e-Yantra Robotics Competition - 2015

Implementation Analysis – Pizza Delivery Service

<eYantra-PD#1909>

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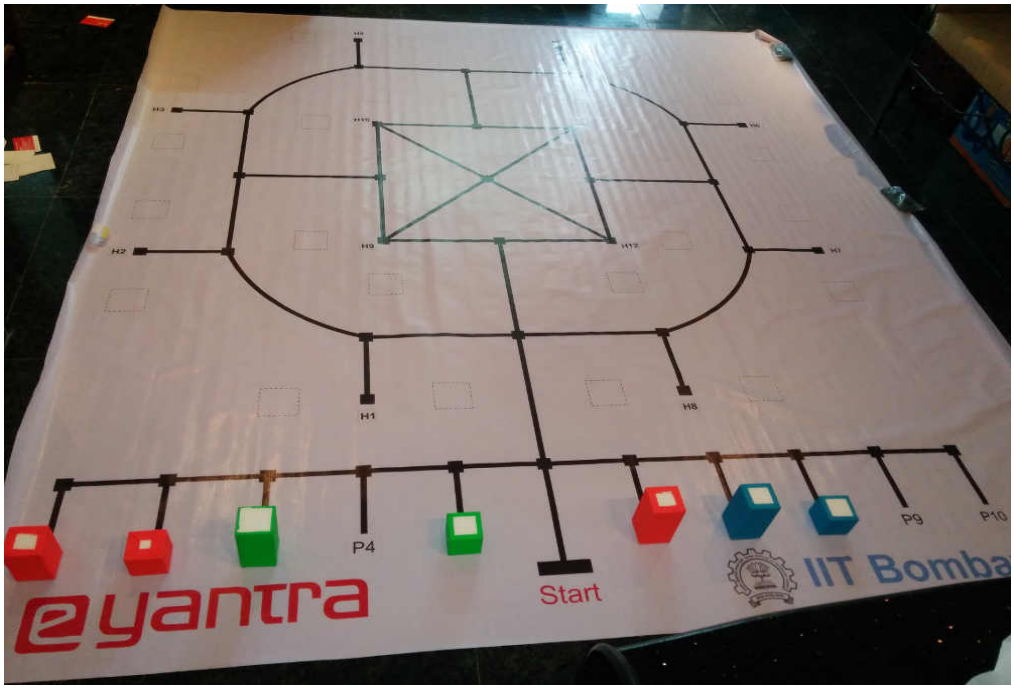
All images required in this document are available on Google Drive in case they aren't visible in the document.

Preparing the Arena **(5)**



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Design Analysis

Q-1. What do you understand by “Internal Timer”? and what is the significance of it in this theme. (5)

An internal timer is a timer controlled by the microcontroller using interrupts in order to separate the execution of time-sensitive code against code that runs and evaluates the functions of the bot that allow it to move, make decisions, and understand its surroundings.

The internal timer is very important because the bot needs to accurately represent how much time it has left for any given order, and the order timeline's solution is optimized using this time. The bot will be scored based on this time too, so it is paramount to ensure that it is reliable.

Q-2. Make a video in which time displays from 000 to 030 seconds on the Seven Segment Module. (10)

All files required to compile task 2's code are available in this zip.

The C code is replicated below. The three files must be linked together and the final hex file is then burned to the atmega2560 processor. This is done using the Makefile(s) seen in the zip.

SevenSegment.c:

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/delay.h>
#include "SevenSegment.h"

void seven_segment_pin_config() {
    // Port D upper nibble for CA connections
    // Port J for a,b,c,d, e,f,g,DEC as per manual
    // Both things above are in decreasing order
    // i.e.
    // Port J = Pin 7, 6, 5...0

    DDRD = DDRD | 0xF0; // set upper nibble of port D to output
    DDRJ = DDRJ | 0xFF; // set all bits to output
}

void seven_port_init() {
    seven_segment_pin_config();
}
```

```
void seven_init_devices() {
    cli(); //Clears the global interrupt
    seven_port_init();  //Initializes all the ports
    sei();   // Enables the global interrupt
}

int seven_convert_to_hex(int num) {
    int ret = 0x00;
    int values[10];
    values[0] = 0x03;
    values[1] = 0x9F;
    values[2] = 0x25;
    values[3] = 0x0D;
    values[4] = 0x99;
    values[5] = 0x49;
    values[6] = 0x41;
    values[7] = 0x1F;
    values[8] = 0x01;
    values[9] = 0x09;

    if (num >= 0 && num <= 9) {
        ret = values[num];
    }
    return ret;
}

void seven_display_num(int num) {
    int digit;
    int MIN_SELECT_VALUE = 0x10;
    int MAX_SELECT_VALUE = 0x40;
    int select_value = MIN_SELECT_VALUE;
    PORTD = PORTD & 0x0F; // Reset upper nibble to 0
    PORTD = PORTD | select_value;
    while (select_value <= MAX_SELECT_VALUE) {
        digit = num % 10;
        PORTJ = seven_convert_to_hex(digit);
        _delay_ms(5);
        select_value *= 2;
        if (select_value <= MAX_SELECT_VALUE) {
            PORTD = PORTD & 0x0F; // Reset upper nibble to 0
             PORTD = PORTD | select_value; // Set upper nibble value to select
                                           // apt CA
        }
        num /= 10;
    }
}
```

timer.c:

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/delay.h>
#include "timer.h"
#include "../buzzer/buzzer.h"

// TIMER4 initialize - prescale:1024
// WGM: 0) Normal, TOP=0xFFFF
// desired value: 1Hz
// actual value:  1.000Hz (0.0%)
void timer_timer4_init() {
    TCCR4B = 0x00; // stop
    TCNT4H = 0x1F; // Counter higher 8 bit value
    TCNT4L = 0x01; // Counter lower 8 bit value
    OCR4AH = 0x00; // Output Compair Register (OCR)- Not used
    OCR4AL = 0x00; // Output Compair Register (OCR)- Not used
    OCR4BH = 0x00; // Output Compair Register (OCR)- Not used
    OCR4BL = 0x00; // Output Compair Register (OCR)- Not used
    OCR4CH = 0x00; // Output Compair Register (OCR)- Not used
    OCR4CL = 0x00; // Output Compair Register (OCR)- Not used
    ICR4H  = 0x00; // Input Capture Register (ICR)- Not used
    ICR4L  = 0x00; // Input Capture Register (ICR)- Not used
    TCCR4A = 0x00;
    TCCR4C = 0x00;
    TCCR4B = 0x04; // start Timer
}

// This ISR can be used to schedule events like refreshing ADC data, LCD data
ISR(TIMER4_OVF_vect) {
    // TIMER4 has overflowed
    TCNT4H = 0x1F; // reload counter high value
    TCNT4L = 0x01; // reload counter low value

    timer_1s_magic();
}

void timer_init_devices() {
    cli(); // Clears the global interrupts
    timer_timer4_init();
    TIMSK4 = 0x01; // timer4 overflow interrupt enable
    sei();   // Enables the global interrupts
}
```

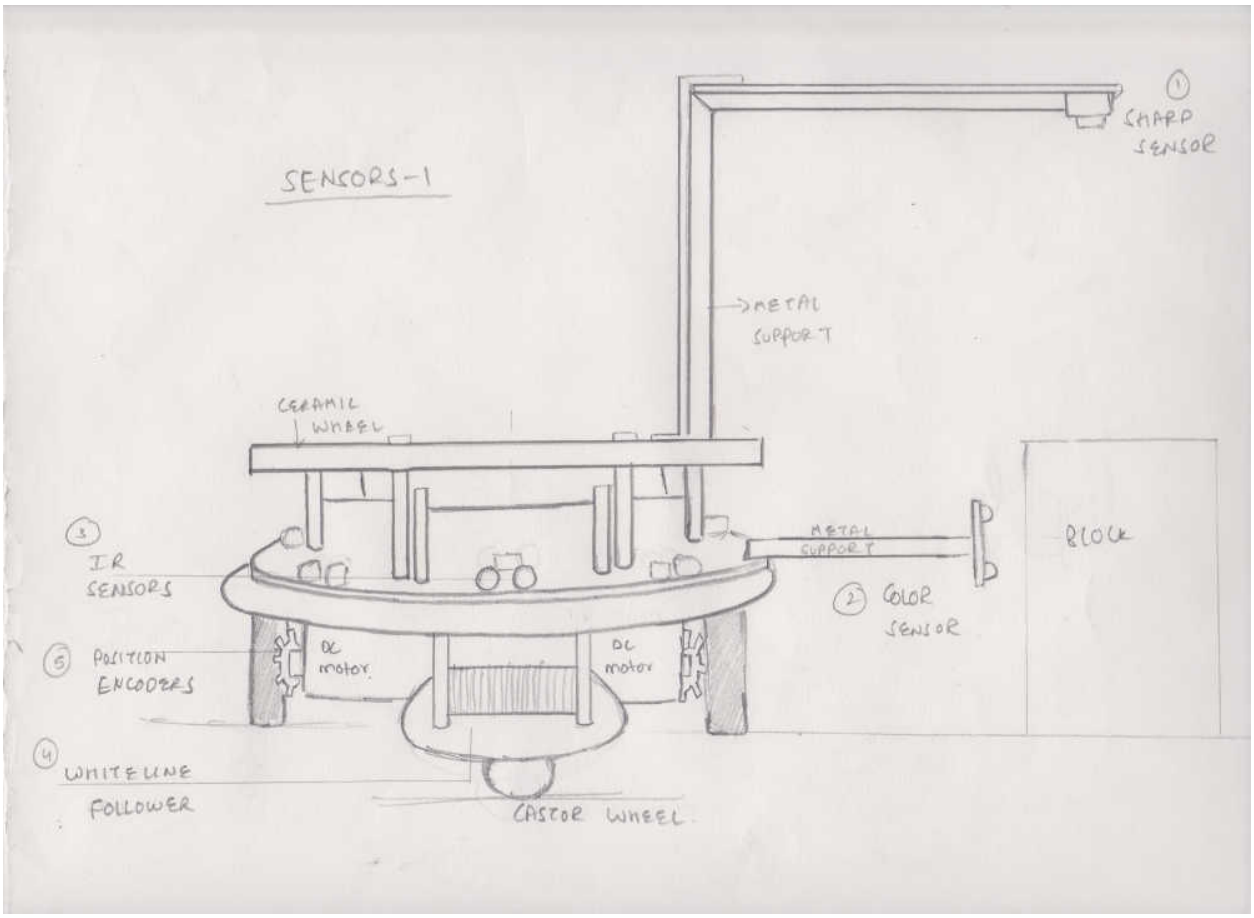
task2.c:

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/delay.h>
#include "../timer/timer.h"
#include "../SevenSegment/SevenSegment.h"

int count = 0;

void timer_1s_magic() {
    count++;
    if (count >= 30) {
        count = 30;
    }
}

int main() {
    timer_init_devices();
    seven_init_devices();
    while(1) {
       seven_display_num(count);
       _delay_ms(1);
    }
}
```

Q-3. Draw a labeled diagram to explain how you have planned to place the sensors on/around the robot? (5)

We have planned to place the **sharp sensor on the left side** of the bot, 21cm above the ceramic plate of the bot, and 11cm away from the edge of the left side of the bot as shown in the diagram.

The **colour sensor will be placed on the left side** approximately 8cm away from the edge of the left side of the bot, no more than approximately 4cm off the ground (in order to detect the colour of small pizzas too).
All the other sensors will be mounted in their original positions.



Q-4. Teams have to make the robotic arm for picking up/placing the packages in the arena.

a. Choose an option you would like to use to position the robotic arm on the robot and why? (2)

1. Front 2. Back 3. Right/Left 4. On both sides

We chose to mount the robotic arm on the **front and back** of the robot because of the following reasons:

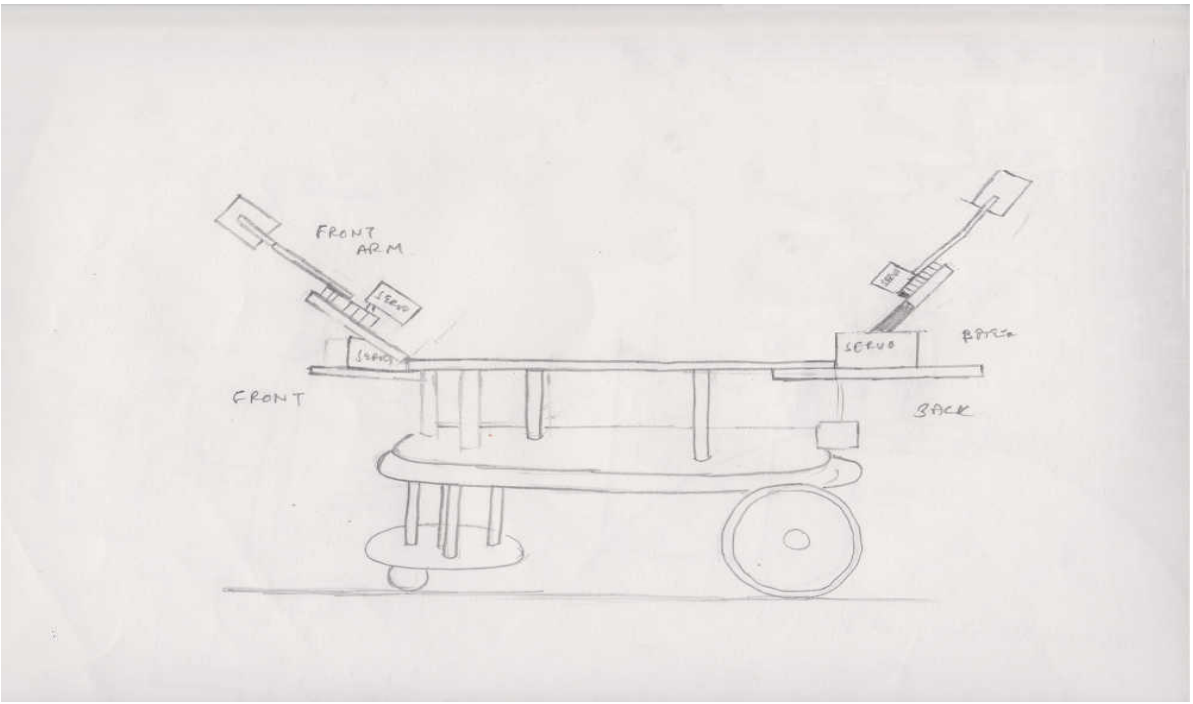
- If we mounted 2 arms, on both sides of the bot, it cannot traverse sideways directly which would result in unneeded time being spent, hindering the bot's performance.
- Having 2 arms, one on the front, and one on the back allows us to carry 2 pizza boxes at once if required, and leaves us with little to no

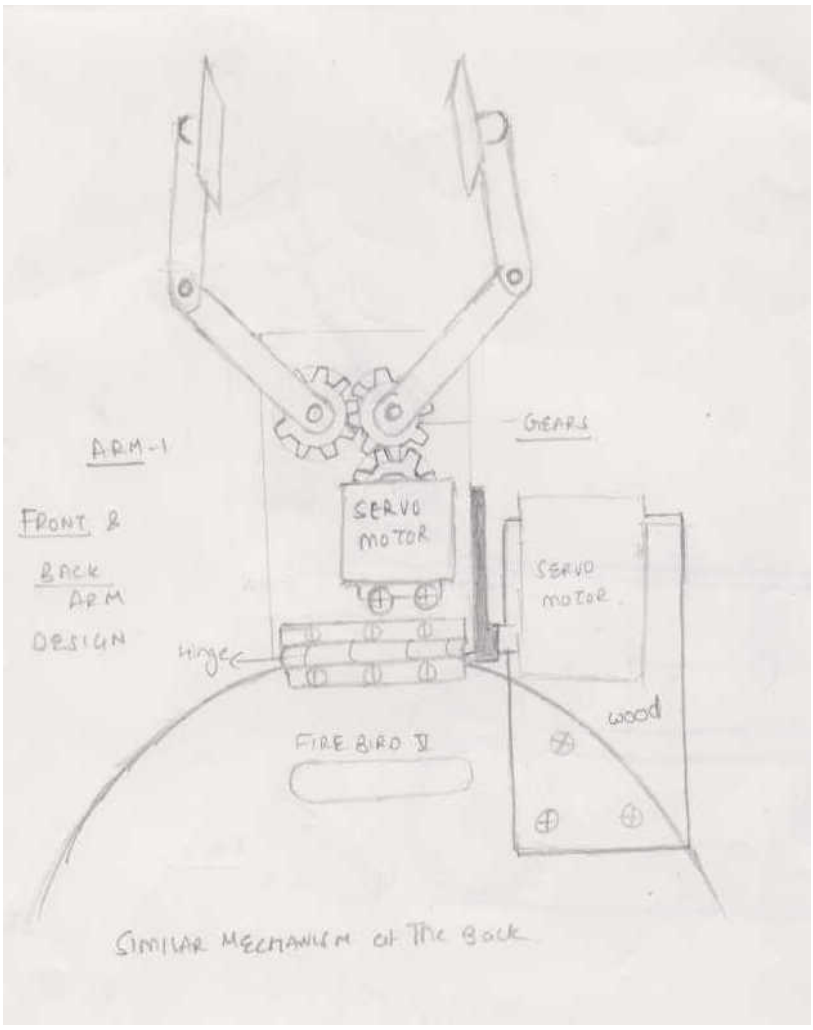
disadvantage if it isn't required. Power consumption should remain low, as the arms will be turned off when they aren't required.

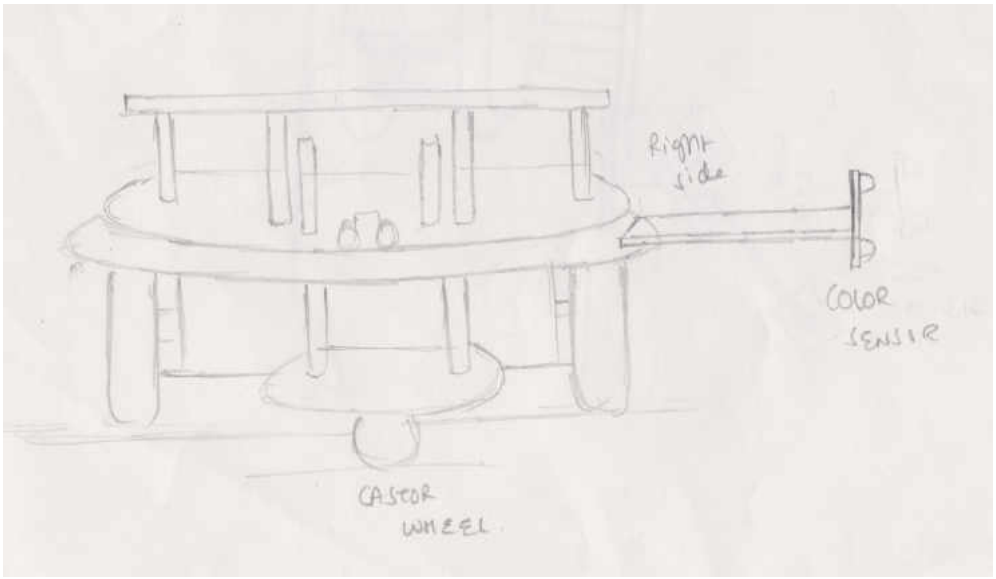
- We have mounted our sharp sensor and the colour sensor on the side, which restricts the space we have to mount the arm on the side.

Seeing these reasons, we've decided to mount an arm on both the **front and back** as we think that the possible advantages overcome the disadvantages.

b. Draw a diagram to show the robotic arm and how it is mounted on the robot. Also show the mounting of the color sensor. (5)




ARM-1
FRONT & BACK ARM DESIGN
GEARS
SERVO MOTOR
SERVO MOTOR
hinge
wood
FIRE BIRD V
SIMILAR MECHANISM at The Back


Right side
COLOR SENSOR
CASTOR WHEEL

Q-5. Choose the actuator you will use to design the robotic arm. (3)

1. DC-Motor 2. Servo Motor 3. Stepper Motor 4. Others

Answer: 2. Servo Motor

We have chosen the servo motor because they are the most accurate and reliable motors for the specific purpose of building an arm. A DC motor is an open-loop system, which means we'd require specific sensors (like position encoders) to track how far the motor had moved. A servo motor on the other hand, is a closed-loop system, and allows us to move the motor with the kind of precision required to control a robotic arm. We don't use stepper motors because stepper motors are generally very expensive, and they generally provide a lot more precision and torque than we require for the arm.

Q-6

a. What is the principle of operation of the color sensor? (5)

The given programmable color light-to-frequency converter is a combination of silicon photo-diodes (where a current is induced due to light) and a current-to-frequency converter on a single integrated circuit. The given light-to-frequency converter takes inputs from photo-diodes arranged in shape of a matrix. The given color sensor also has four LEDs at each of its corners which illuminate when the color sensor is turned on. The light emitted from the LEDs is reflected back from the surface of the pizza blocks and is taken up as the input of the photo-diodes. Pins S2 and S3 are used to select which group of photo-diodes are active (S3=L, S2=L for red, S3=H, S2=L for blue, S3=H, S2=H for green, and S3=L, S2=H for clear). The light is then converted into an analog frequency reading and the pins S0 and S1 are used to control the scaling factor of the device. The color is detected by the intensity of the light detected by the array of photo-diodes and the output is a square wave with the frequency directly proportional to light intensity.

b. Explain frequency scaling. Why is it necessary? (5)

The color sensor's output is a PWM wave where the width is directly proportional to the intensity of the light of the frequency selected using pins S3 and S2. Every wave has a frequency, i.e. the number of oscillations per second. The PWM wave also has a frequency, which is scaled down to 20% of its original frequency, using internal frequency dividers. We select this scale using pins S1 and S0. Our external input, which counts the pulses received

by this PWM wave runs at a frequency below the PWM wave's full-scale frequency. Because of this, we might skip recording pulses because we aren't sampling the wave often enough. To avoid this, we scale the PWM wave's frequency down to 20% so that our interrupt can sample the wave satisfactorily, and we receive an accurate pulse reading.

c. How will you identify Red, Blue and Green colors from the values you get from the color sensor? Explain your algorithm to identify the three colors (Red, Blue and Green). (5)

Step 1: Setup Port H as output
Step 2: Setup Port D, Pin 0 as an interrupt
Step 3: Setup interrupt to increment a “pulse” variable
Step 4: Create a function that returns the character 'r', 'g' or 'b' for red, green or blue respectively
Step 5: Set the “pulse” variable to 0
Step 6: Set pins S3=0 and S2=0 to select for “red” pulses
Step 7: Store output in a variable called “red” after 100ms
Step 8: Repeat this process for green and blue as well, with their respective S3 and S2 combinations
Step 9: Select the highest pulses received and return the apt character ('r' for “red”, etc.)

Actual code:

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/delay.h>
#include "color_sensor.h"

volatile unsigned long int color_pulse = 0;
const int color_data_time = 100;

void color_pin_config() {
    DDRH = DDRH | 0xF0; // Set upper nibble of Port H as output
    DDRD = DDRD & 0xFE; // Set pin 0 of Port D as input (interrupt)
}

void color_interrupt_init() {
    // Enable INT0 (at D0)
    cli();
    EICRA = EICRA | 0x02; // INT0 is set to trigger with falling edge
    EIMSK = EIMSK | 0x01; // Enable Interrupt INT0 for color sensor
```

```
    sei();
}
ISR(INT0_vect) {
    color_pulse++;
}

int color_collect_pulses() {
    color_pulse = 0;
    _delay_ms(color_data_time);
    return color_pulse;
}

int color_get_red() {
    PORTH = PORTH & 0xBF; //set S2 low
    PORTH = PORTH & 0x7F; //set S3 low
    return color_collect_pulses();
}

int color_get_green() {
    PORTH = PORTH | 0x40; //set S2 High
    PORTH = PORTH | 0x80; //set S3 High
    return color_collect_pulses();
}

int color_get_blue() {
    PORTH = PORTH & 0xBF; //set S2 low
    PORTH = PORTH | 0x80; //set S3 High
    return color_collect_pulses();
}

void color_sensor_scaling() {
    PORTH = PORTH | 0x10; //set S0 high
    PORTH = PORTH | 0x20; //set S1 high
}

void color_init_devices() {
    color_pin_config();
    color_interrupt_init();
    color_sensor_scaling();
}
```

```
char color_get() {
    // It will return the following characters:
    // u for unknown, by default (if something went wrong)
    // r for red
    // g for green
    // b for blue

     // It'll ideally take 300ms for this function to run, since we
collect 100ms of data for each filter

    char ret = 'u';
    int red, green, blue;
    red = color_get_red();
    green = color_get_green();
    blue = color_get_blue();
    if (red > green && red > blue) {
        ret = 'r';
    }
    else if (green > red && green > blue) {
        ret = 'g';
    }
    else if (blue > green && blue > red) {
        ret = 'b';
    }

    return ret;
};
```

Note: The timings mentioned below are purely hypothetical. Your robot timings may be shorter or longer than given below.

Consider the following assumptions:

- **The time taken by the robot to travel between the Nodes of Pizza Shop in arena is 1 second.**
- **The time taken by the robot to travel between the Nodes above Pizza Shop in arena is 5 seconds.**
- **The time taken by the robot to travel from Node before the Front Door to Front Door is 1 second.**
  Refer to Figure 1.

  <u>Note</u>: Time for picking and placing the Pizza is not considered in the traversal time.

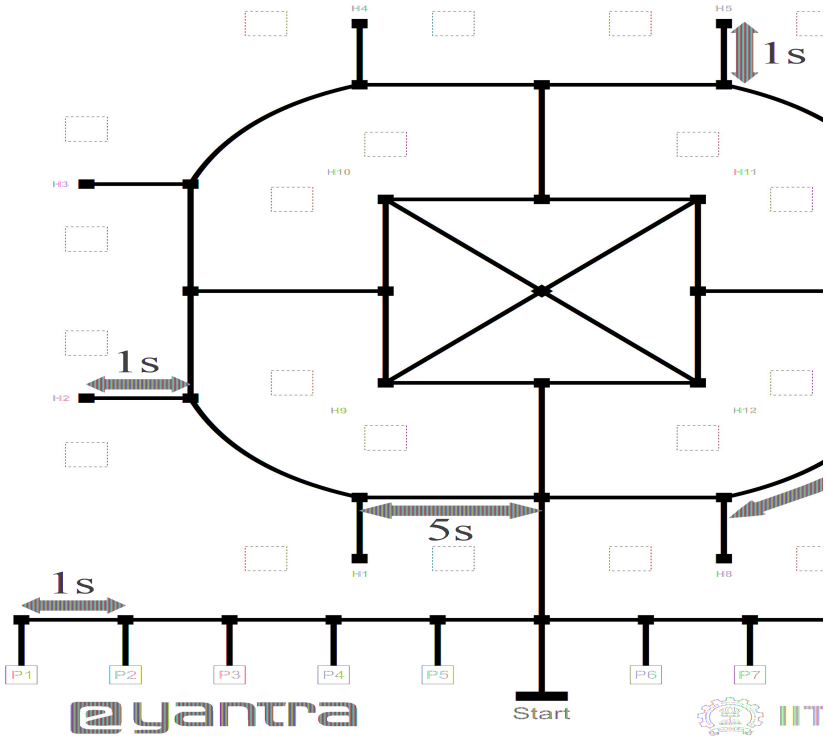


Figure 1: Time for Traversal between Nodes

Q-7 Given an Order Timeline as shown in Figure 2 how you will deliver each and every Pizza such that you score the maximum points as per the Formula in "Scoring System" in the rulebook. (20)

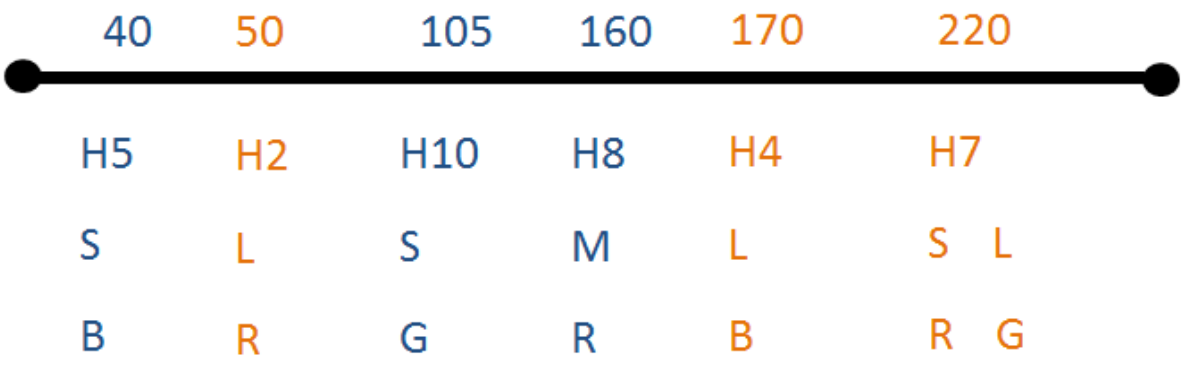
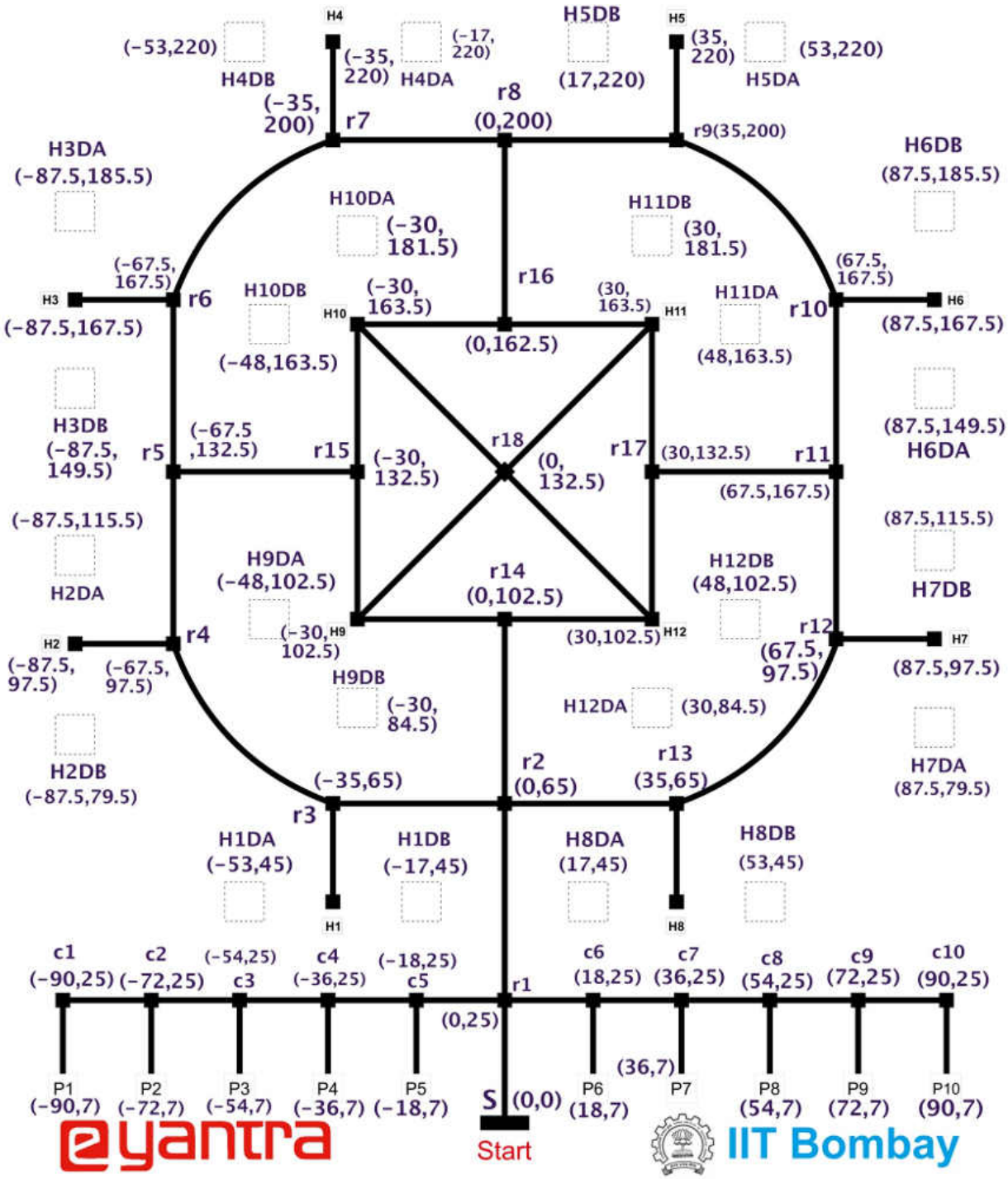


Figure 2: Order Timeline

The placement of Pizzas at Pizza Shop is given below:
Small Blue Pizza that is to be delivered at H5 is placed at P8 (S, B is at P8).
Similarly: L, R is at P6 S, G is at P5 M, R is at P1 L, B is at P7 S, R is at P2 L, G is at P3



Answer: Using the image above for reference, we show the path the bot will take and the time it takes.

We assume that all deliveries are correct in terms of the bot selecting the correct pizza, delivering it to the correct house, and delivering it within the deposition zone.

We also assume the following variables for certain actions. Different assumptions would change the maximum score achieved.
The variables are:
T = Time taken for robot to turn 90 degrees = 1s
A = Time taken for robot to lower / raise arm = 1s
C = Time taken for robot to close / open grip = 0.5s

Our solution to the timeline is as follows:

Deliver Large Red pizza to H2
Step 1) r1->c6
Time taken: 1s
Step 2) TACAT
Time taken: 4.5s
Step 3) c6->r1
Time taken: 1s
Step 4) r1->r2->r3->r4->h2
Time taken: 15s + 1s = 16s
Step 5) TAC
Time taken: 2.5s

Total time taken for operation = 25s
Cumulative tips received = 1 (for delivery in time)

Go back to pizza counter:
Step 1) AT
Time taken: 2s
Step 2) h2->r1
Time taken: 16s

Total time for operation = 18s
Cumulative time taken = 43s

Deliver Small Blue pizza to H5:
Step 1) r1->c8
Time taken: 3s
Step 2) TACAT
Time taken: 4.5s
Step 3) c8->r1
Time taken: 3s

Step 4) r1->r2->r13->r12->r11->r10->r9->h5
Time taken: 30s + 1s = 31s
Step 5) TAC
Time taken: 2.5s

Total time taken for operation = 44s
Cumulative time taken = 87s
Cumulative tips received = 2

Go back to pizza counter:
Step 1) AT
Time taken: 2s
Step 2) h5->r1
Time taken: 31s
Total time taken for operation = 33s
Cumulative time taken = 120s

Deliver Small Green pizza to H10
Step 1) r1->c5
Time taken: 1s
Step 2) TACAT
Time taken: 4.5s
Step 3) c5->r1
Time taken: 1s
Step 4) r1->r2->r14->h9->r15->h10
Time taken: 25s
Step 5) TAC
Time taken: 2.5s
Total time taken for operation = 34s
Cumulative time taken = 154s
Cumulative tips received = 3

Go back to pizza counter:
Step 1) AT
Time taken: 2s
Step 2) h10->r1
Time taken: 25s
Total time taken for operation = 27s
Cumulative time taken = 181s

Deliver Medium Red pizza to H8

Step 1) r1->c1
Time taken: 5s
Step 2) TACAT
Time taken: 4.5s
Step 3) c1->r1
Time taken: 5s
Step 4) r1->r2-r13->h8
Time taken: 11s
Step 5) TAC
Time taken: 2.5s
Total time taken for operation = 28s
Cumulative time taken = 209s
Cumulative tips received = 4

Go back to pizza counter:

Step 1) AT
Time taken: 2s
Step 2) h8->r1
Time taken: 11s
Total time taken for operation = 13s
Cumulative time taken = 222s

Deliver Small Red and Large Green pizza to H7

Step 1) r1->c2
Time taken: 4s
Step 2) TACAT (front arm)
Time taken: 4.5s
Step 3) c2->c3
Time taken: 1s
Step 4) TACAT (back arm)
Time taken: 4.5s
Step 5) c3->r1
Time taken: 3s
Step 6) r1->r2->r13->r12->h7
Time taken: 15s + 1s = 16s
Step 7) TAC (simultaneous delivery)
Time taken: 2.5s
Total time taken for operation = 35.5s
Cumulative time taken = 257.5

Cumulative tips received = 6 (incremented by 2 for 2 pizza deliveries)

Go back to pizza counter:
Step 1) AT
  Time taken: 2s
Step 2) h7->r1
  Time taken: 16s
Total time taken for operation = 18s
Cumulative time taken = 275.5s

Deliver Large Blue pizza to H4:
Step 1) r1->c7
  Time taken: 2s
Step 2) TACAT
  Time taken: 4.5s
Step 3) c7->r1
  Time taken: 2s
Step 4) r1->r2->r3->r4->r5->r6->r7->h4
  Time taken: 31s
Step 5) TAC
  Time taken: 2.5s
Total time taken for operation = 42s
Cumulative time taken = 317.5
Cumulative tips received = 6 (no tip for late delivery)

Formula = (600 - T) + (CPD * 50) + (CPCD * 50) + (TIP * 50) + (CD * 10) - (IPD * 20) - (P*50)
According to our solution, the variables are:
T = 317.5
CPD = 7
CPCD = 7
TIP = 6
CD = 7
IPD = 0
P = 0

Therefore:
Score = (600 - 317.5) + (7 * 50) + (7 * 50) + (6 * 50) + (7 * 10)
Score = 1352.5

Algorithm Analysis

Q-1 Draw a flowchart illustrating the major functions that are used. (20)

pos_encoder(): Increments a variable to count the distance traveled.

init_pwm(): Initializes the PWM wave required for the motor control.

rotate_towards_node(source_node, target_node): Calculate the shortest angle between the source_node and target_node and rotates the bot toward it within a certain angle of tolerance, relying on the white line sensors to align with the black line.

rgb_led_glow(color): Make the RGB led glow red, green, or blue according to the characters passed: 'r', 'g', 'b'.

setup_interrupts(): Initialize interrupt service routines to run every 1 second, and call the functions **timer_run()** and **analyze_timeline()**.

timer_run(): Increments the timer counter.

analyze_timeline(): Determine the order of delivery of pizzas every 1 second, based on any new information that is found. This allows the bot to make decisions dynamically. For example, when the bot doesn't know where a pizza is, it will assume a certain random or average time to find the pizza. But if the bot finds the pizza faster than expected, it might prioritize its delivery, since it may maximize the score to do so.

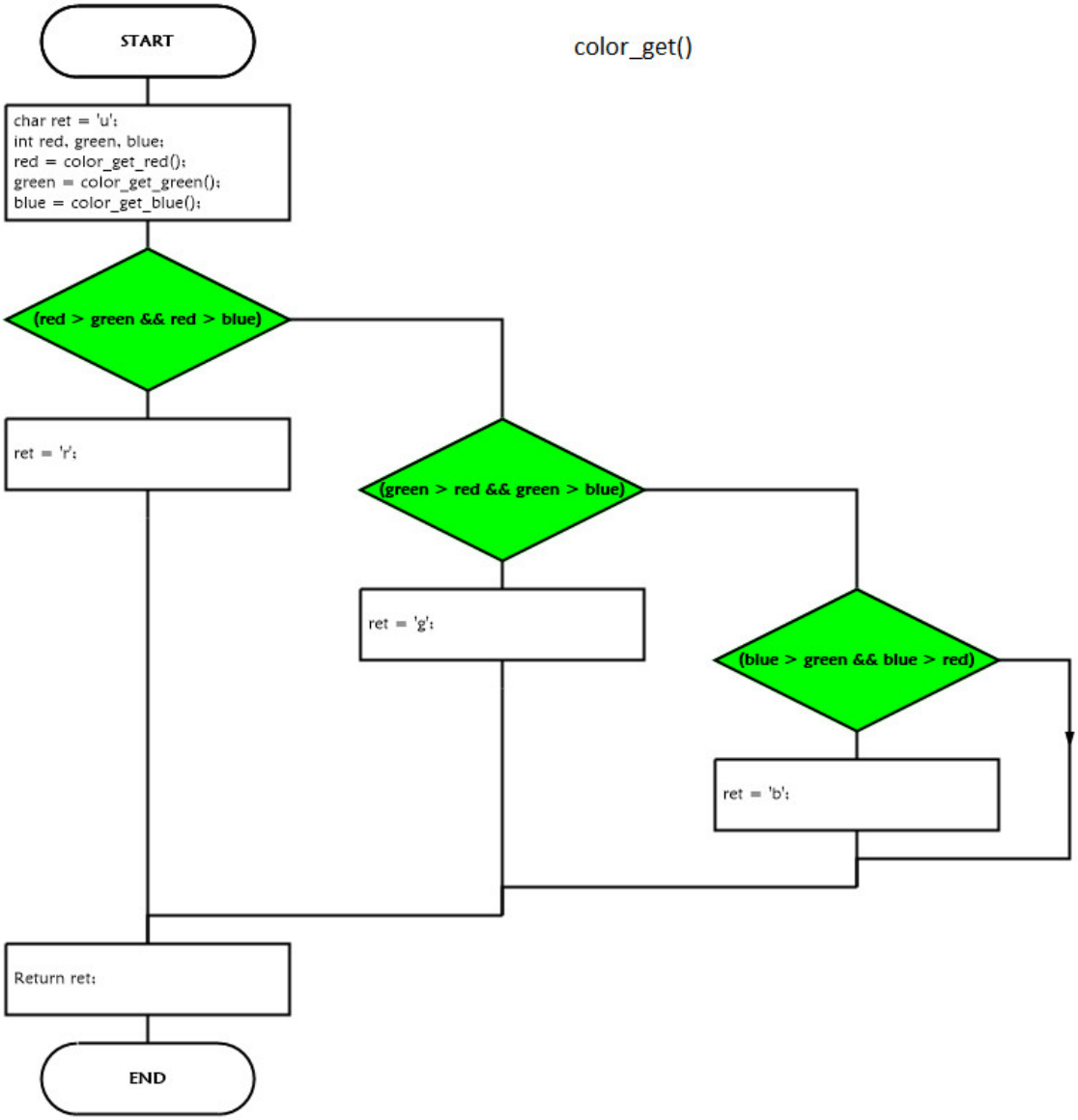
find_path(): Use Dijkstra's algorithm to find the shortest route from one node to another.

white_line_align(): Keeps the bot aligned with the black line, using the white line sensors.

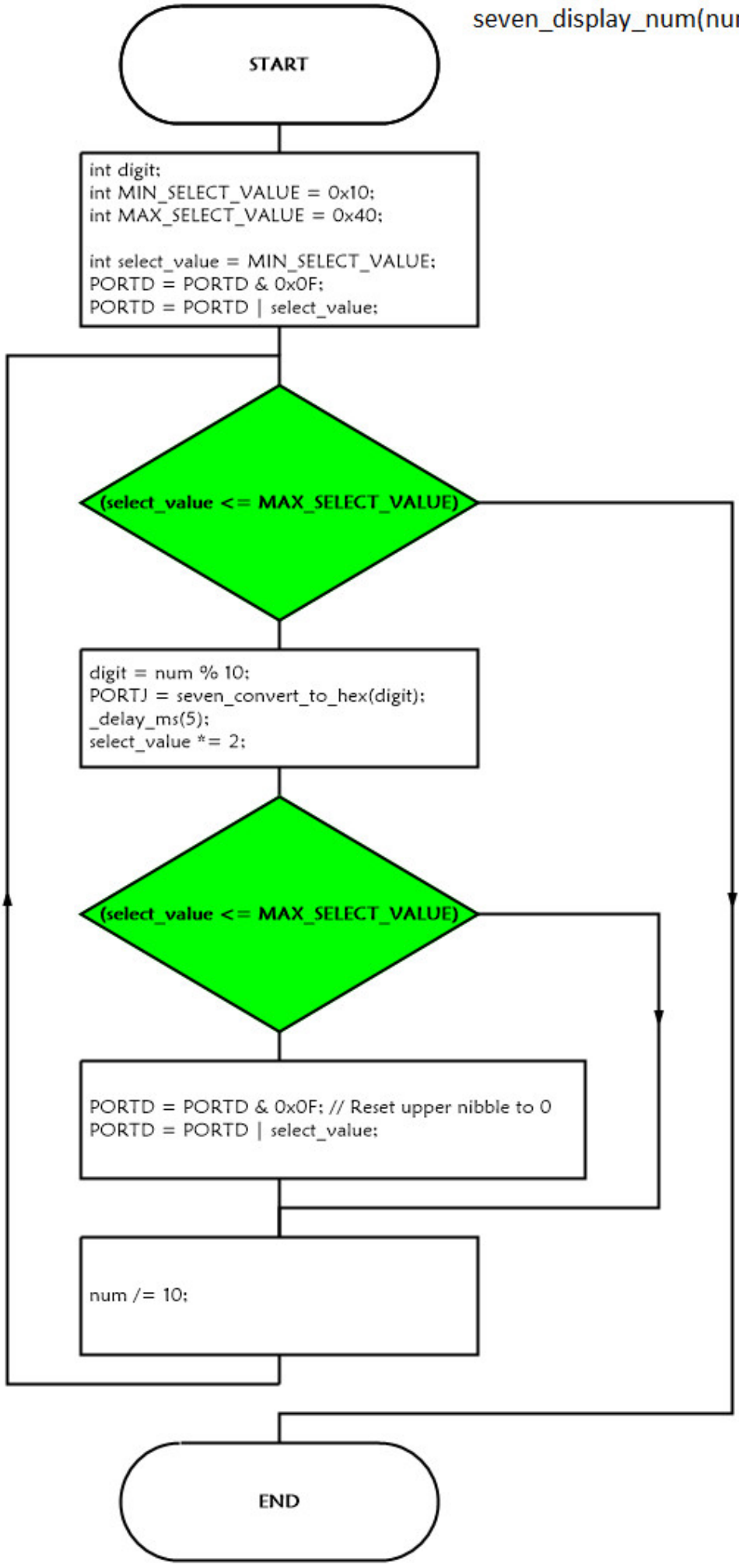
motor_forward(): Moves both motors at the same speed in order to move the bot forward.

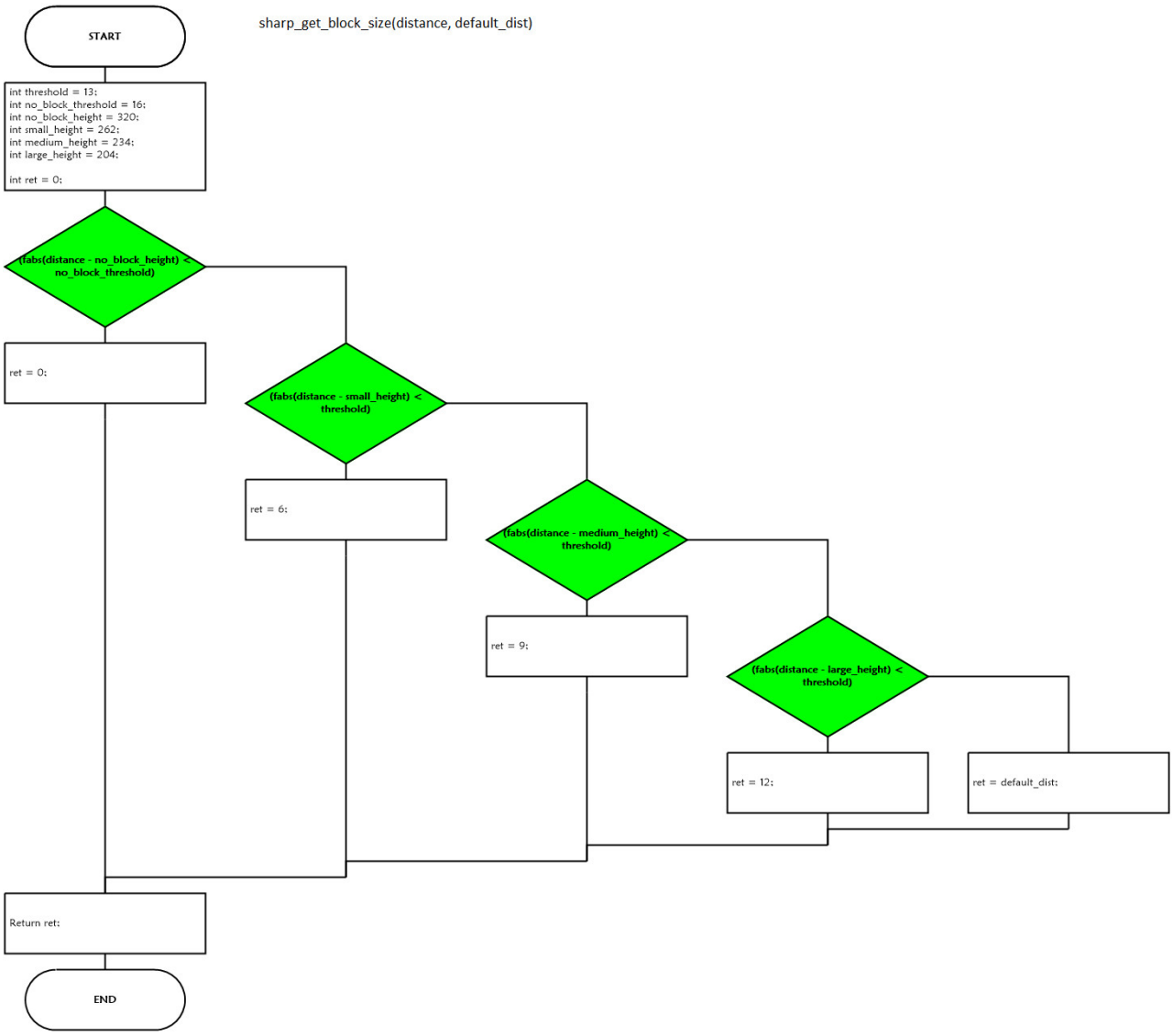
move_curve(source_node, target_node): Uses hard-coded values combined with the white line sensor to follow the curves in the map.

seven_convert_to_hex(): Converts a numerical value to the hex value required by the pins on the seven segment display.

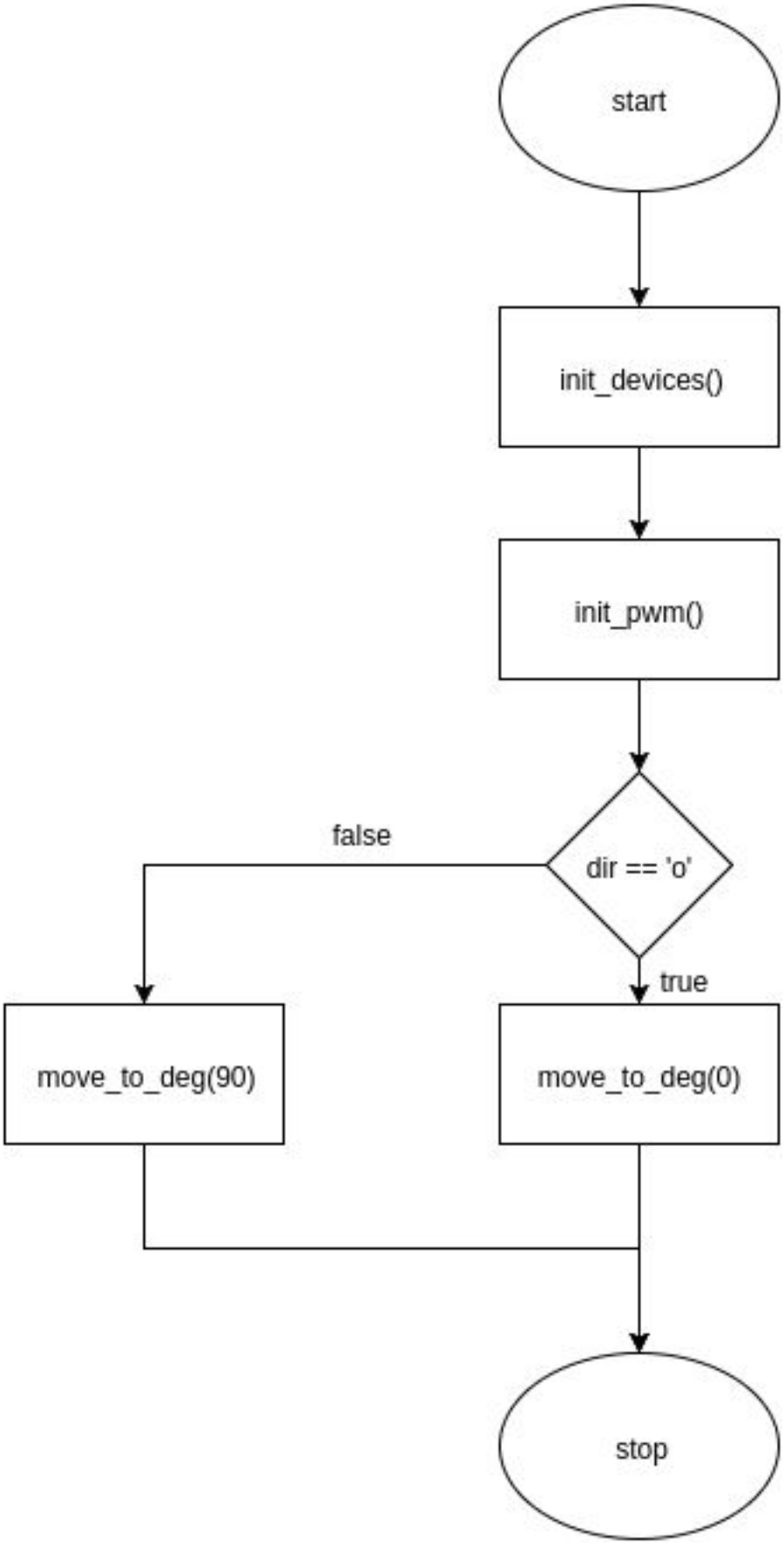

color_get()
START
char ret = 'u';
int red, green, blue;
red = color_get_red();
green = color_get_green();
blue = color_get_blue();
(red > green && red > blue)
ret = 'r';
(green > red && green > blue)
ret = 'g';
(blue > green && blue > red)
ret = 'b';
Return ret;
END

seven_display_num(num)

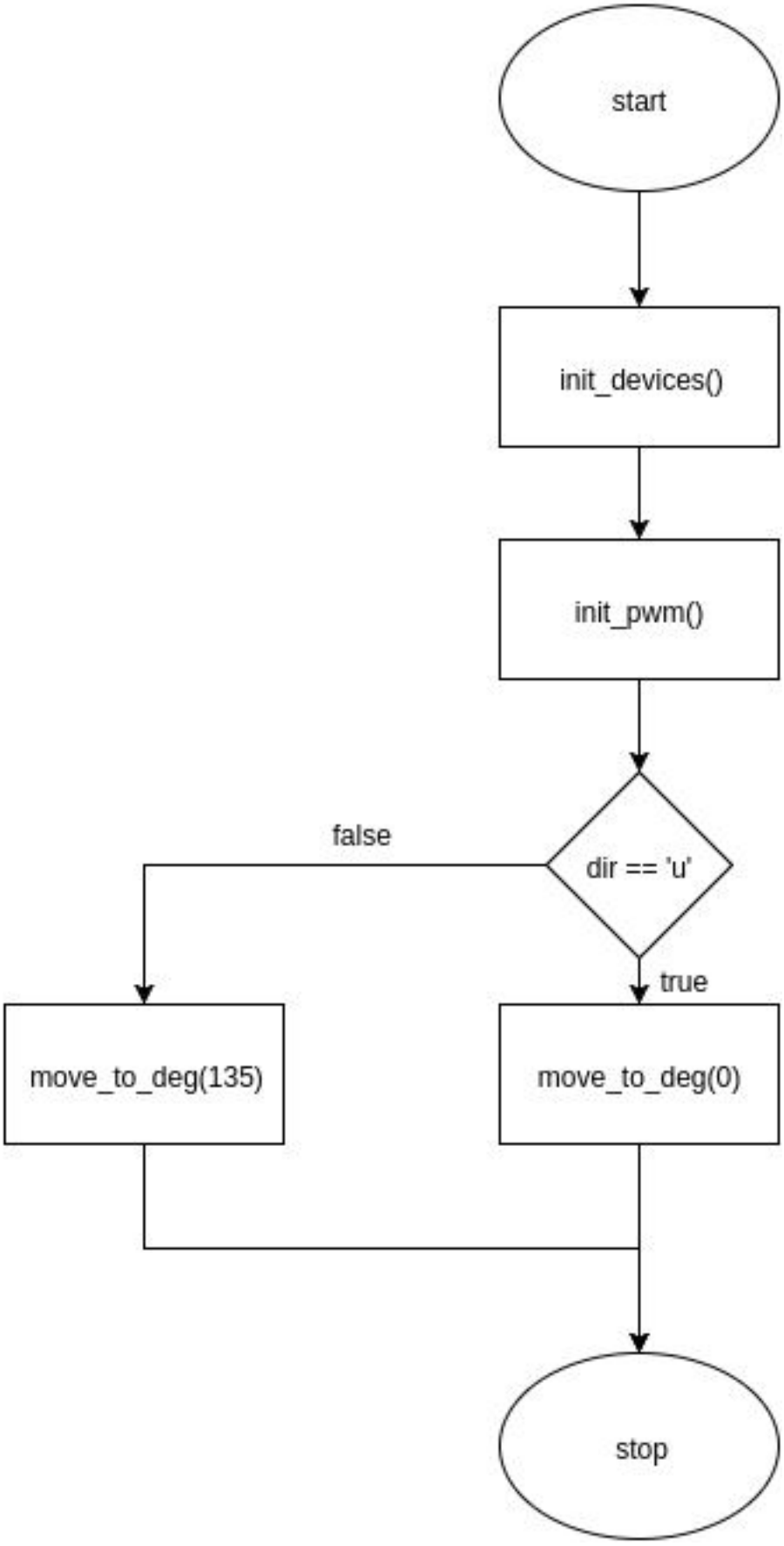


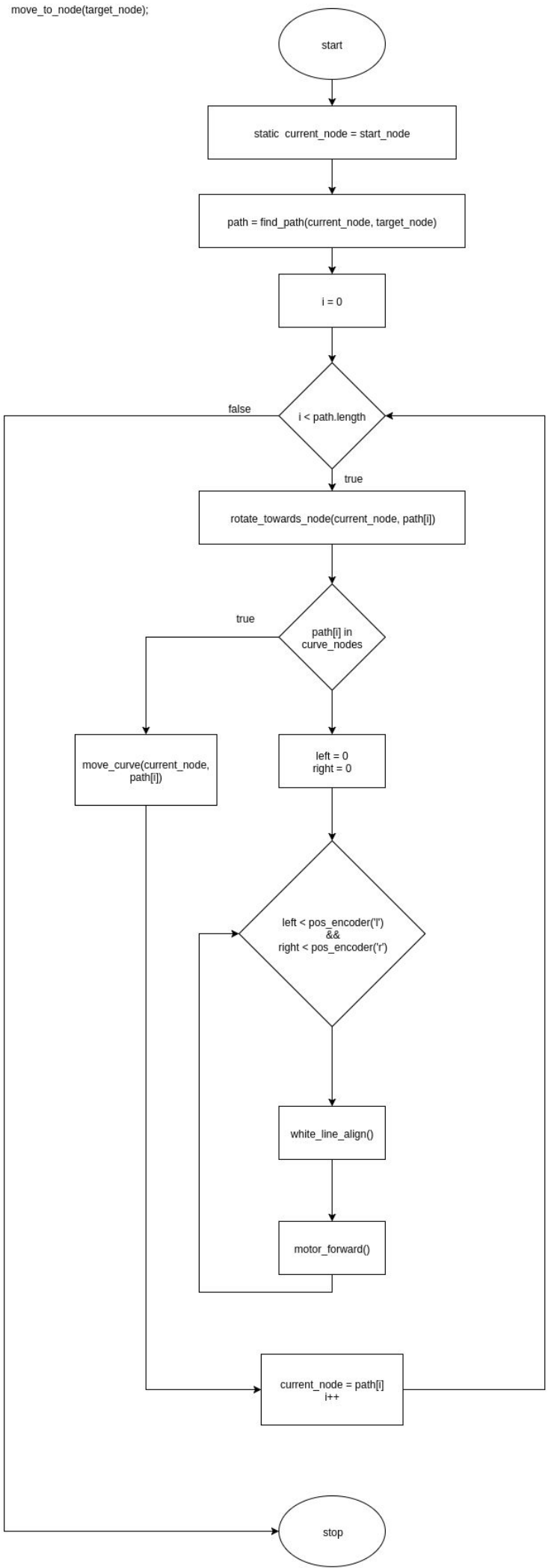

sharp_get_block_size(distance, default_dist)
START
int threshold = 13;
int no_block_threshold = 16;
int no_block_height = 320;
int small_height = 262;
int medium_height = 234;
int large_height = 204;
int ret = 0;
(fabs(distance - no_block_height) < no_block_threshold)
ret = 0;
(fabs(distance - small_height) < threshold)
ret = 6;
(fabs(distance - medium_height) < threshold)
ret = 9;
(fabs(distance - large_height) < threshold)
ret = 12;
ret = default_dist;
Return ret;
END

grip_control(char dir)

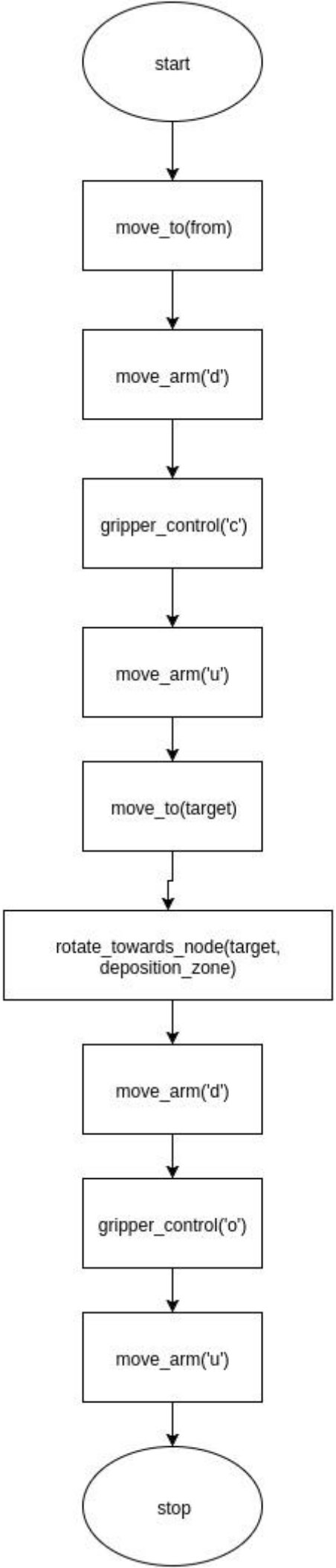


move_arm(char dir)

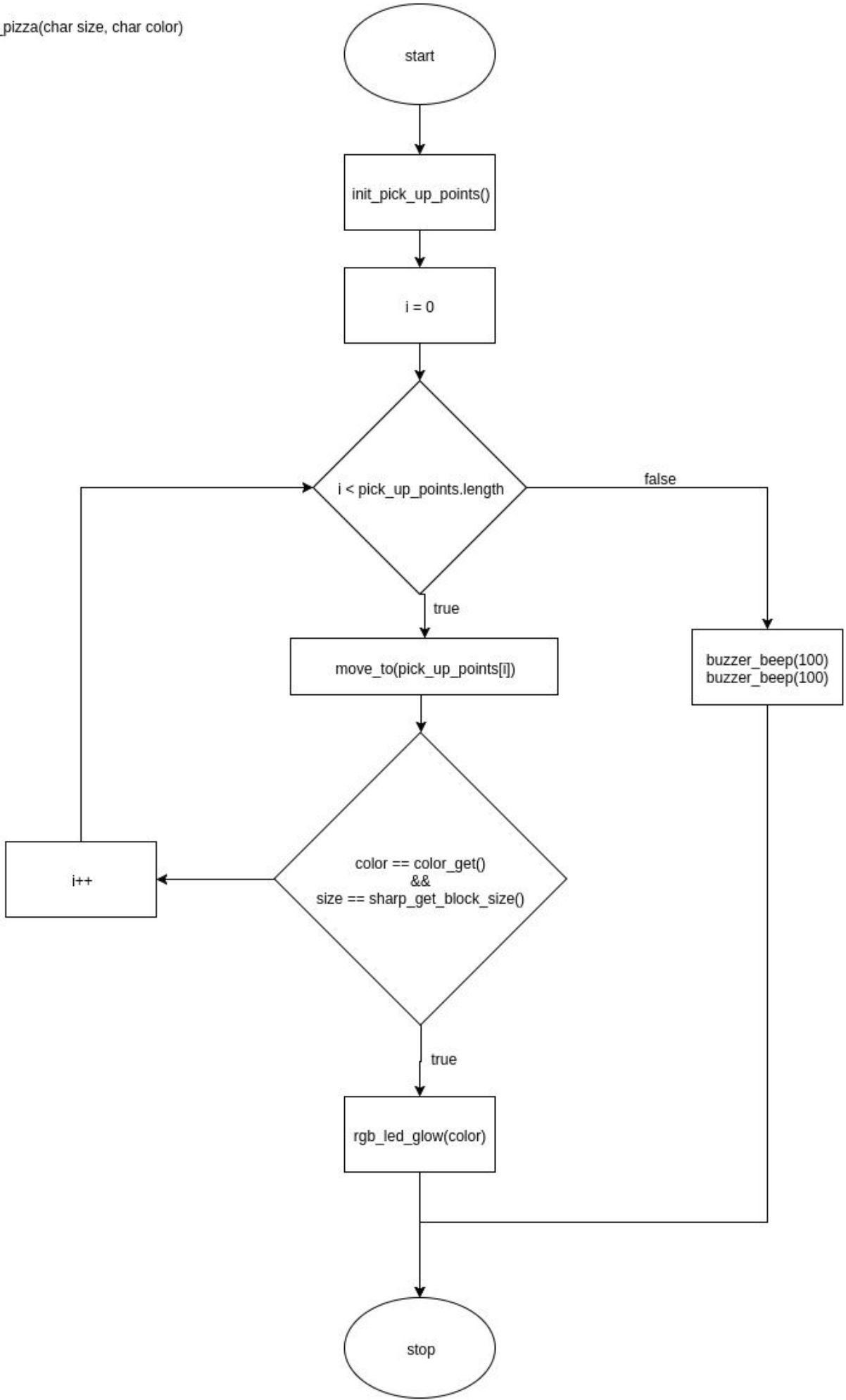



move_to_node(target_node);
start
static current_node = start_node
path = find_path(current_node, target_node)
i = 0
i < path.length
false
true
rotate_towards_node(current_node, path[i])
path[i] in curve_nodes
true
move_curve(current_node, path[i])
left = 0
right = 0
left < pos_encoder('l') && right < pos_encoder('r')
white_line_align()
motor_forward()
current_node = path[i]
i++
stop

deliver_to(from, target)

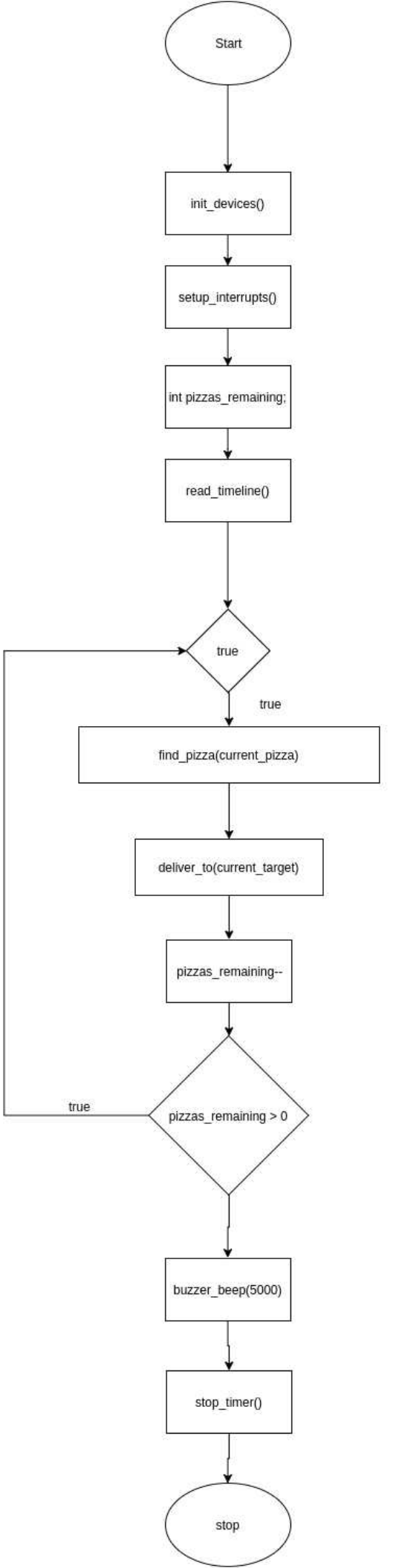


find_pizza(char size, char color)



Q-2 Draw a flowchart illustrating main function of your code. (10)

init_devices(): Initialize all the ports required by every module as output or input pins, as appropriate.
setup_interrupts(): Function which initializes interrupts to run every 1 second. The interrupts call a function to run the background timer (which counts how much time has elapsed) and a function to analyze the order timeline given the details we have currently.
int pizzas_remaining: initialize global variable
read_timeline(): Read the timeline in, and update appropriate variables like pizzas_remaining.
find_pizza(current_pizza): Function which finds a pizza by moving the bot to the pizza pick-up points and uses the sharp sensor and colour sensor to identify pizzas. Upon finding the correct pizza, this function will also glow the appropriate color on the RGB LED, and save the pizza's location internally. (current_pizza is a global variable which is set in the “analyze_timeline()” function which runs in an interrupt.
If the pizza wasn't found, it beeps the buzzer twice.
deliver_to(current_target): This function will pick up the pizza using either the front or back arm, move to the delivery spot, and drop the pizza in the deposition zone. Also, freeze the timer for 5s.
buzzer_beep(X): Functions that turns the buzzer on for X ms and off for X ms. This lets us beep the buzzer for 5s at the end.
stop_timer(): Freeze the timer display indefinitely.


Start
init_devices()
setup_interrupts()
int pizzas_remaining;
read_timeline()
true
true
find_pizza(current_pizza)
deliver_to(current_target)
pizzas_remaining--
pizzas_remaining > 0
true
buzzer_beep(5000)
stop_timer()
stop