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IEOM Society

6th North American Conference on
Industrial Engineering &
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MTY, México. **November 3-5**, 2021
CINTERMEX-Monterrey Convention Center

Engineering Forum
Escuela de Ingeniería y Tecnologías

NEW WORLD, RENEWED ENGINEERING

TITLE: *Real-time Biofeedback System for Interactive Learning using Wearables and IoT*

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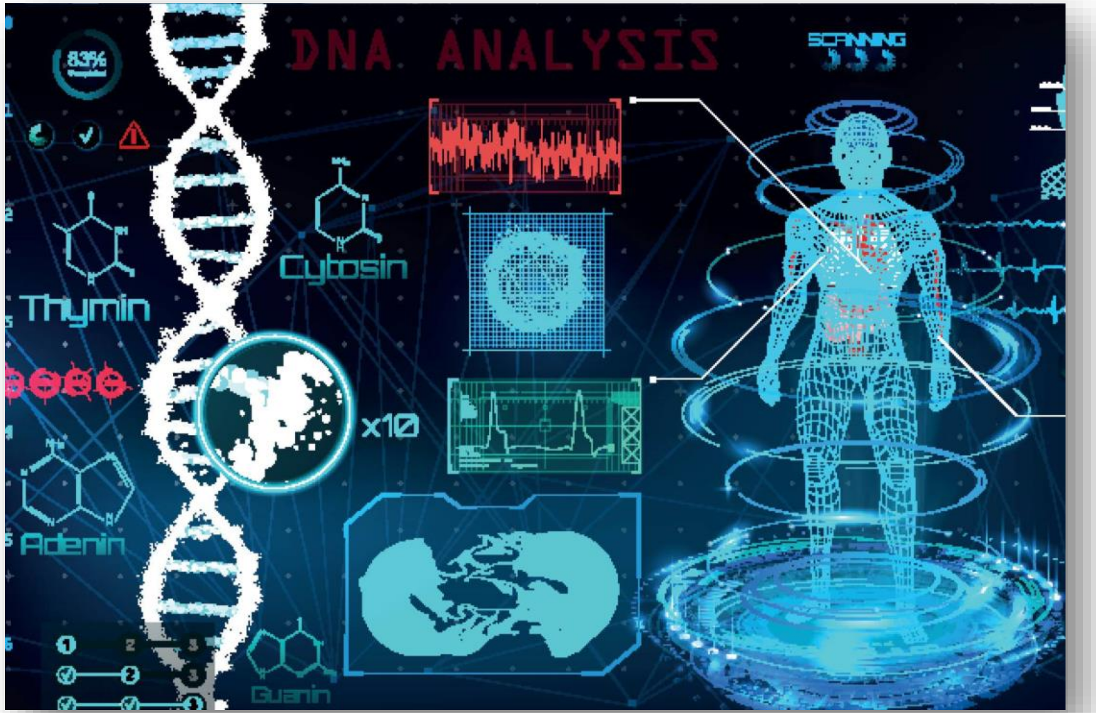
Introduction

Education needs to adapt constantly, hence **trustworthy evaluation** and **teaching methods** need to be employed.

Biometrics, a **biofeedback tool**, could work as an intelligent system for both students and teachers, to **improve** their learning performance.



(Ulster University, 2020)

Objectives

An **interactive** application that uses student's **biometrics** to create a report, used by the teacher or the student itself.

Capable of using **additional** biometrics (Hexiwear and Empatica), and so add new **features** to the interactive platform.

(Kolesnikova, 2019)

Literature Review

EEG for student's level of **attention** (Brawner and Avelino 2016).

ECG features can identify **stress** conditions (Zhou et al. 2021).

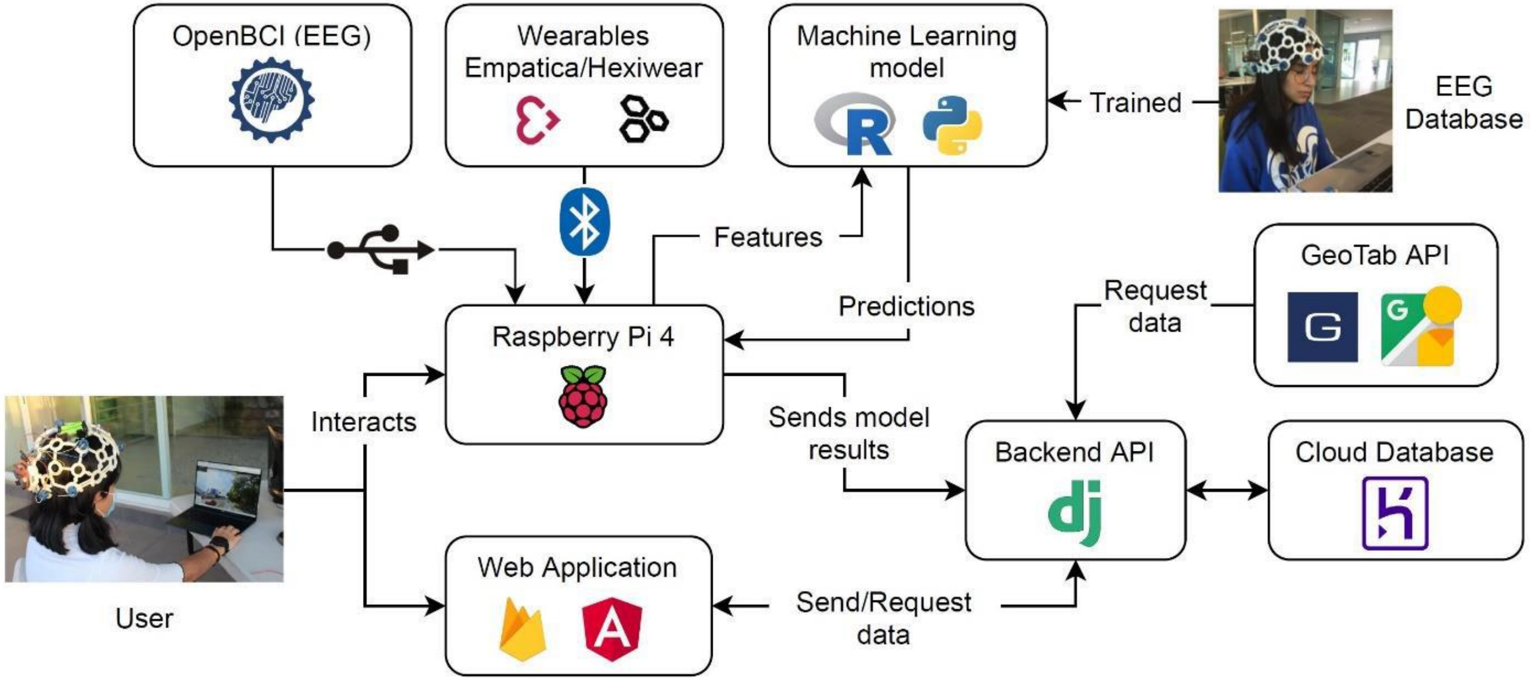
Direct feedback to students with appropriate teaching methods, **improve learning** pace and **retention** (Gruzelier et al. 2014).

(Parfitt, 2016)

Methods

Four key **modules**:

1. Data Acquisition.
2. Data Integration.
3. IoT and Web Server.
4. Interactive Visualization for Students.



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Data Collection

Feature generation: EEG frequency band Powers, using Fast Fourier Transform (FTT) and the following **band power ranges**: δ (1-4 Hz), θ (4-7 Hz), α (8-12 Hz), β (13-29 Hz), γ (30-50 Hz). Fatigue scores using Fatigue Assessment Scale (FAS), via their self-answered questionnaire in Spanish.

Normalization: Using each feature's **mean**, similar to Z-Score (Eq. 1).

Hybrid feature selection method:

1. **Mean Decrease Impurity** (MDI) in Gini index, using Random Forest Classifier (RF) (Eq. 2).
2. Decrease in **Residual Sum of Squares** (RSS) using Multivariate Adaptive Regression Splines (MARS) (Eq. 3).

$$x_{norm} = \frac{x - \mu}{\mu} \quad (1)$$

$$Gini = \sum_{i=1}^{C} f_i(1 - f_i) \quad (2)$$

$$RSS = \sum_{i=1}^{n} (y_i - \hat{y}_i) \quad (3)$$

Numerical Results

Modeling:

- Random Forest (RF).
- Radial-kernel Support Vector Machine (svmRadial).
- Gradient Boosted Machines (GBM).
- Classification and Regression Trees (CART).
- Linear Discriminant Analysis (LDA).

Validation: 20 random splits with an 80:20 split ratio, 5-fold **cross-validations** using accuracy (Table 3).

Table 2. Feature selection using decrease in RSS and Mean Decrease Impurity (MDI).

Feature	MARS (RSS)	RF (MDI)	Feature	MARS (RSS)	RF (MDI)
θ (O1)	100.00000	62.04875	δ (FP2)	51.3624	63.51241
θ (C4)	87.56760	52.23073	δ / γ (O2)	41.53791	52.94083
β (P7)	82.80721	100.00000	θ (FP2)	29.02988	23.06057
β (P8)	74.26629	73.19926	δ / β (P8)	26.46342	14.35046
δ / γ (P8)	56.99946	48.53941	δ (P8)	23.53160	11.45306
β (FP1)	56.29914	37.63690	β (C4)	21.46678	40.13383

Table 3. Testing accuracy using 80:20 split on balanced dataset with 5-fold cross-validation.

Model	Minimum Accuracy (%)	Average Accuracy (%)	Maximum Accuracy (%)
RF	91.74384	92.69576	93.56949
svmRadial	74.78683	76.29217	77.74977
GBM	74.56579	76.07552	77.53790
CART	53.79128	55.52461	57.24792
LDA	52.17807	53.91520	55.64522

Graphical Results

- Integrative System (Figure 2).
- Web Application (Figure 3).

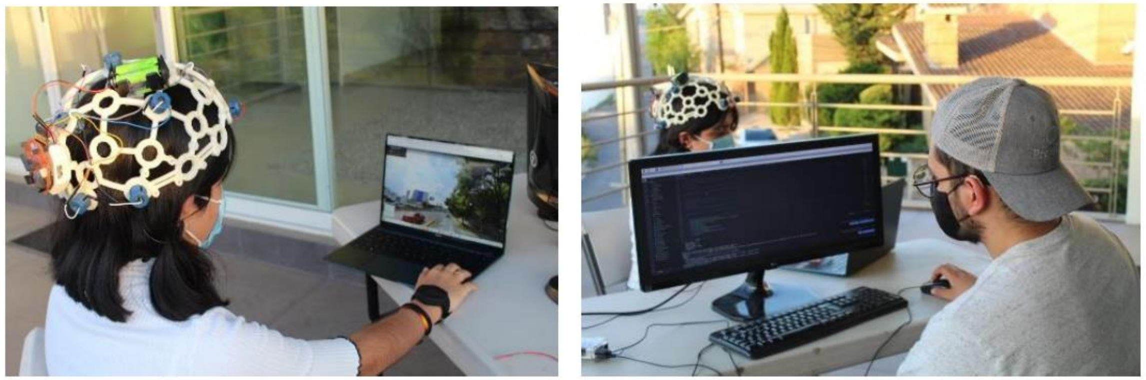


Figure 2. (Left) A participant using the created interactive environment and biometric devices, (Right) Data acquired during the experiment is sent to another PC wirelessly for visualization and analysis.

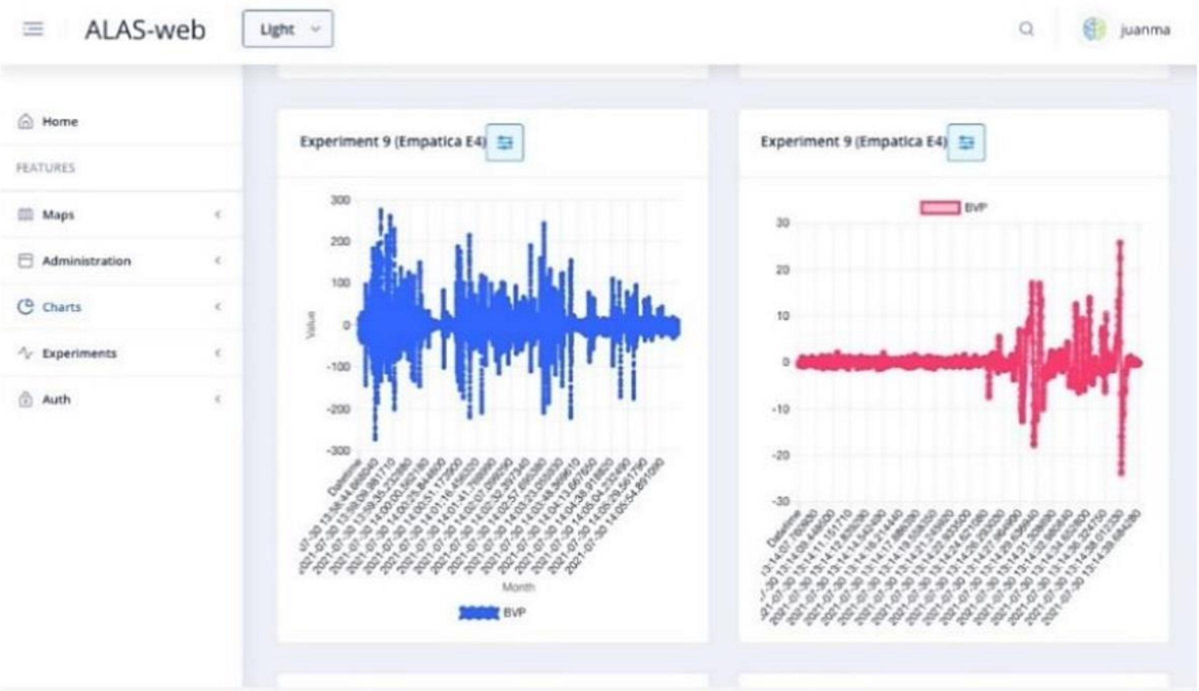


Figure 3. Screenshot of the web application created, where the Blood Volume Pulse (BVP) of two takes from a participant is shown on two different plots.

Proposed Improvements

System can be further improved with additional biometrics and ML **models**.

Used in a video lecture about Automotive Engineering, which included **Geotab**.

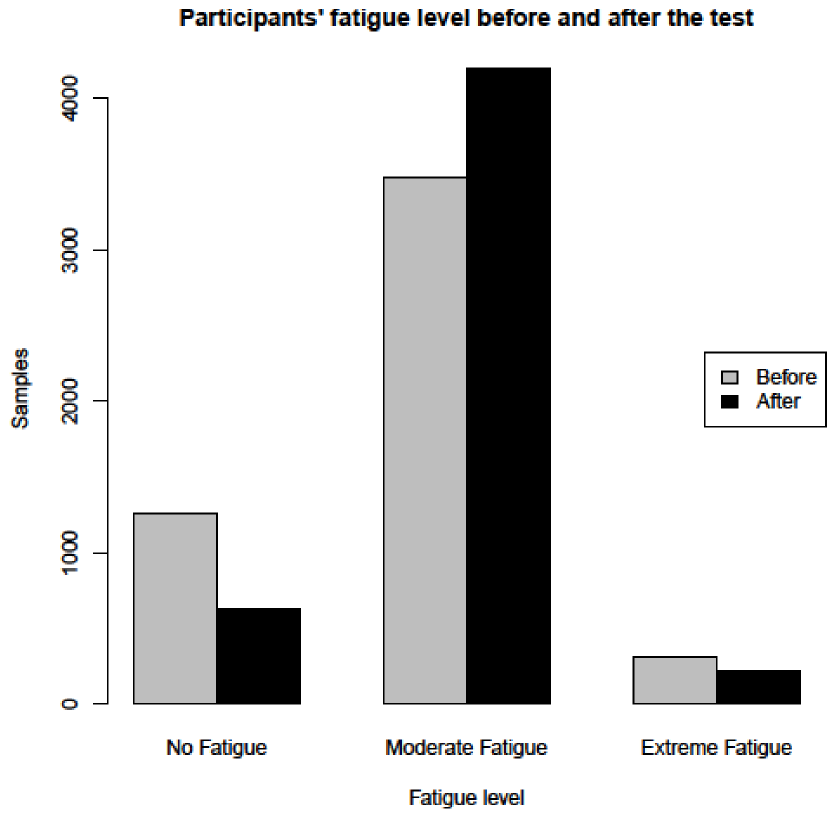
(Salt, 2018)

Validation

Predictive RF model was tested on a **hold-out** unlabeled dataset.

After a 1.5-hour class, an **increase** in the overall mental fatigue is observed.

The model was successfully predicted the **expected trend** (students experiencing more mental fatigue).



Conclusion

Biometric-based systems might lead to the creation of new **educational models.**

Both teaching and learning can be continuously **improved**, by analyzing student's physiological variables during a class.

(Baines, 2021)

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