On failures of RGB cameras and their effects in autonomous driving applications

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Type of presentation: Technical presentation

Sensor technology, data-fusion and inference algorithms as Artificial Intelligence and Machine Learning (AI/ML) applications are the enabling technologies that play a cornerstone role in autonomous driving systems. Amongst sensors, the RGB (red, green and blue) camera is acknowledged as the most commonly used and an irreplaceable one. Vehicle cameras are already exploited in many applications such as traffic sign recognition, lane detection, obstacle detection, etc. Additional prospective applications are being researched; for example, at intersections, knowing the location of pedestrians and bicyclists can allow the car to make sophisticated precedence decisions. Also, cameras are amongst the cheapest solutions to build autonomous driving systems that are capable of sensing the surroundings.

When the images provided by the camera are degraded, fatal accidents may occur. The trained agents of the AI/ML applications responsible for the elaboration of inputs may rely on biased data and consequently lead to wrong (unsafe) decisions. Consequently, we can observe that cameras failures and their effects on the overall system should be systematically studied to fully understand the resulting safety threats at system-level, and possible mitigations should be identified carefully. Such study would benefit system and software engineers, both for architecting systems and for the robustness assessment of image-based AI/ML applications.

To discuss this subject, the presentation is organized as follows. First, we will describe failure modes for vehicle cameras in the domain of autonomous driving, by analyzing the different failures, their causes and their effects on the system through an FMEA (Failure Modes and Effects Analysis) on the components of an RGB camera. Second, we will review the state of the art to report on existing mitigations at component-level and at camera-level. Third, we will show how we were able to reproduce the failures effects on the images acquired by a camera, by developing a failure library in Python. Fourth, we will confirm the effects and discuss the associated safety risks using as reference a vehicle simulated in the Carla autonomous driving simulator, where a trained agent for autonomous driving based only on the RGB camera is running. We will show that injecting failures in the frontal camera of such vehicle leads the trained agent to misbehave, and we will observe that slight modifications to the produced image are sufficient to deceive such trained agent. Fifth, the presentation will discuss our ongoing works on this subject, which are focused on the definition of a failure detector that can identify incorrect images, by training an agent that detects images produced by a failed camera.

The majority of the contributions of this presentation are from:

Francesco Secci, Andrea Ceccarelli, "On failures of RGB cameras and their effects in autonomous driving applications", 31st International Symposium on Software Reliability Engineering (ISSRE 2020).

Note: Due to the pandemic and possible travelling restrictions, I cannot commit to participate in presence.