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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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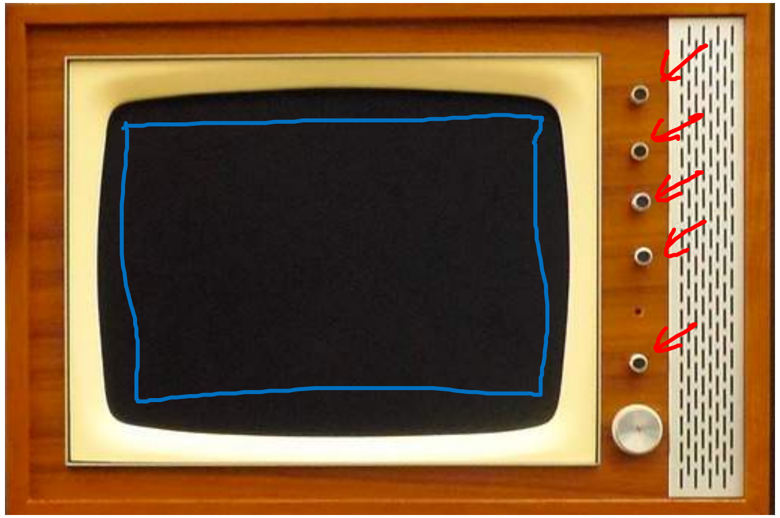
Introduction to ML strategy

Orthogonalization

TV tuning example



Orthogonalization

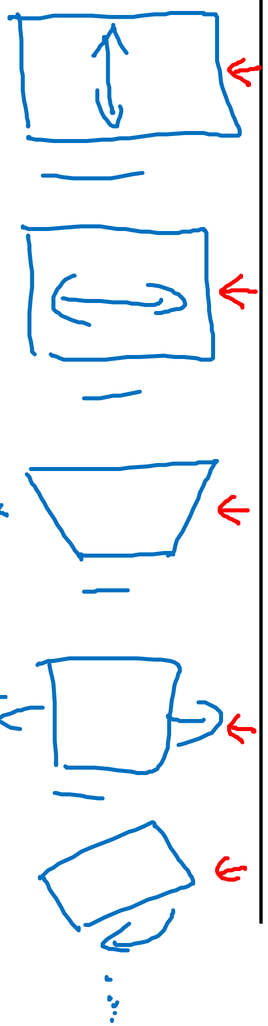
0.1 x

+ 0.3 x

- 1.7 x

+ 0.8 x

+ ...



Car

→ Steering

→ { Acceleration, Braking }

→ $0.3 \times \text{angle} - 0.8\ \text{speed}$

→ $2 \times \text{angle} + 0.9\ \text{speed}$.

Chain of assumptions in ML

→ Fit training set well on cost function

(≈ human-level performance)

width

- bigger network
- Adam
- ...

early stopping

→ Fit dev set well on cost function

height

- Regularization
- Bigger train set

→ Fit test set well on cost function

- Bigger dev set

→ Performs well in real world

(Happy cat pic app users.)

- Change dev set or cost function

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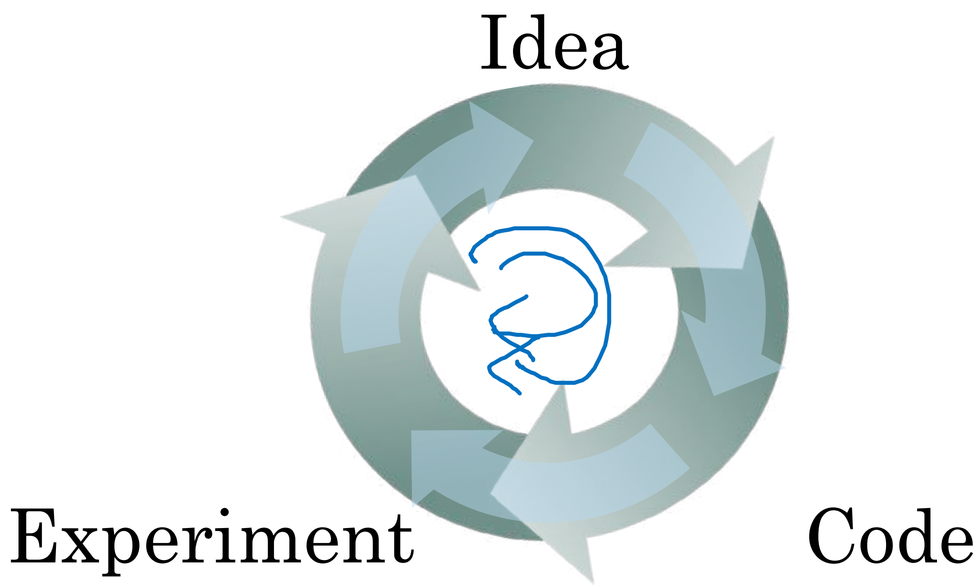
Setting up your goal

Single number evaluation metric

Using a single number evaluation metric



→ Of examples recognized as cat, what % actually are cats?

→ what % of actual cats are correctly recognized

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

F_1 score = "Average" of P and R.

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

Dev set + Single number evaluation metric

real

Speed up iterating

Andrew Ng

Another example

Algorithm	US	China	India	Other
A	3%	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

optimizing Satisficing

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

cost = accuracy − 0.5 × running time

maximize accuracy

subject to running time ≤ 100 ms.

N metrics: 1 optimizing

N−1 satisficing

Wakewords / Trigger words

Alexa, OK Google,

Hey Siri, nihaobaidu

你好百度

accuracy.

#false positive

maximize accuracy.

s.t. ≤ 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:

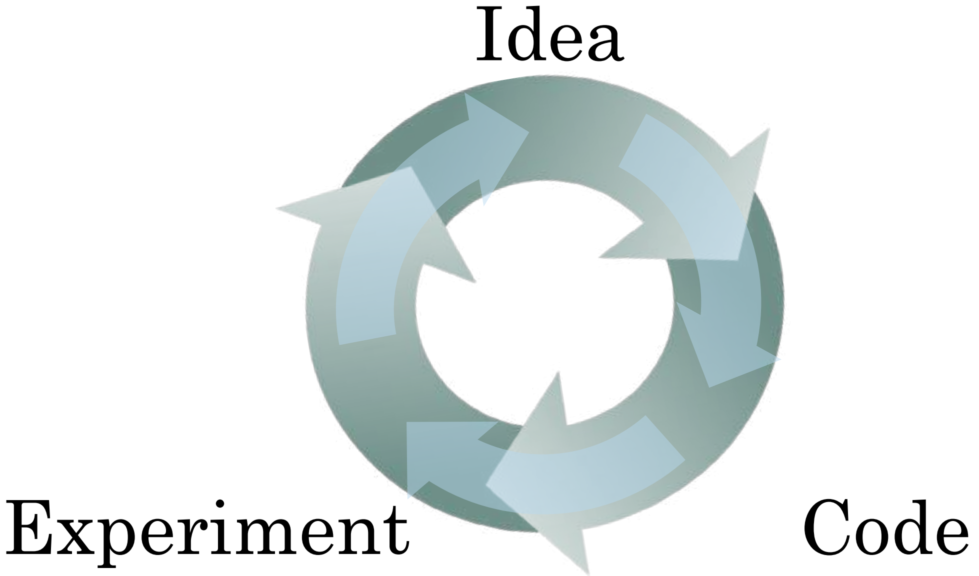
- US
- UK
- Other Europe
- South America
- India
- China
- Other Asia
- Australia

Dev

Test

Randomly shuffle into dev/test

dev set + metric



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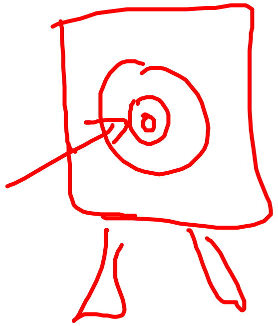
True story (details changed)

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

$x \longrightarrow y$ (repay loan?)



Tested on low income zip codes

~3 month

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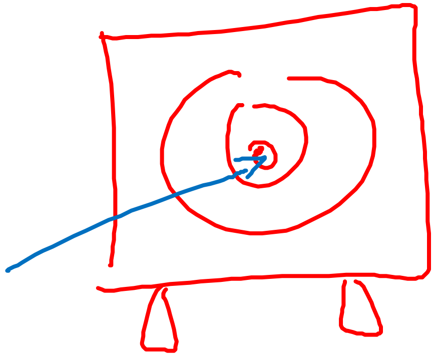
Guideline

Same distribution

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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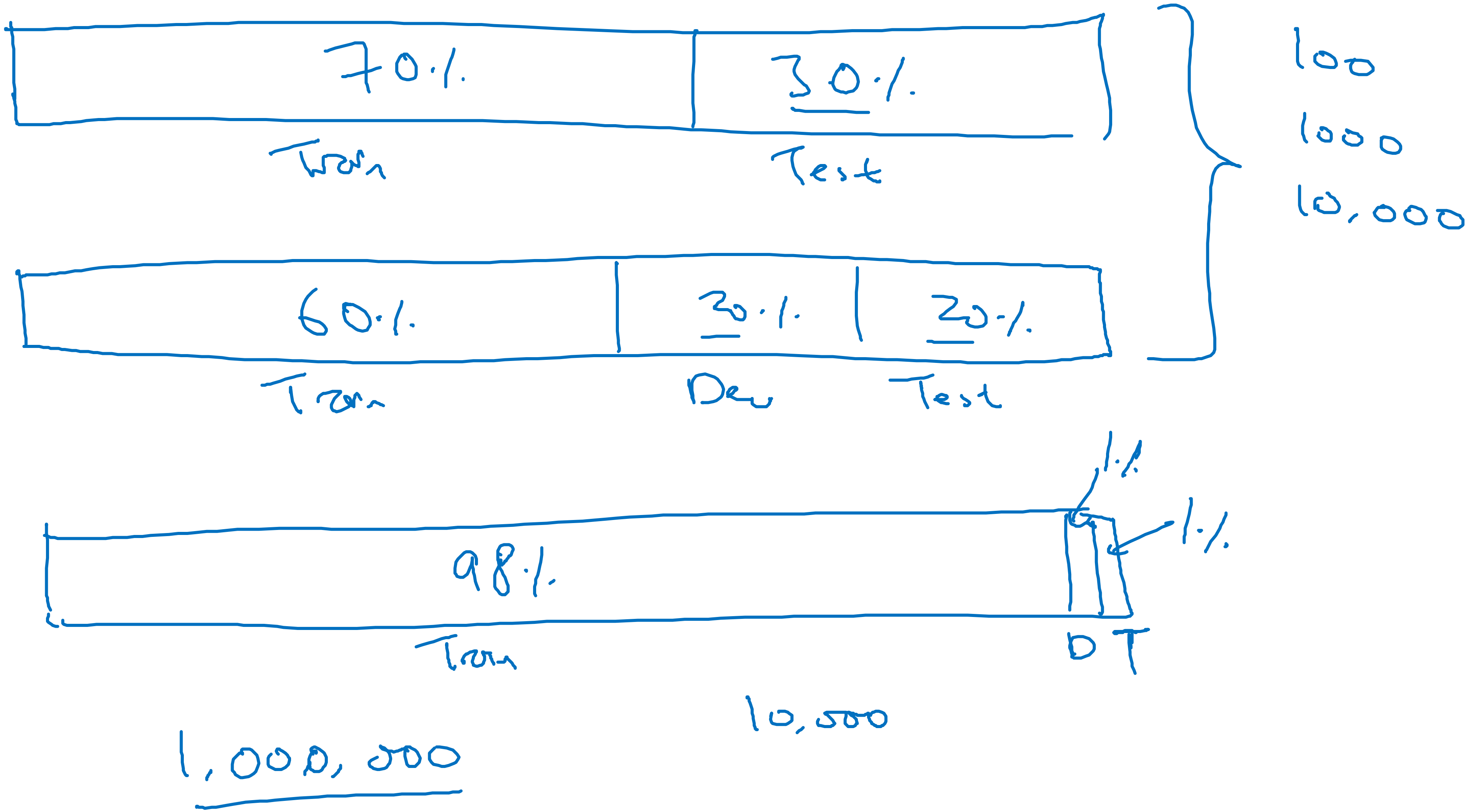
Setting up your goal

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

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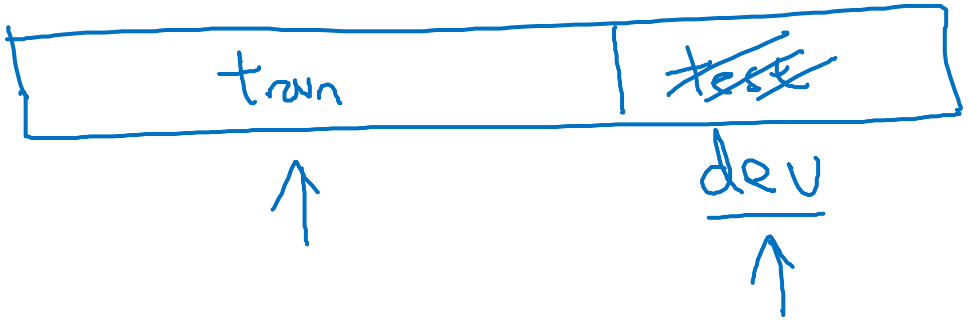
Size of test set

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

10,000

100,000

Train + Dev.   No test set.



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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

$$\text{Error: } \frac{1}{\sum_i w^{(i)}} \cancel{\frac{1}{m_{dev}}} \sum_{i=1}^{m_{dev}} w^{(i)} \, \mathcal{I}\{ y_{pred}^{(i)} \neq y^{(i)} \}$$

$y_{pred}^{(i)}$ ← predicted value (0/1)

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

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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

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

$\Sigma w^{(i)}$

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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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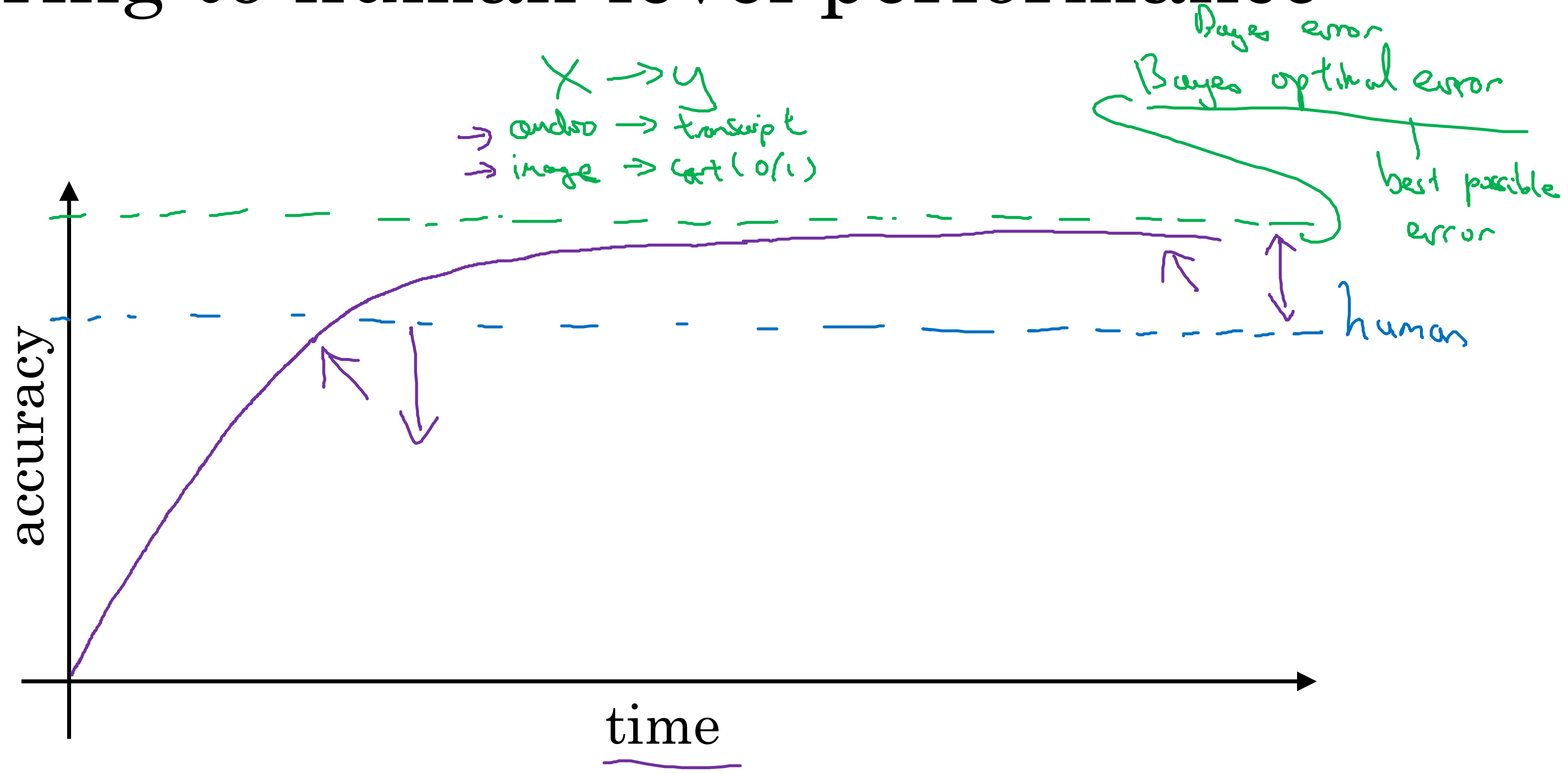
Comparing to human-level performance

Why human-level performance?

Comparing to human-level performance



Cat classification example

Humans (≈ Bayes)	1%	7.5%
Training error	8%	8%
Dev error	10%	10%

0.5% Avoidable bias

2% variance

2% Variance

Focus on bias	Focus on variance

Human-level error as a proxy for Bayes error.

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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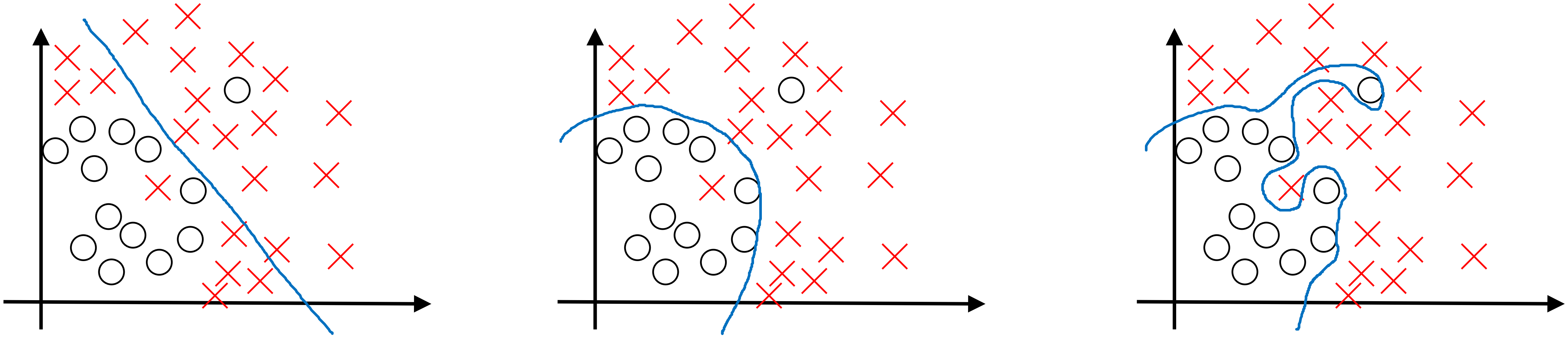
Comparing to human-level performance

Avoidable bias

Bias and Variance



high bias — "just right" — high variance

underfitting — overfitting.

Bias and Variance

Cat classification

$\boxed{\text{Human-level} \approx 0\%}$ ....

Training set error:

Dev set error:

high variance

high bias

high bias
high variance

low bias
low variance

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Cat classification example

Humans ($\approx$ Bayes)	$\boxed{1\%}$	$\boxed{7.5\%}$
Training error	$\boxed{8\%}$	$\boxed{8\%}$
Dev error	10%	$\boxed{10\%}$

7%

2%

2%

0.5%

Avoidable bias

variance

2%

Variance

Focus on bias

Focus on variance

Human-level error as a proxy for Bayes error.

Comparing to human-level performance

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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

Baye error ≤ 0.5%

What is "human-level" error?

Error analysis example

Human (proxy for Bayes error)	1% / 0.7% / 0.5%	1% / 0.7% / 0.5%	0.7% / 0.5% / 1%
Avoidable bias	4% / 4.5%	0% / 0.5%	0.2% / 0.0%
Training error	5%	1%	$\boxed{0.7\%}$
Variance	1%	4%	0.1%
Dev error	6%	5%	0.8%
	Bias	Variance	

Summary of bias/variance with human-level performance

0%

"Bias"

Human-level error

(proxy for Bayes error)

"Avoidable bias"

Training error

"Variance"

Dev error

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Comparing to human-level performance

Surpassing human-level performance

Surpassing human-level performance

Team of humans		0.5%	0.5%
	0.1		
One human		~~1%~~	1%
Training error		0.6%	0.3%
	0.2		
Dev error		0.8%	0.4%

0.1%
0.2%
0.3%

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

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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