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Systems and conceptual design of a train cab front cleaning robot

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Abstract

This paper presents and briefly describes the methodology used to get the systems and conceptual design of a train cab front cleaning robot. While the sides of the trains are cleaned by a mechanised washer, the cab fronts are cleaned manually which imply a number of health and safety issues. The aim of this project is first to carry out an analysis of the current procedures in order to detect the possible gaps in the process, generating a list of requirements that will make possible the conceptual design of a cleaning system that fulfil those requirements. The proposed solution includes the division of the system in various subsystems where different solutions for each subsystem will be considered, analysed and selected as a final option to develop a prototype. This paper focuses in the main structure of the robot that holds the end-effector; different conceptual designs are shown that comply with the requirements set in the systems design.

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Keywords: Cleaning robot, systems design, conceptual design, product development

1. Introduction

Train exterior cleaning is usually conducted by a mechanised washer. However, this washer cleans only the sides of the body. It does not clean the cab front nose or the body-end panels between carriages. The train cab front nose often consists of complicated shapes and the body-end panels between carriages sometimes are not cleaned at all. This leads to a huge amount of manual labour work for exterior body washing, creating a number of health and safety issues including working under 25kV overhead wires, working around electrified third rails, and working at heights, especially problematic during the night and in bad weather conditions (See Figure 1).

Cab front cleaning is carried out in a very similar way at every depot in the UK. However, it lacks of any standard procedure, efficiency and post-process inspection. Sometimes the timings available for this task are very short and each time the process is slightly different. The pressure applied when scrubbing the train surface is varied, the time spent cleaning different areas of the front cab nose is relatively random and even the quantity of detergent and water applied is not constant every time.

Figure 1: Member of the depot staff performing the cleaning procedure of the train cab front.

For the reasons pointed out above, Cranfield University in collaboration with Heriot-Watt University proposed a

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feasibility study of a cab front cleaning robot. This paper presents the systems and mechanical design aspects of that study. This idea screening stage, according to the New Product Development process [1], have focused on data gathering by visiting different depots, analysing the current processes in order to identify gaps and develop the systems design following set based concurrent engineering practice [2]. That results in obtaining the design requirements and creation of the functional diagram in order to establish the specifications necessary for the conceptual design. Once the specifications were pointed out the system was divided in different subsystems of which the main one was the end-effector of the robotic arm cleaner. Different solutions were evaluated resulting a number of candidates for the prototype in the next phase of the project.

2. Aim and Objectives

2.1. Aim

The aim of this project is to develop a proof-of-concept prototype of a semi-autonomous robotic cleaner for train nose-head as well as body-end panels. This stage of the project focused on performing a concurrent innovative design to address the mechanical structure and end-effector.

Besides detecting the specific requirements by the methods that will be explained later in this paper, the system should be also cost effective, robust, retrofitable and easy to operate.

In terms of the scientific approach the procedures presented in this paper must answer two different questions. First is how many devices or arms the system needs. Secondly what is the best arm mechanism to provide basis for the end-effector design?

2.2. Objectives

The main goals of the entire project are:

- To design the entire system considering the current infrastructure at the depot.
- To design the robot arm including kinematics analysis, dynamics analysis, and optimisation of the arm design considering the control aspects.
- To design the cleaning device (end-effector) including chemicals and water supply, brush moving mechanisms and contact detection mechanisms.
- To design the robot arm control system for surface detection and surface coverage for the cleaning purpose of train cab front nose and in-between the carriages.
- To build a 1/10 scale demonstrator to prove the feasibility of the concept.

While the main objectives of the procedures presented in this paper are:

- To present a detailed report of the actual situation of the cab front cleaning procedures pointing out the gaps and possible areas of improvement.
- To establish list of requirements and design parameters using set based concurrent engineering approach [2]
- To present the conceptual design of the cleaning device that fulfil the specifications and will be the starting point for the basic engineering or Front-End Engineering Design (FEED) stage.

3. Methodology

This project aims to resolve feasibility issue of incorporating and designing an autonomous robot for train cleaning. That is essentially a project of a new product development. Any products in the market try to solve problems that its buyer would potentially seek to solve. The same was in this case and following the guidance of Goffin [3] the first part of the methodology bellow was created. First step, the data acquisition, is the most important, since if the problems of the customer are not effectively collected or are miscommunicated, then it is likely that the end product will fail to deliver the desired performance. The next step is data processing in which the information gathered is organised and translated to an engineering language. That allows to see the project in an objective and quantifiable (as much as possible) perspective. This serves as a foundation for a successful solution development at the last stage of the methodology. In this stage ideas are created and tested, the best ones are developed into concepts and in the end the one with the best design is selected to be prototyped.

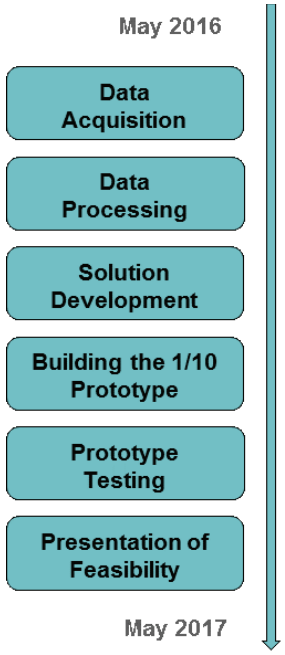

Figure 2: Overall project methodology.

Although the whole project consists of also prototype building and testing that is out of the scope of this paper.