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Measuring the capacity limit in children's school bags using ESP32 microcontroller and GPS tracker

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ABSTRACT

Backpacks are the main choice for students as a means of carrying school supplies and materials, but often they do not pay attention to the weight of the load they carry every day, potentially causing injuries and pain in the back. This study aims to design and implement a capacity limit measuring device on children's school bags using the ESP32 microcontroller as the control center. The tool is equipped with a 10kg load cell sensor to accurately measure the weight of the bag, as well as a keypad as a user interface to easily enter the child's weight. Safety is also considered with the addition of a buzzer as an alarm if the weight of the bag's capacity exceeds the set limit. GPS trackers are also integrated to monitor the geographical location of bags, allowing parents to monitor the movement of children and the location of bags directly through Telegram bots. With ESP32 as the brain, this tool provides a comprehensive solution to maintain the health and safety of children in carrying their school load. This tool also utilizes Telegram technology to provide direct notifications about the weight and location of children's bags to parents or other users. Telegram bots connected to this tool automatically transmit this information, providing additional convenience and security for users.

Introduction

When children go to school, they often carry books, stationery, and other utensils in their bags. The heavy weight of a child's bag can hurt their health, such as problems with the spine and poor posture (Faridah, 2023). Therefore, it is crucial to ensure that the weight of the child's bag remains within safe limits for their health. Using a backpack is considered the best method to distribute the load symmetrically, thus reducing pressure on the spine (Trisnawati, 2020). Choosing a backpack with two shoulder straps is obviously more advisable than a duffel bag or a sling bag, because in such a bag, the entire load will be carried by one shoulder only. Although there is no absolute limit regarding the standard weight of the bag that is allowed, it is necessary to pay attention to it in order to continue to prioritize the health of the child (Putri, Oktarin, & Setiawan, 2020).

Pain in the back of the body can be described as discomfort that is felt locally or involves nerve roots, or both, that are localized around the thoracolumbar or lumbosacral region (Handayani, 2023). The results of a survey conducted by the Archives of Disease in Childhood on 1,403 students showed that as many as 61.4% of them experienced pain in the lower back. This incident is more commonly experienced by students aged 12-17 years (Setiaji, 2020). These findings reflect that pain in the lower back is a common complaint, especially in 12-17-year-olds, which is a period of rapid growth. Another factor that plays a role is the habit of carrying backpacks with excessive weight when children should not carry more than 10% of their body weight [2].

The American Occupational Therapy Association (AOTA) and the American Physical Therapy Association (APTA) recommend that students do not carry backpacks that weigh more than 15% (or are in the range of 10% to 20%) of their body weight. In 2012, this recommendation was changed to a maximum of 10% of the student's body weight. Meanwhile, the American Chiropractic Association (ACA) recommends that children's backpack weight not exceed 5–10% of their body weight (Widyantari, Patni, & Paramurthi, 2023).

The purpose of this study is to design and implement a capacity limit measuring device on children's school bags that can help overcome the problem of lack of attention to the weight of backpacks which can cause the risk of injury and pain in children's backs.

Research related to capacity limit measuring tools on children's school bags using ESP32 microcontroller and GPS Tracker (Ratih, Saraswati, Antari, & Negara, n.d.). This research is titled "Smart Bag Weight Detection Equipped with Loadcell Sensor with Brainstorming Method". The tool uses an Arduino Uno with a loadcell sensor that can load a capacity of up to 5 kg. In addition, the HX711 module converts the change of resistance into voltage. The voltage is then converted to ground, which is displayed on the LCD. If the weight of the bag reaches more than 10% of the user's weight, the message "Overload" will appear on the LCD screen and a beep will be heard as a warning [4].

The next research is entitled "Making a Prototype of a Backpack for School Children with an Arduino Uno Microcontroller". In this study, the tool was made using an Arduino Uno microcontroller coupled with a 5 Kg loadcell weight sensor with an HX711 scale module with buzzer supporting components and LCD (Liquid Crystal Display) 2 x 16 characters. The way this tool works is to detect if the weight of the load exceeds the safe limit, then there is a danger warning and alarm that the weight of the load is not suitable to be carried if the weight of the load exceeds 10-15% of the body weight. The weight sensor performs well with calibration of less than 5 % accuracy difference with perpendicular position weighing measurements [5].

In 2021, the research was entitled "Design and Build a NODEMCU-Based Backpack Security System ESP8266 with Android Application Notifications". In this study, NodeMCU and GPS module function to help find out the position of the backpack so that its existence status can be known. The vibration sensor and buzzer function to help the user if someone opens the bag so that when the vibration sensor is in the HIGH condition, a notification will be displayed on the "Secure Bag" application and the location of the bag can be seen. The location accuracy level on the Android application was 95% from three trials with different locations (REVITA LARASATI, 2021)

The research is titled "Smartbag with Arduino-Based Security System with PIR Sensor and GPS via SMS". The design of programs and algorithms on backpacks with quick response has been carried out and obtained good results because overall the design consisting of emergency alarms, motion detectors, and tracking devices that can be controlled via SMS has been appropriate and can be applied to backpacks (Mohammad Farid Susanto, M. Azam Gresa Mahendra & Anggraeni, 2020)

Method

The research method for the project of developing a children's school bag capacity limit measuring device with an ESP32 microcontroller can involve several stages of research and development. Here are the general steps that can be taken:

1. Literature Studies

A literature study was conducted to identify previous research related to the use of load cell sensors, ESP32 microcontrollers, keypads, buzzers, and GPS in similar projects.

2. Tool Planning

The design of the tool aims to design a scheme of the device system for measuring the capacity limit of children's school bags.

3. Prototyping

Prototyping is done to implement the design into a physical prototype.

4. Final Evaluation

The final evaluation aims to evaluate the system's response to bag weight variations, the accuracy of the loadcell, and the sensors to the success of the system.

Tool Work System Flow Chart

The flow diagram of the work system of the tool used in this study can be seen in Figure 1. In the initial stage, the microcontroller will initialize the module module connected to the microcontroller, after all the modules are ready, the ESP32 will try to connect to wifi to get an internet connection. After successfully connecting to the new internet, the tool will allow to input the child's weight. After the weight is inputted, the maximum load that can be carried by the child will be automatically calculated. After success, the LCD will display the words "SMART BAG" where he will enter the loop to send the current location to the telegram, and if the weight of the bag exceeds the maximum capacity that the child can carry, the buzzer will automatically turn on and notify the telegram that the child is carrying a load that exceeds the capacity. If the load has been reduced then the buzzer will stop.

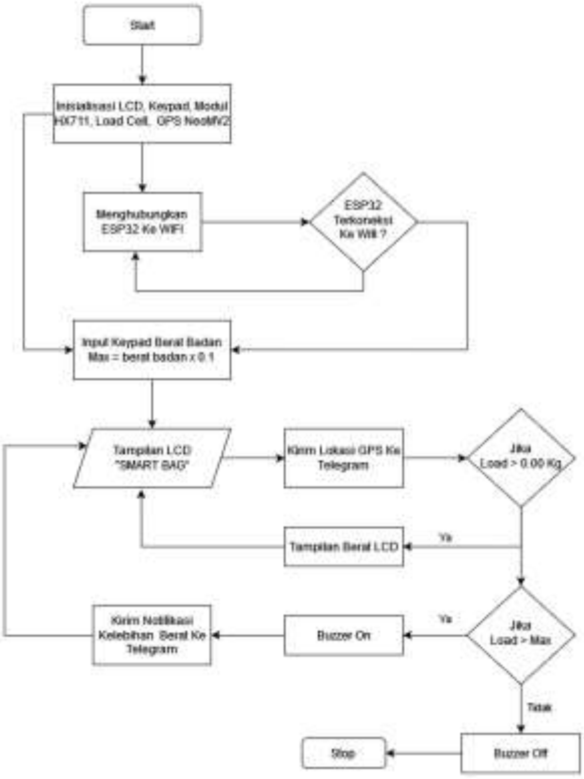

Figure 1. Tool Flow Diagram

Schematic Networks

Schematic circuits are created to combine the components used with fritzing applications. It can be seen that the LCD is connected to an I2C pin, where I2C will minimize the use of ports on the ESP32. The LCD will display the weight of the bag (load weight) as well as the maximum weight of the backpack. Furthermore, there is an HX711 module that is connected to an Arduino Uno pin as a module to calculate the weight of the load on the load cell. Then there is a 3x4 keypad that is useful for inputting the child's weight. Then there is a buzzer that functions as a warning alarm when the load on the loadcell exceeds the set maximum weight. Lastly, there is GPS which is used to track the geographical location of the bag and provide information to parents through Telegram notifications. The overall schematic range can be seen in Figure 2.

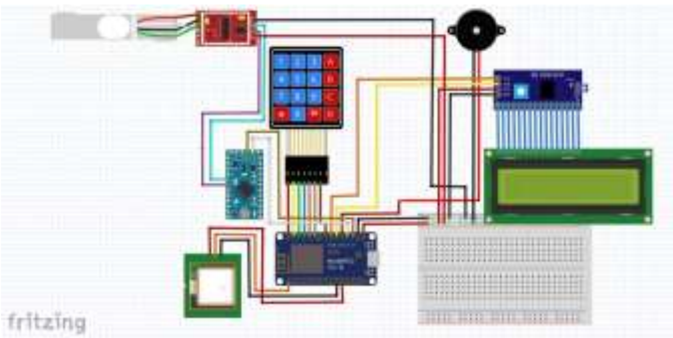

Figure 2. Overall Schematic Network

Tool Design and Design

At this stage, the researcher designs the tool in the form of a 3D design design. The 3D design of the bag and tools can be seen in the image below:

Figure 3. Backpack Design

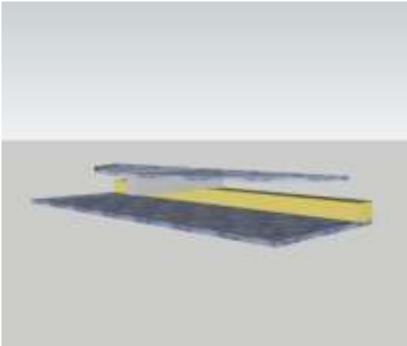

Figure 4. Mechanical Design

Results and Discussion

Load Cell Testing

Load cell testing is the first step to obtaining the necessary measurement results and data. The test was carried out by applying a load on the load cell and was carried out 3 times. After that, look at and record the change in the weight of the load read by the loadcell, and compare the weight of the load read by the loadcell with the actual weight of the load.

Table 1
Load Cell Testing

Name Thing	Sum	Load Weight Yield Loadcell Measurement				Heavy Burden Actually	Error (%)
		Ke-1	Ke-2	Ke-3	Rata-Rata		
Tumbler	1 pcs	0.39	0.38	0.39	0.38	0.39	97%
Buku Tulis	5 buah	0.61	0.61	0.61	0.61	0.61	100%
Lunch Box	1 pcs	0.46	0.45	0.45	0.45	0.46	97%
Package Book	3 buah	1.26	1.26	1.26	1.26	1.26	100%
Hp	1 pcs	0.22	0.22	0.22	0.22	0.22	100%

From Table 1. The overall results of the test and measurement of the weight of the load placed on the sensor *load cell* are displayed. The measurements and calculations obtained from the 1 pcs lunch box are as follows:

$$\text{Average load weight} = \frac{\text{Total}}{\text{Amount of Data}} = \frac{0.47+0.47+0.47}{3} = 0.47 \text{ Kg}$$

$$\text{Error} = \frac{\text{Average Weight}}{\text{Actual Weight}} \text{x } 100 = \frac{0.47}{0.46} \text{ x } 100 = 97\ \%$$

LCD Testing

LCD testing is carried out to find out if the LCD can display the display according to the given program and can receive input from the keypad. When the device is turned on the LCD will display "SMART BAG", then when the weight is input through the keypad the LCD will display "Child Weight: ... kg" after the load is put into the child's bag or placed on the loadcell, the LCD will display "Bag Weight: ... Kg" "Max Weight: ... kg". The LCD can be seen in the image below.

Figure 5. LCD Initial Display

Figure 6. LCD Display When *Child Weight* Input

Figure 7. LCD Display When Load Has Been Inserted

3x4 Keypad Testing

The keypad test is carried out to find out the truth of the working principle of the microcontroller through the keypad. The keypad is used to input the child's weight which will later be displayed on the LCD. The keypad test can be seen in the image below.

Figure 8. *Kid Weight* Input Keypad Testing

Buzzer Testing

Buzzers are used to provide warnings or signals that the load put in the child's bag exceeds the maximum capacity or weight. The results of the buzzer test can be seen in Table 2., below.

Table 2. Buzzer Testing

Percobaan	Input Berat	Bag Contents Weight, Loadcell Detection (kg)	Status	*Buzzer*
1	24 Kg	1.9 Kg	Normal	No Sound
2	24 Kg	2.1 Kg	Normal	No Sound
3	24 Kg	2.5 Kg	Commemoration	Sound
4	24 Kg	2.7 Kg	Commemoration	Sound
5	24 Kg	2.8 Kg	Commemoration	Sound

GPS Testing

GPS testing is carried out to test the accuracy of distance data on the device. So that parents can find out the position of the bag used by the child. Here are the images from the GPS test.

Figure 9. Bag Location

Overall System Testing

The results of testing and analysis of the tool are carried out to find out whether the tool is functioning properly as a whole, either in the mechanical circuit or the electronic circuit. The overall testing of the tool began with weight input, bag weight readings, warning alarms, and bag geographic location notifications. The following overall test results obtained by placing varying loads on the *load cell* can be seen in Table 3.

Table 3
Overall Testing

Percobaan	Indikator	Keterangan
Percobaan 1	Tampilan *“SMART BAG”*	Berhasil
	Input Berat Anak	30 kg
	Input Berat Beban	1.00 kg
	Tampilan Berat Tas	1.80 kg
	Tampilan Berat *Max*	3.00 kg
	Buzzer	Tidak Berbunyi
	Notifikasi Telegram	Berhasil
	Status	Normal
Percobaan 2	Tampilan *“SMART BAG”*	Berhasil
	Input Berat Anak	30 kg
	Input Berat Beban	1.50 kg
	Tampilan Berat Tas	2.30 kg
	Tampilan Berat *Max*	3.00 kg
	Buzzer	Tidak Berbunyi
	Notifikasi Telegram	Berhasil
	Status	Normal

Percobaan 3	Tampilan *“SMART BAG”*	Berhasil
	Input Berat Anak	30 kg
	Input Berat Beban	2.00 kg
	Tampilan Berat Tas	2.80 kg
	Tampilan Berat *Max*	3.00 kg
	Buzzer	Tidak Berbunyi
	Notifikasi Telegram	Berhasil
	Status	Normal
Percobaan 4	Tampilan *“SMART BAG”*	Berhasil
	Input Berat Anak	30 kg
	Input Berat Beban	2.50 kg
	Tampilan Berat Tas	3.30 kg
	Tampilan Berat *Max*	3.00 kg
	Buzzer	Berbunyi
	Notifikasi Telegram	Berhasil
	Status	Peringatan
Percobaan 5	Tampilan *“SMART BAG”*	Berhasil
	Input Berat Anak	30 kg
	Input Berat Beban	3.00 kg
	Tampilan Berat Tas	3.80 kg
	Tampilan Berat *Max*	3.00 kg
	Buzzer	Berbunyi
	Notifikasi Telegram	Berhasil
	Status	Peringatan

From Table 3. Above is displayed the overall test results. The measurements and calculations of the bag weight display obtained from experiment 4 are as follows.

Bag Weight Display = Bag Weight + Load Weight Loadcell Measurement Result
= 0.80 + 2.50
= 3.30 Kg

Conclusion

With the development of this system, it is hoped that it can increase the awareness of parents and teachers about the burden of bags carried by children. This smart solution is expected to be the first step in preventing back injuries due to excessive burden on children. Further research can be conducted to optimize the system and expand its application to the wider educational environment.

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