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Feature: On sleep and fatigue

Reading the driver's eyes using machine learning

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AS A CHILD, my favourite place in a car was directly behind the driver. I liked to peek over their shoulder and I found it fascinating to perceive their perspective. Somehow, I figured out when a driving manoeuvre was about to take place. Observations of the driver's eyes can reveal not only their level of fatigue, but can also be used to infer their intent. With advances in technology, machines can be trained to do just what I tried as a child: to watch the driver and predict his or her intent.

My career started with a five-year Master's degree in Psychology at the TU Braunschweig (TUBS) in Germany, where I specialised in cognitive neuroscience and mathematical psychology. While studying for that Master's degree, I was a visiting student at the University of Padova in Italy, was an intern and student assistant at TUBS, as well as interning at the Radboud University and the Max Planck Institute for Psycholinguistics in the Netherlands, where I wrote my Master's thesis with Anne Cutler. After that, I joined the Behavioural Brain Sciences Centre at the University of Birmingham. I was working as a research assistant there, with a focus on cognitive science, eye tracking and speech production. Due to my desire to do applied work, I decided to further broaden my skill set and I became a student again. I obtained an MSc in Computer Science with a focus on machine learning at the University of Birmingham. Soon after graduation, in 2005, I found myself working at the German Aerospace Center (DLR) in the automotive field. My work utilises research vehicles equipped with eye tracking systems in order to develop the Advanced Driver Assistance Systems (ADAS) of the future. My current role provides me with a happy balance of theoretical and practical work.

Monitoring drivers using machines: A brief history

Monitoring a driver's eyes in order to elicit information about the current driver-state has been an active area of research for the last 40 years. A large body of research was driven by the automobile industry's desire for vehicle technology which detects fatigue and sends a warning signal to the driver. Fatigue was initially measured by the degree to which the driver's eyes were open. The scope of the technology has advanced rapidly since then. Nowadays, many lorries are equipped with a computer system that detects fatigue. The system then alerts the driver via an acoustic warning. Other car manufacturers have gone further and inserted technology which makes the vehicle automatically stop and park on the side of the road if the driver is deemed to have ignored the fatigue warnings. Currently, though, these gadgets tend to be found in executive-class vehicles only.

Human-Machine interaction

In order to correctly deliver appropriate detection and intervention in a timely manner, the machines need to accurately infer the driver's intentions, that is, correctly predict what they are about to do. The use of 'manoeuvre recognition' can help to avoid mismatches between the driver's intention and the system's reaction. A pertinent example is a situation, where a driver intends to change lanes in order to overtake the car in front but the ADAS emits an incipient collision warning potentially confusing and irritating the driver, and constituting a false alarm. Such false alarms can lead to additional driving errors which actually negate the benefits of such systems. This would mean that as well as aiming to improve overall accuracy of manoeuvre recognition it should be ensured that a collision warning system is biased towards avoiding false alarms.

This collision warning example highlights the importance of developing machines which identify driving manoeuvres well in advance. This temporal advantage allows the driver to be kept in the loop by the system. They are informed early enough to have enough time to select an appropriate response. With reference to the collision warning example, the warning should be issued by the system only if it is recognises that the driver does not plan to overtake the car in front and that a critical situation is developing.

My research using machine learning

When I started conducting research into driver intent, I asked the question: Do characteristic eye movement patterns precede particular driving manoeuvres? In certain situations, eye movements have been shown to indicate information gathering. The patterns of eye movements before a certain action can be characterised and thereby a driver's intent can be inferred by an appropriate system using the driver's eye movements.

I conducted both simulator and real-world studies in order to investigate whether we can reliably predict a driver's intent (with respect to lane changing behaviour) using eye gaze data only. We recorded drivers' patterns of gaze behaviour while they drove on multi-lane roads and carried out lane change manoeuvres. The eye gaze data gathered was divided into data segments representing the time preceding both left- and right-lane change manoeuvres and instances of lane keeping. We then fed these data segments into machine learning models (e.g. Artificial Neural Networks) which were trained to classify the segments of gaze data as the precursor to either lane changing to the left, lane changing to the right, or lane keeping. Our research showed that it is possible to predict the onset of these manoeuvres with a high level of accuracy using this machine learning approach.

The future: Automated driving and fatigue tests

The ability to infer driver intent will be a necessary property of some future Advanced Driver Assistance Systems. Some of these systems will monitor a driver's eyes with the objective of inferring the driver's intent which could allow specific driving errors to be spotted before a critical situation develops. Timely intervention would then be possible. For the time being, the driver will remain in charge, being able to switch-off any ADAS when they choose. The integration of such ADAS is a step towards 'Highly Automated Driving', where driver and vehicle decisions are merged, and is seen by many as an essential step towards the ultimate acceptance of 'Autonomous Driving', where the driver's role becomes passive.

It is planned that driver fatigue will not only be monitored by devices inside the vehicle; it has also proven desirable for law enforcement to be able to measure the degree of fatigue of a driver during a stop-check. This would involve running a test which monitors the stability of a driver's gaze during a set of exercises conducted within a closed environment at the roadside. This approach is currently in development. Based on the driver's performance, researchers working on that technology seek to allocate a numerical value to the level of a driver's fatigue. That will allow a more fine-grained judgement to be made as to whether the driver is capable of operating their vehicle safely. Just what will be defined in law as a 'safe' level of fatigue has yet to be seen and in itself will be a complex area of debate and study.

About the Author

Firas Lethaus is a research scientist and project manager at the German Aerospace Center (DLR). He holds MSc degrees in Psychology (TU Braunschweig) and Computer Science (Birmingham). He wrote his doctoral thesis at the TU Braunschweig in the field of Mechanical Engineering and is an expert in human factors, machine learning, cognitive engineering, and eye tracking. He advises the DLR Executive Board on scientific and technical issues.

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