

Explainable Automotive Emissions

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1 Extended Abstract

In modern cars, embedded software controls the combustion and exhaust purification process. A multitude of parameters is being influenced so as to lower the emissions of toxic exhaust gases. In order to ensure that these emissions do indeed stay within reasonable limits, cars need to pass certain test procedures on chassis dynamometers for type approval. Until recently, the test setup and conditions were specified precisely, for reproducibility and comparability reasons. In what has been known as the diesel emissions scandal, *doped* [1] control software has been put in place to detect running emission tests and alter the combustion and purification process to manipulate the test results effectively rendering the results meaningless.

In response, the European Union has defined a new test procedure to test for *Real Driving Emissions* (RDE) [4]. The RDE is designed to provide insights into the actual in-the-wild emissions of vehicles. With the emerge of *Portable Emissions Measurement Systems* (PEMS) which can be carried with a vehicle under scrutiny, it is now possible to gather these insights, also in combination with other relevant parameters influencing emissions.

This opens a research agenda from emission monitoring to emission analysis, and eventually emission explanation. Making exhaust emissions explainable will enable answers to questions like: Does a vehicle emit increased levels of certain gases because of the driving behavior, a manipulated purification or combustion process, or a fault in the system?

In recent work, we formalized the RDE test procedure using the stream-based specification language Lola [3]. Based on this formalization a runtime monitor was synthesized which we used to conduct RDE-like tests based on low-cost equipment we developed. The results are promising. We were able to gather valuable insights into the exhaust emissions and purification control software of an Audi A7. Our results suggest that our particular car contains an illegal defeat device manipulating the exhaust purification process under certain circumstances [2], a suspicion which recently has been confirmed by Audi.

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What is an ES4CPS problem that I am interested in? The diesel emissions scandal has demonstrated that opaque control software can easily be used against the interest of society. Based on our earlier success with monitoring the in-the-wild behavior of an Audi A7, I would like to develop means to understand the emission behavior of vehicles in-the-wild. From a broader perspective, I would like to enable laypersons with low-cost equipment to get valuable insights into complex CPS. To this end, I am interested in explanatory models for systems controlling chemical processes eventually allowing us to explain and predict automotive emissions based on driving behavior and external circumstances.

What is the ES4CPS-related expertise that I can contribute? Related to the aforementioned problem, I have expertise based on my previous work in how to gather insights in automotive emissions, both, from a theoretical and practical perspective.

What external expertise do I need? Considering the theoretical part, I could use external expertise on how to faithfully model the software controlled chemical processes found in modern cars. Considering the practical part, I could use expertise on how extract information from embedded car controllers using non-standardized interfaces.

References

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