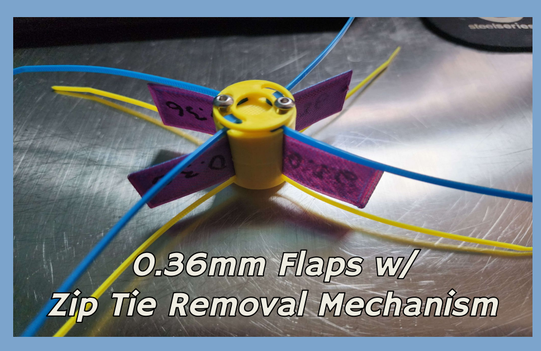
Debris Removal System
- Performance: Over 30% cleaning efficiency in both wet and dry conditions.
- Motor: 12V, 159 rpm, 235.4 mNm, with a front-facing D-type shaft for optimal positioning.
- Cleaning Tool: Zip ties act as compliant interfaces that easily mold to gutters.

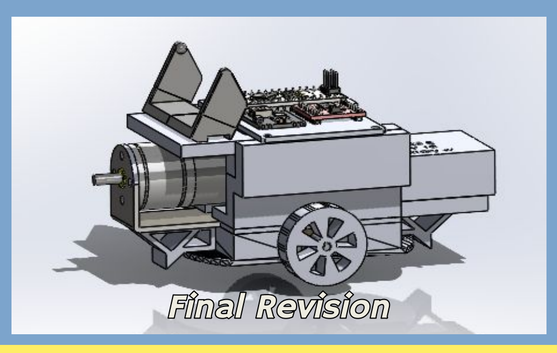
Movement/Base System
- Performance: Oscillates cleaning rate ~2 ft/min with zero-radius turning.
- Design: Compact size (330g), featuring high-friction wheels for enhanced maneuverability.
- Stability: Includes two drive motors and caster supports for static and dynamic stability.

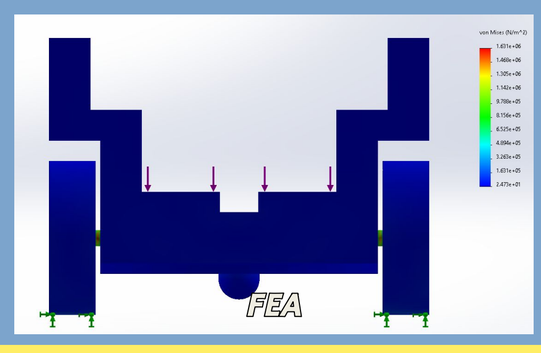
Controls and Electronics System
- 1000mAh Battery, Live camera, wifi controllable
- Software-based stability and speed control

Product Characteristics	Functional Requirements	Constraints	Evaluation
Cleaning Efficiency	Robot must remove at least 30% of debris in one pass by weight	Cannot damage gutters during operation.	P_1= 81.67% /30% =2.72>1
Energy Usage	Clean 60 linear meters of gutter on a single charge	Cannot charge midway through gutter cleaning.	P_2= 60m /60m =1
Durability	Withstand 1 cleaning cycles without general upkeep	Must operate in diverse weather conditions.	P_3= 18m /18m =1
Cost-effectiveness	Total cost under $500 for 2 years of operation.	Cost includes purchase and maintenance.	P_7= 500 /114.88 =4.35>1









Conclusion

The prototype achieves five of the seven key performance metrics—highlighting strengths in efficiency, durability, connectivity, and cost-effectiveness, while challenges remain in survivability and navigation, essential for competitive market positioning. Planned enhancements include optimizing the prototype's casing and electrical components to withstand drop tests and integrating advanced navigation technologies such as an IMU or ESP32-CAM for improved autonomous decision-making.

Further redesign efforts will focus on adjusting the form factor to accommodate these technologies effectively, ensuring the prototype fulfills all performance metrics. This refinement is aligned with the project's core goal of reducing the risks associated with traditional gutter maintenance—enhancing home safety, simplifying maintenance, and mitigating environmental impacts. This development trajectory not only promises a market-ready product but also a transformative approach to home care, prioritizing safety and efficiency.

References and Acknowledgements

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