Design and Development of an Electric Skateboard Controlled Using Weight Sensors

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Abstract. Existence of non-electric skateboards in the past few decades which involved a lot of physical effort while riding has now been overthrown with the invention of electric ones. As we moved onto a generation where everything is electric controlled, this paper introduces the skateboard as an electric vehicle based on weight sensing technology. The board is propelled by an electric motor powered by a battery pack and it is designed for easy and fast commuting where the rider just need to lean forward to advance and lean backward to slow down or stop. The proposed board is easy to carry anywhere because of its compatible design and also suitable for off road conditions. As of now we are testing the performance of the board and hoping for satisfactory results.

Keywords: Belt-driven board · Electric skateboard · Robotics Personal mobility · Weight sensing electric skateboard

1 Introduction

Witnessed as one of the more suitable innovations for this century, origin of these kinds took place in 1975 which was a gasoline powered long board called as the Moto board [9]. Although being non-electric skateboard, this was considered to be first of its kind. But it wasn't until the late 90's an electric skateboard had been produced. Following this there were several attempts made in order to achieve the goal. Gradually showing increase in the interest of people in the market it achieved a good percent increase in success in the late 2000's [12].

Originated from the idea of simplifying the methods of portable commuting [7], it seems to be satisfying the needs of a consumer. Our idea has originated in our university [10, 11, 16] to make the students life less stressful and reduces fatigue [3] in our muscles while commuting between classes. But there is a drawback of this board; Most of the youngsters who are already habituated with the skateboards are finding the rides on these electric boards less comfortable. In order to address this complication, we decided to build a board which gives comprehensive experience to all the users. It is hoped that they will address challenges relating to transport, the environment and human health [5].

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This paper discusses about objective and our approach towards constructing an electronic skateboard. As a part of our approach we began by researching on the boards available [6, 8] in the market and started to implement the best compatible feature into our design to make it more efficient, reliable and affordable. In order to make the previously said things achievable, we have taken some measures in choosing the accessories like battery, sensors, motor, speed controller etc. Although choosing a component and testing their compatibility of them with rest other components seemed to be a little tricky, we had to deal with the construction part of our board in order to make it easily controllable [2] by a normal human being is what we believe makes our board unique.

Moreover, this paper also states our purpose on why we chose a certain component to be suitable in the prototype discussion. Further, since we know that the most important thing is the mechanical transmission, we have given a detailed description on it as said by many of them, 'efficiency gives us more time to spend on becoming efficient' likewise, we believe that our product is efficient and better.

2 Literature Survey

As a part of our research [4] we gathered most of the information on the boards existing in the market. Firstly, we classified those boards into 2 divisions on their type of working i.e. Skateboards based on remote control [1] and boards based on weight sensing. After our observation on few established boards on both of the categories, we have decided to discuss about three boards which could describe all the major features present in rest of the boards. The following details give an understanding on the Electric skateboard.

2.1 Boosted Board

Boosted board is one of the first commercially produced remote controlled skateboards. The board consists of two Brushless motors which along with lithium batteries and some other custom electronics and trucks. It has got different power levels depending on the proficiency of the rider. The higher the level, the more power it produces and more the top speed (Fig. 1).

Fig. 1. Boosted board [13]

Specifications [13]: This board has the motor power of about 2000 W where its top speed is around 20 mph. This is a remote-controlled skateboard, with a range of 6 miles and the time to completely charge the lithium ion battery is close to 2 h. The boards manufactured by this company weighs from 12 to 15 lbs each.

Although the Boosted belt drive system allows it to produce more torque and more responsive, we need to replace their customized belts as they wear out frequently which can be seen as the drawback.

2.2 In Board

Inboard is the electric skateboard which has motors embedded into the wheels. One of its major features include:

Power Shift Swappable Batteries: Inboard is the world's first electric skateboard brand with swappable battery packs. The depleted battery can be recharged inside the board or on its own with a separate charging cable (Fig. 2).

Fig. 2. In board [14]

Specifications [14]: This remote-controlled skateboard with the specialty of motors embedded in the wheels has a top speed of 24 mph where the battery range is up to 10 miles and has the weight of 17 lbs. The material of the deck is light weight composite and is designed for speed and stability.

But, one of the major drawbacks in Inboard is slow start-up speeds and poor low-end torque hubs.

2.3 Z - Board

The first ever electric skateboard to use weight sensing technology. The skateboard uses footpads as their pressure sensors. The design allows for a more natural coast, allowing on to push the board many miles even after the battery expires. This board includes a belt-driven motor, integrated lights, and of course two pressure pads for your feet to move the board forwards and backwards (Fig. 3).

Fig. 3. Z-board [15]

Specifications [15]: Z board has a Brushless DC motor of power 500 W which can achieve a top speed of 20 mph. This skateboard has a high range compared to that of other skateboards available in the market i.e. 16 miles. The time taken to fully charge the board is around 2 h and it uses lithium ion battery. This board weighs around 18 lbs.

Although our initial attempts on building our skateboard were related to boosted and inboard both being remote control, we have later decided to build skateboard based on weight sensing mechanism. Since, by sensing weight difference instead of simply having an acceleration switch like in remote controlled board, it allows the rider to accelerate and decelerate without modifying stance. This weight sensing feature allows for a more intuitive and smooth riding system as well as faster actuation time for acceleration and deceleration. Almost similar to the z board in terms of technique but we have embedded the sensors inside the board instead of having foot pads. The idea of the belt driven mechanism has been taken from boosted board but the pulley system in our board unique compared to the former.

3 Objective

The objective of this project is to successfully build a weight sensing electric skateboard that is completely controlled by the rider's body movements. There are no footpads or remote control involved. The rider just needs to lean forward to advance and lean backward to slow down or stop.

4 Methodology

4.1 System Overview

This board is controlled using load sensors. The input is processed by Arduino and the speed of the board is controlled by VESC. Parallelly, the power is supplied to both the above-mentioned components. The motor transmits the power to the wheels. The block diagram of the system is shown in Fig. 4.

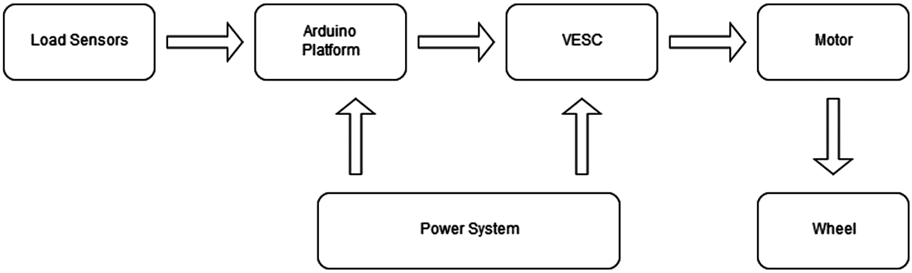

Fig. 4. Overview of the system

4.2 Construction Overview

The entire control system consists of two components: Sensor and Motor control. For the sensor control, Arduino is used to collect data from Force Sensitive resistors and process the analog signal. Secondly for the motor control, Arduino will connect to the motor through VESC. This allows the skateboard to have a steady acceleration and deceleration .

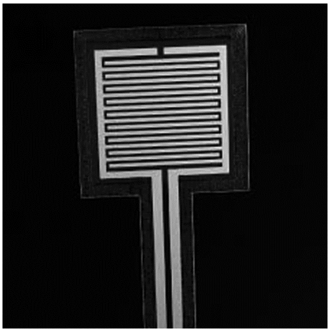

Fig. 5. RFP-602

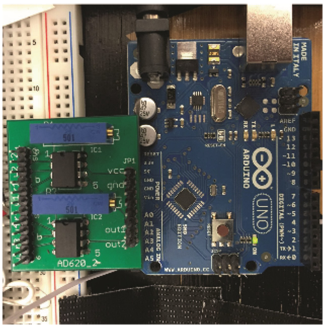

Fig. 6. Arduino Uno

5 Prototype Description

5.1 Sensor Mode

The board has Force sensitive resistors sensors (RFP-602) embedded on the front and back of the deck respectively. Now depending upon the pressure applied by the rider on the deck, the sensor sends the analog value to the A0 or A1 input of the Arduino, depending upon the pressure applied on the front or back of the deck. The sensor calibration was done by taking 5 different levels and thresholds each with a different pressure applied on the sensor in an incremental way. The algorithm written in the Arduino IDE ensures that if the input value crosses a certain value or threshold value, the value is mapped upon to the output value or the output pin which is connected to the VESC.

Depending upon the value VESC receives, it controls the motor rpm to increase or decrease speed linearly so that the board has smooth acceleration and deceleration (Figs. 5 and 6).

5.2 Customized VESC

This VESC has an open source platform (BLDC Tool) especially for Electronic Speed Controllers so that we can customize every parameter depending on our requirements from limiting the power and current to the motor, to safeguard the electronics equipment from heating up and fired. The maximum rpm limit is also set for safe riding and also the regulations of the power modes for up and down hill. This VESC also includes a regenerative braking method which comes into action when brakes are applied, and the VESC stops supplying power to motor and in turn takes the power produced by the motor back to the battery. The VESC we used, is the BLDC speed controller and it is calibrated for the particular motor we used, so that the board achieves a smooth start when starting from complete rest. It has a v4.12 Hardware, Latest v2.18 for Firmware for FOC, 10 awg motor wires w/5.5 mm bullet connectors and 2 mm JST-PH Connectors (Fig. 7).

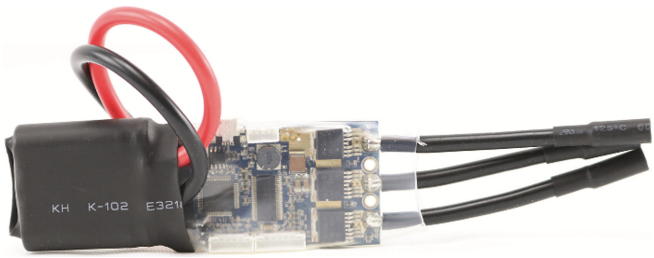

Fig. 7. VESC

5.3 Battery System

We have used Lithium polymer (Li-Po) rather than Lithium ion (Li-on) battery as they have really high discharge rates and are high in power density. A C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. This is a 12 S 3 Ah 45 C battery pack which gives a maximum output of 44.4 V to drive motor and 45 C rating ensures that maximum amount of current is drawn from it which can easily go up to 20+ miles range. Also, a 2.1 A power adapter is used to fully charge the batteries in 5 h safely.

5.4 Long Board

The long board used here is of size 42 in. long and 7-in.-wide making it sufficient spacious to add all equipment in the circuitry. Under the board, near to back axle, all the main components like motor, battery, ESC are arranged. All the components are arranged in a rugged casing for protection from ground. Drive generated by motor will be provided to one of the wheels using belt drive mechanism. Belt drive mechanism creates enough force and torque for application (Figs. 8 and 9).

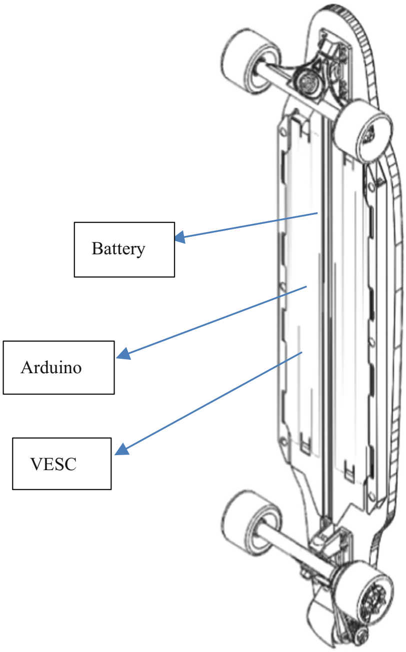

Fig. 8. Back view of the model

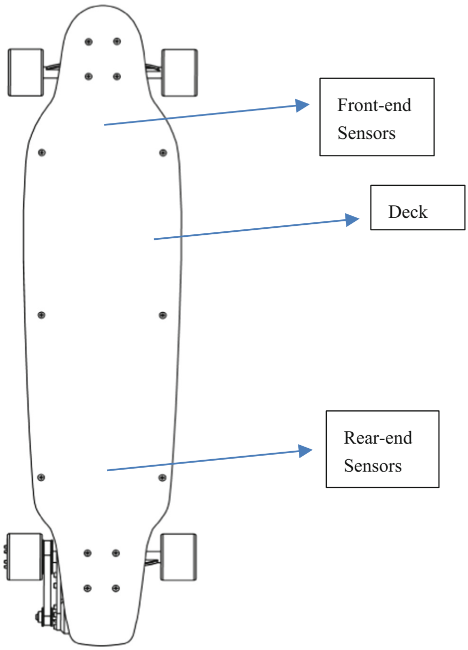

Fig. 9. Front view of the model

6 Mechanical Transmission/Drive Train

There are few parameters that need to be determined so we can design and build Drivetrain. They are gearing reduction ratio, Motor KV, Battery Voltage, Wheel diameter. These parameters are all related to each other and if one is changed, the top speed of our propulsion system will also change. That is why we determined our desired top speed as 22 mph (36 km/h) then worked backwards to determine the others. The overall design overview of the mechanical drive train is shown in Fig. 10.

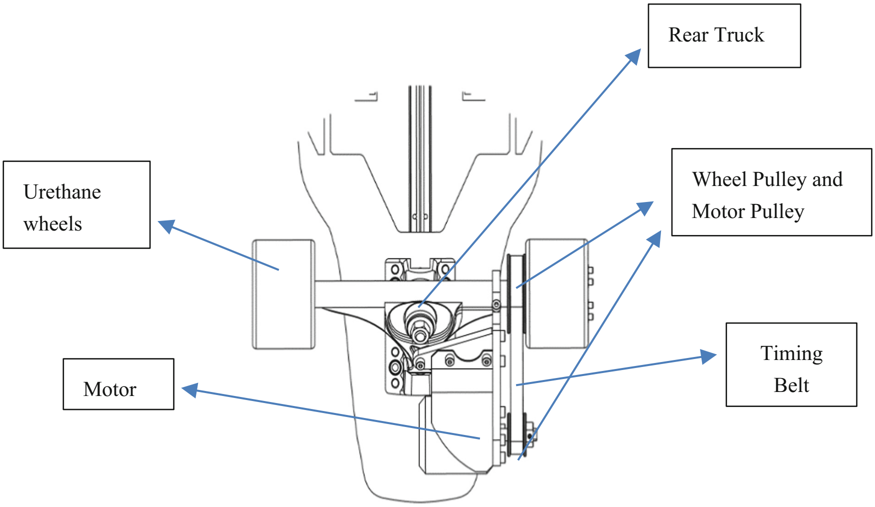

Fig. 10. Detailed view of the drive train.

6.1 Wheels

The preferable wheels for electric skateboards are of 80 mm–90 mm diameter as they have a good ground clearance and can also safely hold the electronic components from touching the ground. We chose to use 80 mm diameter wheels as they have a hollow core that is perfect for passing bolts through & securing the wheel pulley. The size of the wheels also matters a lot. The bigger wheel diameter produces more top speed and less torque whereas, the smaller the wheel diameter results in producing low the top speed and more torque which is required when riding the skateboard uphill. But also considering the ground clearance and acquiring max torque for a given drive train we chose to use 80 mm diameter wheels.

6.2 Gearing Reduction Ratio

The gearing ratio depends upon the motor pulley and the wheel pulley used in the drive train. The reduction ratio is directly proportional to the torque and inversely proportional to the top speed, so more the reduction ratio, the more the torque but less the top speed. But in general, it is recommended to use high reduction ratio to increase torque and considerable motor to achieve top speed. The pulleys we used here are 16 teeth motor pulley (Pinion), 54 teeth wheel pulley (Spur). The pitch of the pulleys we chose is 3 mm which is comparatively less because, the higher the pitch, the more the pulley circumference and less the ground clearance, but also keeping in mind that less the pitch value, less the number of teeth is intact with belt and less the output torque. 3 mm pitch pulleys are fit to satisfy the mentioned constraints.

6.3 Motor KV Rating

The motor we used is a 6355 190 kV rating with a maximum stator size of 55 mm width. The lower the kV rating, the more the torque and less the top speed but as we are powering the motor with 12 S 44.4 V, we could get our desired top speed with more torque. The maximum power and torque this motor can produce is 2500 W and 2.83 Nm respectively which is sufficient for general usage of the board.

6.4 Center Distance

Our next constraint is the center distance 'D_c' which is the distance between the motor pulley and the wheel pulley. It is always best to keep the center distance as low as possible to avoid the mount to flex, bend or snap while braking hard or accelerating quick. A shorter D_c value also means that less leveraging force is being applied onto the motor mounting hardware and also helps in reducing vibrations of the hardware.

6.5 Drive Train and Motor Mounting Plate

The customized mount shown in Fig. 11 did an imperative role to hold the motor to connect with the wheel and transmit the power smoothly.

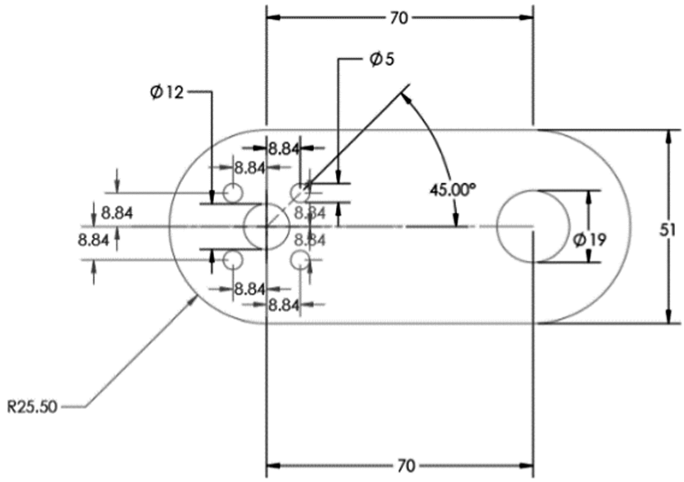

Fig. 11. CAD model of motor mount

7 Working and Discussion

The weight sensing electric skateboard we have built creates an effective interaction between human and machine based on intuitive control. The integrated sensor system allows to quickly accelerate or decelerate depending upon the pressure applied on the deck. The VESC used ensures a smooth speed-up process based on the data from Arduino. The regenerative braking used can conserve battery power and increase range.

We opted for a Belt driven motor rather than in-wheel Hub motor as the former has an advantage of high power and also it is better in absorbing shocks while riding on rough roads. So here we have used pulley and belt drive mechanism between motor and the wheel to which drive will be connected. For mechanical parts we manufactured certain parts like Motor Mount, timing belt and pulleys to reduce the overall cost.

8 Conclusion

We have built an Electric Skate board on weight sensing method which needs to be tested on different age groups and diverse road conditions. This weight sensing feature allows for a more intuitive and smooth riding system. In addition, the customized VESC and battery pack allows us to pre-set different maximum speed of the skateboard to meet the purposes for different level of users so that people having no experience can easily learn and ride it. Right now, we are using only one motor to drive one of the rear wheels. Later, we could add another motor to achieve a full rear wheel drive so that it is more powerful and more torque is attained.

The features of this board include low cost, less weight, regenerative braking and easy operation. We want to make it more user friendly improve by taking feedback from the users.

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