

TECHNICAL PAPER FOR STUDENTS AND YOUNG ENGINEERS**- FISITA WORLD AUTOMOTIVE CONGRESS, BARCELONA 2004 -**

TITLE:

DEVICE THAT PREVENTS ACCIDENTS CAUSED BY DROWSINESS AT THE WHEEL

Topic:

- FUTURE AUTOMOTIVE TECHNOLOGY INTELLIGENT TRANSPORTATION SYSTEMS
 USER FRIENDLY AUTOMOBILE ADVANCED PRODUCTION AND LOGISTICS
 VEHICLES & THE ENVIRONMENT

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National Society:

 YES NO

Name of the National Society:

Abstract:

In this project we have worked to develop a device that can reduce the number of accidents caused by drowsiness and lack of sleep on the road. A PDA is used in connection with an electronic device the size of a thick wallet which conducts an electroencephalogram of the driver on the road. Both the PDA and electronic device are already being sold in the USA. To obtain the information needed, the electronic device is hooked to sensors placed on a baseball cap which lays on the drivers head. We have designed a block in Mathematica® capable of analyzing brainwaves graphs and able to warn the driver with a beeping sound when he is about to doze off on the road. Our targeted groups are truck and bus drivers, and to achieve success we have interacted closely with neurologists

Place / Date:

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BACKGROUND OF THE PROBLEM

To doze off while driving is a very important cause of accidents on the road. Apart from bus and truck drivers, people who suffer sleeping disorders or are over the alcohol limit have more chances to become asleep at the steering wheel. In a study of the causes of accidents happened in the Basque Country in the year 2002 (2) (Appendix 1), 6% of the deaths accounted for tiredness, sickness or drowsiness at the steering wheel. Although that figure may not seem too large, it becomes quite important if the cost in human lives is taken into account. That year 11 people died on the road and 27 were seriously injured in a relatively small developed region of Spain.

We dug for information on methods to prevent those accidents. None of the projects we found involved the analysis of brainwaves. An individual can be monitored by measuring the frequency and amplitude of pulses emitted by the brain. This concept is the foundation of the designed device. The project is focused mainly on bus and truck drivers, as they spend many hours a day driving, therefore being more likely to cause this sort of accidents. Also, the relatively high price of the device makes it easier to be implemented in trucks and buses. However, it can be implemented in cars and we hope it will when large production begins, as prices fall.

Previous surveys were conducted before the beginning of the project. They provided positive results, as almost all bus drivers and many truck drivers showed deep interest in the device. Some ideas were collected from interviews with people from those groups, as well as doctors. The project is not over since the device has not been tested yet, and we are still working with neurologist to improve our wave filter, which is a very simple one at the moment. The overall price of the device could be around 3000 Euros.

FEATURES OF THE DEVICE

To understand how the device works, an approach to brainwaves must be made (1). A human's brain generates the following waves:

Gamma: Excited State. Frequency: (maximum) between 30 and 50 Hz. Amplitude: (minimum) below 15 μV

Beta: Fully Awake and Concentrated. Frequency: between 15 and 40 Hz. Amplitude: between 10 and 30 μV

Alpha: Awake and Relaxed. Frequency: between 9 and 14 Hz. Amplitude: between 20 and 40 μV

Theta: Very Relaxed, Light Sleep, Meditation. Frequency: between 3.5 and 8 Hz. Amplitude: between 40 and 70 μV

Delta: Deep Sleep. Frequency: (minimum) below 3 Hz. Amplitude: (maximum) above 75 μV

When a person feels drowsy, his or her brain is emitting Theta waves. Theta waves will be the object of our study then. However, studies have shown people who do a lot of freeway driving are in high Theta for long periods of time while they drive. The limit between consciousness and sleep is not so clear at times. In our device, we will control both Frequency and Amplitude of the waves using an electroencephalogram (EEG). Depending on many factors, each person might doze off at a different Frequency and Amplitude, so a periodical medical check of the driver is needed.

Waves must be obtained by electromagnetic sensors placed on the head of the driver. In one of our visits to the Neurology Department of the Clínica Universitaria de Navarra (one of Navarra's hospitals), we were shown a hat which had sensors inside. We did some research on the subject and in many websites caps and hats that had sensors to measure waves were found. Those hats are caps are said to be comfortable and easily wearable, and can be worn for hours. The headset accurately locates the sensors in adults using four standard head sizes and maintains sufficient downward pressure on the sensors to ensure high quality recordings without the use of a chin or chest strap. Disposable sensors have been developed that dispense a small amount of conductive gel without the need to abrade the skin or part the hair. A miniaturized battery-powered data acquisition system incorporates the electronic components required to acquire, digitize and transmit the signals. The following pictures correspond to a cap which is advertised by Advanced Brain Monitoring inc. in its website (3).



The signals obtained are transmitted by radio frequency, without cables that could be a problem in case of accident. Similar hats can be found in many other websites. Prices are not shown, possibly because although the product has already been designed and constructed, it is not ready yet for the general public. In the surveys that were carried out, 13 out of 31 (42 %) truck drivers mentioned that wearing a cap does not bother them while they drive.

Now the data that the sensors have acquired needs to be processed in order to obtain the electroencephalogram. In web sites many companies advertise small devices able to carry out an EEG. We will be using a small instrument a little larger than a cigarette

pack called C2-RF that is sold by J&J Engineering on its website (4). It is connected to a PC. A system to receive the information sent by the sensors has to be implemented in the C2-RF device. It has the following technical specifications:

<p style="text-align: center;">Range</p> <p style="text-align: center;">Transmission Type</p> <p style="text-align: center;">Radio Frequency</p> <p style="text-align: center;">Input Channels</p> <p style="text-align: center;">Amplifier Failure Protection</p> <p style="text-align: center;">Static Discharge Protection</p> <p style="text-align: center;">Power Source</p> <p style="text-align: center;">Electrode Impedance Test</p> <p style="text-align: center;">EMG Bandpasses</p> <p style="text-align: center;">EEG Bandpass</p> <p style="text-align: center;">EMG Artifact Detector Channel</p> <p style="text-align: center;">Heart Rate Bandpass</p> <p style="text-align: center;">R Wave Filter & Detector</p> <p style="text-align: center;">IBI or HR Output</p> <p style="text-align: center;">Temperature Range</p> <p style="text-align: center;">Skin Conductance Range</p>	<p style="text-align: center;">100 ft. maximum</p> <p style="text-align: center;">Digital with error detection</p> <p style="text-align: center;">ISM band (no FCC license required)</p> <p style="text-align: center;">6 (2 EMG, EEG, ECG and 4 SR, TEMP, RESP)</p> <p style="text-align: center;">50 μA maximum</p> <p style="text-align: center;">+15,000V</p> <p style="text-align: center;">2 AA alkaline batteries</p> <p style="text-align: center;">250 Ohm to 1 Mohm at 5 Hz</p> <p style="text-align: center;">100Hz to 400Hz, 20Hz to 400Hz</p> <p style="text-align: center;">1 to 50Hz</p> <p style="text-align: center;">30Hz to 100Hz RMS</p> <p style="text-align: center;">1Hz to 400Hz</p> <p style="text-align: center;">Single Beat Update</p> <p style="text-align: center;">40 to 200 beats/minute</p> <p style="text-align: center;">60° to 100°F (15° to 38°C)</p> <p style="text-align: center;">1 to 100 μS</p>
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It works with the following computer software installed in the PC:

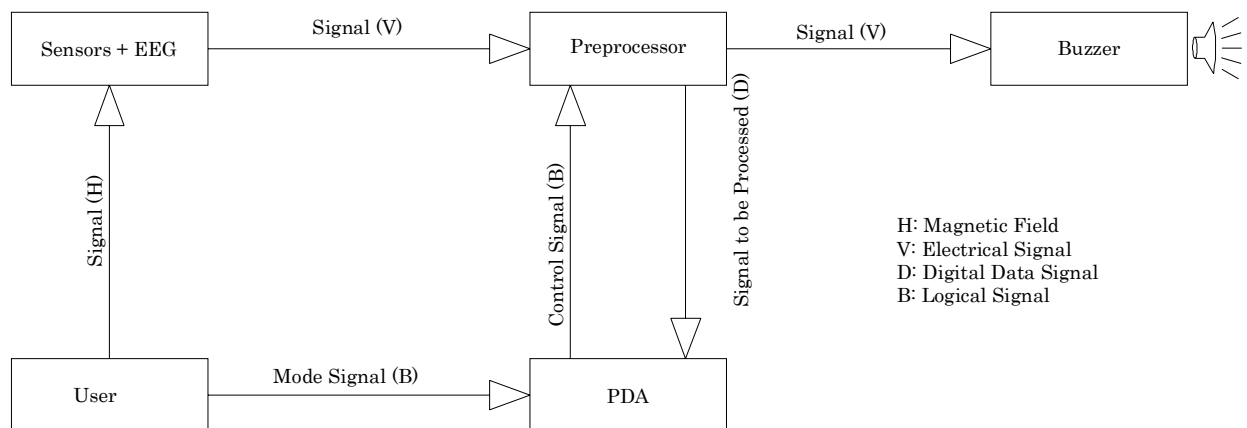
- Windows 98
- Windows ME
- Windows NT
- Windows 2000

With the development of computers and PDAs, nowadays most PDAs fit those specifications. Thanks to the “Bluetooth” technology, the C2 device and the PDA can be joined with a wireless connection. The PDA plays an essential role in this project, since it controls the device. The user can choose between two modes. EEG mode, in which the EEG is shown in the PDA screen while the user is not driving; and Anti-Sleep mode, used on the road to prevent people from dozing off. It can also offer the truck and bus drivers a wide variety of functions that ease their jobs. From GPS (which we found missing in most trucks according to the information obtained by the surveys) to Internet. In the surveys, 65 % of truck drivers were quite used to computers, so the use of a PDA should not be a challenge for them.

The mission of the preprocessor is to free up the PDA from processing work needed to carry out Fourier analysis of the signal, and also to save up memory. The preprocessor is needed since the PDA can also be used for other applications, like GPS, audio, video or communications. Those applications require many resources that might prevent the device from working properly.

A buzzer is installed to warn the driver he is starting to doze off and that he should pull the car over and rest.

Software – Block Diagram



The preprocessor receives the electrical signals that have been treated in the C2 device. It has a memory where it keeps a variable B whose value can be 0, 1 or 2. The value of this variable is chosen by the user on the PDA. The following values represent:

B=0, EEG mode

B=1, Anti-Sleep mode

B=2, Warning mode

The signal takes different ways depending on the value of B. If B is 1 or 2, the digital signal passes on to a program which carries out a frequency and an amplitude analysis. This program is located in the preprocessor, and returns the value of the most significant frequency and amplitude of the signal treated. This value is sent to the PDA to be analyzed. That way the PDA does not have to conduct a Fourier analysis. If B = 2, a signal to the buzzer is also sent to warn the driver that he is dozing off.

The PDA receives the treated signal and behaves according to the value of B. If the value is 0, then the signal is sent to a program that shows the EEG on the screen of the PDA. If B is 1 or 2, the signal is sent to a program that analyzes its frequency and amplitude to know whether the driver should be at the wheel or not. If he should (normal state), B is assigned the value of 1. If he should not (he is feeling drowsy), B is given the value of 2. After this, the PDA has access to the value of B and actualizes it (Appendix 2).

Program for the Frequency Analysis

Knowing from the Fourier analysis

$$F_j = \frac{1}{N} \sum_{k=0}^{N-1} f_k e^{-i \frac{2\pi}{N} kj}$$

This expression can be obtained:

$$F_j = \frac{1}{N} \sum_{k=0}^{N-1} f_k e^{-i \frac{2\pi}{N} kj} = \sum_{k=0}^{N-1} f_k \frac{1}{N} \left(\cos\left(\frac{2\pi}{N} kj\right) + i \sin\left(\frac{2\pi}{N} kj\right) \right)$$

This can be divided into a real part and an imaginary part

$$|F_j| = 2\sqrt{\text{Re}(F_j)^2 + \text{Im}(F_j)^2}$$

The frequency that corresponds to each amplitude is the following:

$$f_j = \frac{j}{T_{\text{muestreo}}}$$

N is the number of samples per second. A sufficiently high N must be chosen so that aliasing does not happen. The Theorem of Shannon will be taken into account. The amplitude of brainwaves is most of the times under 30 Hz, which makes N at least 60. A N of 100 samples per seconds will be picked.

This program takes as input data an array of data and returns the most significant frequency # after a Fourier Analysis.

Constants

These constants will be stored in memory and are read only.
It is not necessary to calculate them every time the program starts.

N = N

Sampling Time = Sampling Time

RealMatrix_{ij} (1<=i,j<=N) = (1/N)*sin(2*pi*k*j/N)

ImaginaryMatrix_{ij} (1<=i,j<=N) = (1/N)*cos(2*pi*k*j/N)

Program

Read Input Data

Store Input Data in a variable vector: InputData

Create variable vector: Vector1 = InputData x RealMatrix

Create variable vector: Vector2 = InputData x ImaginaryMatrix

Vector1= Vector1* Vector1

Vector2= Vector2* Vector2

Vector=Vector*Vector rises each component to the second power

Create variable vector: V = 2*SquareRoot(Vector1+Vector2)

SquareRoot(Vector) finds the square root of what is inside the parenthesis.

Create Real Variable: max = Maximum(V)

Create Integer Variable: Ind= Index(max,V)

Index(max,V) finds the index where the variable max is placed in the vector V

Create Real Variable: Freq = (ind-1)/SamplingTime

Return Output Data (Freq)

The value of the most significant frequency is returned.

End

Program for the Amplitude analysis

This program calculates the amplitude of the input signal based on Fourier Analysis. It finds the mean square value of the signal. This mean square value is related to the amplitude of the wave and is represented by the following value:

$$v_L = \sqrt{\frac{1}{T} \int_0^T v^2(t) dt}$$

This can be approximated as

$$v_L \approx \sqrt{\frac{\Delta t}{T} \sum_{i=0}^T v^2(t)} = \sqrt{\frac{\sum_{i=0}^n v_i^2}{n}}$$

In which n is the number of samples taken in each period of the signal

$$n = \frac{N}{f}$$

N is the number of samples per second (as used in the Fourier Analysis) and f is the frequency of the signal that comes from the Fourier Analysis.

$$v_L \approx \sqrt{\frac{f}{N} \sum_{i=0}^n v_i^2}$$

This is a value that can be taken as a measure of the amplitude of the signal

Sleep Analysis Program

```
# This program takes a pair of real values as input data that represents the significant  
# frequency and amplitude of the signal and returns a Boolean value that indicates  
# whether the state is normal or not.
```

Constants

```
# We need a reference that indicates the normal state and a tolerance related to the  
# reference. These will be obtained at a medical center by specialists. They are different  
# for each individual.
```

```
RefFrequency = 8 Hz  
RefAmplitude = 70 mV  
Tolerance = Tolerance
```

Program

Read Input Data

```
Store Input Data in a real variable: InputFrequency
Store Input Data in a real variable: InputAmplitude
Create Boolean Variable :Mode = 1
# Mode =1 means the state of the user is normal , Mode = 0 means the person is asleep
# or dozing off.
If InputFrequency < (1+Tolerance)*RefFrequency
    Then Mode = 0
If InputAmplitude > (1+Tolerance)*RefAmplitude
    Then Mode = 0
Return Output Data (Mode)

End
```

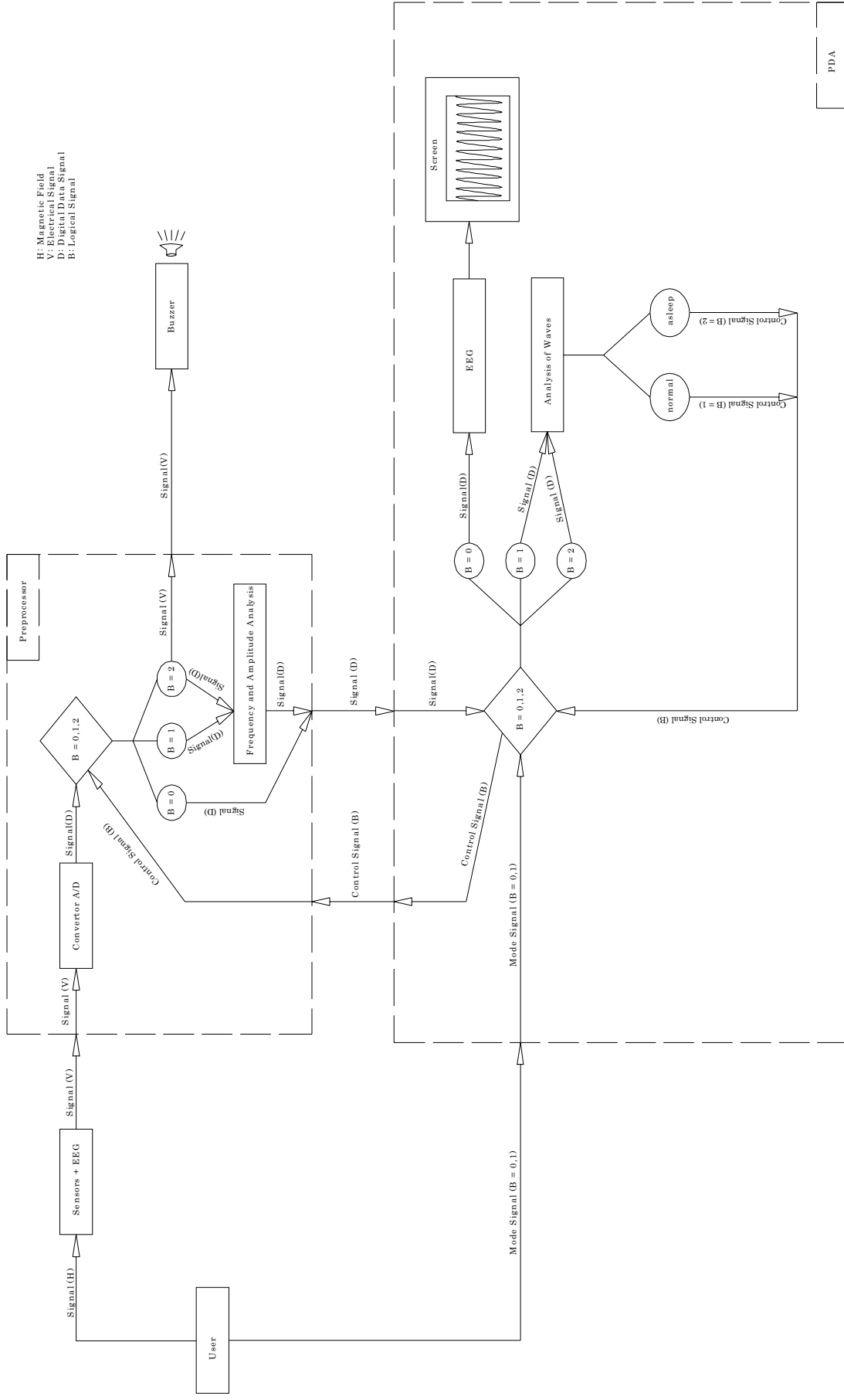
APPENDIX

(Appendix 1) Accidents and their causes in the Basque Country Region (Spain) in the years 2002 and 2001.

2002	Dead	Seriously Injured	Injured	Unhurt	Total
Distraction	40	271	2.051	7.914	10.276
Driver Inexperience	3	13	99	517	632
Alcohol or Drugs	8	40	265	972	1.285
Tiredness, Drowsiness or Sickness	11	27	110	229	377
Excessive Speed	61	256	1.271	2.625	4.213
Driving Infraction	16	85	683	2.097	2.881
Road Condition		13	153	1.397	1.563
Road Signs Condition			4	84	88
Road Work		1	14	211	226
Vehicle Condition		2	17	50	69
Car Wreck		2	37	281	320
Adverse Weather Conditions	1	8	89	774	872
No Definite Opinion	22	91	358	3.625	4.096
Load Fall		1	26	802	829
Other Factors	8	43	316	3.041	3.408
Total	170	853	5.493	24.619	31.135
2001	Dead	Seriously Injured	Injured	Unhurt	Total
Distraction	54	325	2.028	7.828	10.235
Driver Inexperience	1	18	129	575	723
Alcohol or Drugs	3	48	302	1.221	1.574
Tiredness, Drowsiness or Sickness	9	31	106	251	397
Excessive Speed	56	280	1.204	2.849	4.389
Driving Infraction	9	81	554	2.233	2.877
Road Condition	2	11	200	1.457	1.670

Road Signs Condition			6	72	78
Road Work			18	197	215
Vehicle Condition	1		6	52	59
Car Wreck	1	15	46	298	360
Adverse Weather Conditions	1	14	100	790	905
No Definite Opinion	11	100	506	3.934	4.551
Load Fall	1	2	30	1.352	1.385
Other Factors	18	57	383	3.415	3.873
Total	167	982	5.618	26.524	33.291
Source: Service of Statistics of the Basque Government Traffic Department					

(Appendix 2) Software – Block Diagram of the device



REFERENCES

- (1) Clínica universitaria (Hospital): Information about brainwaves, how to measure waves, etc.
- (2) Servicio de Estadísticas del Departamento de Tráfico del Gobierno Vasco
(Service of Statistics of the Basque Government Traffic Department): Tables of Accidents
- (3) Advanced Brain Monitoring inc.: Company that produces the baseball cap with sensor.
Website: www.b-alert.com/psh.htm
- (4) J&J Engineering: Information on EEG devices.
- (5) B.P.Lathi/ Signal Processing and Linear Systems/Oxford University Press/1998