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Smart RunnerBot

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Abstract: In the present competitive world, it is believed that a lot of human activities will be dominantly automated. There are very few universities in our country that implement this automated system. This project is the very first approach to bring the intelligent and automated system into our university cafeteria. The peak period during lunch break can directly affect the amount of labour required by the cafeteria workers. Each cafeteria operator has a minimum staffing level in order to limit financial constraint. The cafeteria operators may be able to run efficiently with limited workers. Due to this, they may be unable to meet the demands of a high volume of sales during peak hours. This consequently leads to the same workers having to work multiple roles to cater everyone's needs contributing to poor working performance and reduced productivity. Hence, the main objectives of this project are to develop a smart robot that will help minimize the amount of labour required, boost the productivity of the cafeteria operators and make the targeted university cafeteria a more convenient and technology-friendly environment. In this project, the moving platform is equipped with the aid of Arduino microcontroller with built-in coding, two 15kg load cells with HX711 Amplifier and LED lighting sensor to notify the container is fully-loaded. This moving platform is activated only when the dish container reaches 30kg. Upon activation, it will automatically make it way to the respective cafeteria operators in a fixed route as programmed. Methods used for the study are evaluation of the load distribution of the structure using SolidWorks software. The simulation results and calculation analysis show that the battery life is up to seven hours operation and its main body is able to withstand a maximum burden of 30kg. Therefore, this project has the capability to operate effectively in managing the dish container in the cafeteria.

Keywords: Automated System, Cafeteria, Moving Platform, Simulation

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1. Introduction

University cafeteria serves hundreds of students on a daily basis, and requires a substantial amount of resources to operate. Manual labour accounts for a disproportionate amount of labour cost but currently is a vital part and life blood of the cafeteria system. Though the world experiences rapid development in technology, a smart and automated device is yet available to help lift the burden of cafeteria workers.

Based on the literature survey carried out, a significant number of cafeteria workers complained that they have to work harder and multitask to meet demand over peak periods due to shortage of other workers. These workers need to walk to-and-fro in quite a fair distance to deliver a full container of used dishes to their respective cafeteria for cleaning purpose. Pursuant to the information attained, it could be inferred the method that is used to manage used dishes in the university cafeteria is conventional and the manual labour that needs to be invested by the limited workers is physically taxing.

Thus, this project planned to identify opportunities for consolidation of various kitchen tasks, new ways of having these dishes delivered and managed, and looking for ways to minimize the amount of labour that the workers need to invest. This project wished to receive input from the cafeteria operators, its workers and dishwashing staffs as it assists to provide valuable and prominent insights on the efforts on the dish management aspect of the cafeteria. The targeted primary stakeholder in this project would be the cafeteria operators because they will be the ones purchasing this product if it is made upon request.

It was the primary aim of this project to develop an autonomous moving platform. This fully automated moving platform will deliver a loaded container of dishes to the cafeteria operators with the aid of built-in Arduino system. The system will be activated once the maximum load of 30kg is reached and this will be detected by load cell sensors. This project also hoped to achieve other objectives, namely to develop a closed connection between café operators and prototype via automation system, as well as to help reduce the burden of limited workers by minimizing the amount of labour required, at the same instant, to boost the productivity of the cafeteria operators and last but certainly not least, to make the targeted university cafeteria a more convenient, technology-friendly and energy efficient environment.

This project focused on solving the problems aforementioned by fabricating an autonomous system. This project was limited in terms of area, maximum burden and motion of prototype. The key concern of this project was to encourage the use of automation systems in all areas of university through the design of a low cost and easy to use automation system; ultimately helping in providing a convenient, energy efficient, and technology friendly environment to the stakeholders. The university cafeteria can be considered as a mass production as it operates in anticipation of demand. Therefore, an essential role is being played by automation [1]. The roles played are to minimize worker' fatigue by reducing work load and the time taken to serve customers while at the same time to ensure mass production achievement.

2. Materials and Method

The detail of various materials such as specifications and functions has been included in this section. Moreover, the detail related to the preparation or methods adopted has also been the interest of the following section.

2.1 Materials

Table 1 refers to the materials that will be utilised in the project after the material selection process is executed. Material selection is a process of selecting a suitable material or a set of similar materials for the designed product to perform its intended operation [2]. An extensive research has been conducted in this meticulous task to make sure the product functions well. Before this process is taken into consideration, the project functionality has first to be understood. Hence, the function of each material is also detailed out in **Table 1**.

Table 1: Details on materials used and their functions

No.	Material	Function
1.	Main Body (Pine Wood)	A platform to accommodate the components
2.	Load Cell Sensor	A transducer that transforms force or pressure into electrical output
3.	DC Motor	Converts direct current electrical energy into mechanical energy
4.	Arduino UNO	An open source microcontroller board meant to make the application more accessible
5.	LiPo Rechargeable Battery / Power Supply	To provide electric power from a source to power the load cell sensor, DC motor and Arduino UNO
6.	HX711 Amplifier	Allows to read the changes of resistance in load cell to get accurate weight measurement
7.	Cast Wheel	A single tyre which can rotate 360˚
8.	Tyre	To provide tractive force on the surface travelled

2.2 Methods

The methods of design adopted in this project are segregated into three parts which are mechanical design, electrical design and programming. **Figure 1** illustrates the complete design of this project's protoype which is drawn using SolidWorks 2018 software.

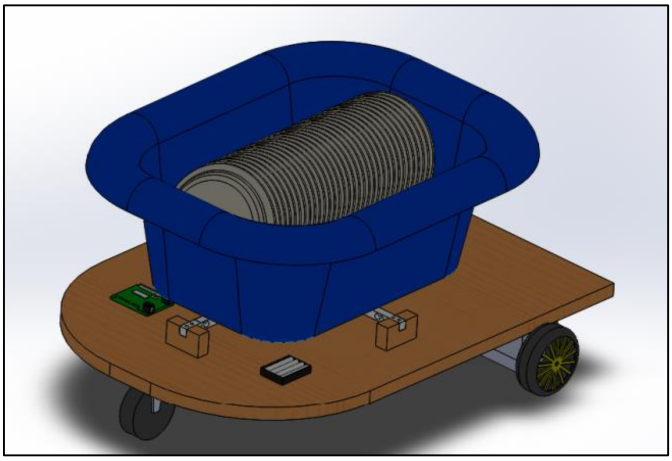

Figure 1: Project's prototype

2.2.1 Mechanical Design

Mechanical design process includes cutting, machining and assembly process. The component involves in mechanical design process is pine wood which acts as this project's main body or platform to accommodate all the electrical components used in this project. Pine wood is selected over metal as the joining process is much easier and produces minimal heat compared to metal which involves welding process that produces high temperature which will damage the components of the likes of

Arduino UNO and load cell sensors. The joining processes that are executed in this project include mechanical fasteners such as nuts and screws and adhesive bonding, for instance, glues. As for cutting process, it is one of the design tasks that is deemed essential in this project as the pine wood provided by the supplier is in sheet shape. Cutting process is performed to produce the sheet to desirable shape and size and to remove waste material. Finally, the machining process that is involved is drilling. Drilling process is carried out to produce cylindrical holes intended to aid in assembly.

2.2.2 Electrical Installation

Electrical installation process includes testing and analysis of electrical components such as DC motor, power supply and load cell sensors. The exact parametric values with the permissible tolerances for each parameter of electrical component are determined and calculated, for instance, the value of torque and battery life required to ensure the voltage and stall current of the DC motor has the ability to run the prototype at expected speed and time.

The electrical distribution system implemented in this project can be depicted by Single Line Diagram (SLD). SLD is a representation of a complicated electrical distribution system into a simplified description using a single line, which represents the conductors, to connect the components [3]. Main components in this project such as battery or power supply, DC motors, Arduino UNO and load cell sensors are indicated by their simple images. **Figure 2** illustrates the SLD for load cell sensors, whereas **Figure 3** illustrates the SLD for DC motors.

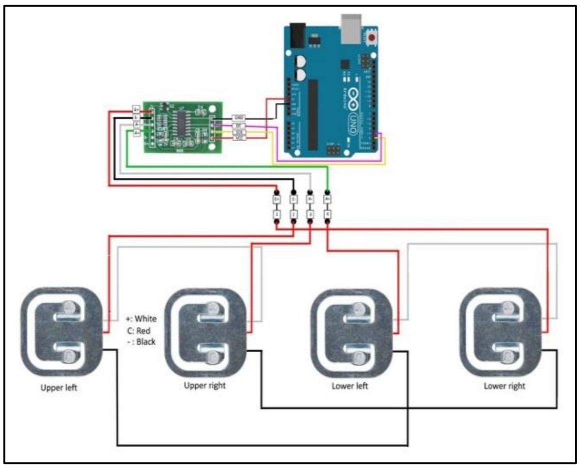

Figure 2: Single Line Drawing of load cell sensors

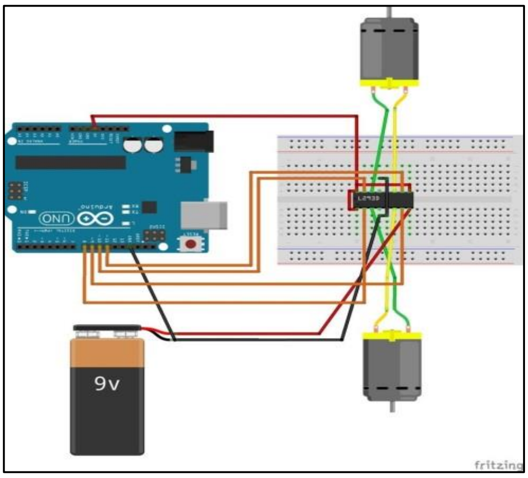

Figure 3: Single Line Drawing of DC motors

2.2.3 Programming

Built-in Arduino UNO coding is implemented to this project to run the protoype in a fixed route and motion. The Arduino UNO, a board based on the ATmega328 microcontroller, is used. For the board's programming software, an IDE development environment and core libraries are involved. The IDE is written in Java, while the code libraries are written in C and C++. **Figure 4** represents the circuit diagram for Arduino UNO.

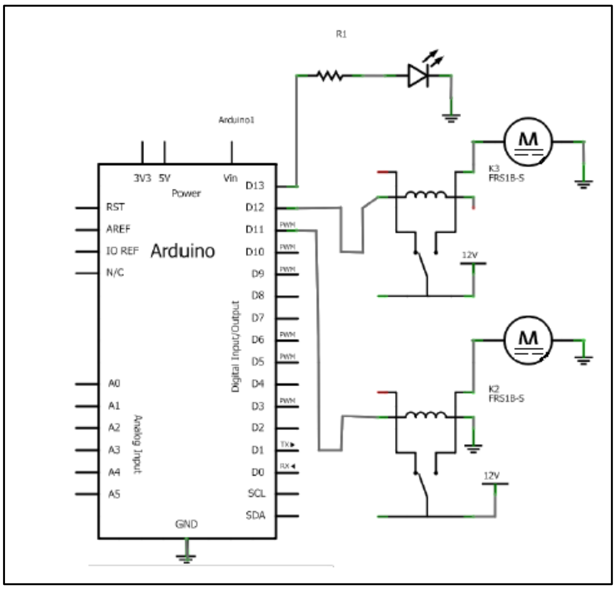

Figure 4: Arduino UNO circuit diagram

3. Results and Discussion

This analysis proved that the current design safe to operate under required parameters and conditions. This analysis includes component analysis and load cell sensor analysis.

3.1 Component Analysis

3.1.1 DC Motors

In the project, DC motor is utilized. The primary advantage of the DC motor is that it can develop constant torque over a wide speed application [4]. When selecting the motor, the voltage and current rating are considered. A DC motor of 11.1V, 2A is choosen in this project. An analysis to calculate the torque required has been carried out to ensure that DC motor is capable of supplying the carrying torque. Table 2 details out all the parameters involved in torque calculation along with their remarks.

Table 2: Parameters and remarks in torque calculation

Parameters	Remarks
T	Torque (Nm)
L_{max}	Maximum Load (N)
r	Radius (m)
C	Coefficient of Tyre Resistance
m	Mass (kg)
a	Acceleration (m/s^2)
g	Gravitational Acceleration (9.81 m/s^2)
F_t	Total Force (N)

Before the value of torque required can be obtained, the maximum load must be first determined.

$$L_{max} = mg \quad [5]$$

$$= 30\text{kg} \times 9.81\ \text{m/s}^2$$

$$= 294.3\ \text{N}$$

Next, the total force, F_t of the system is calculated. The required tractive torque of the motor shall be equal to tractive torque at wheel. Hence, the coefficient of tyre resistance (rubber on ceramic dry tile) is taken into account which is 0.78 [6]. The acceleration required to reach the prototype's designed speed is also determined.

$$F_t = C \times L_{max} \times ma \quad [5]$$

$$= 0.78 \times 294.3 \times (30 \times 0.12)$$

$$= 826.39\ N$$

After all the important parameters are calculated, the value of the torque can be obtained.

$$T = (F_t \times r) \div 2 \quad [5]$$

$$= (826.39 \times 0.06) \div 2$$

$$= 24.79\ Nm$$

3.2 Load Cell Sensor Analysis Using Finite Element Software

The study was carried out on three-dimensional load cell sensor model with finite element modelling and analysis using computer software SolidWorks 2018. Referring to **Figure 5**, the red circle indicates the load cell sensors that are subjected to the analysis.

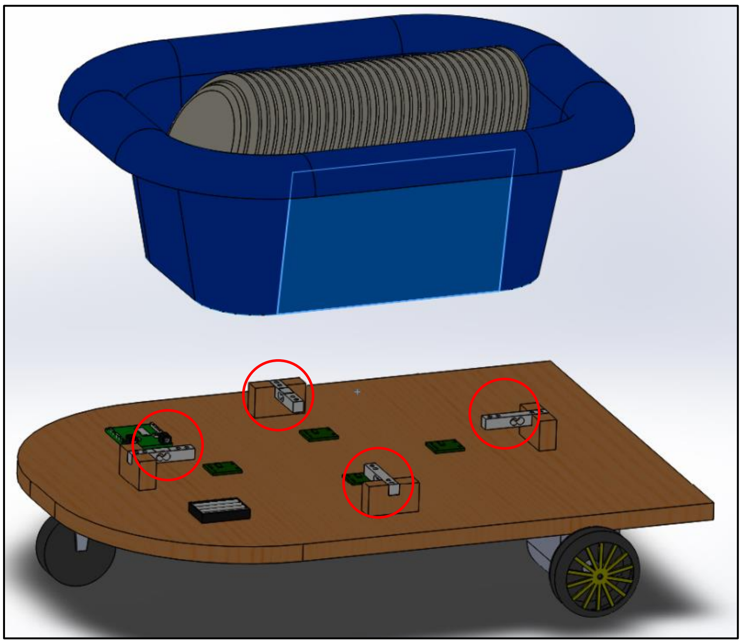

Figure 5: Load cell sensors that are subjected to Finite Element Analysis

There are three stages in the finite element analysis which are pre-processing, numerical analysis and post processing. The pre-processing included the construction of geometry modelling and finite element mesh. The parameters defined at this stage are the geometry, type and size of element, material properties and boundary conditions, which represent the actual structures to be solved. The numerical analysis stage involved the complex solution by the finite element software, SolidWorks 2018 to obtain the results required. The post processing is the stage after the analysis. It concerns about the statistical or graphical presentation of the results obtained from the result. The result of the analysis will be used to evaluate the performance of the load cell sensor which will be utilised in this project the under maximum applied force of 30kg. **Figure 6** shows the analysis of load cell sensor conducted on SolidWorks 2018.

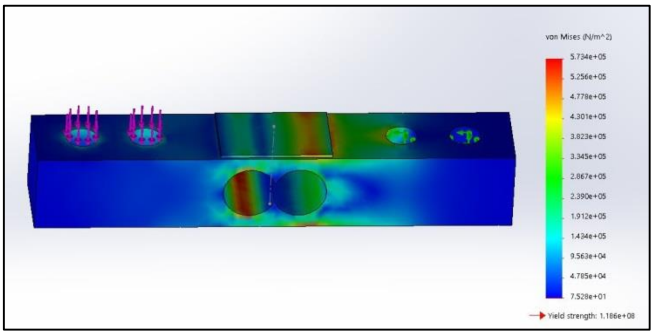

Figure 6: Finite Element Analysis on load cell sensor using SolidWorks 2018 Simulation

Under loading condition, maximum Yield Strength has been obtained. Based on the analysis, the maximum Yield Strength according to von Mises stress for load cell sensor is 5.734e + 05 N/m^2 (refer **Figure 6**). The von Mises stress is often used in determining whether an isotropic and ductile metal will yield when subjected to a complex loading condition. This is accomplished by calculating the von Mises stress and comparing it to the material's yield stress, which constitutes the von Mises Yield Criterion [7].

Figure 6 also points out that the yield strength shows a greater median value than the total mass of maximum load which is 30 kg. The median value given in the von Mises stress is 3.345e + 05 N/m^2 which is the equivalent of 334.5 kN/m^2. Thus, it indicates that the load cell sensor utilised in the project is safe and suitable to use to withstand the maximum load of 30 kg.

4. Conclusion

Design and analysis of Smart RunnerBot prototype were completed successfully using SolidWorks 2018 software hence achieving the aim of this project which is to design an automated moving platform. All the major components have been designed completely in SolidWorks 2018. Analysis of the design was done successfully to determine its performance such as battery life, carrying torque and maximum Yield Strength. It can be deduced that Smart RunnerBot is able to operate efficiently within the constrained and expected conditions and parameters.

4.1 Recommendations

There are several recommendations to be proposed for future enhancements of this project. These are as follow:

1. Implementing remote internet access via Arduino IoT in the automation system. This will allow the user or cafe operator to monitor and be notified of the prototype anytime and anywhere.
2. Developing a control system based on electronically controlled braking system with the aid of ultrasonic sensor. The ultrasonic sensor senses the obstacle closer to the prototype within a desired distance, and then the control signal is given to the braking system [8].

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