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Risk Management: Applying Ethics to Engineering Problems

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University of Southampton
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Moral Duty

- In 2015, 35,092 people died, 2.4 million were injured in crashes in the US
- Of all crashes:
  - 93% partly due to human error
  - 33% single vehicle
  - 36% distracted drivers
  - 2.8% fell asleep
  - 2.1% heart attacks or other physical impairments
- Airbags, anti-lock brakes have some AI (?)
- Yet still no speed limiters or alcohol detection

Ethics Decisions Moving to Industry

- U.S National Highway Traffic and Safety Administration released guidelines
  - 2016 version asked developers to consider ethics
  - 2017 version removed this guideline
- Any specific ethical standards will be industry-driven
- Engineers may think about ethics differently

October 2010

SCIENCE

Google Cars Drive Themselves, in Traffic

By JOHN MARKOFF OCT. 9, 2010

Dmitri Dolgov, a Google engineer, in a self-driving car parked in Silicon Valley after a road test.
Ramin Rahimian for The New York Times

MOUNTAIN VIEW, Calif. — Anyone driving the twists of Highway 1 between San Francisco and Los Angeles recently

20 months later in *The Economist*

The Economist | World politics | Business & finance | Economics | Science & technology | Culture

Robot ethics

Morals and the machine

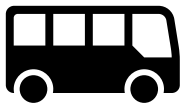
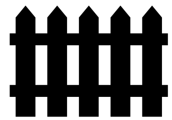
As robots grow more autonomous, society needs to develop rules to manage them

Jun 2nd 2012

Timekeeper · Like 3.1K · Tweet

As that happens, they will be presented with ethical dilemmas. Should a drone fire on a house where a target is known to be hiding, which may also be sheltering civilians? Should a driverless car swerve to avoid pedestrians if that means hitting other vehicles or endangering its occupants? Should a robot involved in disaster recovery tell people the truth about what is happening if that risks causing a panic? Such questions have led to the emergence of the field of "machine ethics", which aims to give machines the ability to make such choices appropriately—in other words, to tell right from wrong.

It Continues…

- 2012:  vs. 

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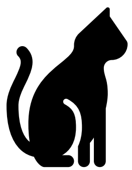
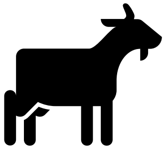
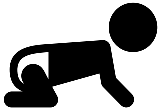
- 2013:  vs.  vs. 

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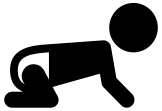
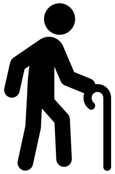
- 2015:  vs. 

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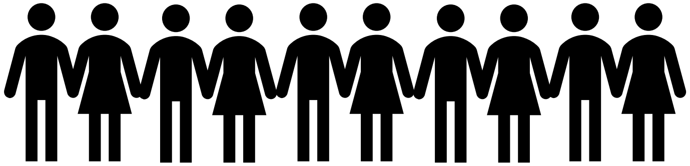
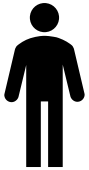
- 2016:  vs. 

road sidewalk

Bonnefon, J.-F., Shariff, A. & Rahwan, I. The social dilemma of autonomous vehicles. *Science* **352,** 1573–1576 (2016).

Why it’s Useful

- Stark example of a situation with serious consequences and obvious moral complexity
- Let’s researchers control the experiment, test theories
- Useful for surveys
  - – Adding ambiguity only encourages participants to invent ways to avoid the crash entirely

Industry Criticism

- Seen as unrealistic
- Focus on outlandish examples, e.g. deciding between striking a criminal and a nun
- Responding to low-likelihood scenarios is an inefficient use of resources
  - Should focus on mistakes that lead to the crash
- A little disrespectful to AV developers

Driving and Risk

- Ethics is about more than deciding how best to crash
- All driving creates risk
- Decisions about how to *measure* and *distribute* that risk have ethical components
- These decisions occur during *routine driving*

Examples of Ethics in Routine Driving

Following Distance

- Most driver's education courses recommend 2-4 seconds
- France is enough distance to avoid a crash, or 2 seconds
- Audi with adaptive cruise control between 1 and 3.6 seconds

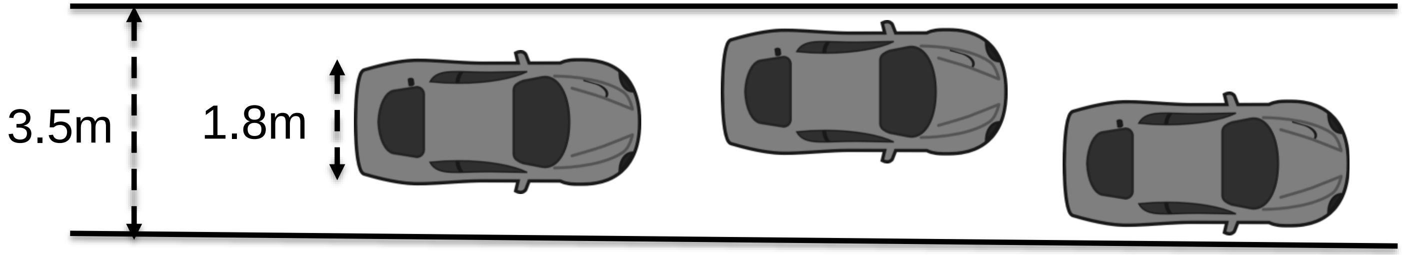
Assured Clear Distance Ahead

- Doctrine requires that a driver be able to stop within his range of vision
- Interpretation drastically affects capacity
  - Vehicle ahead may not stop
    - 2.21-2.63 second following distance
    - 1,367 veh/lane/hour
  - AV can assume vehicle ahead will stop
    - 0.29-0.88 second following distance
    - 4,108 veh/lane/hour

Le Vine, S., Kong, Y., Liu, X. & Polak, J. *Vehicle Automation, Legal Standards of Care, and Freeway Capacity*. (Social Science Research Network, 2016).

Lateral Position within Lane

- Vehicles mostly free to position themselves anywhere laterally within a lane



(12) **United States Patent**
Dolgov et al.

(10) **Patent No.: US 8,781,670 B2**
(45) **Date of Patent: *Jul. 15, 2014**

(54) **CONTROLLING VEHICLE LATERAL LANE POSITIONING**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Dmitri Dolgov**, Mountain View, CA (US); **Christopher Urmson**, Mountain View, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/903,693**

(22) Filed: **May 28, 2013**

(65) **Prior Publication Data**

US 2014/0121880 A1 May 1, 2014

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Primary Examiner — Michael J Zanelli

(74) *Attorney, Agent, or Firm* — McDonnell Boehnen Hulbert and Berghoff

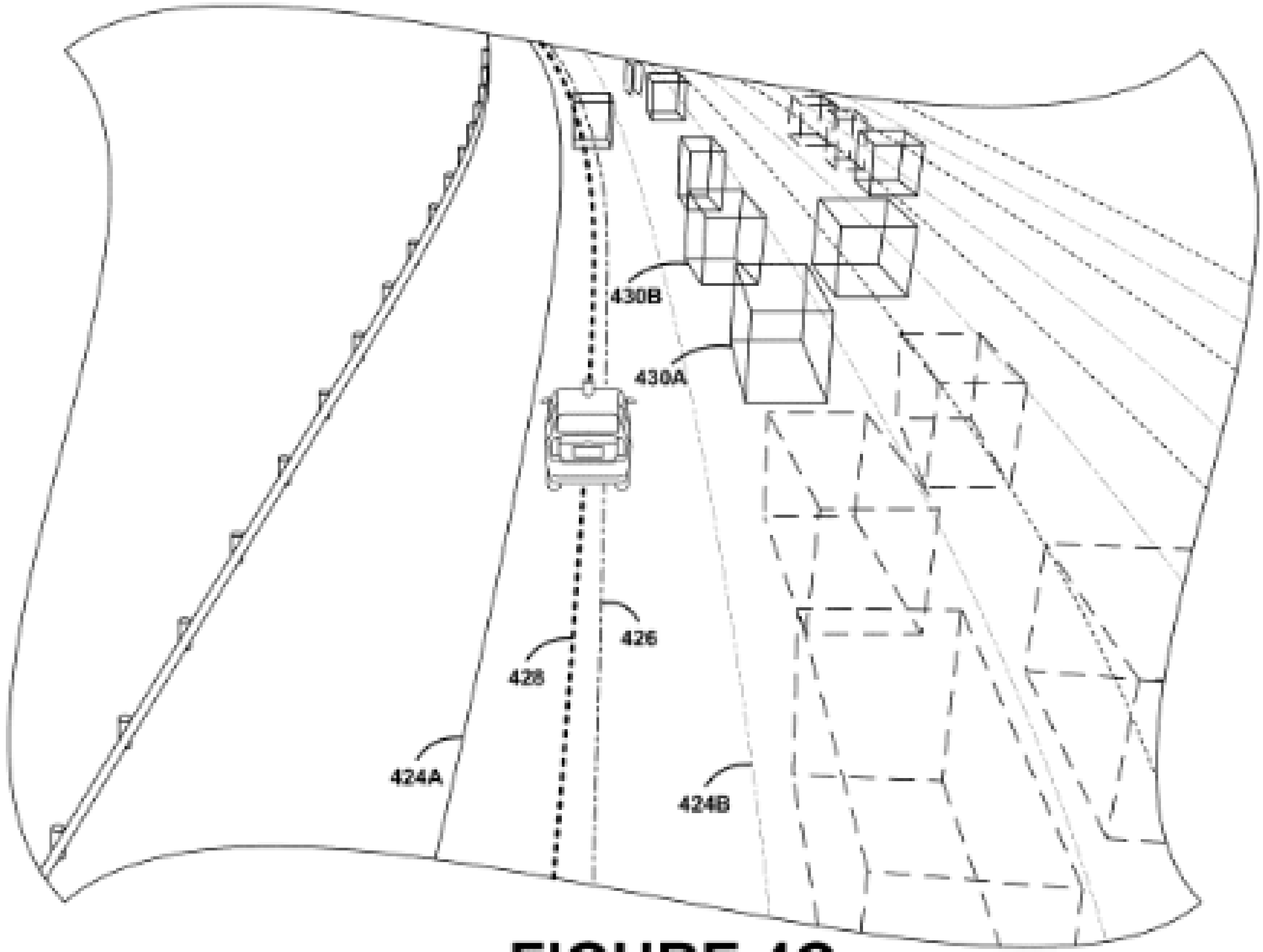


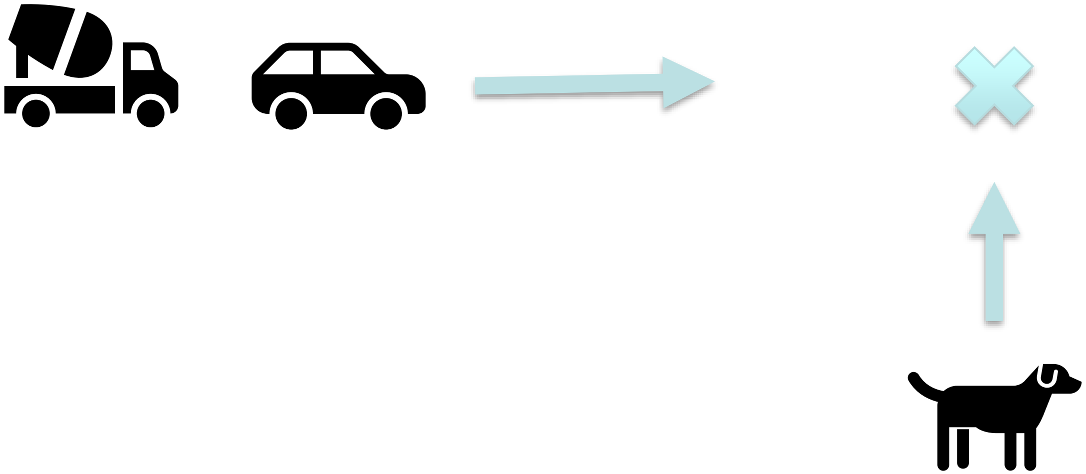
FIGURE 4C

Bias Towards Smaller Vehicles

"…modify the trajectory of the vehicle such that the vehicle has a larger lateral distance with the first object than with the second. Thus, the modified trajectory may be biased, relative to a center of a lane of the vehicle, towards the small vehicle."

- Dolgov, D., and C. Urmson. *Controlling Vehicle Lateral Lane Positioning*, US Patent 8781670, Jul 15, 2014.

Braking Strategies



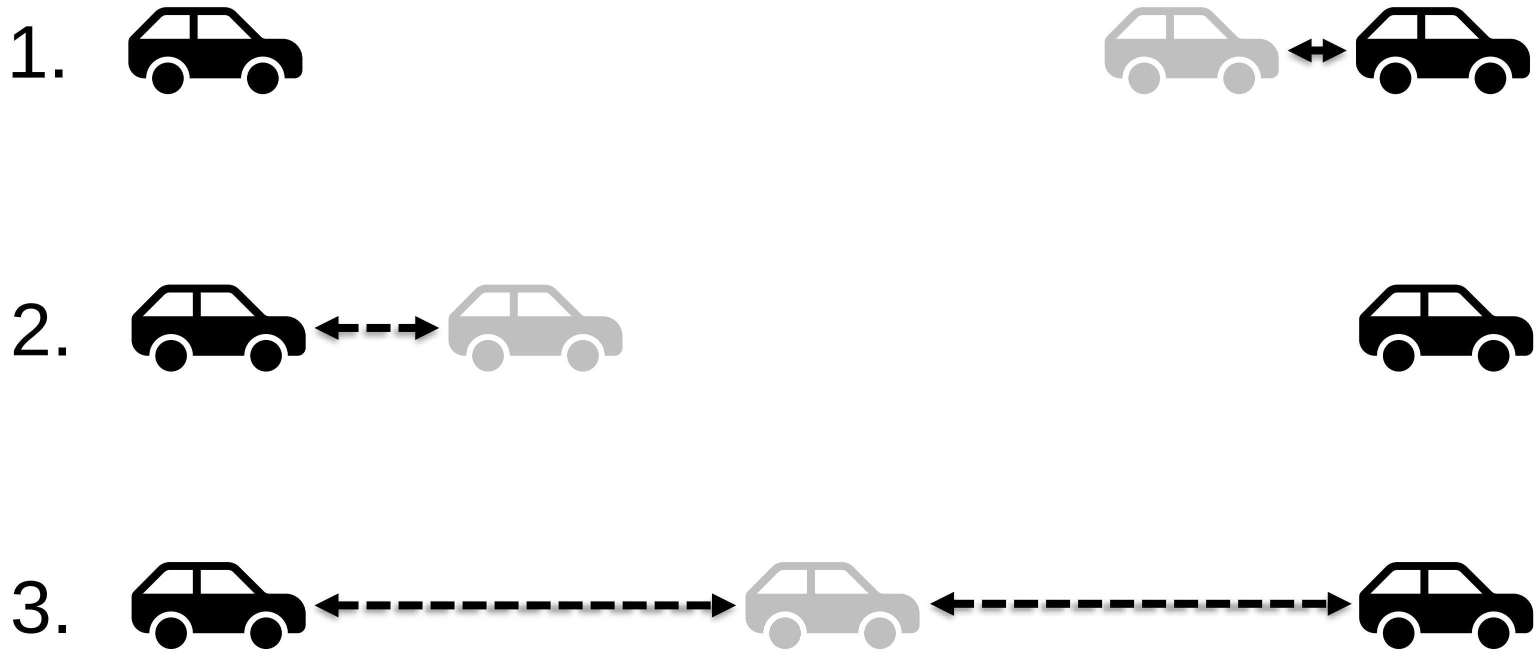
Considerate Braking

- Study of Google's AV crash rate found that in the 19 months prior to Feb 2016, 7 of 12 crashes were AV struck from behind
- Several theories:
  - Not high rate, in line with suburban streets where Google was testing
  - Drivers distracted by AV's sensors
  - AV not decelerating as drivers expect

Considerate Braking

- Google claims their braking is modeled after human behavior
- Can we brake better than today's drivers, while also considering the vehicle behind?

Considerate Braking Strategies



Considerate Braking Strategies

- Ethics comes into play here
  - Value of AV passenger safety vs. others
  - Following vehicle failed to keep a safe following distance, is morally blameworthy

Pre-emptive Acceleration

On the Potential of Accelerating an Electrified Lead Vehicle to Mitigate Rear-End Collisions

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Marco Dozza [**] **Mats Svensson** [**] **Mathias Lidberg** [**]

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[**] *Applied Mechanics, Chalmers University of Technology, SE-412 96 Göteborg, Sweden (e-mail: <first name>.<last name>@chalmers.se)*

Abstract: This paper analyzes the potential safety benefit from autonomous acceleration of an electrified lead vehicle to mitigate or prevent being struck from behind. Safety benefit was estimated based on the expected reduction in relative velocity at impact in combination with injury risk curves. Potential issues and safety concerns with the operation and implementation of such a system in the real world are discussed from an engineering and human factors stand point. In particular, the effect of the pre-collision acceleration in reducing whiplash injury risk due to change in head posture and reduction of crash severity is also discussed. In general, this

Pre-emptive Acceleration

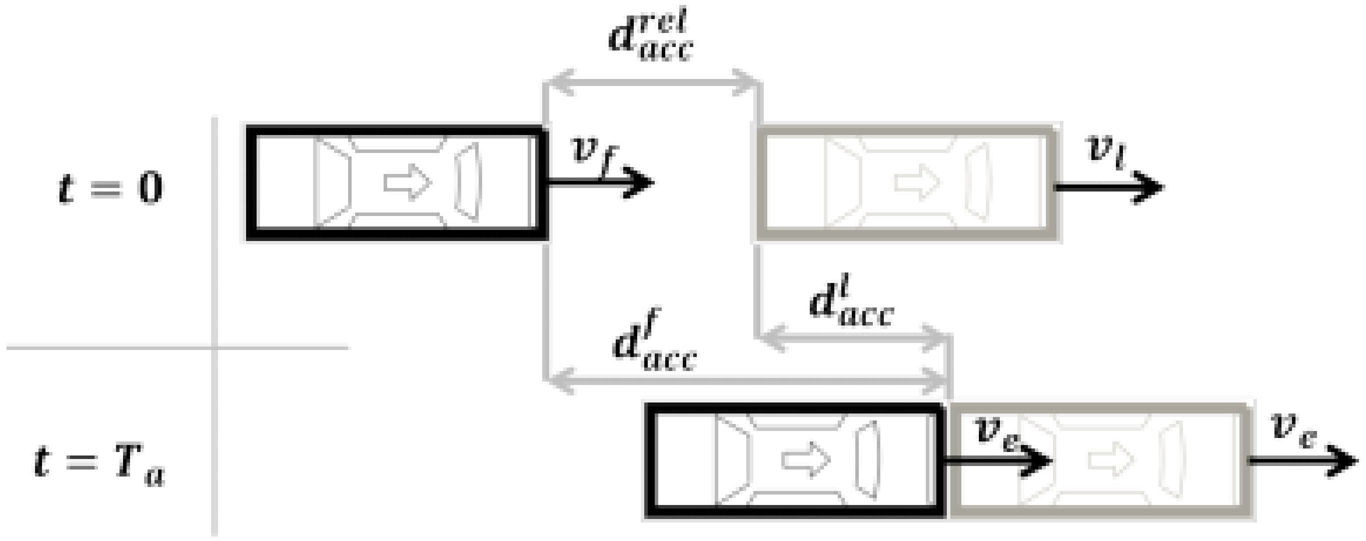
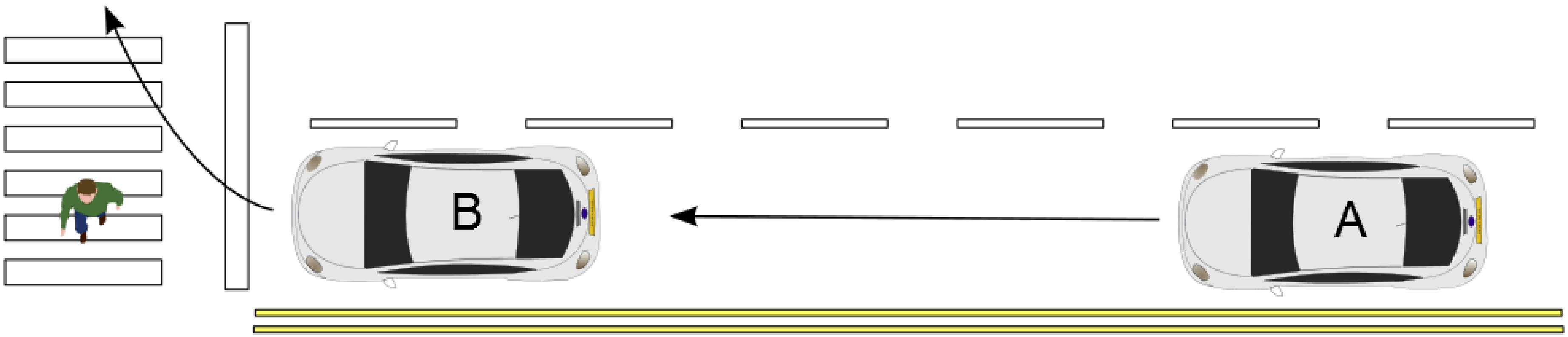


Fig. 4. Collision avoidance by acceleration

Pre-emptive Acceleration

- Automated vehicle could also swerve to avoid being struck from the rear
- May create new harm in this case



Violating the Law

- Vehicles today allow users to speed
  - Many vehicles aware of location and speed limit, yet allow cruise control to be set well above speed limit
- Google acknowledges their AVs speed
  - They defend citing safety benefits of matching surrounding traffic speed
  - Some research findings support this claim

Calculating Risk

(12) **United States Patent**
Teller et al.

(10) **Patent No.: US 8,781,669 B1**
(45) **Date of Patent: Jul. 15, 2014**

(54) **CONSIDERATION OF RISKS IN ACTIVE SENSING FOR AN AUTONOMOUS VEHICLE**

(75) Inventors: **Eric Teller**, San Francisco, CA (US); **Peter Lombrozo**, Santa Cruz, CA (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 235 days.

(21) Appl. No.: **13/471,184**

(22) Filed: **May 14, 2012**

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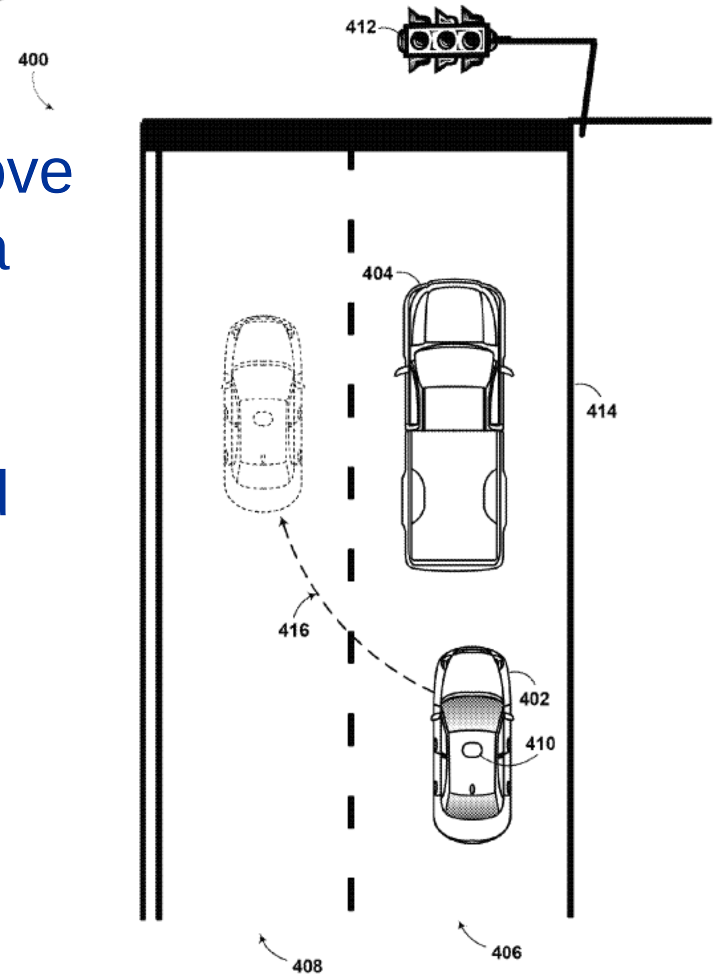
- Discretionary move to get better data
- Patent weighs expected costs against expected benefits before moving

Figure 4



Should also consider uncertainty.

TABLE 1

Bad Event	Risk Magnitude	Probability (%)	Risk Penalty
getting hit by large truck	5,000	0.01%	0.5
getting hit by an oncoming vehicle	20,000	0.01	2
getting hit from behind by vehicle (not shown) approaching in the left-hand lane 408	10,000	0.03%	3
hitting pedestrian who runs into the middle of the road	100,000	0.001%	1
losing information that is provided by camera in current position	10	10%	1
losing information that is provided by other sensor in current position	2	25%	0.5
Interference with path planning involving right turn at traffic light 412	50	100% (if turn is planned)/0% (if no turn is planned)	50/0

Assessing vs. Managing Risk
(In Theory)

Assessment

- Calculate probabilities
- Done by engineers, experts

Management

- Determine magnitudes
- Done by elected officials, regulators, juries

Two roles should be performed by separate actors.

Cost-Benefit Analysis

- Dominant risk management methodology in the US
- Required on most federal projects
  - Transportation infrastructure
  - Environmental impact statements
- Requires monetization of costs and benefits

Values

- Value of time
  - $14.10/hr local, $20.40/hr intercity
    - US Dept. of Transportation, 2015 figures
    - Value is a percentage of income
    - Different values for mode, type/length of trip, cargo
  - Data from dynamic congestion pricing suggests $20/hr
  - £11.21 UK (~$14.97)

Value of a Statistical Life (VSL)

- $9.6 M (USDOT)
- Based on examples from industry, what additional wages workers will accept for jobs with higher risk of fatality
- In government use, figure is rarely adjusted for specific populations

Value of Injury

AIS-Code	Injury	Example	AIS % prob. of death	% of VSL	Value of Satistical Injury
1	Minor	superficial laceration	0	0.3	$28,800
2	Moderate	fractured sternum	1 – 2	4.7	$451,200
3	Serious	open fracture of humerus	8 – 10	10.5	$1.0 M
4	Severe	perforated trachea	5 – 50	26.6	$2.6 M
5	Critical	ruptured liver with tissue loss	5 - 50	59.3	$5.7 M
6	Maximum	total severance of aorta	100	100	$9.6 M

Problems with CBA

- Inconsistently averages costs and benefits across a population
- Provides a number, but often needs human guidance
  - Meant for large, slow decisions
- Often horrifies the public

Be Sensitive to Non-Experts

- Fear of new technology not totally irrational
  - AV capabilities do not correlate to humans'
  - Surprisingly good at staying in the lane, bad at seeing a stopped vehicle ahead
- New safety technologies always create some crashes that would never have happened. Acknowledge this.
- Improve our language of risk. "100 year flood" is often misinterpreted.

Conclusions

- Industry could use input from ethicists
- Risk is a very productive approach
- A successful approach doesn’t need to please everyone, but must be thoughtful and defensible
- Be sensitive when talking about cost-benefit analysis

Questions

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