Ethics of Connected and Automated Vehicles

Noah J. Goodall, Ph.D., P.E.

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Ensuring Safety

• How often does this happen?
• We trust a driver will self-correct
• To ensure safety, an automated vehicle must respect every threat—not sustainable
Optimizing Safety

• A dog runs out in the road—what do you do? Assume things are happening in slow-motion (time is not a factor).
  – Are you boxed in?
  – Can you safely swerve?
  – Is that really a dog?
  – Who’s behind you, and how closely are they following?

• Math completely changes if it’s not a dog but a person
Optimizing Safety

• Crashing safely can be complicated, depending on your definition of safety
• Hard to articulate what’s right
• Hard to define rules that apply across novel situations
• Hard to define rules acceptable to different people
Not About “Whom to Kill”

- **2012**: 🚌 vs. 🏰

- **2013**: 🐱 vs. 🐐 vs. 🐘

- **2014**: 🛵 vs. 🛵

- **2015**: 🐳 vs. 🍀

- **2016**: 🏩 vs. 🕵️

road vs. sidewalk
Industry Hates These

• 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 for automated vehicles 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
Ethics in Routine Driving

• Following distance
  – Leave enough distance to stop for an object?
  – Capacity down 4108 to 1367 vehicles per lane per hour (67%)

• Violating the law
  – Google acknowledges they speed to keep pace with traffic
  – Some evidence that this is ultimately safer
Lateral Position within Lane

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

Dolgov et al.

CONTROLLING VEHICLE LATERAL LANE POSITIONING

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

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

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.

Appl. No.: 13/903,693
Filed: May 28, 2013

Prior Publication Data

US 2014/0121880 A1 May 1, 2014

Patent No.: US 8,781,670 B2
Date of Patent: Jul. 15, 2014

DE 10 2012 005245 9/2012

FOREIGN PATENT DOCUMENTS

OTHER PUBLICATIONS


Primary Examiner — Michael J Zanelli
(74) Attorney, Agent, or Firm — McDonnell Boehnen Hulbert and Berghoff
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.”

Calculating Risk

United States Patent
Teller et al.

CONSIDERATION OF RISKS IN ACTIVE SENSING FOR AN AUTONOMOUS VEHICLE

Inventors: Eric Teller, San Francisco, CA (US); Peter Lombrizo, Santa Cruz, CA (US)

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.

Appl. No.: 13/471,184
Filed: May 14, 2012

Patent No.: US 8,781,669 B1
Date of Patent: Jul. 15, 2014


* cited by examiner
• Discretionary move to get better data
• Patent weighs expected costs against expected benefits before moving
<table>
<thead>
<tr>
<th>Bad Event</th>
<th>Risk Magnitude</th>
<th>Probability (%)</th>
<th>Risk Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>getting hit by large truck</td>
<td>5,000</td>
<td>✗ 0.01%</td>
<td>0.5</td>
</tr>
<tr>
<td>getting hit by an incoming vehicle</td>
<td>20,000</td>
<td>0.01%</td>
<td>2</td>
</tr>
<tr>
<td>getting hit from behind by vehicle (not shown)</td>
<td>10,000</td>
<td>0.03%</td>
<td>3</td>
</tr>
<tr>
<td>approaching in the left-hand lane 408</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hitting pedestrian who runs into the middle of the road</td>
<td>100,000</td>
<td>0.001%</td>
<td>1</td>
</tr>
<tr>
<td>losing information that is provided by camera in current position</td>
<td>10</td>
<td>10%</td>
<td>1</td>
</tr>
<tr>
<td>losing information that is provided by other sensor in current position</td>
<td>2</td>
<td>25%</td>
<td>0.5</td>
</tr>
<tr>
<td>Interference with path planning involving right turn at traffic light 412</td>
<td>50</td>
<td>100% (if turn is planned)</td>
<td>50/0</td>
</tr>
<tr>
<td>Interference with path planning involving no turn at traffic light 412</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

• Value of time
  – $14.10/hr local, $20.40/hr intercity
  – Percentage of income

• Value of statistical life
  – $9.6 M
  – Based on examples from industry, what additional wages workers will accept for jobs with higher risk of fatality
# Value of Injury

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

• Inconsistently averages costs and benefits across a population
  – Value of statistical life rarely adjusted for a local population

• Provides a number, but often needs human guidance
  – Meant for large, slow decisions

• Often horrifies the public
Ford Pinto

- Ford justified their refusal to recall the Pinto using cost benefit analysis

**BENEFITS:**

- Savings: 180 burn deaths, 180 serious burn injuries, 2100 burned vehicles.
- Unit Cost: $200,000 per death, $67,000 per injury, $700 per vehicle.
- Total Benefit: 180x($200,000) + 180x($67,000) + 2100x($700) = $49.5 million.

**COSTS:**

- Les: 11 million cars, 1.5 million light trucks.
- Unit Cost: $11 per car, $11 per truck.
- Total Cost: 11,000,000x($11) + 1,500,000x($11) = $137 million.
Ethics Approaches

• CBA represents consequentialism
  – The (expected) outcome determines whether the action was right

• Other ethical theories
  – Deontological ethics: right action based on something other than outcome
  – Virtue ethics: right action maximizes character (bravery, compassion)
Other Fields Combine Ethical Theories

- **Military draft**
  - *Lottery* (deontological ethics) and *instrumental value* (consequentialism), e.g. exemptions for farmers, students

- **Organ donation**
  - *First-come-first-served* (deontological ethics) and *sickest first* (consequentialism)

- **Radiation exposure**
  - *Justification* (virtue ethics), *individual dose limits* (deontological ethics), and *optimization* (consequentialism)
Moral Duty

• In 2015, 35,092 people died, 2.4 million were injured in crashes in the US
• Of all 6.3 million 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
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.
  - For AVs, mean distance between failures, or humansafe?
Conclusions

• Industry is doing ethics, whether they acknowledge it or not
• 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

Noah Goodall
noah.goodall@vdot.virginia.gov