Screening Consumer Complaints for Safety Concerns: A Topic Model for Decision Automation

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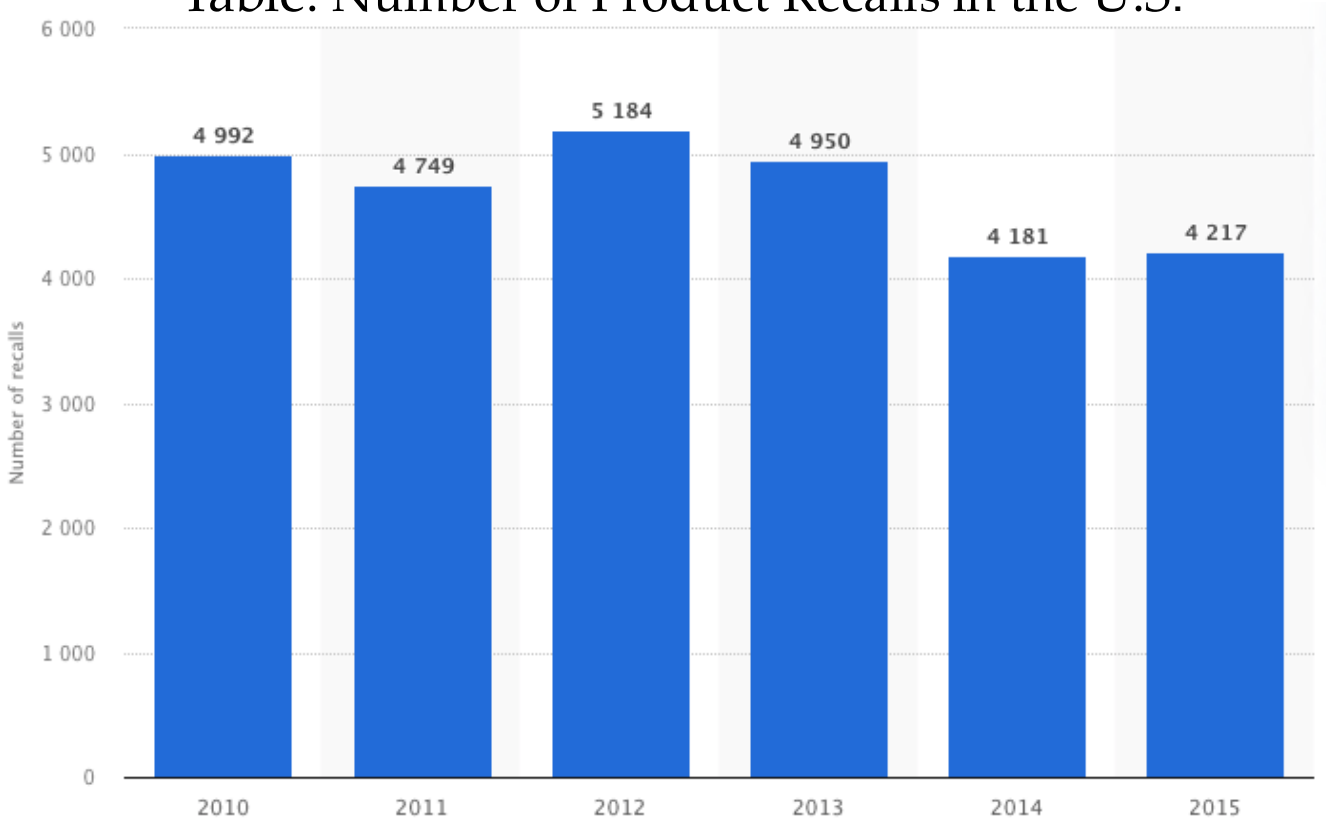
Table: Number of Product Recalls in the U.S.



Negative consequences

- Direct costs, e.g., communication and disposition (Chen et al., 2009, Yao and Parlar, 2019)
- Stock price (Chen et al., 2009)
- Future product reliability (Kalaignanam et al., 2012)
- Brand reputation (Cleeren et al., 2013; Liu and Shankar, 2015)

Vehicle Recall

Over the past 10 years:

- More than 280 million vehicles have been recalled
- More than $230 billion economic loss per year

General Motors' (GM) "don't tell": 124 deaths, 275 injuries, and $900 million fine (Lareau, 2019)

Hyundai and Kia: the delayed recall actions lead to $210 million fine (Gardner, 2020)

Platforms for Collecting Consumer Complaints

MedWatch (FDA)

SaferCar (NHTSA)

12365auto (China)

- In these recall-intensive sectors, almost all recalls, voluntary or not, are prompted by complaints that consumers make to the firm (Geiger, 2014; ConsumerReports.org, 2015; NHTSA, 2019)

Severe Lack of Labor and Data Analytical Tools

"7 to 9 people to look through 77,000 safety complaints."
– from the head of the NHTSA

"We **only** have *3-4 people* to look through over *40,000* complaints each year."
– from the regulation agency in China

NHTSA has been criticized for its failure to analyze data and spot threats (Astvansh et al., 2022)

FDA has also been criticized for unacceptably slow response to complaints of contaminated formula (Committee, 2022)

An Increasing Investment in Industry

- In 2021, the NHTSA allocated a budget of $28 million for trend analyses using consumer complaint datasets
- ***McKinsey & Company*** posits that the capacity to promptly foresee and execute timely recalls can help businesses preempt potential issues through knowledge transfer, risk evaluation, and rigorous testing and validation
- Deploying such technological solutions is estimated to potentially save the automotive industry a staggering $50 billion annually

Research Objectives

Automatically extract insights from consumer complaints

- Defected topics
- Complaint importance

Main challenge: lack of directly labeled data

Proposed solution:

- Defect summary in a recall statement is an accurate representation of the underlying product defects
- Using defect summary of recalled products to supervise the understanding of their associated consumer complaints

The U.S. Automobile Industry

- The U.S. National Highway Traffic Safety Administration (NHTSA) provides a platform for consumers to file complaints.

- The platform is currently the major channel of consumer complaints in this automobile industry.

- The U.S. NHTSA also collects complaints from other sources (e.g., telephone) and stores the complaints in its database as well.

Consumer Complaint

November 1, 2021 **NHTSA ID NUMBER: 11438916**

Components: EXTERIOR LIGHTING

NHTSA ID Number: 11438916

Incident Date August 15, 2021

Consumer Location GRAND RAPIDS, MI

Vehicle Identification Number 3G1BE6SM6HS****

Summary of Complaint

CRASH	No
FIRE	No
INJURIES	0
DEATHS	0

Third rear brake light on my Chevy Cruze hatchback broke off from its mount, and is now dangling against the rear window glass, obstructing the view, obstructing the rear windshield wiper from being able to operate, and held on by nothing but the wiring. It is at risk of falling off into the road, makes the car less visible to drivers while braking, and obscures my view out of the back window, especially when it is raining, as I can no longer use the wiper. It is unable to be reattached without replacing the entire rear spoiler (approximately $1,000 repair according to multiple dealerships I have contacted, with photographs), and it is a manufacturer defect, not caused by outside force. It appears the bolts that hold the spoiler in were over-torqued at the factory, causing excess stress on the plastic holes they mount into, as the plastic surrounding both mounting holes cracked.

1 Affected Product

Vehicle

MAKE	MODEL	YEAR
CHEVROLET	CRUZE	2017

Recall Statement

2017
CHEVROLET CRUZE
4 DR FWD

2 RECALLS

INVESTIGATIONS 0

COMPLAINTS 115

★★★★☆
OVERALL SAFETY RATING

May 10, 2018 NHTSA CAMPAIGN NUMBER: 18V304000

Fuel Leak in Rollover After Crash/FMVSS 301

A fuel leak, in the presence of an ignition source, increases the risk of a fire.

NHTSA Campaign Number: 18V304000

Manufacturer General Motors LLC

Components FUEL SYSTEM, GASOLINE

Potential Number of Units Affected 111,966

Summary

General Motors LLC (GM) is recalling certain 2016-2018 Chevrolet Cruze LS vehicles, equipped with a gasoline engine and a tire inflator kit instead of a spare tire. The vehicles may leak gasoline following a rear-impact crash and a rollover. As such, these vehicles fail to comply with the requirements of Federal Motor Vehicle Safety Standard (FMVSS) number 301, "Fuel System Integrity."

Remedy

GM will notify owners, and dealers will install a lock-ring on the fuel tank that will shield the fuel tank vapor pressure sensor from damage in a rear-impact crash, free of charge. The recall began June 7, 2018. Owners may contact Chevrolet customer service at 1-800-222-1020. GM's number for this recall is 18159.

Notes

Owners may also contact the National Highway Traffic Safety Administration Vehicle Safety Hotline at 1-888-327-4236 (TTY 1-800-424-9153), or go to www.safercar.gov.

3 Affected Products ▲

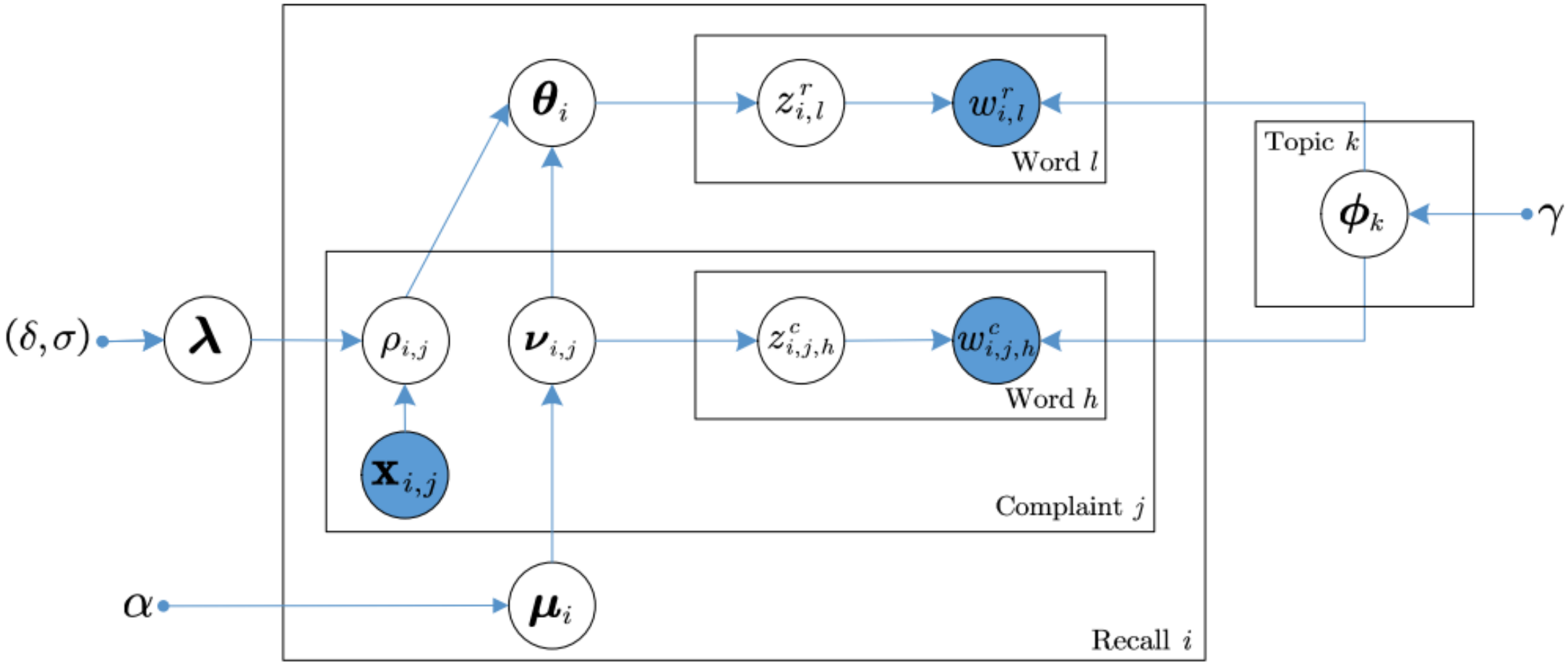
Vehicle

MAKE	MODEL	YEAR
CHEVROLET	CRUZE	2016-2018

Data

- Top 20 automakers from 2000 to 2019
- Unit of analysis: model-make-year (MMY)
- MMY selection criterion
  - The first recall or never-recalled MMYs
  - At least 5 complaints
- Final datasets
  - 1,693 unique MMYs (76% recalled)
  - 62,353 complaints
  - 1,280 recalls (an average of 947 days after MMY launch)

Hierarchical Dual Pitman-Yor Process (HDPYP)



Empirical Approach

Dataset
(1,693 MMYs)

- *In-sample dataset*
  (1,355 MMYs)
  - *Training dataset*: Model parameter estimation
    (1,185 MMYs)
  - *Tuning dataset*: *Hyper-parameters* determination
    (170 MMYs)
- *Out-sample dataset*: *Evaluate model performance*
  (338 MMYs)

Substantive Outputs of HDPYP

- Defective topics and components
- Topic distributions of complaints and defect summary
- What complaints are important
- Estimating importance weights across complaints

Validating the Estimated Complaint Importance

Compared with using all complaints or complaints with sever outcomes, being able to identify the few most important consumer complaints using HDPYP can improve

1. The quality of AI-Generated defect summary: 20% 

Sample Generated Recall Statements

MMY: Ford Escort 2000 **Recall campaign**: 00V228001 **Components**: Seat belts

Recall defect and consequence summary:

Vehicle description: passenger vehicles, light duty trucks, sport utility vehicles, and mini vans equipped with TRW seat belt buckle assemblies. The buckle base of these seat belt assemblies were not properly heat treated and therefore do not pass the load bearing requirement of federal motor vehicle safety standard No. 209, "seat belt assemblies." in the event of a vehicle crash, the occupant may not be properly restrained.

Top-10 complaints ranked by HDPYP:

Vehicle description: passenger vehicles equipped with TRW seat belt buckle assemblies. The buckle base of these seat belt assemblies were not properly heat treated and therefore do not pass the load bearing requirement of federal motor vehicle safety standard No. 209, "seat belt assemblies." in the event of a vehicle crash, the occupant may not be properly restrained.

Random 10 complaints:

On certain passenger vehicles, the fuel pump may corrode and separate from the motor housing. This could result in corrosion of the fuel pump housing which could lead to leakage of fuel. Loss of fuel may increase the risk of a fire.

Complaints with fired, crashed, injured or death:

On certain passenger vehicles, the rear suspension struts may not have been properly assembled. The rear struts could become loose or loose due to an improper welding process. This could result in the front struts becoming loose and thus increasing the risk of a crash.

All complaints:

Vehicle description: passenger vehicles. Some of these vehicles fail to comply with the requirements of federal motor vehicle safety standard (FMVSS) number 108, "occupant crash protection." In the event of a crash necessitating deployment of an air bag, the driver may not be properly restrained.

Validating the Estimated Complaint Importance

Compared with using all complaints or complaints with sever outcomes, being able to identify the few most important consumer complaints using HDPYP can improve

1. The quality of AI-Generated defect summary: 20% 
2. Predicting the recall incidence a few months ahead: 15% 
    - Can detect these crippling recall events 2 years ahead

Predicting Crippling Recall Events in Advance (AUC)

Affected MMY	Lifetime (months)	$HDPYP_\rho$-based Inputs				n.a.-based Inputs			
		3 months ahead	6 months ahead	12 months ahead	24 months ahead	3 months ahead	6 months ahead	12 months ahead	24 months ahead
Toyota 4runner 2004	84.03	0.777	0.736	0.741	0.724	0.200	0.180	0.185	0.183
Toyota Avalon 2007	30.60	0.755	0.714	0.702	0.719	0.692	0.662	0.651	0.668
Toyota Avalon 2008	18.43	0.715	0.710	0.704	–	0.618	0.584	0.594	–
Toyota Camry 2009	6.23	0.738	0.716	–	–	0.676	0.641	–	–
Toyota Camry Hybrid 2007	30.60	0.702	0.669	0.673	0.680	0.367	0.299	0.314	0.304
Toyota Highlander 2005	15.60	0.759	0.741	0.714	–	0.68	0.678	0.671	–
Toyota Prius 2007	30.60	0.839	0.818	0.822	0.820	0.777	0.785	0.760	0.766
Toyota Prius 2008	18.43	0.773	0.729	0.742	–	0.687	0.683	0.676	–
Toyota Sequoia 2008	22.03	0.692	0.651	0.680	–	0.414	0.403	0.407	–
Toyota Venza 2009	10.03	0.732	0.710	–	–	0.590	0.565	–	–
Chevrolet Camaro 2011	39.20	0.767	0.764	0.743	0.739	0.625	0.639	0.624	0.630
Chevrolet HHR 2010	47.03	0.826	0.827	0.819	0.824	0.246	0.227	0.238	0.255
Chevrolet HHR 2011	34.87	0.742	0.686	0.688	0.704	0.632	0.59	0.601	0.618
Chevrolet Impala 2013	14.93	0.733	0.697	0.694	–	0.614	0.593	0.636	–
Chevrolet Tahoe 2012	33.47	0.718	0.705	0.692	0.687	0.246	0.188	0.179	0.174
Volkswagen Golf 2010	18.33	0.755	0.697	0.706	–	0.407	0.381	0.373	–
Volkswagen Golf 2011	6.17	0.778	0.751	–	–	0.720	0.687	–	–

Validating the Estimated Complaint Importance

Compared with using all complaints or complaints with sever outcomes, being able to identify the few most important consumer complaints using HDPYP can improve

1. The quality of AI-Generated defect summary: 20% ↑
2. Predicting the recall incidence a few months ahead: 15% ↑
    - Can detect these crippling recall events 2 years ahead
3. Predicting the defect component in advance: 25% ↑

Predicting Defect Components in Advance

Input Method	0 month ahead	1 month ahead	3 months ahead	6 months ahead
$HDPYP_{Top10}$	0.271*	0.283*	0.270*	0.270*
$HDPYP_{All}$	0.247	0.256	0.254	0.251
LDA_{All}	0.114	0.110	0.115	0.119
$Component_{All}$	0.212	0.224	0.221	0.224

Summary

- We propose a semiparametric topic model, the HDPYP, that links safety-related consumer complaints to recall statements

- The output of the HDPYP can
  - Generate meaningful substantive insights
  - Predict recall incidence and components

- We empirically demonstrate that our proposed approach is valuable in achieving the above objectives for practical applications


Thank You
Merci
Obrigado
Dank Je
Grazie
Kiitos
Juspaxar
Mamana
Spasibo
Terma Kasih
Maake
Welalin
Asante
Chokrane
Obrigado
Dankon
Dank Je
Mochchakkeram
Ua Tsaug Rau Koj
Matondo
Multumesc
Kia Ora
Nirringrazzjak
Multumesc
Salamat
Cam on ban
Vinaka
Raibh Maith Agat
Asante
Merci
Dyakuyu
Arigato
Matur Nuwun
Maake
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Spasibo

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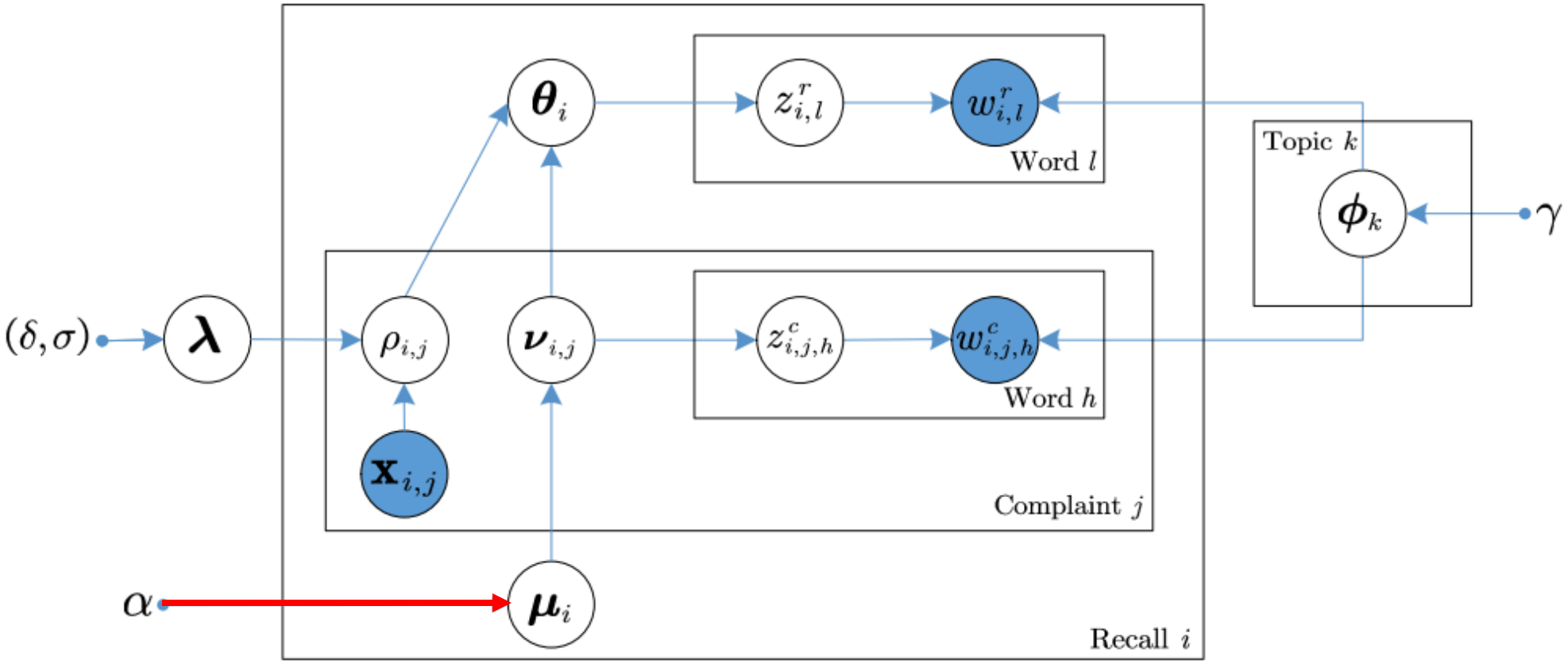

Base topic distribution of complaints that are associated with the same recall

$$\mu_i \sim \text{Dirichlet}_K(\alpha)$$

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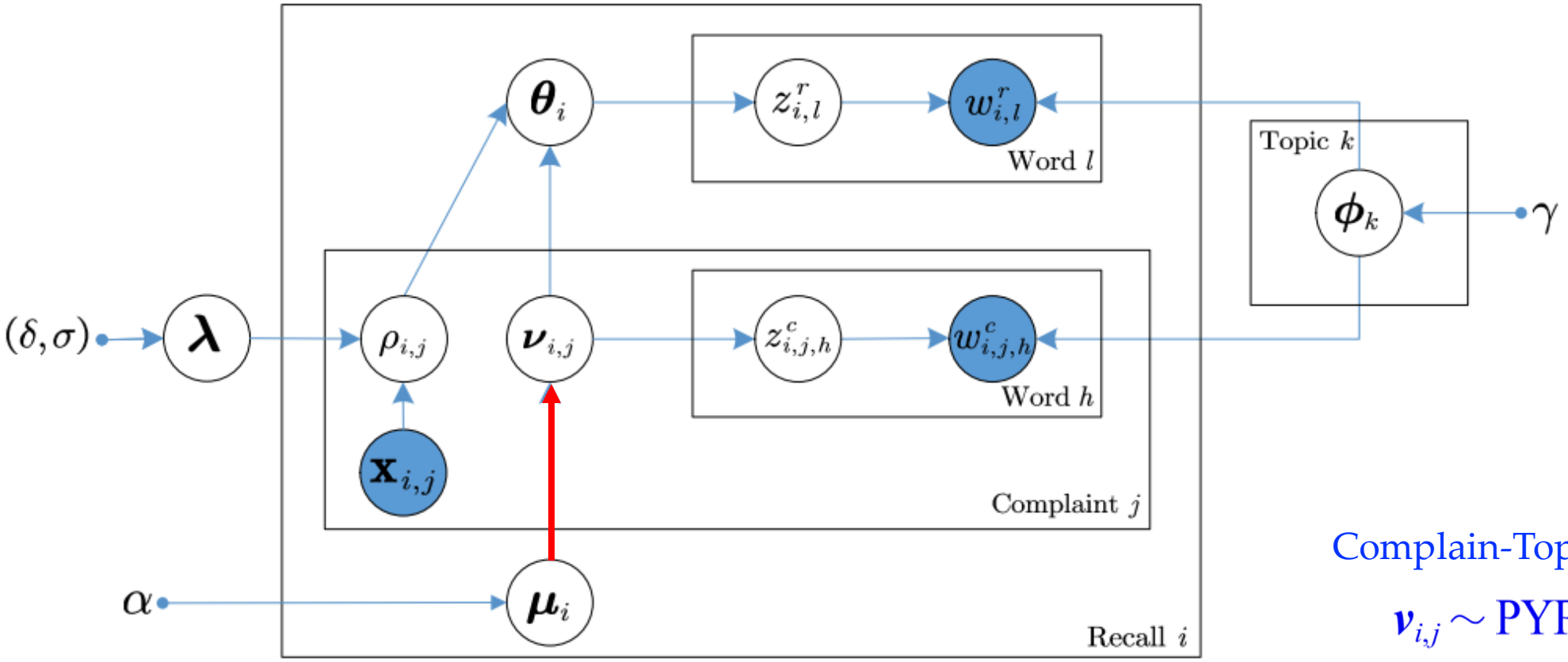

Complain-Topic Distribution

$$\nu_{i,j} \sim \mathrm{PYP}(a^{\nu}, b^{\nu}, \mu_i)$$

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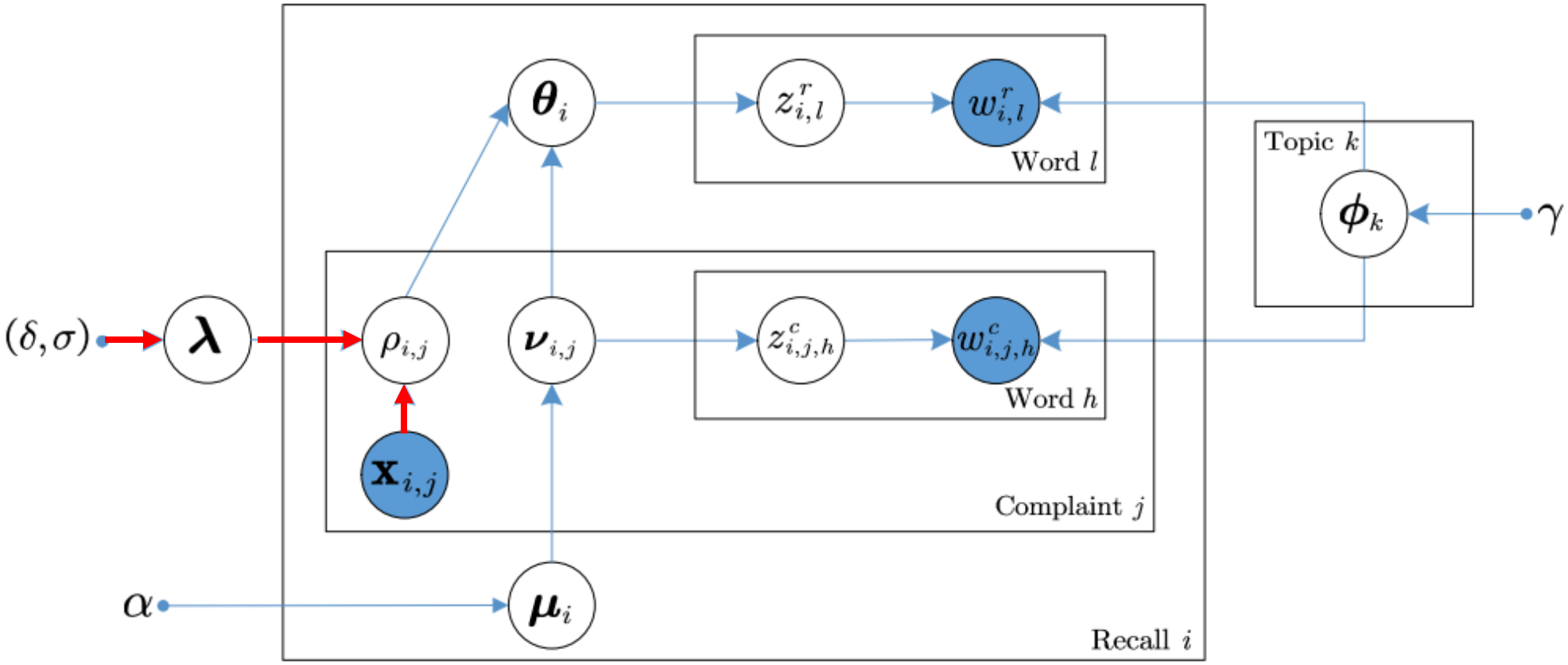

The relative importance of each observed complaint to the topic distribution of a recall statement

$$\boldsymbol{\rho}_i \sim \text{Dirichlet}_{J_i}\left(\exp(\boldsymbol{\lambda}^\top \boldsymbol{x}_{i,1}), \exp(\boldsymbol{\lambda}^\top \boldsymbol{x}_{i,2}), \ldots, \exp(\boldsymbol{\lambda}^\top \boldsymbol{x}_{i,J_i})\right)$$

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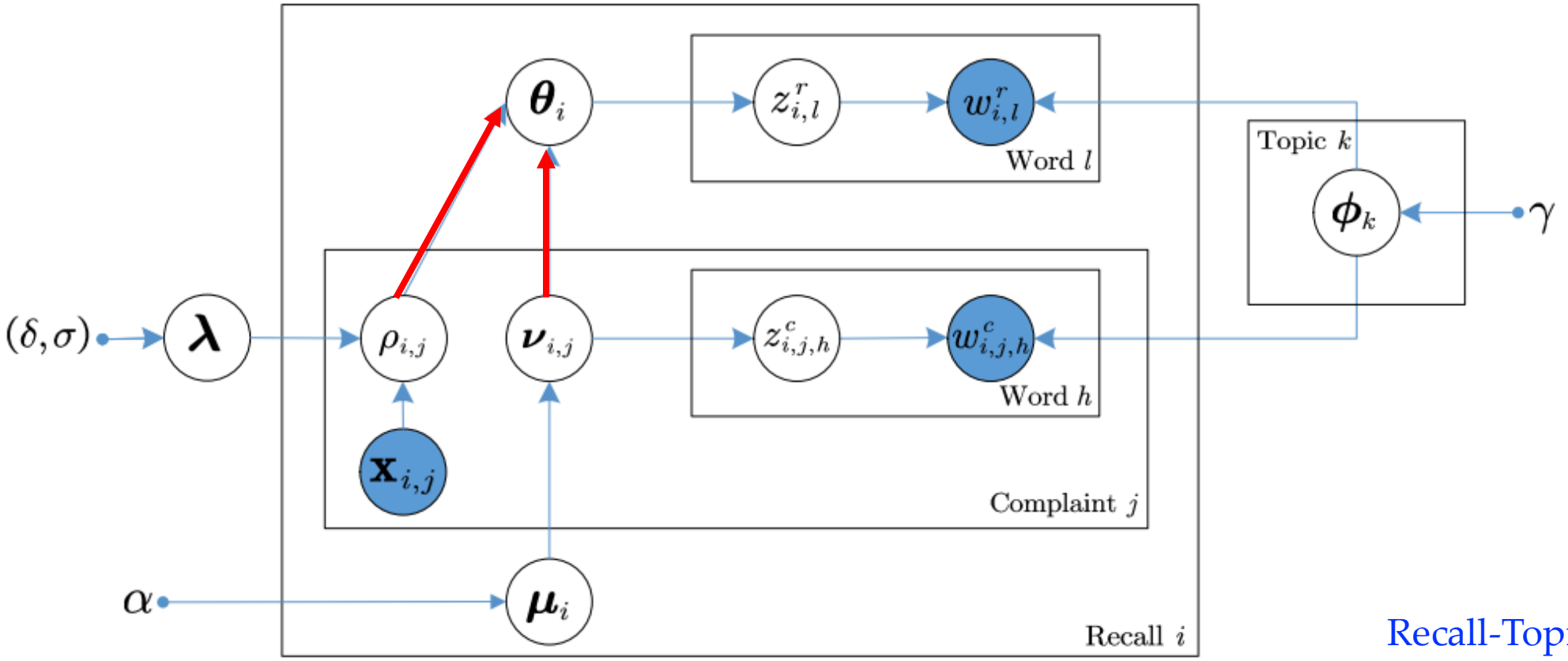

Recall-Topic Distribution

$$\boldsymbol{\theta}_i \sim \mathrm{PYP}(a^{\theta_i}, b^{\theta_i}, \sum_{j=1}^{J_i} \rho_{i,j} \boldsymbol{\nu}_{i,j})$$

Model Inference

Markov chain Monte Carlo

$\{\lambda, \mu, v, \theta, \Phi, \rho, z^r, z^c\}$

Intractable parameter inference via traditional Bayesian inference

Inefficient MCMC
- PYP nodes
- Hierarchical structure

Chinese Restaurant Process

Cast each PYP node as a CRP restaurant and each word as a customer
- Require large computational storage for assignment information
- Low efficiency

Tech for Efficiency

Adopt the notion of *table indicator* (Chen et al., 2011)

Blocked and collapsed Gibbs

Stochastic Kriging metamodeling method for optimizing model hyper-parameters