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Research paper

Smart E bicycle: an efficient and effective way to greener future

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Abstract

This paper presents and proposes a smart electric bicycle(SeB) leveraging the power of wireless technologies, artificial intelli- gence and cloud computing in order make its user's experience smooth, safe and enjoyable hence encouraging the user to choose SeB over other modes of transportation. The proposed system introduces an Electric Bicycle connected with a smartphone in one variant or with "smartphone and cloud" in another variant for smart decision-making and efficiency and other related tips for the user. The range of bicycle is predicted based upon the user profile (weight, age etc.), route details (inclinations, distances of al- ternative routes), State of Charge(Soc) and State of Health(SoH) of the battery used. Multiple user profiles and minute details of the route (slope, speed breakers etc.) are captured using sensor like accelerometer and basis on these data smart decisions for pow- er saving and range extensions are made. Also, safety critical and predictive maintenance features are presented.

Keywords: *Accelerometer; Bluetooth; GPS; GSM; SOC; SOH*

1. Introduction

Electric vehicles have been around since early 1900s [1]. However, improved intercity road communications marked a need for Internal Combustion Engine (ICE) vehicles capable of operating at longer distances. Along with the capability to fathom longer distances, ICE brought the disadvantage of depleting fossil fuels and raising the pollution levels.

Increase in pollution, increased awareness levels among people and government policies for keeping the pollution under control is paving its way to massive developments in Electric Vehicle tech- nology. Electric Vehicles industry is looking forward to developments in charging infrastructure, lightweight and high capacity batteries, smart charging options, efficient motors and user- friendly ecosystem.

With the advancements in Information Systems and popularity of Internet, there is a scope to leverage the research with the practical behavior of the electric vehicles. In current scenario, data is a valuable asset and the more data we collect, the more insights it can give into a technology.

This paper leverages the benefits of the electronics and sensors to make the electric bicycle sense its surroundings, the power of wireless technologies to transfer sensor data to cloud, the power of cloud to make inferences out of the data collected and user- friendly interface in Smartphone or bicycle's display to improve the user experience. So a complete ecosystem is built around an electric bicycle to make it as user friendly and as efficient as it can be in terms of value for money. Improved, predictable and reliable user experience will in turn work as a motivating factor for poten- tial users for using the electric bicycle for commuting on day-to-day basis.

One of the works done in this direction to improve user experience is Mobile Cockpit System [2] which uses smartphone sensors to collect various sensor data like temperature, location, altitude etc. and sends it to the remote repository for analysis. Then range predictions, route predictions are done based upon the data collected. Smart eBicycle project enhances the features presented in the paper and takes the features and hence user experience to a next level.

First, to motivate users to use the Smart eBicycle, we must sys- tematically understand the users present in market and their vary- ing needs. Keeping this in mind, the Smart eBicycle (SeB) project proposed in this paper has multiple variants depending on user group and market needs. SeB can have various user groups. First variant is Personal SeB (SeB1.0) which is used by an individual and can be shared by his/her family members or relatives and gives customized predictions, provided a smartphone is always tethered with the bicycle during all its journeys. Second variant is based upon Sharing Business model and is named SeB1.1, which can be used in bicycle renting business and has enhanced features compared to SeB1.1 discussed in this paper. Third variant is based upon Sharing Business model and is named SeB1.2, which can be used in bicycle renting business and has full-fledged fea- tures with or without smartphone in range

This paper will explore the proposed architecture and technology required for SeB1.0, SeB1.1 and SeB1.2.

2. Smart E bicycle

Components of SeB common to all variants are listed as:

1) Charging circuitry
2) Battery management system
3) Battery Pack
4) User Console
5) Motor
6) Regeneration/Pedal charging circuit
7) Main Controller and Accelerometer
8) Bluetooth

The components listed above are represented in block diagram below:

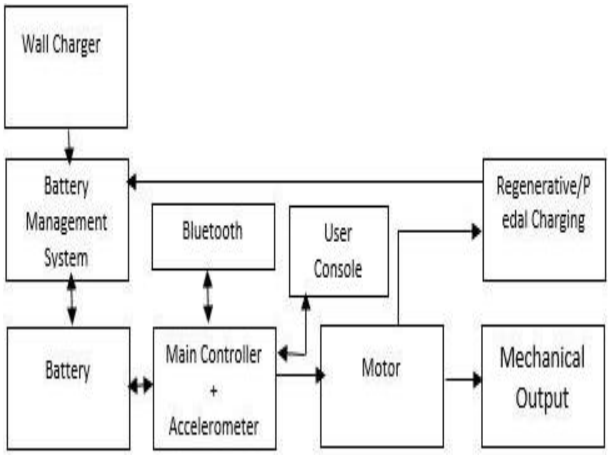

Fig. 1: Block Diagram of Common Components I.E. Basic Version Seb1.0.

Each block can be detailed as:

1) Wall Charger: Wall Charger circuitry efficiently converts AC to DC and hence charges the battery pack.
2) Battery Management System (BMS): Battery manage- ment system efficiently controls balanced charging, dis- charging, gives State of Charge(SoC) and State of Health(SoH) of the battery, temperature of battery pack hence helps in estimating the range precisely.
3) Battery: Battery is Li-ion battery pack, which powers the motor on the go.
4) Main Controller and Accelerometer: Main controller collects data from battery Management System (BMS), accelerometer, and regenerative/pedal charging system and provides to smartphone to provide range information, pre- dictive route management. It also gets input from user console to set modes, start trips, start training session etc. It also takes care of speed control of motor according to user requirements. Accelerometer helps in detecting incli- nation and hence provides pedal assistance to user accord- ing to real time need.
5) Bluetooth Module: Bluetooth module helps connect the SeB to cloud for powerful computation. It also helps in locking/unlocking and communicate the user profile to SeB for user specific response.
6) Motor: The motor is driven by motor controller in order to provide pedal assistance to the bike rider. The level of assistance depends on factors like mode selected, level of inclination, rider fatigue level.
7) Regenerative/Pedal Charging: Regenerative charging will happen while slowing down (manual or auto braking) or downhill as well. Also, pedaling can charge the battery for range extension.
8) User Console: User console has a display and input but- tons. Display helps in conveying information like current speed, expected range, battery levels, user name, riding tips etc. Buttons help in getting inputs regarding the mode of operation, real time speed control of bicycle etc. It also has a beeper for important warnings to the user.

A Smartphone Application is a user interface for the user to see the preferred routes, efficiency, his trips, distances covered in each trip etc.

2.1. SeB1.0 variant details

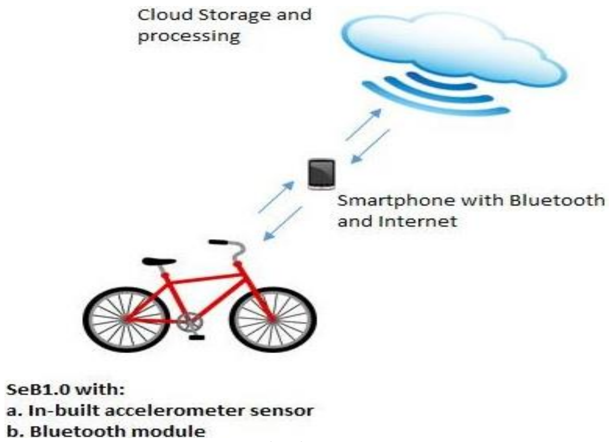

Fig. 2: Flow of Information in Seb1.0.

Features proposed in SeB1.0 are:

1) Contactless lock/unlock: User can lock/unlock the bicy- cle using the phone itself. If paired phone is not in range, the SeB1.0 will not deliver power to the motor and will keep the wheels locked.
2) Console for user-friendly information and alerts: Alerts like over speeding, battery low, helmet check, tilt alert can be displayed on the display provided on handle bar. Ap- propriate beeper will beep in case of critical alerts. In addition, general information like mode of operation, user infor- mation, Odometer, speedometer, smartphone connection status etc. will be visible on display. Various input buttons are provided to change mode of operation, to set certain settings, to bring the screen in stop watch mode, to turn off the alerts etc.
3) Audio alerts: As already mentioned, appropriate beep patterns will be audible depending on alert type. Beeper is used to keep the solution low cost.
4) Crash alert: If the tilt angle of the bicycle is greater than a threshold, an SMS alert from the smartphone can be triggered to emergency contacts provided in smartphone application.
5) Auto Speed Control: Auto speed control mode will con- trol the bicycle speed basis of the past experience collected from previous trips i.e. past known speeds mapped to loca- tion will be attained by the SeB when the SeB will reach the corresponding location. User can enter this mode easi- ly using input console. So, this will mark an autonomous mode for bike.
6) User Specific mode selections: User can select modes like highway, sports, urban etc. Range and speed will be- havior will vary accordingly.
7) Speed Regulation: User can set a particular speed and the SeB1.0 will maintain that speed irrespective of pedaling speed of the user.
8) Range prediction based on route taken and user pro- file: Road conditions will be recorded based on accel- erometer readings, road inclinations , user pedaling pat- tern, SoC, SoH, temperature etc. The values are mapped with a route and latitude/longitude values taken from phone's GPS and stored on cloud for effective pattern learning. Effective and reliable range predictions can be made given enough learning sample size. User profile like weight, age will also play a role in range predictions. The user will automatically be identified basis on the smartphone paired.
9) Regenerative/Pedal charging: A provision for regenera- tive charging in case of braking and even downhill will be provided. Also, pedal charging will also be provided.
10) Route suggestion based on current traffic: Route sug- gestion based on route parameters like slopes in particular route and traffic density will be provided to the user.
11) Fatigue/inclination based pedal assistance: Additional assistance will automatically kick in when fatigue of user or inclination in road is detected. Also, beeper will beep to keep the user alert.

12) Trip Analysis: Analysis of trip will be provided at the end of each trip
13) Auto turn indicators: If suggested route is chosen by the user, the turn indicators will automatically start blinking on respective turns.
14) Rider behavior summary: This will provide a rider be- havior summary (excessive breaking etc.) and hence pre- dict life of various wear and tear components like brake shoe, tires and hence help in predictive maintenance. Also, time taken from braking to halt can also provide a score of effectiveness of current brake shoes and tire treads.

This version is effective for personal users where the user will be carrying a smartphone in order to make use of each and every feature explained above. But in sharing business model, where the owner wants to provide these user friendly features and also wants to track the bicycle live or at least wants the history as to what route did the bicycle travel, how many kilometers did the SeB1.0 travel for billing purpose and to provide better experience to future users, SeB1.1 will prove to be a better solution compared to SeB1.0.

2.2. SeB1.1 variant details

SeB1.1 does not require a smartphone to be in range to collect route based information. Since it has a GPS, it can still map accel- erometer/inclinations/scope, battery health, speed data with loca- tions in internal memory. It will upload this stored data after pair- ing up with smartphone when it comes back to the Sharing busi- ness owner. This stored data will help him analyze the past trips for billing purpose or any other intended purpose. This data might also prove helpful for future trips for the same customer (driving pattern learning) or future trips on same route for different cus- tomers (route based learning). This history data can also help the sharing business owner to know if the SeB1.1 was taken outside the geographical boundaries agreed with the customer and also the driving behavior of the customer.

A simple block diagram of SeB1.1 is given in fig. 3. Note the presence of GPS chip in place to maintain a map of data vs loca- tion. If a smartphone is paired with the SeB1.1, the smartphone's GPS will be used and internal GPS of SeB1.1 will be off to reduce power consumption.

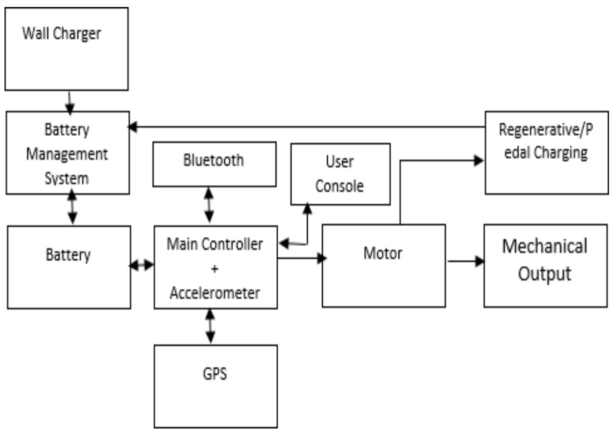

Fig. 3: Block Diagram for Seb1.1.

This architecture, though better than SeB1.0 still has its limita- tions of not giving live data to track the SeB1.1 in real time. Hence, SeB1.2 variant is employed to overcome this limitation.

2.3. SeB1.2 variant details

This version of SeB overcomes the limitations of previous versions by including a GSM/LTE module in the architec- ture. This architecture is represented using a block diagram representation in fig. 4.

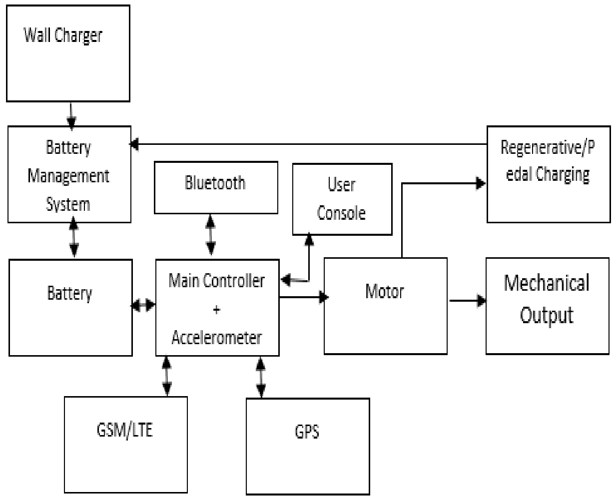

Fig. 4: Block Diagram for Seb1.2.

In this case, if a Smartphone is connected, the analytics data is collected and transmitted to cloud using the smartphone itself and GM/LTE and GPS module are kept OFF to save power (this behavior will be kept configurable by user). If a smartphone is not connected, the sharing business owner can still track the vehicle and console can still guide the user to best possible route, reliable range and all other features explained in SeB1.0 section. Also, emergency alerts can also be triggered from SeB1.2 directly with- out any dependency on a smartphone.

So, in addition to SeB1.0, this version adds following features:
1) Theft alert: This can trigger a theft alert and intimate the owner about the theft.
2) Live tracking: Sharing business owner will be able to live track the bicycle.
3) Remote immobilizing: In case of theft, the SeB1.2 owner can easily immobilize the bicycle.
4) Real time fence alert: If the SeB1.2 crosses the prede- fined fence, an alert can be triggered to owner's login

2.4. Future enhancements

With the connected vehicle revolution taking place, having a GPS on bicycle will enable the bicycles to be a part of connected vehicle ecosystems. So, data from these bicycles will connect driverless cars to bicycle and hence help make their decision mak- ing more accurate and reliable. Also, the Bluetooth on bicycle can also be used a beacon (depending on mode) and hence it will make it visible to similar devices in proximity. This may prove helpful for other vehicles to visualize the vehicle on which this beacon is mounted in foggy or low visibility conditions. This will prove to be a safety feature.

Also, adding voice controls for adjusting the screen for naviga- tion purpose, for manual assistances etc. will also prove to be helpful in safety of the user (so that user's hands are used for con- trolling bicycle only) and also it will be a user friendly feature.

3. Conclusion

In essence, the proposed technology will create interest in users to use electric bikes in a user-friendly manner and will satisfy the needs of personal as well sharing business users. Also, the best suitable routes and regeneration in downhill will extend the range of the SeB. Special focus on predictability of the bicycle, predic- tive maintenance and safety features(like accident alert and voice con- trolled operation) will also prove to increase the popularity of SeB in users. In short, this will prove to add value to the lives of all types of consumer and hence will pave the way to a greener and cleaner future.

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