Braking/Deceleration Mechanism in Hyperloop System Using Sensor Values and Feedback

Himanshu Thakur, Ankit Rastogi, Ritik Raj Singh, Shubham Khanduri

Abstract--- Hyperloop system is no longer a far-fetched idea and has got a lot of teams start to work on this seemingly futuristic concept. Hyperloop system involves a high-speed pod travelling at a proposed speed of 700 mph. The involvement of superlative speed at which the pod would be travelling brings down the entire focus on how to decelerate and gradually stop the pod (i.e.) the braking system.

Keywords--- Hyperloop, BLDC Motors, Arduino ATmega328P, Deceleration mechanism, RGB Sensor.

I. INTRODUCTION

The project involves prototyping a braking system/mechanism which involves sensory readings from Color Sensor TCS3200. The system uses color sensor present on top of the pod inside the vacuum tube which will sample different shades of the three primary color strips i.e. Red, Green and Blue present inside the vacuum tube on the top surface. The TCS3200 sensor will sense the colors and hence will alter the RPS (Rotation per second) of the BLDC motors whose values are predefined in the code using sampling of the primary colors. The motor rpm will decrease when the sensor samples the targeted frequency through the photodiode array.

Components

The prototype involves the use of both hardware components and software applications. The prototype hardware consists of ATmega328P based Arduino UnoR3, TCS3200 RGB colour sensor, BLDC Motors (A2212 1400kV), Electronic Speed Controllers-30A, 11.1V 3S LiPo-Battery Pack, breadboard, Jumper wires.

The software used is Arduino IDE (1.8.19.0) which basically does the compilation and the code is uploaded to the microcontroller. The prototype also incorporates Bluetooth module in the to control the system wirelessly.

Arduino UnoR3-(ATmega328P-PU PDI-28 micro controller)

The ATmega328P 8-bit RISC-based single chip microcontroller plays here as the brain of the system. It is a low-powered, low-cost microcontroller containing In System-Programmer of 32kB flash memory, 2kB Static-RAM and 23 universal Input-Output lines, SPI serial port. It operates between 1.8- 5.5 volts. It approaches 20 MIPS at 20 MHz's. It receives the input
values from the computer and acts promptly according to the code stored in the microprocessor to alter the motor's speed.

Brushless DC Motor

The A2212 1400 kV Brushless DC out runner motors are connected to the Electronic Speed Controller, which are further connected to parallel XT-60 to Star Connector which is connected to the battery pack. The signal pins of the Electronic Speed Controller are then connected to the digital pins of the Arduino board. Whereas the ground pins are pinned to the breadboard by connecting the ground terminal to the ground rail of the breadboard due to the shortage of ground pins on the Arduino Uno R3.

Electronic Speed Controller

The 30A BLDC ESC or the Electronic speed controllers are used to control the speed of the BLDC motors by adjusting the duty cycle or by switching frequency of the transistors. The ESC consists of high quality MOSFETs for BLDC motor drive and low-voltage cut-off protection. Also, the direction of motor rotation can be decided by switching any two leads from the ESC to the motor to make it Clockwise or Anti-Clockwise.

HC-05 Bluetooth Transmitter/Reciever

The Bluetooth Device used to transmit and receive data strings is a serial port protocol module designed for wireless interfacing of the controller and the serial monitor. The module has a UART interface with programmable baud rate. The module has up to +4dBm RF transmission power along with integrated antenna. It is connected to the breadboard and is paired with the Serial Monitor of the pc via Bluetooth Serial Terminal software. It is a software terminal which interfaces the Bluetooth module to the PC without need of Master-Slave setup of BT module and the output values of TCS3200 can be received at the serial monitor. The Receiving pin of microcontroller is connected to the Transmitting pin of Bluetooth module breakout board and the Transmitting pin of microcontroller is connected to the Receiving pin of the Bluetooth breakout board. The Bluetooth module bridges the signal between microcontroller and the serial monitor. The pairing password for the HC-05 Bluetooth module is by default set to 1234.

Revised Version Manuscript Received on 22 February, 2019

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TCS3200 RGB SENSOR

The RGB Sensor (TCS3200) consists of 8x8 array of photodiodes with Color filters and a frequency convertor circuit on a breakout board to facilitate its wiring with the microcontroller. It plays most important role in the setup. The sensor has 8 terminals for various purposes and are listed as follow:

PIN REFERENCE	Input/output	DESCRIPTION
GND		Ground pin
OE	Input pin	Enable pin for output
OUT	Output pin	f_0 -sampled frequency
S_0, S_1	Input pin	Frequency scaling pins
S_2, S_3	Input pin	Color detecting pins
Vcc		Supply

It is connected to Arduino Uno and is sampled against the three primary colours (RGB).

Arduino IDE

The whole code required for the working of the mechanism is written and compiled by the Arduino IDE. The Serial monitor interface is also sideways used for communicating between the microcontroller board and Bluetooth Sensor.

II. DRAWBACKS OF BRAKING

The braking mechanism used here involves deceleration of the BLDC Motors using inputs given by the Colour sensor through Bluetooth module via ESCs to provide controlled output. Although some drawbacks will be encountered along the way and are listed below:

1) At very high speed, the RGB sensor may be unable to sample the correct colour frequency and/or would entirely fail to capture any frequency at all.

2) The torque ripples of the brushless dc motor are an issue along with speeed fluctuation, vibration, and presence of acoustic noises.

III. PROPOSED SOLUTION

To counter-measure the drawbacks occurred during the run of the system the following procedures need to be incorporated:

3) In the advanced prototyping stage an optical camera rather than an RGB Sensor will be incorporated, which is much efficient and robust than the RGB Sensor with more precise and sensitive sampling.

4) The Braking of the motors mainly depends on the deceleration of the motors, thus by reducing the rpm of the motor in a controlled and early stage would result in smooth and effortless braking by the end by the test run.

5) The rpm of the motors would increase automatically according to the RGB coloured strips present on top of the vaccum tube . For initial acceleration the Green shade and its various shades are used for a linear acceleration of the prototype and blue for constant motion and lastly Red for deceleration and for slowing down and finally stopping the prototype.

6) So to counter the ripple torque in the brushless dc motors, a certain threshold speed must be tested and chosen as the default case.

Model for proposed solution

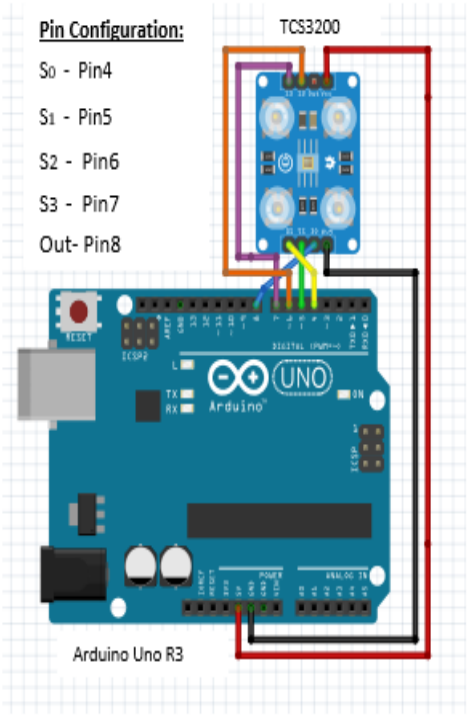

Fig. 1: TCS3200-RGB Sensor Interfacing with Arduino Uno R3

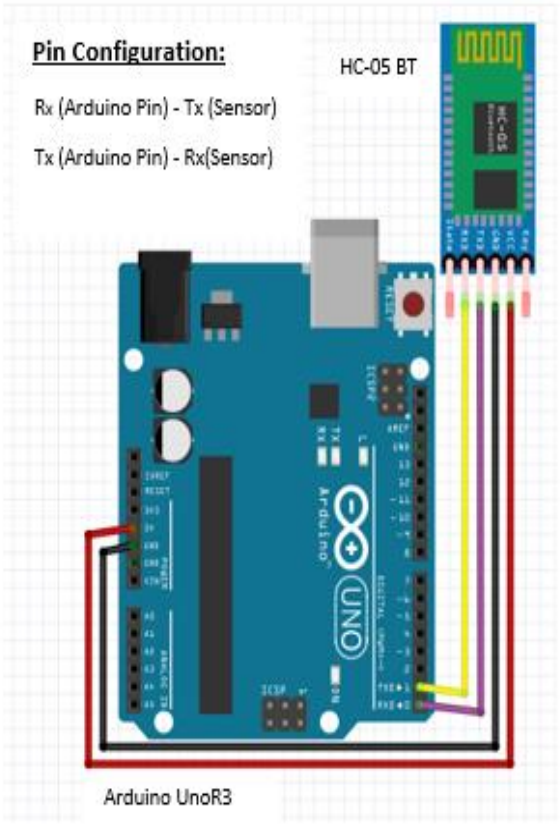

Fig. 2: HC-05 Bluetooth Module interfacing with Arduino

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Blue Eyes Intelligence Engineering
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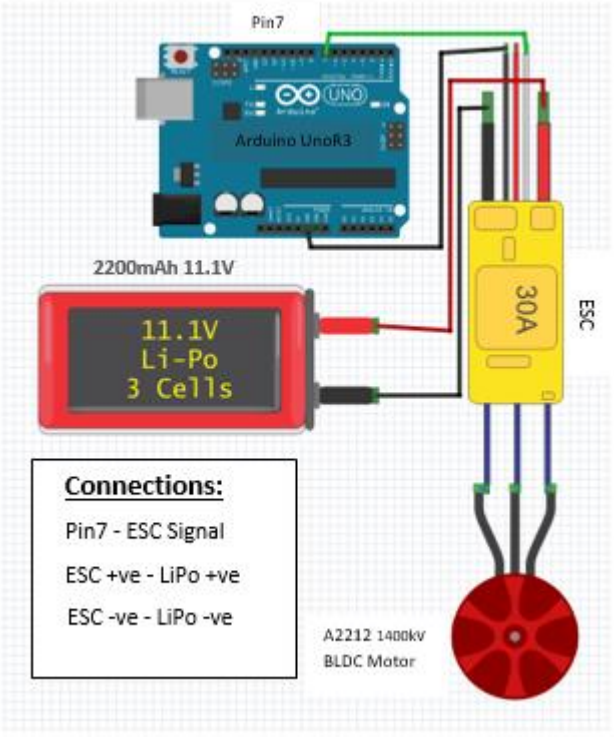

Fig. 3: Interfacing BLDC motor with Arduino UnoR3 using 30A pre-programmed ESC

IV. WORK DONE

The Bluetooth module HC-05 is paired and connected to the computer terminal and is mounted on the structure of the prototype and the code written in the Arduino IDE is uploaded to the Arduino board. The setup uses colored strips pasted on top of the setup at a regular distance for the detection using primary colors. Since the prototype will be moving beneath the pasted colored strips, the color sensor is placed on top of the prototype. The connections are made and the 11.1V battery pack is connected to the motors via 30A-ESCs and the parallel XT-60 to Star connectors and the pod is tested for short run. Furthermore, the successful powerup and connection of the motors can be determined by two continuous beeps after connecting the battery pack to the motor.

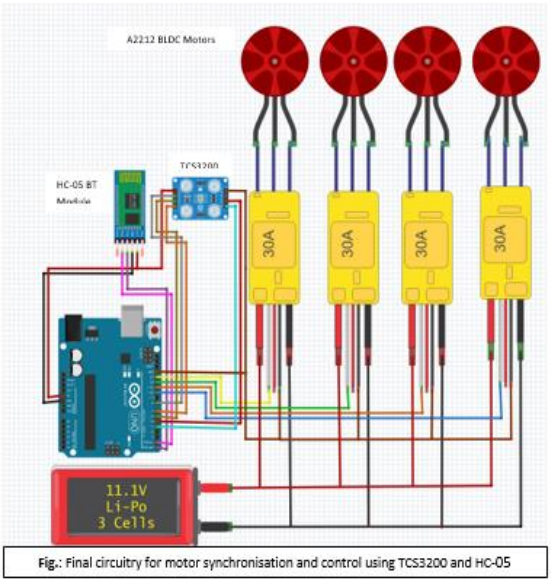

Fig.: Final circuitry for motor synchronisation and control using TCS3200 and HC-05

The Bluetooth serial terminal software is now used to input values to the Arduino and the feedback values is displayed on the output serial terminal as shown in the figure below:

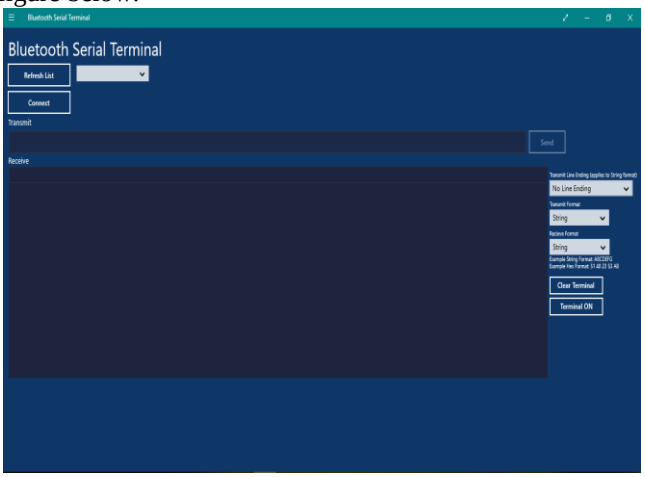

Fig. 4: Bluetooth Serial Terminal Interface

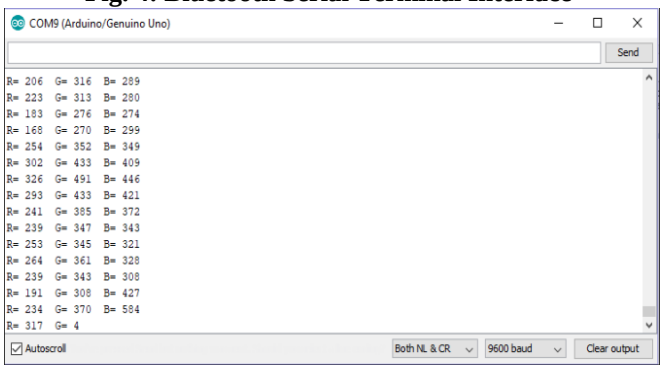

Fig. 5: TSC3200 readings corresponding to random color sampling

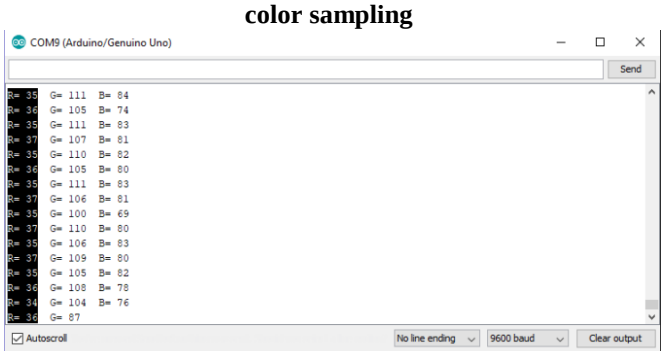

Fig. 6: TCS3200 readings corresponding to red color Sampling

Fig.7: TCS3200 readings corresponding to Green color sampling

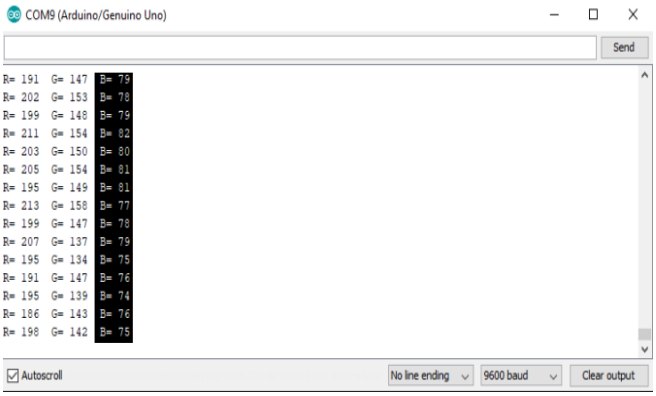

Fig. 8: TCS3200 readings corresponding to Blue color sampling

As the pod moves forward the color strips are encountered by the RGB color sensor in a sequential manner.

The colored strips are arranged in a manner of increasing frequency of Green, Blue and Red strips. Firstly, the green color strip of minimum frequency is encountered by the sensor which is bounded a minimum acceleration value in the code and then the color becomes darker or the frequency of green color increases. Similarly, as the prototype advances forward, it attains a constant speed during the interaction with the different color shades of the blue stripes. For the final section of the track the prototype encounters increasing shades of red which prompts it to start decelerating until the whole prototype comes to a halt. This whole sensing of the frequency of the stripes is incorporated into the Arduino which sends signals to the BLDC Motors via the ESCs which basically controls the speed or RPM of the motors.

V. OUTPUTS

During the run of the system the real time values are registered in the feedback terminal of the Bluetooth serial monitor and according to the data observed the wide array of frequencies are observed and hence used to pre-define the values in code for acceleration values of the BLDC Motors.

The following outputs were measured by placing the R, G, B sensor at a fixed height from the color samples comprising of different shades of the three primary colors namely red, green, and blue

Table I: Output against Different Shades of Green Sample in Corresponding R,G,B Values

SHADES OF GREEN	RED	GREEN	BLUE
I	31	24	28
II	48	31	37
III	55	34	37
IV	69	41	35

Table II: Output against Different Shades of Blue Sample in Corresponding R,G,B Values

SHADES OF BLUE	RED	GREEN	BLUE
I	60	32	19
II	77	39	22
III	83	49	26
IV	76	59	34

Table III: Output against Different Shades of Red Sample in Corresponding R,G,B Values

SHADES OF RED	RED	GREEN	BLUE
I	19	33	39
II	22	51	40
III	24	60	46
IV	26	61	43

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