

# Multi-label classification via joint space embeddings

Andrija Đurišić



# Not to be confused with multi-class classification

Instances

Labels

10.1101/2016.05.19.058705

## A Role for Parasites in Stabilising the Fig-Pollinator Mutualism

David W. Simons<sup>1,2</sup>, Simon J. Suggs<sup>3,4</sup>, Ian Hutton<sup>5</sup>, Ruth Chadwick<sup>6</sup>, Ross A. Crooks<sup>6</sup>, Douglas M. V. James<sup>6</sup>, James M. Cook<sup>1,2</sup>

**Abstract** Parasites are thought to play a role in stabilising mutualisms, but the mechanisms by which they do this are unclear. We hypothesised that parasites might stabilise mutualisms by reducing the fitness of the most abundant partner, thereby reducing the risk of over-exploitation. We tested this hypothesis using a mutualism between figs and fig wasps. We found that parasites reduced the fitness of the most abundant partner, and this led to a more stable mutualism. Our results suggest that parasites may play a role in stabilising mutualisms in other systems.

**Introduction** Parasites are thought to play a role in stabilising mutualisms, but the mechanisms by which they do this are unclear. We hypothesised that parasites might stabilise mutualisms by reducing the fitness of the most abundant partner, thereby reducing the risk of over-exploitation. We tested this hypothesis using a mutualism between figs and fig wasps. We found that parasites reduced the fitness of the most abundant partner, and this led to a more stable mutualism. Our results suggest that parasites may play a role in stabilising mutualisms in other systems.

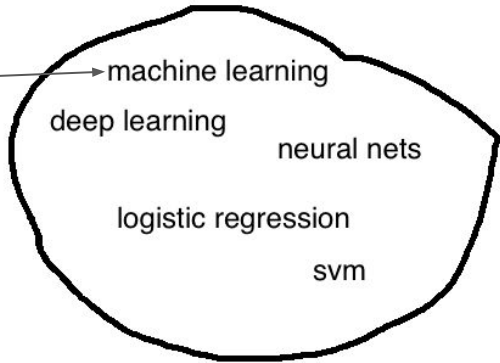
10.1101/2016.05.19.058705

## A Role for Parasites in Stabilising the Fig-Pollinator Mutualism

David W. Simons<sup>1,2</sup>, Simon J. Suggs<sup>3,4</sup>, Ian Hutton<sup>5</sup>, Ruth Chadwick<sup>6</sup>, Ross A. Crooks<sup>6</sup>, Douglas M. V. James<sup>6</sup>, James M. Cook<sup>1,2</sup>

**Abstract** Parasites are thought to play a role in stabilising mutualisms, but the mechanisms by which they do this are unclear. We hypothesised that parasites might stabilise mutualisms by reducing the fitness of the most abundant partner, thereby reducing the risk of over-exploitation. We tested this hypothesis using a mutualism between figs and fig wasps. We found that parasites reduced the fitness of the most abundant partner, and this led to a more stable mutualism. Our results suggest that parasites may play a role in stabilising mutualisms in other systems.

**Introduction** Parasites are thought to play a role in stabilising mutualisms, but the mechanisms by which they do this are unclear. We hypothesised that parasites might stabilise mutualisms by reducing the fitness of the most abundant partner, thereby reducing the risk of over-exploitation. We tested this hypothesis using a mutualism between figs and fig wasps. We found that parasites reduced the fitness of the most abundant partner, and this led to a more stable mutualism. Our results suggest that parasites may play a role in stabilising mutualisms in other systems.



10.1101/2016.05.19.058705

## A Role for Parasites in Stabilising the Fig-Pollinator Mutualism

David W. Simons<sup>1,2</sup>, Simon J. Suggs<sup>3,4</sup>, Ian Hutton<sup>5</sup>, Ruth Chadwick<sup>6</sup>, Ross A. Crooks<sup>6</sup>, Douglas M. V. James<sup>6</sup>, James M. Cook<sup>1,2</sup>

**Abstract** Parasites are thought to play a role in stabilising mutualisms, but the mechanisms by which they do this are unclear. We hypothesised that parasites might stabilise mutualisms by reducing the fitness of the most abundant partner, thereby reducing the risk of over-exploitation. We tested this hypothesis using a mutualism between figs and fig wasps. We found that parasites reduced the fitness of the most abundant partner, and this led to a more stable mutualism. Our results suggest that parasites may play a role in stabilising mutualisms in other systems.

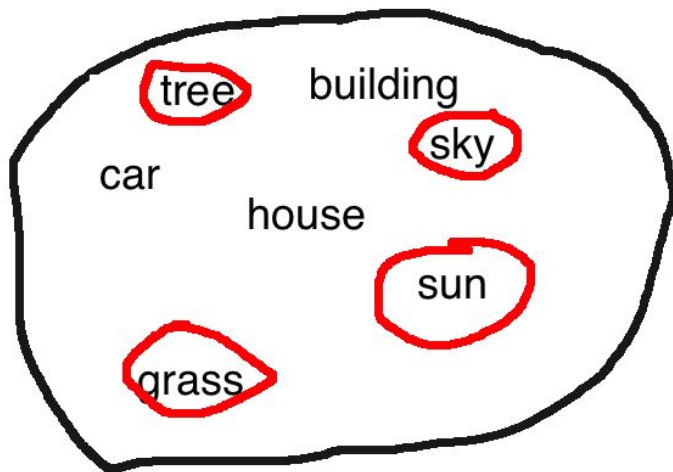
**Introduction** Parasites are thought to play a role in stabilising mutualisms, but the mechanisms by which they do this are unclear. We hypothesised that parasites might stabilise mutualisms by reducing the fitness of the most abundant partner, thereby reducing the risk of over-exploitation. We tested this hypothesis using a mutualism between figs and fig wasps. We found that parasites reduced the fitness of the most abundant partner, and this led to a more stable mutualism. Our results suggest that parasites may play a role in stabilising mutualisms in other systems.

# Image annotations problem

Instance



Labels





# Image annotations problem

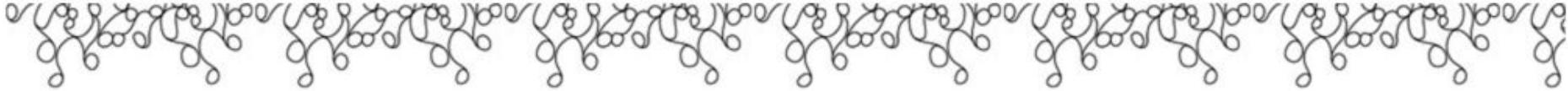
Datasets:

- Caltech-256
- Pascal-VOC
- ImageNet 2010 (4m imgs / 16k labels)
- Web (16m imgs / 109k labels)

Requirements:

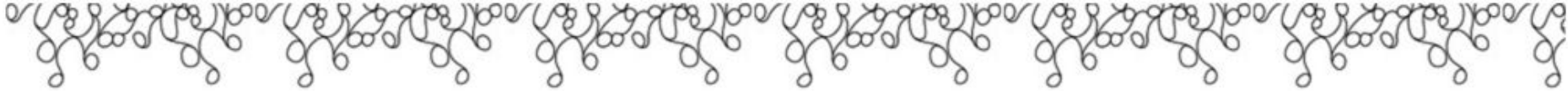
- Scalable training and testing times
- Scalable memory usage

Ideally, we would like a fast algorithm that fits on a laptop.



# Joint space embeddings

IJCAI 2011 - Wsabee - [jweston@google.com](mailto:jweston@google.com)



# Embeddings

- Embedding of an object is vector representation of that object in that vector space
- Similar objects are mapped to close vector representations
- In case of low-dimensional representations savings in memory and computing time are possible

# Joint space embeddings

images  $x \in \mathbb{R}^d$

annotations  $i \in \mathcal{Y} = \{1, \dots, Y\}$

$\mathbb{R}^D$

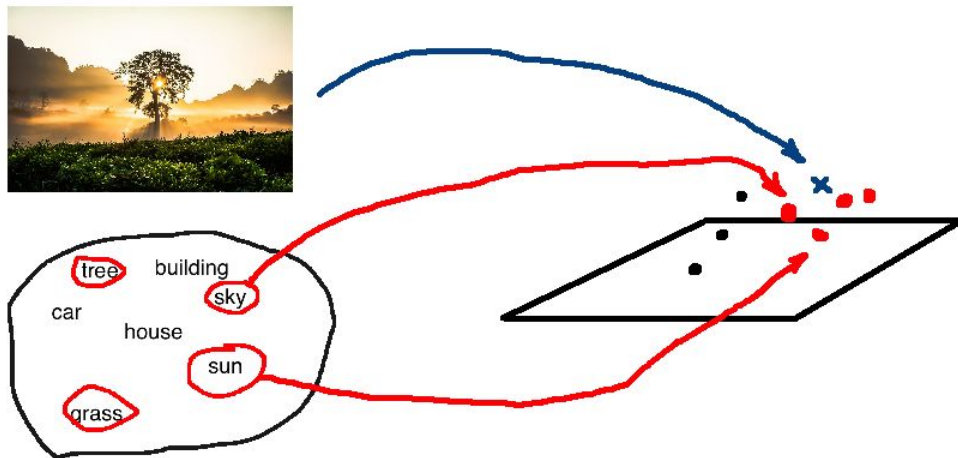
$\Phi_I(x) : \mathbb{R}^d \rightarrow \mathbb{R}^D$

$\Phi_W(i) : \{1, \dots, Y\} \rightarrow \mathbb{R}^D$

$\Phi_I(x) = Vx$

$\Phi_W(i) = W_i$

$f_i(x) = \Phi_W(i)^\top \Phi_I(x) = W_i^\top Vx$





# Joint space embeddings - rank function

$$f(x) = W^T V x$$

$$f_{tree}(x) = 13.6 \quad \mathbf{0}$$

$$f_{building}(x) = 2.1 \quad \mathbf{4}$$

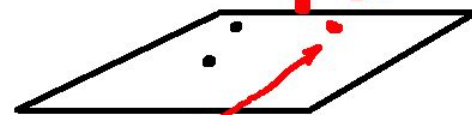
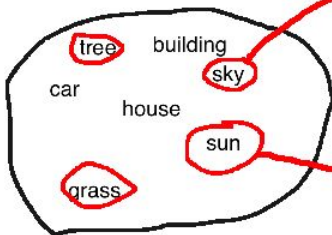
$$f_{house}(x) = 1.5 \quad \mathbf{5}$$

$$f_{car}(x) = 1.2 \quad \mathbf{6}$$

$$f_{sun}(x) = 11.6 \quad \mathbf{3}$$

$$f_{grass}(x) = 12.6 \quad \mathbf{1}$$

$$f_{sky}(x) = 11.7 \quad \mathbf{2}$$



$$\text{rank}_y(f(x)) = \sum_{i \neq y} I(f_i(x) \geq f_y(x))$$

$$\text{rank}_y^1(f(x)) = \sum_{i \neq y} I(1 + f_i(x) > f_y(x)).$$

# Joint space embeddings - loss function

$$\text{rank}_y(f(x)) = \sum_{i \neq y} I(f_i(x) \geq f_y(x))$$

$$\text{err}(f(x), y) = L(\text{rank}_y(f(x))) \frac{\text{rank}_y(f(x))}{\text{rank}_y(f(x))}$$

$$\text{err}(f(x), y) = L(\text{rank}_y(f(x)))$$

$$\text{err}(f(x), y) = \sum_{i \neq y} L(\text{rank}_y(f(x))) \frac{I(f_i(x) \geq f_y(x))}{\text{rank}_y(f(x))}$$

$$L(k) = \sum_{j=1}^k \frac{1}{j}$$

$$\text{err}(f(x), y) = \sum_{i \neq y} L(\text{rank}_y^1(f(x))) \frac{I(1+f_i(x) \geq f_y(x))}{\text{rank}_y^1(f(x))}$$

$$\overline{\text{err}}(f(x), y) = \sum_{i \neq y} L(\text{rank}_y^1(f(x))) \frac{|1 - f_y(x) + f_i(x)|_+}{\text{rank}_y^1(f(x))}$$

# Joint space embeddings - optimization

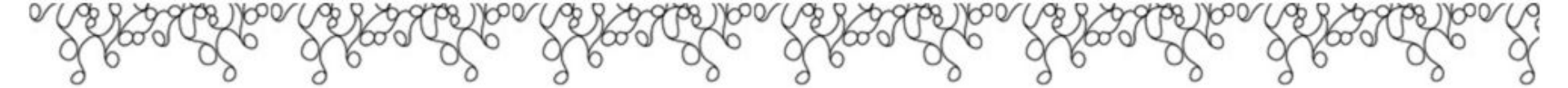
$$\overline{err}(f(x), y) = \sum_{i \neq y} L(\text{rank}_y^1(f(x))) \frac{|1 - f_y(x) + f_i(x)|_+}{\text{rank}_y^1(f(x))} \quad Risk(f) = \int \overline{err}(f(x), y) dP(x, y).$$

$$\overline{err}_{\bar{y}}(f(x), y, \bar{y}) = L(\text{rank}_y^1(f(x))) |1 - f_y(x) + f_{\bar{y}}(x)|_+$$

$$\text{rank}_y^1(f(x)) \approx \left\lfloor \frac{Y-1}{N} \right\rfloor$$

$$f_{\text{tree}}(\text{img}_{\text{tree}}) > 1 + f_{\text{car}}(\text{img}_{\text{car}})$$

$$\beta_{t+1} = \beta_t - \gamma_t \frac{\partial \overline{err}(f(x), y, \bar{y})}{\partial \beta_t}$$



# Wsabie - Algorithm

---

**Algorithm 1** Online WARP Loss Optimization

---

**Input:** labeled data  $(x_i, y_i)$ ,  $y_i \in \{1, \dots, Y\}$ .

**repeat**

Pick a random labeled example  $(x_i, y_i)$

Let  $f_{y_i}(x_i) = \Phi_W(y_i)^\top \Phi_I(x_i)$

Set  $N = 0$ .

**repeat**

Pick a random annotation  $\bar{y} \in \{1, \dots, Y\} \setminus y_i$ .

Let  $f_{\bar{y}}(x_i) = \Phi_W(\bar{y})^\top \Phi_I(x_i)$

$N = N + 1$ .

**until**  $f_{\bar{y}}(x_i) > f_{y_i}(x_i) - 1$  or  $N \geq Y - 1$

**if**  $f_{\bar{y}}(x_i) > f_{y_i}(x_i) - 1$  **then**

Make a gradient step to minimize:

$$L(\lfloor \frac{Y-1}{N} \rfloor) |1 - f_{y_i}(x_i) + f_{\bar{y}}(x_i)|_+$$

Project weights to enforce constraints (2)-(3).

**end if**

**until** validation error does not improve.

---



## Wsabie results

Method	ImageNet 2010		Web	
	prec@1	prec@10	prec@1	prec@10
approx kNN	1.55%	0.41%	0.30%	0.34%
One-vs-Rest	2.27%	1.02%	0.52%	0.29%
Wsabie	4.03%	1.48%	1.03%	0.44%

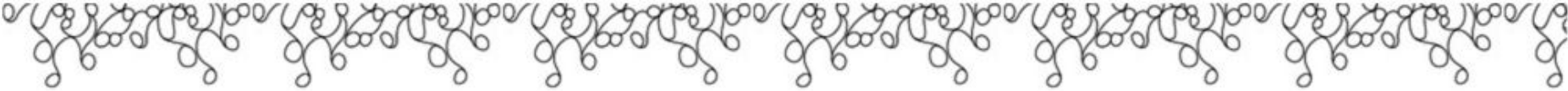


## Wsabie results

Label	Nearest Neighbors
<b>barack obama</b>	barak obama, obama, barack, barrack obama, bow wow
<b>david beckham</b>	beckham, david beckam, alessandro del piero, del piero
<b>santa</b>	santa claus, papa noel, pere noel, santa clause, joyeux noel
<b>dolphin</b>	delphin, dauphin, whale, delfin, delfini, baleine, blue whale
<b>cows</b>	cattle, shire, dairy cows, kuh, horse, cow, shire horse, kone
<b>rose</b>	rosen, hibiscus, rose flower, rosa, roze, pink rose, red rose
<b>eiffel tower</b>	eiffel, tour eiffel, la tour eiffel, big ben, paris, blue mosque
<b>ipod</b>	i pod, ipod nano, apple ipod, ipod apple, new ipod
<b>f18</b>	f 18, eurofighter, f14, fighter jet, tomcat, mig 21, f 16

# Wsabie results

	delfini, orca, <b>dolphin</b> , mar, delfin, dauphin, whale, cancan, killer whale, sea world
	blue whale, whale shark, great white shark, underwater, white shark, shark, manta ray, <b>dolphin</b> , requin, blue shark, diving
	barrack obama, barak obama, barack hussein obama, <b>barack obama</b> , james marsden, jay z, obama, nelly, falco, barack
	eiffel, paris by night, la tour eiffel, tour eiffel, <b>eiffel tower</b> , las vegas strip, eifel, tokyo tower, eifel tower



# Leveraging label hierarchies

ECML 2016 - Predicting unseen labels using  
label hierarchies in large-scale multi-label  
learning - Jinseok Nam @ TU Darmstadt



# Text classification problem with label hierarchies

Instances

Labels

10.1101/2015.05.01.082101

**A Role for Parasites in Stabilising the Fig-Pollinator Mutualism**

David W. Dunn<sup>1,2</sup>, Isaac I. Sapp<sup>1,2</sup>, Ian Hynes<sup>1</sup>, Ruth Odu<sup>1</sup>, Ross A. Crooks<sup>1</sup>, Douglas W. Yu<sup>1</sup>, James M. Cook<sup>1,2</sup>

**Abstract** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.

**Introduction** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.

10.1101/2015.05.01.082101

**A Role for Parasites in Stabilising the Fig-Pollinator Mutualism**

David W. Dunn<sup>1,2</sup>, Isaac I. Sapp<sup>1,2</sup>, Ian Hynes<sup>1</sup>, Ruth Odu<sup>1</sup>, Ross A. Crooks<sup>1</sup>, Douglas W. Yu<sup>1</sup>, James M. Cook<sup>1,2</sup>

**Abstract** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.

**Introduction** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.

10.1101/2015.05.01.082101

**A Role for Parasites in Stabilising the Fig-Pollinator Mutualism**

David W. Dunn<sup>1,2</sup>, Isaac I. Sapp<sup>1,2</sup>, Ian Hynes<sup>1</sup>, Ruth Odu<sup>1</sup>, Ross A. Crooks<sup>1</sup>, Douglas W. Yu<sup>1</sup>, James M. Cook<sup>1,2</sup>

**Abstract** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.

**Introduction** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.

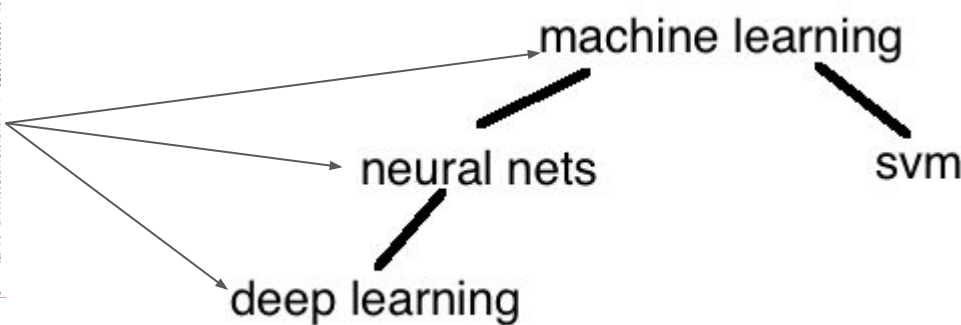
10.1101/2015.05.01.082101

**A Role for Parasites in Stabilising the Fig-Pollinator Mutualism**

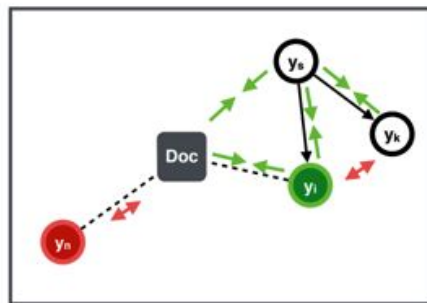
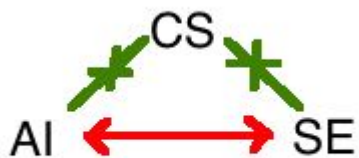
David W. Dunn<sup>1,2</sup>, Isaac I. Sapp<sup>1,2</sup>, Ian Hynes<sup>1</sup>, Ruth Odu<sup>1</sup>, Ross A. Crooks<sup>1</sup>, Douglas W. Yu<sup>1</sup>, James M. Cook<sup>1,2</sup>

**Abstract** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.

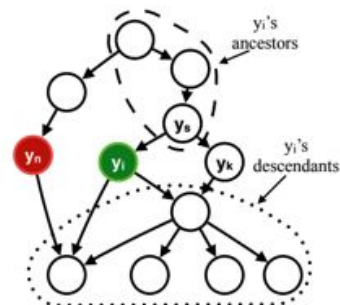
**Introduction** Parasitism can modify mutualisms, but the degree to which this occurs is largely unknown. We used a system of mutualism between a fig and its pollinator to test whether parasitism by a fig wasp affects the mutualism. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability. We found that parasitism by a fig wasp affects the mutualism in a way that is consistent with the predictions of a model of mutualism stability.



# Learning with hierarchical structures over labels



(a) A joint space of instances and labels



(b) A label hierarchy

$$\Omega(\Theta_H) = \sum_{n=1}^N \frac{1}{Z_A} \sum_{i \in \mathcal{Y}_n} \sum_{s \in \mathcal{S}_A(i)} -\log p(y_s | y_i, \mathbf{x}_n) + \sum_{l=1}^Y \sum_{q \in \mathcal{S}_P(l)} \sum_{\substack{k \in \mathcal{S}_C(q) \\ k \neq l}} L(\text{rank}_y^1(\mathbf{u}_l)) [1 - \mathbf{u}_q^T \mathbf{u}_l + \mathbf{u}_k^T \mathbf{u}_l]_+$$

$$p(y_s | y_i, \mathbf{x}_n) = \frac{\exp(\mathbf{u}_s^T \hat{\mathbf{u}}_i^{(n)})}{\sum_{v \in L} \exp(\mathbf{u}_v^T \hat{\mathbf{u}}_i^{(n)})}$$



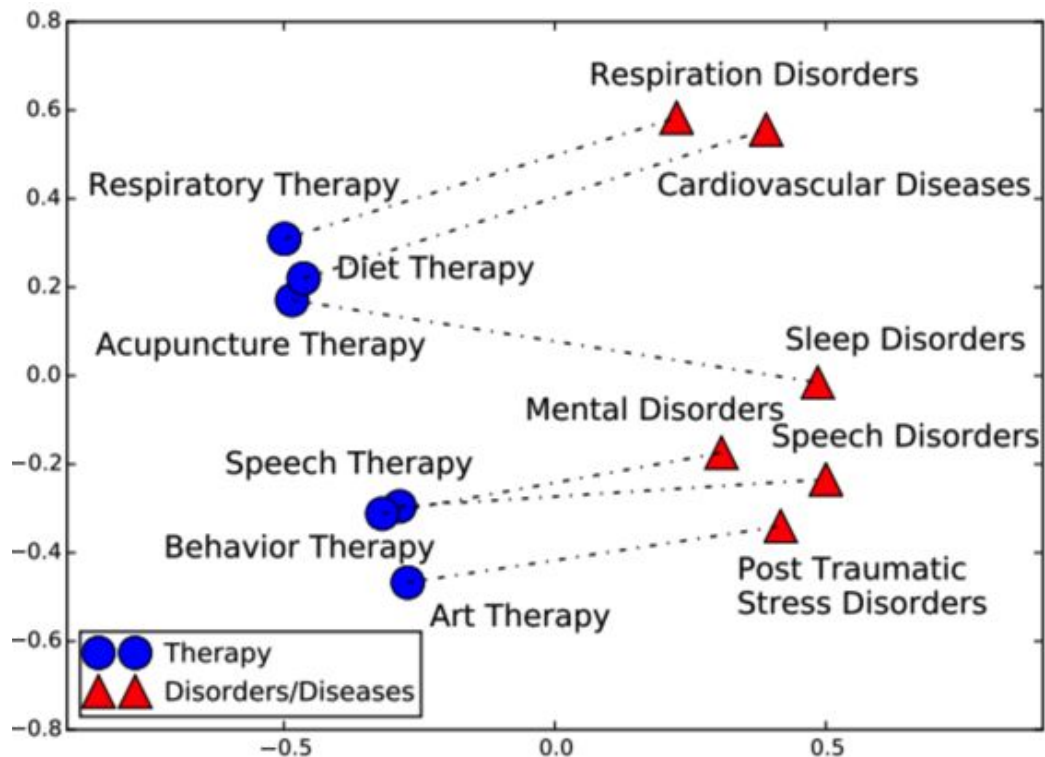
# WsabieH results

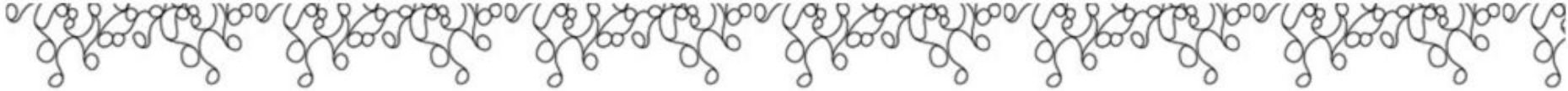
## Datasets

- RCV1-v2 newswire articles - 103 labels organized in a tree - 800k documents
- OHSUMED medical articles - 350k documents

	<b>RCV1-v2</b>		<b>OHSUMED</b>	
	Wsabie	Wsabie <sub>H</sub>	Wsabie	Wsabie <sub>H</sub>
<b>AvgP</b>	94.34	94.39	45.72	<b>45.76</b>
<b>RL</b>	0.44	0.44	4.09	<b>3.72</b>

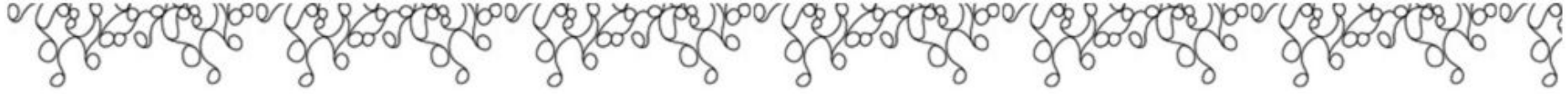
# WsabieH results



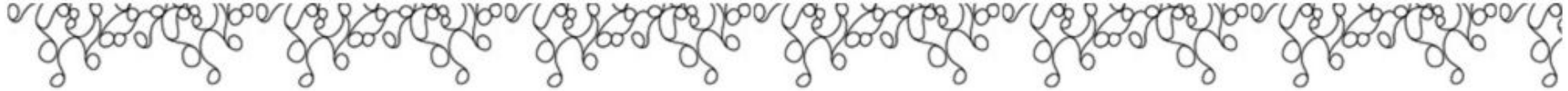


# Predicting unseen labels

Hierarchical relations provide embeddings even of labels which are never seen in data. Therefore, they can appear in predictions in a meaningful way although data don't provide information about it.



Thanks :)



# References

Weston, J., Bengio, S., Usunier, N.: Wsabie: Scaling up to large vocabulary image annotations

Jinseok, N., Eneldo, M., Hyunwoo, J., Furnkranz, J.: Predicting unseen labels using label hierarchies in large-scale multi-label learning

<https://github.com/xdshang/wsabie>