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PAPER

Development of Automatic Object Lifter

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ABSTRACT

Food service is the most significant part of running a successful restaurant. Precise and consistent food order distribution must be synchronized to achieve a remarkable operation. As the food business industry develops, the quality of the technology goes down. It now becomes the burden of the owners, especially on the workers. Developing an automated dumbwaiter with High Torque DC Motor and 1-kg load cell w/ HX711 Amplifier was conceptualized to solve this problem. The study aims to design, fabricate, and test the functionality of an Arduino-based automatic object lifter that will convey the corresponding meal to the following floor. The circuitry comprises an Arduino Uno, 1-kg Load Cell, HX711 Load Cell Amplifier, LCD Display 20x4 HD44780 Controller, Rotary Switch, Limit Switch, L298N Motor Driver, and a High Torque DC Motor. The system begins to operate after the load cell is calibrated. After this, the food was placed on a tray over the top of the dumbwaiter with a 1-kg load cell underneath. The meal weights will be set accordingly and saved as data when the microcontroller analyses the values given by the load cell and HX711 module. The dumbwaiter has only three meals available. Every meal comprises three different combinations of food items per tray, for a maximum of 1 kg. For the first meal: 1-pc Chicken w/ Rice & Drinks, second meal: Spaghetti w/ Fries & Drinks, and the third meal: Burger w/ Fries & Drinks. Whenever there are discrepancies in the weights of the food items, it prevents the system's operation. The dumbwaiter carries the meals up to the next floor. As the dumbwaiter hits the plunger of the limit switch, it instantly stops. Generally, the prototype was functional, with an average transport time of 13.584 seconds and a limit switch-breaking system of 0.5 milliseconds.

KEYWORDS

Food Service, Arduino Uno, DC Motor, Load Cell, Dumbwaiter.

1 INTRODUCTION

Lifts are pieces of machinery that existed hundreds of years ago to help people convey hefty loads [1]. Man, animal, and water power became the earliest lifts. Elevators are typically constructed within a building structure, commonly referred to as hoistways [2]. In other instances, hoistways can also be of metal structures, such as beams configured to surround the space forming it. Today, lifts are carriers in several establishments such as factories, construction sites, industrial operations, food service industries, etc. [3]. Unfortunately, this utility is failing to ride with the economy due to the advancement of high technology. The food industry is the most affected among these establishments, which serves as the restaurant owners' downfall because they fail to provide stable customer service. In the Philippines, one of the biggest problems that coincide with a typical restaurant is getting negative comments from customers. Unlike other foreign countries, third-world countries like the Philippines have always been behind in the more advanced technologies. That is why many food researchers and restaurant experts in the Philippines are trying to create a new way to approach this situation.

The dumbwaiter has also incorporated significant hotels, dining rooms, and kitchens. Instead of a deadlift, it becomes the visual plant for transporting food, tableware, and debris. Practically, dumbwaiters of various hotels and restaurants operate manually [4]. However, some research has suggested that a manual dumbwaiter is not convenient and time-consuming. Current studies regarding this matter aim to provide a better way of service in the food service industry. A kitchen is a place of food production, education, and communication [5].

As it is a more active place than other parts of an establishment, there are a lot of potential ubiquitous computing applications in a kitchen, otherwise making the job easier. A machine called a dumbwaiter is here to overcome this problem [6]. Many hotels and restaurants use different methods to serve customers faster, and one of the most common is using a dumbwaiter. A dumbwaiter is a small freight elevator at waist height with a cabin intended to carry things, especially food and dishes, between the floors of a building [7-11].

It ensures that the load is secured and arrives at a perfect time. Dumbwaiters convey goods to different levels to save time and human resources, which meet the standards of hygiene and aesthetics required for the hospitality and food industry. Many dumbwaiters' elevator designs, parts, and costs make quality different, which this study covers. It has proven very significant for restaurant management to receive positive customer comments [12]. The present invention relates to an elevator structure in which a pulley, a motor, and cables have a ratio of 1:2 to reduce the tension applied and controlled by pushbuttons. It covers only the use of a high torque 12V-DC Motor for conveying meals to the next floor inside a typical restaurant [13]. The device has a motor driver that controls the DC motor. Correctly, if the load is beyond the scale, the system will not function. The input should have the right weight for the system to operate. The load cell of the device has a maximum load of only 1 kg, which is higher than what is prohibited [14-15].

The main objective is to design, fabricate, and test a prototype of an automatic object lifter, a dumbwaiter—specifically, a mechanical design intended for restaurants to function as fast as possible. The main goal is to create a device that will help the crews of the restaurants serve customers consistently.

This study is significant in solving the problems of complaints in any restaurant or fast-food chain in the future. Hence, the attainment of this device can give the customer a faster and more improved of serving the food.

2 MATERIALS AND METHODS

In the system, the 1-kg Load cell with HX711 Load Cell Amplifier and Arduino Uno serves as the weight monitoring system. The HX711 Load Cell Amplifier functions as the weight sensor of the meals[16-17]. Every meal composing the food items is weighed first by the dumbwaiter cabin, for their weights are the only ones allowed to the operation. Using the rotary switch makes selecting meals much easier[18]. The display will show if the set meals are saved and appear on the LCD Display 20x4 HD44780 Controller[19]. The L298N motor driver then prompts the DC motor if it is allowed to function given the weight inputs. The power monitoring is through the utilization of the Arduino Uno. It is the monitoring and control of the processes that circumvent the system.

2.1 System Block Diagram

The system block diagram, shown in Fig. 1, displays the weight sensor located under the dumbwaiter cabin, transferring the data for the software inside the microcontroller to analyze, sending a signal to the L298N motor driver and limit switches, and notifying the DC motor for errors. As for the specified location of the load cell, it should be located under the dumbwaiter cabin so it can quickly gather the weight inputs. The processes in the system are controlled and managed by the microcontroller per the design standard P16141 Standard for Signal and Testing Definition. The standard provides the means to define and describe signals used in testing. It also supports structural textual languages and programming language interfaces for integration.

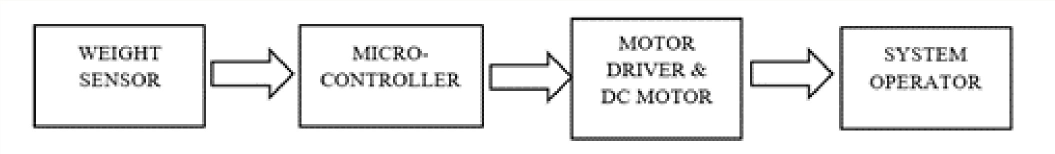

Fig. 1 System Block diagram

2.2 Materials and Resources

For the fabrication of the dumbwaiter, the materials used by the researchers are a 1kg load cell HX711 weighing AD module for the weight sensor; a welded steel frame 6 ft high serves as the hoistway; and a 3-ft wooden table tap is placed below the structure. Second, an Arduino Uno has 20 digital input/output pins, of which six are PWM (Pulse Width Modulation) outputs, and the other six are as analog inputs) as the microcontroller unit[20]. Programs are loaded onto it from the easy-to-use Arduino computer software. For the circuitry, Eagle Software designs the circuit, prints it to the present-sized PCB (PVC Circuit Board), exposes it to the tracing paper for two minutes under UV light, and processes it using Ferric Chloride[21]. Third, a 12-V 70-rpm 12W, high torque DC motor for traction. The proponents use cables to connect the dumbwaiter and the DC Motor. An L298N Motor Driver is connected to the Arduino, allowing speed and direction control[22]. A counterweight, about 1kg, is symmetrically paralleled to the cable opposite the dumbwaiter bus as a counterforce.

2.3 Design Procedures

Firstly, the objectives of the study must be considered. The materials and other external factors, such as temperature and cleanliness, would also contribute to its overall functionality. The equipment should meet the required construction, stability, and safe lifting limit from ISO Standard 11228. The flow of information would be the data accumulated by the weight sensors to the Arduino Uno, which would interpret and decode the data in conformity with the written program stored in the microprocessor

Programs are loaded onto it from the easy-to-use Arduino computer software. There are some considerations determined that are necessary for the suitable means of achieving this project: (1) Noiselessness, (2) Affordability, Parts, and Construction, (3) Safety for users, (4) Reliability and Efficiency, (5) Ease of Operation, (6) Ease of Installation, and (7) Available Technology. The following methods are the traction method and hydraulic system. We selected the traction method from the outcome of a Decision Matrix, comparing the other possible approaches.

2.4 Design Stage

For the design, standards should be followed to attain the specific safety requirements and test methods of the automatic object lifter. The parameters for developing the standard structure for the prototype are involved. First, a wooden frame is crafted temporarily as support for the dumbwaiter. Then, the proponents shall weld a steel frame as a hoistway for the final prototype structure. Second, the dumbwaiter will be on the top of a tabletop at waist height. A counterweight is connected to the cable to maintain equilibrium. The proponents install limit switches for the braking system. The location of the circuitry is basically on the middle portion of the dumbwaiter, where it can be secured and far from short circuit faults. The circuitry comprises the microcontroller unit, rotary switch, limit switch, LCD Display 2x4 HD44780 Controller, L298N Motor driver, and DC motor.

2.5 Testing Methodology

To check the system's overall functionality, various test standards are considered. The ISO TR 11071-1-2004 Standard for Electric Lifts in Industries assures the safe operation of different types of conveying equipment like elevators, cranes, dumbwaiters, etc. Also, in CEN - EN 81-1 – Implementing the safety rules for the installations of lifting equipment. The ASME A17.1 - Errata to Safety Code for Elevators and Escalators Includes Requirements for Elevators, Escalators, and Dumbwaiters that cover the design, construction, operation, and inspection are considered.

3 RESULTS AND DISCUSSION

3.1 Ergonomic Design of the Automatic Object Lifter

The ergonomics of the design were taken fully into account. The main reason is that it was susceptible to a restaurant kitchen involving occupational health and safety parameters subjected to the system's functionality. Filthy surroundings pose a food safety hazard, which can cause various problems and can even lead to severe health conditions. That is why the cleanliness of the system and the proper installation of the components were observed. The dumbwaiter bus is sealed with sanitary wood to avoid contamination of the meals to be delivered. The microcontroller, LCD 20x4 display, rotary switch, and the L298N motor driver were enclosed separately with plywood and away from the dumbwaiter bus. The whole structure is placed over a table tap to maintain good posture for the worker/operator of the device. The fabricated system is in Fig. 2.

3.2 Functionality Testing

The premise of this study's functionality testing of the automatic object lifter relied on the function test. First, an object is placed on the dumbwaiter to calibrate the load cell. There are specific meals to be used as orders. These meals are weighed individually and serve as data to the microcontroller unit. The test is done by choosing a variety of orders using a rotary switch and selecting a meal combination. All the software operations are on the LCD Display 20x4 HD44780 Controller. Considering the time duration of the lifting process during operation, the consistency of the motor when it is operating, and the lifter's automatic braking system using a limit switch.

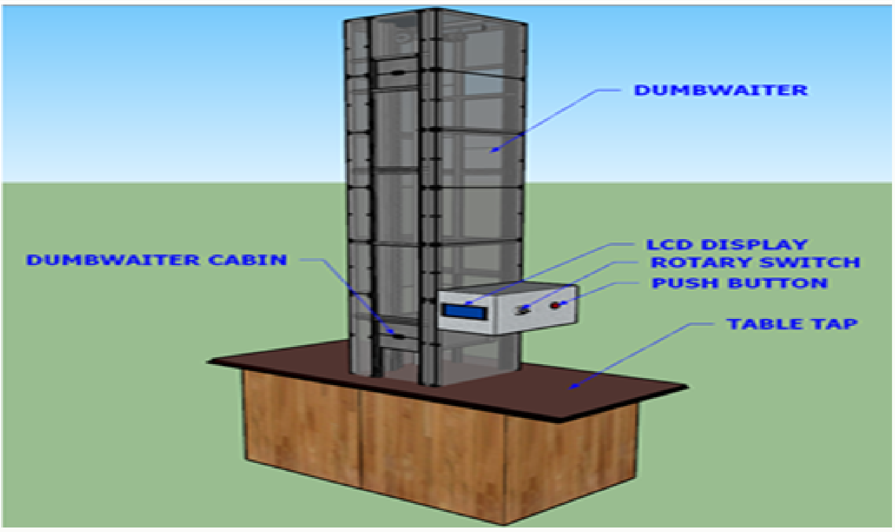

Fig. 2 Fabricated Automatic Object Lifter

1) Calibration: Any food in the range of 1 kg can be used as a load for the dumbwaiter cabin for load cell calibration.

2) Meals: Food items are weighed each to serve as data for the beginning of the operation. The operation is by manipulating the rotary switch.

3) Automatic braking: In testing the functionality of this system, the initial to maximum height of the lifter must reach. The requirements also applied to the associated control devices. Limit switches included in making the prototype.

3.3 Pilot Testing of the Automatic Object Lifter

The tables below present the confusion matrix for the prototype, measuring its accuracy, precision, recall, specificity, and f1 score. The ten separate readings of the load cell for the three meals were the basis of how consistent the device is. The data gathered has four classifications. Registered meal weights are under true positive (TP), where the load cell absorbs the data for the positive class. The actual meal weight during testing was classified under true negative (TN).

Table 1 Confusion Matrix for Meal 1

MEAL 1									
Trial No.	TP	TN	FP	FN	Accuracy	Precision	Recall	Specificity	F1 Score
Trial 1	550	550	180	175	0.756	0.753	0.759	0.753	0.756
Trial 2	550	555	150	155	0.784	0.786	0.780	0.787	0.783
Trial 3	550	557	200	210	0.730	0.733	0.724	0.736	0.728
Trial 4	550	559	100	120	0.834	0.846	0.821	0.848	0.833
Trial 5	550	560	250	230	0.698	0.688	0.705	0.691	0.696
Trial 6	550	540	609	510	0.493	0.475	0.519	0.470	0.496
Trial 7	600	710	800	500	0.502	0.429	0.545	0.470	0.480
Trial 8	600	700	750	510	0.508	0.444	0.541	0.483	0.488
Trial 9	550	545	600	490	0.501	0.478	0.529	0.476	0.502
Trial 10	550	549	610	510	0.495	0.474	0.519	0.474	0.495

Table 2 Confusion Matrix for Meal 2

MEAL 2									
Trial No.	TP	TN	FP	FN	Accuracy	Precision	Recall	Specificity	F1 Score
Trial 1	250	250	180	170	0.588	0.581	0.595	0.581	0.588
Trial 2	250	255	150	170	0.612	0.625	0.595	0.630	0.610
Trial 3	250	270	200	230	0.547	0.556	0.521	0.574	0.538
Trial 4	250	200	330	225	0.448	0.431	0.526	0.377	0.474
Trial 5	250	240	320	200	0.485	0.439	0.556	0.429	0.490
Trial 6	300	310	390	195	0.510	0.435	0.606	0.443	0.506
Trial 7	300	315	360	245	0.504	0.455	0.550	0.467	0.498
Trial 8	300	295	100	120	0.730	0.750	0.714	0.747	0.732
Trial 9	250	245	305	210	0.490	0.450	0.543	0.445	0.493
Trial 10	300	300	250	200	0.571	0.545	0.600	0.545	0.571

Table 3 Confusion Matrix for Meal 3

MEAL 3									
Trial No.	TP	TN	FP	FN	Accuracy	Precision	Recall	Specificity	F1 Score
Trial 1	300	300	180	200	0.612	0.625	0.600	0.625	0.612
Trial 2	300	305	150	170	0.654	0.667	0.638	0.670	0.652
Trial 3	300	310	200	250	0.575	0.600	0.545	0.608	0.571
Trial 4	300	320	100	250	0.639	0.750	0.545	0.762	0.632
Trial 5	300	325	250	230	0.566	0.545	0.566	0.565	0.556
Trial 6	350	360	365	295	0.518	0.490	0.543	0.497	0.515
Trial 7	350	355	390	280	0.513	0.473	0.556	0.477	0.511
Trial 8	350	450	400	285	0.539	0.467	0.551	0.529	0.505
Trial 9	300	290	370	260	0.484	0.448	0.536	0.439	0.488
Trial 10	300	295	385	265	0.478	0.438	0.531	0.434	0.480

The other five tests are under false positive (FP) or registered loads of random objects and false negative (FN) or the actual weight during testing. The classifications may differ depending on how close the real is to the registered. Random object testing may also affect the changes in the result. Table 1 presents the confusion matrix of the first meal tested: 1-pc chicken w/ rice, fries, and drinks. Table 2 for the second meal tested: spaghetti w/ fries and beverages. Table 3 for the third meal tested: burger w/ fries and drinks. The results of the three confusion matrices show relevance, and therefore, the prototype achieved its maximum functionality.

4 CONCLUSION AND FUTURE WORKS

In general, the performance of the prototype is sufficient and reliable. The ergonomic design of the automatic object lifter was achieved. The dumbwaiter had been able to transport a variety of meals consistently. The fabricated system had been proficiently operating with a 7.53-second response time weight sensor and 13.584 seconds for the conveying process. Given these durations, the proponents can conclude that the prototype effectively transports the ordered meals. It will be reliable, efficient, and instantaneous, making it easier to take the corresponding measures. After the fabrication of the system and running a few tests, the proponents have a few recommendations for future studies involving customer service and dumbwaiters. Anticipating rejuvenation and technological advancements, it is recommended to integrate IoT (Internet of Things) into the system. By this, it will be much more accessible, covering the way for a system of automated dumbwaiters that can be monitored instantaneously in a given computer program.

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