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DEQOREL: An Intelligent Service Robot to Improve Restaurant Service Efficiency

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Abstract

Cafes have become a favorite place for various groups by providing a variety of food and drinks. However, challenges such as worker fatigue and human error often interfere with service. To overcome these problems, this research developed an intelligent waiter robot named Deqorel. Deqorel is designed to improve restaurant service efficiency through trajectory sensor-based automatic navigation and optimization algorithms. Deqorel is equipped with a 15-inch interactive screen, an energy-efficient DC motor, and a lithium-ion battery that supports operations for long periods of time. The robot frame uses 304 stainless steel with stress calculations to ensure strength and safety. The results show that Deqorel is able to provide accurate, fast, and responsive service in a dynamic restaurant environment, thereby increasing customer satisfaction as well as restaurant productivity.

Keywords: Intelligent waiter robot, trajectory sensors, restaurant efficiency, Deqorel

INTRODUCTION

Cafe is a place that is very popular with various groups, both young and old. Not just a *hangout* place, Cafe also provides a variety of foods ranging from heavy meals to snacks[1]. No exception is also drinks with various types. One example of a cafe that is currently *popular* in Bukittinggi is *Forest Tree*.

Some cafes have an open-air cafe concept with "*instragramable"* views and building concepts. The cafe is very crowded with visitors from both inside and outside the area. This cafe serves Indonesian and international specialties, such as rawon, fried rice, soup, burgers, spaghetti, udon and others. In addition to food, this tacafe also provides drinks both Coffee and Noncoffee. The price of food and drinks is relatively affordable so that it further increases the interest of visitors, it makes this cafe crowded every day[2]. The cafe which can accommodate approximately 200 people makes the workers overwhelmed, because of the many orders that come from visitors to the cafe. Fatigue may be felt by workers which will reduce effectiveness in serving customers. *Human error* may occur. For example, mixed up orders or customers waiting too long which makes customer satisfaction decrease with the cafe service [3]. Therefore we made an innovation by presenting an intelligent robot waiter dubbed Deqorel.

Deqorel is a technology designed to make work easier. Deqorel is able to deliver orders quickly and accurately. Deqorel is designed using trajectory sensor technology. The trajectory sensor uses a trajectory optimization algorithm that makes Deqorel move according to the programmed trajectory.

In 2013, there was research that discussed developments in the field of industrial robotics. At that time industrial robotics was undergoing a major innovation process that focused on the improvement and multifunctionality of the robot. Industrial robotics is deployed to meet the demands of the industrial work environment[4]. With improvements in *artificial* intelligence (AI), industrial robots are able to perform more complex tasks.

According to several scientific articles, developed countries such as the USA, Japan and China have already used intelligent robot waiters. For example, in the USA the BellaBot intelligent robot is used to welcome guests, take them to their shirts, serve food and drinks, and carry dirty plates or glasses to the kitchen[5].

Intelligent robots are currently considered something out of the ordinary. In recent years, intelligent robots have been very popular in various sectors. In the future, it is expected to apply technology according to the advancement of the times and can help waiter work and save costs and labor.

Robotic control systems are basically divided into two groups, namely open loop and closed loop control systems. Open loop control diagram on robotic system Open loop control or feed forward (feedfoward control) can be expressed as a control system whose output is not recalculated by the controller. The state of whether the robot has actually reached the target as desired according to the reference, is not able to affect the controller's work. This control is suitable for robot operating systems that have that operate based on logic based on sequential step configuration, such as stepper motors. Stepper motors do not need to be fitted with sensors on their shafts to know the final position. If it is in good working order and there is no overload problem, the stepper motor will rotate according to the controller command and reach the target position quickly. If the actual motion results are equal to the reference then the controller input will be zero. This means that the controller no longer provides an activation signal to the robot because the final target motion command has been obtained. The smaller the error, the smaller the controller's driving signal to the robot, until it finally reaches a steady state [6].

RESEARCH METHODS

This research aims to be able to create a technology that in accordance with the times can help the work of waiters and save costs and labor[7]. The steps taken in the research design of the Deqorel intelligent waiter robot can be seen in the research scheme in **Fig. 1.**

Fig. 1. Research Methods

a. Problem identification
In this activity, it starts with recognizing the problems and activities of wanting a product.
b. Data collection
The next stage is to collect the necessary data so that the best solution can be taken and then simplified so that it is more efficient and easy to make decisions[8].
c. Design
At this stage we begin to design what will be designed to be studied analyzed and refined a design.
d. Analysis
The next stage is to analyze, by analyzing, the problem will be able to find out the solution you want to find, in this study analyzing the use of robots in doing about human work, namely guarding the store.
The analysis used is:

1) Axial stress

The axial stress is calculated based on the axial force (F) and cross-sectional area (A) of the frame element, as given in Equation 1.

$$\sigma^{a} = \frac{F}{A} \quad (1)$$

2) Bending stress
The bending stress is calculated based on the bending moment (M), moment of inertia (I), and distance from the neutral axis to the outermost fiber (c), using Equation 2.

$$\sigma^{b} = \frac{M.c}{I} \quad (2)$$

3) Combined stress
For frame elements subjected to a combination of axial and bending, the combined stress (σt) is calculated by summing the axial and bending stresses, as given in Equation 3.

$$\sigma t = \sigma^{a} + \sigma^{b} \quad (3)$$

4) Safety Factor
The factor of safety (FS) is compared to the yield stress (σy) of the material, using Equation 4.

$$FS = \frac{\sigma y}{\sigma^{a}} \quad (4)$$

5) Maximum Deflection
To ensure the frame does not deform excessively, the maximum deflection (δ) needs to be calculated, using elasticity formulas, such as, using Equation 5.

$$\delta = \frac{F.L^{3}}{3.E.I} \quad (5)$$

e. Results
From the analysis carried out, it will produce concepts and frameworks that can be used in the development of robotic projects that will be able to help humans in doing daily work.

RESULTS AND DISCUSSION.

Deqorel was designed and tested to meet the operational needs of restaurants. The research focused on the integration of technologies such as trajectory sensors for automatic navigation, an energy-efficient motor system, and an easy-to-use user interface. The results showed that Deqorel was able to move accurately, avoid obstacles, and serve customers quickly in a busy restaurant environment. In addition, the use of quality materials and efficient design support longer operation and low maintenance. With this technology, Deqorel succeeded in improving service efficiency while reducing errors that often occur with human workers.

The integration between motion sensors, navigation systems, and intuitive user interfaces is key to creating efficient and responsive robots. Deqorel can avoid obstacles and serve customers precisely. The use of lightweight materials for the frame and the energy efficiency of the DC motor also contribute to longer operation and low maintenance costs. In addition, the friendly user interface allows restaurant staff to easily organize the robot's routes and tasks, demonstrating the potential of this technology to improve productivity and customer experience.

The drawing design of the waiter intelligent robot can be seen in **Fig. 2**, as follows:

Fig. 2. Design of Deqorel intelligent robot

Description of picture no 2:
1. Monitor screen
2. Tray support
3. Electrical module storage
4. Robot frame
5. Wheels

There are several plans used in this plan including:

1. Monitor screen
   The monitor screen used uses a 15-inch LCD as a guide to see where the Deqorel is moving and display sensor data. The power used on the 15-inch LCD is about 12V, 1-1.5A. the input used is HDMI / USB-C. GUI Framework: Python (Tkinter/PyQt) or HTML/CSS for interactive display as control software.
   Power consumption calculation:

$$P = V \times I = 12V \times 1A = 12 \text{ Watts}$$

2. Tray support
   The tray support on this Deqorel has a length of 60 cm which is made of stainless steel. This material is chosen to avoid rust and is strong, so as to ensure that the support can support the load stably and safely. This stand is designed to deliver food and drinks safely and to customers.

3. Trays
   The tray on Deqorel measures 60 x 30 cm. Designed to provide ample space to carry about 3 plates on each level. The tray on Deqorel uses Aluminum material. the capacity that can be held on the tray is around 5-6 kg.

4. Electric module storage.
   Storage This electrical module is equipped with various important components, including an ATMEGA 16 microcontroller that functions as a controlling brain, a DC motor that provides motion power [9], and a battery that is the main energy source to run the entire system, The type of battery used is Lithium-ion (Li-ion). Voltage 24V with a capacity of 20 Ah. as well as a battery charger where the battery charger is used to charge the rechargeable battery from the charger source

Table 1. Power used in module storage

component	**Voltage (V)**	Current (A)	Power (W)
DC motor (2 units)	24 V	3 A / unit	2 X 24 X3 =144 W
Monitor screen	12V	1 A	12 X 1 = 12 W
Total expanse			156 W

5. frame
   The frame on Deqorel is solid as seen in **Fig. 3:**

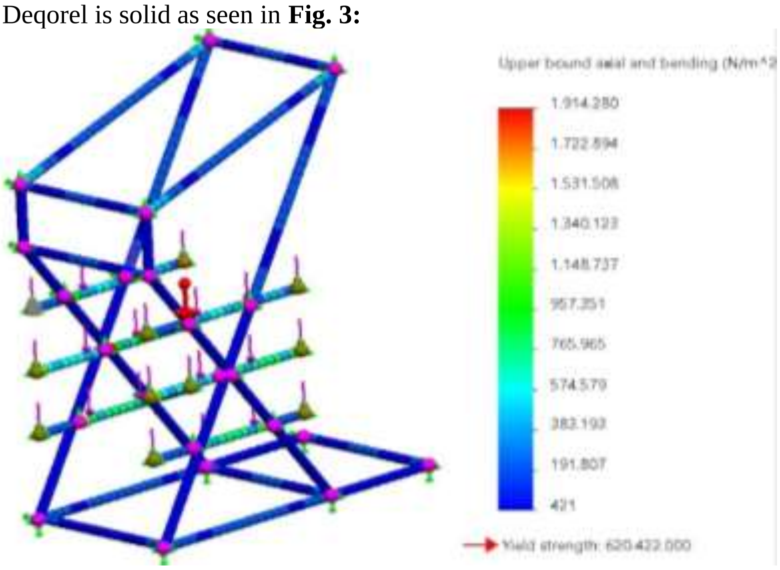

Fig. 3. Frame

This frame uses 304 stainless steel with a thickness of 0.5 mm - 1.5 mm in this frame we can test its strength in several ways, namely:

1) Axial stress
   The axial stress is calculated based on the axial force (F) and cross-sectional area (A) of the frame element:

$$\sigma^{a} = \frac{F}{A} = \frac{1{,}03754}{2{,}37\ x\ 10\text{^}{-4}} = \ 4.38 \text{ Pa}$$

2) Bending stress
   The bending stress is calculated based on the bending moment (M), moment of inertia (I), and distance from the neutral axis to the outermost fiber (c):

$$\sigma^{b} = \frac{M.c}{I} = \frac{0{,}16202\text{N}\ .0{,}01065\text{m}}{2{,}922\times 10*-9} = 0.0005905 \text{ x } 10^{-9}$$

3) Combined stress
   For frame elements subjected to a combination of axial and bending, the combined stress (σt) is calculated by summing the axial and bending stresses:

$$\sigma t = \sigma^{a} + \sigma^{b}$$

$\sigma t = 4.38$ Pa + 0.0005905×10^{-9}
$\sigma t = 4.3805905 \times 10^{-9}$

4) Safety Factor
The factor of safety (FS) is compared to the yield stress (σy) of the material:

$$FS = \frac{\sigma y}{\sigma^{a}}$$

$$FS = \frac{6{,}20422\ x\ 10^{8}}{4{,}38}$$

FS = 1.4164

5) Maximum Deflection

To ensure the frame does not deform excessively, the maximum deflection (δ) needs to be calculated, using elasticity formulas, such as:

$$\delta = \frac{F.L^{3}}{48.E.I}$$

$$\delta = \frac{15.(0.35)^\wedge 3}{3.(2{,}1\ x\ 10^{11}).(2{,}922\ x\ 10^{-9})}$$

δ = 0.349 mm

The following is a detailed table of the results of the frame analysis on Deqorel

Table 2. Detailed results of frame analysis

category	**here**
Name of study	Robot frame
Analysis	static
Materials	304 stainless steel ➢ Yield strength = 6.204 x 10^8 N/m^2 ➢ Tensile strength = 7.238 x 10^8 N/m^2 ➢ Elastic modulus = 2.1 x 10^{11} N/m^2 ➢ Density = 7,700 Kg/m^3
Force and load	➢ Force = 15 N (on 6 beams) ➢ Gravity = 9.81 m/s^3
Mesh	➢ Total nodes = 533 ➢ Total elements = 542 ➢ Mesh time = 00:00:02
Results and style	➢ Resultant force = 208.052 N ➢ Resultant moment = 0.144 N.m.
Simulation results	➢ Maximum stress = 1,914,280 N/m^2 ➢ Maximum Displacement = 0.0028 mm ➢ Minimum safety factor = 324

6. Wheels
The wheel has the main function of allowing the robot to move autonomously or be controlled to deliver food to customers. These wheels allow the robot to navigate around the restaurant area and reach the intended table.

7. Sensor
   At the bottom of the restaurant waiter robot is a series of sensors designed as a line follower. These sensors allow the robot to detect and follow the path of a predefined line on the restaurant floor. When the sensors detect a color change from the background to the line, a signal is sent to the microcontroller which instructs the DC motors to adjust the robot's direction of movement. With these sensors in place, the robot can move with precision along the predefined path, ensuring efficient and error-free delivery of food and drinks to customers' tables.

   The Deqorel is designed with trajectory sensors for precise auto-navigation, energy-efficient motors, and a GUI-based user interface (Tkinter/PyQt or HTML/CSS). The Deqorel is able to move accurately, avoid obstacles, and improve service efficiency by using quality materials such as stainless steel and Lithium-ion batteries. On the other hand, the journal Wireless Waiter Robot proposes a waiter robot with LCD-based E-Menu features and an integrated payment system using a credit card. This robot uses a Bluetooth wireless communication system to take orders and process payments,[10],[11] in contrast to Deqorel which relies more on manual control through a GUI. In addition, the navigation system is still line follower-based, but is equipped with an IR sensor to detect the path and determine the location of the customer's table. Meanwhile, Maysheila P. Sembung's journal also developed a simpler line follower-based restaurant waiter robot. This robot uses LED and photodiode sensors to detect black lines on the floor. The robot is controlled by an ATMega 16 microcontroller with an open-loop control system, and is equipped with a voice module to provide information to customers when food is delivered.

Overall, these three studies have similarities in the use of a line follower as a navigation system and the use of a microcontroller as a control center. However, Deqorel is superior in terms of design reliability and intuitive user interface. The Wireless Waiter Robot offers more interactive payment and E-Menu features, while the robot in Maysheila's journal is equipped with a voice system for a better customer experience. These differences show that innovation in restaurant waiter robots continues to evolve according to industry needs and available technology.

CONCLUSIONS.

This research successfully developed an intelligent waiter robot called Deqorel designed to improve service efficiency in restaurants. Deqorel uses trajectory sensor-based automatic navigation technology and optimization algorithms, which allows the robot to move accurately and quickly in a dynamic restaurant environment.

The results show that Deqorel can reduce errors that often occur due to worker fatigue and human error factors, and increase customer satisfaction. With a design that uses quality materials, energy-efficient motors, and an intuitive user interface, Deqorel is not only operationally efficient but also easy to use by restaurant staff.

This innovation shows great potential in the application of robotics technology in the service sector, and is expected to be a solution to overcome challenges in restaurant service and improve productivity and customer experience.

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