Programming with Estimates

James Bornholt
University of Washington

Dr. Kathryn McKinley
Dr. Matthias Felleisen
Dr. Shan Lu
Dr. Steve Blackburn
Dr. Michael Carbin
Dr. Matthew Might
Dr. Jason Mars
Dr. Mary Hall
Dr. John Davis
Dr. Shan Shan Huang

Dr. Milind Kulkarni
Dr. Armando Solar-Lezama
Dr. Lingjia Tang
James Bornholt
Dr. Ben Wiedermann
Dr. Sam Blackshear
Dr. Alvin Cheung
Dr. Ravi Chugh
Dr. Cindy Rubio-Gonzalez
Dr. Jean Yang


James B.
@siderealed
TWEETS
559
FOLLOWING
152
FOLLOWERS
158


Follow
Matt Might
@mattmight
TWEETS
5,893
FOLLOWING
293
FOLLOWERS
9,555


Jean Yang
@jeanqasaur
TWEETS
4,414
FOLLOWING
1,252
FOLLOWERS
4,914

Programming with Estimates

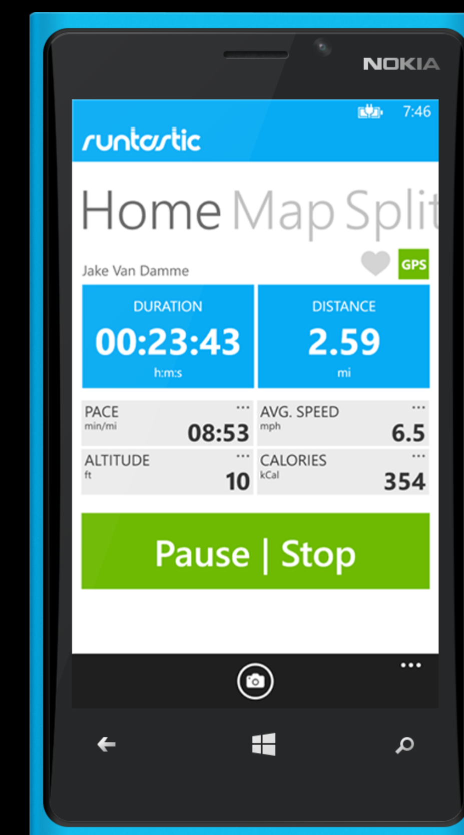
James Bornholt
University of Washington

with:
Todd Mytkowicz
Kathryn S. McKinley
Microsoft Research

Na Meng
Virginia Tech

Adrian Sampson
Cornell

Dan Grossman
Luis Ceze
University of Washington


NOKIA
7:46
runtastic
Home Map Split
Jake Van Damme
GPS
DURATION
00:23:43
h:m:s
DISTANCE
2.59
mi
PACE
min/mi
08:53
AVG. SPEED
mph
6.5
ALTITUDE
ft
10
CALORIES
kCal
354
Pause | Stop

59 mph


MEN'S 100M
RESULT - FINAL
WIND +1.5M/S
1 JAM USAIN BOLT OR 9.63
2 JAM YOHAN BLAKE 9.75
3 USA JUSTIN GATLIN 9.79
4 USA TYSON GAY 9.80
5 USA RYAN BAILEY 9.88
6 NED CHURANDY MARTINA 9.94
7 TRI RICHARD THOMPSON 9.98
8 JAM ASAFA POWELL 11.99
OMEGA


MEN'S 100M
1 AUS James BORNHOLT OR 3.79
1 JAM USAIN BOLT OR 9.63
2 JAM YOHAN BLAKE 9.75
3 USA JUSTIN GATLIN 9.79
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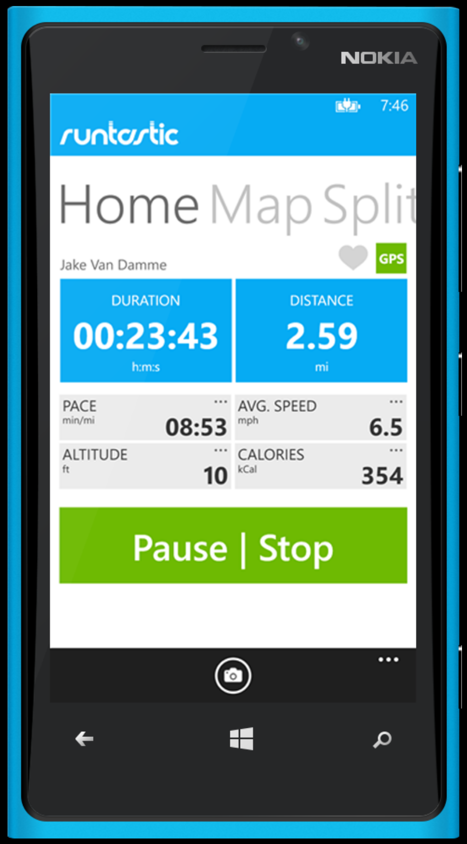
OMEGA

```
GeoPoint Prev = Get();
Sleep(5);
GeoPoint Curr = Get();
double Dist = Distance(Prev, Curr);
double Speed = Dist / 5;
```



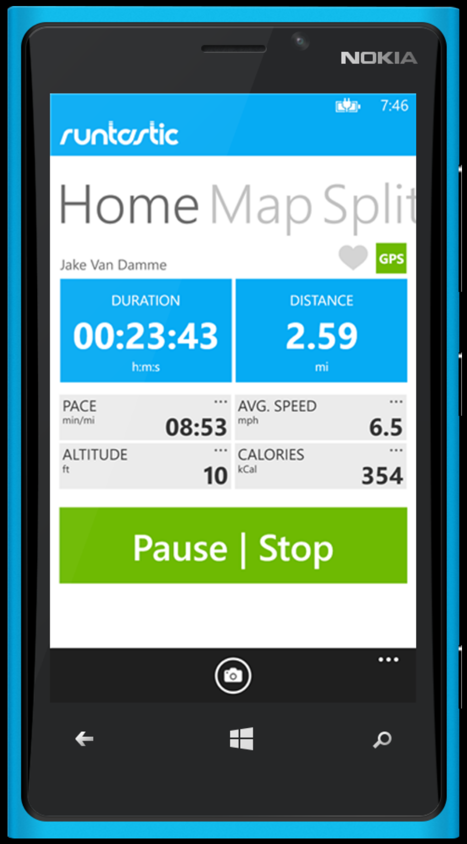
59 mph

Uncertain<T>

An abstraction for programming with estimates

Automates complex statistics!

```
Uncertain<GeoPoint> Prev = Get();
Sleep(5);
Uncertain<GeoPoint> Curr = Get();
Uncertain<double> Dist
            = Distance(Prev, Curr);
Uncertain<double> Speed = Dist / 5;
```



86% more accurate!

5 mph

In the beginning...

We want to make programming with sensors easier.

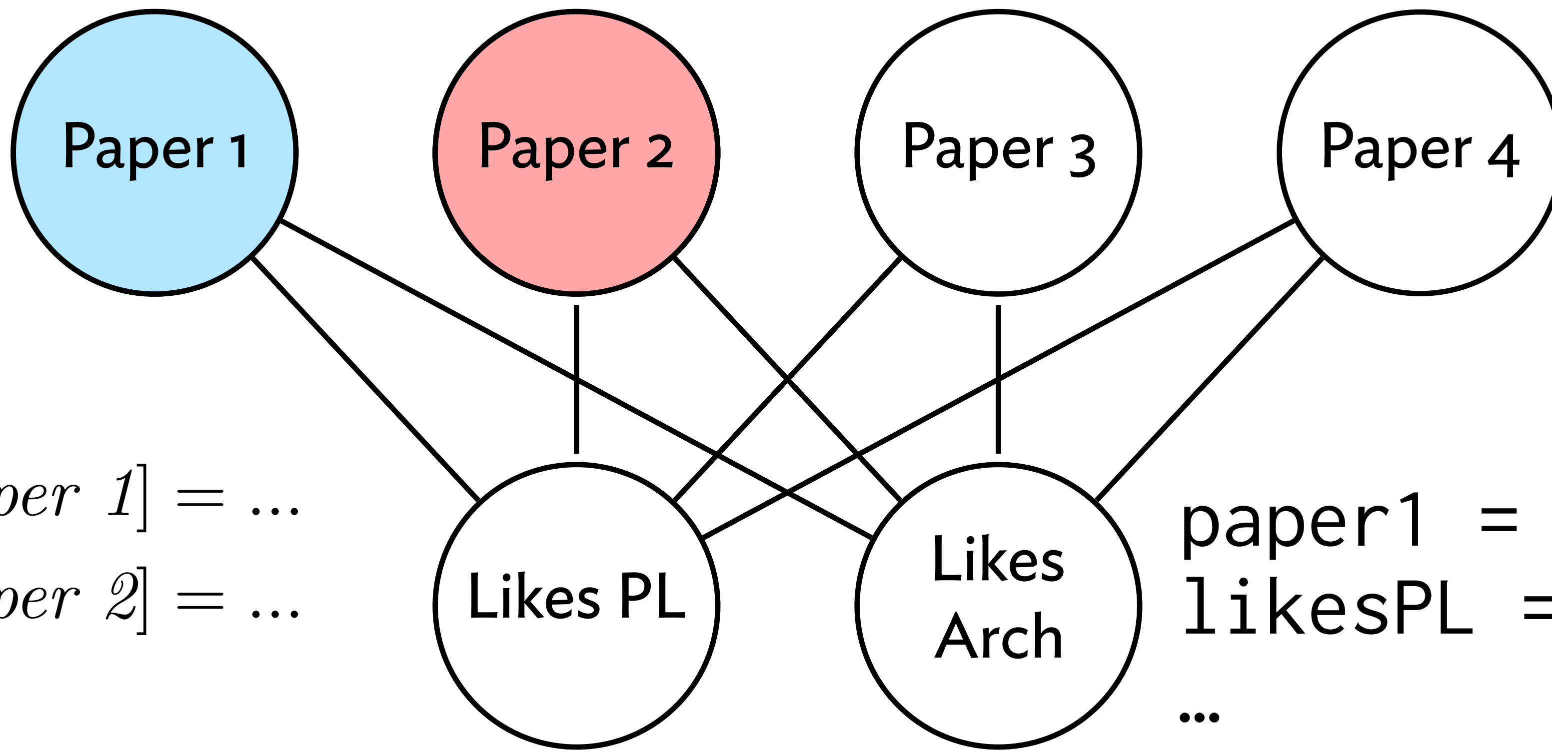
We already have the cute name: Uncertain<T>.

Nah, this will never work.

Probabilistic programming

Programming language support for **probabilistic modeling**

Let's build a recommendation system!



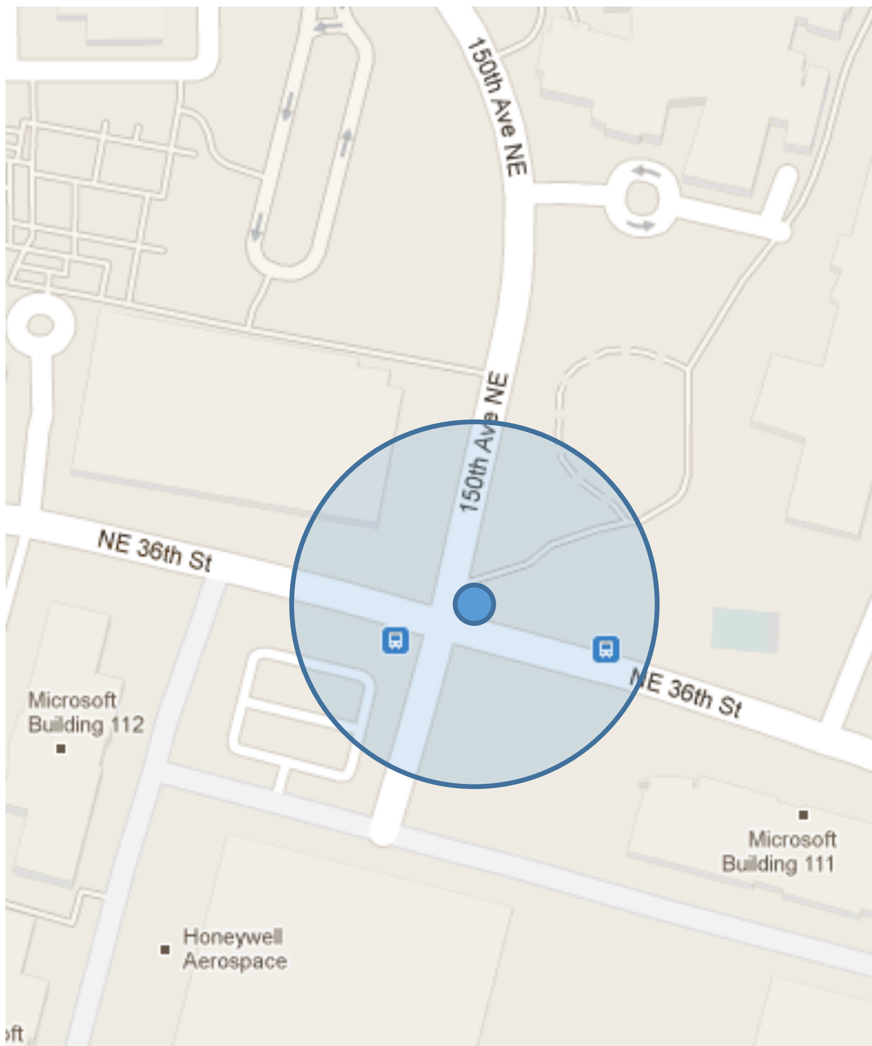
$P[Likes\ PL | Paper\ 1] = \ldots$

$P[Likes\ PL | Paper\ 2] = \ldots$

$P[Paper\ 3 | Likes\ PL] = \ldots$

```
paper1 = …
likesPL = f(paper1, …)
…
```

Applications




```
public class GeoCoordinate {
    public double Latitude;
    public double Longitude;

    public double HorizontalAccuracy;
}
```

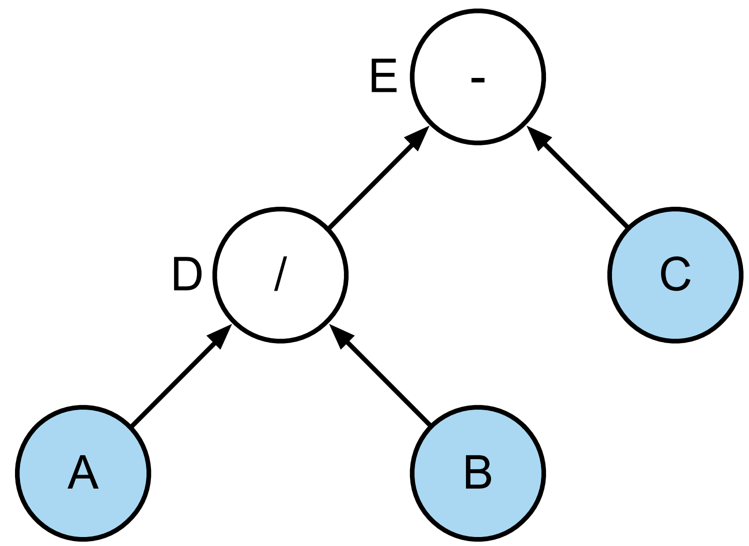
106 apps that use GPS

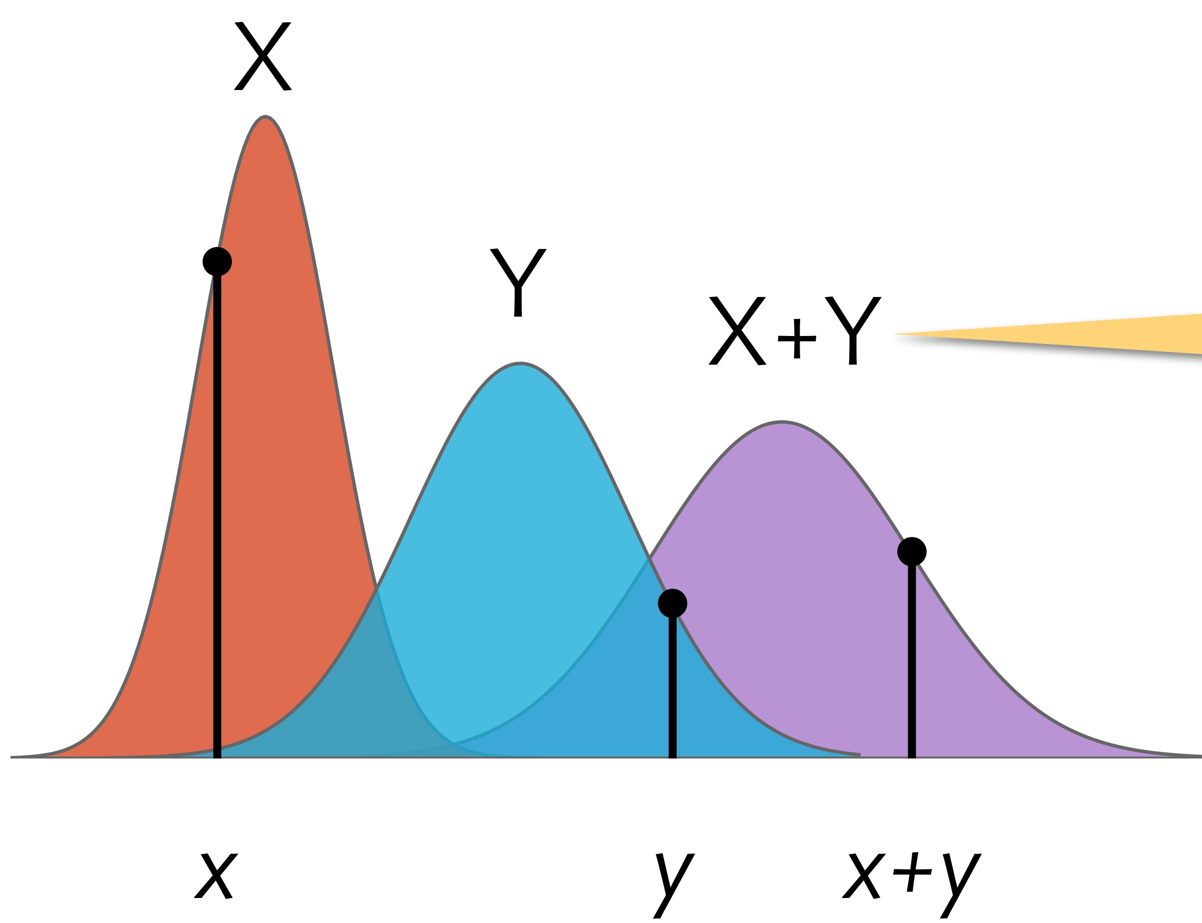
1 app that reads HorizontalAccuracy

Uncertain<T>

Programs are graphical models

```
A = Get()
B = Get()
C = Get()
D = A / B
E = D - C
```





So long as the data sources are updated, we can get distributions for your code for free!

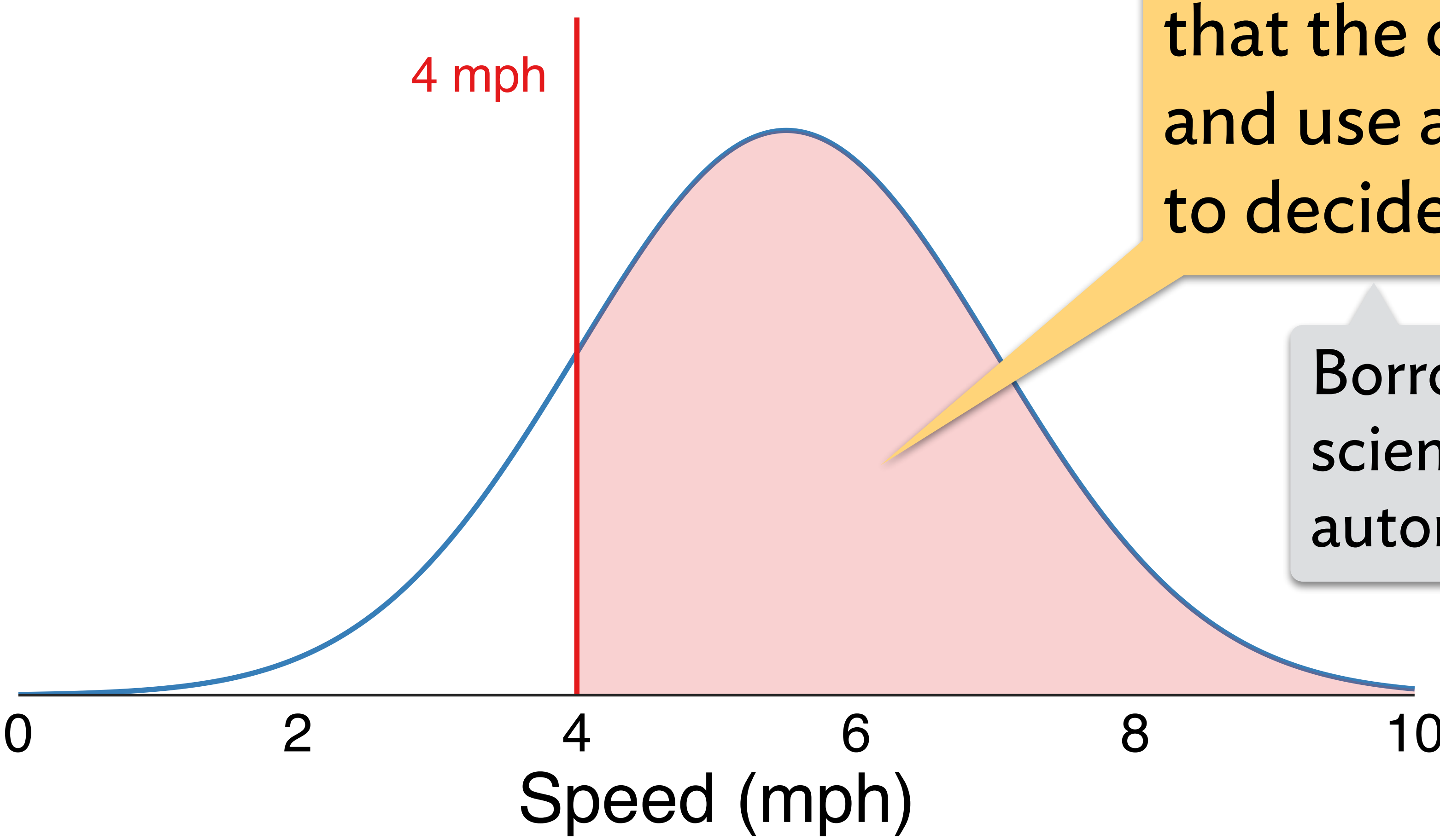
Uncertain<T>

Conditionals in your code are great places to do inference

```
if (Speed > 4)
    Alert("You rock!");
```

Compute the *probability* that the condition is true, and use a *hypothesis test* to decide the branch

Borrow from medical science to provide fully automated inference

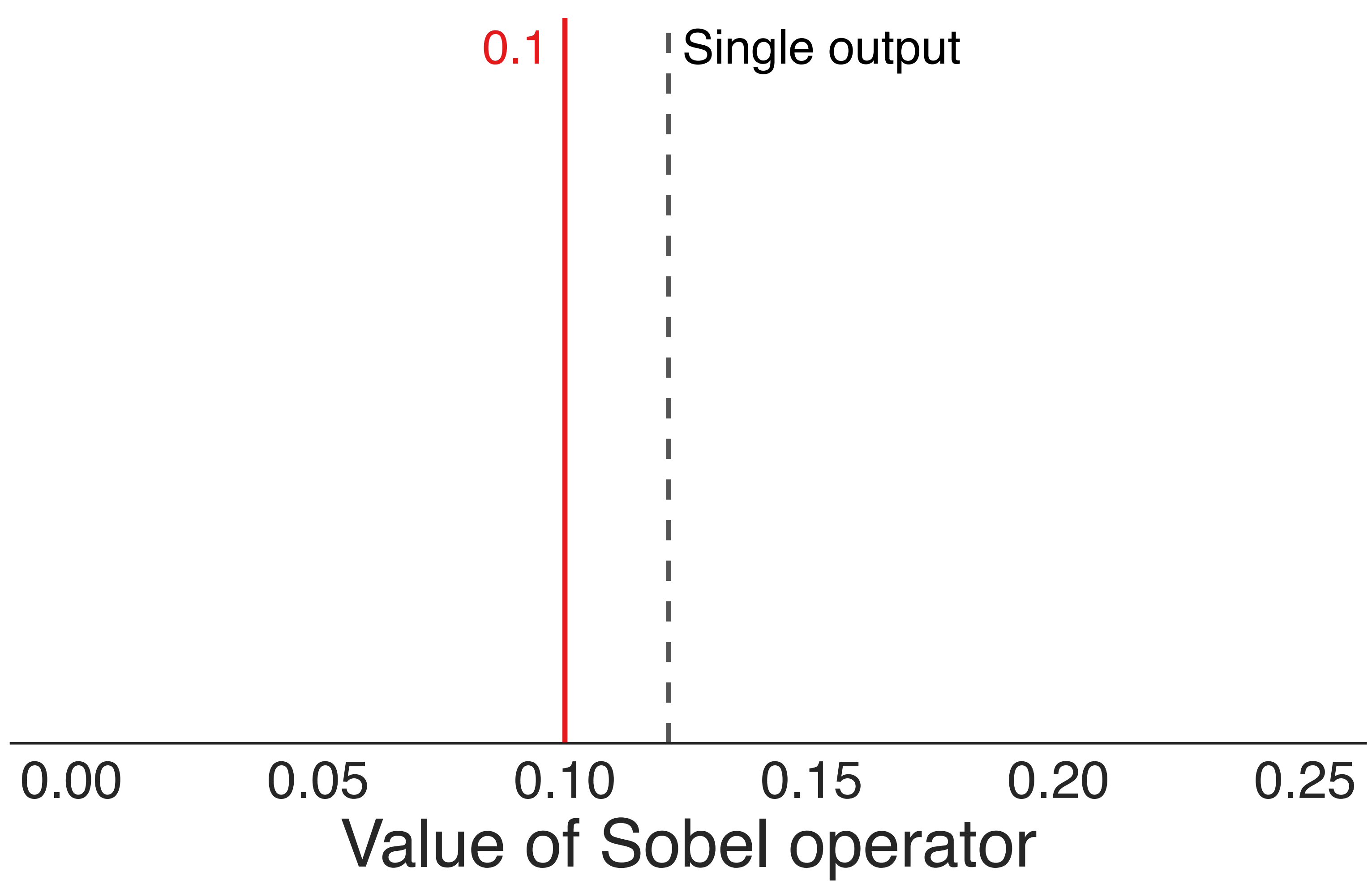


Uncertain<T> for machine learning

Neural networks give only a single output

```
if (Sobel(p) > 0.1)
    EdgeFound();
```

36% false positives!



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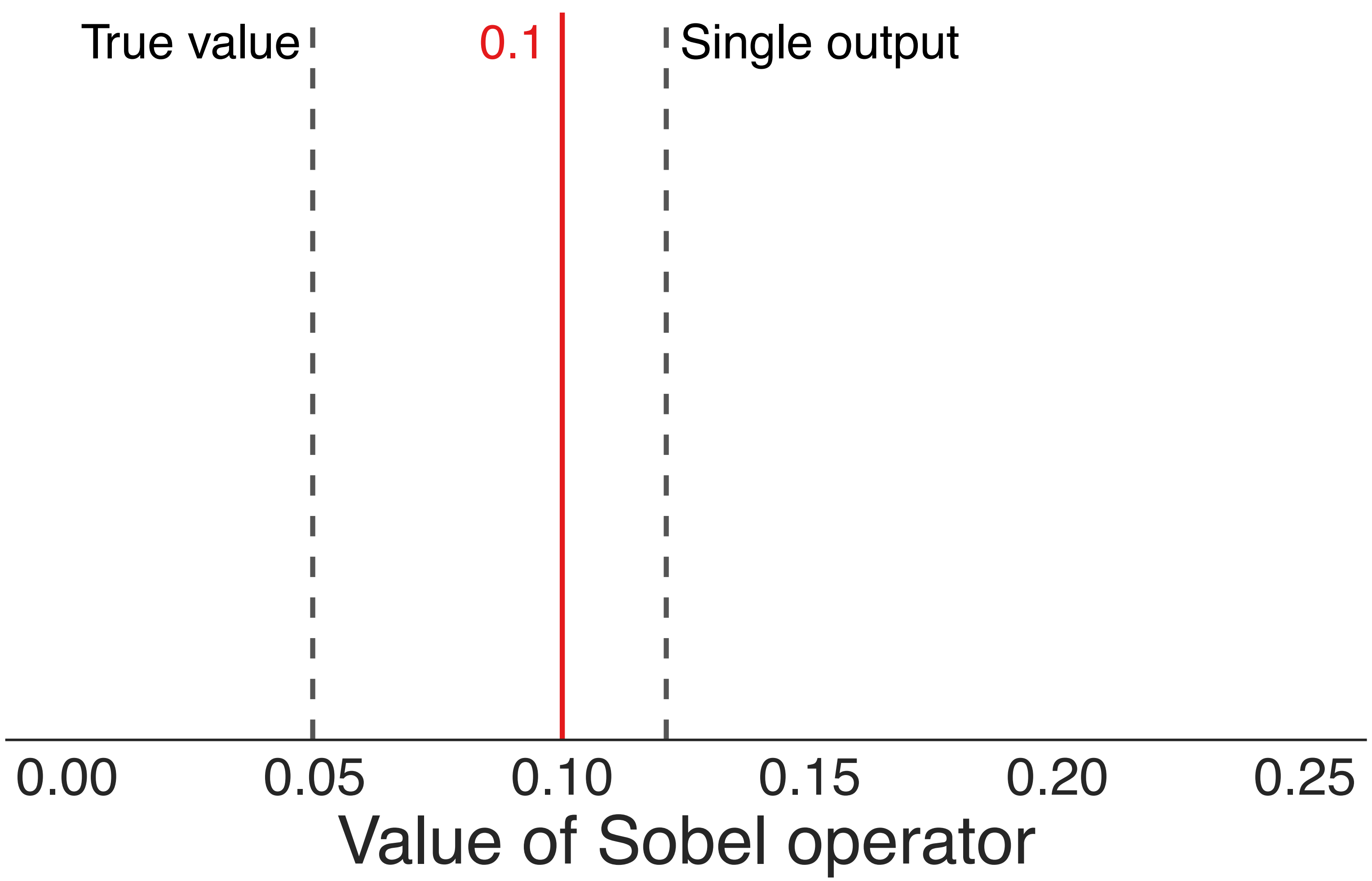

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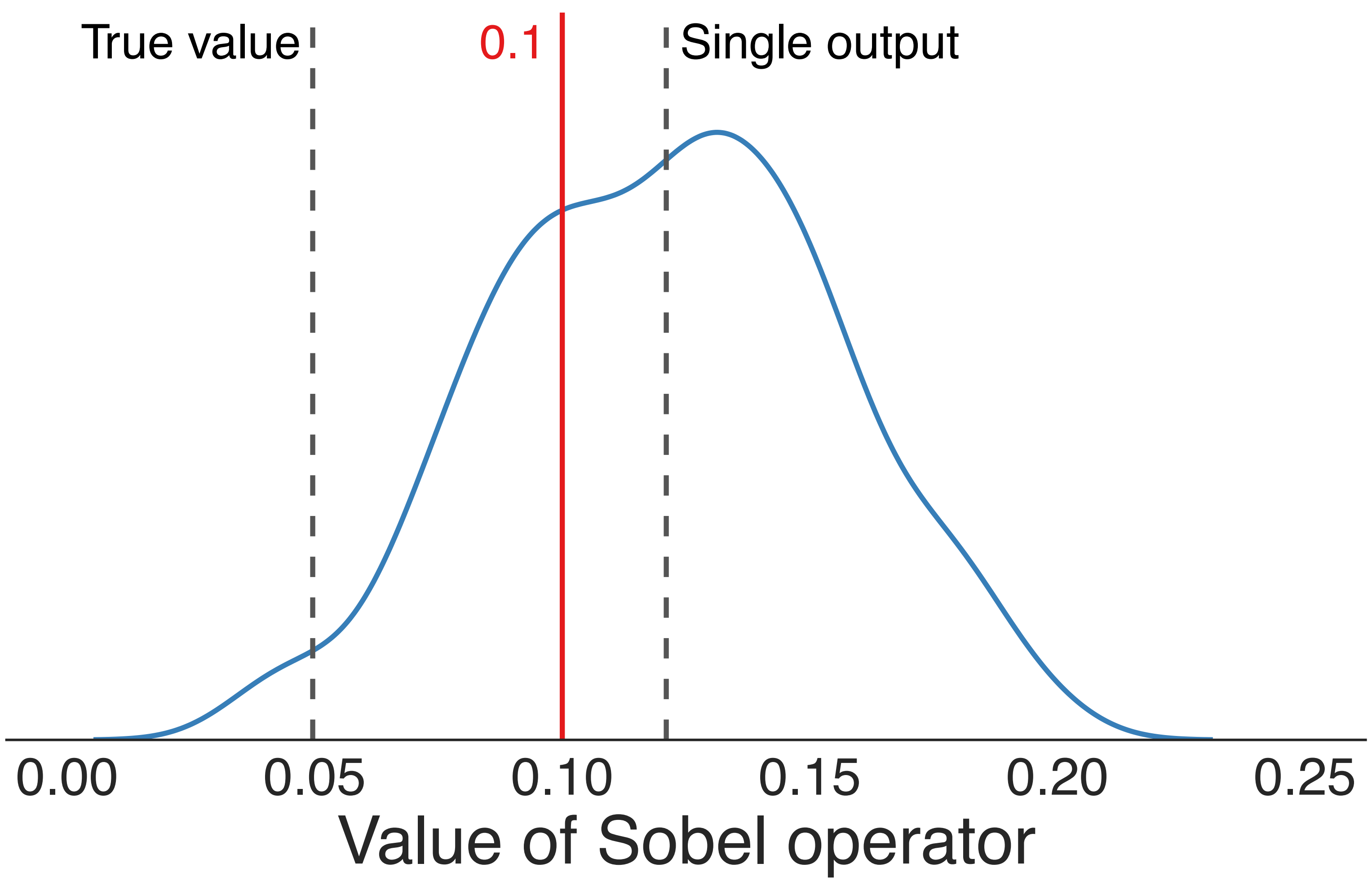

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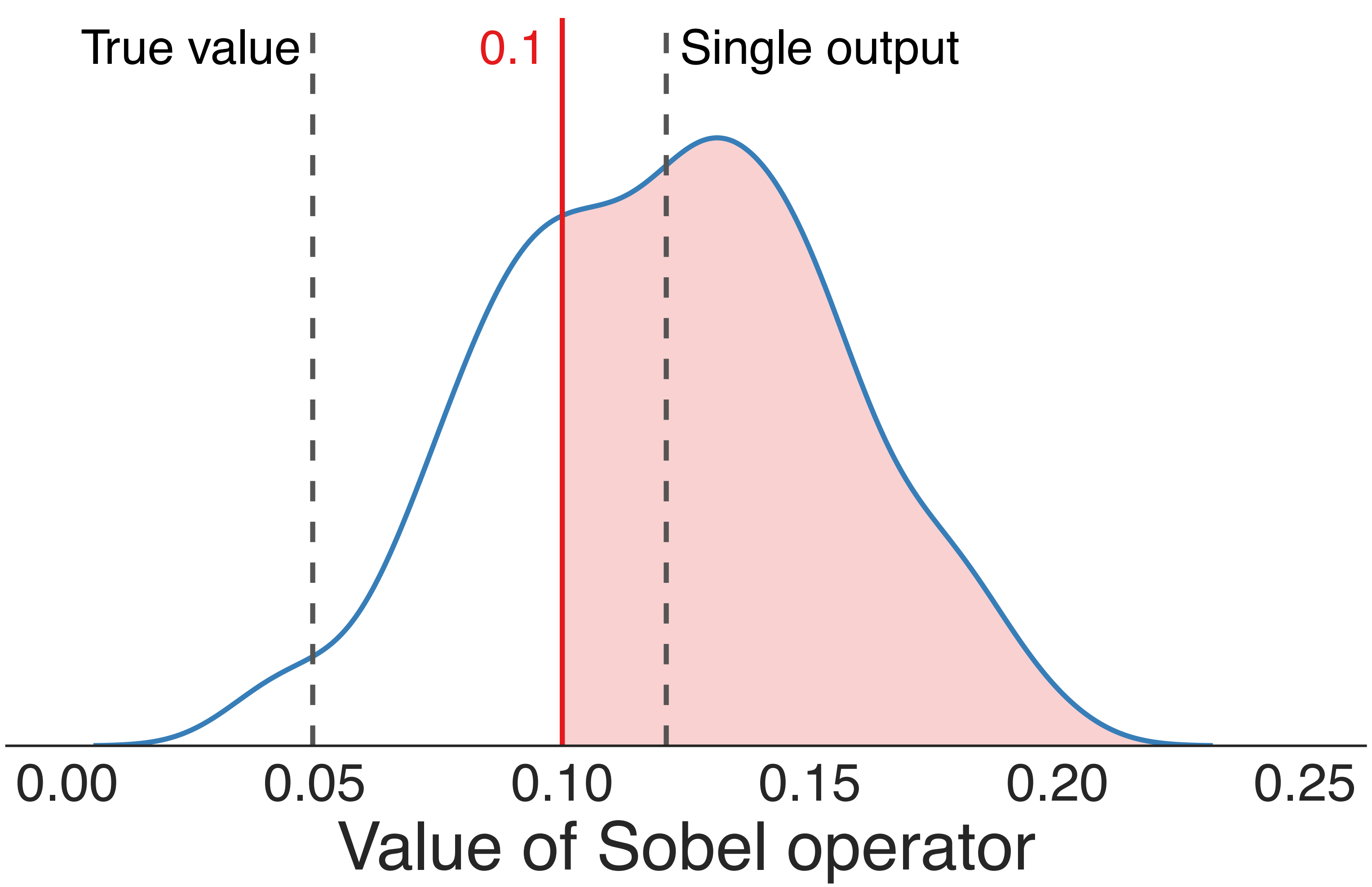

Done is better than good

We really need another case study for the paper.

I've been taking a machine learning class this semester…

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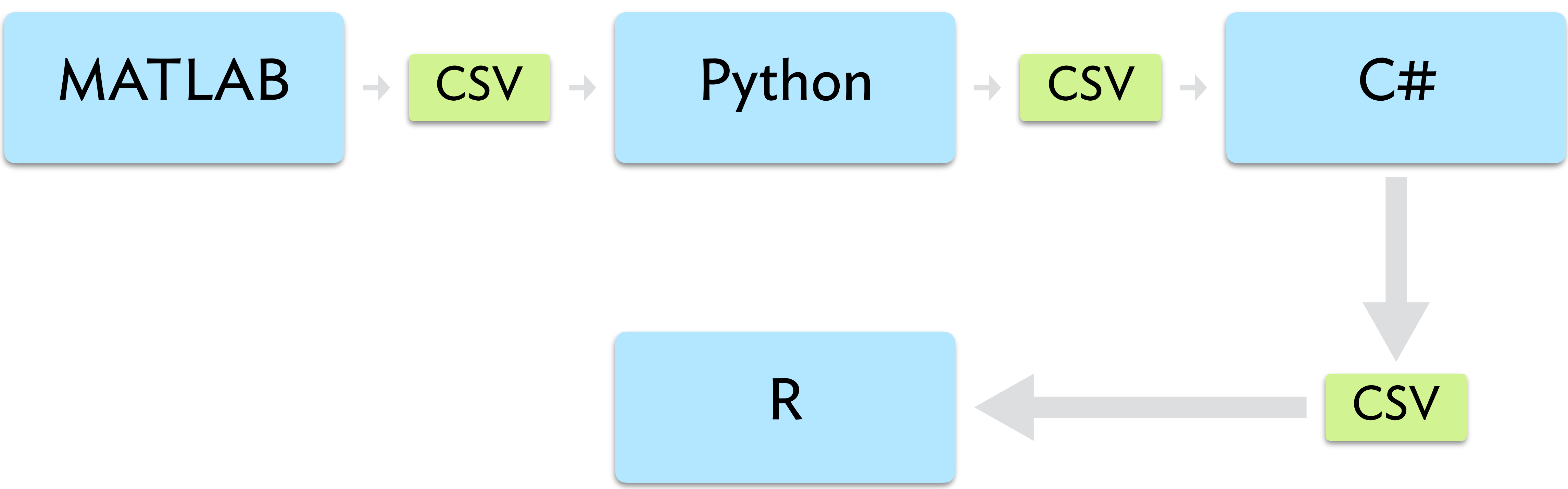

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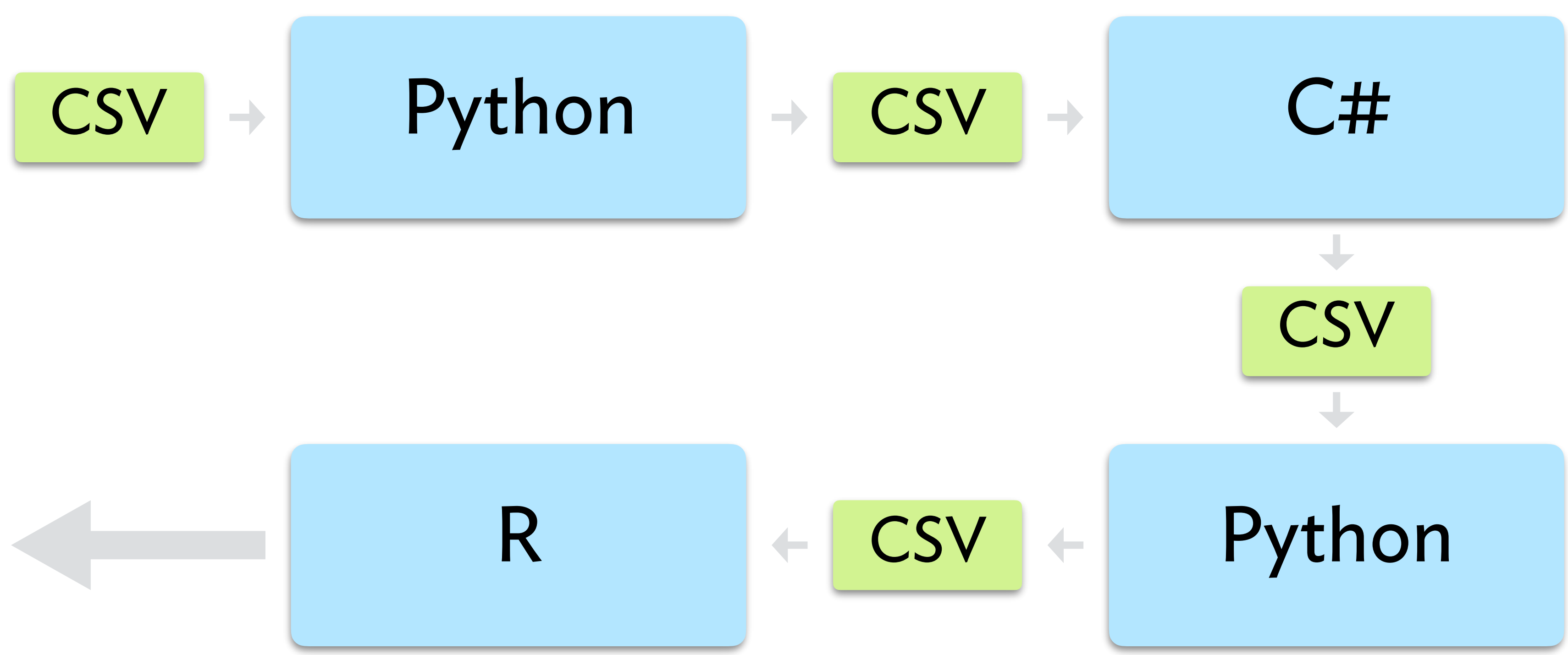

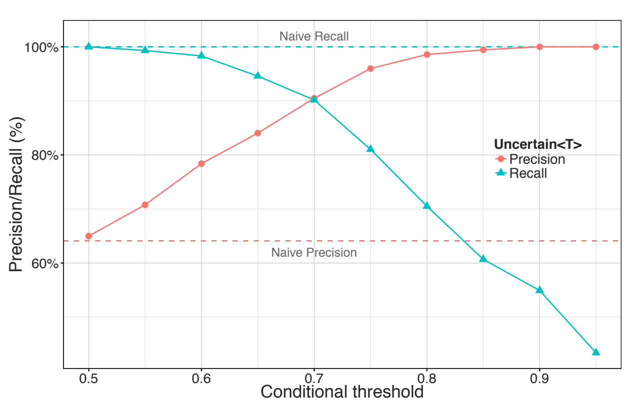

Neural networks make great examples

POPL'16

Optimizing Synthesis with Metasketches

James Bornholt Emina Torlak Dan Grossman Luis Ceze
University of Washington, USA
{bornholt, emina, djg, luisceze}@cs.washington.edu

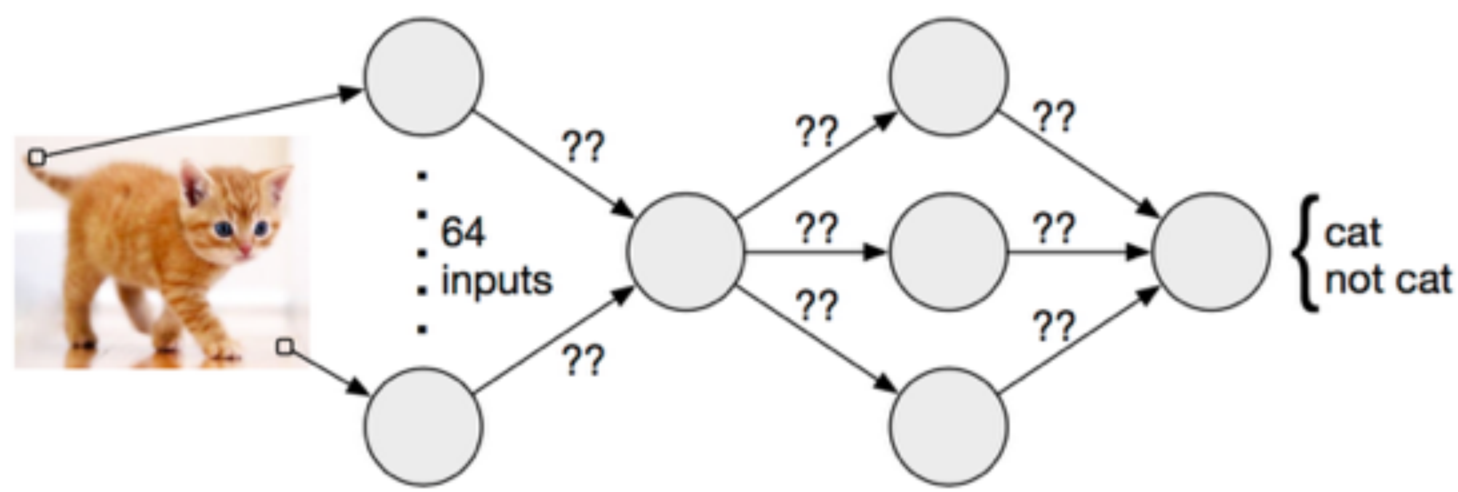

Figure 10. The sketch for a neural network is an SSA-form implementation of its evaluation function, with holes for each weight. In this example, the input nodes are the grayscale values of each pixel in the input image, and the output is a binary classification.

PLSE @ University of Washington