Considerations for Risk Frameworks Relating to Vehicle Control

Prepared for: FG-AI4AD – 16 SEP 2020

Prepared by: Michael Woon, Retrospect

Driving Autonomous Vehicle Safety

retrospect

Agenda

Topics

Motivation

Why Risk?

What is “Risk?”

Safety Argumentation

Ethics and AVs

retrospect

Motivation

Motivation

+ Product Liability
+ Public Safety
+ Realize commercial opportunities
+ Fullfilment of well-trusted safety standards, e.g. ISO 26262, IEC 61508

*"Today, neither industry nor government can **assess the safety of self-driving cars**"*
- EE Times, 'A Wave of Safety Standards to Hit in 2020' [3]

*"NTSB has recommended … **more testing and proof of safety** before large numbers of vehicles are allowed on public roads"*
– Consumer Reports, ' Congress Debates Autonomous Vehicles Car Safety' [2]

*"U.S. secretary for policy at the U.S. Department of Transportation, **stressed the need for objective** and agreed-upon **measures of driverless systems** performance"*
- Venture Beat, 'Autonomous Cars Need better safety metrics to move the industry forward' [1]

1. https://venturebeat-com.cdn.ampproject.org/c/s/venturebeat.com/2020/01/10/ai-weekly-autonomous-cars-need-better-safety-metrics-to-move-the-industry-forward/amp/
2. https://www.consumerreports.org/autonomous-driving/congress-debates-autonomous-vehicles-car-safety/
3. https://www.eetimes.com/a-wave-of-av-safety-standards-to-hit-in-2020/

Agenda

Topics

Motivation

Why Risk?

What is “Risk?”

Safety Argumentation

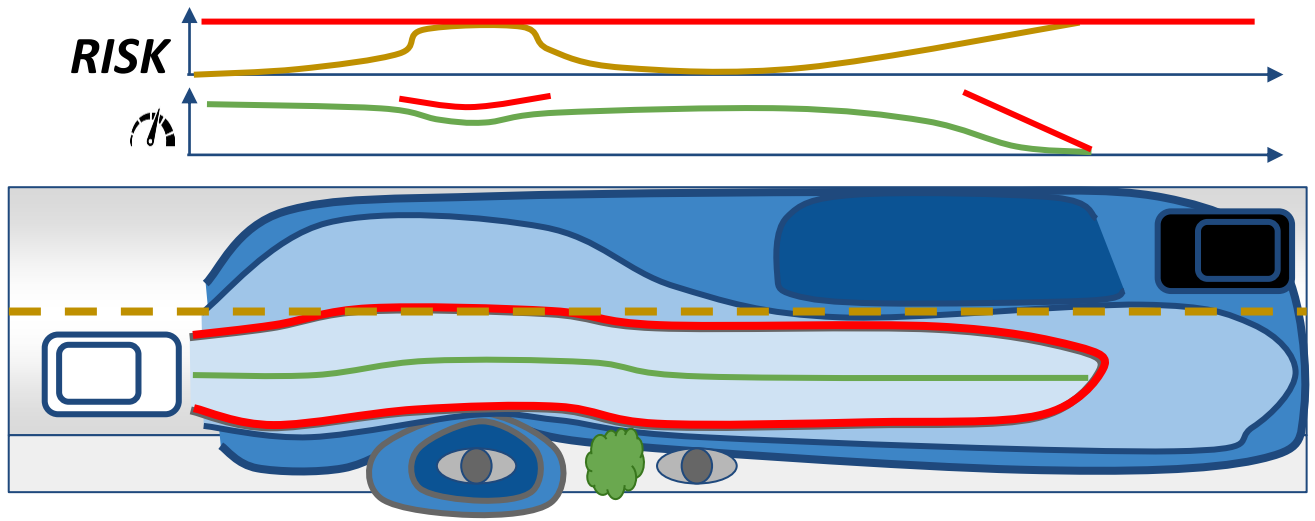
Ethics and AVs

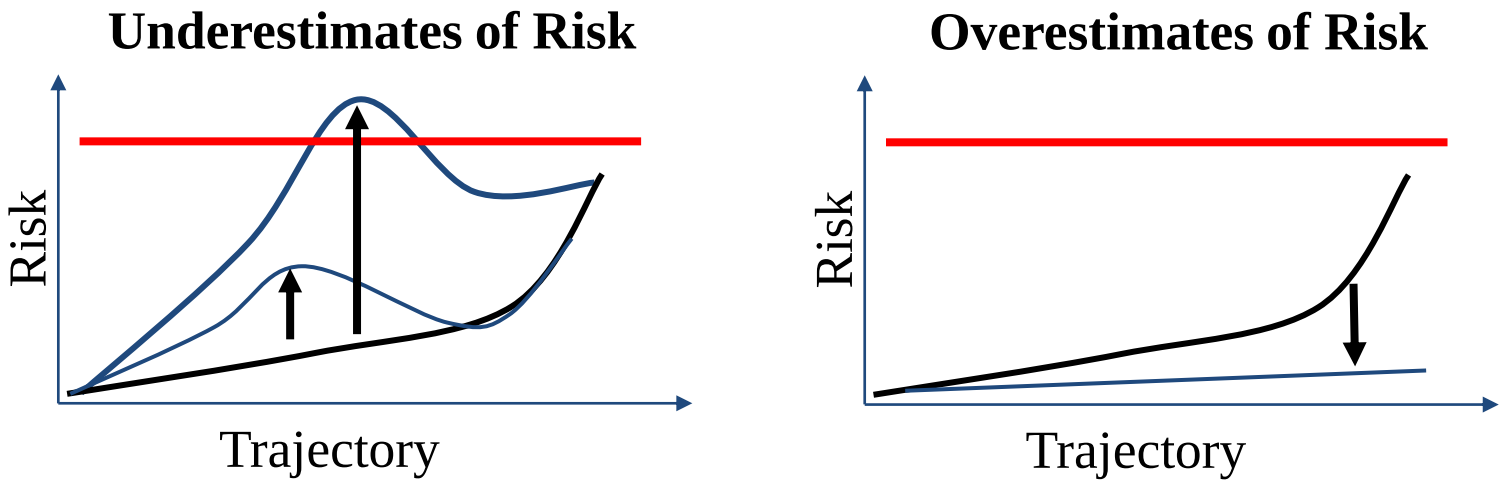
retrospect

Why Risk?

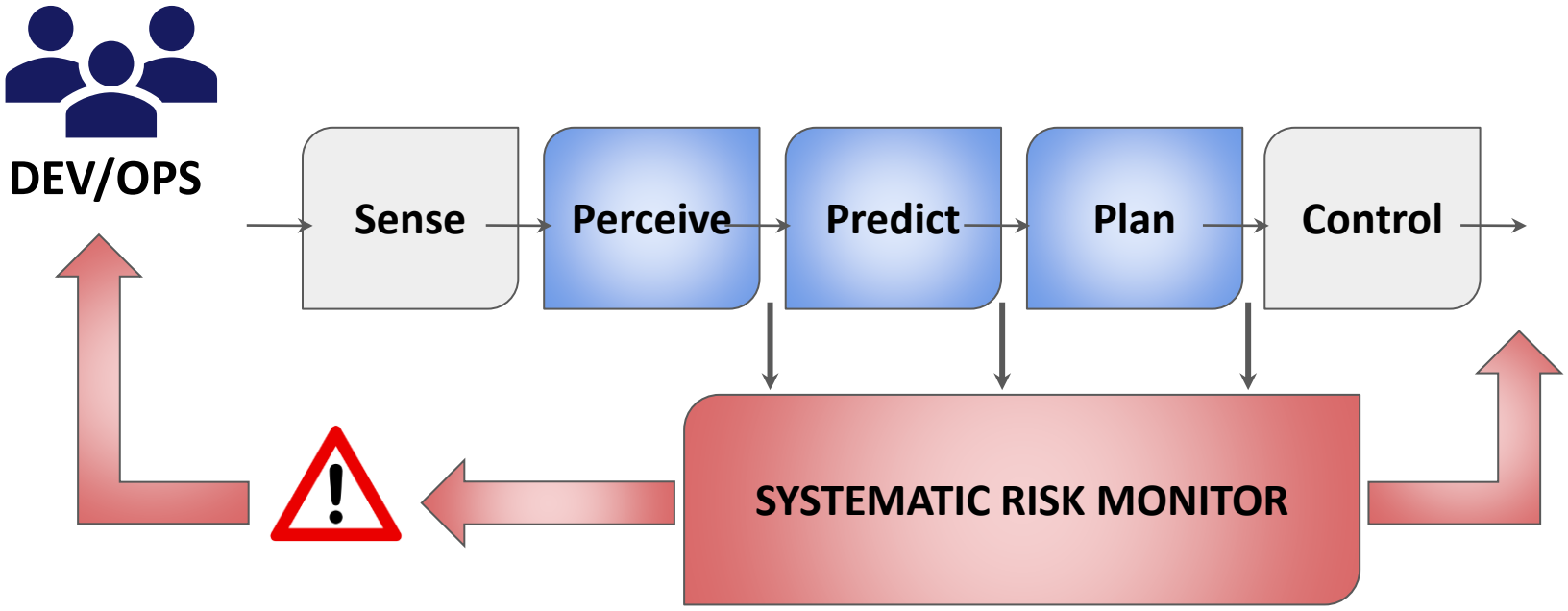
Risk Model Applications

+ Path planning optimization / cost structuring
+ Path planning constraints
+ Scenario identification & classification
+ Safety monitoring

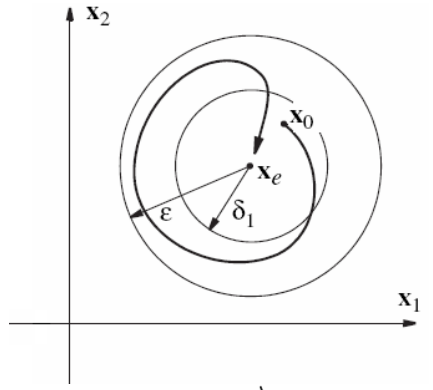




Retrospect's Safety Monitoring Approach

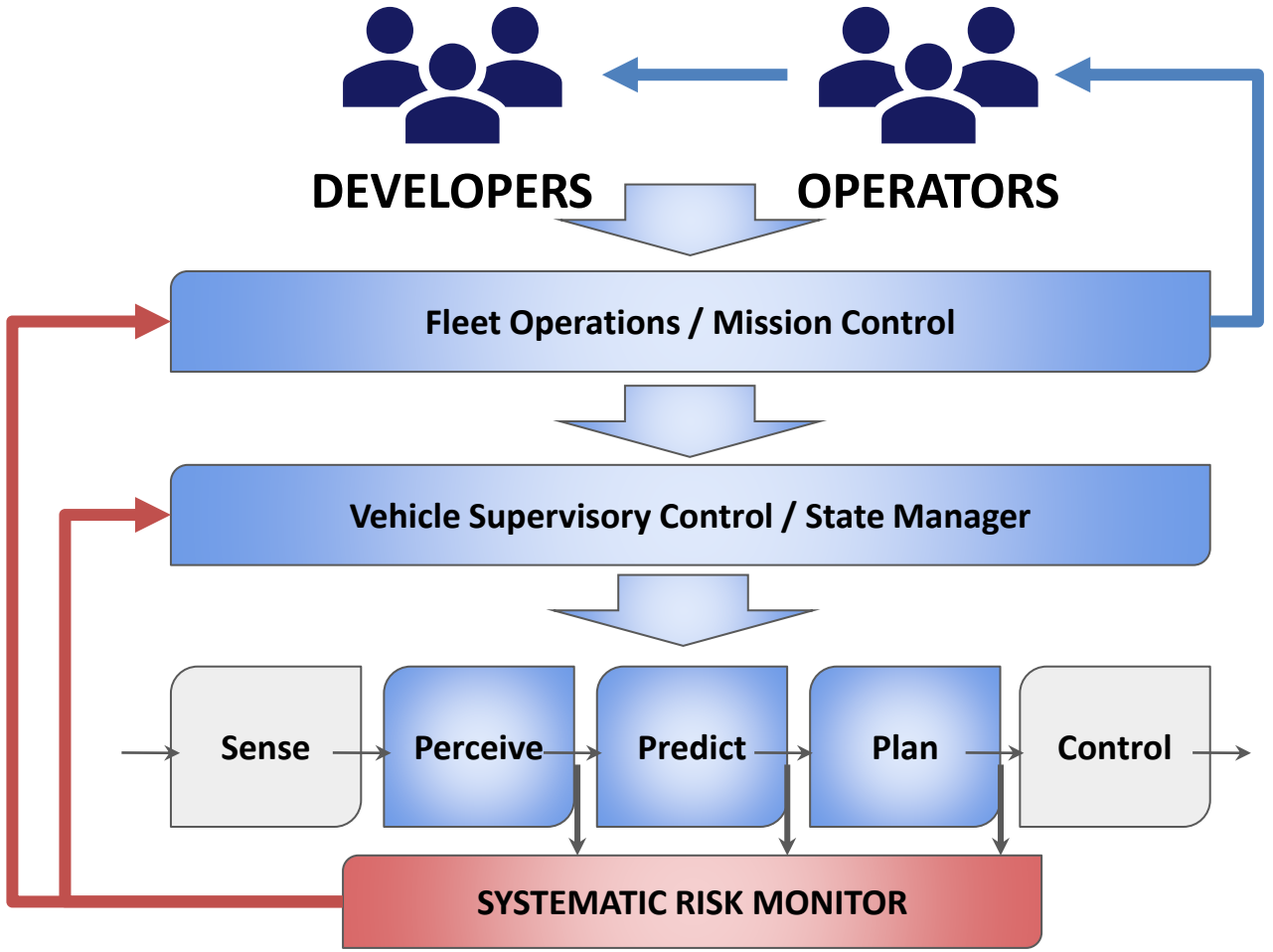


LYAPUNOV STABILITY

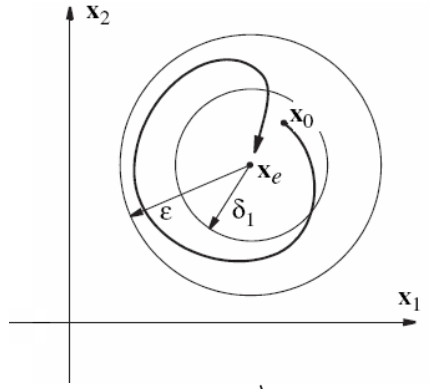


$$\left\| \frac{dRisk(\overrightarrow{Path})}{dt} \right\| \leq \alpha$$

Command Authority for Autonomous Safety



LYAPUNOV STABILITY



$$\left\| \frac{dRisk(\overrightarrow{Path})}{dt} \right\| \leq \alpha$$

retrospect

Agenda

Topics

Motivation

Why Risk?

What is “Risk?”

Safety Argumentation

Ethics and AVs

retrospect

What is “Risk?”

Risk

Reference: The Quantitative Risk Norm - A Proposed Tailoring of HARA for ADS
Warg, Johansson, Skoglund, et al. Proceedings of 2020 50th Annual IEEE/IFIP International Conference on Dependable Systems and Networks Workshops (DSN-W)

ISO 26262: “combination of the probability of…

“physical injury or damage to the health of persons…

[and] “estimate of the extent of harm…”

Hazard Mechanisms

Collision – e.g. front impact, side impact, VRU impact

Roll-over

Jostle / Shake e.g. harmful transient control (oscillatory or high jerk), whiplash, bruising

Crush – underneath wheels, pinch point between parked cars

Exhaust (CO) poisoning

Obstructing emergency access, emergency responders

Surprise / Startle and subsequent unintended reaction

Etc., …

Hazard Mechanisms

Collision	Delta velocity, mass, contact areas
Roll-over	Lateral accel, track width, road surface, wind?
Jostle / Shake	Lateral & Long. accel frequency and magnitude
Crush	Proximity (wheels, bumpers) and Long. force
Exhaust (CO) poisoning	Enclosed volume
Obstructing	Proximity
Surprise / Startle	Transients Lateral & Long., proximity, Delta velocity

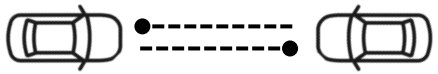
Etc., …

Collision Risk

Combination of the **probability of physical injury** or damage to the health of persons and **estimate of the extent of harm**…”

Delta-V → Injury: Slight, Serious, Fatal

Frontal Impact



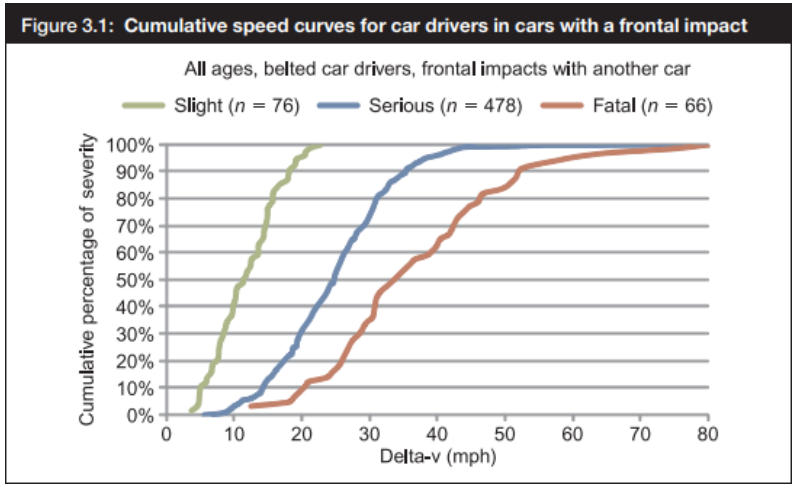
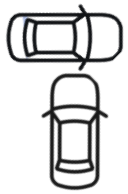


Figure 3.1: Cumulative speed curves for car drivers in cars with a frontal impact

Side Impact



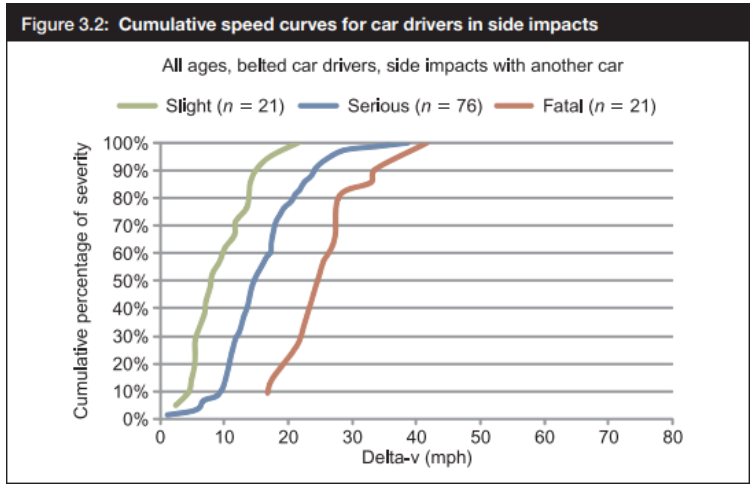
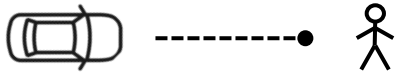


Figure 3.2: Cumulative speed curves for car drivers in side impacts

Pedestrian



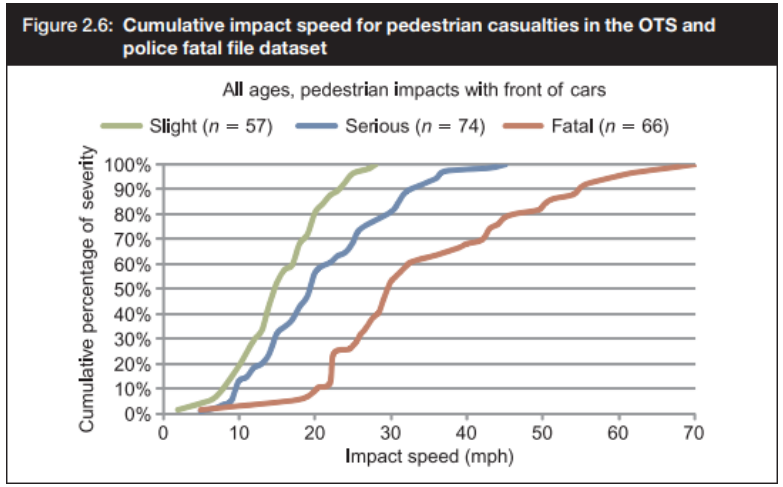
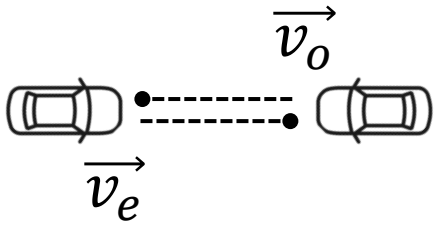


Figure 2.6: Cumulative impact speed for pedestrian casualties in the OTS and police fatal file dataset

Source: NACTO Road Safety Web Publication No. 16 Relationship between Speed and Risk of Fatal Injury: Pedestrians and Car Occupants, D. C. Richards. Transport Research Laboratory, September 2010, Department for Transport: London

Delta-V: Impact Velocity, Pre/Post Velocities, and Peak Acc.

Impact Velocity



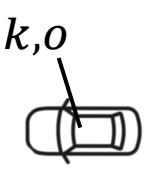
$$\Delta\overrightarrow{v_i} = \overrightarrow{v_e} - \overrightarrow{v_o}$$

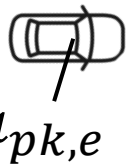
Pre/Post Velocities

$$\Delta\overrightarrow{v_o} = \overrightarrow{v_o}' - \overrightarrow{v_o} = \frac{2m_e}{m_o+m_e}\Delta\overrightarrow{v_i}$$

$$\Delta\overrightarrow{v_e} = \overrightarrow{v_e}' - \overrightarrow{v_e} = \frac{2m_o}{m_o+m_e}\Delta\overrightarrow{v_i}$$

Peak Accelerations

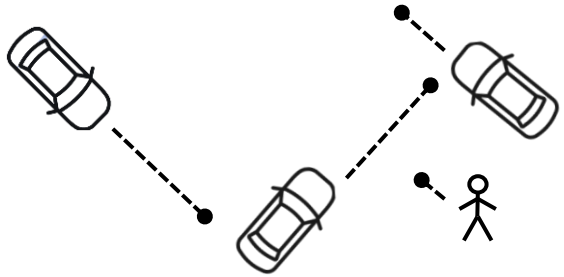




Risk / Injury Severity Predictors

Delta-V from Universal Scenario Definition

- Applies to: Scenario definitions, simulation "gnd truth," track / road tests, path planning internal to AV stack
- Frontal, Side, Pedestrian collision
- Accounts for worst-case mass/momentum

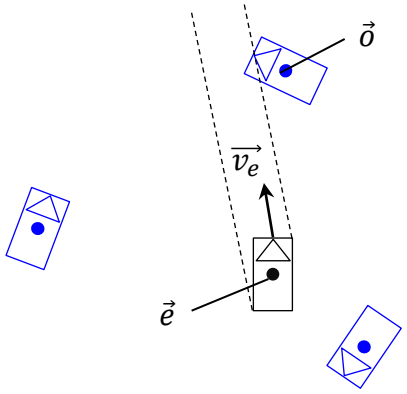


Always generates a reciprocal Delta-V pair: between Ego and Object

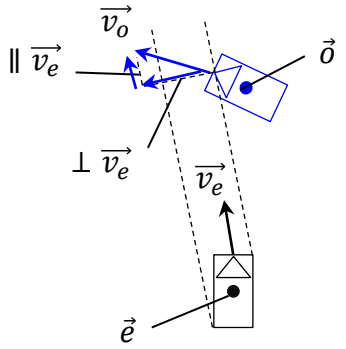
Key:

e	*Position of EGO at instance, t*
o	*Position of OBJECT at instance, t*
v_e	*Speed of EGO at instance, t*
v_o	*Speed of OBJECT at instance, t*
L_E	*Length of EGO*
L_T	*Length of TRGT*

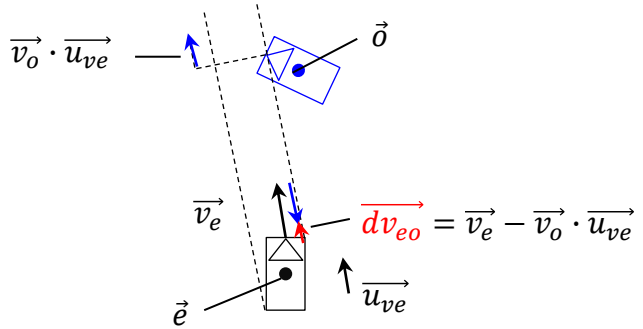
Step 1: Does $\overrightarrow{v_e}$ point to any object?



Step 2: Does $\overrightarrow{v_o}$ contribute to or negate the delta v?



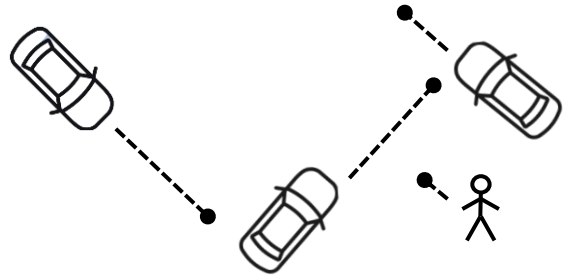
Step 3: Calculate the delta v

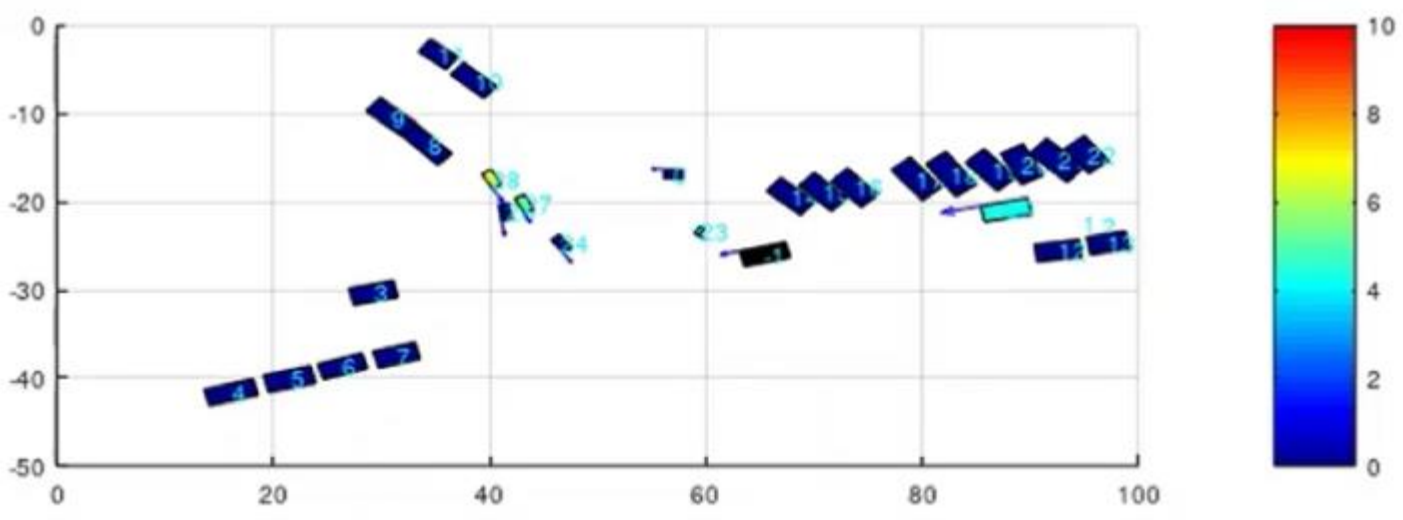


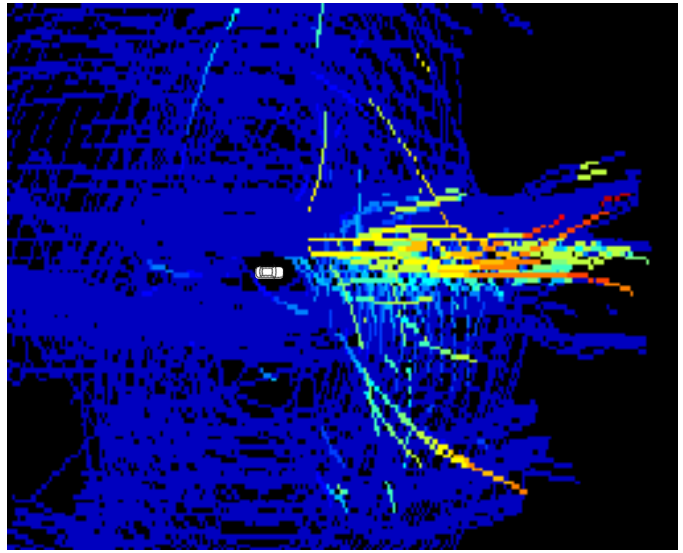
Source: https://github.com/RetrospectAV/RiskFramework/blob/master/RiskWiki.md

Delta-V from Universal Scenario Definition – Validation Efforts

- "Control-Neutral" approach to determining Delta-V; no assumed scenario
- What is the instantaneous momentum in the system? What if nobody did anything?
- Not reduced to time or distance domains



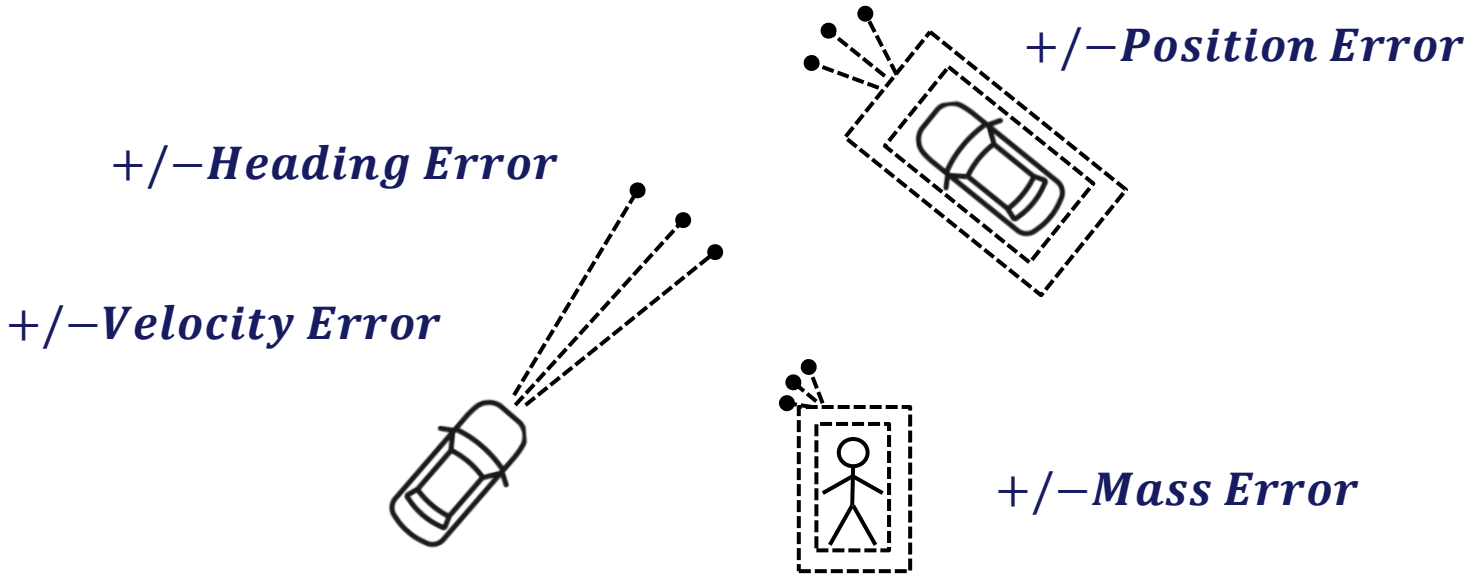




Source: www.levelxdata.com, fka GmbH

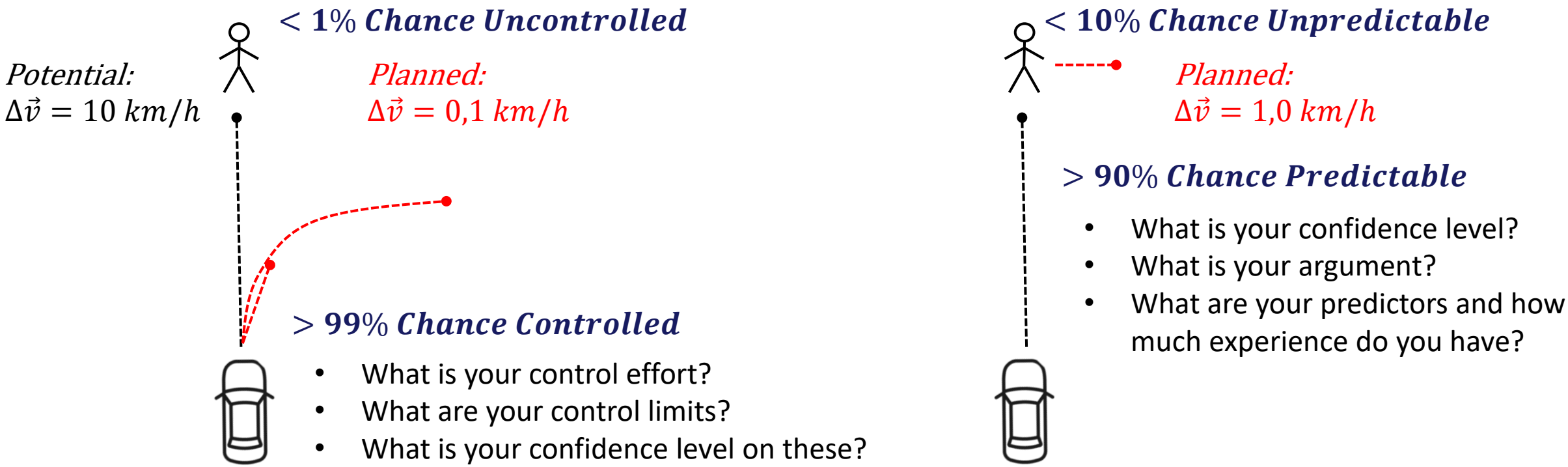
Delta-V Error and Uncertainty

All Data and Measurements have error tolerances (ε)



Delta-V and Controllability

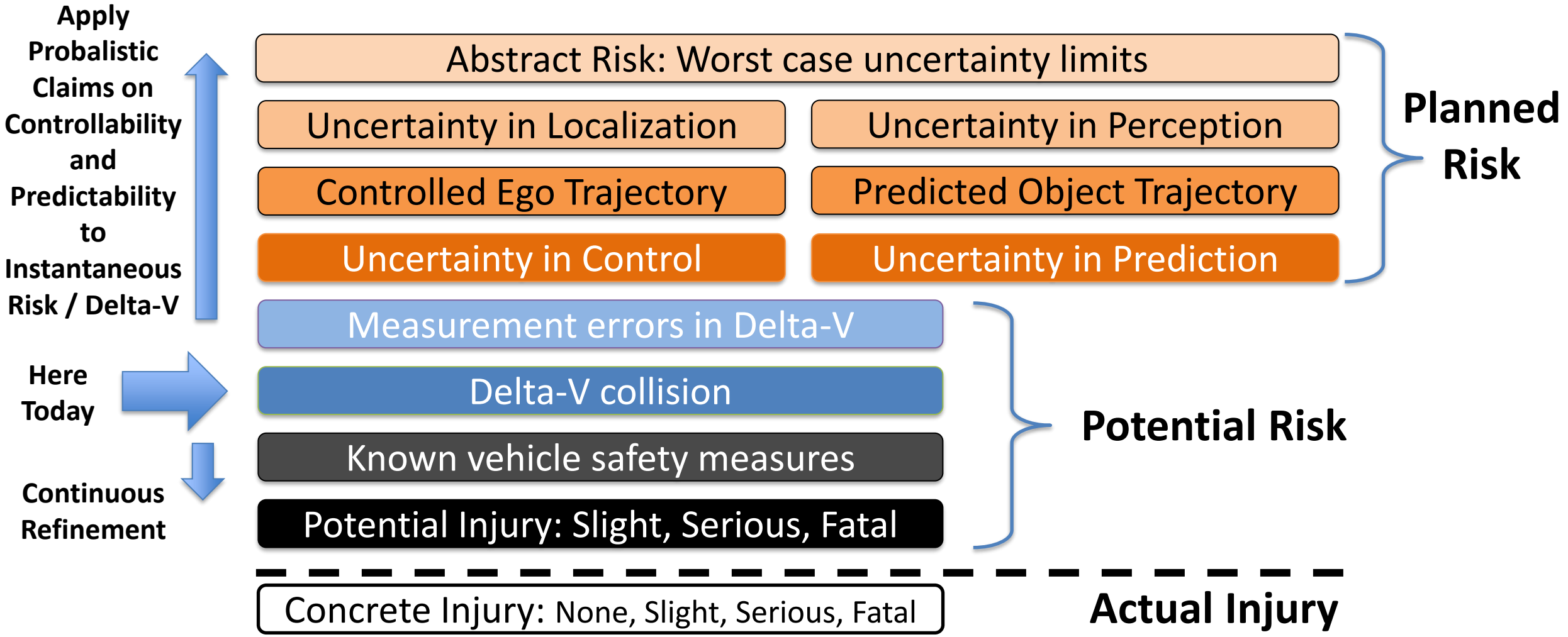
Apply probabilistic claims of Controllability / Predictability



- What is your control effort?
- What are your control limits?
- What is your confidence level on these?
- How far in development is the control platform? Is this well-trusted? Evidence?

- What is your confidence level?
- What is your argument?
- What are your predictors and how much experience do you have?

Risk – Layered Approach



Review What is “Risk?”

+ ***Injury***: probability and severity

+ ***Collision risk:*** largely dictated by Delta-V

+ ***Layers of risk:*** Potential risk, Planned risk, Actual injury

retrospect

Agenda

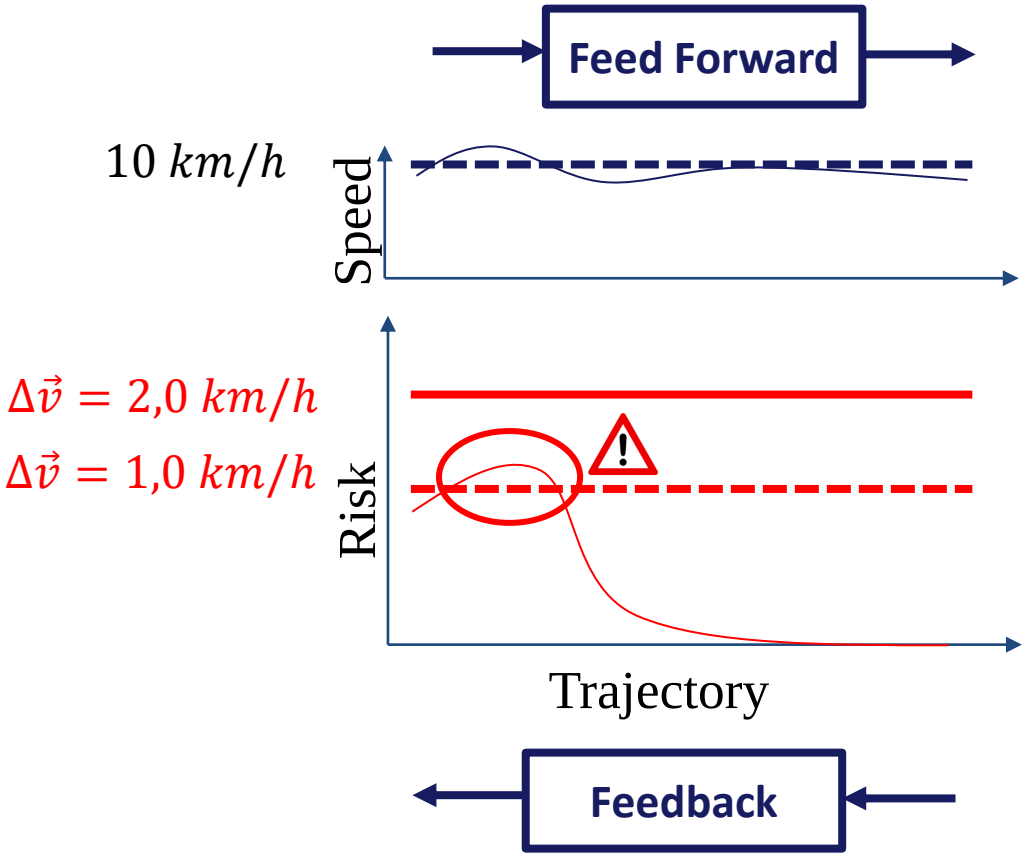
Topics
Motivation
Why Risk?
What is “Risk?”
Safety Argumentation
Ethics and AVs

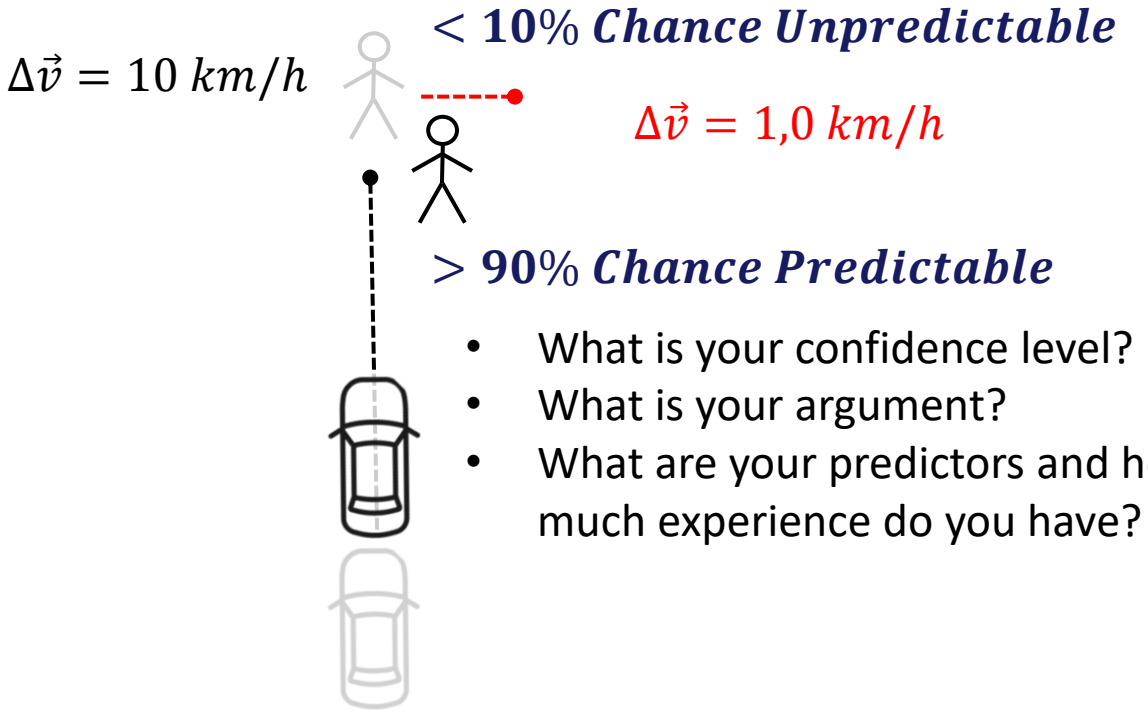
retrospect

Safety Argumentation

Safety Argumentation

Apply probabilistic claims of Controllability / Predictability





- What is your confidence level?
- What is your argument?
- What are your predictors and how much experience do you have?

Why did we underestimate risk?

Safety Argumentation

Underlying causes to Actual Injury are Observable in Risk Error

Errors in perception
Errors in classification
Errors in prediction
Errors in control
Errors in localization
etc.

Feed Forward →

Lead / Lag Indicator

Lead: Detect risk-related errors days, months, years in advance

Lag: Requires finite time, 5-10 seconds

DEV/OPS

Observable Underestimation:
Errors in Planned Risk
Errors in Delta V

← **Feedback**

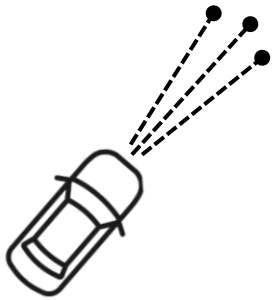
Planned Risk Errors/ Delta-V Errors

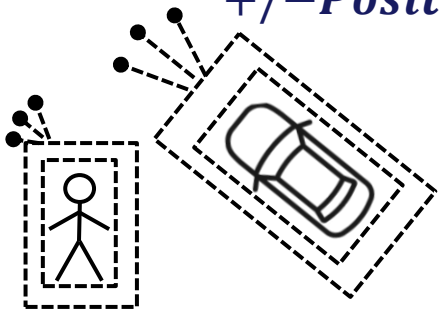
Actual Injury

$+/-Heading\ Error$

$+/-Velocity\ Error$

$+/-Position\ Error$





$+/-Mass\ Error$

Safety Argumentation

Layer 1: Remove rounds
Layer 2: Separate storage
Layer 3: Safety On
Layer 4: Don’t aim at anything of value
Layer 5: Trigger control / finger placed on barrel

Probability of fatality < 10e-9

retrospect

Agenda

Topics
Motivation
Why Risk?
What is “Risk?”
Safety Argumentation
Ethics and AVs

retrospect

Ethics and AVs

Ethics: No (Trolley) Problem

1. ***Superposition principle:*** *Each Risk recipient is accounted for and treated equally & based on first principles, limiting the max Risk*

2. ***No subjective weighting:*** *The only scaling can be done by objective argumentation & still treated conservatively*

Ethics: No (Trolley) Problem

3. ***Instantaneous, not integrated:*** *Derived from first two, Risk is not normalized or weighted*

4. ***Accountable to Dev/Ops:*** *Drivers are always responsible for driving within their limits, even AV Dev/Ops*

Challenges Ahead & Closing Thoughts

Thank You

retrospect

Driving Autonomous Vehicle Safety

Michael Woon
CEO, Founder
+1 734 796 6026
michael.woon@retrospectav.com
Retrospect Consulting | 330 E Liberty, Lower Level **|** Ann Arbor, MI 48104 **|** connect@retrospectav.com **| retrospectav.com**

retrospect