Blending methods to generate safe controllers: combining data-driven control barrier function approximations with Hamilton-Jacobi reachability analysis

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Abstract: While interviewing for faculty positions I was repeatedly asked how the tool I often use for generating safety filters for controllers (Hamilton-Jacobi reachability analysis) compares to the very popular control barrier function (CBF) method. I then spent the first couple years as a faculty member exploring the answer to this, supported by an ONR YIP. In this talk I will discuss:

- The relationship between these two methods
- How we can use reachability analysis to refine CBF approximations to provide safety guarantees
- How we can generalize these safety functions for hard-to-model dynamics (e.g. interaction behavior among pedestrians)

The last topic employs a key observation: the spatial interaction patterns of multiple dynamic obstacles can be decomposed and predicted through temporal sequences of states for each obstacle. Through decomposition, we can generalize control policies trained only with a small number of obstacles, to environments where the obstacle density can be 100x higher. We have no guarantees on safety for that particular project (at least so far), but we empirically show significant improvements to dynamic collision avoidance (compared to other learning methods) without being overly conservative (compared to control theoretic methods). That work is joint with Professor Sicun (Sean) Gao, and recently won the Robocup best paper award at IROS 2023.

Bio: Sylvia Herbert joined the UCSD MAE department as an Assistant Professor after graduating with her PhD from UC Berkeley in 2020. She now has a research group of 8 PhD students along with several MS and undergraduate students. These students work on a range of projects, including:

- Connections between Hamilton-Jacobi reachability and CBFs (this talk)
- More generally blending different computational methods and theory for HJ reachability
- Koopman-Hopf reachability analysis for very efficient approximate reachable sets and control policies
- Reasoning about safety when you are forced to interact with an uncertain stochastic environment (e.g. pushing around debris to reach a goal)
- Control theoretic methods applied to learning frameworks (e.g. when fractal landscapes occur in policy gradient methods)
- Safe reinforcement learning

For more on these topics please see our group website. For questions/comments, Professor Herbert can be reached at sherbert@ucsd.edu