Development of an Automated Sign face Cleaner (ASiC)

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Article Info

Abstract

The prevalence of manual cleaning methods in various industries poses challenges in terms of efficiency, consistency, and labour costs. To overcome these issues, this project proposes the development of an automated surface cleaner that incorporates automation into the cleaning procedure. The goal was to design an automated signboard cleaner controlled by a programmable logic controller and to develop an automation system using a Programmable Logic Controller. The methodology included sensor integration, control systems, and mechanical design concepts. The prototype has some cleaning mechanisms and brushes to efficiently clear surfaces of trash. The prototype's capacity to follow preset routes and carry out cleaning duties precisely was shown by automation testing results. The creation of this automated surface cleaner, which provides a scalable solution that can be adjusted to diverse situations, has important ramifications for enhancing cleaning procedures in a variety of contexts. Upcoming projects will focus on improving the architecture for energy efficiency and investigating the incorporation of artificial intelligence to improve decision-making skills.

1. Introduction

Highway signboards are an important part of road security and navigation. They provide essential information to drivers, guiding people to their desired destinations and alerting them of any hazards. The effectiveness of these signboards, nevertheless, relies heavily on their visibility, which can be limited by dirt, dust, or weather conditions. Every year, millions of people suffer injuries or die in road accidents and the majority of traffic accidents are caused by drivers' negligence, carelessness, and disobeying traffic rules. When someone disobeys a traffic sign, they put at risk not only themselves but also other innocents traveling on the road [1]. To protect the safety of all drivers, all road signs are located in particular locations. Drivers can determine their speed, upcoming turns, diversions, etc. Drivers may run the risk of being inconvenienced by signs that have been moved from their intended locations or have become obscured by wear and tear [1] [2]. The design, functionality, performance, and potential for improvement of highway signboard washers will additionally

investigate the effects of periodic signboard cleaning on highway safety and navigation. The findings of the research may be beneficial for traffic authorities, signage manufacturers, etc.

Highway signboards play a crucial role in road safety and navigation. Despite their significance, preserving their cleanliness is a difficult undertaking, especially in locations with significant amounts of pollution or poor weather conditions. Malaysian Highway Authority (MHA) has established uniform guidelines for lane closures on highways as well as standard techniques for traffic control schemes on all Malaysian highways, namely "Traffic Management Plan Guidelines," in order to perform maintenance on important highway routes [3]. The existing cleaning methods may be inefficient or ineffective, resulting in reduced visibility of the signboards. Due to decreased visibility, a lack of efficient and effective cleaning methods might lead to accidents. Furthermore, it might cause a premature degradation of the signboards, leading to increased replacement expenses. This Automated sign face cleaner will clean the signboard automatically without causing lane closures on highways. The sign face will be cleaned via automation arm automatically hence reducing the high flow of traffic due to lane closures, reducing time consumption to clean the signboard, and reducing the rate of accidents of the highway workers while doing the cleaning process of the signboard. As a result, this study was carried out to identify the design of the signboard cleaner and the movement of the automation. However, the effectiveness and reliability of this product is still unknown. Therefore, we wish to investigate more about the impact of using this product, particularly on the highway's signboard.

Table 1: *Respondent involved in Plus highway maintenance accident [4]*

Involve in highway maintenance accident	Frequency	Percentage (%)
Yes	46	57.50
No	34	42.50
Total	80	100.00

2. Methodology

2.1 System Design

This entails drafting comprehensive blueprints for the automated sign face cleaner, including the mechanical framework specifications, the choice of suitable sensors for movement and obstacle detection, and the design of the control system that will oversee the cleaner's functions. Making SolidWorks design, schematics, and material selections for the prototype's construction are all common steps in the design process.

### 2.2 Requirement Analysis

Identifying the specific requirements the cleaner must meet, such as size constraints, types of surfaces it will clean, and the level of automation desired. Developing initial design concepts that meet the identified requirements. This may involve brainstorming sessions, sketching ideas, and creating preliminary models.

2.3 Stress, strain, and safety factor analysis by SolidWorks

This involves performing static analysis on the designed parts of the automated sign face cleaner using SolidWorks Simulation. Static analysis aids in predicting how the components will respond to operational loads like weight, pressure, and forces. To replicate real-world situations, describe the material qualities, add fixed restrictions, and then apply loads to the model. To make sure the design can sustain operational demands, the software will compute stresses and strains. Displacement analysis is part of the static study that shows how much each part of the system will move under the applied loads. This is crucial for understanding if the movements are within acceptable limits to avoid mechanical failure or undesired contact between parts. Safety factor, also known as the factor of safety (FoS), is a measure of how much stronger the system is compared to its required strength. SolidWorks Simulation can calculate the safety factor by comparing the stresses in the system against the material strengths. A higher safety factor indicates a higher margin of safety; industry standards or project requirements typically dictate the minimum acceptable safety factor.

2.4 Control system design

Designing the hardware and software that will regulate the cleaner's functions is known as control system design. This involves setting up the PLC to react to sensor inputs and managing the motions and cleaning systems of the cleaner.
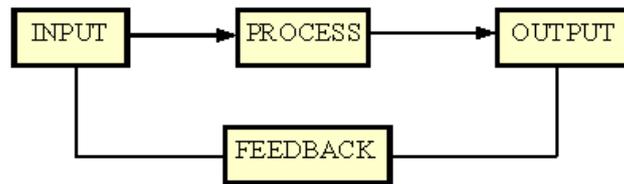

Fig 1*: Control system block diagram*

2.5 Integration of the Programmable Logic Controller (PLC)

Making certain that the system functions. This entails fusing software and electronic controls with mechanical components. Firstly, the mechanical and electrical integration step ensures that all mechanical components, such as motors, actuators, and cleaning mechanisms, are properly connected to the PLC's output interfaces. Similarly, sensors that provide input to the PLC, like proximity sensors or vision systems, must be connected to the PLC's input interfaces. Other than that, software integration is developing the PLC program that will control the system. This involves writing ladder logic or function block diagrams that dictate how the PLC responds to sensor inputs and controls the mechanical components.

3. Results and Discussion

This section discussed the findings from our comprehensive analysis of the initial prototype for the automated sign face cleaner, meticulously designed and evaluated by using SolidWorks. Moreover, this section explores the key findings that came about as a result of our automated sign-face cleaner system implementing a PLC. The PLC's performance was carefully assessed using a series of tests intended to mimic actual operating circumstances. The robustness of the PLC programming as well as its integration with the system's mechanical and electrical components were tested throughout this examination.

3.1 Prototype design
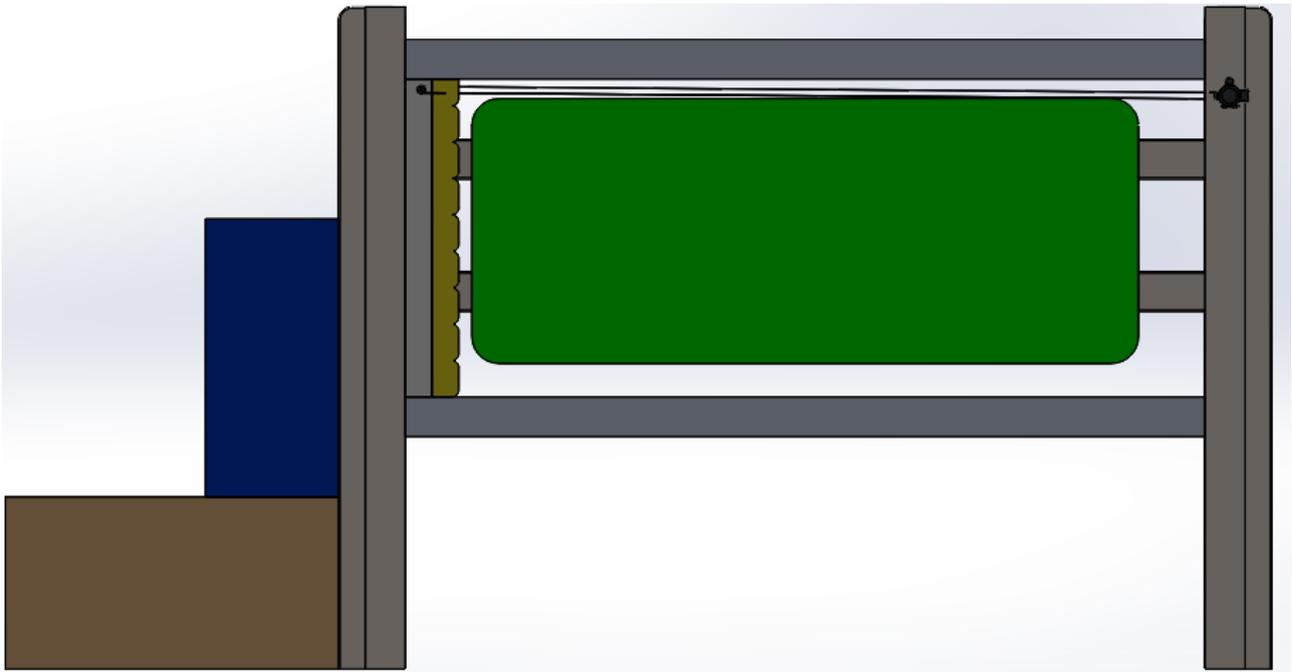
Fig 2: *1st prototype of the sign face cleaner*
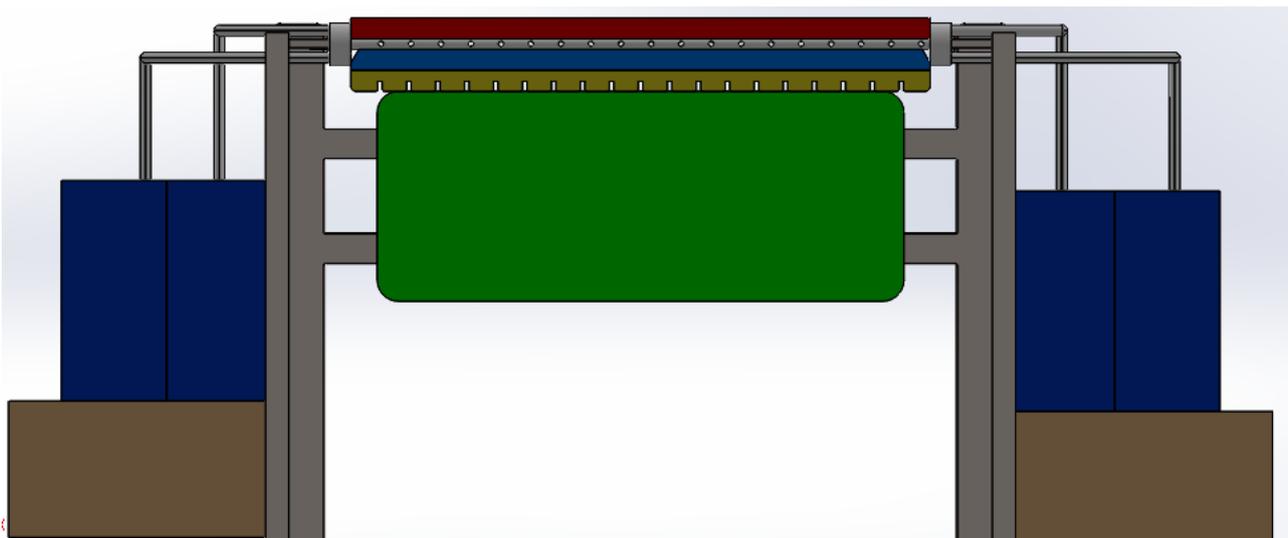
Fig 3: *2nd prototype of the sign face cleaner*

3.2 Results from SolidWorks Analysis

3.2.1 Stress Analysis

Table 2: *Stress Analysis on Selected Parts*

Location	Minimum N/m^2	Max N/m^2
Vertical Pole and Horizontal Pole	307.403	1.114×10^{13}
Motor and Cleaner	155.693	2.418×10^{13}
Water and Solvent Tank	4.171×10^2	9.8749×10^{11}

3.2.2 Strain Analysis

Table 3: *Strain Analysis on Selected Parts*

Location	Minimum N/m^2	Max N/m^2
Vertical Pole and Horizontal Pole	1.165×10^{-7}	2.203×10^3
Motor and Cleaner	8.693×10^{-8}	1.576×10^5
Water and Solvent Tank	4.094×10^{-8}	3.381×10^2

3.2.3 Factors of Safety

Table 4: *FoS Analysis of Selected Parts*

Location	Minimum N/m^2	Max N/m^2
Vertical Pole and Horizontal Pole	1.547×10^{-5}	1.528×10^4
Motor and Cleaner	7.128×10^{-6}	8.455×10^3
Water and Solvent Tank	2.039×10^{-4}	6.756×10^3

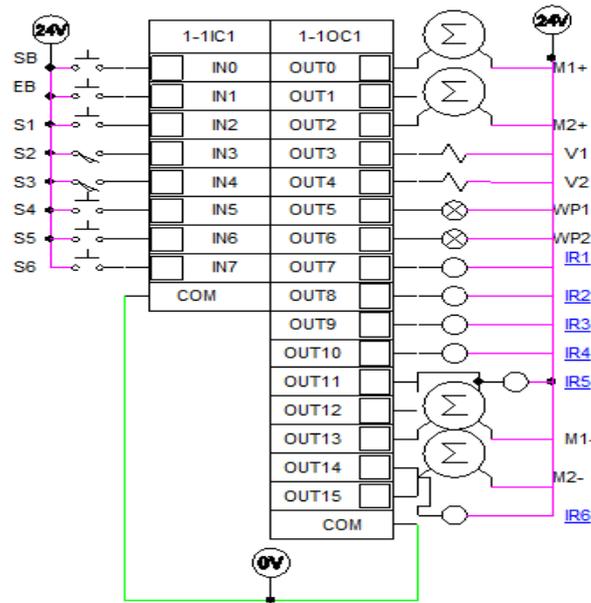## 3.3 Programming of the Programmable Logic Controller (PLC)

Fig 4: *PLC*

4. Conclusion

In conclusion, a thorough design study and the use of PLC automation in the creation of an automated sign face cleaner have been provided in this research article. We have proven that our design is not only structurally solid but also capable of carrying out its intended cleaning functions with great efficiency and dependability through thorough testing and assessment utilizing SolidWorks and PLC programming. The addition of PLC automation has changed everything, providing exact control over the cleaner's functions and enabling adaptability to changing sign-face conditions. The system has been successfully implemented, demonstrating its ability to completely transform signpost maintenance by saving labour expenses and raising cleaning standards. As we draw to a close, it is clear that in the field of maintenance robots, careful design combined with sophisticated automation can produce amazing outcomes. The knowledge gathered from this study establishes a standard for upcoming advancements in this field and adds significantly to the current discussion on maintenance automation. We believe that the automatic sign face cleaner will act as a model for future projects, encouraging further research and development into automated cleaning technologies.

Acknowledgement

References

[1] A. Gudigar, S. Chokkadi, and U. Raghavendra, "A review on automatic detection and recognition of traffic sign," 2016.
[2] D. Akmal, A. Ramlan, M. Fuad Yasak, and H. Hassan, "Safety Performance Analysis for Traffic Management During Activation and Deactivation Lane Closure at Highway New Klang Valley Expressway (Nkve)," Progress in Engineering Application and Technology, vol. 4, no. 1, pp. 122–128, 2023, doi: 10.30880/peat.2023.04.01.012.
[3] Lembaga Lebuhraya Malaysia, "Garis Panduan Pelaksanaan Pengurusan Trafik," 2008.
[4] A. C. Ahmad, I. N. M. Zin, M. N. Rosli, A. M. A. Wahid, and I. F. M. Kamar, "Hazard and Risk of Highway Maintenance Works: Case Study of PLUS Expressways," in MATEC Web of Conferences, EDP Sciences, Jul. 2016. doi: 10.1051/matecconf/20166600106.