

## ECE 579 Intelligent Systems, Winter 2024

### Technology Survey Report

**Project title:** Facial Expression Recognition System (FERSys) for Personalized Vehicle Settings.

**Students in the project group:** Julio Murillo Amezcua and Luis Castaneda-Trejo.

**Responsibilities of each student:**

	J. Murillo	L. Castaneda
1	Data Preparation and Cleaning	Model creation
2	Model creation	Model integration into PC and Embedded target.
3	Model validation	Create state logic for each emotion recognition.
4	Experimental Analysis	Development of CAN communication layer.
5	Model Optimization	CANoe model creation to view traffic messages.
6	System validation	System validation.

### 1. Introduction

Driving is a complex activity that demands a high level of cognitive functioning and emotional regulation. When individuals are experiencing depression, anger, or excitement, their ability to effectively navigate the challenges of driving becomes severely compromised. Depression, for example, can lead to decreased motivation and energy levels, resulting in diminished concentration and slower reaction times. This may manifest as delayed responses to traffic signals, reduced awareness of surrounding vehicles, or an inability to anticipate and appropriately react to potential hazards. Similarly, anger can cloud judgment and lead to impulsive and aggressive driving behaviors such as tailgating, excessive speeding, or engaging in confrontations with other drivers. These behaviors not only increase the likelihood of accidents but also escalate tensions on the road, creating unsafe conditions for everyone involved.

Furthermore, the heightened emotional state associated with excitement can lead to a sense of invincibility and risk-taking behavior behind the wheel. Excited drivers may be more prone to engaging in distractions such as texting, talking on the phone, or fiddling with infotainment systems, all of which divert attention away from the task of driving. Additionally, excitement can manifest as overconfidence, leading drivers to underestimate the dangers of certain maneuvers or road conditions. This combination of diminished attention, impaired decision-making, and increased risk-taking significantly elevates the probability of accidents and poses a serious threat to the safety of all road users. Recognizing the potential dangers of driving under the influence of intense emotions underscores the importance of prioritizing mental and emotional well-being, as well as cultivating mindfulness and self-awareness while operating a vehicle.

Based on the above information, we will develop a Facial Recognition System mounted inside a vehicle that can evaluate the user's emotions. Based on his/her expressions, the system will send a set of custom messages into the vehicle CAN bus and prevent it from exceeding a defined speed limit. The system will also notify a set of emergency contacts via SMS or email.

The applications of this system are very wide and will expand in following phases of the project. The following table shows the road map of the application.

Capability	1 <sup>st</sup> Release	Future Development
Facial expression recognition	✓	
Voice expression recognition		✓
Speed behavior recognition		✓
CAN communication	✓	
Email simulation	✓	
Email notification		✓
SMS notification		✓

The following elements summarize the technologies that will be used for this project:

### **AI Model**

Our project employs a deep neural network (DNN) developed using Python and TensorFlow in Google Colab, designed to be GPU-accelerated, which provides faster processing and greater efficiency in handling large datasets as FER2013 compared to traditional CPU-based methods. As demonstrated in related research, DNNs, especially convolutional neural networks (CNNs), are good in recognizing and interpreting various facial expressions, thus determining a person's emotional state.

### **NI-XNET**

NI-XNET is a software and hardware platform developed by National Instruments (NI) for implementing Controller Area Network (CAN) and other communication protocols in automotive and embedded applications. The NI USB 8506 is part of the XNET card family, and it's controlled by the XNET driver.

### **Vector CANoe**

CANoe is a sophisticated software tool developed by Vector Informatik GmbH for the automotive industry, primarily aimed at the development, testing, and analysis of embedded systems and networks in vehicles. CANoe will be used to verify that the messages sent by FERSys are correct and processed by the simulated vehicle network.

### **NI LabVIEW**

A User Interface (UI) will be developed in LabVIEW. The objective of this UI is just to show the capabilities of the system in a Proof-of-Concept state. The general idea is to deploy the FERSys application into an embedded target which will be a STM32H7-Disco development board using the B-Cam-OMV module.

## **2. Description of main technologies**

This section describes the 3 main papers that we found relevant to our project and how the design approaches from the authors increased their model performance and target functions.

### **2.1 Methods for Facial Expression Recognition with Applications in Challenging Situations [1]**

The May 2022 study by Anil Audumbar Pise et al. conducts an in-depth examination of Facial Emotion Recognition (FER), showing the evolution from basic models to advanced Convolutional Neural Networks (CNNs) that understand emotions from facial expressions and sounds. The paper highlights the challenge of current FER systems being limited to recognizing only seven basic emotions, underscoring the need for a bigger emotion databases and multi-modal approaches to cover full spectrum of human emotions, with the idea of enhancing real-world applicability and emotional understanding by machines.

This research is all about making computers better at understanding how we feel just by looking at us, listening to us, and maybe even by picking other subtle clues in the expressions. The goal is to bridge the gap between the basic emotions that a compute can currently recognize and the complex emotions we experience.

### **2.2 Deep Learning-Based Facial Expression Recognition in FER2013 Database: An in-Vehicle Application [2]**

The authors in this article developed a convolutional neural network (CNN) to perform Facial Expression Recognition and alert the driver that he might not be in the right conditions to operate the vehicle.

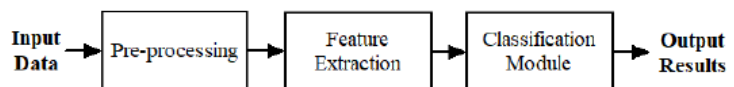


Fig. 1. FER System Overview Using CNN Model.

The general process dataflow diagram is shown in Fig 1, but overall, they evaluated two approaches: a *6-layer* and a *10-layer CNN*. The algorithm for the first approach includes loading the FER2013 database (the same database that the FERSys system will use), utilizing preprocessing methods, splitting the dataset into training and testing models, and building the CNN using defined convolutional layers such as maxPooling, dropOut, and softmax.

Figure 2 of the article (page 2) defines the steps followed by the authors, where they were able to obtain 6,903,367 trainable parameters out of a total of 6,903,879, with only 512 that were not trainable.

The 2nd CNN adds 4 more layers increasing the overall performance of their system. They concluded that the more layers the system has, the better accuracy the system is. The authors also mentioned the use of a special CNN architecture called Visual Geometry Group 16 (VGG16), which incorporates transfer learning into additional layers within the CNN. In summary, the performance using the 6-layer model had an accuracy of 66.67%. The 10-layer model had 68.34% and using VGG16 the system performance had 63.68%.

### 2.3 Facial Emotional Expression Regulation to Control the Semi-Autonomous Vehicle Driving [3]

The authors in this paper describe the role of Facial Expressions in human computer interactions for autonomous vehicles. They mention the challenges that this technology has and how it can be utilized to improve road safety by recalling driver and passenger emotions. The diagram in Fig 2, is the decision path that allows the user to use Manual or Semi-Automatic mode.

The algorithm the authors used was to set a Region of Interest (ROI) and develop a retrained graph which is a separate dataset from the trained dataset original model, then in Real-Time the user's facial emotions are compared with the original dataset images to predict the state of mind of the driver. An interesting element to notice from this paper is that the system also analyzes another passenger in the vehicle that could influence the driver's behavior.

The emotion categories are Calm, Angry, Happy and Sad as seen in Fig 2. The manual driving mode can only be enabled if a Calm emotion is detected, although it is not specified if this mental state applies only to the driver and/or passenger as well. The model the authors used in their research is a Deep Learning algorithm with a squared Euclidean distance classifier.

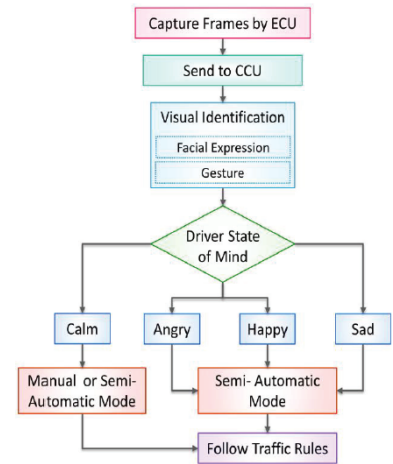


Fig 2. Flowchart to decide the semi-autonomous vehicle driving mode based on driver state of mind.

### 3. Conclusion

The FERSys project is a promising tool that can utilize applied AI to prevent accidents and help save lives, particularly in the context of automated driving systems. Facial Emotion Recognition (FER) technology integrated into vehicles can play a crucial role in enhancing safety on the roads.

The information provided in sections 2.1, 2.2, and 2.3 allows us to understand how other institutions and researchers are using different techniques to detect Human Facial Expression/Emotion Recognition and how they are using AI models to achieve good performance (P) of the target functions. This R&D field looks very promising.

The results obtained by the paper authors in section 2.2 show that having more layers in a Neural-Network provides better performance of the overall system. However, there needs to be a preprocessing stage where we will have to clean or crop the images if they are not good enough to enhance the experience of our trained model. The classification mode is described in section 2.

In summary, the success of a model depends on more than a complex architecture. It also depends significantly on the quality of the dataset the model is trained on, which provides the necessary experience; clear and well-defined objectives that align with the task, in our case accurately recognizing and classifying different human facial expressions; and the selection of appropriate evaluation metrics to determine how well the model accomplishes this task.

## References

- [1] Anil Audumbar Pise, Mejdal A. Alqahtani, Priti Verma, Purushothama K, Dimitrios A. Karras, Prathibha S, and Awal Halifa. Hindawi Computational Intelligence and Neuroscience, Volume 2022, Article ID 9261438, Methods for Facial Expression Recognition with Applications in Challenging Situations <https://doi.org/10.1155/2022/9261438>
- [2] G. K. Sahoo, J. Ponduru, S. K. Das and P. Singh, "Deep Learning-Based Facial Expression Recognition in FER2013 Database: An in-Vehicle Application," 2022 IEEE 19th India Council International Conference (INDICON), Kochi, India, 2022
- [3] H. A. Meshram, M. G. Sonkusare, P. Acharya and S. Prakash, "Facial Emotional Expression Regulation to Control the Semi-Autonomous Vehicle Driving," 2020 IEEE International Conference for Innovation in Technology (INOCON), Bangluru, India, 2020, pp. 1-5, doi: 10.1109/INOCON50539.2020.9298197.