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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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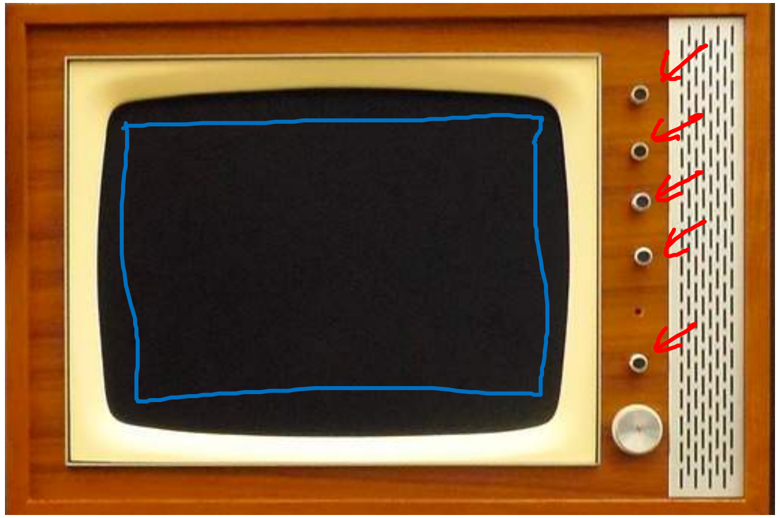
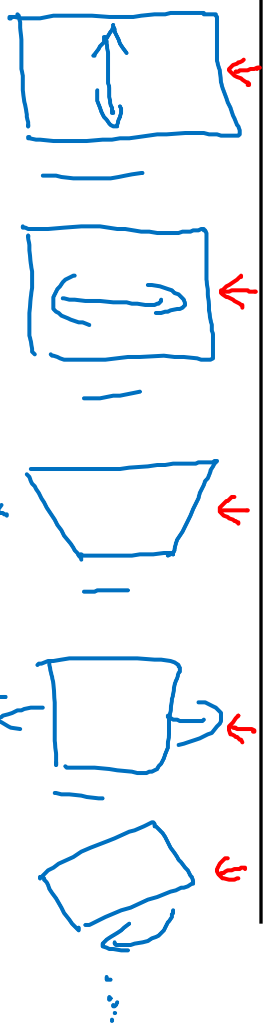
Introduction to ML strategy

Orthogonalization

TV tuning example





0.1 x

+ 0.3 x

- 1.7 x

+ 0.8 x

+ ...

Orthogonalization

Car

→ Steering

→ {Accelerator, Braking}

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

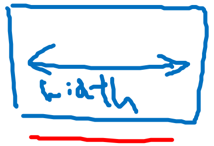
→ $2 \times \text{angle} + 0.9 \text{ speed}$.

Chain of assumptions in ML

→ Fit training set well on cost function

(≈ human-level performance)

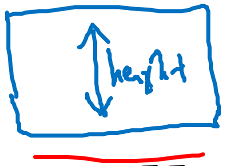
bigger network
Adam
...



early stopping

→ Fit dev set well on cost function

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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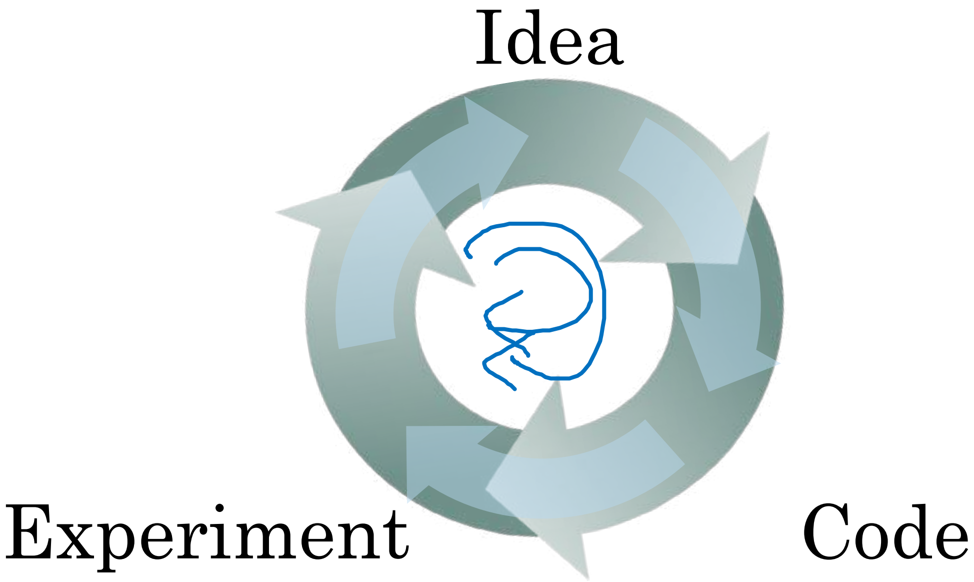
Setting up your goal

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.

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

Dev set + Single number evaluation metric

real

Speed up iterating

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

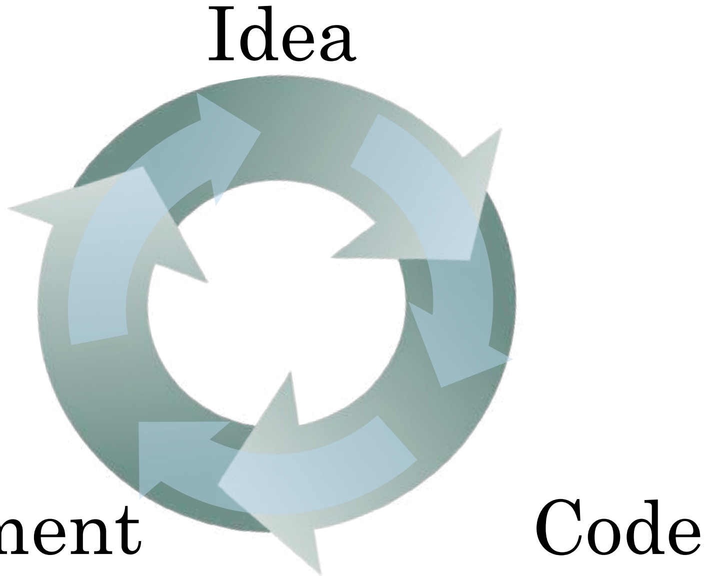
Dev

- India
- China
- Other Asia
- Australia

Test

Randomly shuffle into dev/test

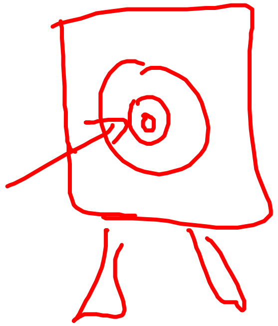
dev set + metric



True story (details changed)

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

$x \longrightarrow y$ (repay loan?)



Tested on low income zip codes

~3 month

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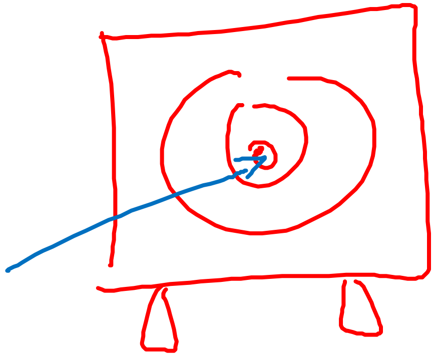
Guideline

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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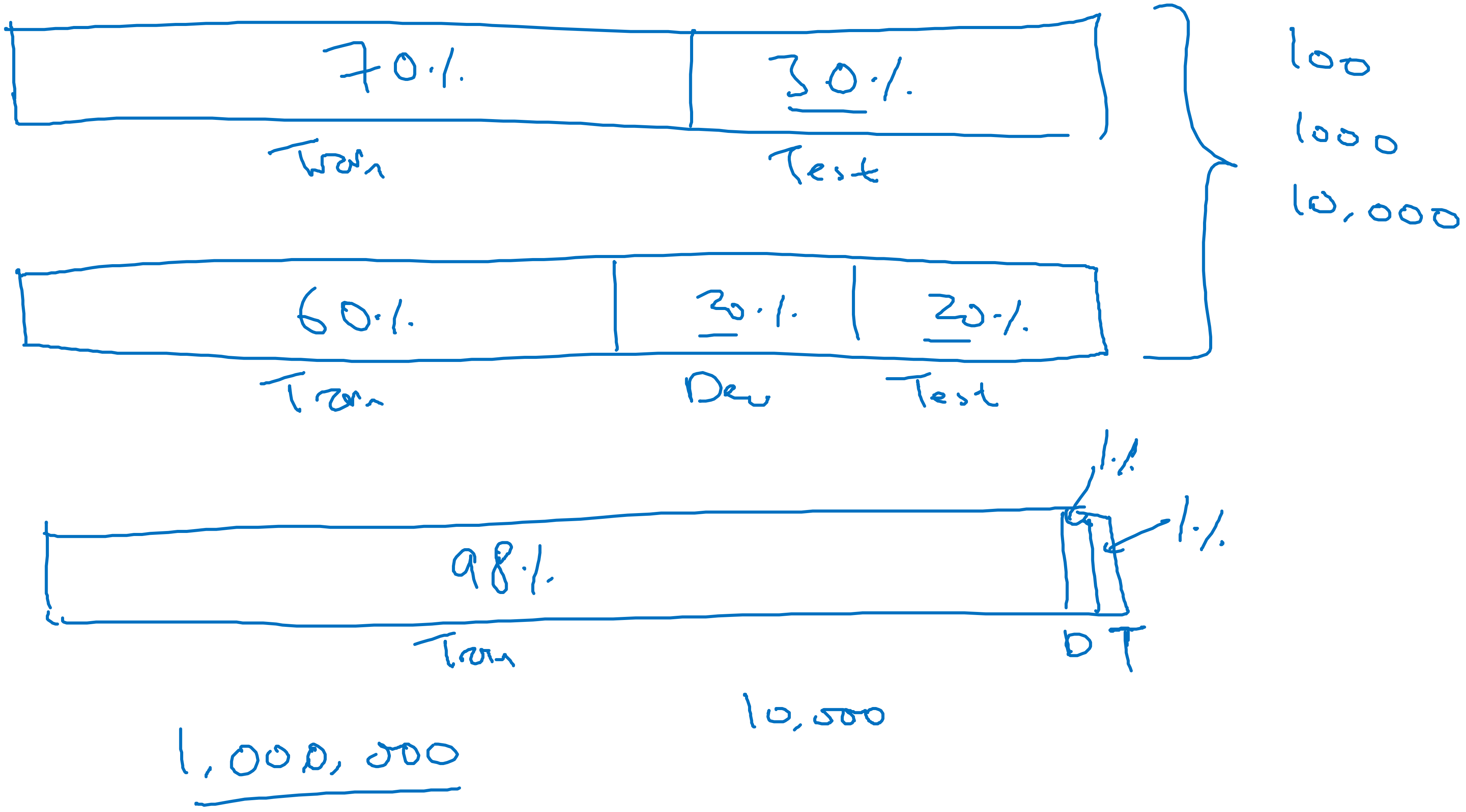
Setting up your goal

Size of dev and test sets

Old way of splitting data



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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 B

97% → 97.1%

0.1%

0.01%

0.001%

Online advertising

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Size of test set

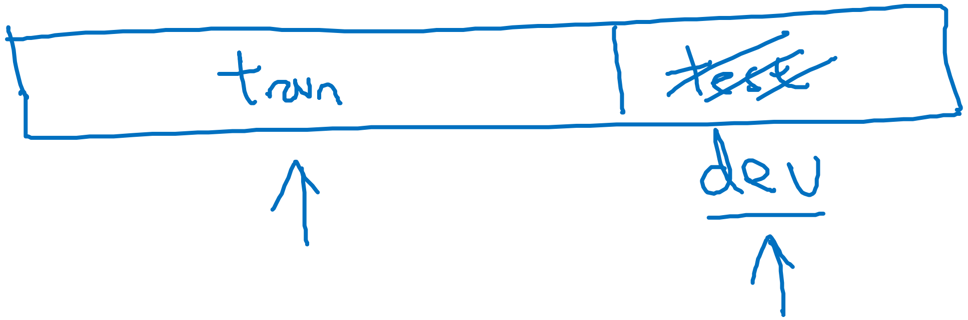
- Set your test set to be big enough to give high confidence in the overall performance of your system.

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

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

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

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

$\sum w^{(i)}$

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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.

Comparing to human-level performance

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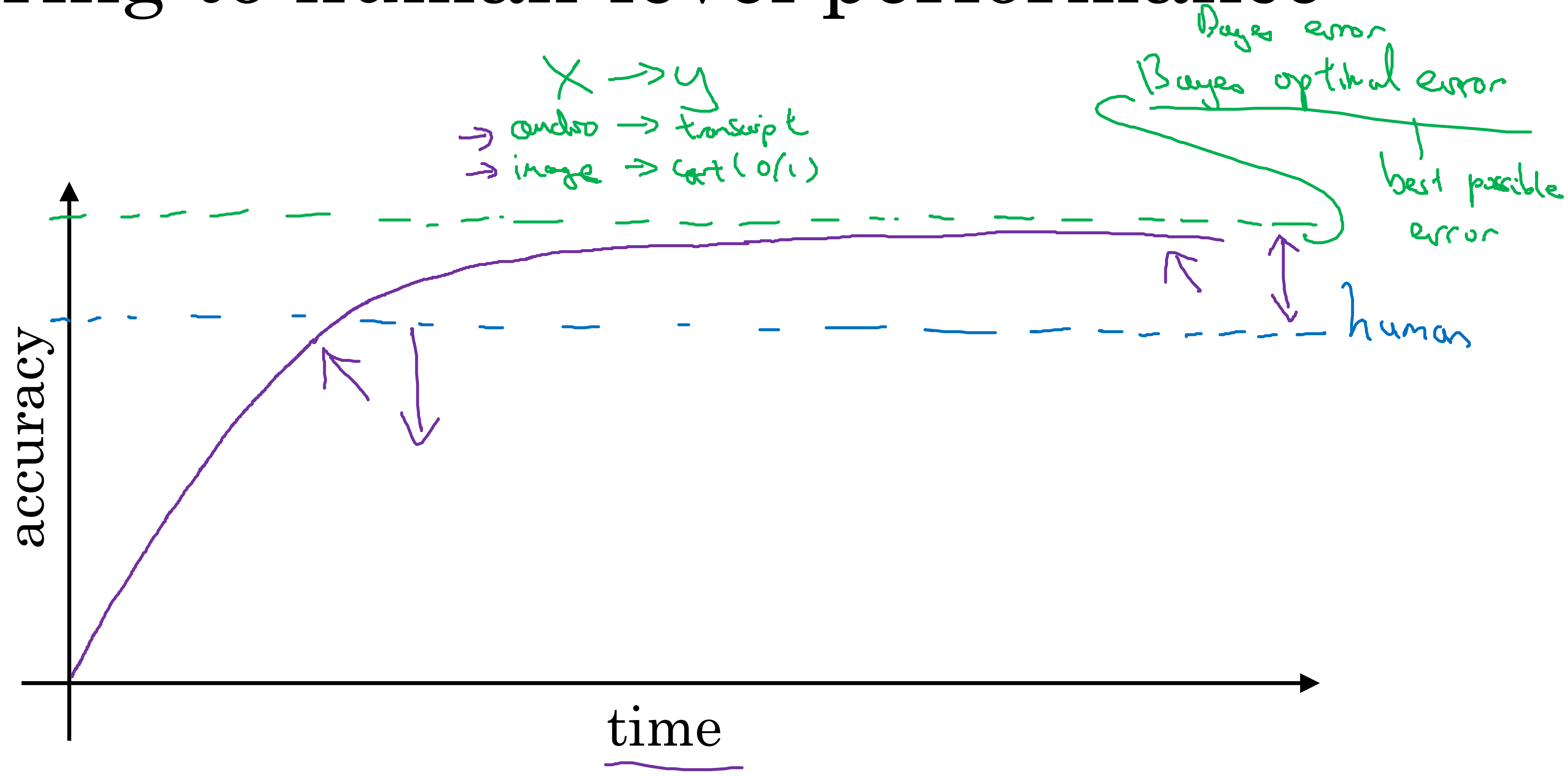
Why human-level performance?

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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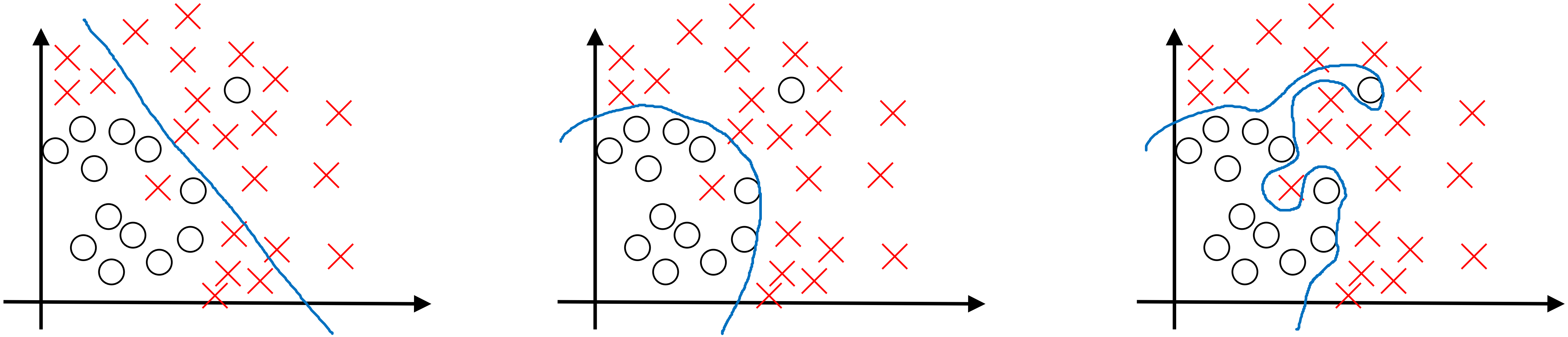
Comparing to human-level performance

Avoidable bias

Bias and Variance



high bias | "just right" | high variance

underfitting | | overfitting.

Bias and Variance

Cat classification

Human-level ≈ 0% ......

Training set error:

Dev set error:

high variance

high bias

high bias
high variance

low bias
low variance

Cat classification example

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

7%

2%

0.5%

Avoidable bias

2%

2%

Variance

Variance

Focus on bias

Focus on variance

Human-level error as a proxy for Bayes error.

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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

Baye error $\leq$ 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%	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%
One human	0.1	~~1%~~	1%
Training error		0.6%	0.3%
Dev error	0.2	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

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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

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