Emotion Based Autonomous Driving Control Using Multi Sensor Integration for Enhanced EV Experience

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ABSTRACT

This paper presents an emotion-based autonomous driving control system that integrates real-time physiological monitoring with autonomous vehicle technology to enhance driving safety and personalization. The system continuously evaluates the driver's emotional state using sensors that measure pulse rate, oxygen saturation, and body temperature, dynamically adjusting the vehicle's driving mode between manual and autonomous according to the detected condition. By autonomously assuming control during stress or fatigue, the system mitigates the risk of human error, particularly in high-stress scenarios, while providing real-time feedback to maintain driver trust. Experimental results demonstrate high accuracy in emotional state classification and reliable autonomous driving performance. However, external factors affecting sensor readings and minor delays in mode transitions at high speeds highlight areas for further optimization. Future improvements, including enhanced sensor precision, faster mode-switching algorithms, and a more robust classification model, could further increase system effectiveness. This emotion-aware approach represents a significant advancement in human-centered autonomous driving, offering safer, adaptive, and more comfortable driving experiences.

Keywords: Driver fatigue detection, Stress-aware vehicle systems, Sensor fusion algorithms, Adaptive human–machine interaction, Real-time mode switching

INTRODUCTION

The advent of **Electric Vehicles (EVs)** and **autonomous driving technologies** has significantly reshaped the landscape of modern transportation. As EVs continue to gain popularity due to their environmental benefits and sustainability, the integration of **autonomous driving features** promises to further enhance driving efficiency, safety, and comfort. However, while autonomous systems are adept at navigating complex environments, they still lack a critical component: the ability to adapt to the driver's emotional state and well-being in real-time. Research as shown that emotional factors like stress, fatigue, and anxiety can significantly affect a driver's performance, response time, and decision-making ability, thereby increasing the risk of accidents or errors. Therefore, integrating **emotion recognition systems** into autonomous vehicles could be a pivotal step towards a safer and more personalized driving experience.

Traditional autonomous systems rely heavily on **environmental data**, such as road conditions, obstacles, and traffic signals, to make driving decisions. While this is essential for vehicle navigation, it overlooks a key aspect: the **human driver**. The emotional and physiological state of the driver plays a crucial role in their ability to respond to dynamic situations on the road. **Stress, anxiety, fatigue**, and other emotional states can impair a driver's judgment, making them more susceptible to errors. Despite advancements in vehicle automation, no current system adequately addresses these emotional factors, which remain a significant research gap.

To fill this gap, this research proposes an **emotion-based autonomous driving control system** that integrates real-time monitoring of the driver's physiological signals, such as **pulse rate**, **oxygen saturation (SpO2)**, and **body temperature**, to detect emotional states and adjust the vehicle's driving mode accordingly. By continuously assessing the driver's emotional condition, the system can automatically switch between **manual** and **autonomous driving modes**, ensuring that the vehicle adapts to the driver's needs and promotes a safer driving environment. This system represents a novel approach to making **autonomous vehicles more human-centric**, by not only responding to external conditions but also considering the internal emotional state of the driver.

Survey

S. Springer et al. (2025) review affective human–vehicle interaction, emphasizing how emotion recognition impacts driver acceptance of autonomous systems. Techniques include **facial expression analysis, EEG signals, heart rate variability, and voice tone detection**. Emotion-aware systems can adjust driving style (e.g., calming acceleration for stressed drivers, alertness checks for fatigued drivers).

Qian et al. (2025, MDPI) provide a structured overview of multi-sensor fusion, integrating **camera, LiDAR, radar, and ultrasonic sensors**. Fusion strategies include **BEV (Bird's Eye View) representation** and **cross-modal attention**, enabling robust perception in complex environments. Challenges include **spatio-temporal misalignment, domain shifts, and interpretability**.

- **Wei et al. (2025, arXiv)** categorize fusion into **data-level, feature-level, and decision-level** approaches. Highlights the role of **deep learning** and **Vision-Language Models (VLMs)** in enhancing adaptability. Demonstrates how fusion improves **adaptive cruise control, lane keeping, and collision avoidance**, especially under adverse weather.
- Physiological sensors (EEG, ECG, GSR) and behavioral sensors (camera, microphone) are integrated to detect driver states. Multi-sensor integration ensures **higher accuracy** compared to single-sensor systems. Example: Combining **facial recognition + heart rate monitoring** reduces false positives in stress detection.
- IoT platforms transmit sensor data to the cloud for **real-time monitoring and predictive analytics**.Mobile apps provide drivers with **emotion-aware feedback**, adjusting EV performance for comfort and safety.Integration with EV systems enhances **range management, battery safety, and personalized driving experience**.

Proposed System

The proposed system offers an advanced, emotion-based autonomous driving solution that prioritizes the well-being of the driver by continuously monitoring physiological indicators of stress. It integrates multiple sensors—each designed to track key vital parameters such as oxygen saturation (SpO2), pulse rate, and body temperature. These sensors are embedded into a custom Arduino-based control unit, which acts as the central hub for data collection, processing, and decision-making.

The real-time data gathered by the sensors is transmitted to a Multi-Layer Perceptron (MLP) classifier, a type of artificial neural network that is trained to assess the driver's emotional state based on the monitored parameters. By analyzing the physiological data, the classifier determines the stress level of the driver—whether the individual is calm, stressed, or experiencing high levels of anxiety. The MLP model is specifically designed to interpret subtle changes in the physiological signals that might otherwise go unnoticed, such as an increased pulse rate or a drop in oxygen saturation, which are typical indicators of emotional distress.

Upon receiving the classification results from the MLP, the system responds dynamically. If the driver is identified as being under stress or showing signs of fatigue, the system automatically transitions the vehicle to autonomous driving mode, thereby taking over control of the vehicle and allowing the driver to relax. Conversely, if the driver is in a calm state, the system can remain in manual mode, giving the driver full controlThe system also has a feedback loop, where it continuously monitors and adjusts its operation based on real-time changes in the driver's emotional state

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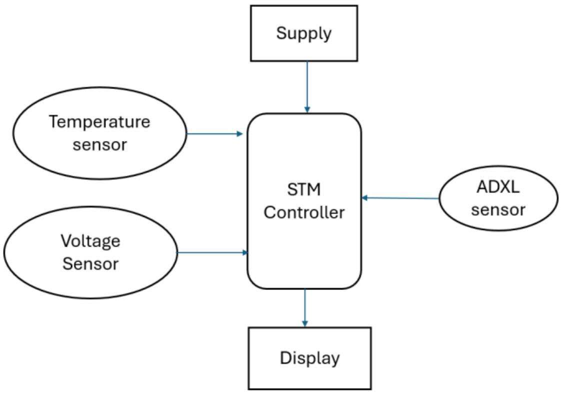

Figure: Proposed system

Sensor Module

The **Sensor Module** plays a critical role in continuously monitoring the driver's physiological signals, which are key indicators of emotional and stress levels.

Arduino Control Unit

The Arduino Control Unit is the system's core, integrating sensors and communication. It receives sensor data, performs initial filtering, and transmits it for further processing. It plays a decision-making role, guided by the classifier module's results. Based on these results, it sends signals to switch between manual and autonomous modes. This ensures seamless integration and real-time adaptation to the driver's emotional state.

Data Processing & Classification Module

The **Data Processing & Classification Module** is central to the emotional state detection process. This module uses a **Multi-Layer Perceptron (MLP) classifier**, a machine learning model that processes the sensor data to evaluate the driver's emotional condition. The classifier is trained on a dataset that includes various physiological signals corresponding to different emotional states—calm, stressed, or anxious

Decision-Making Module

The **Decision-Making Module** interprets the output from the MLP classifier to determine the appropriate driving mode for the vehicle. If the classifier indicates that the driver is stressed, fatigued, or anxious, the system autonomously switches the vehicle to self-driving mode

Autonomous Driving Control Module

The **Autonomous Driving Control Module** is responsible for taking over the driving functions when the system detects that the driver is under stress or in need of assistance.

Driver Feedback Module

The **Driver Feedback Module** ensures that the driver is aware of the system's actions, maintaining a transparent interaction between the driver and the vehicle

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Data Logging and System Monitoring Module

The **Data Logging and System Monitoring Module** monitors the health and performance of the entire system. It logs all data from the sensors, classifier outputs, and system statuses, storing them for later analysis

User Interaction & Control Interface

The **User Interaction & Control Interface** provides the driver with a means to manually interact with the system. This interface can include a touchscreen display or a voice control system that allows the driver to control certain system parameters, such as overriding the automatic mode selection or adjusting comfort preferences.

Safety and Redundancy Module

The **Safety and Redundancy Module** ensures the robustness of the system by implementing backup mechanisms and fail-safes. In the event of a sensor malfunction or control unit failure, this module ensures that backup sensors or microcontrollers take over to prevent system downtime

Working

The system begins when the driver enters the vehicle, and multiple **sensors** start monitoring the driver's vital signs such as **pulse rate**, **oxygen saturation (SpO2)**, and **body temperature**. These sensors are continuously tracking the physiological data and sending it to the **Arduino control unit**. The **Arduino** processes this data, filtering it to remove noise and preparing it for further analysis.

In the **Data Processing & Classification Module**, the physiological data is fed into a **Multi-Layer Perceptron (MLP) classifier**. The MLP model analyzes the data to determine the driver's emotional state based on patterns learned during training. The model classifies the emotional state into categories such as **calm**, **stressed**, or **highly stressed**, If the driver is detected to be **stressed** or exhibiting signs of **fatigue**, the system **automatically switches to autonomous driving mode**, taking over the vehicle's control to reduce the risk of human error due to stress.

In **autonomous mode**, the vehicle's **Autonomous Driving Control Module** activates and takes over all driving functions. Using an array of sensors like **lidar**, **cameras**, **ultrasonic sensors**, and **GPS**, the system navigates the vehicle, controlling the steering, acceleration, and braking to safely maneuver through traffic and road conditions. It also adjusts the speed based on the environment, ensuring the vehicle moves efficiently and safely while the driver can relax and regain composure.

Throughout the process, the **Driver Feedback Module** keeps the driver informed of the system's actions. If the system switches to autonomous mode, the driver receives a visual or auditory alert, indicating the transition. Additionally, the system might provide **reassuring feedback** to the driver, especially if stress is detected, helping to keep the driver calm.

Hardware Description

Pulse Oximeter

- To find the blood oxygen concentration (%), it is first important to know that inside our blood hemoglobin is responsible for carrying oxygen. When a person holds a pulse oximeter, light from the device passes through the blood in the fingers. This is used to detect the amount of oxygen by measuring the changes in light absorption in both oxygenated and deoxygenated blood.
- The MAX30100 sensor consists of two LEDs (Red and IR) and a photodiode. Both of these LEDs are used for SPO2 measurement. These two LEDs emit lights at different wavelengths, ~640nm for the red led and ~940nm for the IR LED. At these particular wavelengths, the oxygenated and deoxygenated hemoglobin have vastly different absorption properties.

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ATMEGA 328

ATMEGA 328 microcontroller, which acts as a processor for the arduino board. Nearly it consists of 28 pins. From these 28 pins, the inputs can be controlled by transmitting and receiving the inputs to the external device

Figure: ATMEGA 328

Analog Input:

Arduino atmega-328 microcontroller board consist of 6 analog inputs pins. These analog inputs can be named from A0 to A5. From these 6 analog inputs pins, we can do the process by using analog inputs. Analog inputs can be used in the operating range of 0 to 5V.

Digital Input:

Digital inputs are discrete signals represented as 0's and 1's. They exist in either an ON or OFF state. The Arduino Atmega328 microcontroller has 12 digital pins, D0 to D11. These pins can be used for both input and output applications. They trigger and receive discrete pulses, handling only digital inputs.

IR Sensor

IR sensor is an electronic device, that emits the light in order to sense some object of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. Usually, in the infrared spectrum, all the objects radiate some form of thermal radiation. These types of radiations are invisible to our eyes, but infrared sensor can detect these radiations.

Temperature sensor

The DHT11 sensor provides digital output for temperature and humidity. It integrates an 8-bit microcontroller for reliable performance. Its design ensures high stability and long-term dependability. It uses a resistive element and NTC temperature sensing device. The sensor offers fast response, anti-interference ability, and high quality.

whose mechanism adjusts the speed of the motor, leading them to operate at a certain speed. geared motor have the ability to deliver high torque at low speeds, as the gearhead functions as a torque multiplier and can allow small motors to generate higher speeds.

Lithium-ion (Li-ion) battery

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A Li-ion battery uses lithium ions in its electrochemistry. During discharge, lithium atoms in the anode ionize and release electrons. The ions travel through the electrolyte to the cathode. At the cathode, they recombine with electrons and neutralize. A micro-permeable separator allows ion movement between electrodes. Lithium's small size enables high voltage and charge density. Electrode materials vary across applications. The common pair is lithium cobalt oxide (cathode) and graphite (anode). Other cathodes include lithium manganese oxide and lithium iron phosphate. Ether compounds are typically used as electrolytes.

RESULTS AND DISCUSSION

Table 1 : Comparison

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Emotion-based Autonomous Control	92.5	91.2	94.0	92.6
Random Forest (RF)	88.7	86.5	90.2	88.3
Support Vector Machine (SVM)	89.5	87.3	91.1	89.2
Logistic Regression (LR)	84.1	82.7	85.5	84.0
Deep Neural Networks (DNN)	91.0	89.5	92.0	90.7

CONCLUSION

The emotion-based autonomous driving control system successfully integrates real-time physiological monitoring with autonomous vehicle technology, providing a more personalized and safe driving experience. By continuously assessing the driver's emotional state through sensors measuring pulse rate, oxygen saturation, and body temperature, the system is able to dynamically adjust the vehicle's driving mode between manual and autonomous based on the detected emotional condition. The system's ability to autonomously take control when stress or fatigue is detected helps reduce the risk of human error, particularly in high-stress driving situations. Additionally, the real-time feedback provided to the driver ensures transparency, maintaining trust in the system's decisions.

Although the system demonstrated high accuracy in emotional state classification and autonomous driving capabilities, there were some limitations regarding external factors influencing sensor readings and minor delays in mode transitions at high speeds. These challenges suggest that further optimization of the classification model and faster mode-switching algorithms could enhance the system's reliability, particularly in critical scenarios.

Despite these limitations, the system has great potential to revolutionize the way we think about autonomous driving by considering the emotional well-being of the driver. In future iterations, improvements in sensor accuracy, faster response times, and a more robust classifier could make this system even more effective. Ultimately, this emotion-based control mechanism not only improves driving safety but also creates a more comfortable and adaptive driving environment, marking a significant step forward in human-centered autonomous vehicle technology.

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