Transfer Learning

http://weebly110810.weebly.com/396403913129399.html

http://www.sucaitianxia.com/png/cartoon/200811/4261.html

Transfer Learning

Dog/Cat Classifier

cat

dog

Data ***not directly related to*** the task considered

elephant

tiger

dog

cat

Similar domain, different tasks

一樣是動物的圖片

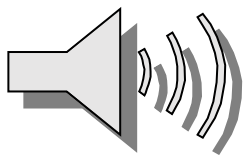
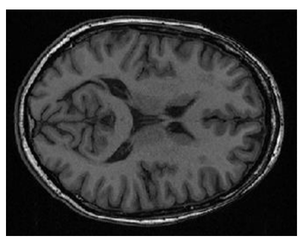
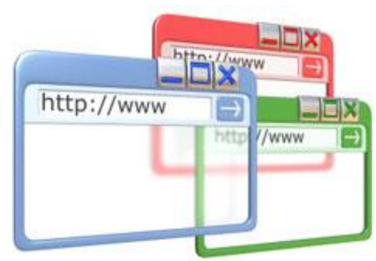
Different domains, same task

一樣要分貓狗

Why?

http://www.bigr.nl/website/structure/main.php?page=researchlines&subpage=project&id=64

http://www.spear.com.hk/Translation-company-Directory.html

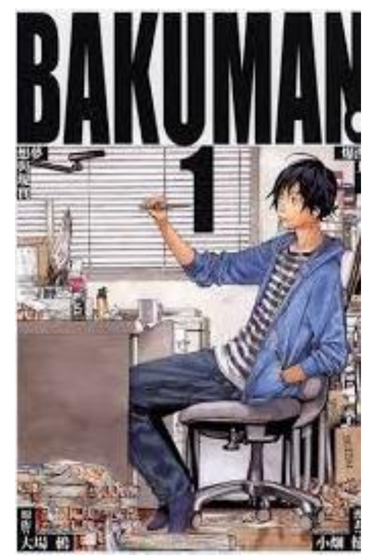
	Task Considered		Data not directly related	
Speech Recognition		Taiwanese	能不能用其他語言的data來improve台語的語音辨識 YouTube	English Chinese ……
Image Recognition		Medical Images		
Text Analysis		Specific domain		Webpages

Transfer Learning

- Example in real life

研究生		*漫畫家*
研究生	←	漫畫家
跑實驗	←	畫分鏡
指導教授	←	責編
投稿期刊	←	投稿 jump

(word embedding knows that)



爆漫王

Transfer Learning - Overview

無關

有關task

		Source Data (not directly related to the task)	
		labelled	unlabeled
Target Data	labelled	Model Fine-tuning	
	unlabeled		

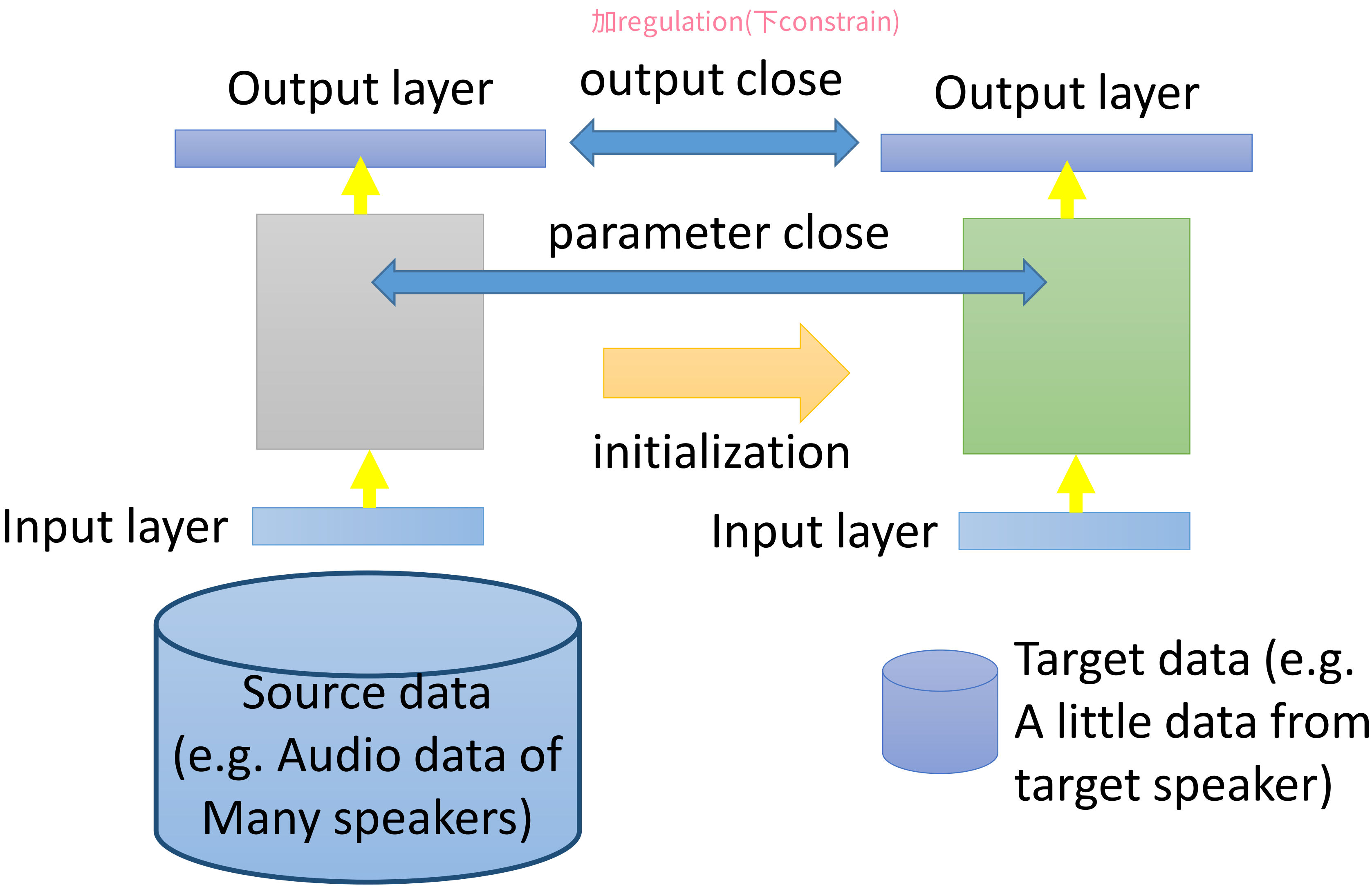
Warning: different terminology in different literature

Model Fine-tuning

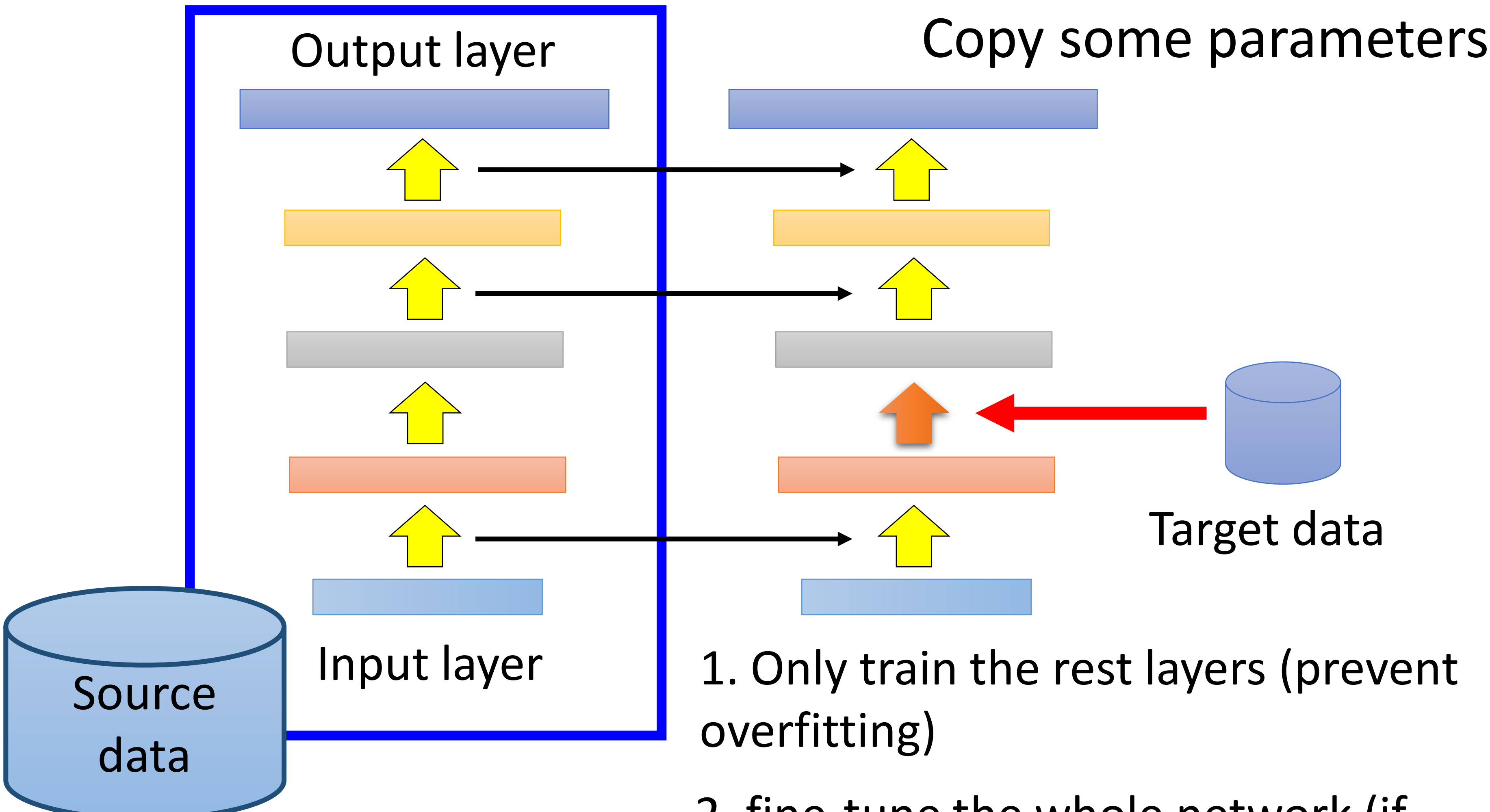
One-shot learning: only a few examples in target domain

- Task description
  - Source data: (x^s, y^s) A large amount
  - Target data: (x^t, y^t) Very little
- Example: (supervised) speaker adaption
  - Source data: audio data and transcriptions from many speakers
  - Target data: audio data and its transcriptions of specific user
- Idea: training a model by source data, then fine-tune the model by target data
  - Challenge: only limited target data, so be careful about overfitting

Conservative Training



Layer Transfer



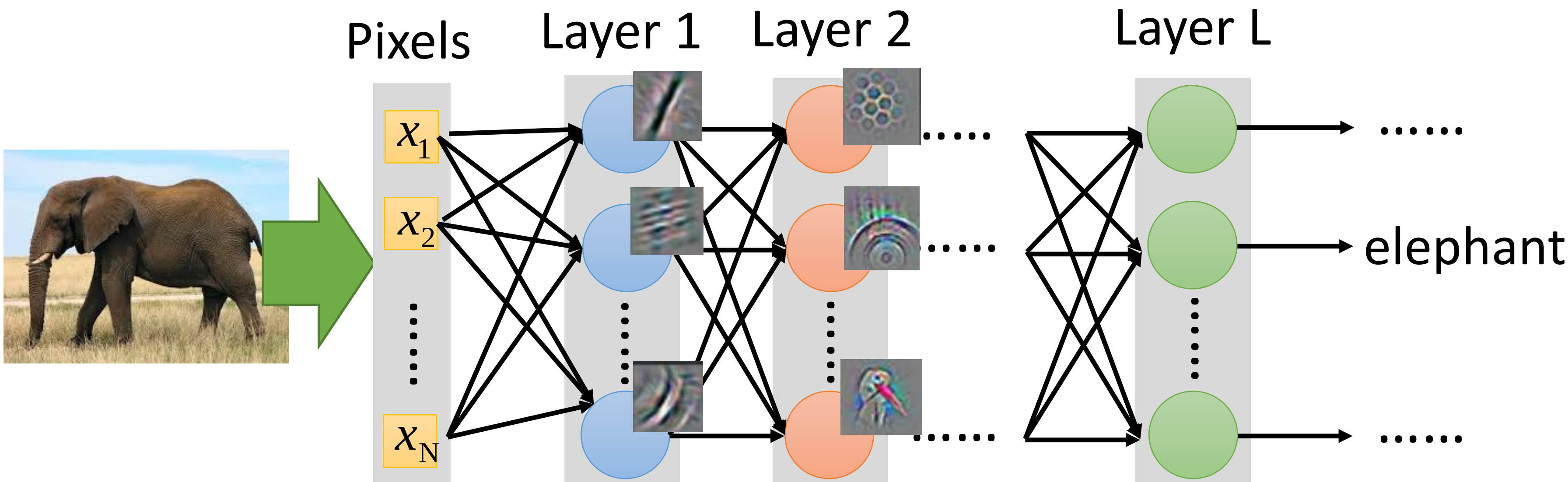
1. Only train the rest layers (prevent overfitting)

2. fine-tune the whole network (if there is sufficient data)

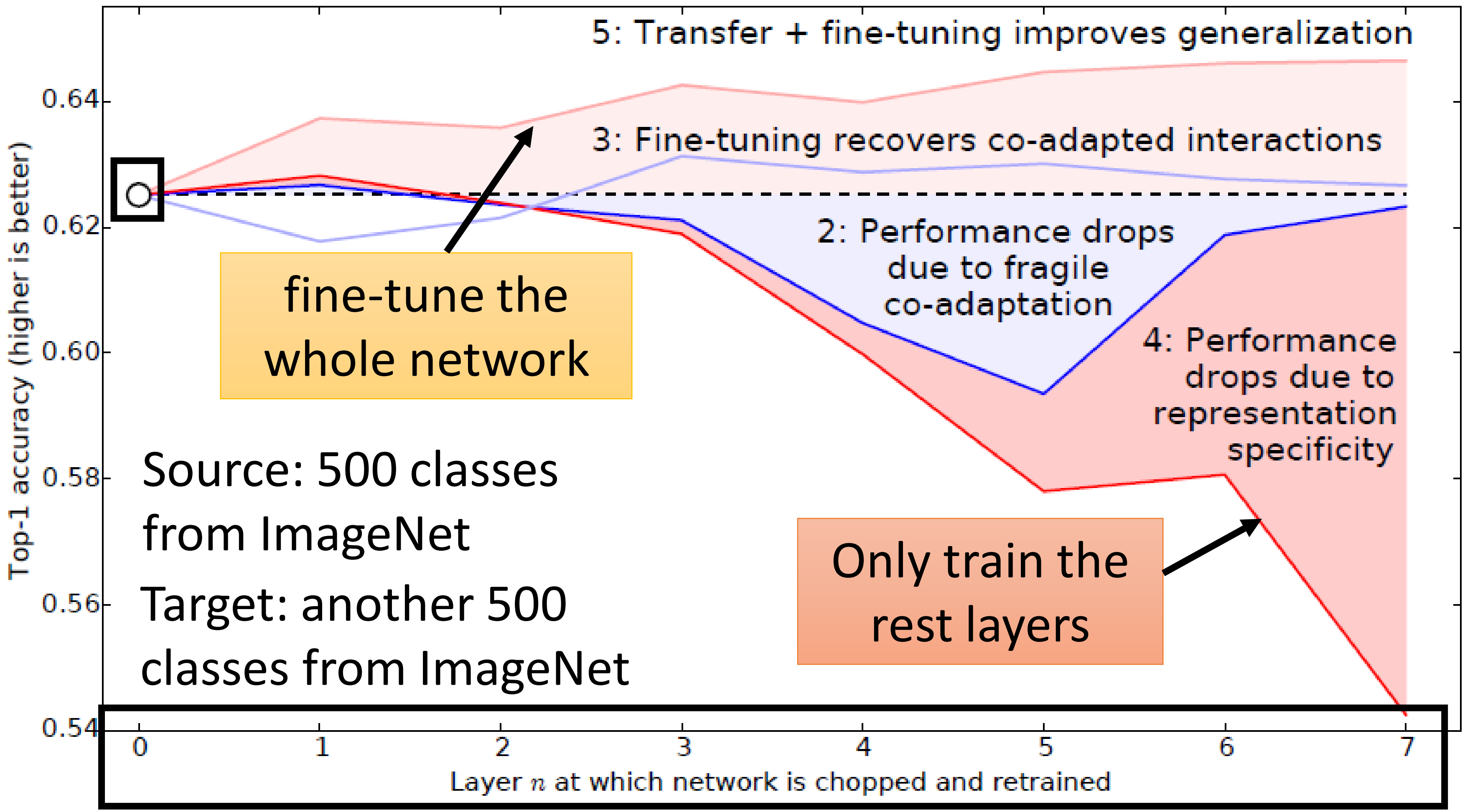
Layer Transfer

在不同的task中，需要被transfer的layer通常不一樣

- Which layer can be transferred (copied)?
  - Speech: usually copy the last few layers
  - Image: usually copy the first few layers



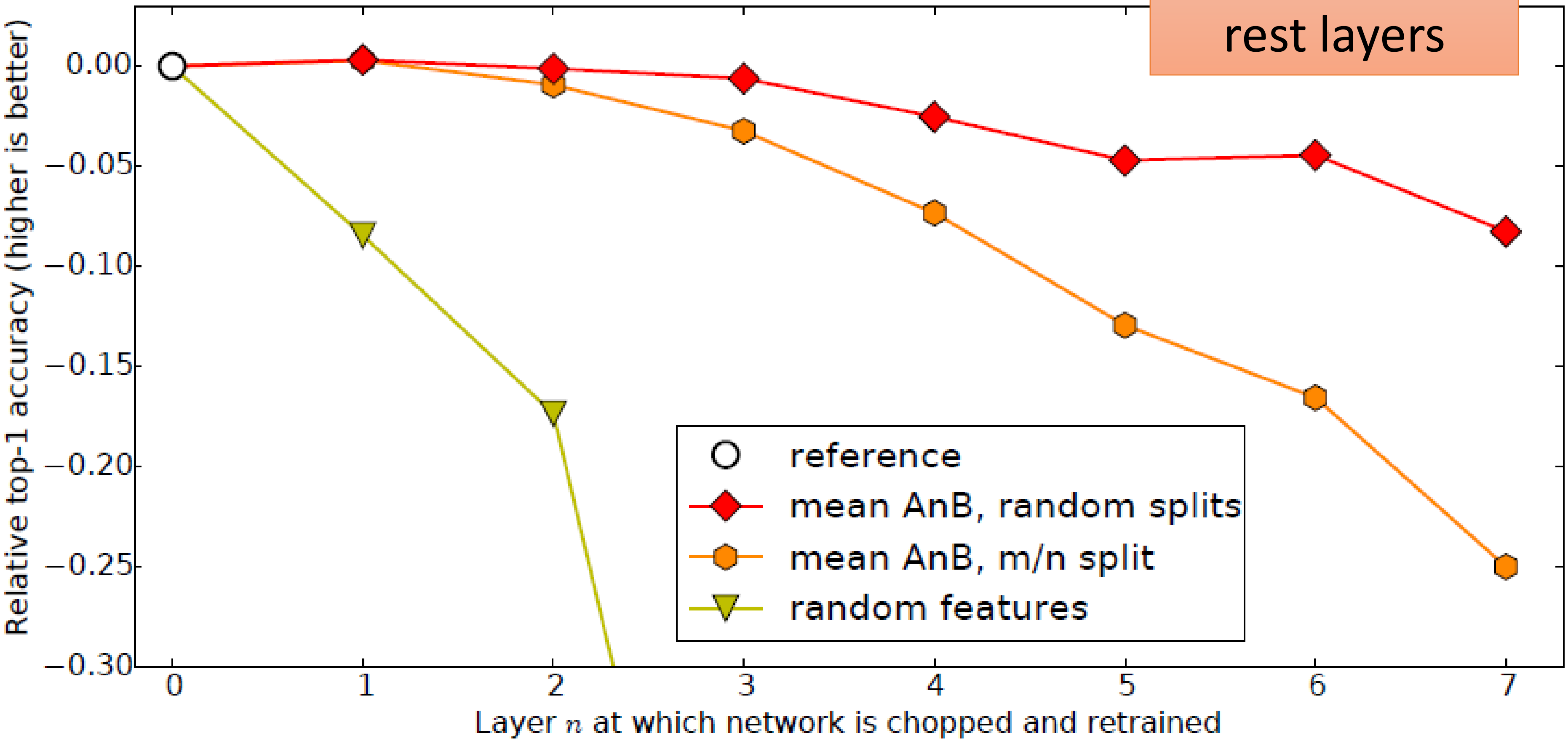
Layer Transfer - Image



Jason Yosinski, Jeff Clune, Yoshua Bengio, Hod Lipson, “How transferable are features in deep neural networks?”, NIPS, 2014

Layer Transfer - Image

Only train the rest layers



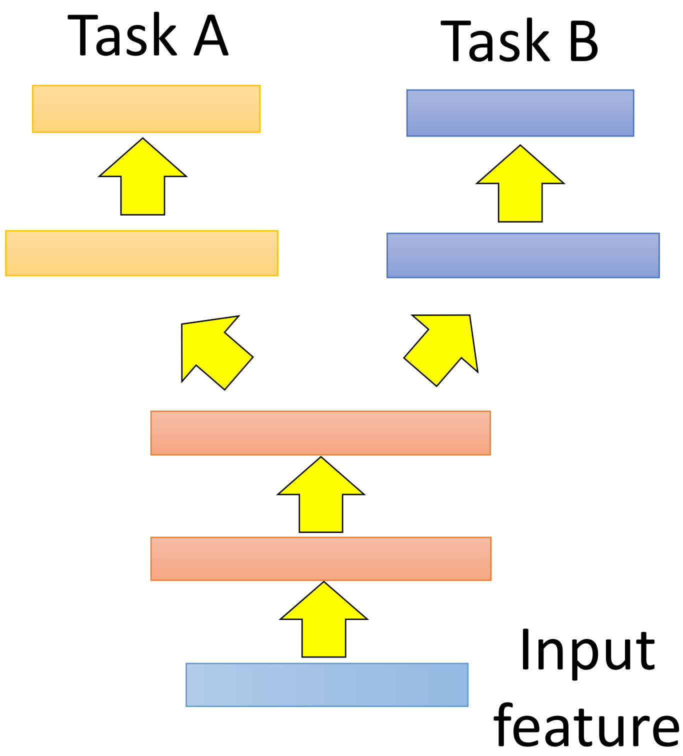
Jason Yosinski, Jeff Clune, Yoshua Bengio, Hod Lipson, “How transferable are features in deep neural networks?”, NIPS, 2014

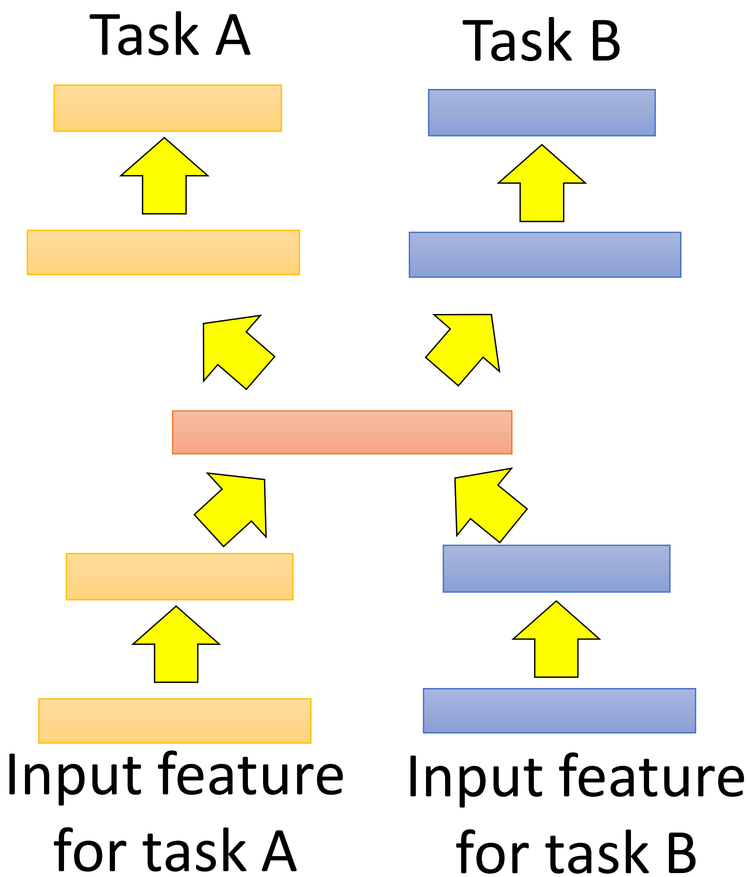
Transfer Learning - Overview

		Source Data (not directly related to the task)	
		labelled	unlabeled
Target Data	labelled	在乎的是target domain做得好不好 Fine-tuning Multitask Learning 同時在乎target domain & source domain做得好不好	
	unlabeled		

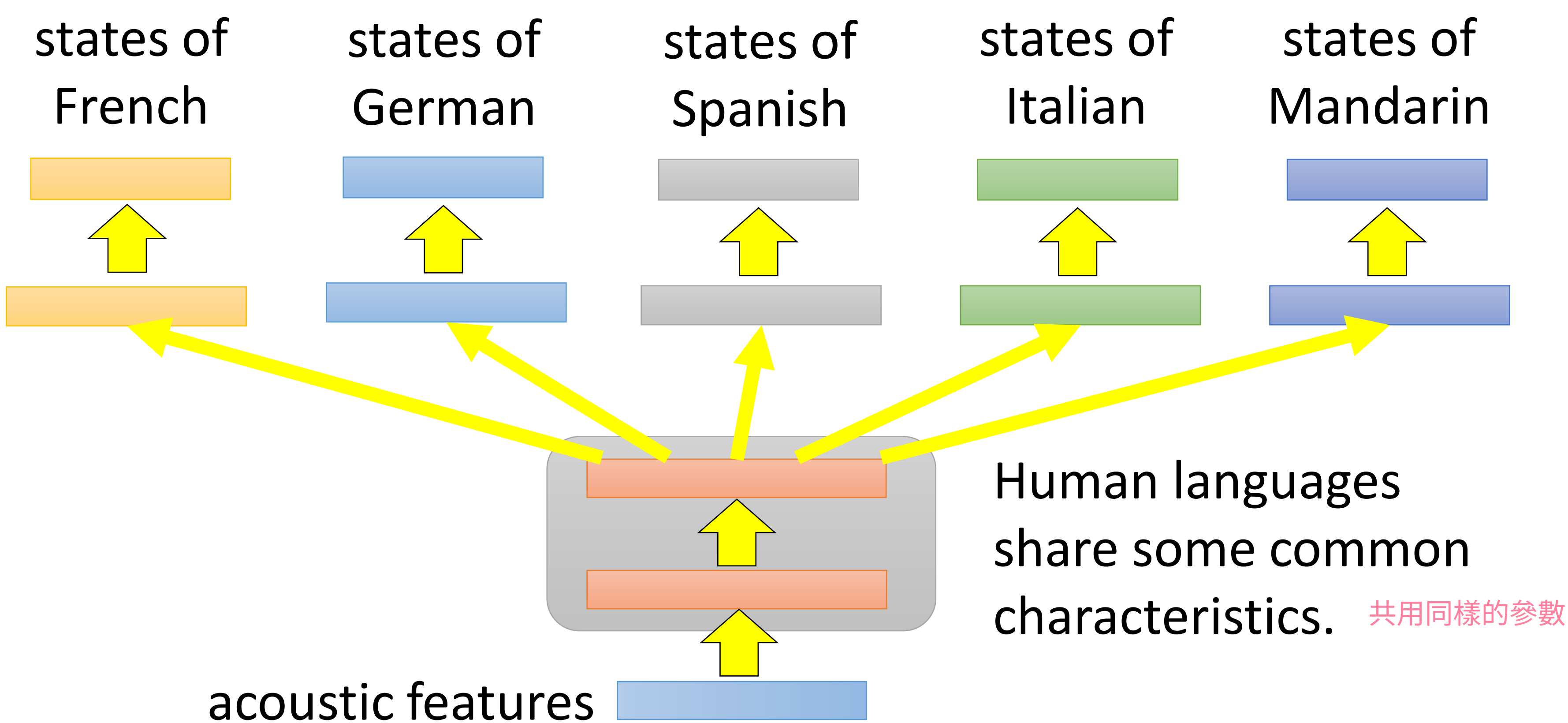
Multitask Learning

- The multi-layer structure makes NN suitable for multitask learning





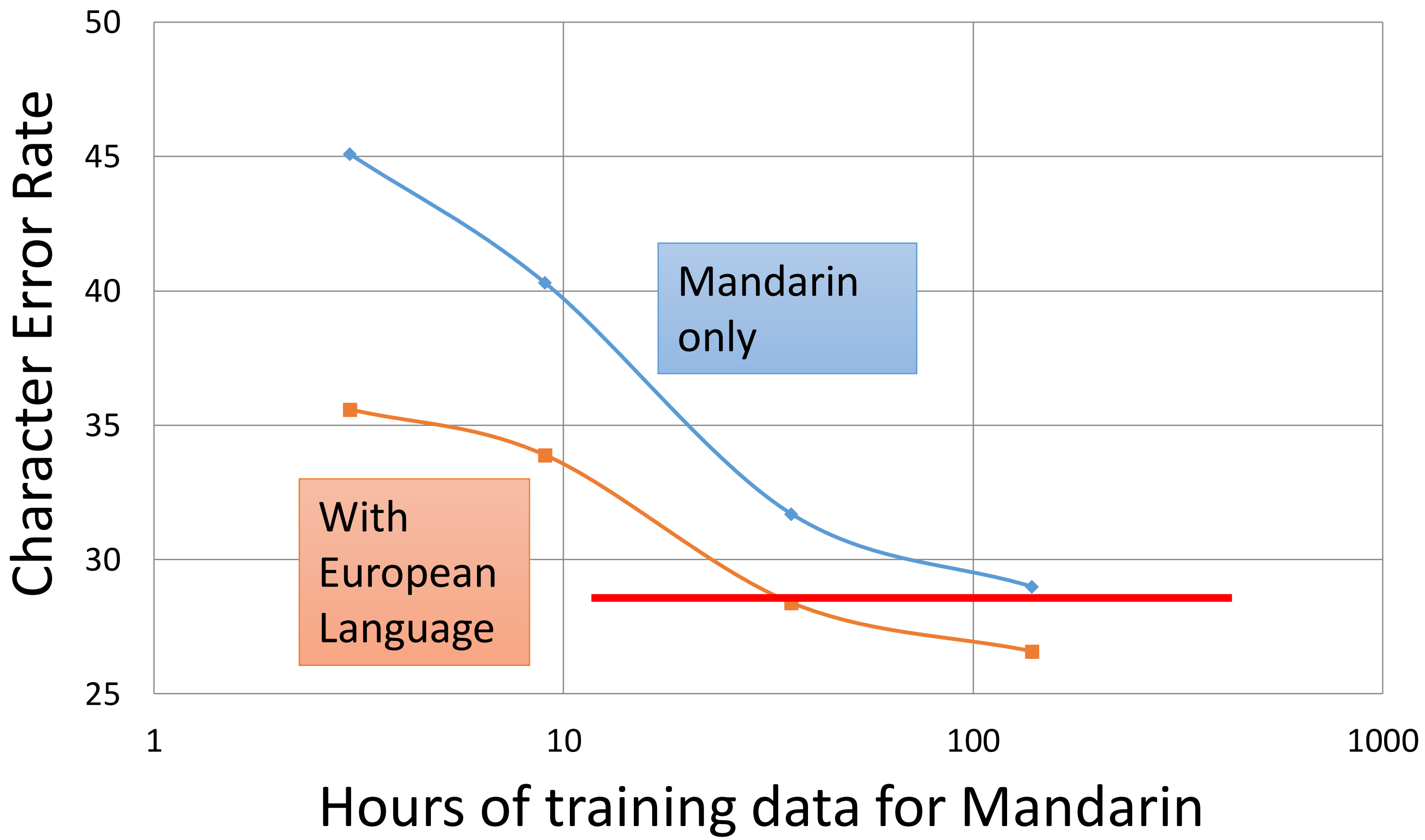
Multitask Learning
- Multilingual Speech Recognition



Similar idea in translation: Daxiang Dong, Hua Wu, Wei He, Dianhai Yu and Haifeng Wang, "Multi-task learning for multiple language translation.“, ACL 2015

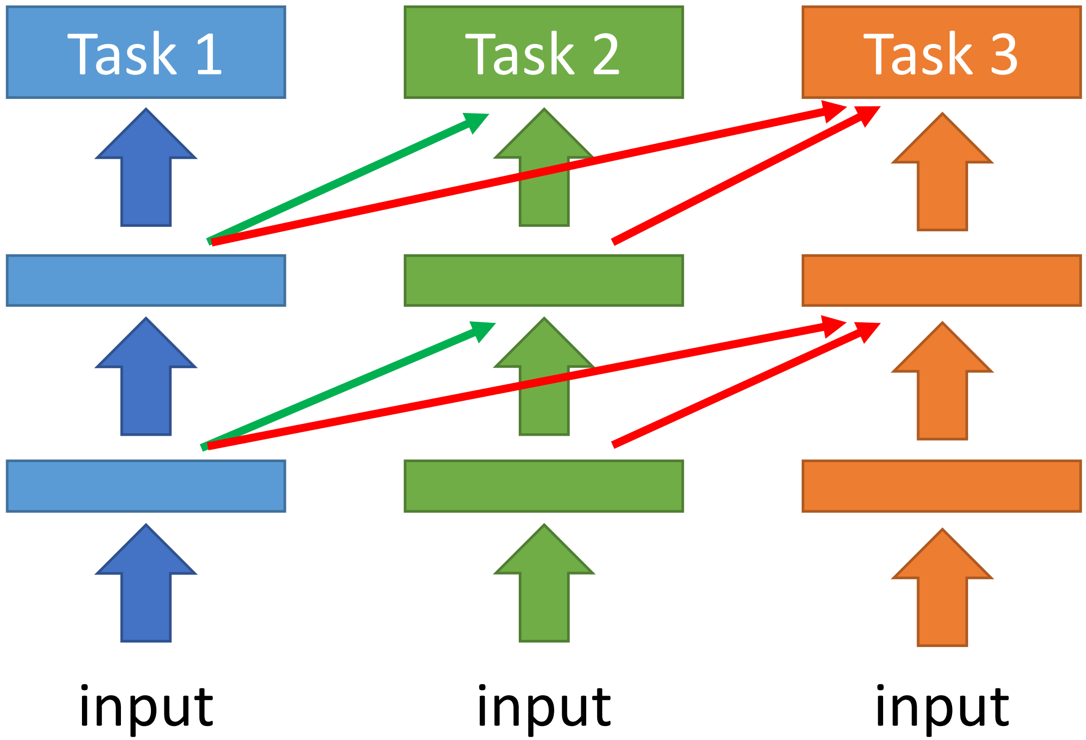
Multitask Learning - Multilingual

不同語系能否transfer?

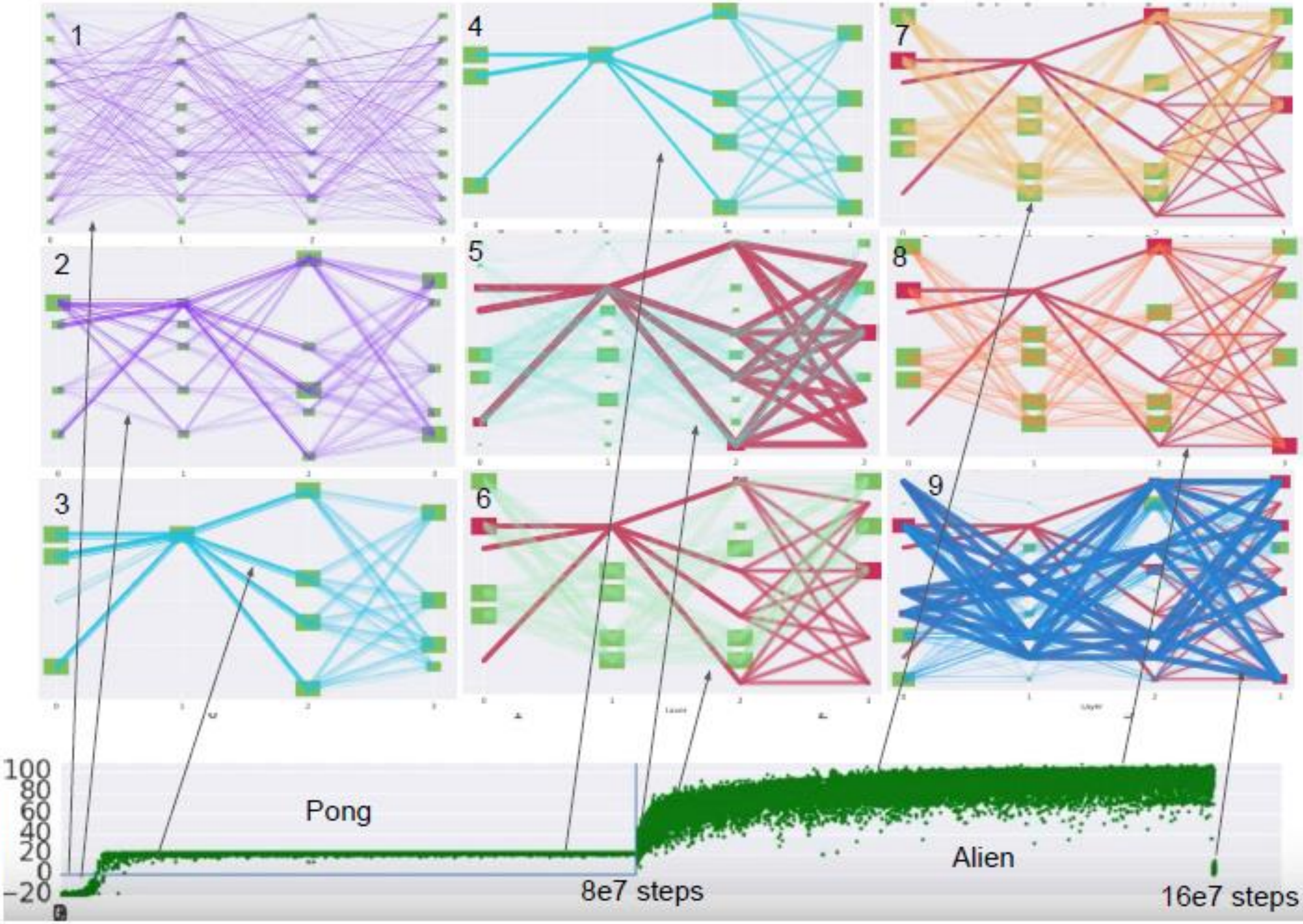


Huang, Jui-Ting, et al. "Cross-language knowledge transfer using multilingual deep neural network with shared hidden layers." *ICASSP, 2013*

Progressive Neural Networks



Andrei A. Rusu, Neil C. Rabinowitz, Guillaume Desjardins, Hubert Soyer, James Kirkpatrick, Koray Kavukcuoglu, Razvan Pascanu, Raia Hadsell, "Progressive Neural Networks", arXiv preprint 2016



Chrisantha Fernando, Dylan Banarse, Charles Blundell, Yori Zwols, David Ha, Andrei A. Rusu, Alexander Pritzel, Daan Wierstra, "PathNet: Evolution Channels Gradient Descent in Super Neural Networks", arXiv preprint, 2017

Transfer Learning - Overview

		Source Data (not directly related to the task)	
		labelled	unlabeled
Target Data	labelled	Fine-tuning Multitask Learning	
	unlabeled	Domain-adversarial training	

Task description

input output

- Source data: (x^s, y^s) → Training data
- Target data: (x^t) → Testing data

Same task, mismatch

MNIST Training data

SOURCE

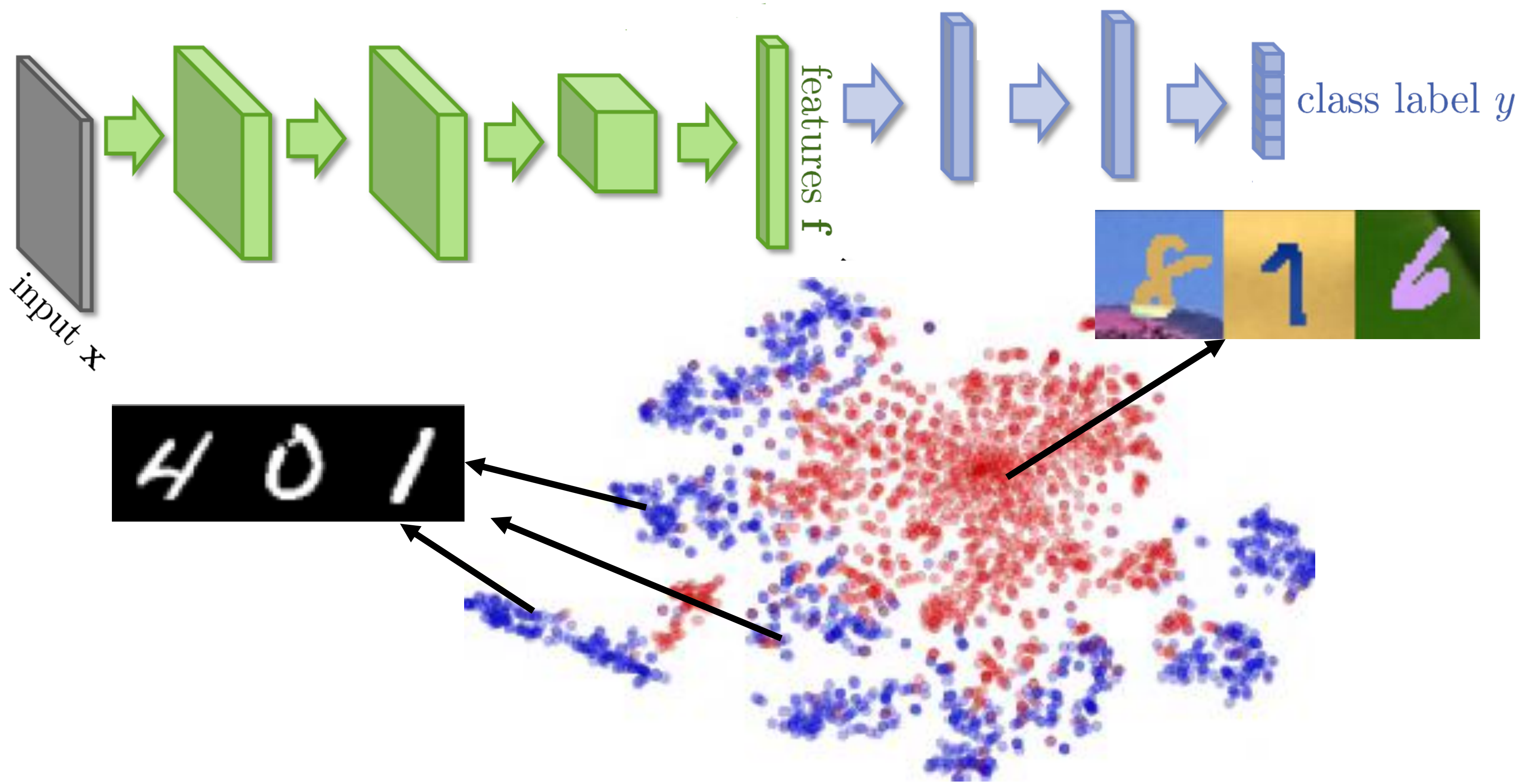
TARGET

with label

without label

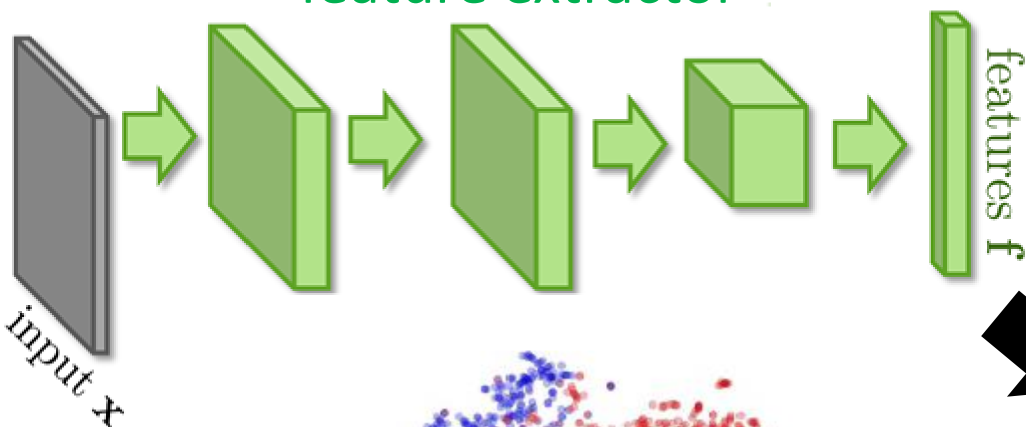
MNIST-M Testing data

Domain-adversarial training



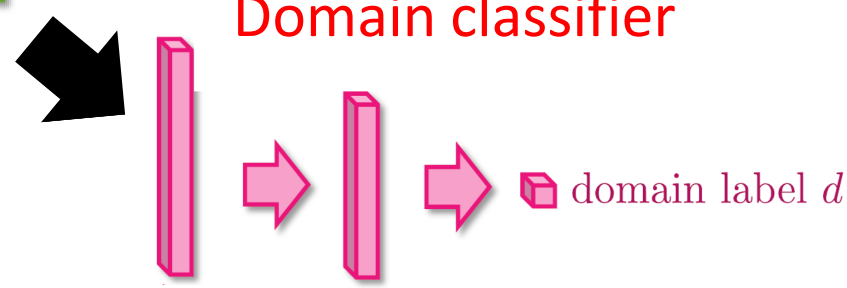
Domain-adversarial training

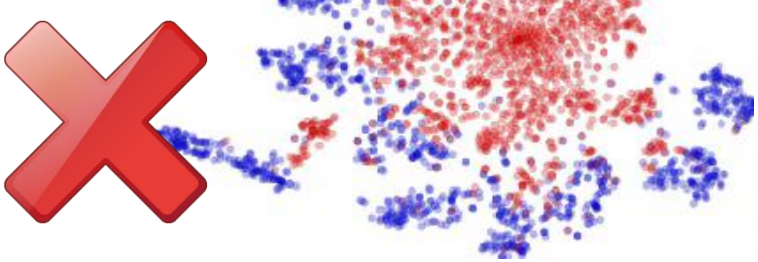
把domain的特性消掉

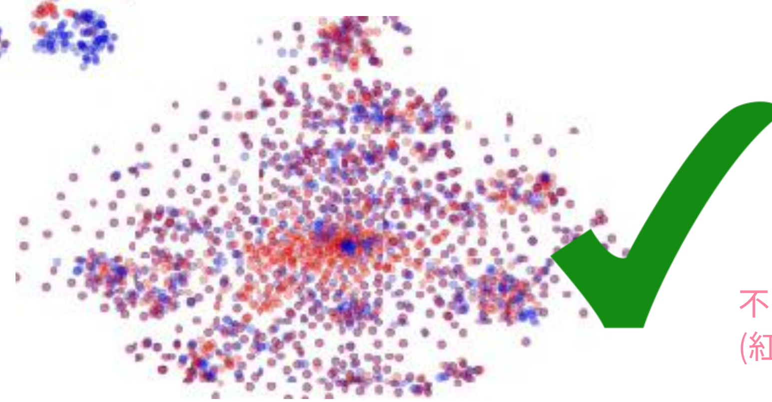


Similar to GAN

Too easy to feature extractor ……





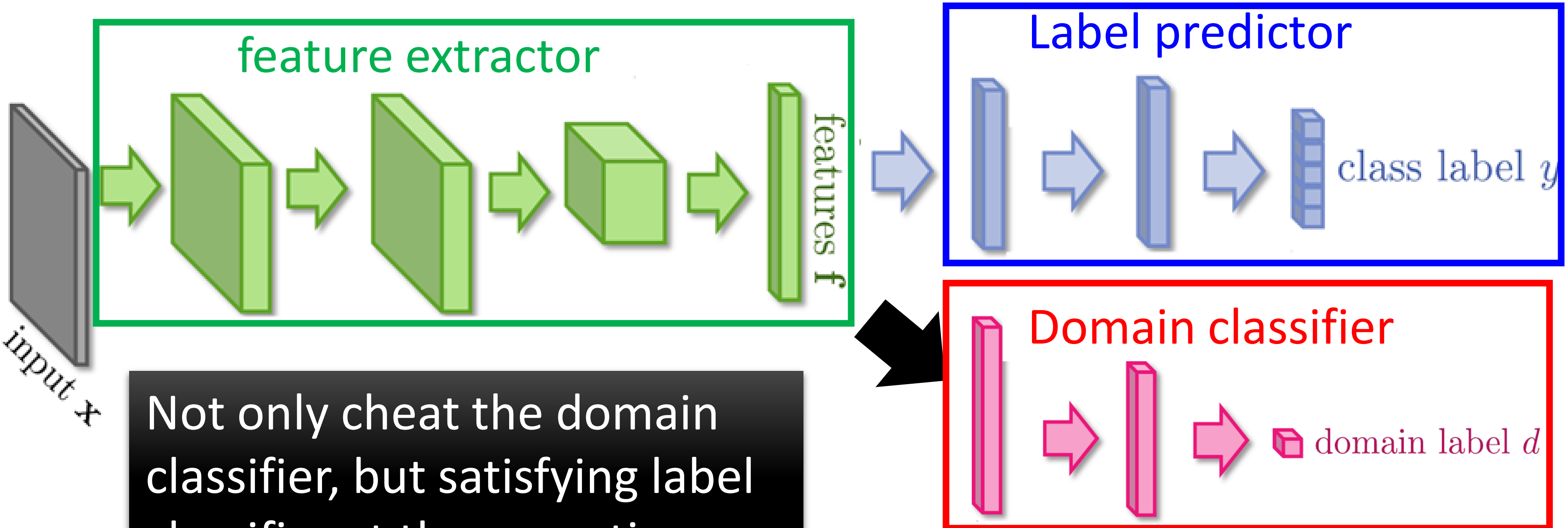


不同domain應該混在一起(紅藍)

Domain-adversarial training

Maximize label classification accuracy + minimize domain classification accuracy

Maximize label classification accuracy

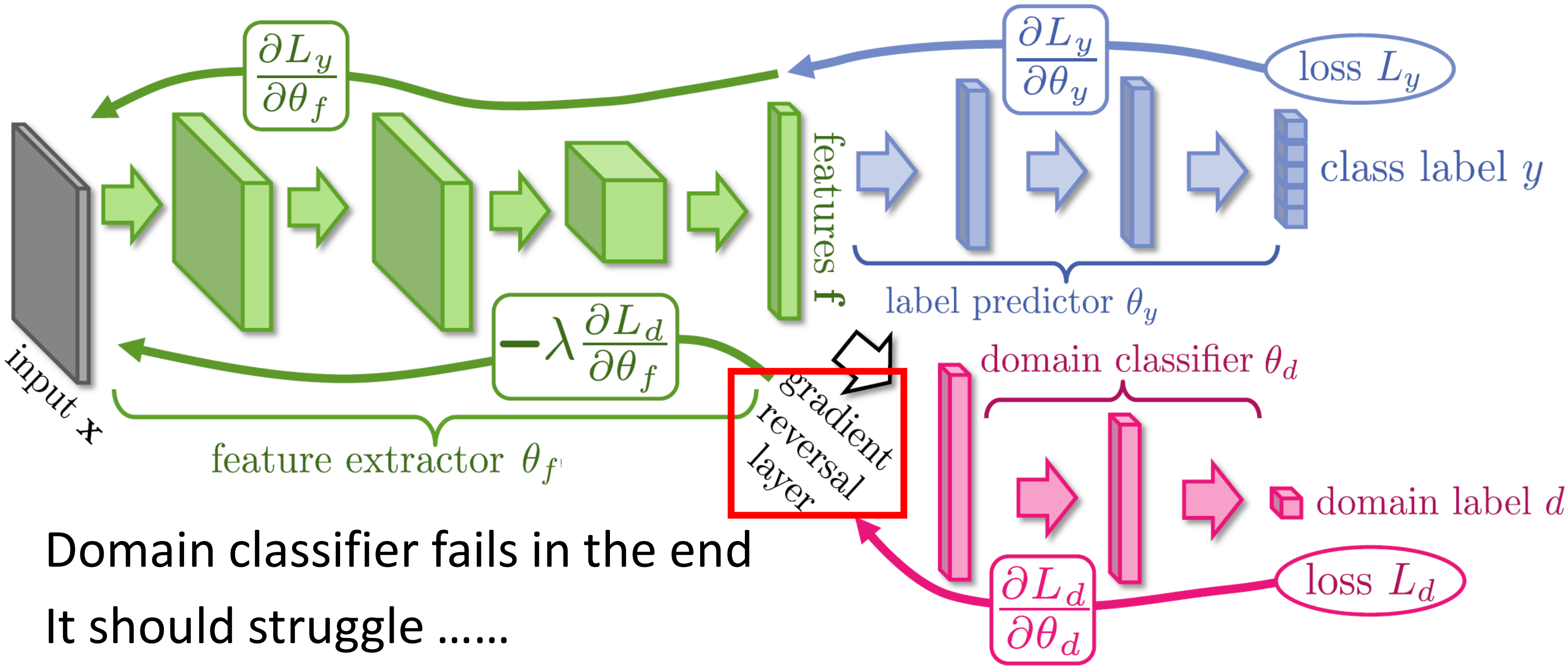


Not only cheat the domain classifier, but satisfying label classifier at the same time

Maximize domain classification accuracy

This is a big network, but different parts have different goals.

Domain-adversarial training



Domain classifier fails in the end

It should struggle ……

Yaroslav Ganin, Victor Lempitsky, Unsupervised Domain Adaptation by Backpropagation, ICML, 2015

Hana Ajakan, Pascal Germain, Hugo Larochelle, François Laviolette, Mario Marchand, Domain-Adversarial Training of Neural Networks, JMLR, 2016

Domain-adversarial training

METHOD (SOURCE / TARGET)	MNIST / MNIST-M	SYN NUMBERS / SVHN	SVHN / MNIST	SYN SIGNS / GTSRB
SOURCE ONLY	.5749	.8665	.5919	.7400
SA (FERNANDO ET AL., 2013)	.6078 (7.9%)	.8672 (1.3%)	.6157 (5.9%)	.7635 (9.1%)
PROPOSED APPROACH	**.8149** (57.9%)	**.9048** (66.1%)	**.7107** (29.3%)	**.8866** (56.7%)
TRAIN ON TARGET	.9891	.9244	.9951	.9987

Yaroslav Ganin, Victor Lempitsky, Unsupervised Domain Adaptation by Backpropagation, ICML, 2015

Hana Ajakan, Pascal Germain, Hugo Larochelle, François Laviolette, Mario Marchand, Domain-Adversarial Training of Neural Networks, JMLR, 2016

Transfer Learning - Overview

		Source Data (not directly related to the task)	
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Target Data	labelled	Fine-tuning Multitask Learning	
	unlabeled	Domain-adversarial training Zero-shot learning	

Zero-shot Learning

http://evchk.wikia.com/wiki/%E8%8D%89%E6%B3%A5%E9%A6%AC

- Source data: (x^s, y^s) → Training data
- Target data: (x^t) → Testing data

Different tasks

x^s:   ……

y^s: cat dog ……

x^t :  

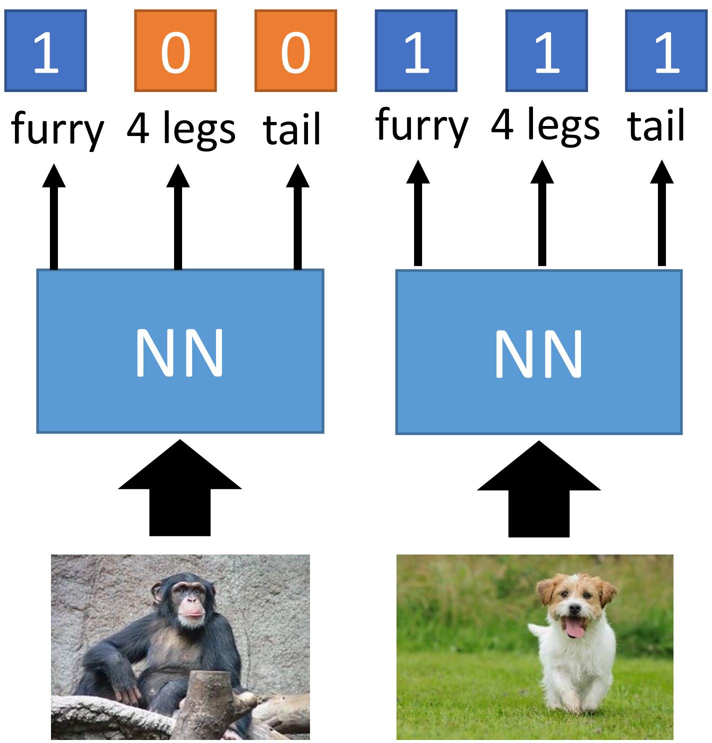
In speech recognition, we can not have all possible words in the source (training) data.

How we solve this problem in speech recognition?

Zero-shot Learning

- Representing each class by its attributes

Training



Database

attributes

class

	furry	4 legs	tail	…
Dog	O	O	O	
Fish	X	X	O	
Chimp	O	X	X	
…				

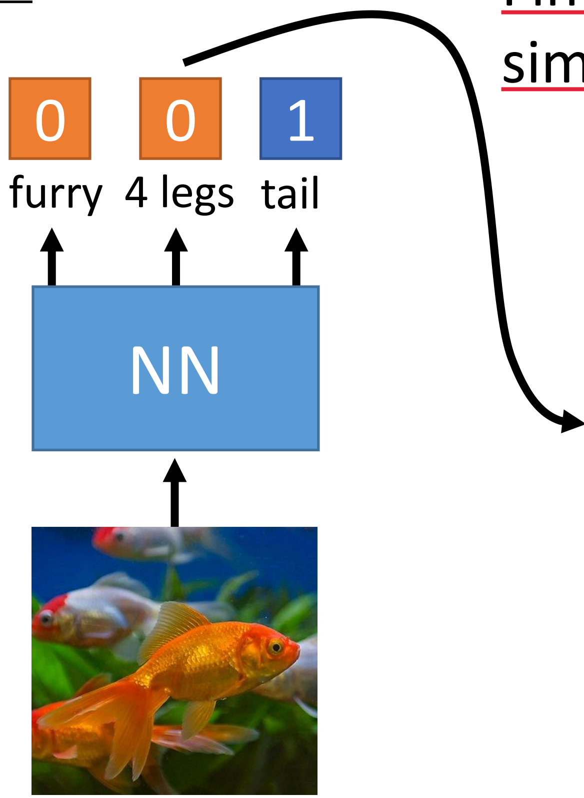
sufficient attributes for one to one mapping

Zero-shot Learning

- Representing each class by its attributes

Testing

Find the class with the most similar attributes



class

attributes

	furry	4 legs	tail	…
Dog	O	O	O	
Fish	X	X	O	
Chimp	O	X	X	
…				

sufficient attributes for one to one mapping

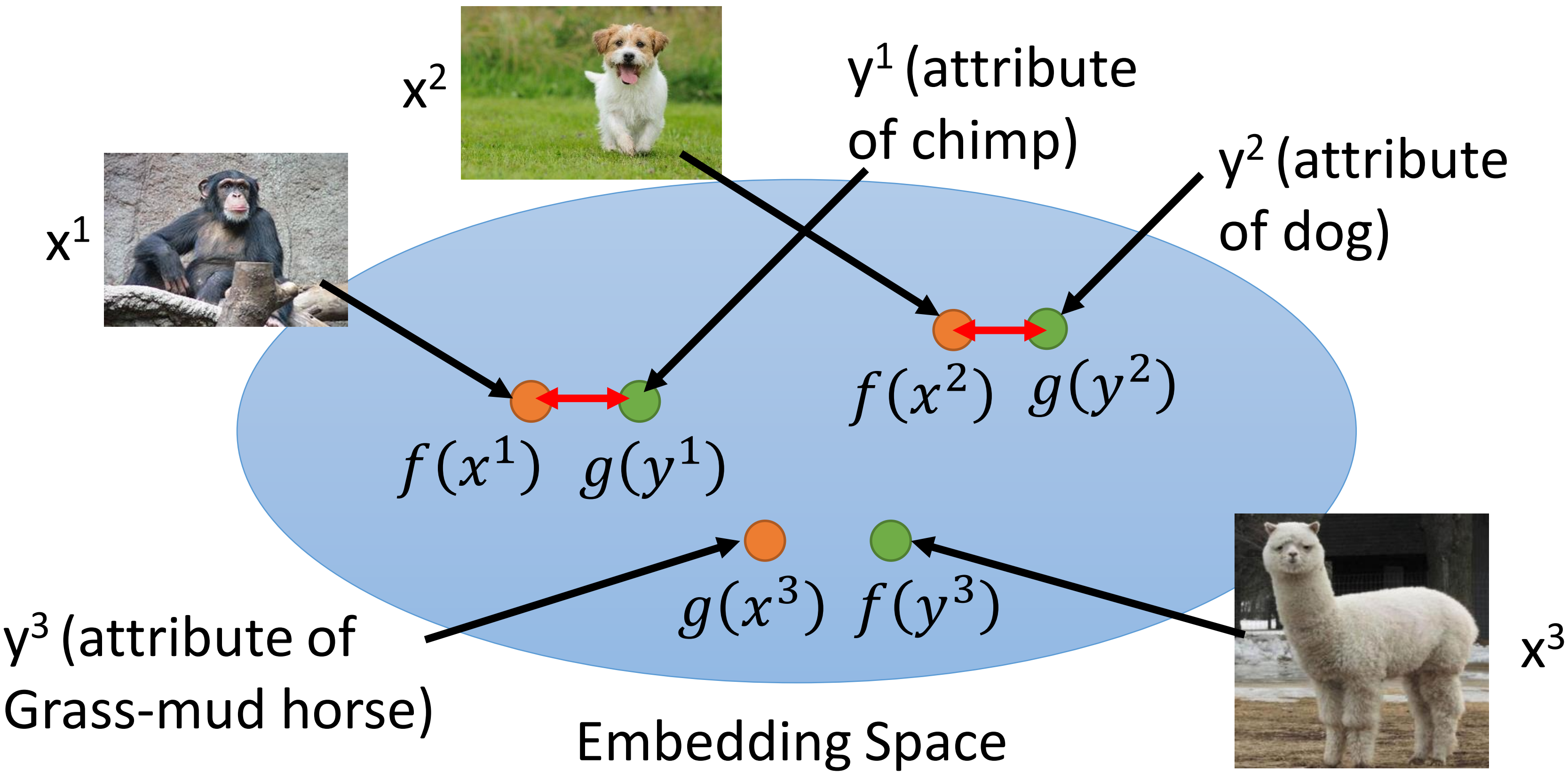
Zero-shot Learning

$f(*)$ and $\mathrm{g}(*)$ can be NN.

Training target:

$f(x^n)$ and $g(y^n)$ as close as possible

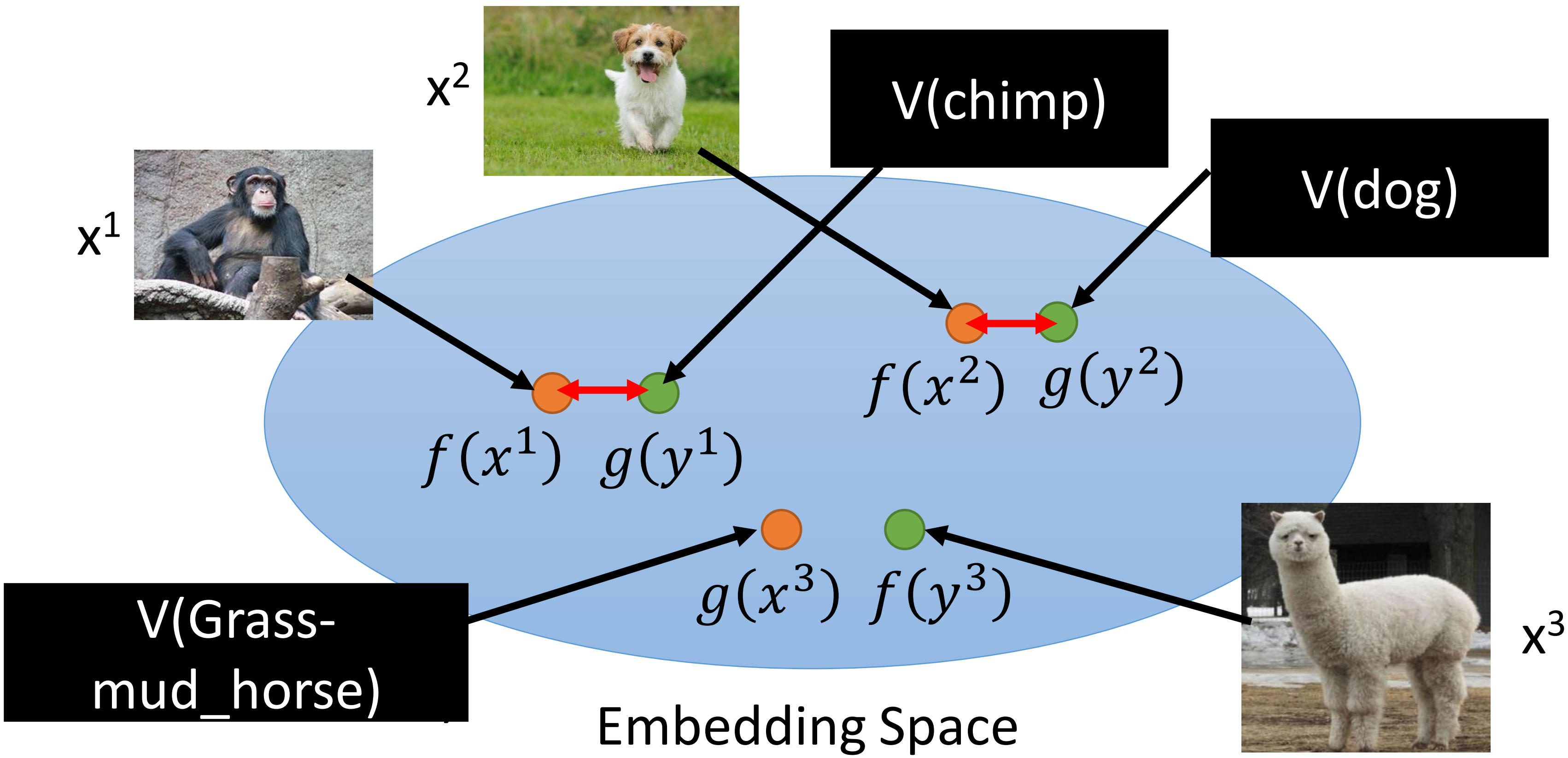
- Attribute embedding



Zero-shot Learning

What if we don't have database

- Attribute embedding + word embedding



Zero-shot Learning

$$f^*, g^* = arg \min_{f,g} \sum_n \|f(x^n) - g(y^n)\|_2$$

Problem?

$$f^*, g^* = arg \min_{f,g} \sum_n max\left(0, k - f(x^n) \cdot g(y^n) + \max_{m \neq n} f(x^n) \cdot g(y^m)\right)$$

Margin you defined

Zero loss: $k - f(x^n) \cdot g(y^n) + \max_{m \neq n} f(x^n) \cdot g(y^m) < 0$

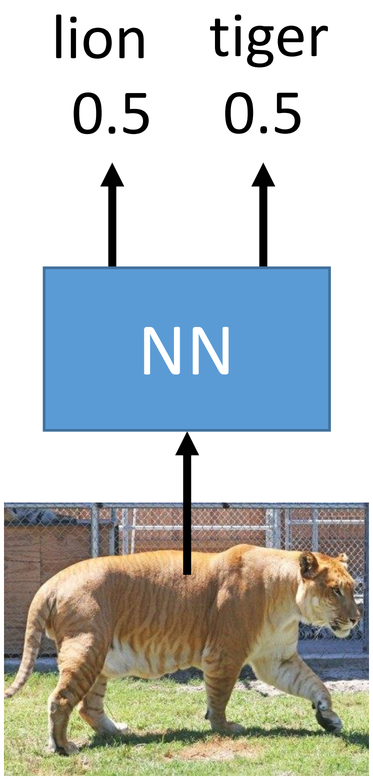
$$\underline{f(x^n) \cdot g(y^n)} - \underline{\max_{m \neq n} f(x^n) \cdot g(y^m)} > k$$

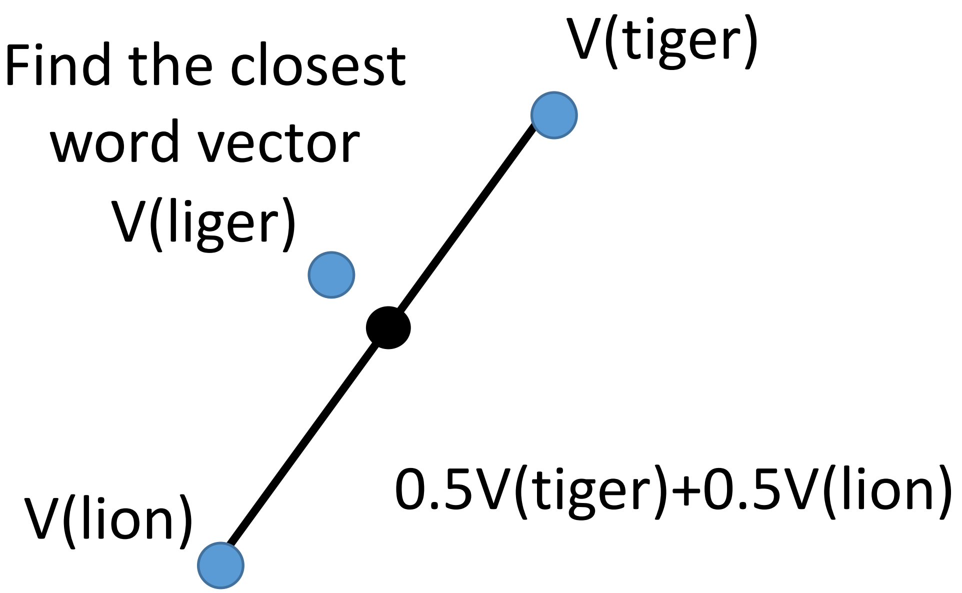
$f(x^n)$ and $g(y^n)$ as close

$f(x^n)$ and $g(y^m)$ not as close

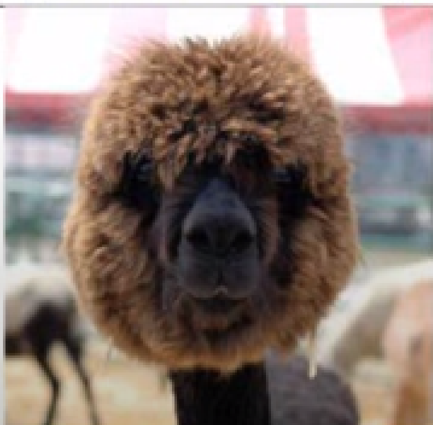
Zero-shot Learning

- Convex Combination of Semantic Embedding



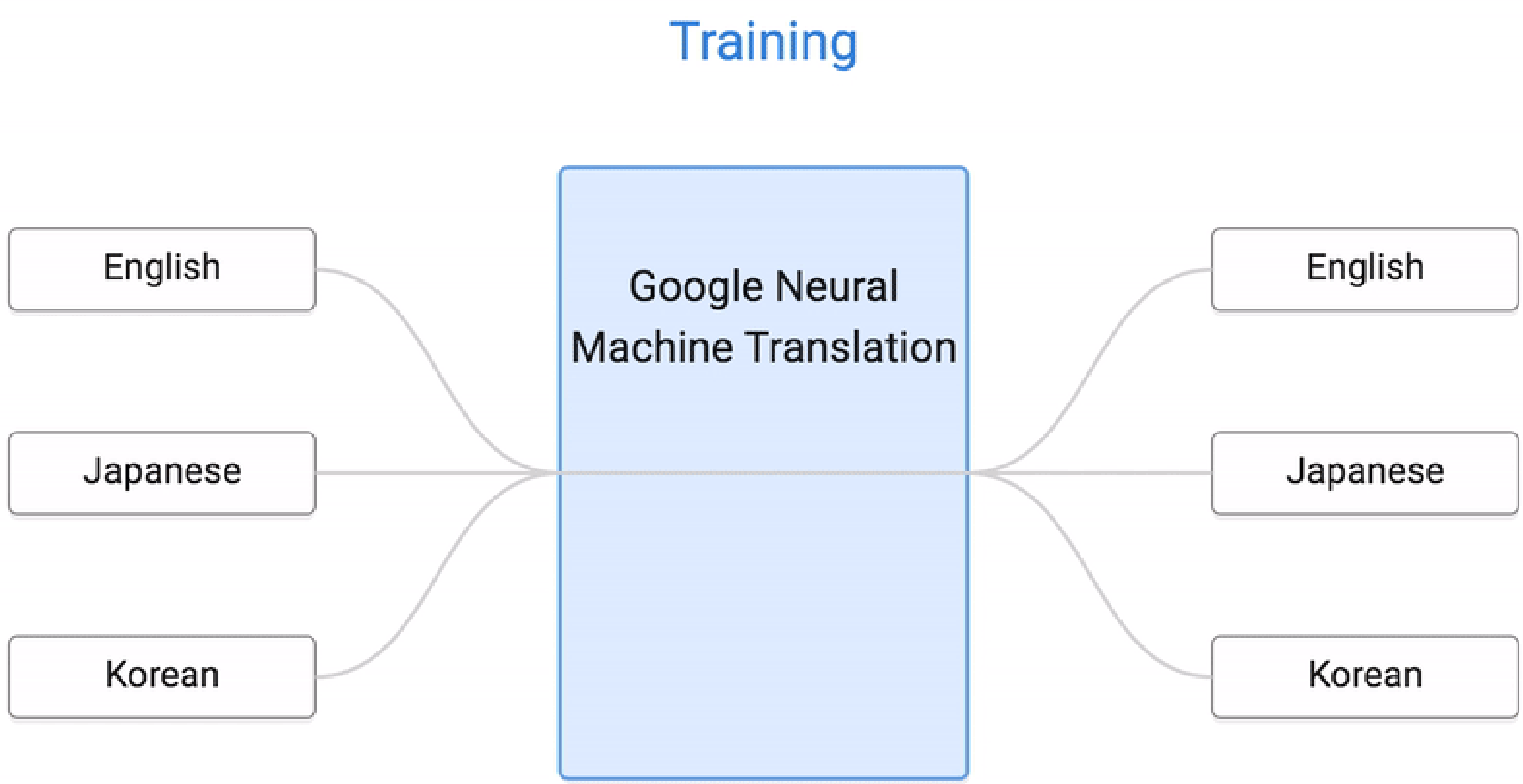


Only need off-the-shelf NN for ImageNet and word vector

Test Image	ConvNet	DeViSE	ConSE(10)
 **(Stellar sea lion)**	sea lion carpenter's plane cowboy boot loggerhead goose	elephant turtle turtleneck flip-flop cart, handcart	California sea lion **Steller sea lion** Australian sea lion South American sea lion eared seal
 **(Lama pacos)**	Tibetan mastiff titi monkey Koala llama chow-chow	kernel littoral zone carillon Cabernet Sauvignon poodle dog	domestic dog domestic cat schnauzer Belgian sheepdog domestic llama

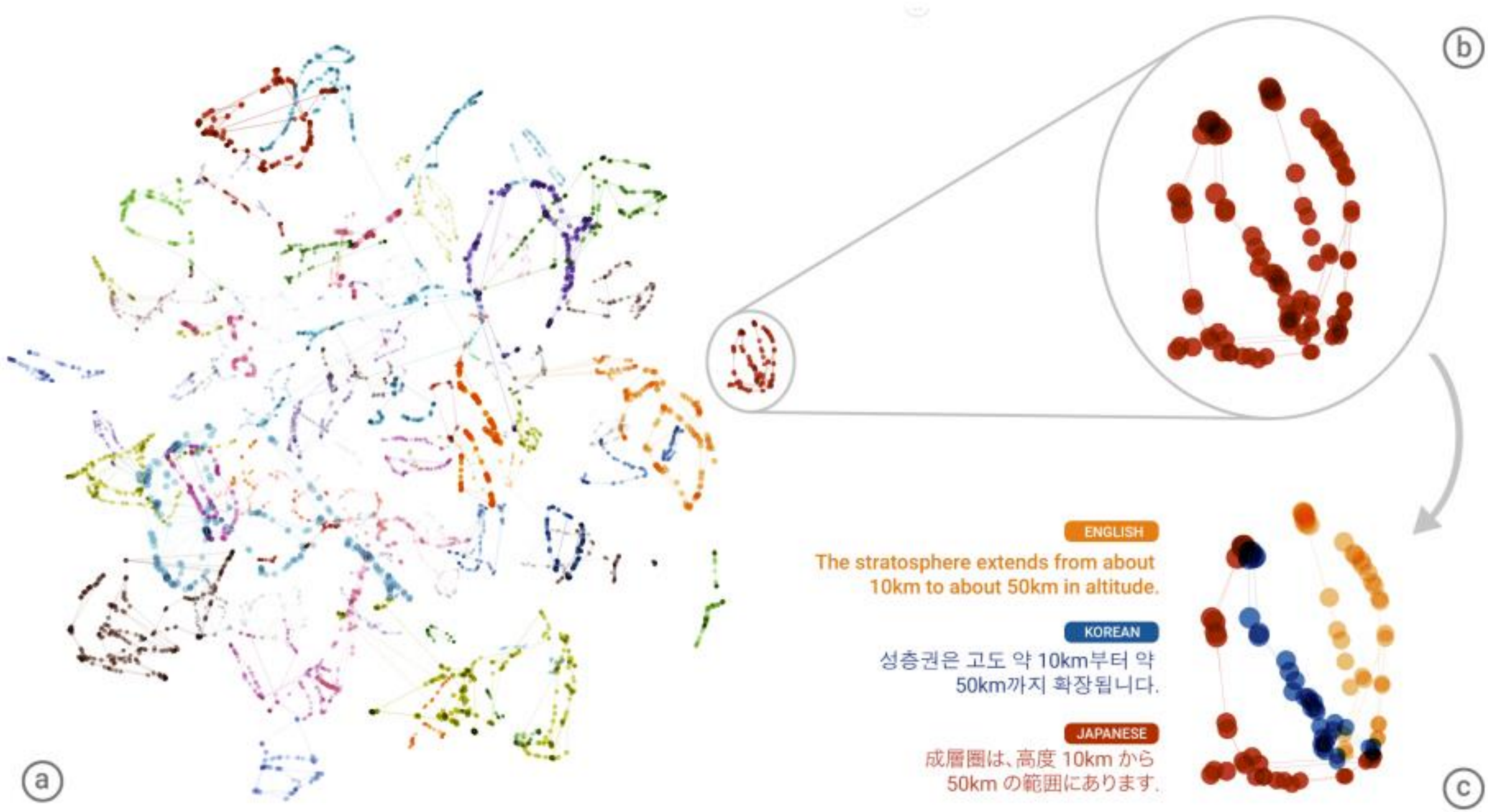
https://arxiv.org/pdf/1312.5650v3.pdf

Example of Zero-shot Learning



Melvin Johnson, Mike Schuster, Quoc V. Le, Maxim Krikun, Yonghui Wu, Zhifeng Chen, Nikhil Thorat. Google's Multilingual Neural Machine Translation System: Enabling Zero-Shot Translation, arXiv preprint 2016

Example of Zero-shot Learning



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		labelled	unlabeled
Target Data	labelled	Fine-tuning Multitask Learning	Self-taught learning Rajat Raina , Alexis Battle , Honglak Lee , Benjamin Packer , Andrew Y. Ng, Self-taught learning: transfer learning from unlabeled data, ICML, 2007
	unlabeled	Domain-adversarial training Zero-shot learning	Self-taught Clustering Wenyuan Dai, Qiang Yang, Gui-Rong Xue, Yong Yu, "Self-taught clustering", ICML 2008

Different from semi-supervised learning

Self-taught learning

- Learning to extract better representation from the source data (unsupervised approach)
- Extracting better representation for target data

Domain	Unlabeled data	Labeled data	Classes	Raw features
Image classification	10 images of outdoor scenes	Caltech101 image classification dataset	101	Intensities in 14x14 pixel patch
Handwritten character recognition	Handwritten digits ("0"–"9")	Handwritten English characters ("a"–"z")	26	Intensities in 28x28 pixel character/digit image
Font character recognition	Handwritten English characters ("a"–"z")	Font characters ("a"/"A" – "z"/"Z")	26	Intensities in 28x28 pixel character image
Song genre classification	Song snippets from 10 genres	Song snippets from 7 *different* genres	7	Log-frequency spectrogram over 50ms time windows
Webpage classification	100,000 news articles (Reuters newswire)	Categorized webpages (from DMOZ hierarchy)	2	Bag-of-words with 500 word vocabulary
UseNet article classification	100,000 news articles (Reuters newswire)	Categorized UseNet posts (from "SRAA" dataset)	2	Bag-of-words with 377 word vocabulary

Acknowledgement

- 感謝 劉致廷 同學於上課時發現投影片上的錯誤
- 感謝 John Chou 發現投影片上的錯字

Appendix

More about Zero-shot learning

- Mark Palatucci, Dean Pomerleau, Geoffrey E. Hinton, Tom M. Mitchell, “Zero-shot Learning with Semantic Output Codes”, NIPS 2009
- Zeynep Akata, Florent Perronnin, Zaid Harchaoui and Cordelia Schmid, “Label-Embedding for Attribute-Based Classification”, CVPR 2013
- Andrea Frome, Greg S. Corrado, Jon Shlens, Samy Bengio, Jeff Dean, Marc'Aurelio Ranzato, Tomas Mikolov, “DeViSE: A Deep Visual-Semantic Embedding Model”, NIPS 2013
- Mohammad Norouzi, Tomas Mikolov, Samy Bengio, Yoram Singer, Jonathon Shlens, Andrea Frome, Greg S. Corrado, Jeffrey Dean, “Zero-Shot Learning by Convex Combination of Semantic Embeddings”, arXiv preprint 2013
- Subhashini Venugopalan, Lisa Anne Hendricks, Marcus Rohrbach, Raymond Mooney, Trevor Darrell, Kate Saenko, “Captioning Images with Diverse Objects”, arXiv preprint 2016