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An Intelligent Following Sensor Shopping Cart

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Abstract: ***Conventional trolley needs to be pushed physically around the building. When more items are placed in the trolley, the trolley becomes heavier and harder to navigate. In order to solve this problem, this paper proposes a modification made to the conventional trolley and discusses the viability of using color as the automatic following mechanism on the shopping cart. Two tests are conducted to investigate the performance of the intelligent shopping cart. The first test is to find the most suitable color whereas the second test is to evaluate the reliability of color to be used as the following mechanism. The assessment of results utilized Euclidean distance equation and Matlab/Simulink. The results shows that the Red Green Blue (RGB) pixel value of the chosen colors are changing as the trolley moves around the building because of the lighting position and intensity around the building. The color detection apps is able to endure a limit of 18.03% of color difference from the original selected color before it loses the reference. The utilization of only color as following mechanism has a high tendency to be disrupted by noise because of an adjustment in light intensity and lighting position.***

Keywords: ***Euclidean distance, Following sensor, Pixel***

I. INTRODUCTION

Today, individuals create technology to make life simpler and better. The utilization of robot is quickly expanding in numerous field [1], [2]. Usually in shopping center or market, the trolley or cart is typically self-served by the client. This situation is less convenient to some of us that have to juggle to look for groceries while guarding children at the same time. Besides, this will be a problem for elderly and pregnant women as the trolley will be heavier to push with more items placed. In relation to that, this paper proposed an Intelligent Following Sensor Shopping Cart that helps individuals to effectively shop at the shopping center or market without driving their trolley around.

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The proposed Intelligent Following Sensor Shopping Cart will be built using Arduino that will be communicating with smart phone installed with color detection Android application via Bluetooth. Ultrasonic sensors are also embedded in the trolley to automatically stop moving when an object is detected and stay in safe distance between the users.

The aim of this research is to design and build a prototype of an Intelligent Sensing Trolley Follower that responses from the data of pre-made Android Application Color Detection which allows the trolley to follow the selected human leader. Other than that, this paper also evaluates the suitable color and the reliability of using color detection for automatic following mechanism. The design of Intelligent Following Sensor Shopping Cart is by utilizing client smartphone camera that is installed with a pre-made Android application as the color detection sensor. This application will differentiate the Red Green Blue (RGB) pixel between the selected leader color and the background images and calculate the pixel movement of the leader. Furthermore, the trolley will be installed with a safety feature, in this case, the obstacle detection.

We organize our paper as follows. In Section II, the related works on robot follower and other suitable components are presented. Section III, we introduced our Intelligent Following Sensor Shopping Cart working principle and setup. In Section IV, we presented our modification results and discussion on the reliability of using color as the following mechanism also introduce our future work. Lastly, Section VI, we concluded our paper.

II. RELATED WORKS

This section describes related works on various approaches of automatic follower mechanisms and the components needed to build the Intelligent Following Sensor Shopping Cart. Summary of this section is tabulated in Table 1.

Zaman et al. [3] proposed a prototype of a line following robot. The robot was integrated with two different modes which are following mode and obstacle detection mode. These two modes were embedded in a processing board, Arduino Uno. The line following robot was installed with three ultrasonic sensors to enable the obstacle avoidance mode and an infrared sensor which was used to differentiate between the white surface and black line as the following mode. The overall design implementation by Zaman et al. has established a low power consumption and cost-efficient robot. However, the design needs a predefined track to operate and it will be a disadvantage to always change the track when a modification to the building is made.

A different design is proposed by Chalke et al. [4] where ultrasonic sensor is also utilized in follower robot. In this research, Chalke et al. introduced a contactless system that allows luggage carrier to automatically follow a human leader using ultrasonic sensor detection. Their prototype was equipped with Atmega Microcontroller, L293D type motor driver and ultrasonic sensor that is installed at the front and top of the luggage carrier.

The use of ultrasonic sensors is suitable as ultrasonic is immune to smoke and dust which allow the design to be used in indoor and outdoor environment. However, the reflected ultrasonic sensor can be interrupted by the surrounding object. Other than that, there is also a design approach that implements infrared sensor to identify the surface material such as proposed by Nanda et al. [5]. They proposed a robot design which focused on safety for an autonomous car. The system design was able to automatically manipulate the speed of the robot according to the surface detected by the infrared sensor. The robot was driven by Direct Current (DC) Motor, Arduino microcontroller and two ultrasonic sensors to for object detection. Nanda et al. also stated that the surface detection module was built using Sony remote which has infrared Pulse Width Modulated (PWM) wave generation. Based on the robot design of this paper, the safety features are important to be taken into consideration. Nonetheless, the design does not include any steering automation implemented in their robot. There is also research such as Pahuja et al. [6] where the paper introduced a wirelessly controlled robot. Their robot was built to integrate with Android application that communicates wirelessly via Bluetooth with the AT89S52 microprocessor board. The processing unit is connected with Serial Bluetooth product, L293D motor driver and DC motor. This design has the advantages of having a remote control robot and a portable controller. However, no safety features are integrated into the design in order to avoid human mistake during operation.

Sefat et al. [7] designed an autonomous robot that implements image processing and pattern matching to the system. The design was utilizing optical flow calculation of the Lucas-Kanade Method and Kalman filter that has been used for obstacle avoidance and control of robot system respectively. The proposed design, however, needs a high processing unit to evaluate the environment for the robot movement and those processes cannot be handled by a small microcontroller such as Arduino.

Based on the literature review, Arduino is chosen as for the main processing unit for the Intelligent Following Sensor Shopping Cart as it is a reliable microprocessor board and has used in a various research project such [8]–[13]. In this prototype development, Arduino 2560 is chosen as it has 54 digital input, output including 15 PWM outputs pins and 16 pins analog type signal. It proves that it has enough pin to connect all the equipment for the trolley [14]. Other than that, the Arduino is also needed to process data from sensors and color movements in order to drive and steer the motor.

The Intelligent Following Sensor Shopping Cart is utilizing a pre-made color detection Android application that is installed in the user's phone. The function of the app is to send data via Bluetooth communication port to the microcontroller on the trolley. In this way, the movement data of the user can be wirelessly transmitted and low data processing can be maintained on the Arduino board. The trolley is also embedded with safety features that allow the trolley to automatically stop the motion when the object is detected and stay in safe distance between the users. Ultrasonic sensors are selected as the module is immune to noise, dust and smoke as stated in [15].

Table. 1 Summary of previous work on follower mechanism

Author(Year)	Related Work	Methodology	Advantages	Disadvantages
H. U. Zaman et.al (2016) [3]	A novel design of line following robot with multifarious function ability	• Robot has the capability to follow a black line by using infrared sensor. • Obstacle detector is implemented using the ultrasonic sensor. • Using Arduino Uno microcontroller.	• Compact design, easy to modify and upgrade	• Need a predefined track to operate
A. Chalke et.al (2017) [4]	Follower Robotic Cart Using Ultrasonic Sensor	• Designed to carry luggage while the cart is following the user. • Three ultrasonic detectors connected to the ADC and the value is compared to the microcontroller • Using Atmega microcontroller.	• Not affected by dust and smoke	• The reflection of ultrasonic waves can be interrupted by object

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S.Nanda et.al (2015) [5]	Real-time surface material identification using infrared sensor to control the speed of an Arduino based car-like mobile robot	• Use infrared as surface detection rather than obstacle avoidance. • The detection module was built by using Sony television remote that has Infrared Pulse width modulation.	• Able to configure speed in different terrain	• Does not have any automatic leader-follower mechanism
R. Pahuja et.al (2014) [6]	Android Mobile Phone Controlled Bluetooth Robot Using 8051 Microcontroller	• Using the Bluetooth connection between Android Phone Controller and the robot. • Android application is created for the controller interface.	• Designed to have portable controller	• Does not have any safety feature to avoid human mistake
M. S. Sefat (2014) [7]	Design and implementation of a vision based intelligent object follower robot	• Using a vision-based robot follower. • Divided into two modules: fast template matching and color detection.	• Image captured is also used as the obstacle avoidance	• Need high processing unit for image processing and color recognition

III. METHODOLOGY

This section describes the design of the Intelligent Following Sensor Shopping Cart such as system flowchart and wiring diagram. It also presents the design sketch and procedure for performance analysis.

System Design

In this paper, a trolley that intelligently senses selected color on human is designed. The trolley has the ability to automatically follow and adjust the parameter such as distance and speed according to its surroundings. The system consists of an automatic cruise system that is controlled via color sensor application and collision avoidance using sensors application. Firstly, for the cart following mechanism, camera sensor will detect the position and direction of the selected color on a human to follow before returning the pixel distance to the Arduino. Then, based on the measured pixel distance, the program in Arduino Mega 2560 microcontroller will determine the response of the motor speed and directions of the color leader. Secondly, the safety braking system will be implemented by using the ultrasonic sensor which is used to stop the cart and ensure that it always operates in a safe distance from the user. Equation (1) is used to determine the distance of the obstacles by capturing the travel duration of the echo pulses of the ultrasonic sensor and divided with the speed of sound. The communication of the Android Application and Arduino are connected using Bluetooth module. The pseudo code and flow cart of the trolley's working principle are shown in Table 2 and Figure 1 respectively. From Figure 1, it shows that the system starts with establishing Bluetooth connection and selecting a preferred color on the apps. The apps will return a string of pixel distance value to the Arduino in order to determine the motor control. During this process, the ultrasonic sensor will continuously check the distance of the user and stop the system if the measured distance is below 25cm.

$$Distance = (PulseIn\ (Echo, High)\ /\ 2)\ /\ 29.1 \quad (1)$$

Table. 2 Arduino pseudo code for the Intelligent Sensor Following Shopping Cart

```
Pseudo code 1: Intelligent Sensor Following Trolley
        Initialize: pin setup; (Trig, Echo, Tx, Rx, Motor Control)
        Define: threshold values and variable;

        loop( )
        while (Serial. Available( ));                    //check bluetooth serial port
              trigger all ultrasonic sensor;
              distance = (PulseIn (Echo, High) / 2) / 29.1;  //measure object distance
               if (data == '#')
                     x = Serial.parseInt();             //read pixel distance from the apps
                      if(data == '@')
                           y = Serial.parseInt();
                         process();                     //goto process function
               end if

        process( )                                       //motor control
        enableRight = map(x, 0, 100, 0, 255);
```

```
enableLeft = map(y, 0, 100, 0, 255);
    //Right motor control
        if (enableRight > 0 & distance > 25 )
          turn right motor clockwise;
        else if (enableRight< 0 & distance > 25 )
          turn right motor counter-clockwise;
        else
            stop right motor;                    //stop when distance below 25cm
    //Left motor control
        if (enableLeft> 0 & distance > 25 )
          turn left motor clockwise;
        else if (enableLeft < 0 & distance > 25 )
          turn left motor counter-clockwise;
        else
            stop left motor;                     //stop when distance below 25cm
Serial.flush();                                  //flush serial port
```

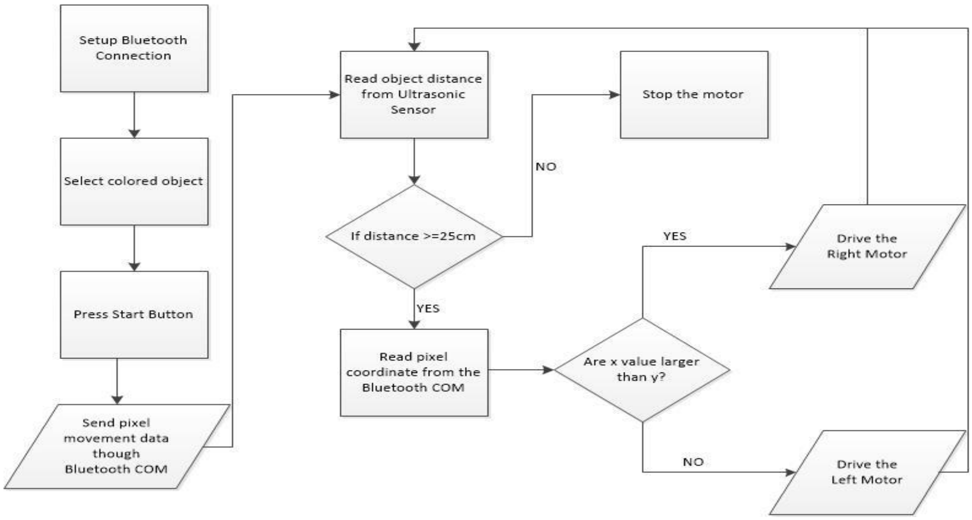

Fig. 1 The system flowchart for Intelligent Sensor Following Shopping Cart

Electrical Circuit Design

The block diagram of the entire component for the Intelligent Trolley Follower integrated on the Arduino is shown in Figure 2. The trolley prototype is installed with Arduino Mega 2560, a pair of direct current motors and driver, single Bluetooth module, 12V battery for motor power source, and three Ultrasonic modules for distance measurement. The pin setup for the circuit is stated in Table 3 below.

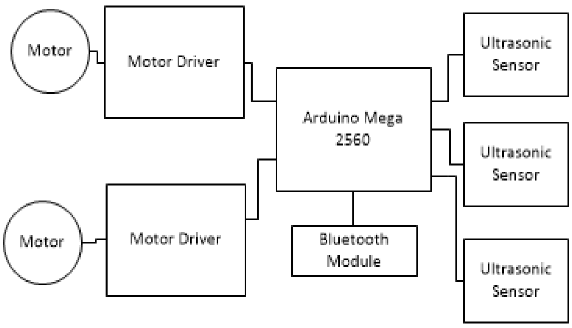

Fig. 2 Block connection of the Intelligent Following Sensor Shopping Cart

Table. 3 The pin setup on Arduino Mega 2560 board

Component	Assigned Pin
Ultrasonic Trigger	30,32,52
Ultrasonic Echo	31,33,53
Motor Enable Right	12
Motor Enable Left	13
Left Motor PWM	9,8
Right Motor PWM	10,11
Bluetooth TX	01(RX)
Bluetooth RX	02(TX)

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Mechanical Design

The shopping cart is designed for shopping complex usage. Therefore, the prototype is built in the same size as actual trolley and must be easy to use with a compact design. The design of the cart is firstly sketched using design software, in this case, is Sketch Up. The sketch is important to build a conceptualize structure of the prototype before any modification work started. Other than that, the prototype is designed to have a strong structure in order to support equipment and devices that are attached to the trolley frame. The design of the prototype is modified from the original structure of small conventional trolley as shown in Figure 3.

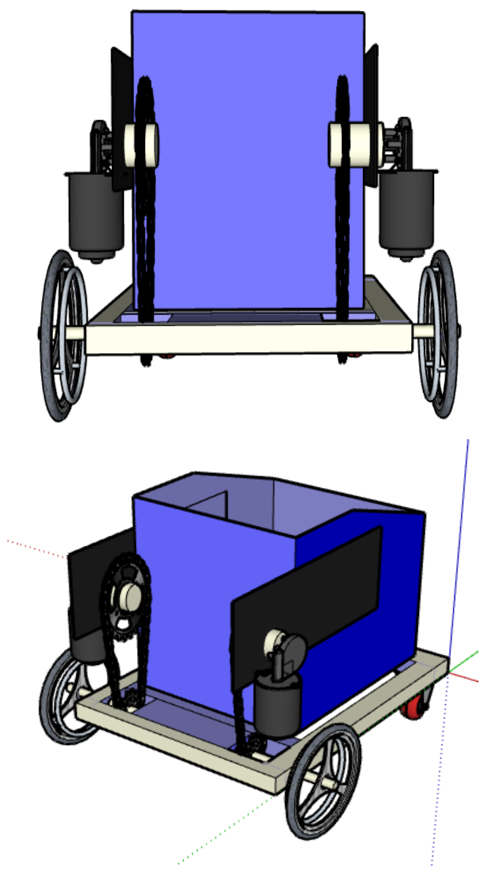

Fig. 3 Rear view and finished modification design sketch of the prototype

Following Mechanism Analysis Setup

The analysis is done to study the behavior of color detected through the Color Detection application in the user's phone. Therefore, suitable color for camera detection will be determined before the actual test run using Euclidean distance Equation (1). Then, Intelligent Following Sensor Shopping Cart will be moved around the shopping complex and the color reaction in the smartphone screen is investigated to discover the contrasts between the first references and surrounding area before the application loses its recognition by using Equation (2). The equation are implemented to identify the distance between two different point where by the r, g, b will be representing Red, Green, Blue value of the respective color. Then, the percentage tolerance of color differences that can be handled by the application is calculated using Equation (3) which compares the corresponding color distance with the initial RGB value.

Equation (3) is also used to find the suitable color for detection by calculating the percent different of the colored paper RGB value with the background RGB value. For this analysis, Droid Cam software is utilized to connect HTC Blade 310 to the Matlab/Simulink video viewer for pixel RGB value evaluation as shown in Figure 4.

$$Color\ Distance = \sqrt{(r2-r1)^2+(b2-b1)^2+(g2-g1)^2} \quad (2)$$

$$Percentage\ tolerance(\%) = \frac{Color\ distance}{\sqrt{inital\ RGB}} \times 100\% \quad (3)$$

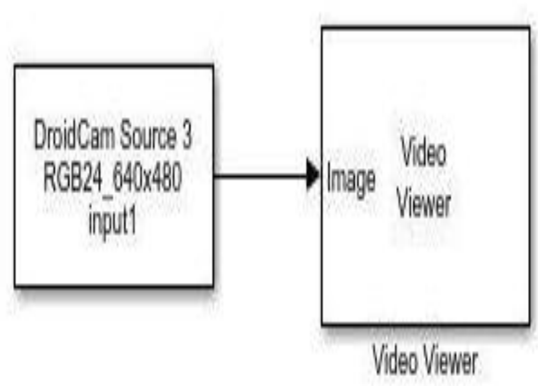

Fig. 4 The block connection in Matlab/Simulink for performance analysis

IV. RESULTS AND DISCUSSIONS

In this section, the outcome from the modification of conventional trolley and the performance analysis of Intelligent Following Sensor Shopping Cart is evaluated. Percentage difference in a color that can be tolerated before the apps lose its references are stated in this section. As stated in the previous section, the comparison is done by using a video view, a Matlab/Simulink block to identify the pixel color values captured by the camera sensor. Then, it is evaluated using the formula discussed in the previous section.

Prototype Results

Firstly, in order to create an automatic trolley mechanism, a prototype is built by modifying the conventional shopping cart. The cart is assembled together with DC- motors, ultrasonic sensors, and phone holder. Not only that, but an electrical box is also attached to secure the microcontroller and motor drivers. A new base is also added to the trolley in order to make the trolley more stable and be able to hold heavy items such as batteries and user groceries. The outcome of the trolley modification is as shown in Figure 5.

Fig. 5 The outcome of the modified trolley for Intelligent Following Sensor Shopping Cart

Color Selection Results

The system designed for Intelligent Following Sensor Shopping Cart is based on color movement that is detected on camera from user's smartphone. Therefore, a suitable color for detection of camera needs to be determined. In order to investigate the suitable color for detection, a simulation is conducted to provide the color differences based on the RGB value at the designated point. For this test, five different color papers which are blue, red, yellow, green and white are selected. Then, the pixel value of the background scenery and colored paper is recorded while the difference in color distance is calculated. Table 4 shows the results from Matlab simulation that is conducted.

Table. 4 Example of Matlab/Simulink results for pixel value different between background scenery and colored paper

	Pixel Value								
Background	R: 180 G: 188 B: 183	R: 179 G: 187 B: 182	R: 190 G: 193 B: 201	R: 193 G: 196 B: 204	R: 190 G: 197 B: 197	R: 185 G: 192 B: 192	R: 187 G: 192 B: 204	R: 185 G: 191 B: 196	R: 182 G: 188 B: 192
Colored Paper	R: 78 G: 166 B: 209	R: 77 G: 165 B: 208	R: 74 G: 165 B: 207	R: 74 G: 165 B: 207	R: 72 G: 165 B: 205	R: 73 G: 166 B: 205	R: 87 G: 160 B: 209	R:82 G: 160 B: 209	R: 80 G: 158 B: 206

The limitation of this test is recognized because of the low-resolution camera on the smartphone. However, it can be improved by utilizing a high-resolution camera. Higher camera resolution is able to improve the general tracking of the color movement as it can differentiate the pixels better. From the test, the most distinctive color that has the highest different from background scenery is Red which gives 41.15% of color different and followed by Green with 33.93%. The White colored paper has the lowest color difference which is just 14.8% as shown in Figure 6. Consequently, based on the simulation and Euclidean equation results, we can conclude that the suitable color for recognition is by utilizing Red color.

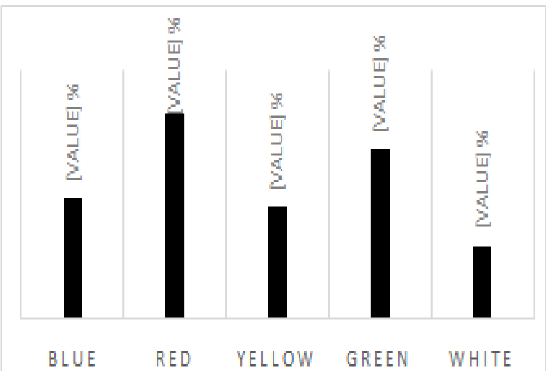

Fig. 6 The percentage different between background scenery and colored paper

Reliability Test Results

The reliability analysis is done to evaluate the viability of using color as the following mechanism for the Intelligent Following Sensor Shopping Cart. Based on the result, the video viewer shows a constant RBG value R:189 G:25 B:32 throughout all the selected colors that have been chosen from the previous test. Nonetheless, during the test run, the colors detected by the camera are consistently changing that also affect the RGB value displayed. This is shown in Table 5 that previews several of the pixel values that are extracted from the results in the video viewer. This result is caused by the lighting positions and differences in light intensity in the building resulting changes in color value detected at a different point. From Matlab/Simulink results, the maximum difference of RGB value that can be tolerated during the run and the initial analysis using the Euclidean distance equation as stated in the methodology section.

Table. 5 Example of Matlab/Simulink results for pixel value changes during the test run

	Pixel Value								
Initial pixel value	R: 189 G: 25 B: 32	R: 189 G: 25 B: 32	R: 189 G: 25 B: 32	R: 193 G: 196 B: 204	R: 189 G: 25 B: 32	R: 189 G: 25 B: 32	R: 189 G: 25 B: 32	R: 189 G: 25 B: 32	R: 189 G: 25 B: 32
Pixel Value During Test Run	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76	R: 243 G: 66 B: 76

From the Matlab/Simulink results, the maximum differences of RGB color value that can be tolerated by the apps during the test run are 18.3% with 80.8270 pixel difference as shown in Table 6. This result shows that if the color pixel detected is changing higher than 18.3% from the initial color selected, the apps will not be able to detect the reference and resulting in no data transmitted to the Intelligent Sensor Following Shopping Cart. Overall, the use of color for robot follower mechanism in this environment setup is because it has a high tendency to be affected by light intensity differences.

Table. 6 The results of the maximum percentage differences before the trolley loses its references

Distance Color Differences	80.8270
Percentage Differences (%)	18.3002

V. CONCLUSIONS

As the conclusion, this paper has proposed a prototype of Intelligent Following Sensor Shopping Cart that can automatically follow selected color using a color detection Android application integrated with the ultrasonic module and Arduino 2560 microcontroller. The objective of this paper is to study the viability of using color detection for automatic following mechanism. Therefore, a full design layout of the trolley is sketched by using Sketch Up software. Then, modifications are done by attaching suitable components such as a microcontroller, sensors, and body frame. The cart is brought to the shopping complex and the behavior of the application during the test run is recorded and analyzed using the Matlab/Simulink model. The results from the color selection test show that the suitable color for detection is Red which gives 41.52% of color differences with the background scenery followed by Green, Blue, Yellow and White. Other than that, based on the reliability test, the RGB values of the selected colors detected are changing inconsistently as the user moves around the shopping complex due to changing of light intensity around the place. The application can only tolerate a maximum of 18.03% of color different from the initial references. The usage of color has a high tendency of disturbance due to changes in light intensity and lighting position.

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