PRODUCT BRIEF

MOBILEYE® RESPONSIBILITY SENSITIVE SAFETY
PROPOSED RULES FOR AN AV'S DRIVER TEST

Challenge of providing safety assurances in AV decision-making

One of the biggest threats to the successful realization of the autonomous driving industry is the lack of agreement on what it means for an AV to drive safely. Until governments, industry, and the public have a common way to understand and assess the driving skill and safety of an automated vehicle (AV), they may not be granted a license to drive.

With human-defined common sense principles for what it means to drive safely as our guide, Intel has proposed a technology neutral formalization of what it means to drive safely. Made up of formal logic and rules, our proposal – called Responsibility-Sensitive Safety – adheres to five safety principles:

1. Don't hit the car in front of you (longitudinal distance)
2. Don't cut in recklessly (lateral distance)
3. Right-of-way is given, not taken
4. Be careful in areas with limited visibility
5. If you can safely and legally avoid a collision without causing another, you must

RULE 1 Don't hit the car in front of you

Based on common laws of physics and a century of driving experience, new human drivers are taught to "leave 2-3 seconds worth of space" between the car in front of them providing the time and space required to react. The 2 second rule is an intuitive way for any driver to leave a safe distance without having to understand the math and physics behind it including calculating the velocities of both cars, the driver's reaction time, and the front vehicle's braking capability.

In RSS, we've formalized this rule into the actual mathematical calculation:

$$d_{min} = \left[v_r \rho + \frac{1}{2} a_{max} \rho^2 + \frac{(v_r + \rho a_{max})^2}{2\beta_{min}} - \frac{v_f^2}{2\beta_{max}} \right]_+$$

Meaning, the moment the distance between the two cars is less than d_{min}, the automated vehicle's "driver" will perform the proper response, which is to brake until a safe following distance is restored, or until the vehicle comes to a complete stop, whichever occurs first.

RULE 2 Don't cut in recklessly

The safest human drivers do well to stay in their designated lane and avoid unsafe cut-ins when merging into other lanes. Rule 2 of RSS formalizes what a safe lateral distance is which enables the AV to be aware of when their lateral safety may be compromised by an unsafe driver turning into its lane.

This formula below accounts for the natural lateral movement within a lane that is performed by human drivers.

For example, if another car moves into or occupies that space, humans first steer back to avoid a collision, stopping its lateral velocity relative to the other car, then continue to move away laterally until safe distance is restored. Similarly, this is the "proper response" for an AV if a violation is made in the safe lateral distance as defined by RSS.

$$d_{min} = \mu + \left[\frac{(v_1 + v_{1,\rho})}{2} \rho + \frac{v_{1,\rho}^2}{2\beta_{1,lat,min}} - \left(\left(\frac{v_2 + v_{1,\rho}}{2} \right) \rho + \frac{v_{2,\rho}^2}{2\beta_{2,lat,min}} \right) \right]$$

"There is currently no accepted, industry-wide approach to [safety] demonstration"[1]

—
Measuring Automated Vehicle Safety, RAND Corporation

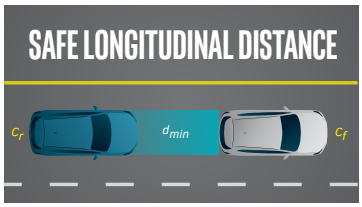
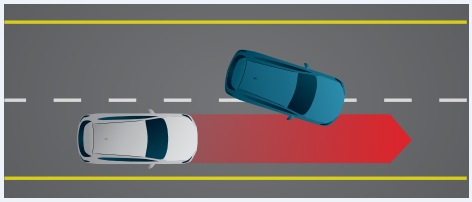


Figure 1: *Maintain a safe longitudinal distance*

"The metrics that are most widely used by self-driving car developers - miles driven and the frequency of human intervention - alone are insufficient to demonstrate the safety of an autonomous automobile."[2]

—
Derek Kan, Undersecretary of Transportation for Policy

Figure 2: Maintain a safe lateral distance even when merging



Danger Threshold Time

A time *(t)* is dangerous for two cars if both lateral and longitudinal safe distance are compromised

The Danger Threshold is the first time *(t)* where safe distance (in either axis) has been compromised

RULE 3 Right of way is given not taken

On well-marked roads, the right of way is clear. Lane lines, signs, and traffic lights establish priority for routes as they intersect one another. However, there are other times when the right of way is less clear and human drivers must negotiate with one another. For AVs, this negotiation must be formalized so that machines can make that same negotiation and be sure to arrive at the same conclusion.

For example, Figure 3 shows a T-Junction without a stop sign. If a stop sign existed, the drivers are expected to give right of way to vehicles without a stop sign. Sometimes they don't, and if a car ran the stop sign and created a dangerous situation, the AV must still respond accordingly. It has right of way on paper but should not let a crash happen just because the rules give it the right of way.

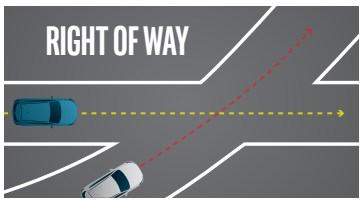


Figure 3: Right-of-way is given, not taken

RULE 4 Be cautious in areas with limited visibility

Many factors can affect visibility while driving. Aside from the weather, factors such as road topography, buildings, and even other cars can obstruct our view of the road and other road users. Depending on the surroundings, humans naturally put bounds on their behavior to avoid unforeseen danger.

On a highway, it is reasonable to expect that pedestrians or cyclists will not suddenly jump into the road. However, on a street near a school or neighborhood, those events are more likely, so drivers proceed cautiously, especially as they approach crosswalks or pass cars parked along the street. AVs will have to make similar assumptions and exhibit caution in areas of occlusion to ensure safety.

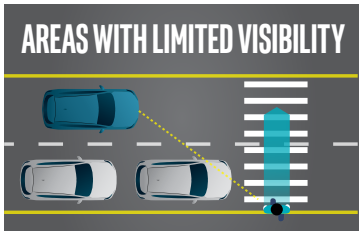


Figure 4: Be careful in areas with limited visibility

RULE 5 If you can avoid a crash without causing another one, you must

Rules 1-4 create formal definitions to identify what a dangerous situation is and what the proper response is for the AV. Rule 5 covers scenarios where a dangerous situation may have been imposed so suddenly that a collision cannot be avoided unless a more evasive action is taken. Rule 5 states that if you can avoid a crash without causing another one, you must do so. For example, if a front car suddenly swerves into the next lane exposing an object in the road the following car's time of exposure to this object is insufficient to stop in time. However, if the next lane is free, the following car can do the same and take evasive action to avoid the accident.

Figure 5: If you can safely and legally avoid a collision without causing another, you must

1. Fraade-Blanar, Laura, Marjory S. Blumenthal, James M. Anderson, and Nidhi Kalra, Measuring Automated Vehicle Safety: Forging a Framework. Santa Monica, CA: RAND Corporation, 2018. https://www.rand.org/pubs/research_reports/RR2662.html.
2. Beene, Ryan. "Self-driving Car Industry Needs Better Metrics, DOT Official Says." Bloomberg, October 23, 2018. https://www.bloomberg.com/news/articles/2018-10-23/self-driving-car-industry-needs-better-metrics-dot-s-kan-says

JOIN THE DISCUSSION!

At Intel, we believe that a common, technology neutral standard that formalizes what it means for an AV to make safe decisions is necessary for regulator and consumer acceptance of automated vehicles. Join us in this important discussion between industry, government, academia and consumers so that together we can define and agree on what it means for an Automated Vehicle to drive safely.

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