Measuring and Evaluating Bias in Search Engines

Valerie Lemuth



Ein **Ei** der Größe S kocht ca. 3 Minuten, um weich, 5 Minuten, um wachsweich, und 7 ½ Minuten, um mittelhart zu werden. Große Eier aus einem L-Karton (63-73 g pro **Ei**) kochen ca. 25-50

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Motivation

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https://www.plannedparenthood.org/learn/abortion

Abortion Information | Information About Your Options

There are two ways of ending a pregnancy: in-clinic abortion and the abortion pill. Both are safe and very common. If you're pregnant and thinking about ...

https://en.wikipedia.org/wiki/Abortion

Abortion - Wikipedia

Anonymous View

Anonymous View

Abortion is the ending of a pregnancy by removal or expulsion of an embryo or fetus. An abortion that occurs without intervention is known as a miscarriage or ...

https://www.who.int/health-topics/abortion

Abortion - World Health Organization

Anonymous View

Anonymous View

Abortion. Overview; Impact of unsafe abortion; Barriers to safe abortion; More. Overview. Every individual has the right to decide freely and responsibly – without ...

https://www.guttmacher.org/state-policy/explore/overview-abortion-laws

An Overview of Abortion Laws | Guttmacher

Physician and Hospital Requirements: 39 states require an abortion to be performed by a licensed physician. · Gestational Limits: 43 states prohibit abortions, ...

https://medlineplus.gov/abortion.html

Anonymous View

Apr 28, 2020 ... Summary. An abortion is a procedure to end a pregnancy. It uses medicine or surgery to remove the embryo or fetus and placenta from the uterus.

https://foundationsoflife.org/facts-about-abortion/

Considering Abortion? Know The Facts | Foundations of Life ...

Abortion | Medical Abortion | MedlinePlus

Anonymous View

Anonymous View

Anonymous View

The late term abortion process, performed 16 to 18 weeks and later, varies according to baby's age. Generally laminaria are inserted to open the cervix (a one or ...

https://prochoice.org/patients/abortion-what-to-expect/

Abortion: What to Expect - National Abortion Federation

There are two common, very safe methods for terminating a pregnancy: medication abortion, in which you ingest pills, or a procedural abortion, in which a ...

https://prochoice.org/

National Abortion Federation: Home

The National Abortion Federation is the professional association of abortion providers. Join now to take advantage of the unique programs we provide.

https://www.britannica.com/science/abortion-pregnancy

abortion | Definition, Procedure, Laws, & Facts | Anonymous View Britannica

Abortion, the expulsion of a fetus from the uterus before it has reached the stage of viability (in human beings, usually about the 20th week of gestation).

https://www.health.state.mn.us/people/wrtk/handbook.html If You Are Pregnant: Information on fetal development, abortion and ...

Anonymous View

However, each woman and unborn fetus are unique. When considering an abortion, a woman should talk to her doctor about the procedures and alternatives ...

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- Users trust the ranking of search engines (Pan et al. 2007)
- Users select the top search results, regardless of their relevance (Keane et al. 2008)
- Users accept false information presented by search engines (White 2013)
- Search engines could influence the results of an election (Epstein and Robertson 2015)

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https://www.bealth.state.mn.us/people/wrtk/bandbook.html	
If You Are Pregnant: Information on fetal development, abortion and	Anonymous View
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https://www.britannica.com/science/abortion-pregnancy abortion Definition, Procedure, Laws, & Facts Britannica	Anonymous View
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https://prochoice.org/ National Abortion Federation: Home	Anonymous View
The National Abortion Federation is the professional association of abor now to take advantage of the unique programs we provide.	tion providers. Join
https://prochoice.org/patients/abortion-what-to-expect/	Anonymous Viev
Federation There are two common, very safe methods for terminating a pregnancy	: medication
abortion, in which you ingest pills, or a procedural abortion, in which a	
Considering Abortion? Know The Facts Foundations of Life	Anonymous View
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Apr 28, 2020 Summary. An abortion is a procedure to end a pregnam or surgery to remove the embryo or fetus and placenta from the uterus.	cy. It uses medicine
https://www.guttmacher.org/state-policy/explore/overview-abortion-laws	Anonymous View
Institute	Anonymous view
Physician and Hospital Requirements: 39 states require an abortion to b licensed physician. · Gestational Limits: 43 states prohibit abortions,	e performed by a
https://www.who.int/health-topics/abortion	
Abortion - wond Health Organization Abortion. Overview; Impact of unsafe abortion; Barriers to safe abortion; Every individual has the right to decide freely and responsibly – without	More. Overview.
https://en.wikipedia.org/wiki/Abortion	Anonymous View
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Do search engines deliver biased search results for controversial topics?

Contributions

- 1. Related Work found big gap
- 2. Approach developed new method
- 3. Experiment implemented method
- 4. Findings

Definitions

- Bias
 - The deviation from the reference distribution
- Reference distributions
 - Stance distributions or facts regarding the topic, from different sources
 - Multiple reference distributions per topic
- Biased search results
 - If the stances of the search results deviate from the expected reference distribution

Related Work

- 25 papers
 - Discussing search engine bias
 - Detecting search engine bias

	This Thesis	Mowshowitz and Kawaguchi [2002]	Chen and Yang [2006]
Information	Web search engines	Thirteen comparable	Ten web search
Retrieval System	(Google)	web search engines	engines
Bias Definition	Deviation of	Balance of items in	Indexical Bias:
	stance distribution	collection retrieved	Mowshowitz et al.
	from reference	from database	Content Bias:
	distribution		Difference of page
			content
Reference	Multiple, from	Distribution of URLs	Indexical Bias:
Distribution	different sources.	of set of comparable	Mowshowitz et al.
	with the opinion of	search engines for	Content Bias:
	the population as	queries	Distribution
	an important part	quarter	of weighted vectors
			(RVV) representing
			the web pages
Topics	Controversial topics	4 topics	-
Ouery Selection	Most asked queries	12 quorios for	Top random hat
Query Selection	for each topic	12 queries ior	quaries from
	for each topic	each topic	queries from
Charles Data data	Ct	Cattle - UDI	Lycos 50
Stance Detection	Stance classification	Getting UKL	Indexical Blas:
	for each search result	collection for each	mowsnowitz et al.
	& aggregated stance	query	Content Bias:
	calculation for each		Create RVV based
	query	-	on Html-tags
Bias Detection	Compare	Deviation of URL	Indexical Bias:
	aggregated stance	collection from	Mowshowitz et al.
	with reference	reference distribution	Content Bias:
	distribution		Similarity between
			RVV and reference
			distribution
	Kulchroetha	Kulshroethn	Ditours of al
	et al. [2017]	et al. [2019]	[2018]
Information	Twitter search	Web search engines	Online Information
Retrieval System	engine	(Google)	Provider (OIP)
Rias Definition	Input Bias	Output Bias:	User Bias:
Bids Delimeton	Input Dias.	Output Dias.	Coci Dias.
	Aggregated stance	Aggregated stance	Different users
	Aggregated stance	Aggregated stance of SERP for query	Different users
	Aggregated stance of data input to ranking system	Aggregated stance of SERP for query	Different users receiving different information based
	Aggregated stance of data input to ranking system Output Bias:	Aggregated stance of SERP for query	Different users receiving different information based on race gender etc.
	Aggregated stance of data input to ranking system Output Bias:	Aggregated stance of SERP for query	Different users receiving different information based on race, gender, etc.
	Aggregated stance of data input to ranking system Output Bias: Aggregated stance of collection	Aggregated stance of SERP for query	Different users receiving different information based on race, gender, etc. Content Bias: Bias in data
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	Aggregated stance of data input to ranking system Output Bias: Aggregated stance of collection produced by ranking system Ranking Bias: Difference between	Aggregated stance of SERP for query	Different users receiving different information based on race, gender, etc. Content Bias: Bias in data received by the user
D. 6	Aggregated stance of data input to ranking system Output Bias: Aggregated stance of collection produced by ranking system Ranking Bias: Difference between output & input bias	Aggregated stance of SERP for query	Different users receiving different information based on race, gender, etc. Content Bias: Bias in data received by the user
Reference	Aggregated stance of data input to ranking system Output Bias: Aggregated stance of collection produced by ranking system Ranking Bias: Difference between output & input bias Input bias	Aggregated stance of SERP for query	Different users receiving different information based on race, gender, etc. Content Bias: Bias in data received by the user - Compare all data
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Approach

- Focus:
 - One search engine
 - Specific topics
 - During a time frame
 - At a selected location
- Detecting bias that has the potential to influence the society at the location

Approach















Topics $t \in T$





Topics $t \in T$ Top Queries $q \in Q_t$ Query Weight w(q)





Topics $t \in T$ Top Queries $q \in Q_t$ Aggregated Stance as(q)Query Weight w(q)





Topics $t \in T$ Top Queries $q \in Q_t$ Aggregated Stance as(q)Query Weight w(q)

$$as(q) = DCG_K = \sum_{i=1}^{K} \frac{\sigma(d_i, t)}{\log_2(i+1)}$$
;





Topics $t \in T$ Top Queries $q \in Q_t$ Aggregated Stance as(q)Query Weight w(q)Constant Amount of
search results

$$as(q) = DCG_K = \sum_{i=1}^{K} \frac{\sigma(d_i, t)}{\log_2(i+1)}$$
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Topics $t \in T$ Top Queries $q \in Q_t$ Aggregated Stance as(q)Query Weight w(q)Constant Amount of

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$$as(q) = DCG_K = \sum_{i=1}^{K} \frac{\sigma(d_i, t)}{\log_2(i+1)} ; \sigma(d_i, t) \in \{-1, 0, 1\}$$





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$$as(q) = DCG_{K} = \sum_{i=1}^{K} \frac{\sigma(d_{i}, t)}{\log_{2}(i+1)} ; \sigma(d_{i}, t) \in \{-1, 0, 1\}$$
Topic





Topics $t \in T$ Top Queries $q \in Q_t$ Aggregated Stance as(q)Query Weight w(q)Constant Amount of

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$$as(q) = DCG_{K} = \sum_{i=1}^{K} \frac{\sigma(d_{i}, t)}{\log_{2}(i+1)} ; \sigma(d_{i}, t) \in \{-1, 0, 1\}$$
Topic
Reduction
factor

Abortion

Google Trends



https://www.plannedparenthood.org/learn/abortion

Abortion Information | Information About Your Anonymous View Options

There are two ways of ending a pregnancy: in-clinic abortion and the abortion pill. Both are safe and very common. If you're pregnant and thinking about ...

https://en.wikipedia.org/wiki/Abortion

Abortion - Wikipedia

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Abortion is the ending of a pregnancy by removal or expulsion of an embryo or fetus. An abortion that occurs without intervention is known as a miscarriage or ...

https://www.who.int/health-topics/abortion

Abortion - World Health Organization

Abortion. Overview; Impact of unsafe abortion; Barriers to safe abortion; More. Overview. Every individual has the right to decide freely and responsibly – without ...

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An Overview of Abortion Laws | Guttmacher Anonymous View Institute

Physician and Hospital Requirements: 39 states require an abortion to be performed by a licensed physician. Gestational Limits: 43 states prohibit abortions, ...

https://medlineplus.gov/abortion.html

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Apr 28, 2020 ... Summary. An abortion is a procedure to end a pregnancy. It uses medicine or surgery to remove the embryo or fetus and placenta from the uterus.

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Considering Abortion? Know The Facts | Foundations of Life ...

Abortion | Medical Abortion | MedlinePlus

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Abortion: What to Expect - National Abortion Federation

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There are two common, very safe methods for terminating a pregnancy: medication abortion, in which you ingest pills, or a procedural abortion, in which a ...

https://prochoice.org/

National Abortion Federation: Home

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The National Abortion Federation is the professional association of abortion providers. Join now to take advantage of the unique programs we provide.

https://www.britannica.com/science/abortion-pregnancy

abortion | Definition, Procedure, Laws, & Facts | Anonymous View Britannica

Abortion, the expulsion of a fetus from the uterus before it has reached the stage of viability (in human beings, usually about the 20th week of gestation).

https://www.health.state.mn.us/people/wrtk/handbook.html If You Are Pregnant: Information on fetal development, abortion and ...

Anonymous View

However, each woman and unborn fetus are unique. When considering an abortion, a woman should talk to her doctor about the procedures and alternatives ...

Abortion

Google Trends

Ähnliche Suchanfragen 🕜 To	op 🔻 🛨 <> <
1 abortion	100
2 abortions	20
3 pill abortion	10
4 abortion clinic	8
5 what is abortion	5
< 1-5 von 25 Suchanfragen w	verden angezeigt 🔉

https://www.plannedparenthood.org/learn/abortion Abortion Information Information About Your Options There are two ways of ending a pregnancy: in-clinic abortion and the abort safe and very common. If you're pregnant and thinking about	Anonymous View
https://en.wikipedia.org/wiki/Abortion Abortion - Wikipedia Abortion is the ending of a pregnancy by removal or expulsion of an embry abortion that occurs without intervention is known as a miscarriage or	Anonymous View yo or fetus. An
https://www.who.int/health-topics/abortion Abortion - World Health Organization Abortion. Overview; Impact of unsafe abortion; Barriers to safe abortion; M Every individual has the right to decide freely and responsibly – without	Anonymous View lore. Overview.
https://www.guttmacher.org/state-policy/explore/overview-abortion-laws An Overview of Abortion Laws Guttmacher Institute Physician and Hospital Requirements: 39 states require an abortion to be licensed physician. · Gestational Limits: 43 states prohibit abortions,	Anonymous View
https://medlineplus.gov/abortion.html Abortion Medical Abortion MedlinePlus Apr 28, 2020 Summary. An abortion is a procedure to end a pregnancy. or surgery to remove the embryo or fetus and placenta from the uterus.	Anonymous View It uses medicine
https://foundationsoflife.org/facts-about-abortion/ Considering Abortion? Know The Facts Foundations of Life The late term abortion process, performed 16 to 18 weeks and later, varies baby's age. Generally laminaria are inserted to open the cervix (a one or	Anonymous View s according to
https://prochoice.org/patients/abortion-what-to-expect/ Abortion: What to Expect - National Abortion Federation There are two common, very safe methods for terminating a pregnancy: m abortion, in which you ingest pills, or a procedural abortion, in which a	Anonymous View
https://prochoice.org/ National Abortion Federation: Home The National Abortion Federation is the professional association of abortion now to take advantage of the unique programs we provide.	Anonymous View n providers. Join
https://www.britannica.com/science/abortion-pregnancy abortion Definition, Procedure, Laws, & Facts Britannica Abortion, the expulsion of a fetus from the uterus before it has reached the (in human beings, usually about the 20th week of gestation).	Anonymous View e stage of viability
https://www.health.state.mn.us/people/wrtk/handbook.html If You Are Pregnant: Information on fetal development, abortion and However, each woman and unbom fetus are unique. When considering an woman should talk to her doctor about the procedures and alternatives	Anonymous View



Topics $t \in T$



Topics $t \in T$ Ref. Distr. $r \in R_t$ r_1 :
60% Pro30% Con10% Neutral

Abortion





Topics $t \in T$ Ref. Distr. $r \in R_t$ *r*₁: 60% Pro 30% Con 10% Neutral

Simulated Ref. Distr. P_r

Sample
$$S_r$$

- Assign "random" stances

based on *r*

- Calc. aggregated stance

- Repeat \geq 1000 times







Probability $p_r(as(q))$

For each query of a topic











Approach

 $p_r(t)$ is the probability that the ranking of the search results, seen by an arbitrary search engine user, on a given topic t, in a time frame and at a location, reflects the expected distribution $r \in R_t$.

Approach

 $p_r(t)$ is the probability that the ranking of the search results, seen by an arbitrary search engine user, on a given topic t, in a time frame and at a location, reflects the expected distribution $r \in R_t$.

The higher $p_r(t)$, the higher the probability that there is no bias.

Experiment

- Search Engine: Google
- Location: US
- Time of measurement: December 2020
- Controversial Topics: Nine
 - abortion, climate change, death penalty, gun control, mandatory vaccination, marijuana legalisation, nuclear power, same sex marriage, universal heart care
- Top Queries: 3 -9 per topic
- Reference Distributions: 2-3 per topic of the categories opinion poll, market information and political landscape





Most asked queries - Abortion:

Topic <i>t</i>	Most asked queries $q \epsilon Q_t$	Frequencies $f(q)$	Weights $w(q)$
Abortion	abortion abortions	100 17	0.79 0.13
	pill abortion	10	0.08



Reference Distribution - Abortion:

Topic <i>t</i>	$r_1 \epsilon R_t$ (Opinion Poll)	$r_2 \epsilon R_t$ (Market Information)	$r_3 \epsilon R_t$ (Political Landscape)
Abortion	46% Pro-Choice 49% Pro-Life 5% Unknown	_	47% Pro-Choice 53% Pro-Life





Reference Distribution - Abortion:

Topic <i>t</i>	$r_1 \epsilon R_t$ (Opinion Poll)	$r_2 \epsilon R_t$ (Market Information)	$r_3 \epsilon R_t$ (Political Landscape)
Abortion	46% Pro 49% Con	_	47% Pro 53% Con
	5% Neutral		



Experiment



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Experiment

Stance Classification - Abortion:



Search Results (merged across queries)	Stance Classifier	Validation
https://www.plannedparenthood.org/learn/abortion	Pro	Pro
https://www.guttmacher.org/gpr/2019/09/us-aborti	Pro	Pro
on-rate-continues-drop-once-again-state-abortion-res		
trictions-are-not-main		
https://medlineplus.gov/abortion.html	Pro	Neutral
https://www.webmd.com/women/abortion-procedures	Pro	Neutral
https://www.guttmacher.org/state-policy/explore/ov	Neutral	Neutral
erview-abortion-laws		
https://www.who.int/health-topics/abortion	Pro	Pro
https://www.wholewomanshealth.com/abortion-care/	Pro	Pro
abortion-options/medication-abortion/		
https://www.plannedparenthood.org/learn/abortion/t	Pro	Pro
he-abortion-pill		
https://www.health.state.mn.us/people/wrtk/handb	Pro	Neutral
ook.html		
https://www.britannica.com/science/abortion-pregna	Pro	Neutral
ncy		
https://www.plannedparenthood.org/learn/abortion/t	Pro	Pro
he-abortion-pill/how-does-the-abortion-pill-work		
https://nwhn.org/abortion-pills-medication-abortion/	Pro	Pro
https://en.wikipedia.org/wiki/Abortion	Pro	Neutral
$https://www.cdc.gov/reproductivehealth/data_stats$	Neutral	Neutral
/abortion.htm		
https://www.amnesty.org/en/what-we-do/sexual-and	Pro	Pro
-reproductive-rights/abortion-facts/		
https://prochoice.org/patients/abortion-what-to-expeduated states and the states of	Pro	Pro
ct/		
https://www.theverge.com/2015/8/25/9174769/abort	Pro	Pro
ion-pill-shot-surgery-medical-women-healthcare		
https://www.mayoclinic.org/tests-procedures/medica	Pro	Pro
l-abortion/about/pac-20394687		
https://foundationsoflife.org/facts-about-abortion/	Pro	Con
https://www.healthline.com/health/abortion-pill	Pro	Pro
https://helloclue.com/articles/cycle-a-z/what-to-exp	Pro	Pro
ect-before-during-and-after-an-abortion		
https://prochoice.org/	Pro	Pro
https://www.bpas.org/abortion-care/abortion-treatm	Pro	Pro
ents/the-abortion-pill/abortion-pill-up-to-10-weeks/		
https://fallschurchhealthcare.com/abortion-pill/	Pro	Pro

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Experiment

Stance Classification - Abortion:

- Trained topic
- Error rate of 0.25



Search Results (merged across queries)	Stance Classifier	Validation
https://www.plannedparenthood.org/learn/abortion	Pro	Pro
https://www.guttmacher.org/gpr/2019/09/us-aborti	Pro	Pro
on-rate-continues-drop-once-again-state-abortion-res		
trictions-are-not-main		
https://medlineplus.gov/abortion.html	Pro	Neutral
https://www.webmd.com/women/abortion-procedures	Pro	Neutral
https://www.guttmacher.org/state-policy/explore/ov	Neutral	Neutral
erview-abortion-laws		
https://www.who.int/health-topics/abortion	Pro	Pro
https://www.wholewomanshealth.com/abortion-care/	Pro	Pro
abortion-options/medication-abortion/		
https://www.plannedparenthood.org/learn/abortion/t	Pro	Pro
he-abortion-pill		
https://www.health.state.mn.us/people/wrtk/handb	Pro	Neutral
ook.html		
https://www.britannica.com/science/abortion-pregna	Pro	Neutral
ncy		
https://www.plannedparenthood.org/learn/abortion/t	Pro	Pro
he-abortion-pill/how-does-the-abortion-pill-work		
https://nwhn.org/abortion-pills-medication-abortion/	Pro	Pro
https://en.wikipedia.org/wiki/Abortion	Pro	Neutral
https://www.cdc.gov/reproductivehealth/data_stats	Neutral	Neutral
/abortion.htm		
https://www.amnesty.org/en/what-we-do/sexual-and	Pro	Pro
-reproductive-rights/abortion-facts/		
https://prochoice.org/patients/abortion-what-to-expedence of the second secon	Pro	Pro
ct/		
https://www.theverge.com/2015/8/25/9174769/abort	Pro	Pro
ion-pill-shot-surgery-medical-women-healthcare		
https://www.mayoclinic.org/tests-procedures/medica	Pro	Pro
l-abortion/about/pac-20394687		
https://foundationsoflife.org/facts-about-abortion/	Pro	Con
https://www.healthline.com/health/abortion-pill	Pro	Pro
https://helloclue.com/articles/cycle-a-z/what-to-exp	Pro	Pro
ect-before-during-and-after-an-abortion		
https://prochoice.org/	Pro	Pro
https://www.bpas.org/abortion-care/abortion-treatm	Pro	Pro
ents/the-abortion-pill/abortion-pill-up-to-10-weeks/		
https://fallschurchhealthcare.com/abortion-pill/	Pro	Pro



Aggregated Stances - Abortion:

• Value range of [-4.54, 4.54]

 q_1 : abortion $\sigma(d_i, t) : 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1$ $as(q_1) = DCG_{10} = 4.1129$

 q_2 : abortions $\sigma(d_i, t) : 1, 1, 0, 1, 1, 1, 1, 0, 1, 1$ $as(q_2) = DCG_{10} = 3.7281$







Simulated Reference Distribution - Abortion:



Aggregated Stance

Bias Assessmen

Simulated Reference Distribution

Stance Classification



Bias Assessment - Abortion:



< { }

Controversial

Topics

Top Queries

Search Engine

ØØ

Reference Distribution



Bias Assessment - Abortion:







Probability $p_r(as(q))$: $q_1 : p_{[0.46,0.49,0.05]}(4.1129) = 0.002$ $q_1 : p_{[0.47,0.53,0.0]}(4.1129) = 0.002$ $q_2 : p_{[0.46,0.49,0.05]}(3.7281) = 0.007$ $q_2 : p_{[0.47,0.53,0.0]}(3.7281) = 0.006$ $q_3 : p_{[0.46,0.49,0.05]}(4.5436) = 0.0$ $q_3 : p_{[0.47,0.53,0.0]}(4.5436) = 0.0$



Bias Assessment - Abortion:



Probability $p_r(as(q))$: $q_1 : p_{[0.46,0.49,0.05]}(4.1129) = 0.002$ $q_1 : p_{[0.47,0.53,0.0]}(4.1129) = 0.002$ $q_2 : p_{[0.46,0.49,0.05]}(3.7281) = 0.007$ $q_2 : p_{[0.47,0.53,0.0]}(3.7281) = 0.006$ $q_3 : p_{[0.46,0.49,0.05]}(4.5436) = 0.0$ $q_3 : p_{[0.47,0.53,0.0]}(4.5436) = 0.0$

Probability $p_r(t)$:

Density

 $p_{\text{opinion}}(\text{Abortion}) = 0.9 \cdot 0.00249 + 0.1 \cdot 1 = 0.1022$ $p_{\text{political}}(\text{Abortion}) = 0.9 \cdot 0.00236 + 0.1 \cdot 1 = 0.1021$

Findings

Торіс	Opinion Poll	Market Information	Political Landscape
Abortion	0.1022		0.1021
Climate Change	0.5702		0.3447
Death Penalty	0.1620	0.1927	
Gun Control	0.4020	0.3583	0.1198
Mandatory Vaccinations	0.5887	0.1	
Marijuana Legalization	0.5410	0.2960	
Nuclear Power	0.8241	0.1	
Same Sex Marriage	0.6137		0.7158
Universal Health Care	0.6197		0.4665

Findings

Торіс	Opinion Poll	Market Information	Political Landscape
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Findings

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Same Sex Marriage	0.6137		0.7158
Universal Health Care	0.6197		0.4665

Conclusion

- The developed approach allows detection of bias in a search engine
- In experiment, approach is successfully used for nine topics and shows a likely bias for two topics

Future Work

- Add more topics and reference distributions to experiment
- Compare multiple search engines using the same topics and location
- Compare behaviour of search engine for multiple locations
- Integration of bayesian statistics to the reference distribution
- Study behaviour of search engine over time

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Questions ?

Appendix

Algorithm	1	Pseudo-Code

1:	for t in T do
2:	for r in R_t do
3:	for q in Q_t do
4:	n = 1000
5:	for $i = 1, 2,, n$ do
6:	$permute(S_r)$
7:	if $ \overline{s} - s > \overline{s} - as(q) $ then
8:	$count \leftarrow count + 1$
9:	end if
10:	end for
11:	end for
12:	$p_r(as(q)) \leftarrow \frac{count}{n}$
13:	end for
14:	end for

Permutation test:

```
Probability p_r(as(q))
```

```
For each query of a topic
```

Top Queries

Topic t	Most asked	Frequencies $f(q)$	Weights $w(q)$
	queries $q \epsilon Q_t$		
Abortion	abortion	100	0.79
	abortions	17	0.13
	pill abortion	10	0.08
Climate Change	climate	100	0.30
	climate change	93	0.28
	warming	47	0.14
	global warming	42	0.12
	climate change is	20	0.06
	global warming is	12	0.04
	what is climate	11	0.03
	global climate	10	0.03
Death Penalty	death penalty	100	0.28
	execution	75	0.22
	the death penalty	44	0.12
	executed	42	0.12
	death row	35	0.10
	executions	19	0.05
	capital punishment	17	0.05
	death penalty states	12	0.03
	death sentence	11	0.03
Gun Control	gun	100	0.49
	gun laws	56	0.27
	gun control	48	0.24
Mandatory	is vaccination mandatory	100	0.21
Vaccination	mandatory vaccination bill	92	0.19
	mandatory vaccination 2020	83	0.17
	mandatory vaccination	59	0.12
	oklahoma		
	mandatory vaccination laws	46	0.10
	stop mandatory vaccination	46	0.10
	mandatory vaccination states	40	0.08
	mandatory vaccination bill	16	0.03
	2020		

Topic t	Most asked	Frequencies $f(q)$	Weights $w(q)$
	queries $q \epsilon Q_t$		
Marijuana	marijuana	100	0.34
Legalization	legal marijuana	94	0.31
	is marijuana legal	69	0.23
	states legal marijuana	20	0.07
	legal cannabis	14	0.05
Nuclear Power	nuclear	100	0.63
	nuclear power	19	0.13
	energy	15	0.09
	nuclear energy	15	0.09
	nuclear plant	10	0.06
Same Sex	gay marriage	100	0.56
Marriage	gay marriage legal	22	0.12
	gay marriage legalized	13	0.07
	is gay marriage legal	13	0.07
	supreme court	11	0.06
	gay marriage us	11	0.06
	gay wedding	10	0.06
Universal Health	uhc	100	0.48
Care	uhc provider	26	0.12
	uhc login	22	0.11
	universal health	22	0.11
	universal healthcare	20	0.09
	universal health care	19	0.09

Ref. Distr.

Topic t	$r_1 \epsilon R_t$	$r_2 \epsilon R_t \left(\mathbf{Market} \right)$	$r_3 \epsilon R_t$ (Political
	(Opinion Poll)	Information)	Landscape)
Abortion	46% Pro-Choice 49% Pro-Life 5% Unknown Saad [2019]	-	47% Pro-Choice 53% Pro-Life Diffen [2020], Votesmart [2020], Votesmart [2018]
Climate Change	79% Exists 7% Doesn't exist 14% Not sure YouGov and TheEconomist [2019]	-	47% Exists 53% Doesn't exist Salant [2019], Votesmart [2020], Votesmart [2018]
Death Penalty	60% Acceptable 35% Wrong 5% Depends Gallup [2019a]	53290 Prisoners serving life sentences 2814 Prisoners under sentences of death Davis and Snell [2018]	-
Gun Control	66% Support 26% Oppose 8% No opinion Consult and Politico [2019]	30% Own gun 68% Don't own gun 2% Unknown Parker et al. [2017]	47% Support 53% Oppose Diffen [2020], Votesmart [2020], Votesmart [2018]
Mandatory Vaccinations	72% Pro 19% Con 9% Don't know ^{Murad} [2019]	1.1% Unvaccinated children Hill et al. [2017]	-
Marijuana Legalization	66% Support 33% Oppose 1% No opinion Gallup [2019c]	52% Have tried marijuana 48% Haven't tried marijuana MaristPoll [2017]	-
Nuclear Power	49% Pro 49% Con 2% Unknown Reinhart [2019]	36.7% Petroleum 32% Natural gas 11.3% Coal 11.5% Renewable energy 8.5% Nuclear power Administration [2019]	-
Same Sex Marriage	61% Pro 31% Con 8% Unknown PewResearchCenter [2019]	-	46% Pro 53% Con 1% Unknown Diffen [2020], Votesmart [2020]
Universal Health Care	54% Pro 45% Con 1% Unknown ^{Gallup} [2019b]	-	47% Pro 53% Con Diffen [2020], Votesmart [2020], Votesmart [2018]

Topic t	$r_1 \epsilon R_t$	$r_2 \epsilon R_t$ (Market	$r_3 \epsilon R_t$ (Political
	(Opinion Poll)	Information)	Landscape)
Abortion	46% Pro	-	47% Pro
	49% Con		53% Con
	5% Neutral		0% Neutral
Climate Change	7% Pro	-	53% Pro
	79% Con		47% Con
	14% Neutral		0% Neutral
Death Penalty	60% Pro	5% Pro	-
	35% Con	95% Con	
	5% Neutral	0% Neutral	
Gun Control	66% Pro	68% Pro	47% Pro
	26% Con	30% Con	53% Con
	8% Neutral	2% Neutral	0% Neutral
Mandatory	72% Pro	98.9% Pro	-
Vaccinations	19% Con	1.1% Con	
	9% Neutral	0% Neutral	
Marijuana	66% Pro	52% Pro	-
Legalization	33% Con	48% Con	
	1% Neutral	0% Neutral	
Nuclear Power	49% Pro	8.5% Pro	-
	49% Con	91.5% Con	
	2% Neutral	0% Neutral	
Same Sex Marriage	61% Pro	-	46% Pro
	31% Con		53% Con
	8% Neutral		1% Neutral
Universal Health	54% Pro	-	47% Pro
Care	45% Con		53% Con
	1% Neutral		0% Neutral

Agr. Stances

Topic t	Most asked	Aggregated
	queries $q \epsilon Q_t$	Stances $as(q)$
Abortion	abortion	4.1129
	abortions	3.7281
	pill abortion	4.5436
Climate Change	climate	-0.0973
	climate change	-3.1552
	warming	-2.4783
	global warming	-3.3311
	climate change is	-3.5421
	global warming is	-2.8634
	what is climate	-0.9592
	global climate	-3.0777
Death Penalty	death penalty	-2.5972
	execution	-1.8362
	the death penalty	-2.6116
	executed	-0.6759
	death row	-0.6309
	executions	-1.2317
	capital punishment	-3.7567
	death penalty states	-3.854
	death sentence	-2.3927
Gun Control	gun	2.8367
	gun laws	3.6057
	gun control	3.9126
Mandatory	is vaccination mandatory	1.6625
Vaccinations	mandatory vaccination bill	1.4307
	mandatory vaccination 2020	1.8332
	mandatory vaccination	1.7465
	oklahoma	
	mandatory vaccination laws	2.0858
	stop mandatory vaccination	1.6023
	mandatory vaccination states	1.3507
	mandatory vaccination bill	0.8755
	2020	

Topic t	Most asked	Aggregated
	queries $q \in Q_t$	Stances $as(q)$
Marijuana	marijuana	-2.3018
Legalization	legal marijuana	2.1924
	is marijuana legal	1.7554
	states legal marijuana	2.1666
	legal cannabis	2.3225
Nuclear Power	nuclear	0.0558
	nuclear power	0.5158
	energy	2.6653
	nuclear energy	1.8898
	nuclear plant	0.8379
Same Sex	gay marriage	0.8333
Marriage	gay marriage legal	-0.2891
	gay marriage legalized	-0.1296
	is gay marriage legal	0
	supreme court	0
	gay marriage us	0
	gay wedding	0
Universal Health	uhc	1.005
Care	uhc provider	0.5
	uhc login	0
	universal health	2.1095
	universal healthcare	3.0828
	universal health care	2.8805