FairTest:

discovering unwarranted associations in data-driven applications

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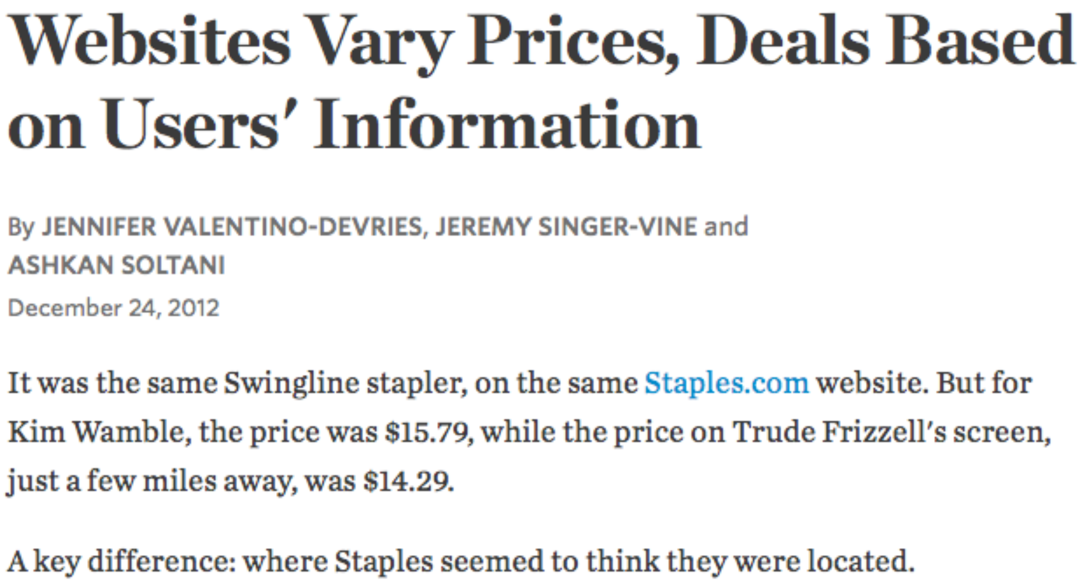
Jean-Pierre Hubaux[#], Mathias Humbert[#], Ari Juels[@], Huang Lin[#]

[#]École Polytechnique Fédérale de Lausanne, [*]Columbia University, [@]Cornell Tech

“Unfair” associations + consequences



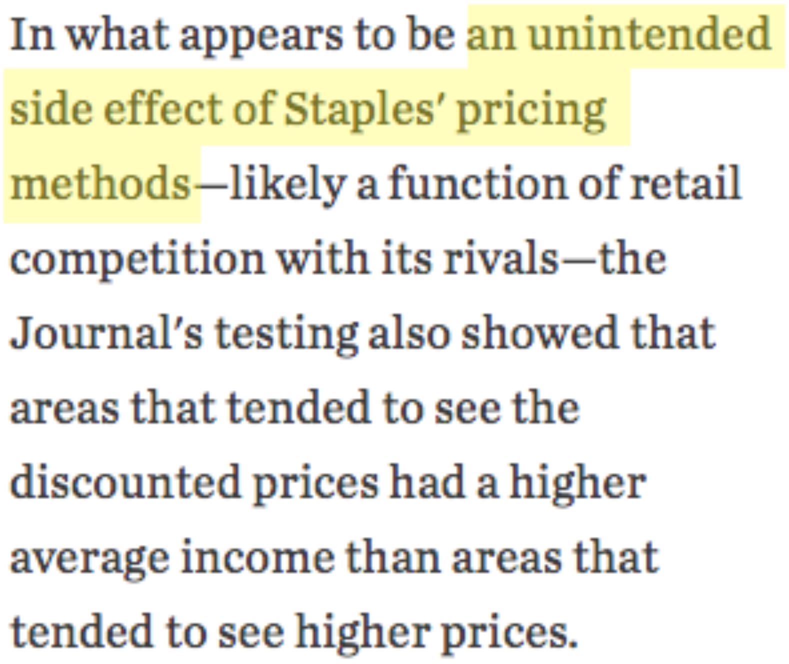
Websites Vary Prices, Deals Based on Users’ Information

By JENNIFER VALENTINO-DEVRIES, JEREMY SINGER-VINE and ASHKAN SOLTANI

December 24, 2012

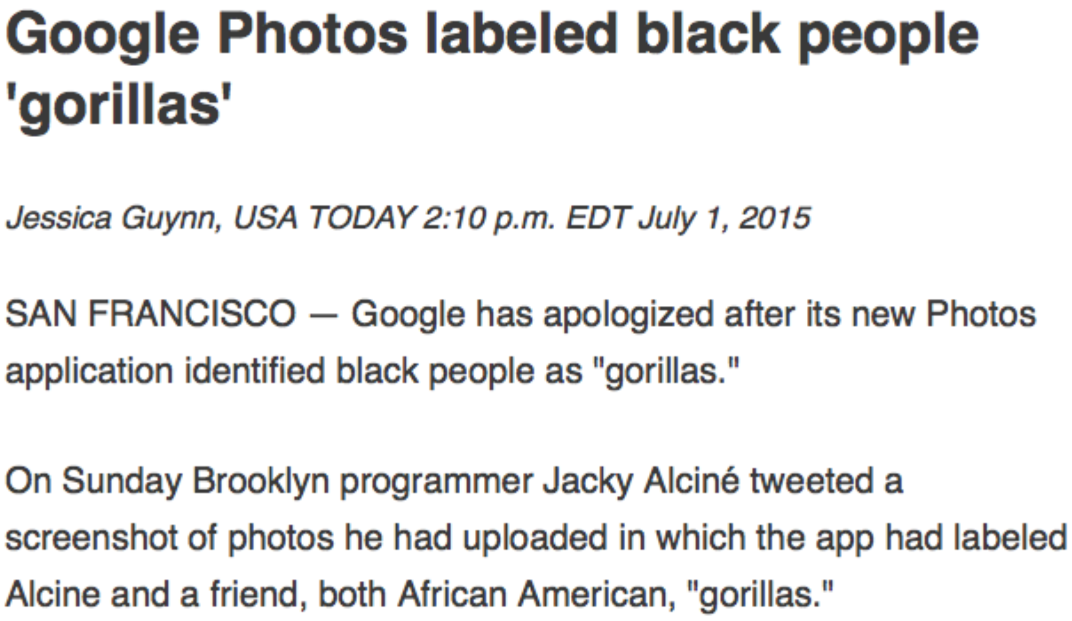
It was the same Swingline stapler, on the same Staples.com website. But for Kim Wamble, the price was $15.79, while the price on Trude Frizzell’s screen, just a few miles away, was $14.29.

A key difference: where Staples seemed to think they were located.



In what appears to be an unintended side effect of Staples’ pricing methods—likely a function of retail competition with its rivals—the Journal’s testing also showed that areas that tended to see the discounted prices had a higher average income than areas that tended to see higher prices.

“Unfair” associations + consequences

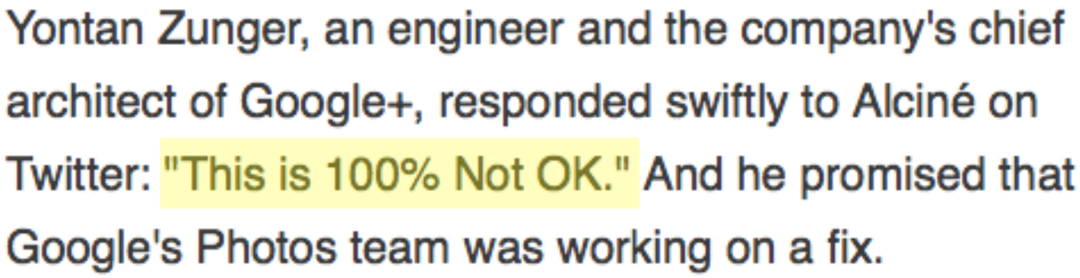


Google Photos labeled black people 'gorillas'

Jessica Guynn, USA TODAY 2:10 p.m. EDT July 1, 2015

SAN FRANCISCO — Google has apologized after its new Photos application identified black people as "gorillas."

On Sunday Brooklyn programmer Jacky Alciné tweeted a screenshot of photos he had uploaded in which the app had labeled Alcine and a friend, both African American, "gorillas."



Yontan Zunger, an engineer and the company's chief architect of Google+, responded swiftly to Alciné on Twitter: "This is 100% Not OK." And he promised that Google's Photos team was working on a fix.

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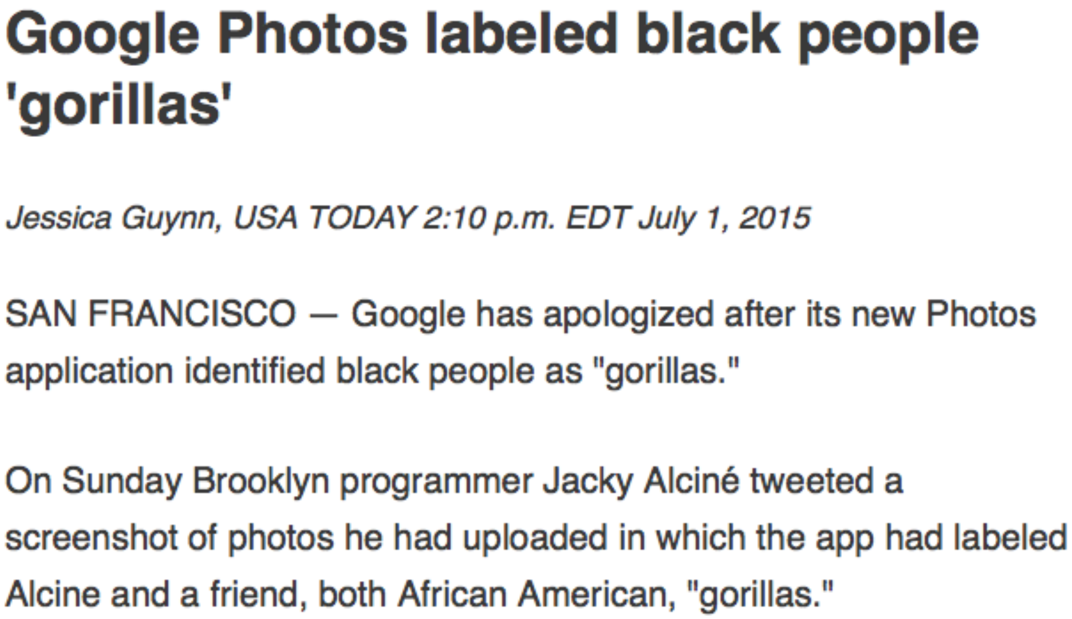

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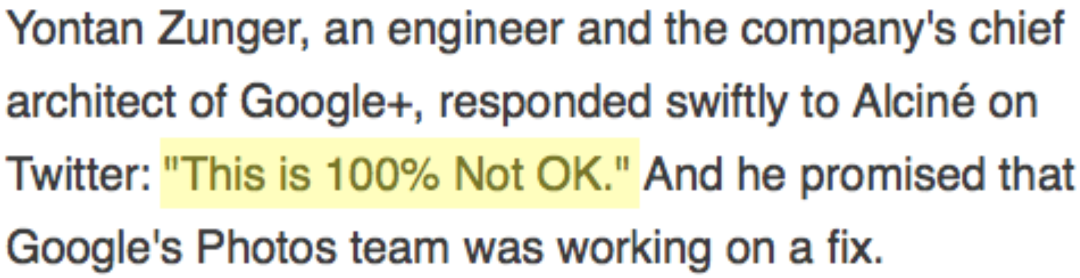

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These are **software bugs**: need to *actively test for them* and *fix them (i.e., debug)* in data-driven applications…
just as with functionality, performance, and reliability bugs.

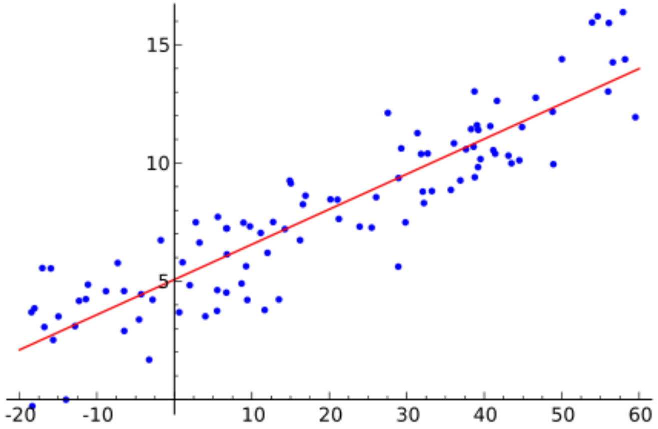
Limits of preventative measures

What doesn’t work:

Limits of preventative measures

What doesn’t work:

- Hide protected attributes from data-driven application.



Limits of preventative measures

What doesn’t work:

- Hide protected attributes from data-driven application.
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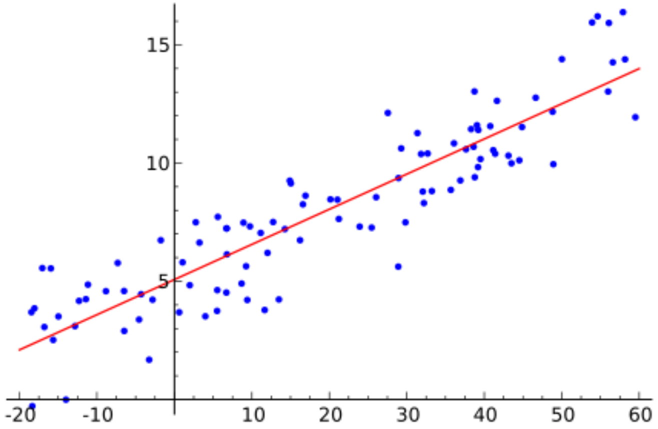

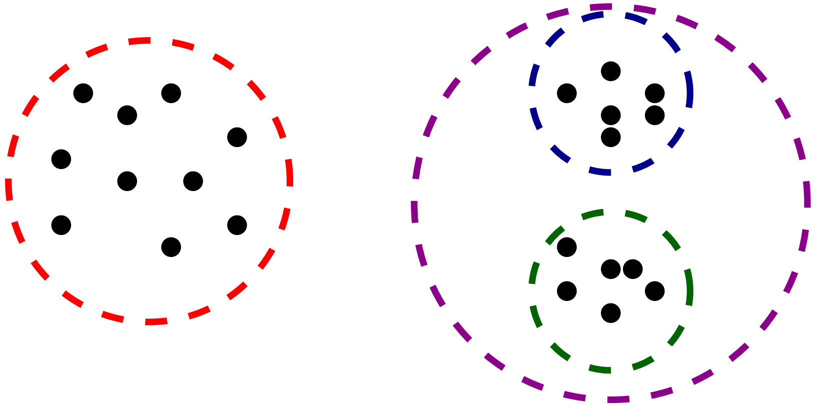

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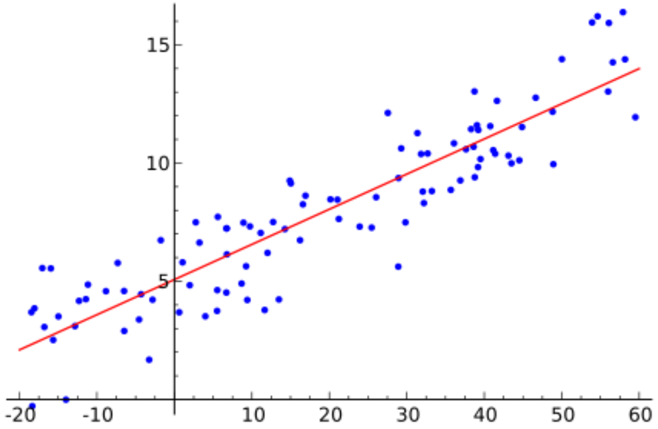
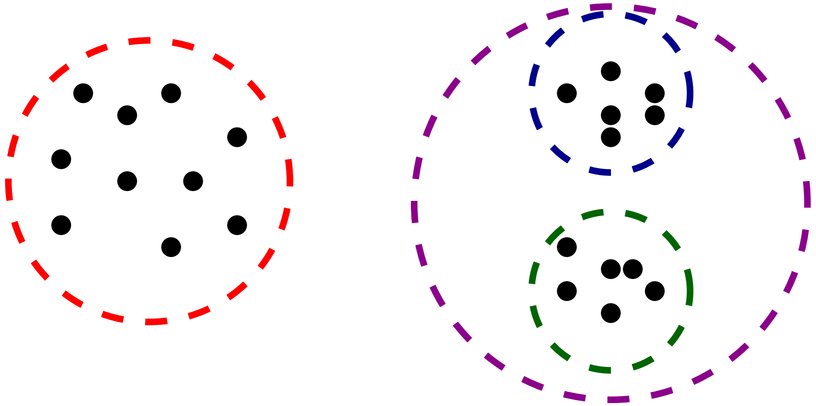
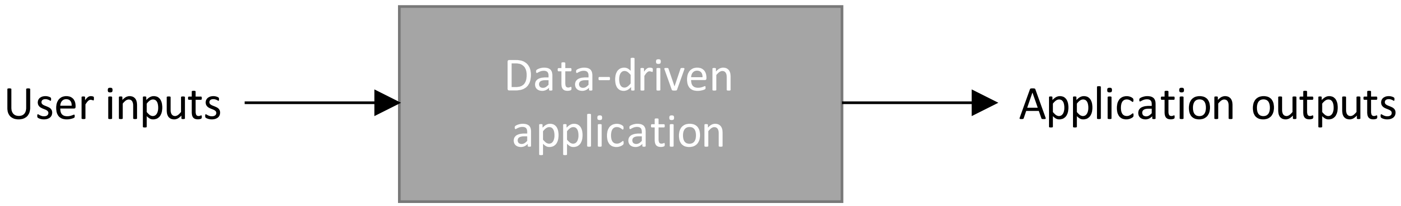


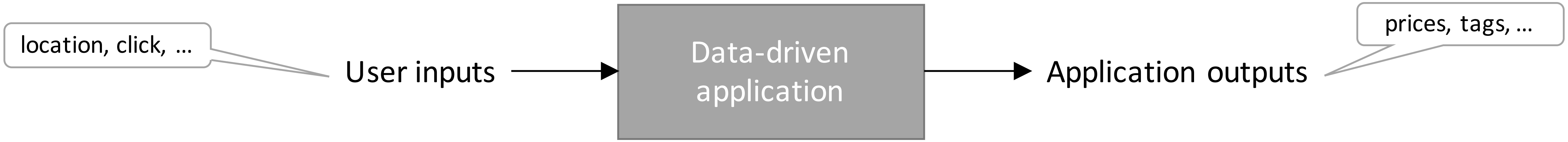


Foremost challenge is to even detect these unwarranted associations.

FairTest: a testing suite for data-driven apps



FairTest: a testing suite for data-driven apps



location, click, …

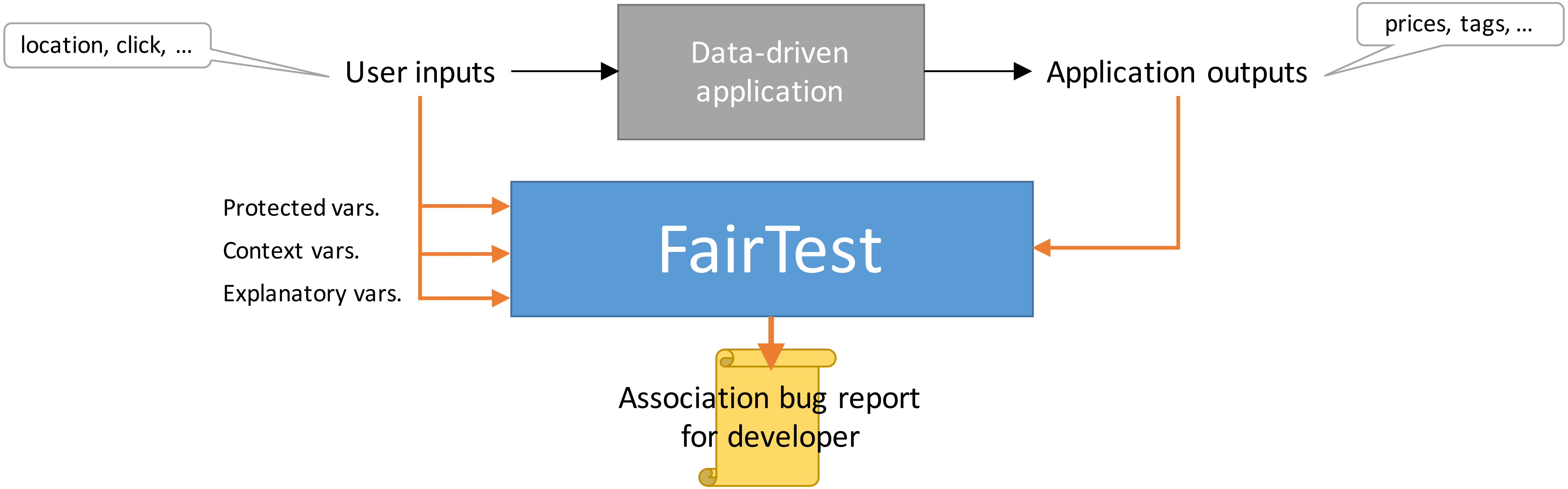
User inputs

Data-driven application

Application outputs

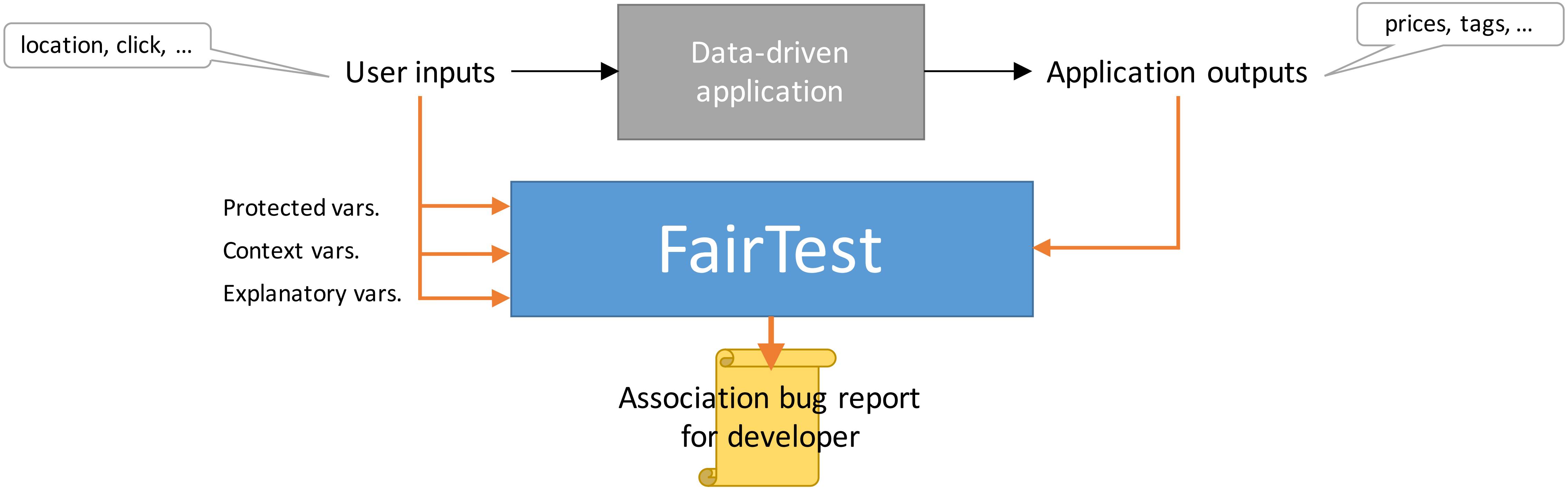
prices, tags, …

FairTest: a testing suite for data-driven apps



FairTest: a testing suite for data-driven apps

- Finds context-specific associations between protected variables and application outputs



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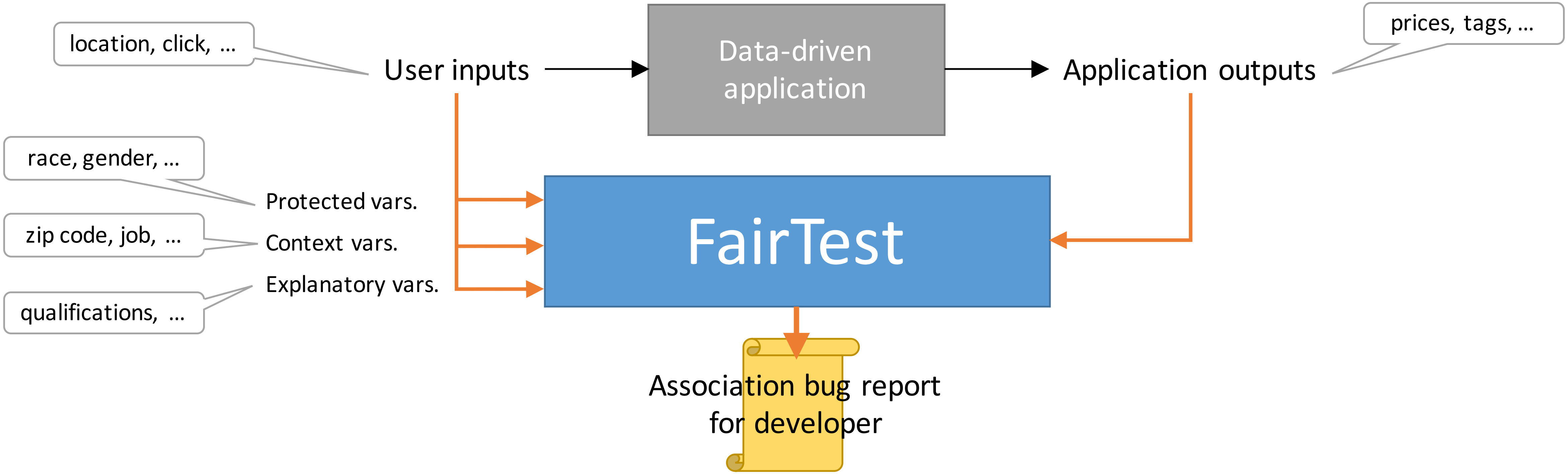
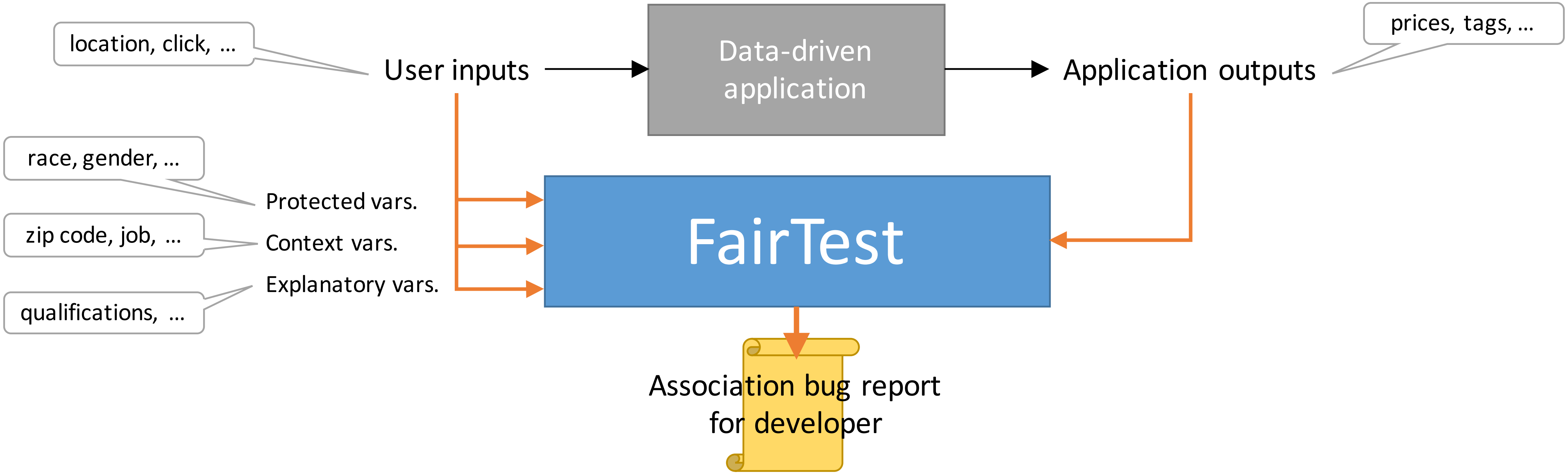


FairTest: a testing suite for data-driven apps

- Finds context-specific associations between protected variables and application outputs
- Bug report ranks findings by assoc. strength and affected pop. size



A data-driven approach

Core of FairTest is based on statistical machine learning

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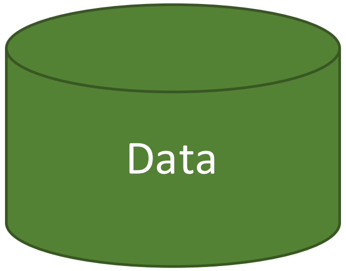

Data

Ideally sampled from
relevant user population

A data-driven approach

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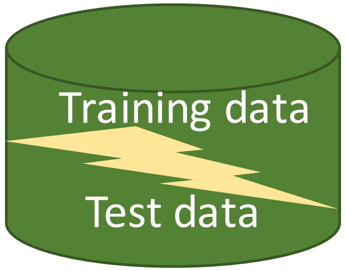

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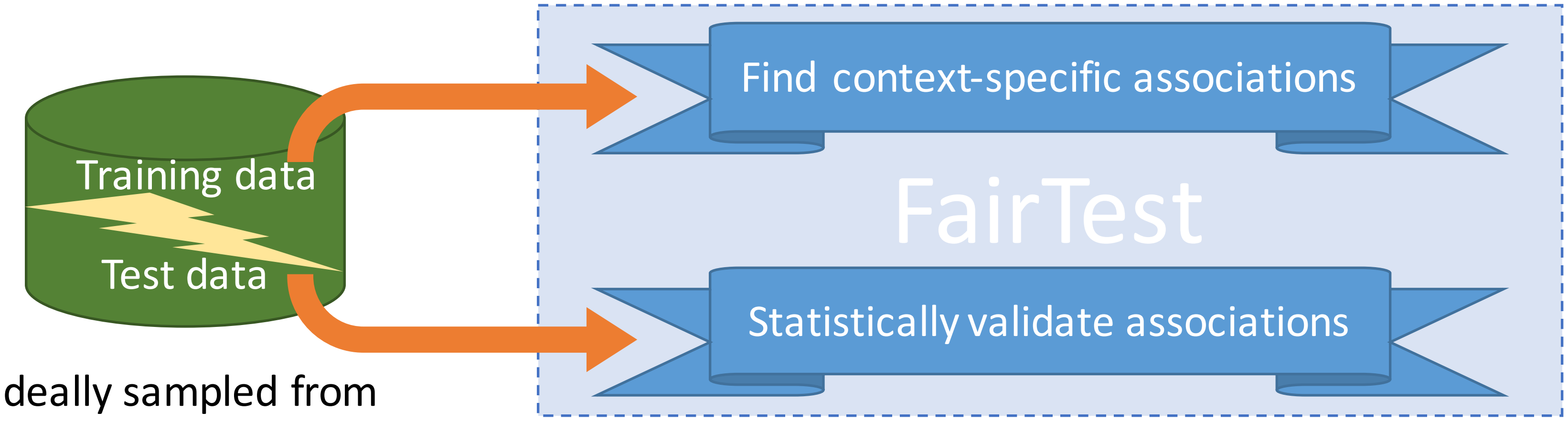
Training data
Test data
Find context-specific associations
FairTest
Statistically validate associations

Ideally sampled from
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Statistical machine learning internals:

- top-down spatial partitioning algorithm
- confidence intervals for assoc. metrics
- …

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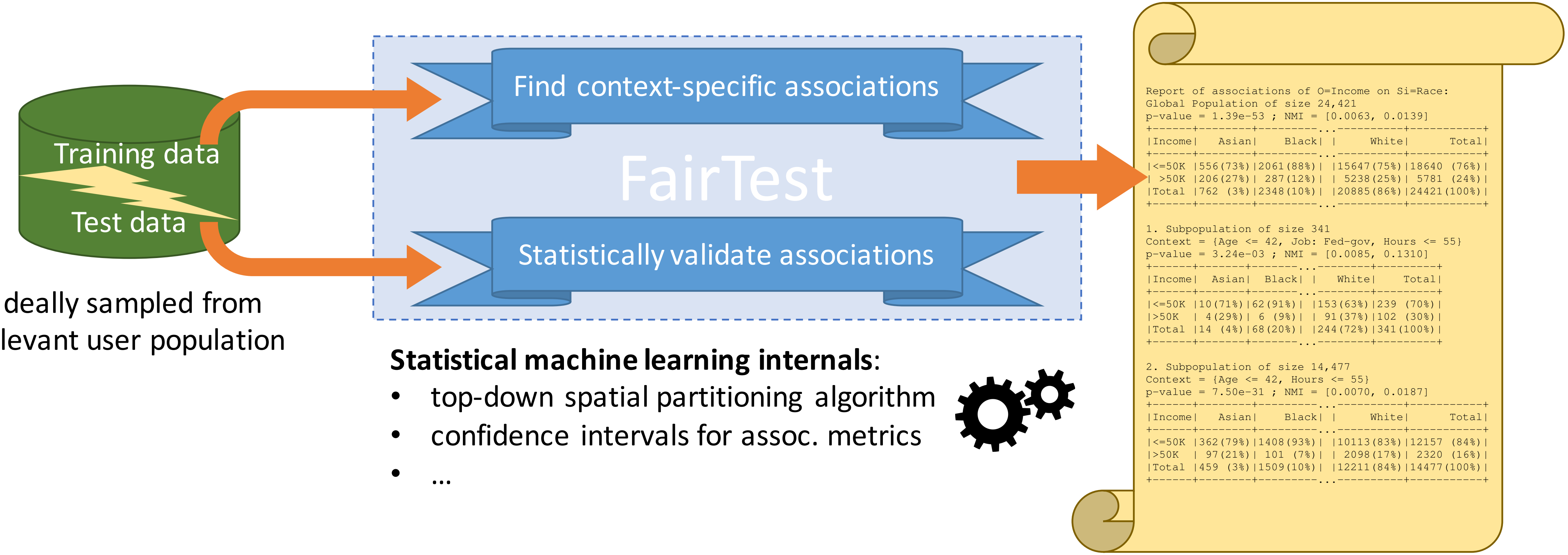
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Ideally sampled from relevant user population

```
Report of associations of O=Income on Si=Race:
Global Population of size 24,421
p-value = 1.39e-53 ; NMI = [0.0063, 0.0139]
+------+--------+---------...----------+-----------+
|Income|   Asian|    Black| |     White|      Total|
+------+--------+---------...----------+-----------+
|<=50K |556(73%)|2061(88%)| |15647(75%)|18640 (76%)|
| >50K |206(27%)| 287(12%)| | 5238(25%)| 5781 (24%)|
|Total |762 (3%)|2348(10%)| |20885(86%)|24421(100%)|
+------+--------+---------...----------+-----------+

1. Subpopulation of size 341
Context = {Age <= 42, Job: Fed-gov, Hours <= 55}
p-value = 3.24e-03 ; NMI = [0.0085, 0.1310]
+------+-------+-------...--------+---------+
|Income|  Asian|  Black| |   White|    Total|
+------+-------+-------...--------+---------+
|<=50K |10(71%)|62(91%)| |153(63%)|239 (70%)|
|>50K  | 4(29%)| 6 (9%)| | 91(37%)|102 (30%)|
|Total |14 (4%)|68(20%)| |244(72%)|341(100%)|
+------+-------+-------...--------+---------+

2. Subpopulation of size 14,477
Context = {Age <= 42, Hours <= 55}
p-value = 7.50e-31 ; NMI = [0.0070, 0.0187]
+------+--------+---------...----------+-----------+
|Income|   Asian|    Black| |     White|      Total|
+------+--------+---------...----------+-----------+
|<=50K |362(79%)|1408(93%)| |10113(83%)|12157 (84%)|
|>50K  | 97(21%)| 101 (7%)| | 2098(17%)| 2320 (16%)|
|Total |459 (3%)|1509(10%)| |12211(84%)|14477(100%)|
+------+--------+---------...----------+-----------+
```

Statistical machine learning internals:

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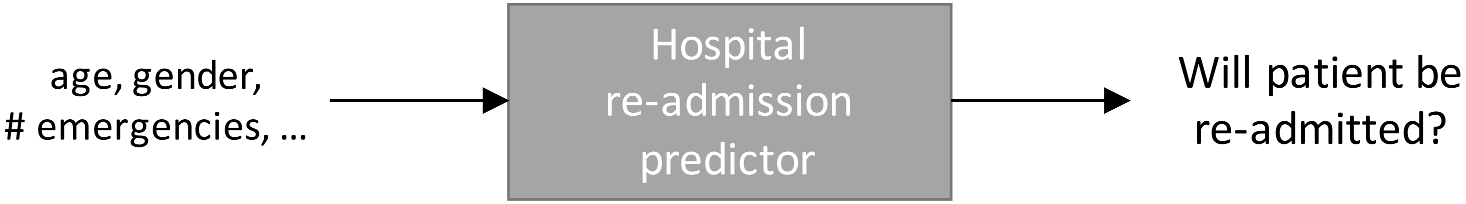
Example: health care application

Predictor of whether patient will visit hospital again in next year
(from winner of 2012 Heritage Health Prize Competition)



age, gender,
# emergencies, …

Hospital
re-admission
predictor

Will patient be
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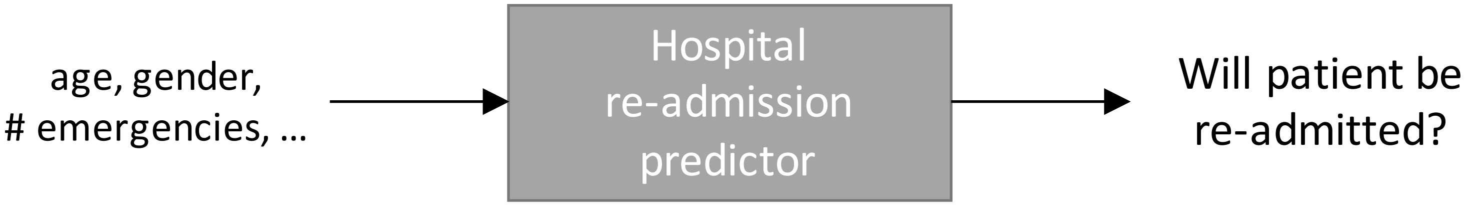
FairTest's finding: significant contexts exhibiting strong association between age and prediction error rate.



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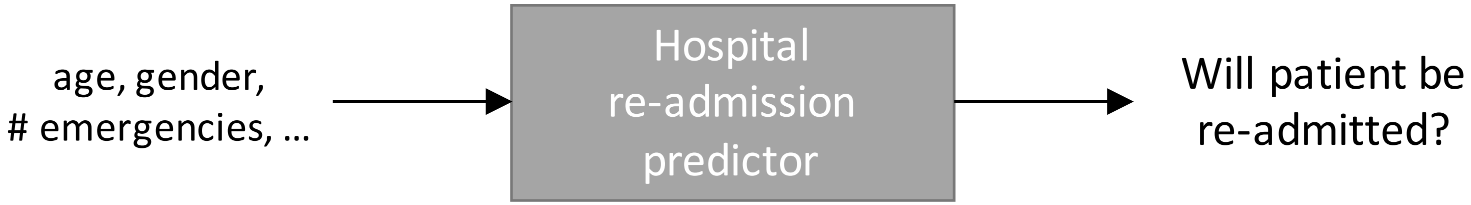

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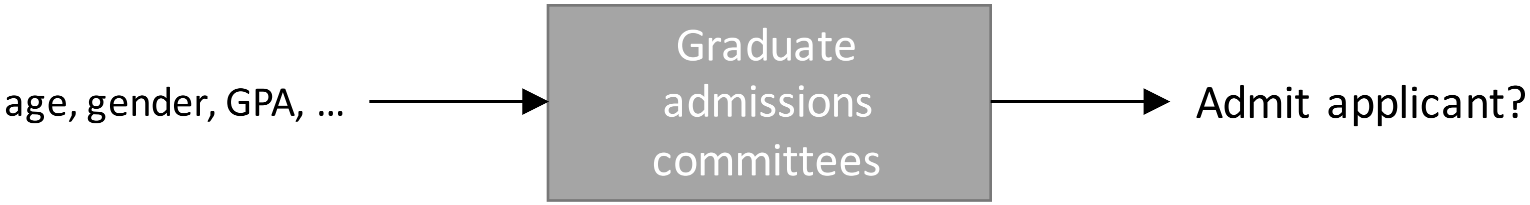
Association may translate to quantifiable harms
(e.g., if app is used to adjust insurance premiums)!

Example: Berkeley graduate admissions

Admission into UC Berkeley graduate programs
(Bickel, Hammel, and O’Connell, 1975)



age, gender, GPA, …

Graduate admissions committees

Admit applicant?

Example: Berkeley graduate admissions

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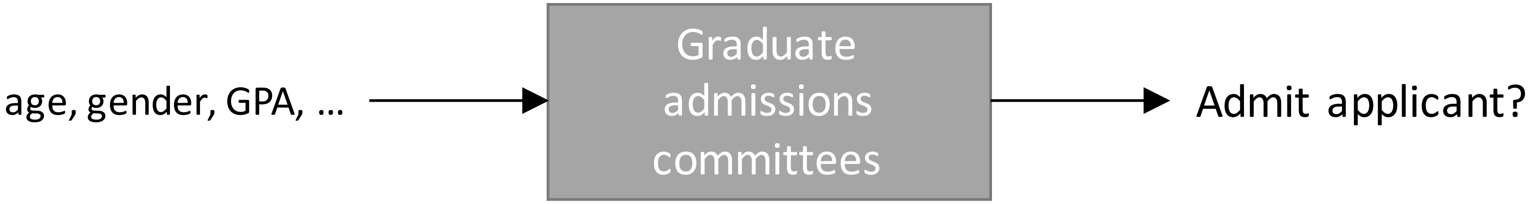
Bickel *et al*'s (and also FairTest's) findings: gender bias in admissions at university level, but mostly gone after conditioning on department



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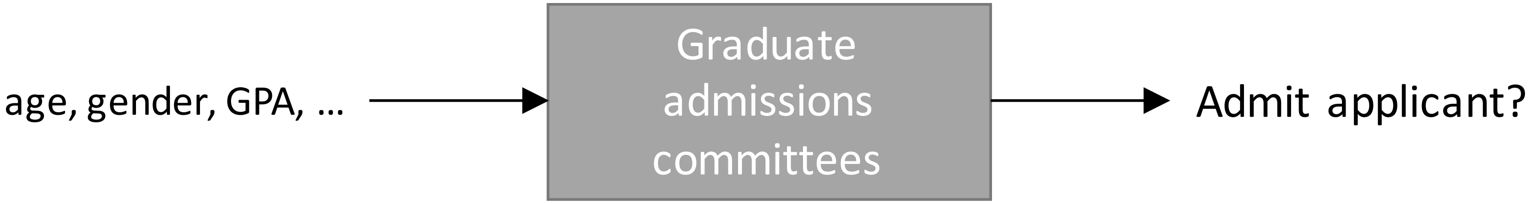

FairTest helps developers understand & evaluate potential association bugs.

Closing remarks

- **Other applications studied using FairTest** (http://arxiv.org/abs/1510.02377):
  - Image tagger based on deep learning (on ImageNet data)
  - Simple movie recommender system (on MovieLens data)
  - Simulation of Staple's pricing system

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