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Introduction to ML strategy

Why ML Strategy?

Motivating example



90%

Ideas:

- Collect more data ←
- Collect more diverse training set
- Train algorithm longer with gradient descent
- Try Adam instead of gradient descent
- Try bigger network
- Try smaller network
- Try dropout
- Add L_2 regularization
- Network architecture
 - Activation functions
 - # hidden units
 - ...

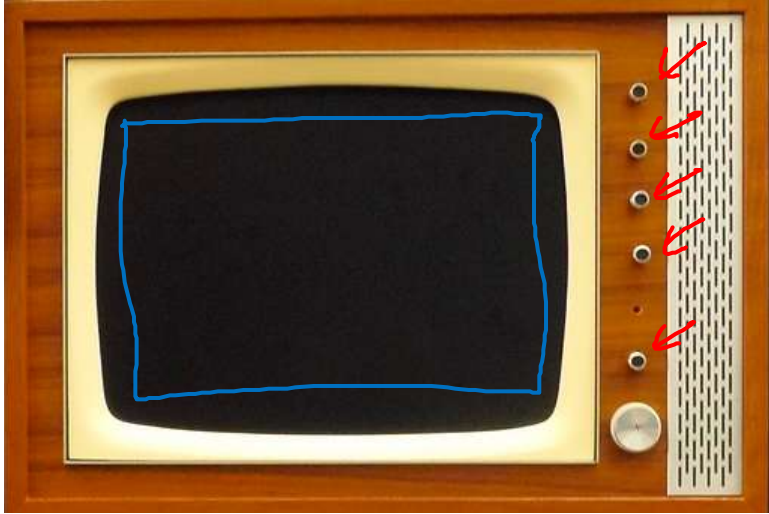


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Introduction to ML strategy

Orthogonalization

TV tuning example



Orthogonalization

$$\begin{aligned}
 &0.1 \times \begin{array}{|c|} \hline \updownarrow \\ \hline \end{array} \\
 &+ 0.3 \times \begin{array}{|c|} \hline \leftarrow \rightarrow \\ \hline \end{array} \\
 &- 1.7 \times \begin{array}{|c|} \hline \text{trapezoid} \\ \hline \end{array} \\
 &+ 0.8 \times \begin{array}{|c|} \hline \leftarrow \rightarrow \\ \hline \end{array} \\
 &+ \dots
 \end{aligned}$$

Car

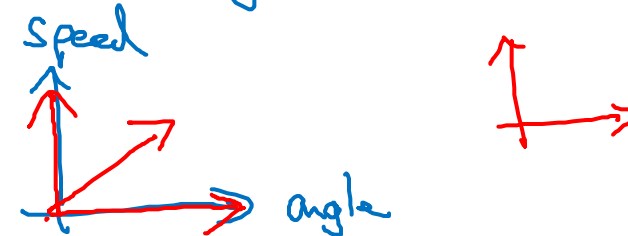


→ Steering]

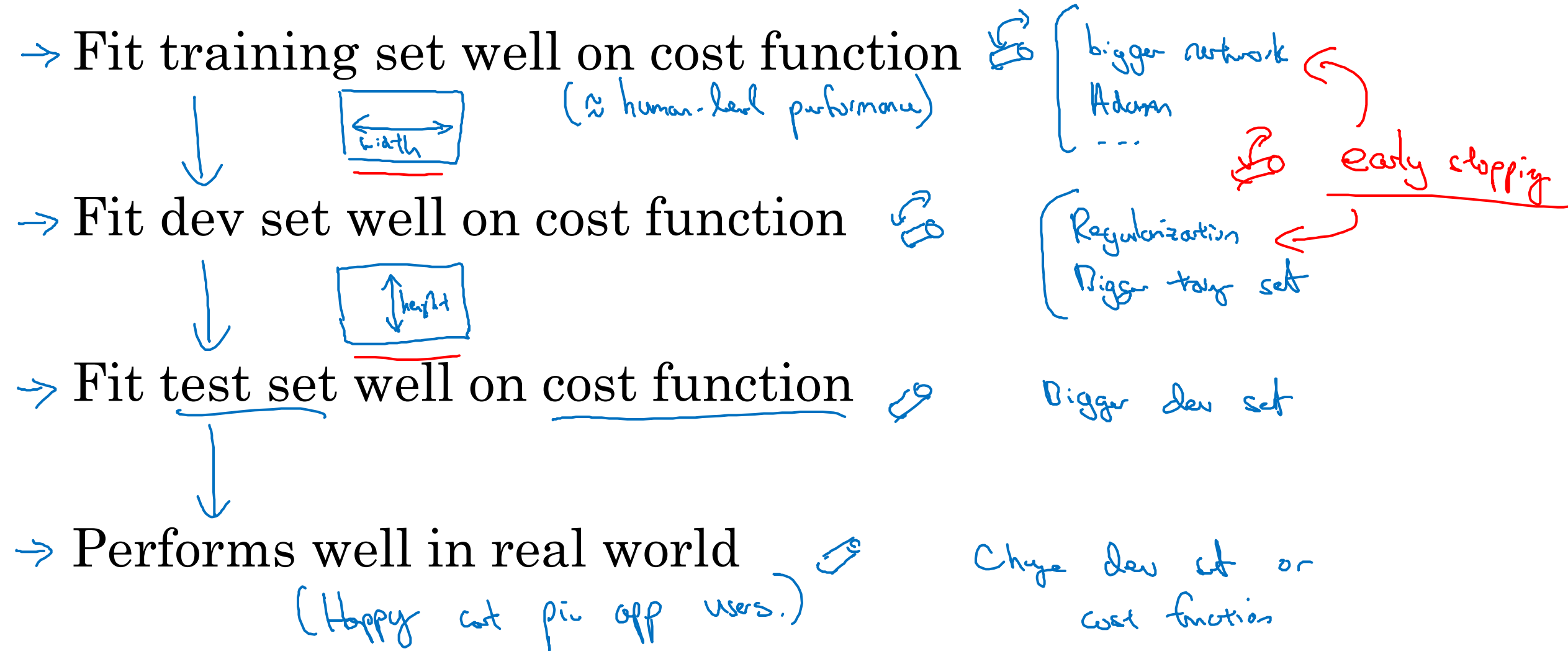
→ {Accelerate
Braking}

$$\rightarrow \underline{0.3 \times \text{angle} - 0.8 \text{ speed}}$$

$$\rightarrow 2 \times \text{angle} + 0.9 \text{ speed}$$



Chain of assumptions in ML



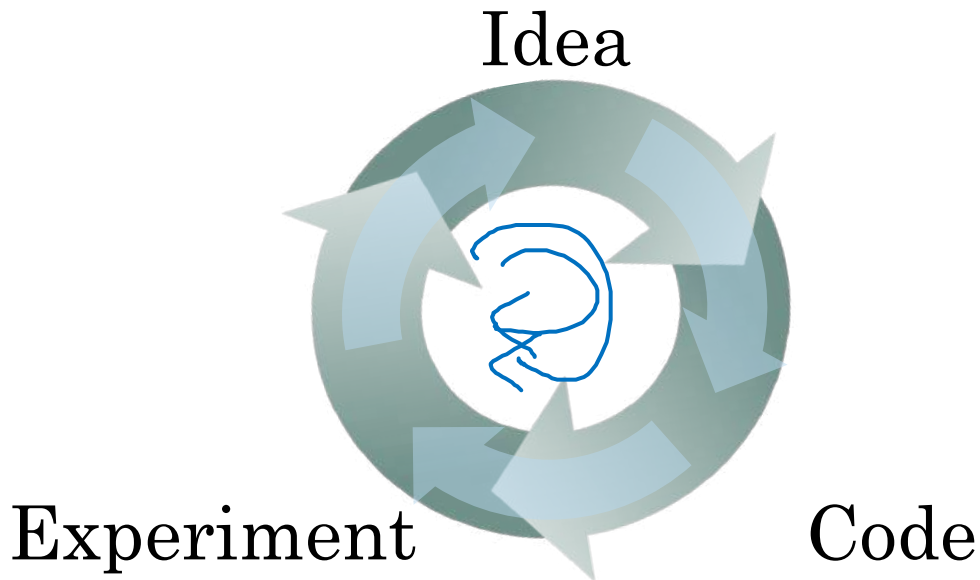


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Setting up
your goal

Single number
evaluation metric

Using a single number evaluation metric



→ Of examples recognized as cost, what % actually are costs?

→ what % of actual costs are correctly recognized

Classifier	Precision	Recall
A	95%	90%
B	98%	85%

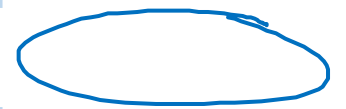
F₁ score = "Average" of P and R.

$$\left(\frac{2}{\frac{1}{P} + \frac{1}{R}} \right) \text{ "Harmonic mean"}$$

Dev set + Single number evaluation metric
real speed up iterating

Another example

Algorithm	US	China	India	Other
A	<u>3%</u>	7%	5%	9%
B	5%	6%	5%	10%
C	2%	3%	4%	5%
D	5%	8%	7%	2%
E	4%	5%	2%	4%
F	7%	11%	8%	12%





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Setting up
your goal

Satisficing and
optimizing metrics

Another cat classification example

Classifier	Accuracy	Running time
A	90%	80ms
B	92%	95ms
C	95%	1,500ms

$$\text{Cost} = \text{accuracy} - 0.5 \times \text{Running Time}$$

maximize accuracy

subject to Running Time \leq 100 ms.

N metrics : 1 optimizing
N-1 satisfying

Wakewords / Trigger words

Alexa, OK Google,

Hey Siri, nihao baidu
你好 百度

accuracy.

#false positive

maximize accuracy.

s.t. \leq 1 false positive
every 24 hours.



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Setting up
your goal

Train/dev/test
distributions

Cat classification dev/test sets

development set, hold out cross validation set

Regions:

- US
- UK
- Other Europe
- South America
- India
- China
- Other Asia
- Australia

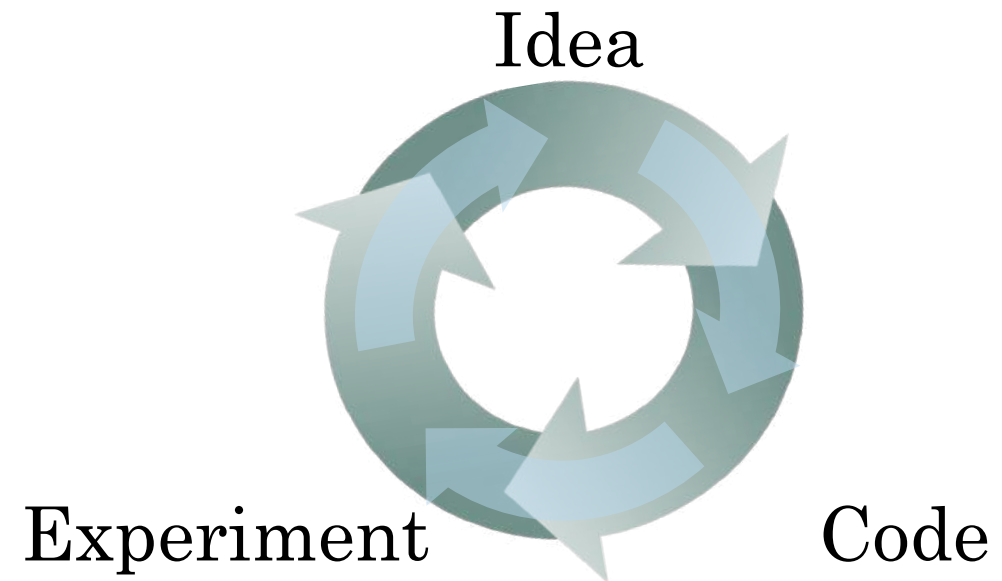
Dev

Test

→ Randomly shuffle into dev/test



dev set
+
metric



True story (details changed)

[Optimizing on dev set on loan approvals for
medium income zip codes

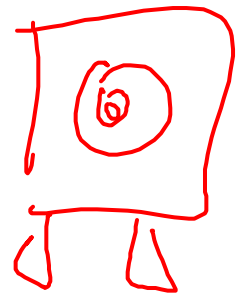


$x \rightarrow y$ (repay loan?)



[Tested on low income zip codes

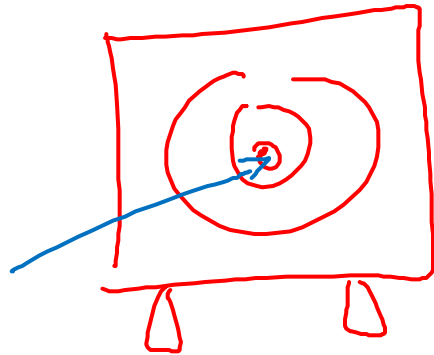
~ 3 month



Guideline

Choose a dev set and test set to reflect data you expect to get in the future and consider important to do well on.

training



dev
metric

test

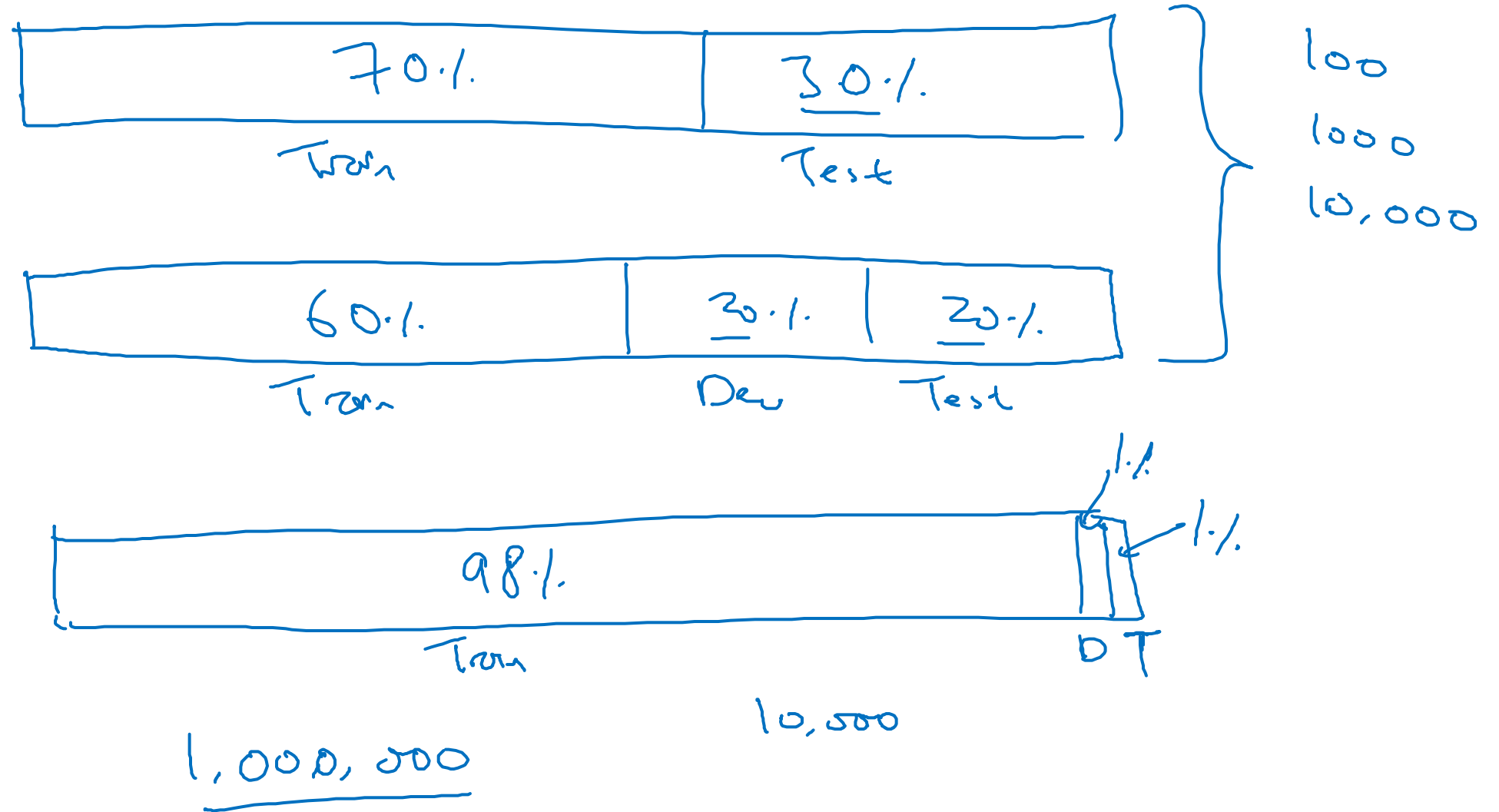


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Setting up
your goal

Size of dev
and test sets

Old way of splitting data



Size of dev set

A B

Set your dev set to be big enough to detect differences in
algorithm/models you're trying out.

100 : small
└ 1%

1,000

10,000

100,000

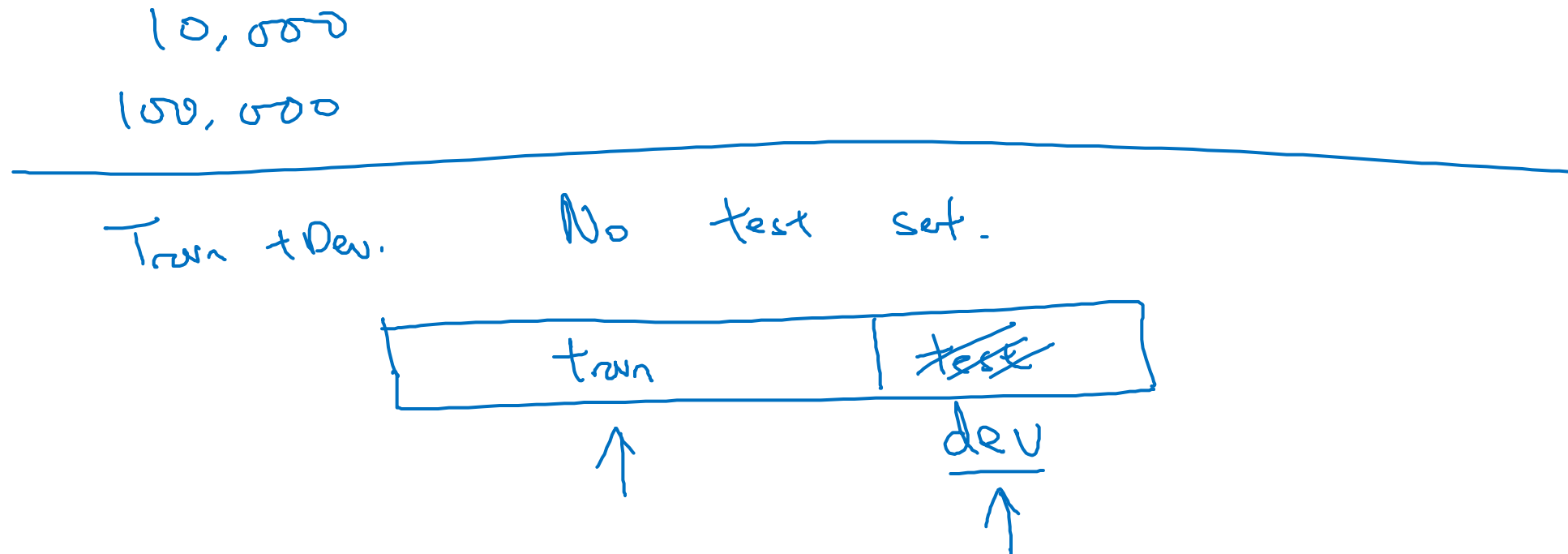
^A 97% → ^B 97.1%
0.1%
└

0.01%
└
0.001%

Online advertising

Size of test set

- Set your test set to be big enough to give high confidence in the overall performance of your system.





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Setting up
your goal

When to change
dev/test sets and
metrics

Cat dataset examples

Metric + Dev : Prefer A
You/users : Prefer B.

→ Metric: classification error

Algorithm A: 3% error

→ pornographic

✓ Algorithm B: 5% error

Error: $\frac{1}{\sum_i w^{(i)}} \cdot \frac{1}{m_{dev}} \sum_{i=1}^{m_{dev}} w^{(i)} \mathbb{I}\{y_{pred}^{(i)} \neq y^{(i)}\}$

↪ $w^{(i)} = \begin{cases} 1 & \text{if } x^{(i)} \text{ is non-porn} \\ 10 & \text{if } x^{(i)} \text{ is porn} \end{cases}$

$\mathbb{I}\{y_{pred}^{(i)} \neq y^{(i)}\}$
predicted value (0/1)

Orthogonalization for cat pictures: anti-porn

- 1. So far we've only discussed how to define a metric to evaluate classifiers. ← Place target ↗
- 2. Worry separately about how to do well on this metric. ↗
- ↖ Aim (shoot at target)

$$\rightarrow J = \frac{1}{\sum w^{(i)}} \sum_{i=1}^m w^{(i)} \mathcal{L}(\hat{y}^{(i)}, y^{(i)})$$



Another example

Algorithm A: 3% error

✓ Algorithm B: 5% error ←

→ Dev/test



→ User images



If doing well on your metric + dev/test set does not correspond to doing well on your application, change your metric and/or dev/test set.

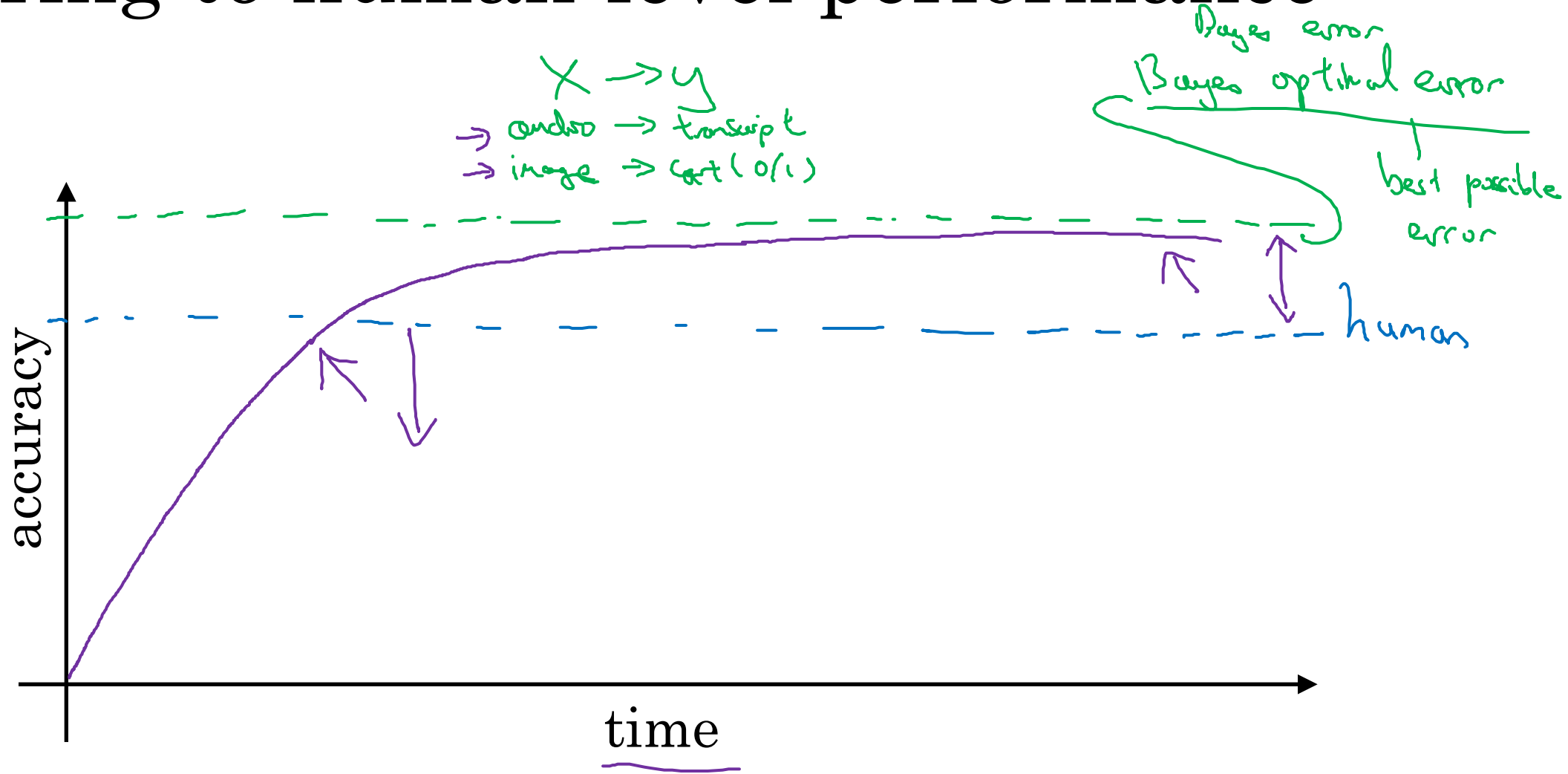


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Comparing to human-
level performance

Why human-level
performance?

Comparing to human-level performance



Why compare to human-level performance

Humans are quite good at a lot of tasks. So long as ML is worse than humans, you can:

- - Get labeled data from humans. (x, y)
- - Gain insight from manual error analysis:
Why did a person get this right?
- - Better analysis of bias/variance.

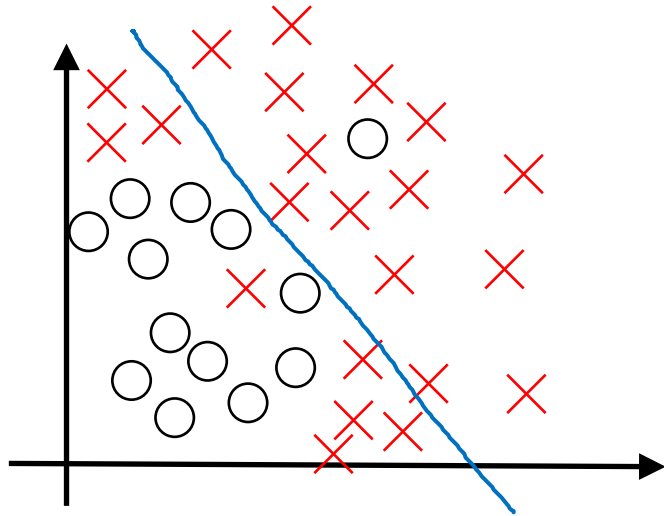


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Comparing to human-
level performance

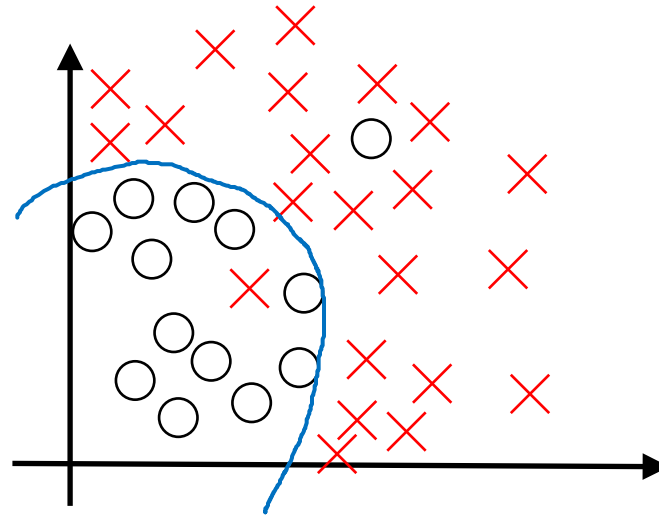
Avoidable bias

Bias and Variance

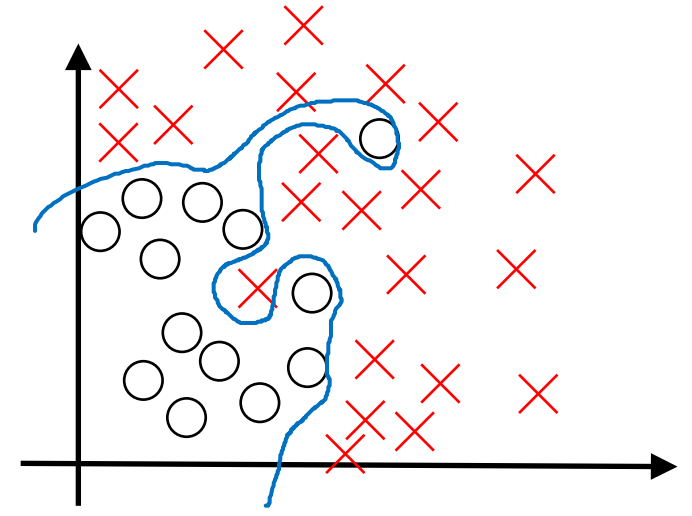


high bias

underfitting



"just right"



high variance

overfitting

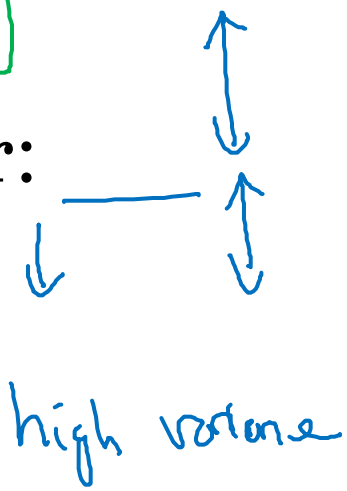
Bias and Variance

Cat classification

Human-level $\approx 0\%$ ----

Training set error:

Dev set error:



high variance

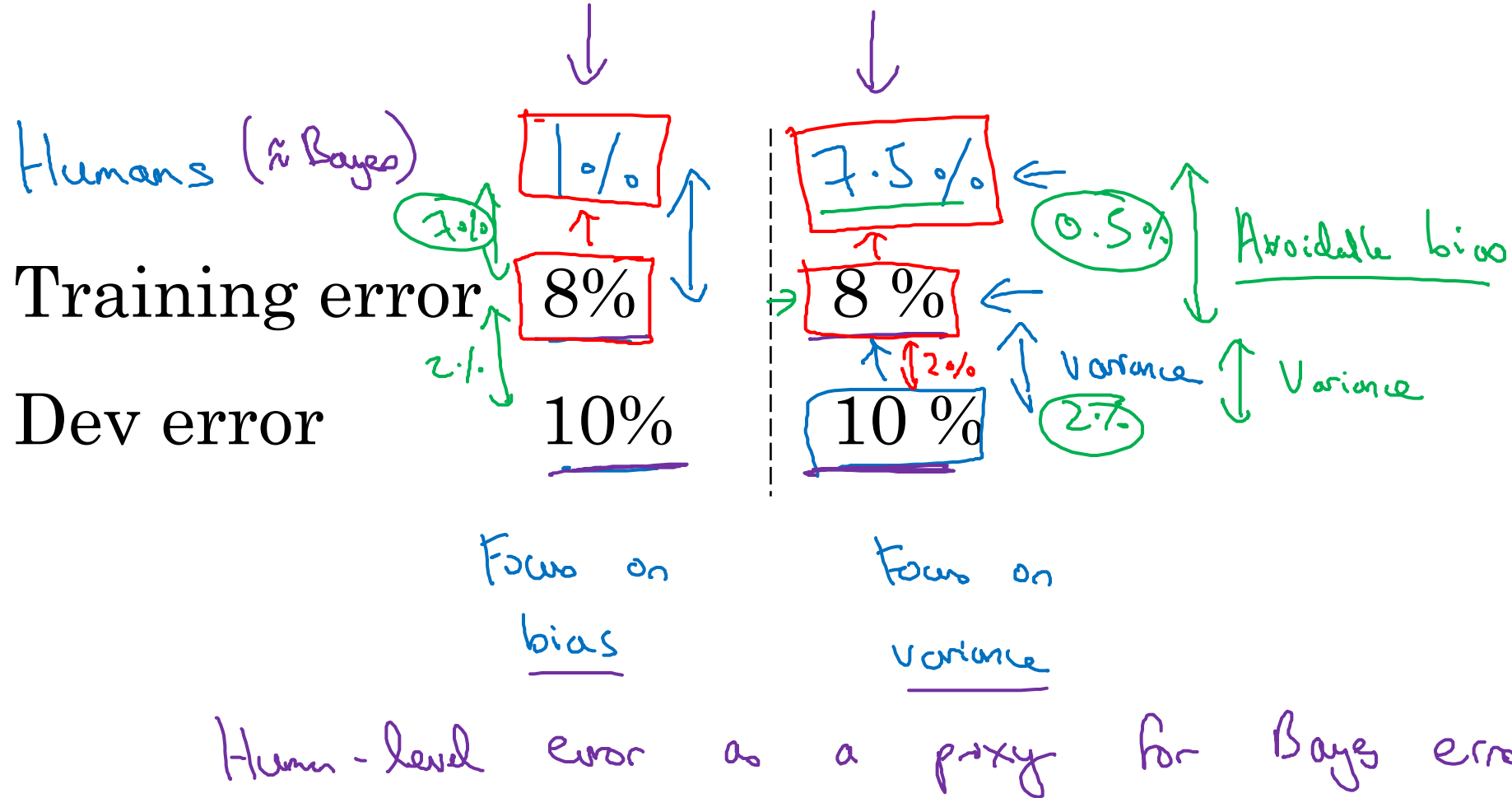


high bias

high bias
high variance

low bias
low variance

Cat classification example





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Comparing to human-level performance

Understanding
human-level
performance

Human-level error as a proxy for Bayes error

Medical image classification example:

Suppose:

(a) Typical human 3 % error

→ (b) Typical doctor 1 % error

(c) Experienced doctor 0.7 % error

→ (d) Team of experienced doctors .. 0.5 % error ←

Bayes error \leq 0.5 %

What is “human-level” error?



Error analysis example

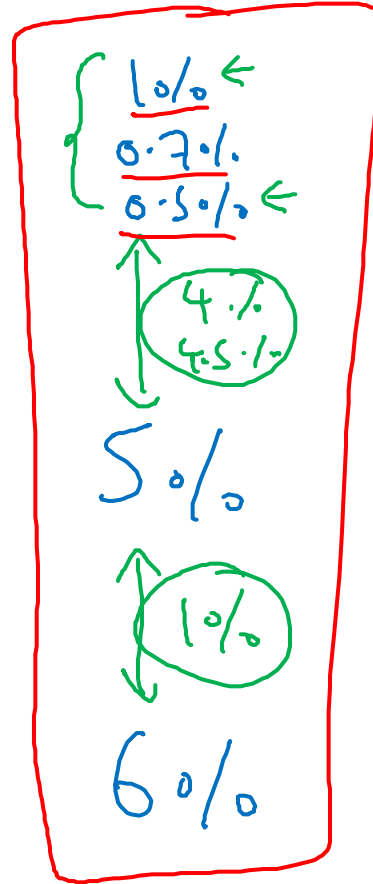
Human (proxy for Bayes error)

↕ Avoidable bias

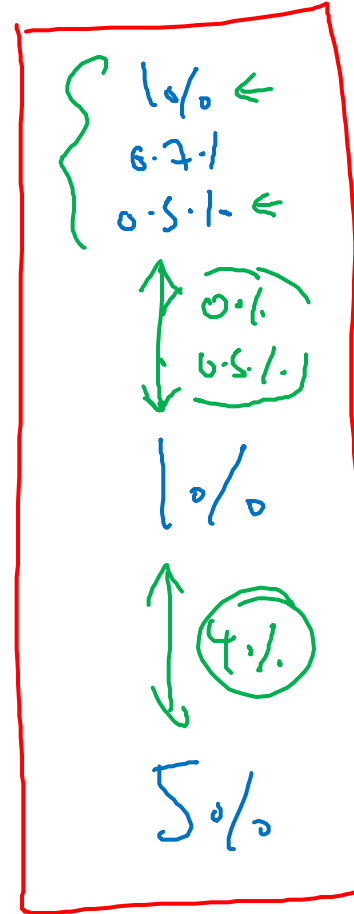
Training error

↕ Variance

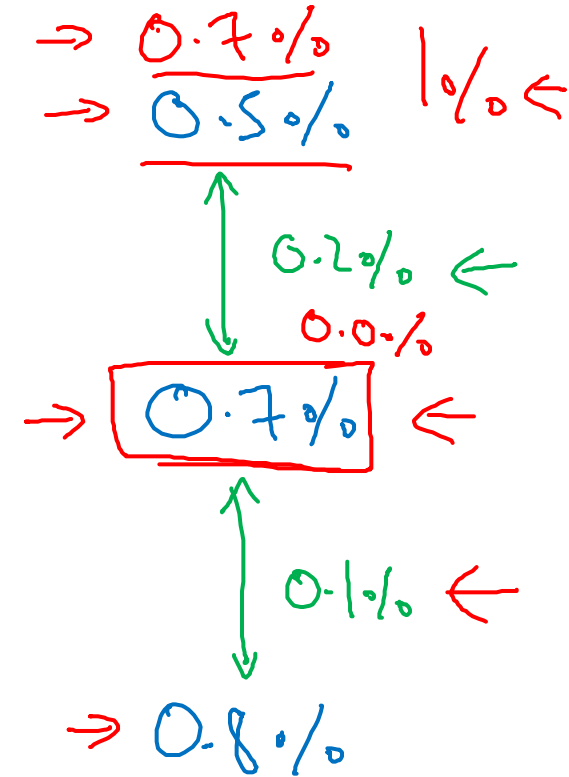
Dev error



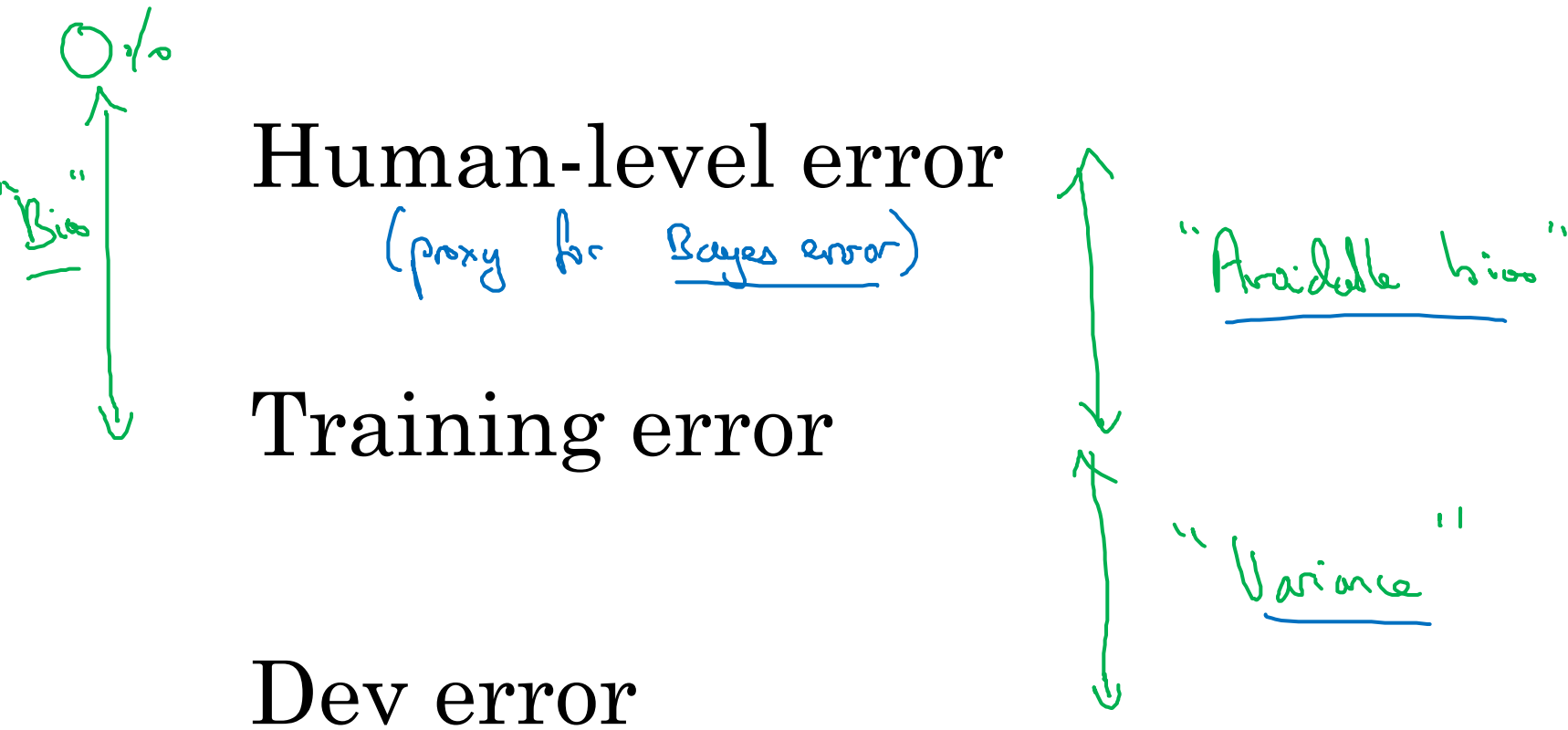
↑ Bias



↑ Variance



Summary of bias/variance with human-level performance





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Comparing to human-
level performance

Surpassing human-
level performance

Surpassing human-level performance

Team of humans

0.5%

One human

0.1 ~~1.0%~~

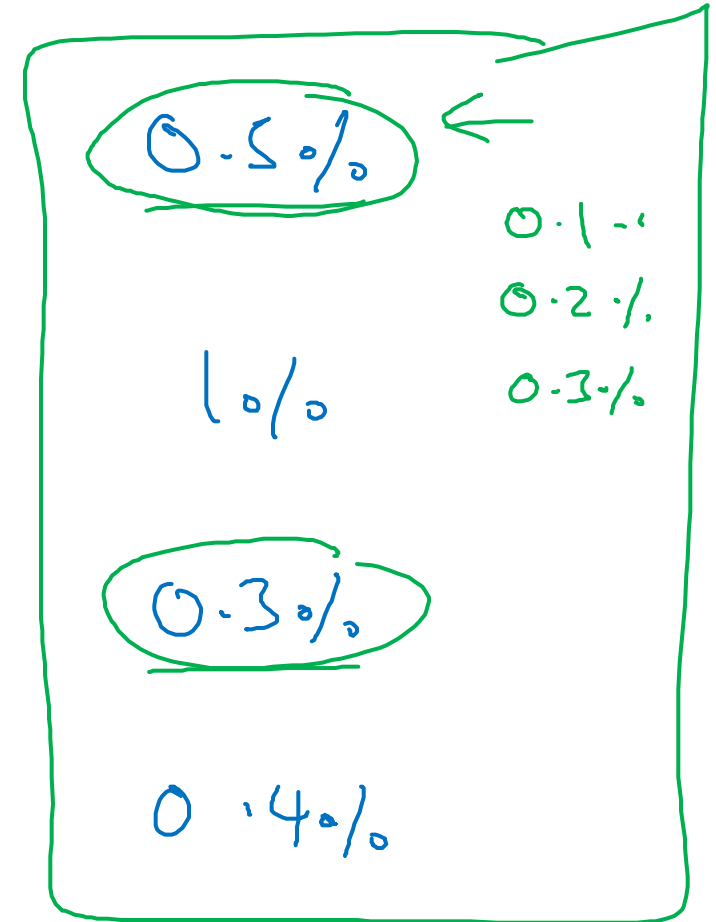
Training error

0.6%

Dev error

0.2
0.8%

What is avoidable bias?



Problems where ML significantly surpasses human-level performance

- - Online advertising
- - Product recommendations
- - Logistics (predicting transit time)
- - Loan approvals

Structured data

Not natural perception

Lots of data

- Speech recognition
- Some image recognition
- Medical
 - ECG, Skin cancer, ...



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Comparing to human-
level performance

Improving your model
performance

The two fundamental assumptions of supervised learning

1. You can fit the training set pretty well.



~ Avoidable bias

2. The training set performance generalizes pretty well to the dev/test set.



~ Variance

Reducing (avoidable) bias and variance

Human-level



Avoidable bias

Training error



Variance

Dev error

Train bigger model

Train longer/better optimization algorithms

- momentum, RMSprop, Adam

NN architecture/hyperparameters search

RNN
CNN

More data

Regularization

- L_2 , dropout, data augmentation

NN architecture/hyperparameters search