Fast, Lean, and Accurate: Modeling Password Guessability Using Neural Networks

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Carnegie Mellon University

Guessing Methods

Guessing Methods

- **John the Ripper + Hashcat**

Guessing Methods

- **John the Ripper + Hashcat**

Dictionary word + Rules

Guessing Methods

- **John the Ripper + Hashcat**

Dictionary word + Rules

`password` + append 2 digits

Guessing Methods

- **John the Ripper + Hashcat**

Dictionary word + Rules

`password` + append 2 digits

```
password11
password12
...
```

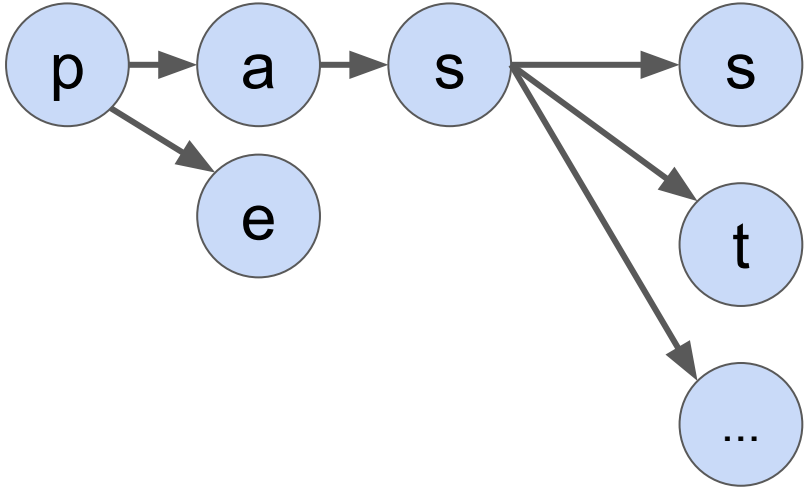
Guessing Methods

- **John the Ripper + Hashcat**
- **Markov Models**

Guessing Methods

- **John the Ripper + Hashcat**

- **Markov Models**



Guessing Methods

- **John the Ripper + Hashcat**
- **Markov Models**
- **PCFGs**

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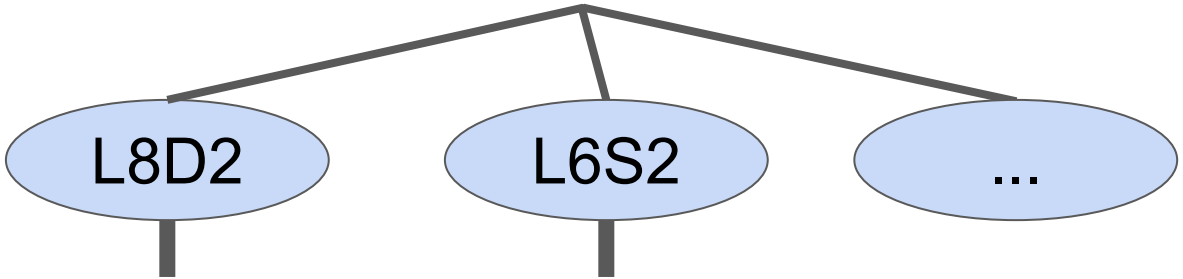
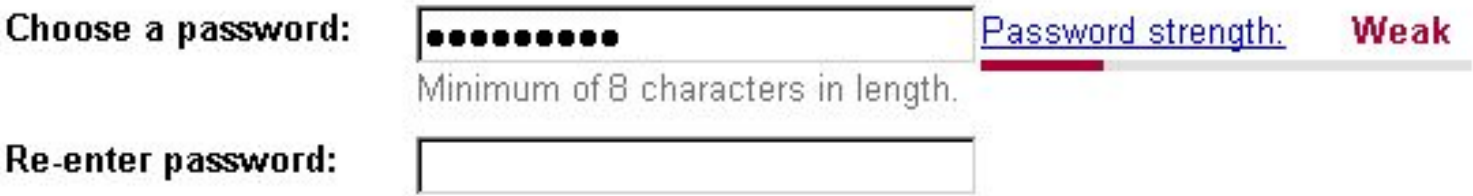



```
password12   monkey!!
password11   qwerty..
...          ...
```

Guessing Methods

- **John the Ripper + Hashcat**
- **Markov Models**
- **PCFGs**

Why Model Guessing Attacks?



Can we guess more accurately?

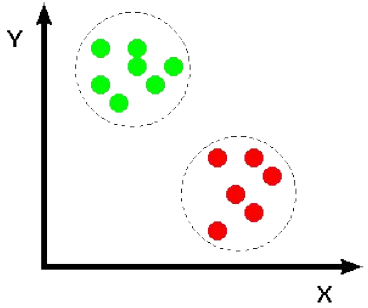
Quicker?

With fewer resources?

Our Approach: Neural Networks

Hello = Здравствуйте

Handwriting Recognition →
Handwriting recognition



Outline: Guessing with Neural Networks

- Password guesser design
- Comparison to other methods
- Real-time, in-browser feedback

Generating Passwords by Predicting

Generating Passwords by Predicting

`passw` → o or maybe `0` or 0 or ...

Generating Passwords by Predicting

passw →

Next char is:

A: 3%
B: 1%
C: 0.6%
…
O: 55%
…
Z: 0.01%
0: 20%
1: ...

Generating Passwords by Predicting

“”

P: 100%

Generating Passwords by Predicting

“”

P: 100%

Next char is:

A:	3%
B:	2%
C:	5%
…	
O:	2%
…	
Z:	0.2%
0:	1%
1:	…
END:	2%

Generating Passwords by Predicting

“”

P: 100%

Next char is:

A:	3%
B:	2%
C:	5%
…	
O:	2%
…	
Z:	0.2%
0:	1%
1:	…
END:	2%

Generating Passwords by Predicting

“”

P: 100%

Next char is:

A:	3%
B:	2%
C:	5%
…	
O:	2%
…	
Z:	0.2%
0:	1%
1:	…
END:	2%

Generating Passwords by Predicting

“C”
P: 5%

Generating Passwords by Predicting

“C”

P: 5%

Next char is:

A:	10%
B:	1%
C:	4%
…	
O:	8%
…	
Z:	0.02%
0:	3%
1:	…
END:	6%

Generating Passwords by Predicting

"C"

P: 5%

Next char is:

A:	10%
B:	1%
C:	4%
…	
O:	8%
…	
Z:	0.02%
0:	3%
1:	…
END:	6%

Generating Passwords by Predicting

"CA"
P: 0.5%

Next char is:

A:	3%
B:	10%
C:	7%
…	
O:	1%
…	
Z:	0.03%
0:	2%
1:	…
END:	12%

Generating Passwords by Predicting

"CAB"

P: 0.05%

Next char is:

A:	3%
B:	10%
C:	7%
…	
O:	1%
…	
Z:	0.03%
0:	2%
1:	…
END:	3%

Generating Passwords by Predicting

"CAB"
P: 0.05%

Next char is:

A:	4%
B:	3%
C:	1%
…	
O:	2%
…	
Z:	0.01%
0:	4%
1:	…
END:	12%

Generating Passwords by Predicting

"CAB"

P: 0.05%

Next char is:

A:	4%
B:	3%
C:	1%
…	
O:	2%
…	
Z:	0.01%
0:	4%
1:	…
END:	12%

Generating Passwords by Predicting

“CAB”
P: 0.006%

Generating Passwords

`CAB` - 0.006%
`CAC` - 0.0042%
`ADD1` - 0.002%
`CODE` - 0.0013%
...

Generating Passwords

CAR - 0.006%

CAC - 0.0042%

ADD1 - 0.002%

CODE - 0.0013%

...

MUST BE LONGER THAN 3 CHARACTERS

Password Policies: 1class8

1 character class and 8 characters minimum

`password123`

`12345678`

`monkey99`

Password Policies: 3class12

3 character class and 12 characters minimum

llamalove123

Mypassword#3

N@rut0_r0ck5

Outline: Guessing with Neural Networks

- Password guesser design
- **Comparison to other methods**
- Real-time, in-browser feedback

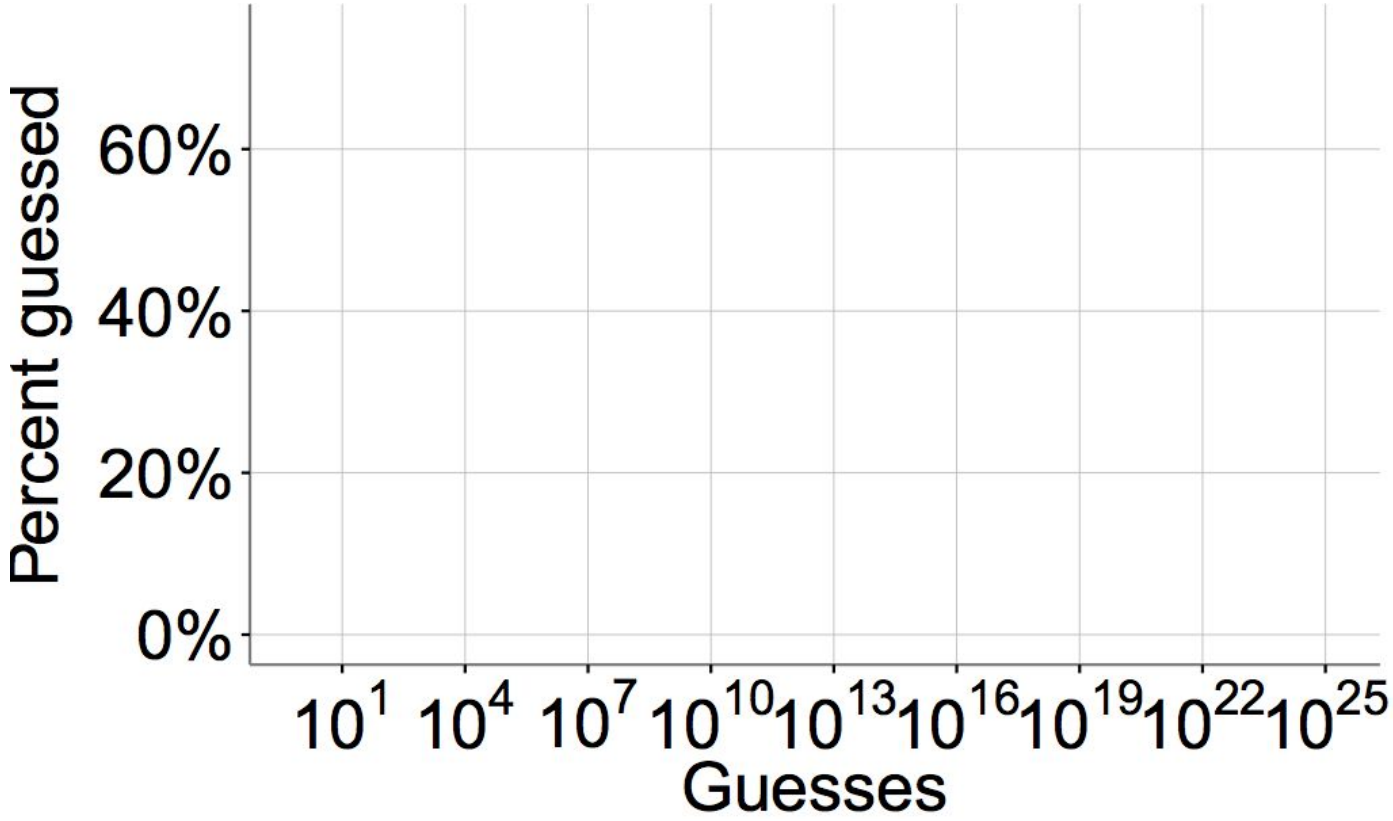
We Had to Try Many Parameters

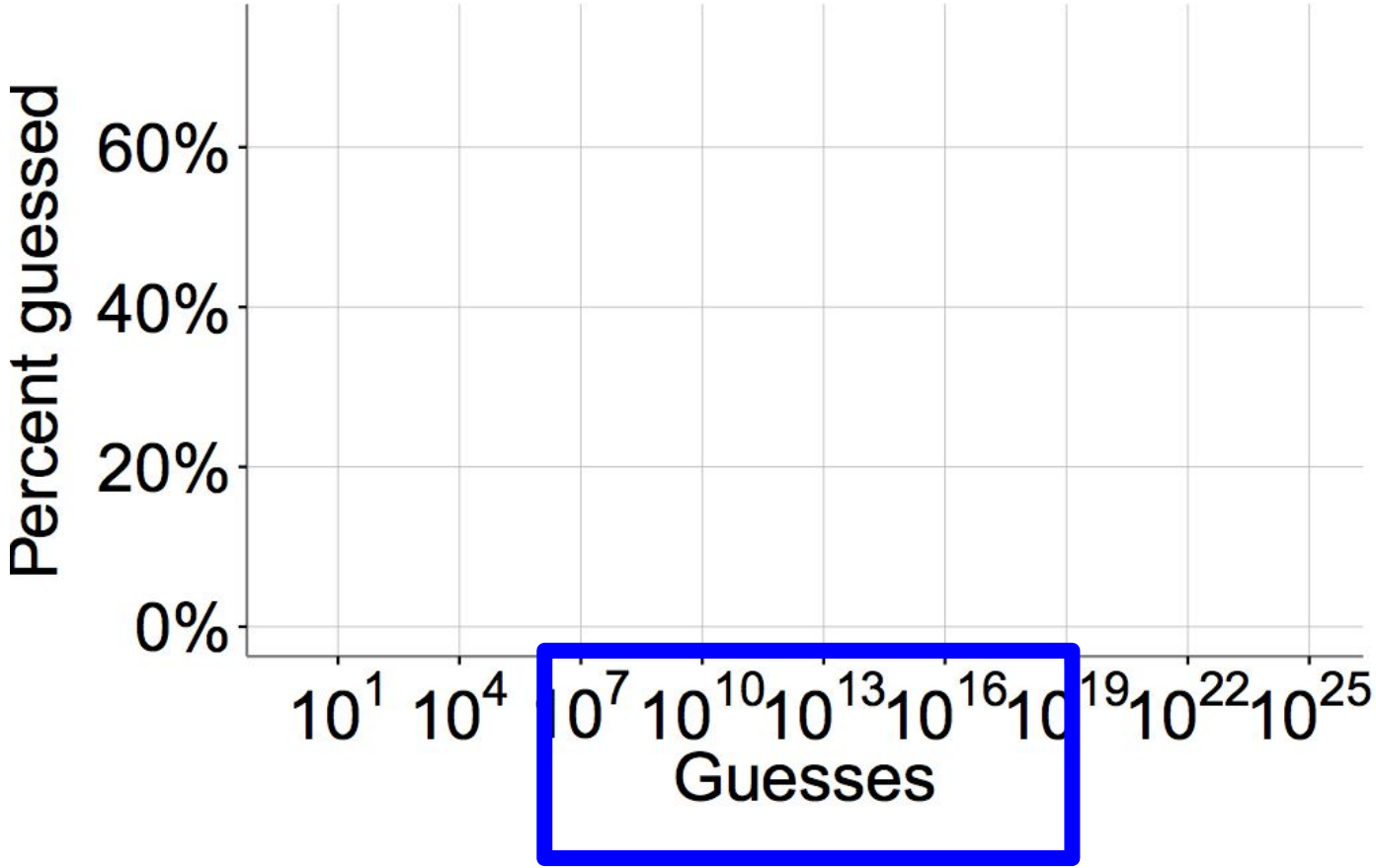
- Model size: 60MB, 3MB
- Transference learning
- Training data
- Model architecture
- Alphabet size
- Password context

Testing Methodology

- Approach: measure # guessed passwords
- Training data: leaked password sets
- Testing data
  - MTurk study passwords: 1class8, 4class8, 1class16, 3class12
  - Real passwords: 000webhost password leak
- Estimate guess numbers with Monte-Carlo technique (Dell'Amico and Filippone, CCS '15)

Comparison to other approaches


Percent guessed
60%
40%
20%
0%
10^1 10^4 10^7 10^{10} 10^{13} 10^{16} 10^{19} 10^{22} 10^{25}
Guesses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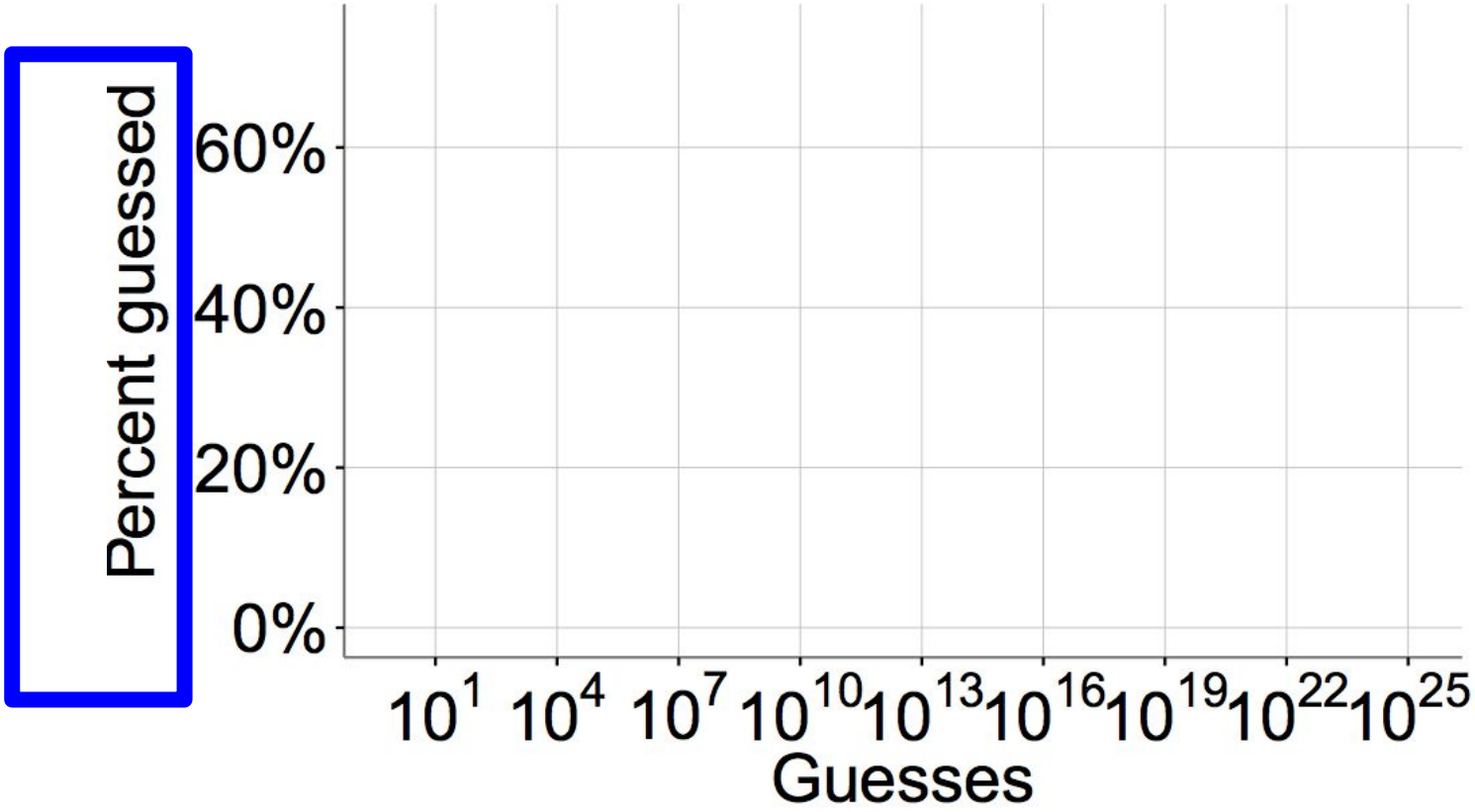
Percent guessed
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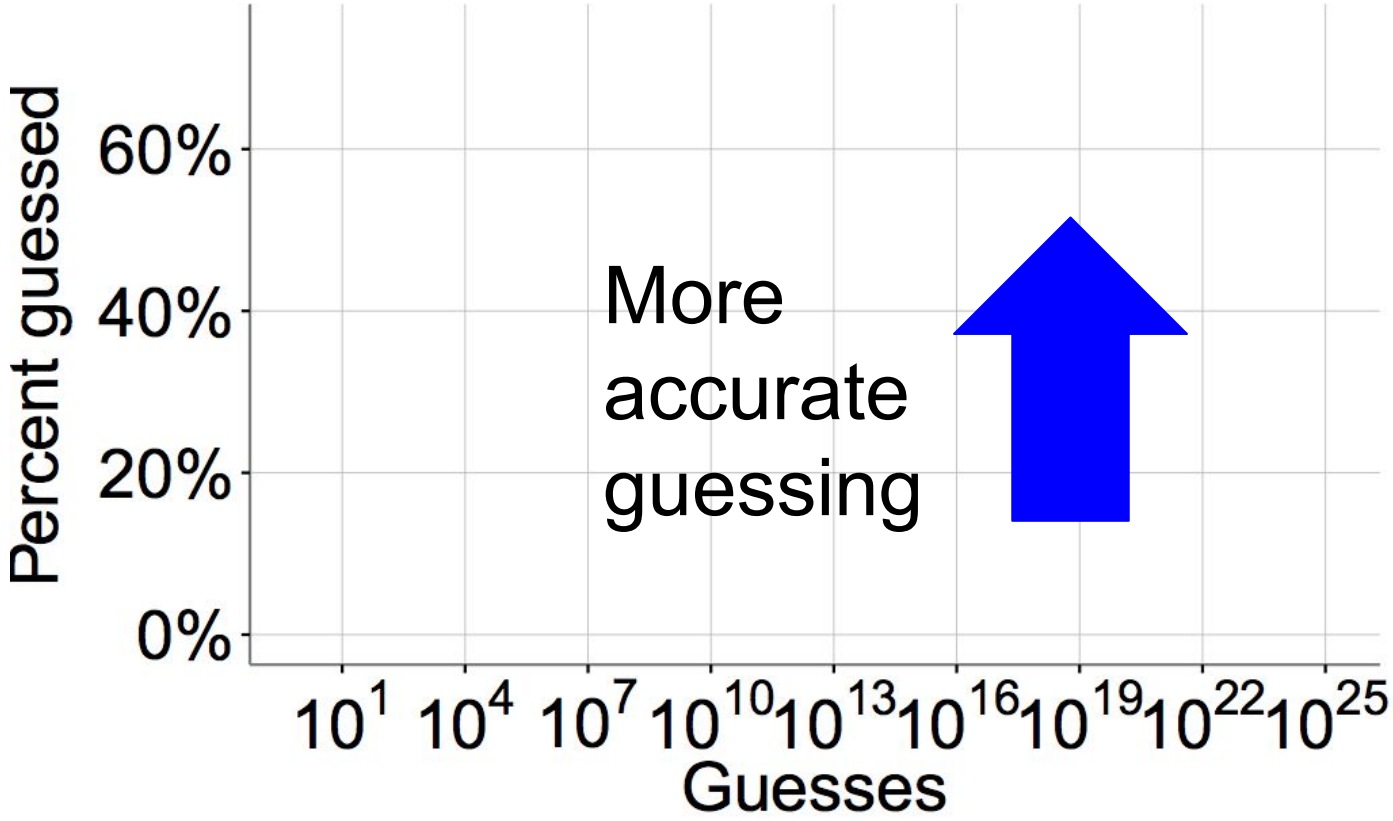
Guesses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More
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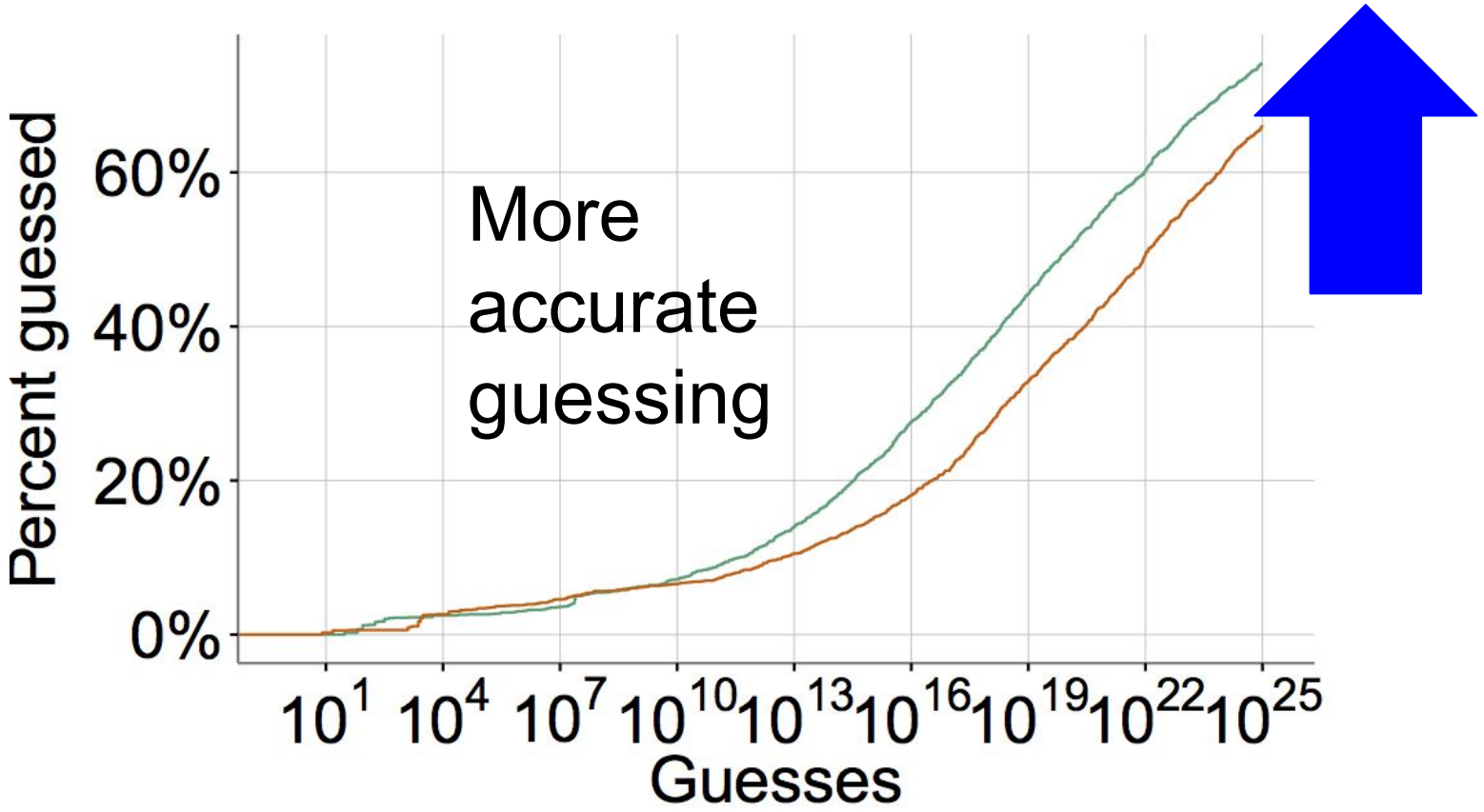
Guesses


Percent guessed
60%
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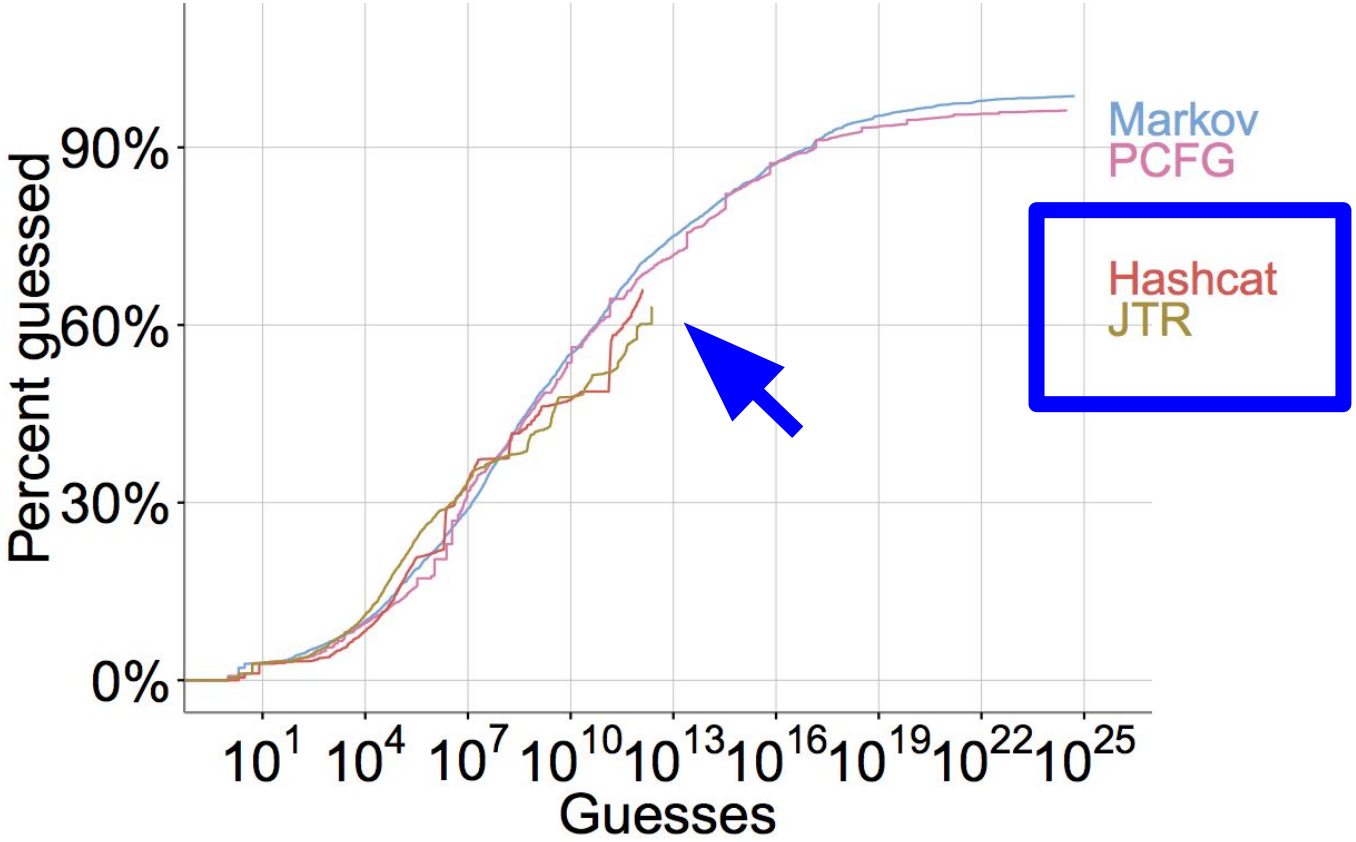
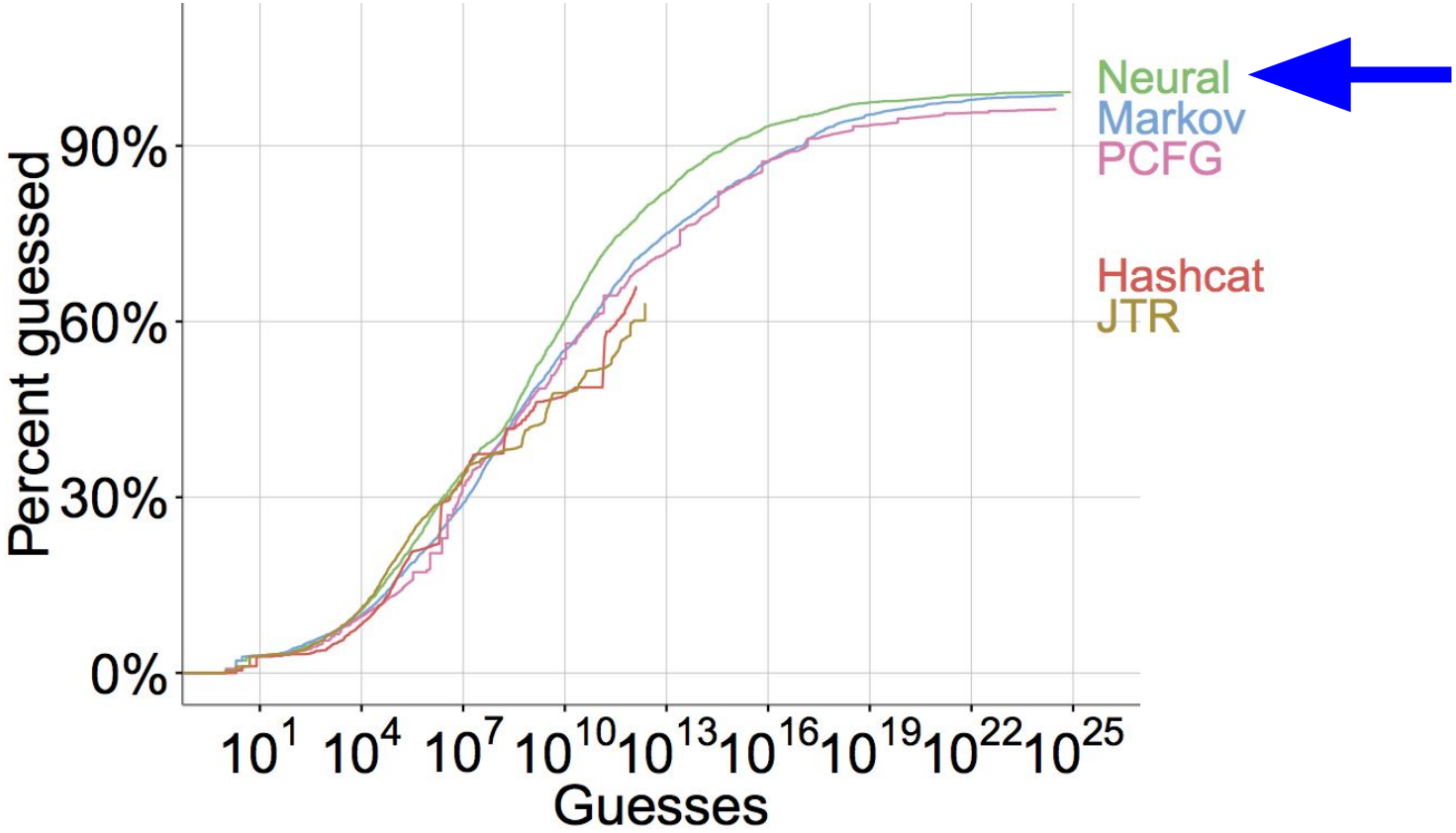
0%
More accurate guessing
10^1 10^4 10^7 10^{10} 10^{13} 10^{16} 10^{19} 10^{22} 10^{25}
Guesses

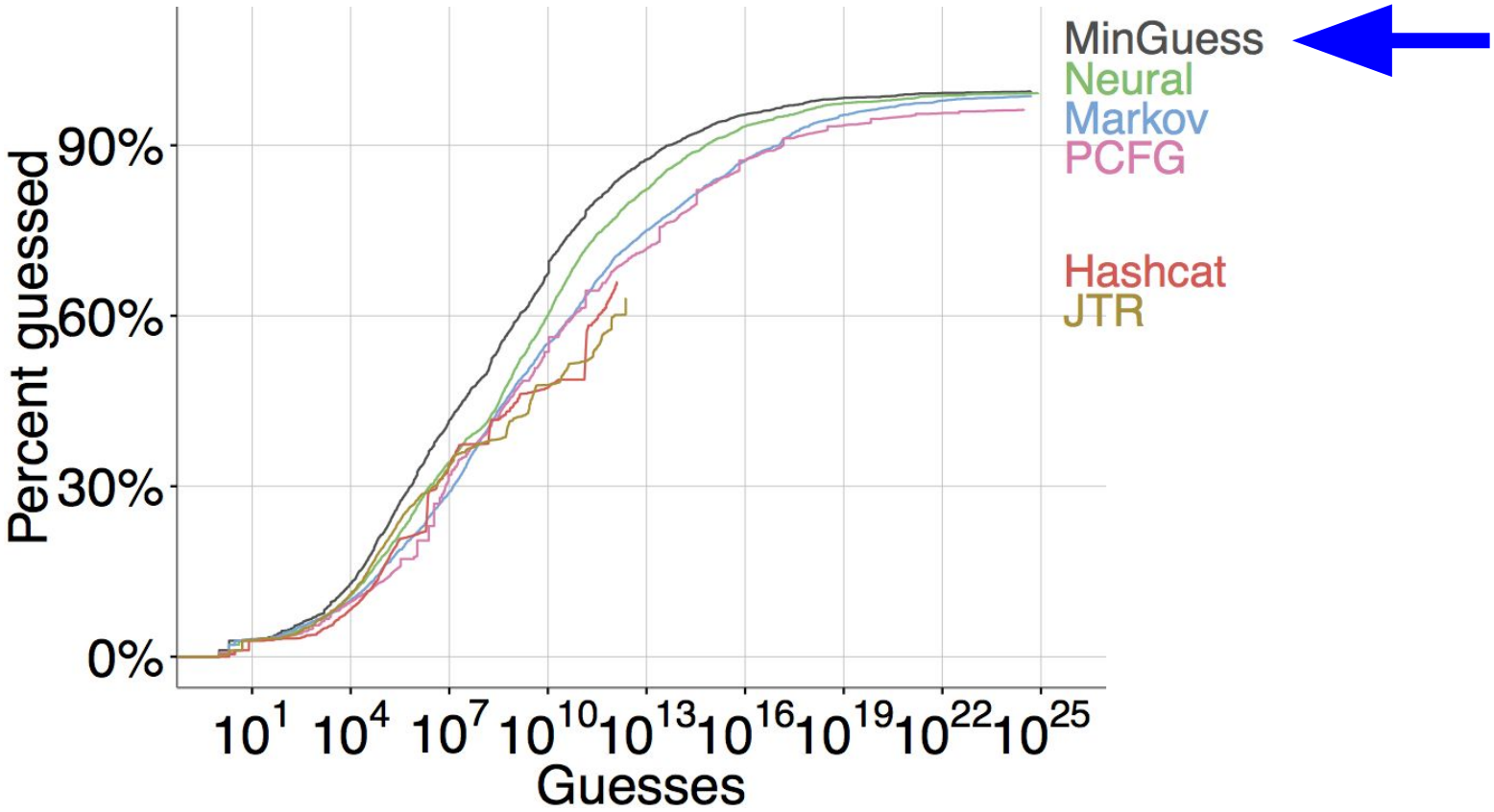
1class8: Comparison



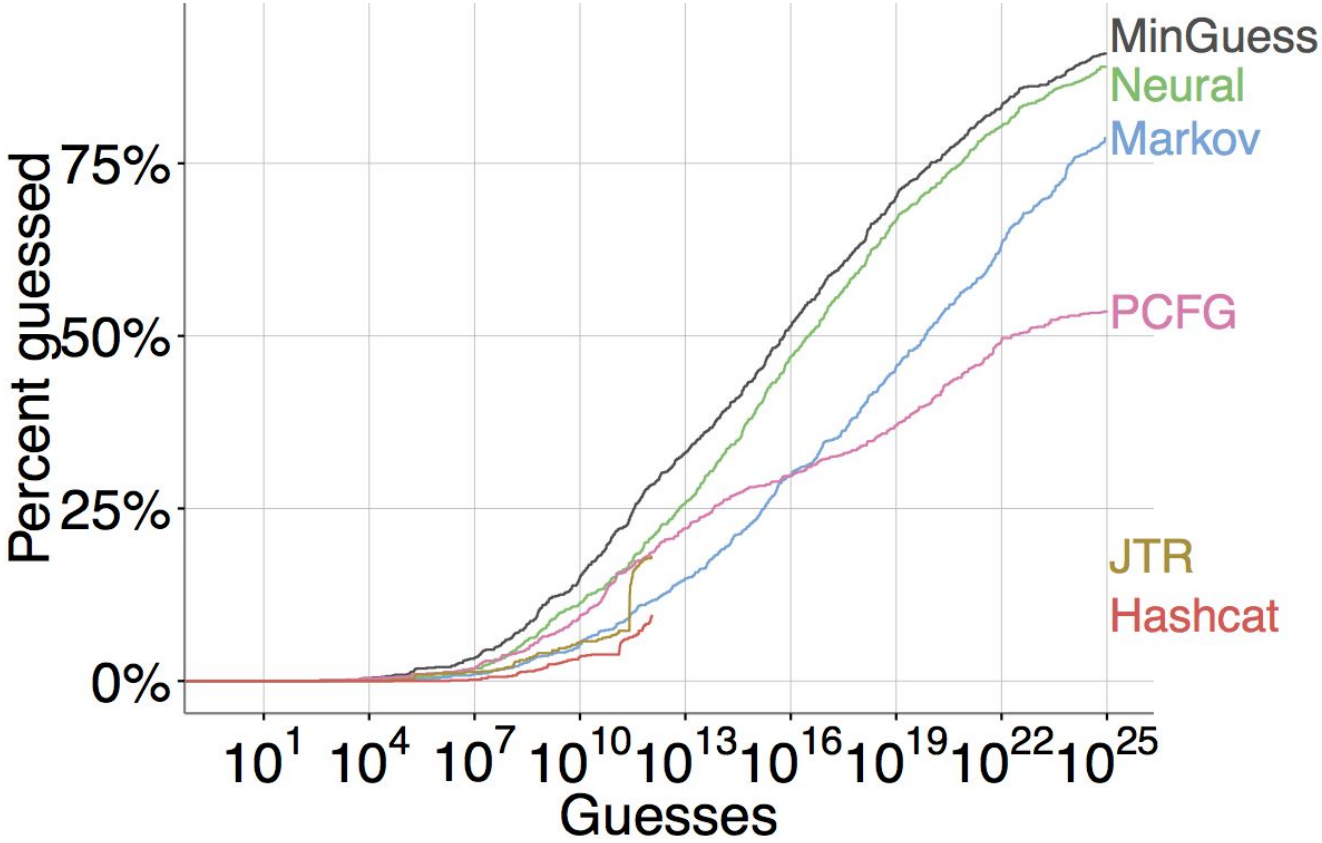
1class8: Neural Networks Guess Better



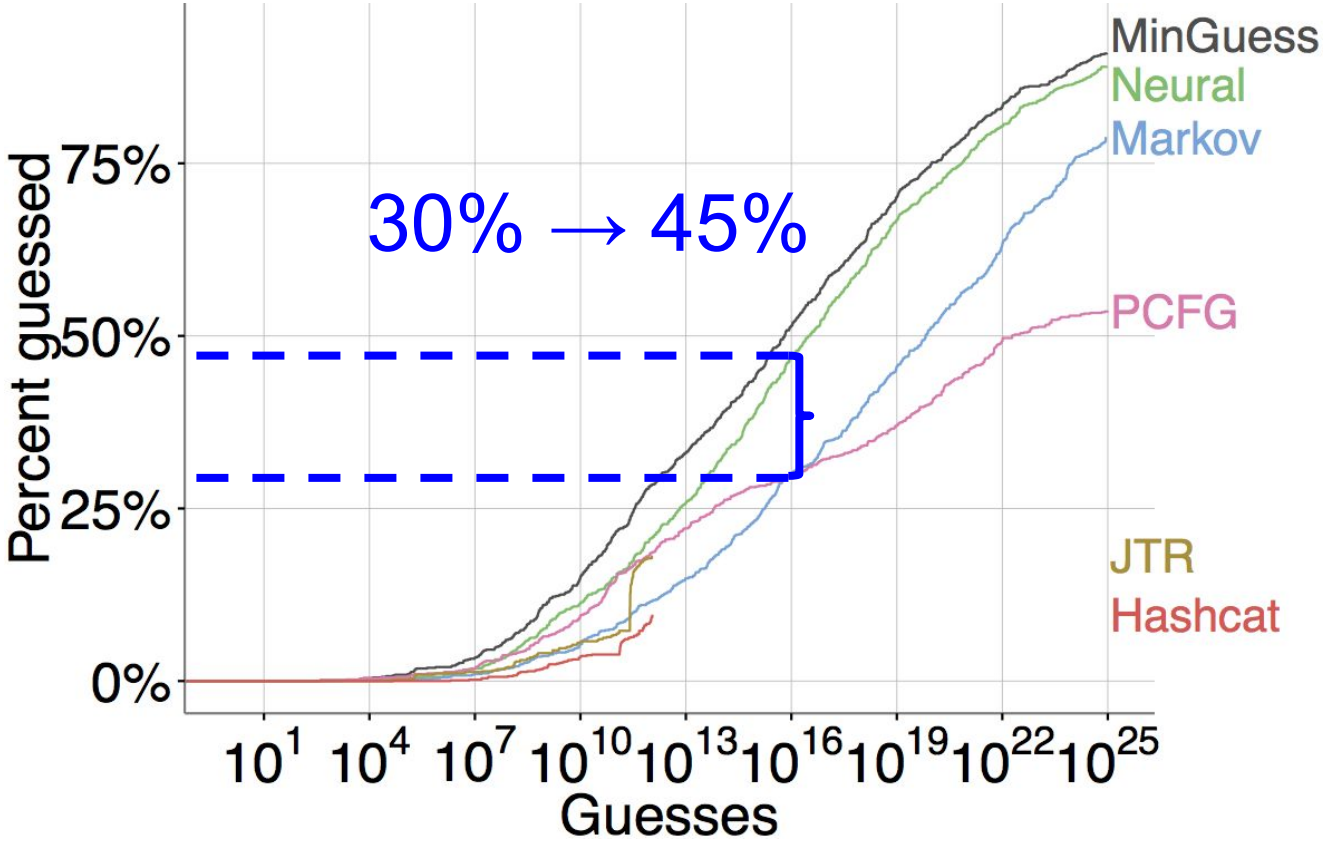
1class8: Neural Networks Guess Better



3class12: Neural Networks Guess Better



3class12: Neural Networks Guess Better



Outline: Guessing with Neural Networks

- Password guesser design
- Comparison to other methods
- **Real-time, in-browser feedback**

Current password feedback:

Quick ***or*** accurate

Accurate Guessing Methods

100s MB to GBs!

Accurate Guessing Methods

100s MB to GBs!

Accurate Guessing Methods

100s MB to GBs!

Neural networks: 60MB, 3MB

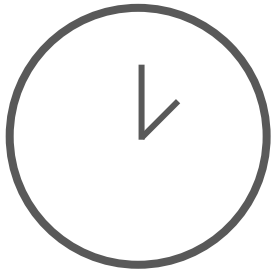
Accurate Guessing Methods

?

Neural networks: 60MB, 3MB

Accurate Guessing Methods

Hours to days!



Can neural networks give real-time feedback?

Ideal Model Targets

- Small: < 1MB
- Fast: < 0.1 sec
- JavaScript
- Accurate

Making Model Small

- Small version of neural network
- Quantize parameters of model
- Lossless compression

850KB < 1MB

Making Model Fast

- Pre-compute inexact mapping from prob to guess number
- Cache intermediate results
- Run on separate thread

17 ms < 0.1 sec

How Accurate Is the Small, Fast Model?

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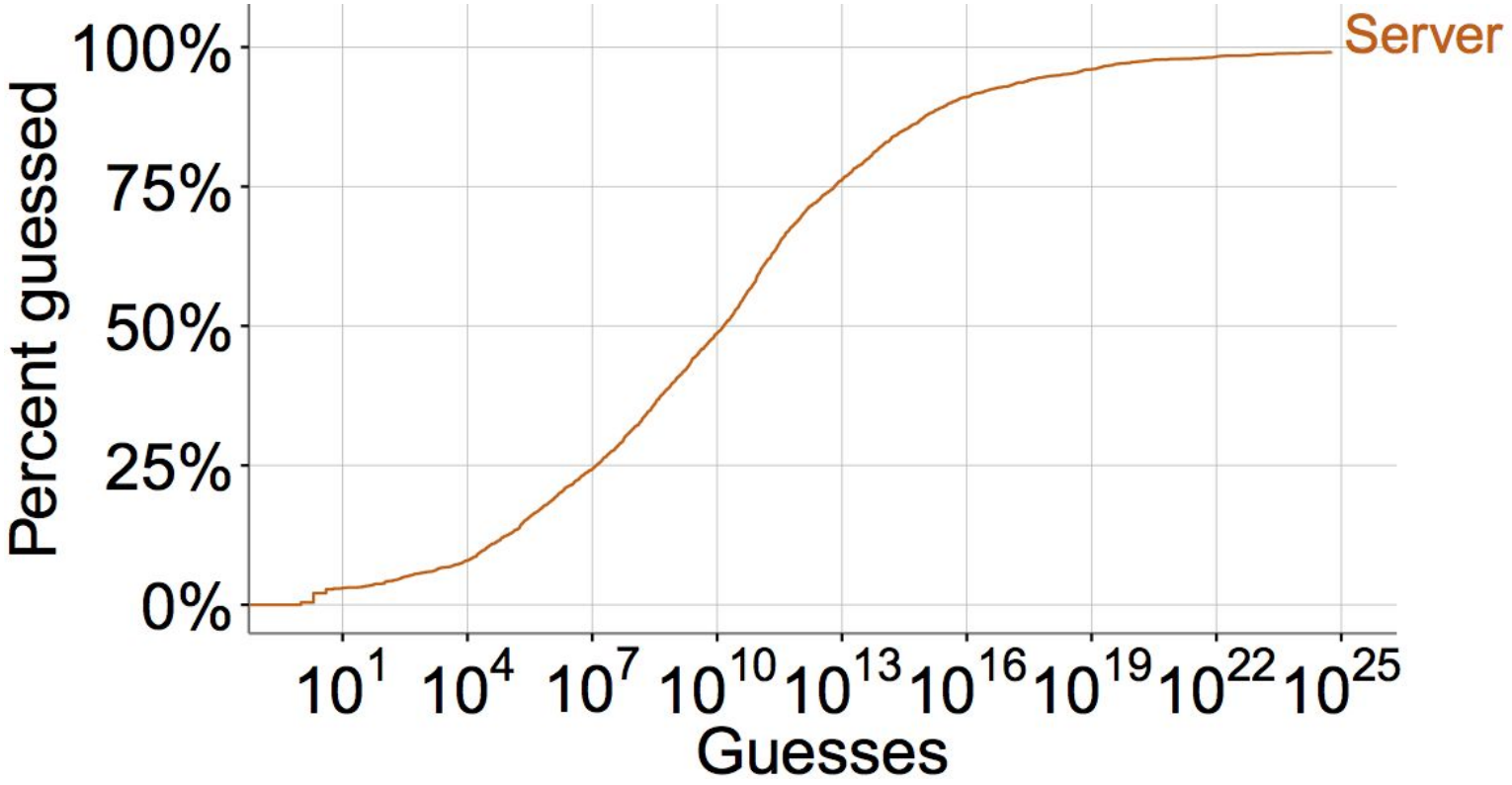

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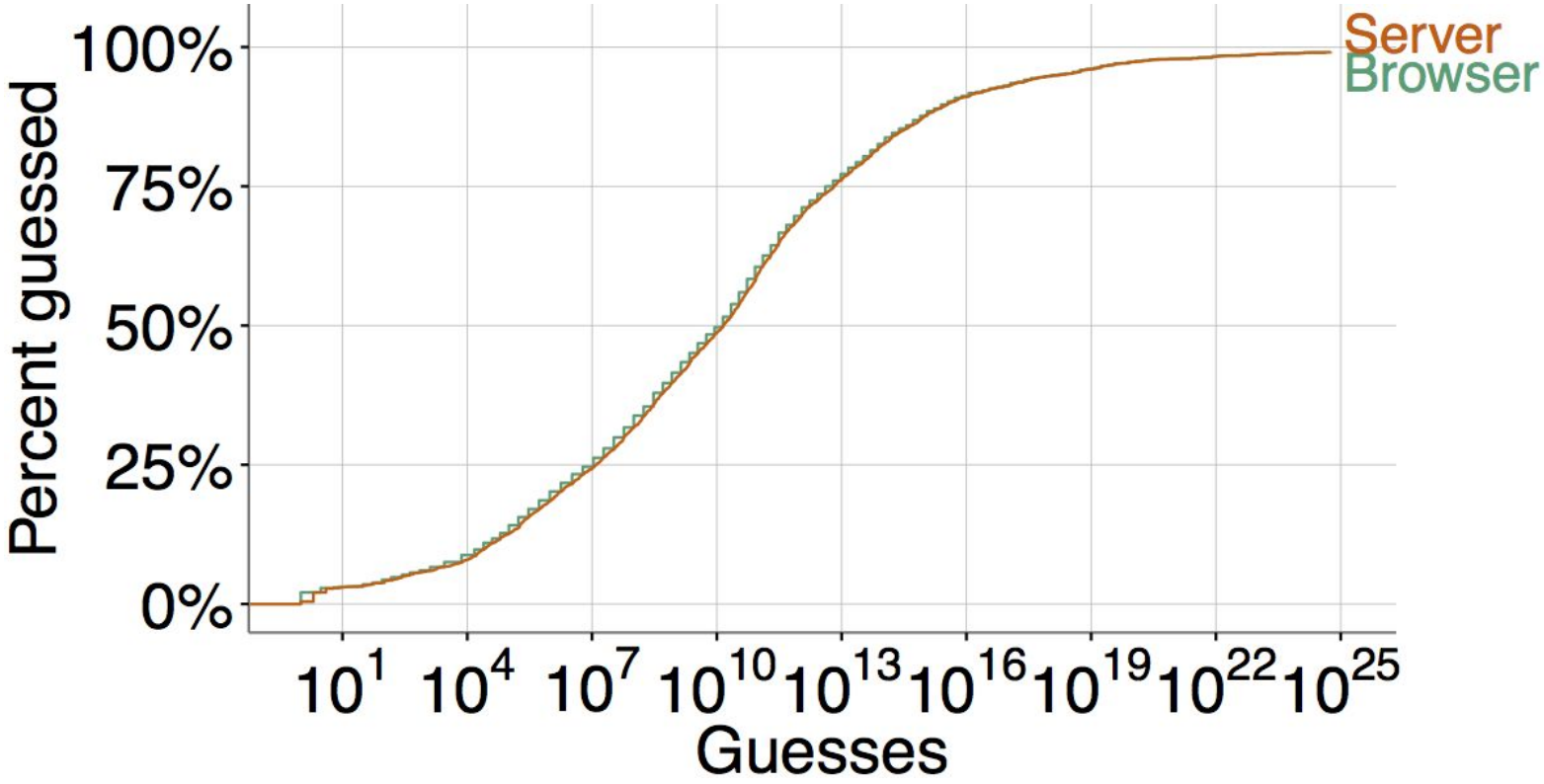
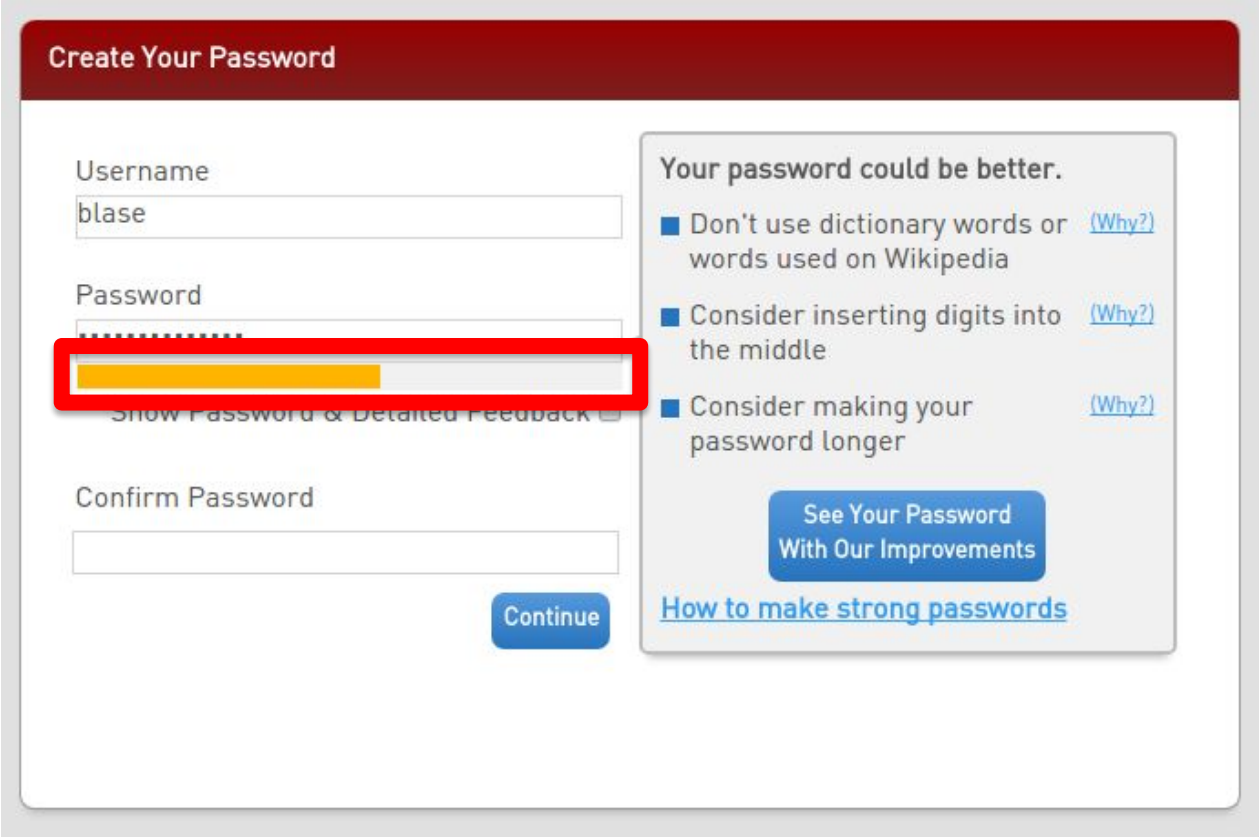


How Accurate Is the Small, Fast Model?

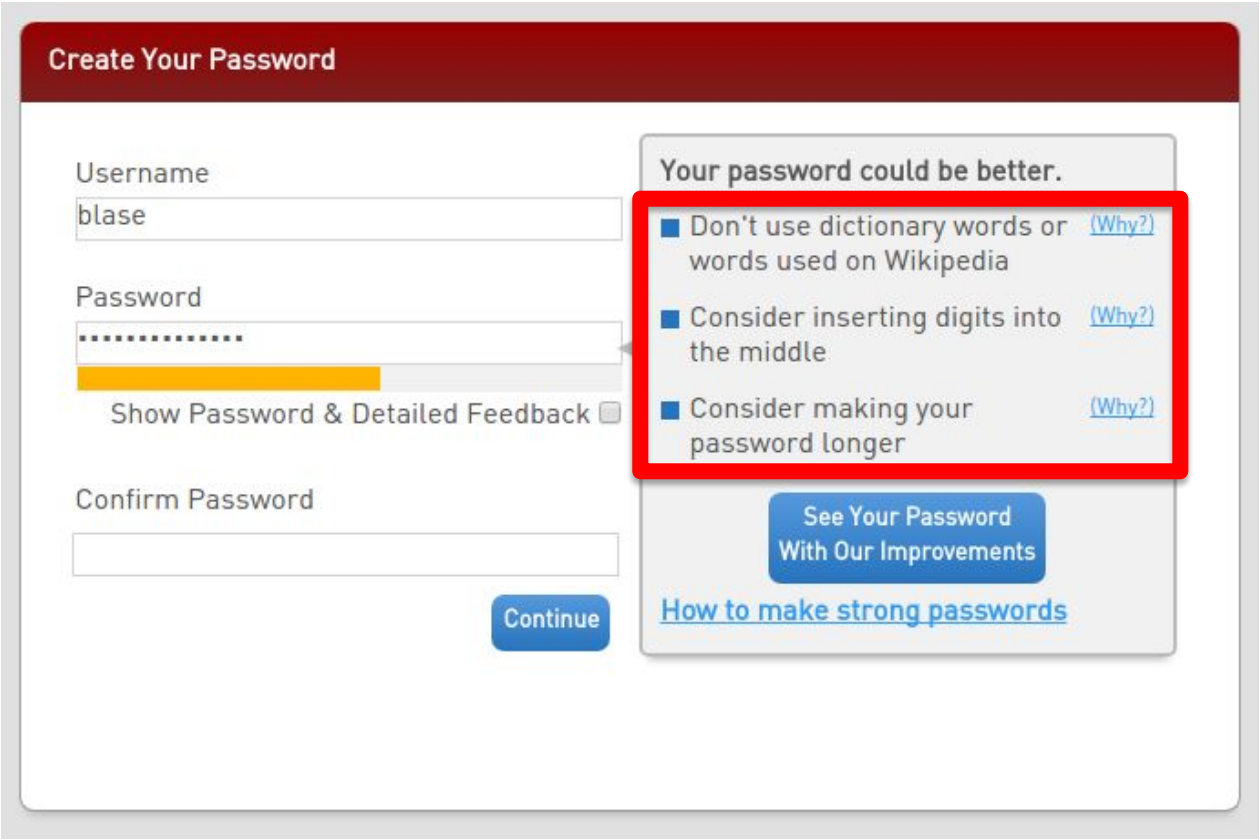
Does Measuring Password Strength Help?

[Design and Evaluation of a Data-Driven Password Meter
B. Ur, F. Alfieri, M. Aung, L. Bauer, N. Christin, J. Colnago, L. Cranor, H. Dixon, P. Emami Naeini, H. Habib, N. Johnson, and W. Melicher. CHI'17]

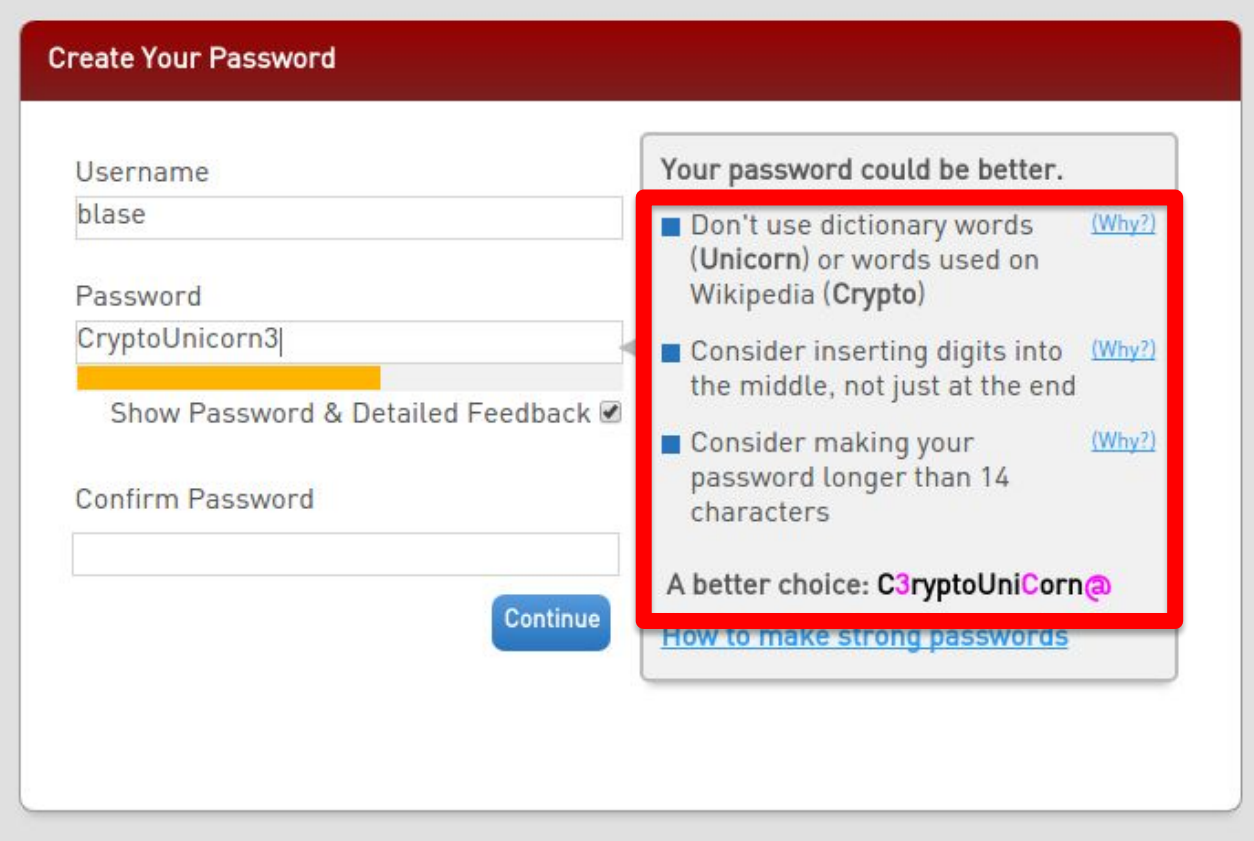
We Developed and Tested a Meter GUI



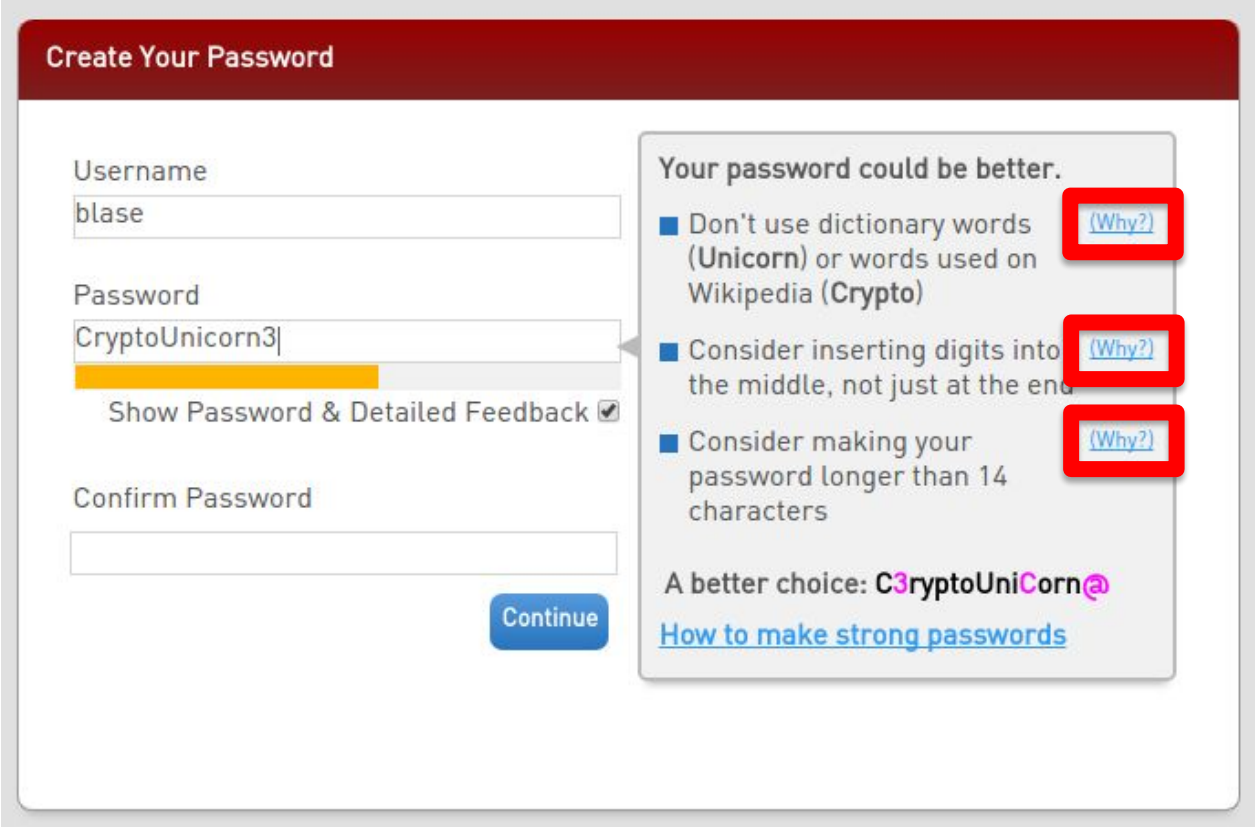
Provides Text Feedback



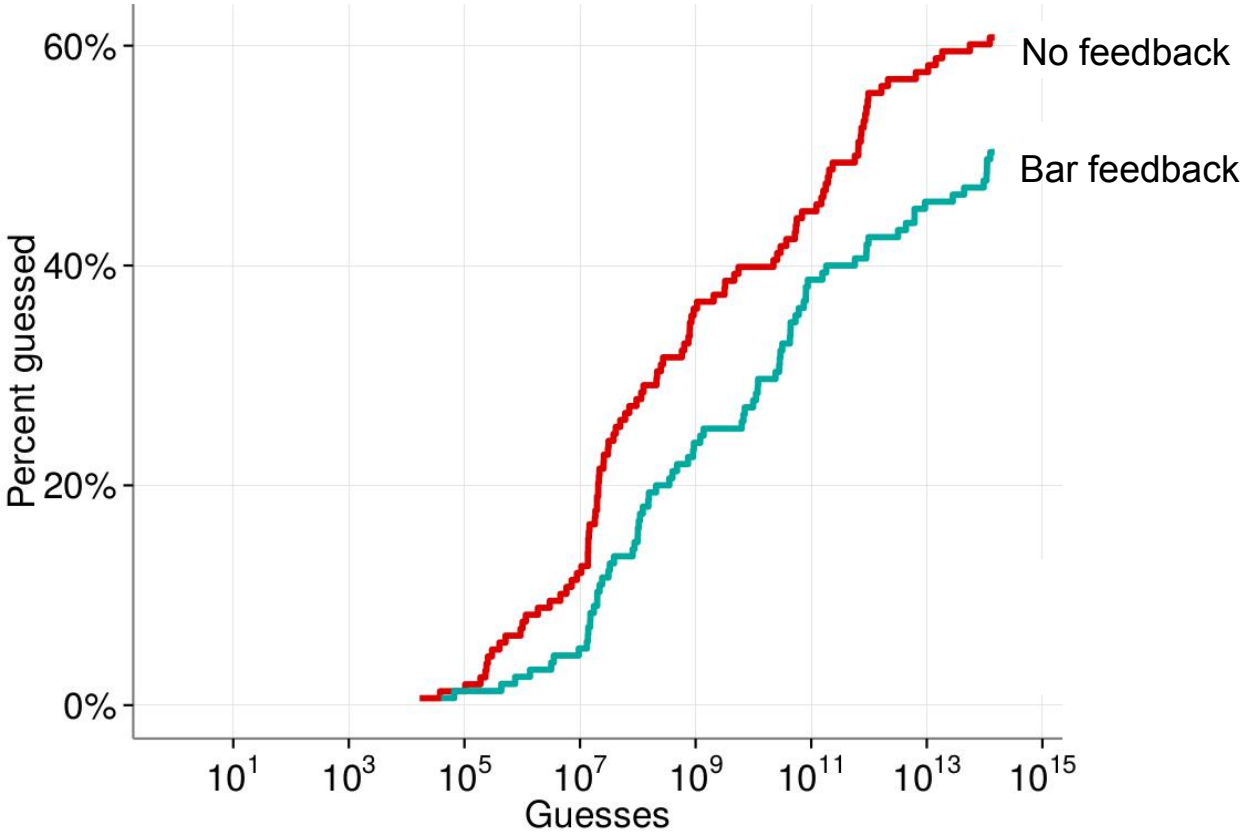
Gives Detail (Password Shown)



Offers Explanations



Does Measuring Strength Help? Yes!



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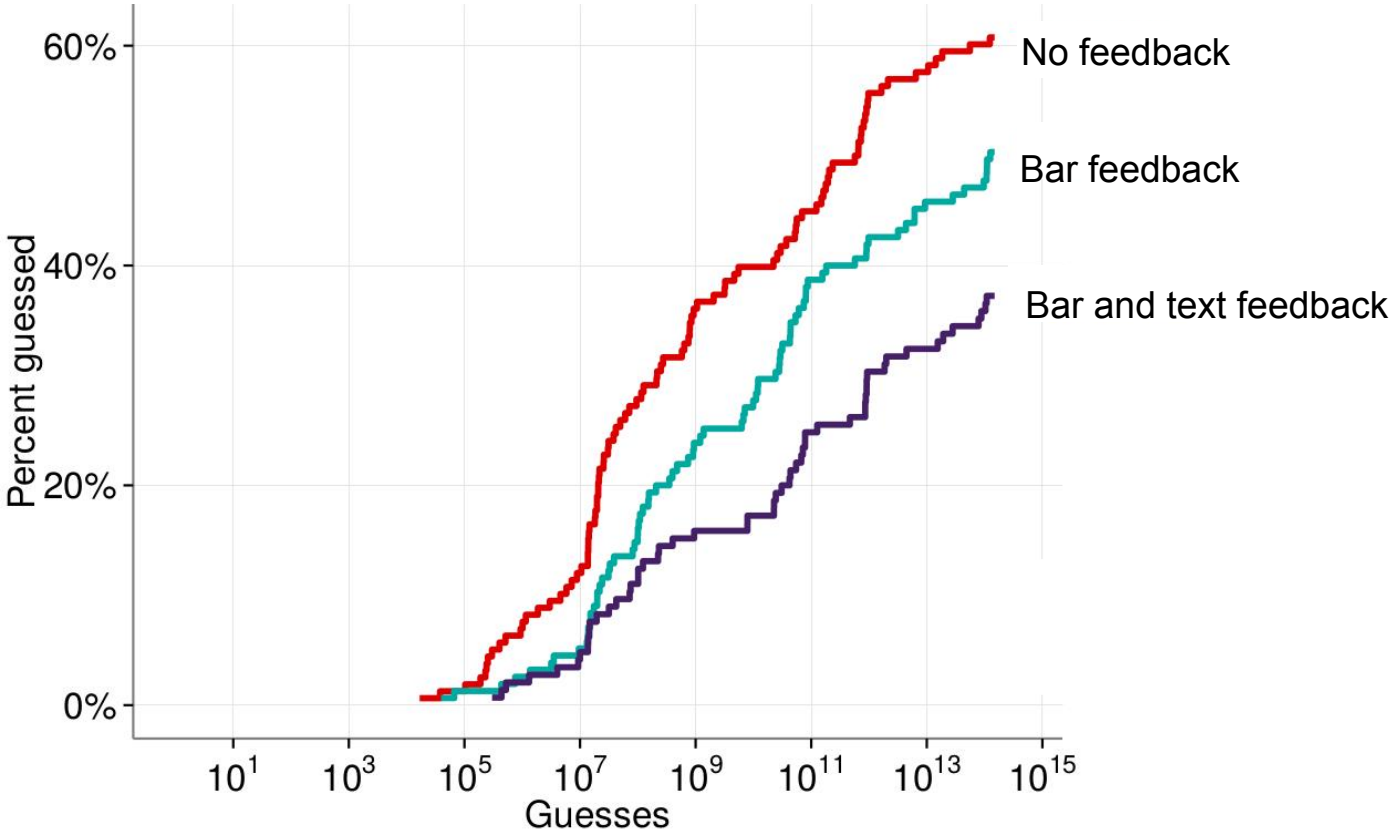

Modeling Passwords Using Neural Networks

- Neural networks guess passwords accurately
- Can be made small and fast for client-side feedback

`github.com/cupslab`

William Melicher, Blase Ur, Sean M. Segreti, Saranga Komanduri, Lujo Bauer, Nicolas Christin, Lorrie Faith Cranor

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