Scientists design learning-enabled safe control for systems in uncertain environments

April 22 2022

Credit: CC0 Public Domain

Humans live in a world where safety-critical systems are at work all around them. Scientists want to ensure that the proper safety constraints are in place so these systems can operate safely while also performing as needed. Toward this goal, researchers at Michigan State University have developed a method for designing a learning-enabled safe controller for systems that operate in uncertain environments.

This study, conducted by Bahare Kiumarsi and Zahra Marvi, from Michigan State University, focused on the safe maneuver of an autonomous vehicle in an urban area. They published their findings in the March Issue of *IEEE/CAA Journal of Automatica Sinica*.

Over time scientists have successfully designed safe control methods based on control barrier functions (CBFs) for use with a broad range of applications, including adaptive cruise control, safe control of robots, and collision-free multi-agent systems. These methods generally combine CBFs and Lyapunov functions to certify that a controller is safe and stable. What the Michigan State University researchers propose is a novel learning-enabled zeroing control barrier function (ZCBF), which is capable of safe operation while learning, even with unknown dynamics at work in the environment.

As more and more safety-critical systems are deployed in the real world, scientists have to be able to assure that their states evolve within safe boundaries. The uncertain factors in the environment can affect a system's safe operation. As the researchers studied the autonomous vehicle in the urban environment, they had to take into account these uncertain factors. For example, there are the autonomous vehicles, semi-autonomous vehicles, human-driven vehicles and pedestrians, all engaged in the same area.

So scientists have to design a controller that can ensure the system operates safely despite the uncertainty of how the other vehicles and humans navigating in the same space will behave. The scientists need to be able to count on the safety of the system while also allowing the system to perform as well as possible. The Michigan State University researchers' method solves the problem of how to design a learning-enabled safe controller for systems that must operate in uncertain environments. Their novel learning-enabled method is capable of safety guarantee of the autonomous vehicle, even while operating alongside the uncertain behavior of other vehicles on the road.

Existing safe control methods require scientists to have complete knowledge of the safe set. Where there is uncertainty in the environment, it becomes much more challenging to design safe controls for the system. These safety-critical systems must be able to quickly learn the uncertainties, while also achieving maximum safe performance. A slow model-learning approach can provide the needed safety features, but cannot reach the desired performance. A naïve model-learning approach based on minimizing the modeling error cannot achieve the desired safety requirements, even if the expected estimation error decreases over time. "Novel learning algorithms are required to avoid misrepresentation of the safe set as much as possible," said Zahra Marvi, a Ph.D. candidate. The method the researchers developed is capable of quickly learning the uncertainties in the environment and rapidly reaching safe performance.

"Satisfaction of safety constraints is crucial and needs to be considered during the control design phase because their violation can have catastrophic consequences," said assistant professor Bahare Kiumarsi. With this method the Michigan State University researchers have designed, the controller in a system can take less conservative actions, resulting in better performance, thereby improving both the safety and performance for a system.

More information: Zahra Marvi et al, Barrier-Certified Learning-Enabled Safe Control Design for Systems Operating in Uncertain Environments, *IEEE/CAA Journal of Automatica Sinica* (2021). DOI:

10.1109/JAS.2021.1004347

Provided by Chinese Association of Automation