Modeling Truck Safety Critical Events

Efficient Bayesian Hierarchical Statistical and Reliability Models

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1 The problem

Transportation

Transportation safety deserves attention:

- The 8-th leading cause of death globally in 2016,[1]
- 1.4 million people killed, mostly aged 4 to 44 years old,[1]
- 518 billion dollars.[2]

Trucks are the backbone of the economy:

- 70% of freight delivered by trucks,
- 73.1% of value and 71.3% of domestic goods,[3,4]

Challenges for trucking industry

Drivers:

1. drive alone for long hours,
2. work under time demands, challenging weather and traffic conditions,
3. sleep deprivation and disorder

Trucks:

1. huge weights,
2. large physical dimensions,
3. potentially carry hazardous cargoes.

Truck crash studies

Traditional studies almost exclusively use data that ultimately trace back to **post hoc vehicle inspection**, **interviews** with survived drivers and witnesses, and **police reports**.[5,6]

1. rare events $\longrightarrow$ difficulty in estimation,[7]
2. retrospective studies $\longrightarrow$ recall bias,[8]
3. crashes are underreported $\longrightarrow$ selection bias.[9,10]

Naturalistic driving studies (NDS)

*NDS uses **unobtrusive** devices, sensors, and cameras installed on vehicles to **proactively** collect frequent naturalistic driving behavior and performance data under **real-world driving** conditions*[5,11]

1. driver-based data (compare rates),
2. high-resolution driver behavior and performance data,
3. less costly and difficult per observation.

Safety critical events (SCEs)

SCEs are

> *a chain of adverse events following an initial off-nominal event, which can result in an accident if compounded with additional adverse conditions.*[12]

Examples of SCEs are:

1. hard brakes,
2. headways,
3. rolling stability,
4. . . .

The problem

NDSs are relatively new and less studied. Here are several problems remained in NDS.

1. Are SCEs associated with real crashes among truck drivers?
2. Can we predict SCEs?
3. How can we innovate existing models to account for features of NDS?

2 Methods

The Good Day Hypothesis

We know the following about Ice Cube's day.

1. The Lakers beat the Supersonics.
2. No helicopter looked for a murder.
3. Consumed Fatburger at 2 a.m.
4. Goodyear blimp: "Ice Cube's a pimp."

The Good Day Hypothesis

This leads to two different hypotheses:

- H_0: Ice Cube's day is statistically indistinguishable from a typical day.
- H_1: Ice Cube is having a good (i.e. greater than average) day.

These hypotheses are tested using archival data of Ice Cube's life.

LaTex Equations

The likelihood function of a non-homogeneous Poisson process (NHPP) with a power law process (PLP) intensity function is:

$$
\begin{aligned}
f(n, t_1, t_2, \cdots, t_n) &= f(n) f(t_1, t_2, \cdots, t_n | n) \\
&= \frac{e^{-\int_0^\tau \lambda(u)du} [\int_0^\tau \lambda(u)du]^n}{n!} n! \frac{\prod_{i=1}^n \lambda(t_i)}{[\Lambda(\tau)]^n} \\
&= \Big(\prod_{i=1}^n \lambda(t_i) \Big) e^{-\int_0^\tau \lambda(u)du} \qquad (1) \\
&= \Big(\prod_{i=1}^n \frac{\beta}{\theta} (\frac{t_i}{\theta})^{\beta-1} \Big) e^{-(\tau/\theta)^\beta}, \\
n &= 0, 1, 2, \cdots, \quad 0 < t_1 < t_2 < \cdots < t_n
\end{aligned}
$$

3 Results

Include figures

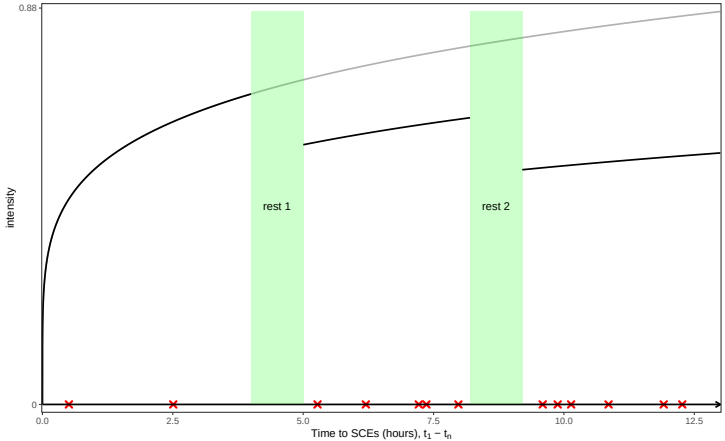

Figure 1: The intensity function, SCEs, and rests of a jump-point PLP

A Total Conflict Game Between Sheena Easton and Her Baby

	XX	YY
Baby Home Again	-100, **100**	**100**, 0
Baby Stays at Work	**50**, 0	-100, **100**

Sheena Easton and her baby are playing a **zero-sum (total conflict) game**.

- Akin to Holmes-Moriarty game (see: von Neumann and Morgenstern)
- Solution: **mixed strategy**

4 Conclusion

Python

Wonderful Python packages are available:

- `pandas`,
- `numpy`,
- `sci-kit`,
- `...`
- `keras`

R

Wonderful R packages are available:

- `tidyverse`
- `data.table`
- `caret`

The best language

PHP is the best language.

References

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