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Automotive Health Functions

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Health Features in the Software-defined Vehicle

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Health and comfort are figuring ever more prominently at work and at play – and lately also on the road. Indeed, smart software and in-vehicle sensors can monitor occupants' health metrics. And that could help prevent accidents triggered by medical issues. ITK Engineering shows ways in which illness-related accidents can be avoided in the future.

It is a glorious morning on a summer's day. A married couple is motoring down a country road. Suddenly and without warning, the driver'sblood pressure plummets. The husband in the passenger seat just manages to intervene, bringing the automobile to a halt and out of harm's way. An emergency of this nature is no rare event in road traffic. Software-defined vehicles could soon help defuse such situations, thereby reducing injuries to people and damage to property.

CARDIOVASCULAR DISEASE AS AN ACUTE HAZARD ON THE ROAD

The World Health Organization says that 1.2 billion people worldwide suffer from high blood pressure. This means roughly one in three adults has to contend with hypertension, and that figure is rising [1]. An estimated 5 to 10 % of the population has low blood pressure, or hypotension. Studies show that 3.4 % of all accidents are attributable to sudden medical incapacitation. The most common causes are cardiovascular and neurological diseases, epilepsy, strokes, and diabetes [2]. This problem could be addressed with health features in the passenger car. Engineered to monitor occupants' health on the road, such systems could initiate preventive measures in the event of a pending emergency.

AUTOMOTIVE HEALTH FEATURES REDUCE ACCIDENTS

Health systems benefit automakers in several ways. For one, they can be unique selling points that set the company's cars apart from competitors' models. They can also help widen the profit margin. Vehicle components and assemblies can be operated more efficiently and effectively without incurring a lot of additional development costs. Finally, they enable new digital business models, for example, paywalls for features on demand. All this hinges on automotive health features based on smart software. This intelligence is the key to detecting and preventing health-related hazards in the vehicle and to enhancing occupants' well-being. It is also conceivable that existing medical conditions could be treated on the go.

Now that smartphones and smartwatches abound, the ability to track one's health metrics 24/7 is no longer

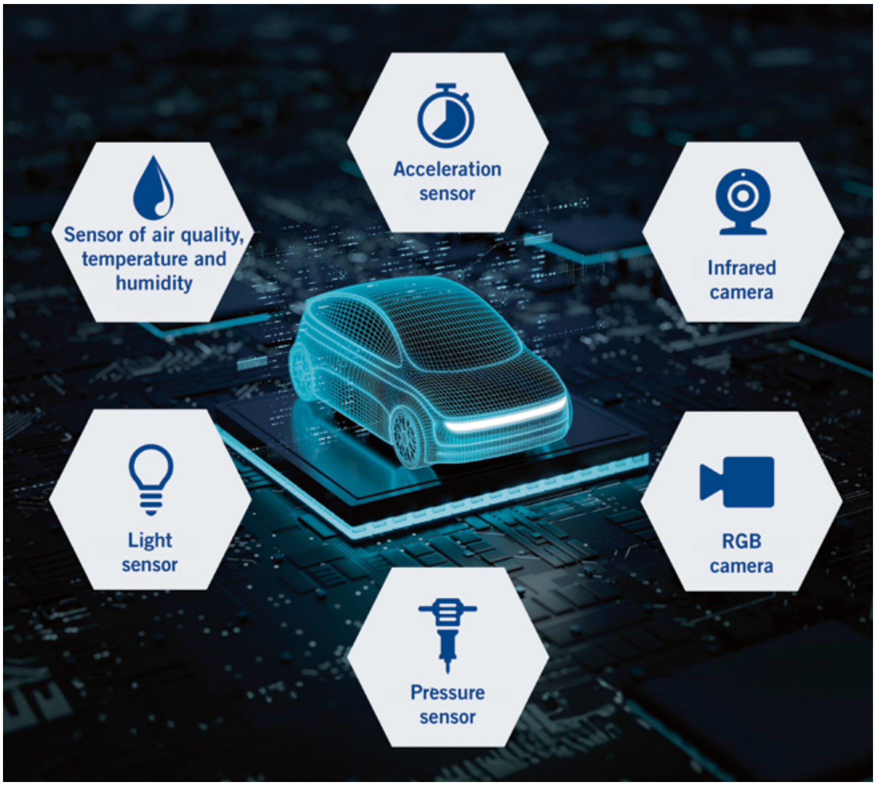

FIGURE 1 Types of interior sensors (© cono0430 I Shutterstock I ITK Engineering)

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a novelty. Even so, these devices are no substitute for in-vehicle health features. For one, there are limits to how well carryables and wearables connect and integrate into the mobility ecosystem surrounding the vehicle. For the other, there is no guarantee that data communications will work reliably and in real time when they are needed most.

SENSORS IN THE VEHICLE'S INTERIOR

The best solution is for on-board sensors to monitor occupants' vital signs. They could provide the underpinning for all kinds of automotive health features. These sensors come in many guises. The following section focuses on interior cameras, **FIGURE 1**.

The idea of collecting additional data in the vehicle in order to better assess the driver's condition leads to emotion recognition, which is based on analyzing the facial expressions of the occupants. This would certainly be a logical step seeing as how facial expressions already serve as a measure of driver alertness.

CHALLENGES IN EMOTION RECOGNITION

This gives rise to the question of how reliable and valid emotion recognition systems really are. Lisa Feldman Barrett, a professor of psychology, says that under ideal conditions the best facial recognition software available today could detect what the face is doing. However, she adds that there is currently no way of inferring a person's feelings from their facial movements or predicting what they will do next based on their expressions [3]. This means emotion recognition systems that read expressions cannot predict human actions, but can only recognize emotional responses to stimuli, albeit with some limitations. There is also the risk that occupants will feel uncomfortable with the notion of in-vehicle emotion recognition systems invading their privacy.

VALUABLE READINGS: PULSE RATES AND BLOOD PRESSURE LEVELS

Pulse rate and blood pressure readings are ideal for determining occupants' condition, not least because many people already routinely use smartwatches to monitor their pulse rates. Both are valid measures of health and fatigue. Studies have shown that heart rate variability can point to fatigue, and that an increased likelihood of driver error can be predicted by analyzing frequency components [4]. Heart rate variability and the pulse rate are also good indicators of nausea [5].

Blood pressure levels can indicate medical emergencies such as a hypertensive crisis – a sudden rise in blood pressure often associated with loss of consciousness, heart failure, or stroke. Hypotension – that is, low blood pressure – can cause symptoms such as blurred vision, lightheadedness, and fainting, all of which impair one's ability to drive [6]. It would be possible to make inferences about emotional states by combining heart rate variability and blood pressure readings [7], but that would give rise to the aforementioned concerns about occupants' acceptance of this tech and data labeling.

Pictured on the left in **FIGURE 2** is the first functional level – that is, the physical sensing of facial expressions, emotions, temperature, and other physical parameters. This data is fed

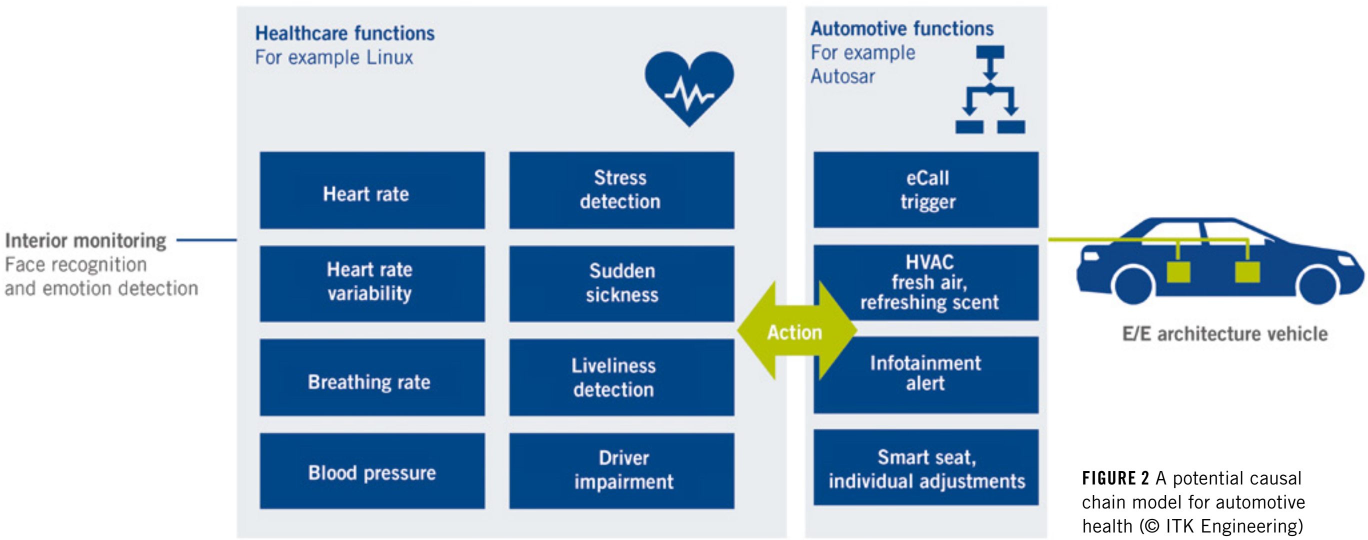


FIGURE 2 A potential causal chain model for automotive health (© ITK Engineering)

into the health features' functional cluster. Artificial intelligence and other algorithms then interpret the data and identify anomalies. A graphical display, infotainment system, or audio warning can then serve to alert the driver to any anomalies. Someday, vehicle health features may be able to actively intervene in critical situations.

CAMERA-BASED BLOOD PRESSURE MEASUREMENT

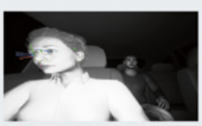
Pulse rates and blood pressure levels can be gauged using both color (RGB) and near-infrared (NIR) cameras. The same data serves to determine both blood pressure levels and pulse rates. Video streams from an RGB camera and images from an NIR camera can be used to estimate pulse rates. **FIGURE 3** compares the two technologies' benefits and drawbacks.

Both options require uniform lighting to reliably estimate the pulse rate. Visible lighting can irritate occupants, and many vehicles already have an infrared camera installed for fatigue and alertness detection, so an NIR camera is a good choice for detecting pulse rates. Drivers concentrate on the traffic ahead, so their heads generally do not move much over long periods. This works to the NIR camera's advantage. [8, 9, 10]

CALCULATING PULSE RATES WITH NIR CAMERAS

The concentration of hemoglobin changes over time as blood circulates through the forehead and cheeks. This triggers changes in the amount and color of light absorbed by the skin. An NIR camera detects these slight variations in intensity, which are called Imaging Photoplethysmography (iPPG) signals, and uses them to determine the pulse rate [10], **FIGURE 4**. It takes some preprocessing to calculate the iPPG signal. For one, the system has to first rec-

NIR camera

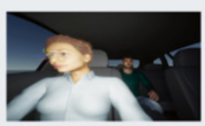


A NIR (Near-infrared) camera operates in the short-wave near-infrared light region (760 to 2500 nm), the part of the infrared spectrum immediately adjacent to visible light. It provides high sensitivity and contrast even in low-light conditions. An NIR camera is not to be confused with a thermal imaging camera, which operates in the mid-wave and long-wave infrared region (3.5 to 15 µm).

Benefits:
- Robust in most lighting conditions
- Works well in dim light
- Suitable for varying lighting conditions
- Reliable in controlled lighting environments
- Handles small motions effectively

Drawbacks:
- Not robust for large motions

RGB camera



An RGB (red, green, blue) camera captures images in the visible light range (400 to 700 nm) in the three primary colors red, green, and blue. It delivers color images.

Benefits:
- More motion-robust
- Works well for small motions
- Also functions for large motions
- Robust in controlled light

Drawbacks:
- Fails in uncontrolled ambient light
- Works poorly in dim light
- Unsuitable for varying lighting conditions

FIGURE 3 A comparison of NIR and RGB cameras for pulse rate estimation (© ITK Engineering) ognize the relevant sections of the face. An NIR camera's signal is noisier than that of an RGB camera because of its sensitivity and monochromaticity. This signal has to be denoised. Factoring multiple areas of the face into the equation makes for a more robust iPPG signal.

DETERMINING BLOOD PRESSURE LEVELS WITH NIR CAMERAS

Changes in the face's skin color are indicative of changes in blood volume. The iPPG signal registers these changes so that diastolic and systolic blood pressure levels can be determined. Peaks in the normalized iPPG signal are the reference points for estimating blood pressure levels. Blood pressure levels can be gleaned from these signal peaks' amplitudes by way of regression analysis or artificial intelligence. This method has yet to be applied in driving situations [11], **FIGURE 5**.

DATA PRIVACY

Engineers have to conduct data campaigns to apply, calibrate and, in some cases, train these methods. Some of the collected data will be health-related. If it is of a personal nature, it has to be better protected. Personal data does not have to be stored when gathering the information developers need. It suffices to simply record preprocessed sections of the face or iPPG signals and then align this data with health data. Less is more: If engineers opt for this approach, they will have to comply with less rigorous data privacy rules, devote less time and effort to managing data, and spend less on development.

OUTLOOK

Automotive health features can create a great deal of value for automakers and their customers. Taking advantage of legacy systems such as interior cameras to roll out new features can be very lucrative. All parties involved in automotive product development should be pursuing the same goal – to make time spent in a vehicle as pleasant as possible. Health features are indispensable to this end. Cameras for video-based pulse rate and blood pressure measurement are not the only option. Other on-board sensors such as interior radar sensors can enable even more automotive health features, for example, an option for measuring respiration rates. Collectively, these sensors culminate in a multivariate system that enables occupants' health to be assessed with even greater accuracy. And there is vast potential to be tapped by connecting all this to smart seats, smart glass, ambient lighting, scent diffusers, and other intelligent actuators to create tomorrow's automotive health system. Simulation tools such as the ITK iVESS (Individual Virtual Environment and Sensor Simulation) framework can support efforts to verify and validate the occupant monitoring system.

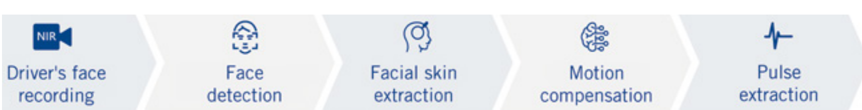


FIGURE 4 An algorithmic approach to estimating the pulse rate based on NIR camera data (© ITK Engineering)

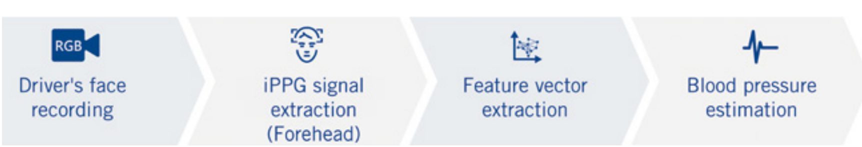


FIGURE 5 An algorithmic approach to estimating the blood pressure based on RGB camera data (© ITK Engineering)

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