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Design of Artificial Intelligence Based Speed Control, Automation & Braking System For Cars Using Open Source Brain-Computer Interface Technology

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Abstract: A new design of speed control, automation and braking system for cars incorporating open source Brain-Computer Interface technology is proposed in this paper. In traditional cruise control system, accidents may occur, if there exist any lack of concentration. To overcome this automated system controlled by brain waves is proposed. In the open source BCI, Brain waves are obtained as voltage fluctuations and Ionic current through high sensitivity electrodes from which they are categorizes based on its frequency limit. The signal acquisition part conditions the extremely low frequency radio waves. By employing machine learning algorithm, a signal is converted into codes- machine language and is transmitted. The received signals after error detection and filtration process is compared with the actual value determined by the Hall sensor fixed at the rear wheel of the car. The output of the comparator is fed to decision device which controls the mechanical system and performs the operation. Along with this automated system, additional guidance is provided to the user by means of Voice Guidance based Bluetooth module. The proposed mind reader section is in the form of a head set.

Keywords: Open source Brain-Computer Interface (BCI), Duemilanove Arduino board, Machine Learning algorithm, automated control, Integrated Computer System, Bluetooth module.

INTRODUCTION

Road fatalities are one of the major problems faced in today's world. From the Bibliometric statement of World Health Organisation (WHO), India leads in road fatality rate of about 20.1 percent. Whereas from the another analysis of Economic Times about 13 people die per hour in road accidents in India, that results in annual mortality of about 1,19,860 per year. Among this death rate, car accidents stands top of about 54%. The major reason for car accidents is due to lack of concentration of the driver. Every year about 78.5% of car accidents occur due to this lack of concentration. The road fatality rate for last five years is shown in Fig 1.

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Artificial Intelligence has become a tremendously growing technology for production, Instrumentation and automated Control systems. In this current state of art most cars uses the ordinary speed control technology, in which the pedal pressure is to be maintained.

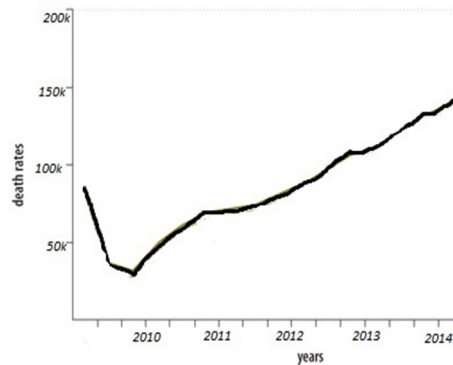


Fig 1: Statistical Death Rate In India

For this high degree of concentration is required, hence by this method road accidents cannot be completely eliminated. By taking the above factor in consideration a speed control system that results in higher efficiency and reduced mechanical stresses even in case of rash driving is proposed. The major theoretical background of this proposal is from Electroencephalography. Brain- it is the most complex system ever existed in this world with greater speed of response and higher degree of accuracy. Human- Brain produces different responses as waves for various situations; these responses are tracked as voltage fluctuations and ionic current from which the frequency limits of the response can be easily determined.

Open source Brain-Computer Interface is a fully customizable optimum device that is available to track brain wave at a faster rate with better accuracy. In particular, the waves are obtained through the scalp region by high sensitivity electrodes. By employing “Reducing Electrode” concept, the number of electrodes required for analysis is reduced to half such that the complexity is reduced [section IV-A]. From the potential difference and ionic current the frequency of wave is calculated and is injected to the signal acquisition part. The signal is amplified with Gain factor (i.e.) signal with poor characteristics is converted into a better characteristics signal [section IV-B]. Translation part converts the signal into codes by employing machine learning algorithm and is transmitted. Signal is transferred at the rate of 120 signals/minute. The receiver section receives the BPSK code and is filtered and processed to retrieve the original signal. In order to remove noisy interferences a band-pass filter is introduced at processing unit [section VI]. The original retrieved signal is assigned previously, for a specified speed limit, this value is compared with the original speed calculated from the digital hall sensor fixed to rear wheel of the car. The comparator output is fed into a decision device which is normally an integrated computer system. Based on the output, computer system controls the mechanical system and performs the desired operation [section VII]. An efficient operation is only possible when the comparator continuously compares the original speed with the reference speed. In addition guidance is provided by APR9600 microcontroller, to which voice guidance’s system (bluetooth module) is connected. For different mind state, different guidance are played which are pre-recorded. The method proposed in this paper is an initial step to avoid the limitations posed by the traditional speed control strategy, and incorporate open source BCI making the system more stable, feasible, reliable and economical. The proposed control system is independent and does not require high degree of concentration level. This is achieved with a simple BCI circuit without adding complexity to the system.

LITERATURE SURVEY

[1] Arelene Ducao, a post graduate student of MIT has designed a prototype model of helmet that can read the brain waves to determine the current status of mind of the cyclist. She has used coloured LED lights to show alert for various moods. Prototype model works on electroencephalography technique, that tracks and analyse the brain waves from the specified frequency limit is calculated and with respect to that instruction LED will glow. The main shortcoming of her proposal model is that it acts only as a mood detector helmet with alert guidance, in visual mode.

[2] Joel Murphy and Conor Russomanno designed a fully integrated and customizable device that performs the action of an EEG with reduced size thus forming an interface between Human and computer. This design comprises both hardware and software

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toolkits thus eliminating long lines of codes and circuit diagrams. This design led to the development of next generation technology.

[3] Ankita Mishra and Pranav paranjpe proposed a paper on RF based speed control system for cars. The system runs on embedded programming. The major drawback of the system is that it includes only the speed control operation. Moreover the efficiency of the system is limited and in certain cases of rash driving accidents is unavoidable.

PROPOSED SPEED CONTROL & BRAKING SYSTEM

The block diagram of the proposed speed control and braking system is illustrated in fig.2. The proposed system consists of the Brain Wave analysis, wave amplification (EEG hardware amplifier), transmission and operational stages connected through a wireless medium. The wave analysis stage consists of high sensitivity active electrodes, to convert the physical vibrations in the scalp regions to its respective voltage fluctuations (V_t) and Ionic current (i_c). The amplification stage amplifies the extremely Low frequency Radio Signals with a high gain factor, along with signal processing unit. The transmission stage performs the code conversion by employing machine learning algorithm along with BPSK transmission and reception. The receiver end converts the binary codes to retrieve original signal. The output signal is filtered with the help of a band pass filter before sending it to the computer automated system. The corresponding reference speed of the signal is compared with original speed of the vehicle, based on comparator output decision device performs the operation in stages. The measurement of quantities of voltage and current from the analysis stage is very important for guidance system.

BRAINWAVE PROCESSING UNIT

It is something exclusive and impressive to define about the organ- human brain. Brain is the complex system ever existed in this universe with most complicated structure with higher degree of consciousness. Brain- the complex machine system capable to response for emotions, thoughts and memories. It is capable to transfer data between neurons at a rate of hundred terabytes. When a human brain thinks or responds, it transfers information as spontaneous electrical activity between lakhs and lakhs of neurons, which can be tracked and analysed by implementing an interface. EEG processor plays a major role in detecting the status of brain such as sleep disorder, coma or condition of agitation. No wonder that every minute section of brain can dictate and target disease in whole body.

Table 2
Brain Wave Analysis & its Parameters

Brain wave	Status	Frequency pulse/second	Amp (μV)
Beta β	Consciously alert	13-16	5-10
Alpha α	Mental relaxation	7-13	20-200
Delta δ	Reduced Consciousness	4-7	10
Theta θ	Deep sleep or Catalepsy	0.1-4	20-200

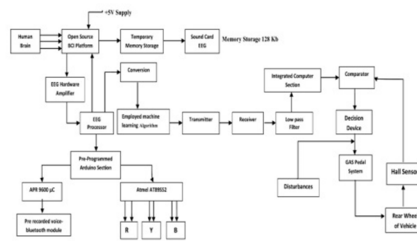


Fig 2: Block Diagram of Proposed System

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BRAINWAVE CLASSIFICATION:

Human brain produces four distinct types of pulses for various responses. The description of the pulses are as follows:

- (i). **Beta**: human brain produces beta (β) pulse under conscious alert stage, with a frequency range of 13-16 pulses/second
- (ii). **Alpha**: it is produced under relaxation stage. It is further classified into two short pulses
 - a). μ Wave: Relaxed Mental state
 - b). REM wave: Sleep stage

The frequency range is between 7-13 pulses/second
- (iii). **Delta**: these waves are analysed when human brain faces reduced consciousness level with a frequency limit of 4-7 pulses/second.
- (iv). **Theta**: It is the state of deep sleep or catalepsy with extremely low frequency of 0.1-4 pulse/second.

BRAIN WAVE TRACKING USING ACTIVE ELECTRODES:

One square millimetre of cerebral cortex has more than 100,000 neurons. When electrical activity takes place on scalp surfaces can be tracked by using high sensitivity active metal electrodes. Large quantities of neurons are present in the scalp regions of frontal, sulcus, temporal,

Parietal and occipital. Hence, a configuration with 64 pair of electrodes is to be placed in these regions with a ground electrode placed in ear. Potential difference action majorly takes place in soma and dendrites. This results in ionic current flow consisting of Na^+ , K^+ , Ca^{++} and Cl^- ions that can be obtained by metal electrodes.

Mostly, seven sets of electrodes have predefined activity that can never be altered.

- F7- rational activity of brain (Delta wave)
- F8- Emotional activity impulses (Alpha wave)
- C3, C4 & Cz- Sensory and motor functions
- P3, P4- Perceptual activity (μ wave)
- T3, T4- processor unit for alpha waves
- O1, O2- Bellow points

Various types of electrodes are there, for this proposal the electrode should meet the following specifications:

- 1). Reusability Behaviour
- 2). Metal electrode [Au, Ag, tin]
- 3). Active material- Should eliminate need of gel and needle
- 4) Thickness of electrode: imm-1.5mm
- 5). Diameter of electrode 1-3mm

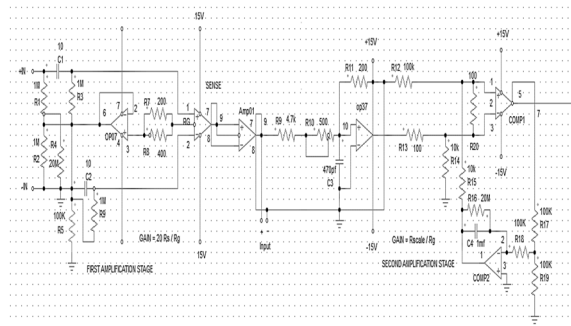


Fig 3: Amplification Circuit for Brain Wave Processing Stage

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BRAIN WAVE CONDITIONING UNIT:

The obtained weak electrical signals are massively amplified for next stage process and also stored in SCEEg for future analysis. The received signal is of 100µV, but for next stage analog to digital process the signal should be of 0 to 10V. Hence the signal requires a gain of about 10,000 or more. The next major issue is the frequency range, with 0.1 to 64 Hz creates a large noise levels. To reduce the complexity level and for better performance two stage amplification with a gain inverter is proposed here. MC34084- ‘Instrumentation amplifier’ overcomes the basic issues and produce balanced output with a very low noise characteristics. The above fig. shows the first stage amplification of brain wave coupled with second stage through a gain inverter.

$$\text{Gain} = 20[R_s / R_G]$$

The selection of Rs and Rg depends on that the first stage amplification should produce a gain of 1000. Error may occur due to the improper pattern aligned of brain wave analysis electrodes which leads to the development of Offset voltages. To remove this a non-polarised capacitor is coupled with amplifier. The unity gain inverter removes the common mode signal. The operational amplifier Op-37 removes the noise signal and eliminate the effect of phase shift. The second amplification stage is configured for variable gain described as

$$\text{Gain} = R_{\text{scale}} / R_g$$

AF-100 filters are employed as an anti-aliasing filter. The phase shift applied by this filter is linear, maintaining composite waveform. Thus the total gain of 1x10⁴ is achieved.

MACHINE LEARNING ALGORITHM

Machine Learning Algorithm is one of the popular Artificial Intelligence technique employed to manage conversion of ELF radio waves to binary codes. A specified Minimum Redundancy Maximum Relevance (mRMR) with accurately identified subset of data constraints are used. The supervised mRMR type algorithm automatically identifies the data subset relevant to the initial parameters already employed. The next feature of the mRMR algorithm is the sequential selection behaviour. This type of heuristic algorithm reduces the dependency of the system.

Step 1: Problem description: At the very first stage the problem statement is defined and observed. From that the formal constraints of data and initial design of the solution is found.

Step 2: Analysis of Data: This stage involves summarise the structure of data and visualization of data.

Step 3: Preparation of Data: here the pre-processing of data along with transformation is carried out.

Step 4: Evaluation of result: For this specified application supervised linear formal Machine learning algorithm.

Step 5: Improvement of Data: Final stage content, problem, solution, limitations and conclusion are considered for improvement and the process is again carried out for better performance.

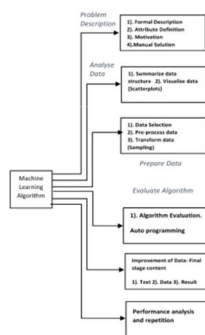


Fig 4: STRUCTURE OF APPLIED MACHINE LEARNING ALGORITHM

TRANSMISSION OF CODES

The signal is converted into code with a carrier signal to a balanced modulator. Redundancy is a major problem faced in bit conversion which is easily reduced by employing minimum redundancy technique. The model includes the square law device and band pass filter that removes the noisy interferences. The transmission and reception of the code sequence is manipulated by the Binary Phase Shift Keying methodology.

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Let the signal is represented as

$$f(x) = A \cos(\omega t) \dots (1)$$

A is the peak value of the sinusoidal wave. $\omega = 2\pi f$; Where 'f' corresponds to the frequency of the analysed wave. The continuous signal is converted into a discrete one with a phase shift of 180 degree, when the value of the symbol is changed. The phase shift depends on the time delay between the transmitter and the receiver. The received BPSK signal is passed into a square law device and then to a band pass filter for filtering process. After this the frequency of the halved and compared with the received signal. The bit synchroniser controls the switch s1 and s2 of the integrator system by which the phase

For symbol '0' $\rightarrow f(x) = A \cos(\omega_o t) \dots (2)$

For symbol '1' $\rightarrow f(x) = A \cos(\omega_o t + \pi) \dots (3)$

Then the signal from the square law device will be

$$\begin{aligned} \cos^2(2\pi ft + \theta) &= \frac{1 + \cos 2(2\pi ft + \theta)}{2} \dots (4) \\ &= \left(\frac{1}{2}\right) + \left(\frac{1}{2}\right) \cos 2(2\pi ft + \theta) \end{aligned}$$

Here (1/2) represents the DC voltage level, hence it can be neglected.

$$S(kT) = b(kT) \sqrt{\frac{p}{2}} \int_{(k-1)T}^{kT} [1 + \cos 2(2\pi ft + \theta)] dt \dots (5)$$

By expanding and substituting the limits

$$S(kT) = b(kT) \sqrt{\frac{p}{2}} \int_{(k-1)T}^{kT} [1] dt \dots (6)$$

From the above integration process the original signal is retrieved at the receiver end section. The important issue is to determine the distance 'd' between the symbols, by.

$$d = +\sqrt{E_b} - (-\sqrt{E_b})$$

'E_b' is termed as bit energy.

AUTOMATION & CONTROL LOOP

In the propose system, automated operations are performed based on the analysed output of the decision chamber. The lookup table provides the status of the brain and its corresponding binary value. The original signal is compared with the reference signal obtained by the digital Hall sensor that is fixed to the rear wheel of the vehicle.

Table 2:
LIST OF OPERATIONS FOR BRAIN WAVES

Binary Sequence	Pulse	Specified operation
00	Theta	Brake
01	Delta	Speed=30Km
10	Alpha	Speed=40Km
11	Beta	No change

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DETERMINATION OF SPEED FROM HALL SENSOR

For better accuracy DRV5013 digital hall sensor is fixed at the rear wheel of the car. This hall sensor determines the accurate and current RPM status of the car. But for comparison speed is required, so it is converted into speed using the following relation.

$$\text{Actual rpm of wheel} = N \text{ revolutions/minute}$$

$$\text{Drive shaft speed} = \frac{[N]}{[X1]} \text{ revolutions/minute}$$

$$\text{Drive shaft speed} = \frac{[N]}{[X1]} \text{ revolutions/minute}$$

$$\text{Actual rpm of wheel} = N \text{ revolutions/minute}$$

For speed (i.e. Km conversion);

1 mile = 5280 feet = 63,630 inches

1 hour = 60 minutes = 3600 seconds

X2 = Rear axle speed

R = Radius of Wheel

From the above equation the speed of the vehicle is determined.

CONDITIONS FOR OPERATIONS:

Condition 00: Here the reversal order of the wave is used. Binary sequence '00' represents the Delta wave. Since the pulse produced per second is in order of 0.1 to 4, the response rate is low. So the speed control of the system takes place in a faster manner. Suppose the car is running at a rate of 3000 RPM, the RPM rate is reduced in steps at the rate of 1000 rotations/minute. Finally the speed is completely reduced and braking is applied for safety purpose.

Condition 01: Condition '01' stands for Theta wave. Along with the guidance measure provided by the LED blinking and the Bluetooth module the speed is also reduced in two steps. Suppose the speed of the car is 60km/hour. The speed is reduced in three steps. This is done that the final speed of the car will be equal to 30Km/hour.

Formula used: $[(\text{Current speed} - 30) \text{ km/hour}] / 3$

Step actions: from the above analysis when the current speed is 60Km/hour. Then $[60-30]/3 = 10\text{Km}$. So, in each step 10Km speed is reduced. In the decision device the time can be altered within which the speed of the system want to reduce in one step. For better performance and to reduce the accident occurrence rate. The time should be less than 60 seconds for a step.

Condition '10': Condition '10' is used for the Alpha pulses, at this time the user is in relaxation stage, also aware of what is happening around him. But when a sudden change occur in surrounding may make the brain to change its response, accidents may occur. So in this stage the speed is maintained at 40Km/hour (Maximum City Speed limit in India). The speed is reduced in a single step.

Formula used: $[(\text{current speed})-40]/1$

Example: suppose when the speed of the car is 60Km/hour. Then it is reduced to 40Km/hour in a single step.

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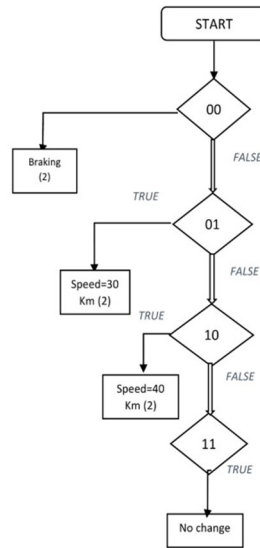


Fig 5: CONTROL FLOW STRUCTURE

Condition ‘11’: Binary sequence ‘11’ represents the Beta wave. At this state the human brain is completely aware about what is happening around it. So in this the speed control action is not performed and the speed is maintained and can be controlled by the driving person. So based upon the output of the decision device the speed of the system can be controlled.

WORKING OF COMPUTER AUTOMATED OPERATIONAL SYSTEM:

The control scheme of car controls the speed by adjusting the throttle. The car will maintain the desired speed by adjusting throttle value cable with a solenoid. This runs a vacuum driven servomechanism completely controlled by a microcontroller, built electronic section. The original speed which is to be maintained is compared with the reference internal speed pulses produced by the speed sensor and the difference in speed is calculated. Let the actual speed of the car is 70km/hour. The original speed is to be maintained at 40km/hour calculated from the automated system. The difference in speed is about 30km/hour. Hence the microcontroller controls throttle cable that drives the vacuum driven servomechanism and alters the pressure of the braking pedal. Thus when the actual speed equals to reference speed then the movement of throttle cable is stopped and maintained throttle is majorly controlled and operated by an actuator; stepper motor.

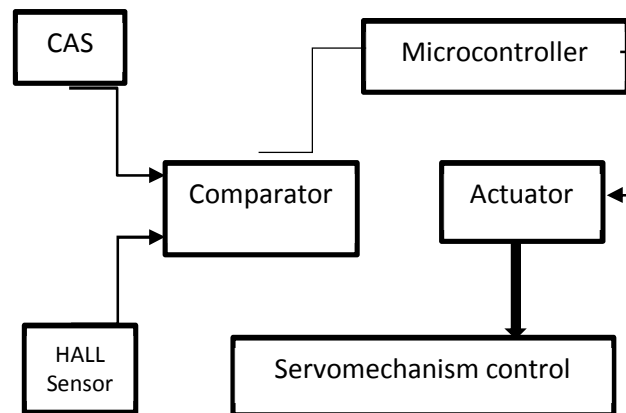


Fig 6: MECHANICAL CONTROL OF SYSTEM

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DECISION DEVICE:

Here Decision device includes a main computer which compares the input from Hall sensor (which continuously monitors the velocity of the vehicle) and the reference speed which is already predefined for each concentration level or mood. This classification is done with the signal received. Then the decision device compares and by employing the formula the speed of the vehicle is altered with the help of the throttle.

BRAKING SYSTEM:

The brake action is the most critical, since it must be able to stop the car in case of a failure of the autonomous system. For safety purpose electro hydraulic braking is used. Two shuttle valves are connected to the input of the braking system in order to keep the system independent. Each valve permits flow from either of two inlet ports to a common outlet by means of a free-floating metal ball that shuttles back-and-forth according to the relative pressures at the two inlets.

BLUETOOTH BASED VOICE GUIDANCE MODULE:

The signal from open source BCI is transmitted to the microcontroller through serial port using RS-232 protocols. Corresponding to the string received, the microcontroller places data on the pin activates, which transmits a string of 0's and 1's to the **APR9600 IC**. A LOW signal placed on the pin activates it and voice stored in that memory location is played back through the headphone.

RESULT

Here, the graphical representation of the brain wave scatter plots (i.e.) sudden change in mind set is shown in figure (7). It is plotted by taking Time (in second) versus Frequency of the Brain wave in Hertz.

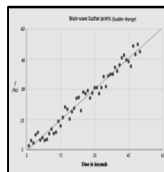


Fig 7: BRAIN WAVE SCATTER PLOTS.

The major aim of this proposal is to provide an initial stage design of an automated speed control and braking system that should be much efficient to overcome the limitations of ordinary cruise speed control system. Thus the speed control strategies are yet to be standardized for the brain wave responses. In reality, concentration level of human brain varies and this may lead to inaccuracies and accidents, if the ordinary cruise control system is not efficient. To overcome this problem, four different brain response characteristics are analysed and these data is provided as input for further operation. The brain wave pattern and arrangement characteristics used in this design is based on the real data measured by EEG. Brain is the high speed system which commands and controls all the other parts of body. Here, the brain is direct the way connected to the automated system. So, the system will function with high accuracy and speed.

CONCLUSION

The automated speed control system and braking system using an open source Brain-Computer interface Technology and Arduino section has been discussed in this paper and the control, operation conditions was proposed. The system reduces the complexity and the shortcoming of the normal Cruise control scheme. The Machine Learning Algorithm for conversion is very simple, that completely overcomes the limitations in transmission of the extremely low frequency radio waves. The proposed system has been developed for the real time access application to limits the road accidents due to lack of concentration.

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