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Health Monitoring and Analysis using in-cabin sensors in automobiles: A feasibility study

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Abstract: Artificial Intelligence application for early identification of health issues is a diverse and promising research field. This research is mainly based on information from medical devices, dedicated wearables or smartphones. Similar research in automotive sector considers in-cabin sensors of vehicles to detect driving-related health issues but misses the broader perspective of health monitoring. Thus, this position paper proposes exploration of the benefits of broader perspectives on traffic safety (e.g. detecting diseases impacting driving capabilities) and health monitoring using the potential of in-cabin sensors. In doing so, we will focus on technical feasibility but also hint to regulation- and business-related issues.

I. Introduction

Artificial Intelligence (AI) has become a major research subject over the past decade in almost every sector. For instance, health sector uses AI for disease detection and progression over time analysis using data from medical devices, wearables and smartphones, and the automotive industry is using AI for exploring autonomous driving.

The automotive industry also focuses on AI based detection of health issues impacting driving like attention analysis and fatigue detection using in-cabin sensors for traffic safety purposes. This application of in-cabin sensors raises some important research questions, like, given the amount of time people spend in cars, how big the spectrum of health-issue detection with in-cabin sensors can be, what kind of sensors can be incorporated in a car, and what is the trade-off between the efficiency with in-cabin health analysis and breach of privacy by use of such sensors. These research questions are necessary because it is not only essential to identify and cure disease but also focus on their early detection through various means, before it reaches an acute stage where its treatment is not possible. The use of various in-cabin sensors can measure, for instance, the vitals of the human body at regular intervals (in hours, days or weeks). Any irregularities can be reported to the driver based on this information. In this position paper, we aim to explore this niche aspect of health monitoring and analysis using in-cabin sensors, what challenges do we face, and what future research in this field can look like.

II. Literature Review

Some of the previous studies in this field include the work by Siam et al. [1] on stress detection in car drivers using machine learning on Electrocardiogram, Electromyogram, Galvanic skin response and respiration rate, with a binary classification accuracy of 97%. A limitation of the paper is that it treats stress as a binary classification task, whereas, stress should have more categories, ranging from low to high, depending on the situation and their health status. Another study employed a deep convolutional neural network-based classification of driver distraction using ECG, with only an accuracy of 67% [2].

The more advanced aspect of this field includes some studies [3] to determine the behavior of dementia patients by making use of in-cabin sensors, like camera, microphone, infrared, etc., and driving data, like speed, acceleration, steering wheel rotation, and GPS. These studies focus on how dementia affects the driving ability of individuals by analyzing their route (to determine if they lost their way home), the number of traffic signals broken, and other aspects, which can endanger traffic safety. However, no study exists which can make use of these factors in combination with state-of-the-art AI techniques to predict the early-symptoms of dementia among drivers.

III. Material and methods

Performing health monitoring and analysis using in-cabin sensors requires that the car is equipped with the necessary sensors. The basic set of in-cabin sensors includes:

- Camera, with an added eye tracking functionality
- Microphone
- Respiratory tracker
- Blood volume pressure sensor
- Electrocardiogram sensor
- Skin conductance tracker
- Driving data

With these sensors, different types of information related to the health status of an individual can be captured. They can be used directly or indirectly to predict any minor health issues or developing symptoms of any acute disease, with the following being a few applications:

- Camera can be used to determine the person's attention level on the road (through the eye tracker), or his/her fatigue or alcohol levels.
- Speech patterns help identify symptoms of developing neurological disorders, like Alzheimer's disease.
- Respiratory tracker analyzes breathing patterns to predict sleep quality and imply the presence of some breathing problems (e.g., bradypnea or tachypnea), if irregular breathing patterns persist over a long time.
- Stress level of the person can be determined by the combined analysis of data from respiratory tracker, electrocardiograph, blood volume pressure sensor and skin conductance.
- Blood volume pressure sensor can estimate the heart rate, the heart rate variability, the blood oxygen content and the blood flow patterns.
- Electrocardiograms can also detect important health problems, like Myocardial Infarction, blood supply issues to the heart (Ischemia) and heartbeat problems.
- The skin conductance tracker measures the electrodermal activity of the skin, which can detect emotional arousal (including anxiety).
- Driving data including speed and acceleration patterns, steering wheel rotation, and GPS data, collectively should give some insight into the driver's cognitive and motor control ability. GPS data when analyzed in a known area of the driver and compared with the source and destination, can also give an intuition about the driver's memory retention capability.

When data collected from different sensors are combined and analyzed in the long run, they can become indicative of the development of some underlying disease inside the driver's body, that can then be later confirmed through medical examination for an early diagnosis. As a case study, we consider dementia, a neurodegenerative disease with no cure, that does not overnight, but rather there are multiple symptoms observed since the initial stage, which are mostly ignored for being considered as some non-serious, short-term health issues, until they intensify over the years into an irreversible stage. The symptoms of dementia include sleep issues, increased anger and mood swing problems, communication difficulties, memory loss over time, decreasing cognitive and motor skills, etc. The in-cabin sensors for health monitoring can detect these symptoms, and a longitudinal analysis over time (few weeks or months) using deep learning should indicate this disease, recommending the driver to get a medical checkup.

III.I. Challenges

While all of this sounds very promising, there are some major hurdles on the way, that is preventing the development of such systems by car companies:

- Incorporating such sensors raises a question about the privacy of people. As a result, these systems might face strong opposition from the general public perspective.
- These systems are not cheap. The cost of incorporating them inside the car, besides all other existing systems, might result in a large increase in the price of the car.
- Apart from the sensors, specialized equipments are also required for storing and analyzing the data; or equipments should be there that transmits the data to a remote server for storage and analysis purposes, resulting in increased overhead costs for businesses.
- Additional requirements also arise when the data security aspect jumps in. The sensor data contains people's face, voice, location from GPS tracker, and other sensitive health information; as a result, this kind of information is gold for the hackers, and special security measures should be in place to tackle it.
- Governmental and International regulations, like the GDPR data protection laws in the European Union, impose strict restrictions on devices and organizations that deal with such data. Getting approval for including such sensors inside vehicles is also a huge challenge.
- Most health analysis is performed by expert AI agents, which need training over huge datasets, representative of all possible situations. Collecting such diverse data is a problem, further complicated by the international regulations that bring data protection and subject safety issues (especially for patients) into the scenario.

Due to these reasons, many companies and organizations refrain from developing such technologies, in addition to their narrow sightedness, which hinders their vision towards potential contribution in other fields. Thus, future work in this aspect first includes overcoming all the above-mentioned hurdles, and motivating researchers to focus on this field, followed by motivating the government and the industry to invest in such technology, motivating people to participate in the studies, ensuing that their sensitive data is stored securely and handled professionally, and developing a safety assured study plan for data collection that satisfies the internationally set standards to get the approval.

IV. Conclusions

In this study, we discussed the various ways to exploit the in-cabin sensor in an automotive setting for health monitoring and analysis purposes. We discussed how long-term data analysis from those sensors can be synchronized to indicate the development or presence of any disease, which otherwise is not easily detectable, until a very later stage, with irreversible damage. We further discussed the major challenges, which led to limited research in this field, and that focus should be on overcoming those hurdles and promoting potential advantages of in-cabin health analysis.

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