Structured Prediction and PyStruct

Andreas Müller

November 19, 2014

Motivation

Multi-Label Classification

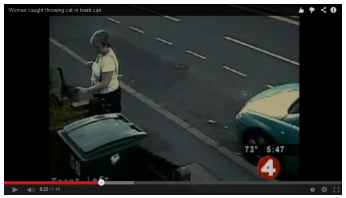
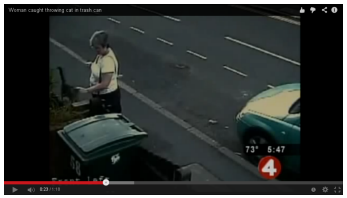
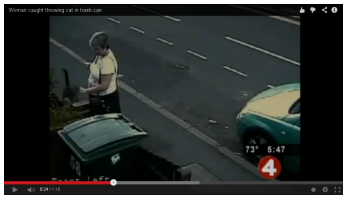
	Politics	Sports	Finance	Domestic	Religion
News Story1	1	0	0	1	1
News Story2	0	1	0	1	0
News Story3	0	0	1	0	0

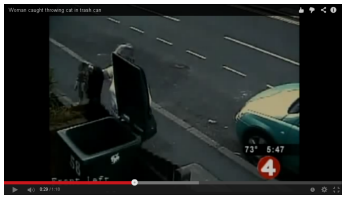
Multi-Label Classification

	Politics	Sports	Finance	Domestic	Religion
News Story1	1	0	0	1	1
News Story2	0	1	0	1	0
News Story3	0	0	1	0	0

	Owns Car	Smokes	Married	Self-Employed	Has Kids
Customer1	1	0	1	0	1
Customer2	1	1	0	1	0
Customer3	0	1	1	0	0

Sequence Tagging



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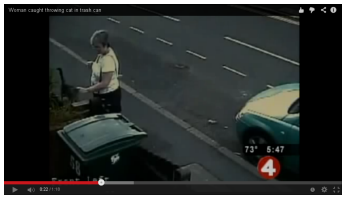
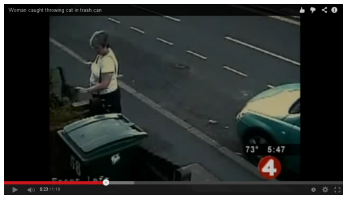


Stroke cat.



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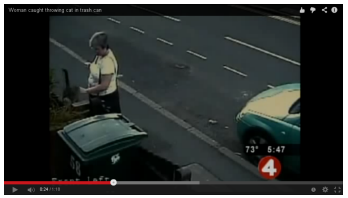

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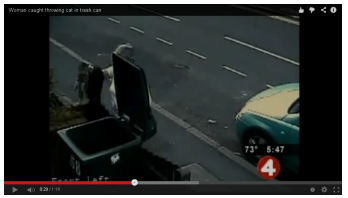
Open trash can.



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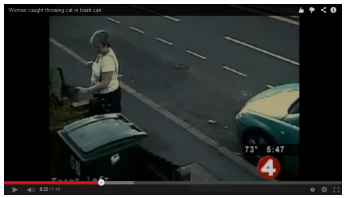

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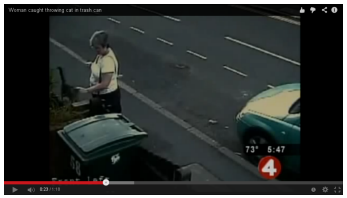

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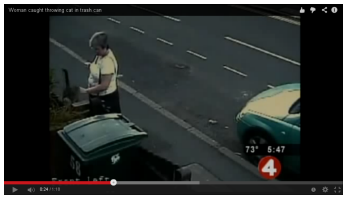

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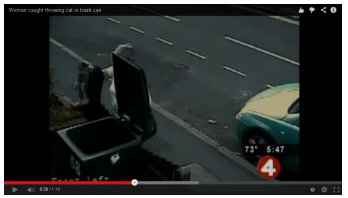

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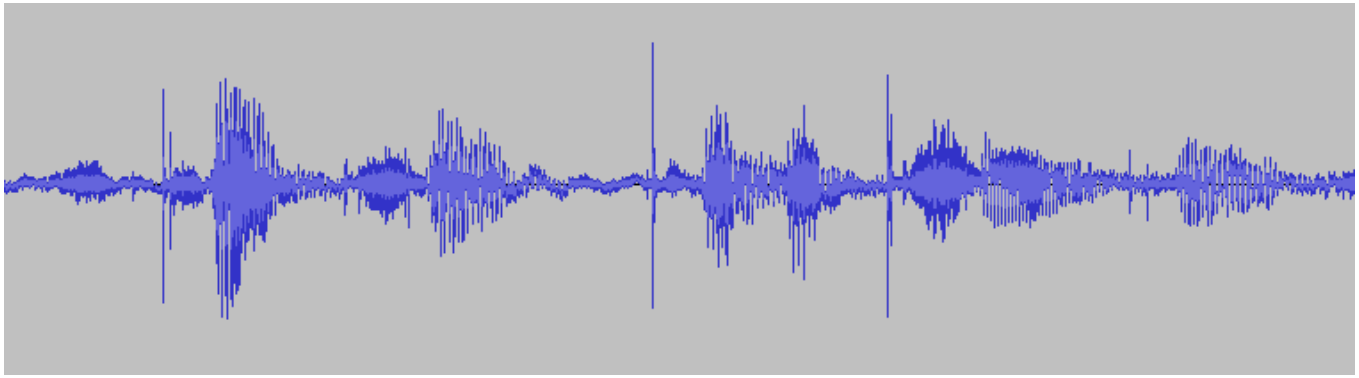

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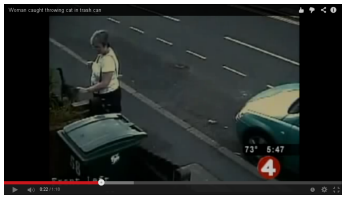

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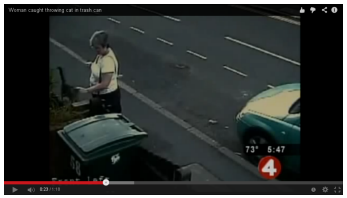

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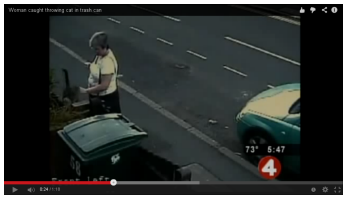

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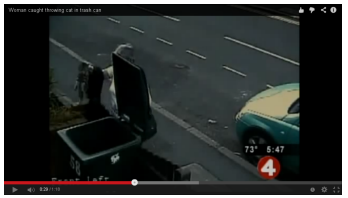

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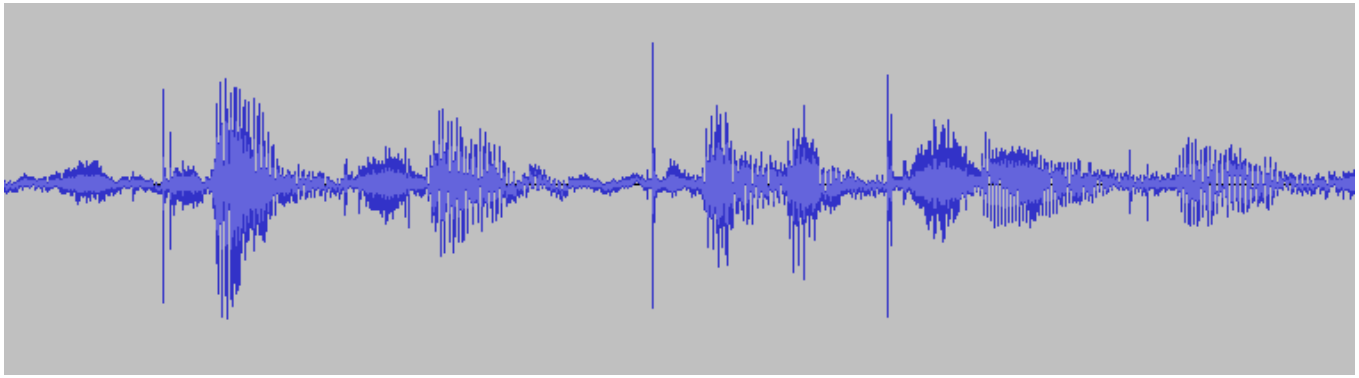
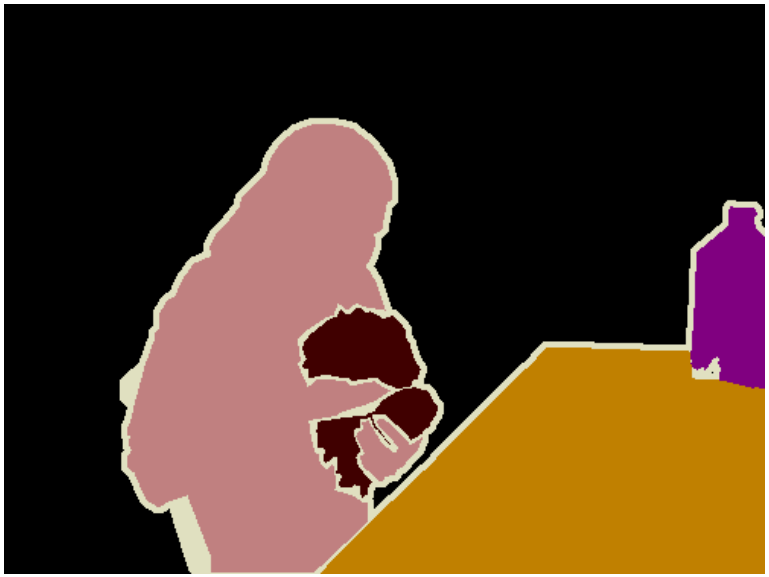


Struc-tured pre-dic-tion in Py-thon

Predicting Parse Trees

Semantic Images Segmentation

Semantic Images Segmentation



Predicting Structured Objects

$$f(x, w) := \arg\max_{y \in \mathcal{Y}} g(x, y, w)$$

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If you like:

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If you like:

$$\arg\max_{y \in \mathcal{Y}} p(y|x, w)$$

$$f(x, w) := \arg\max_{y \in \mathcal{Y}} w^T \psi(x, y)$$

Inference and Factor Graphs

Predicting discrete vectors

$$y = (y_1, y_2, \ldots, y_{n_i})$$

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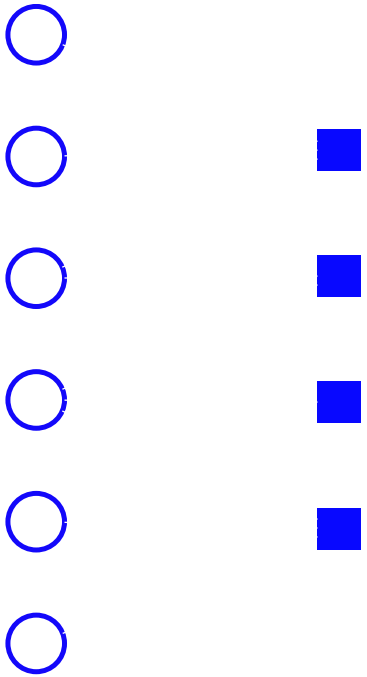
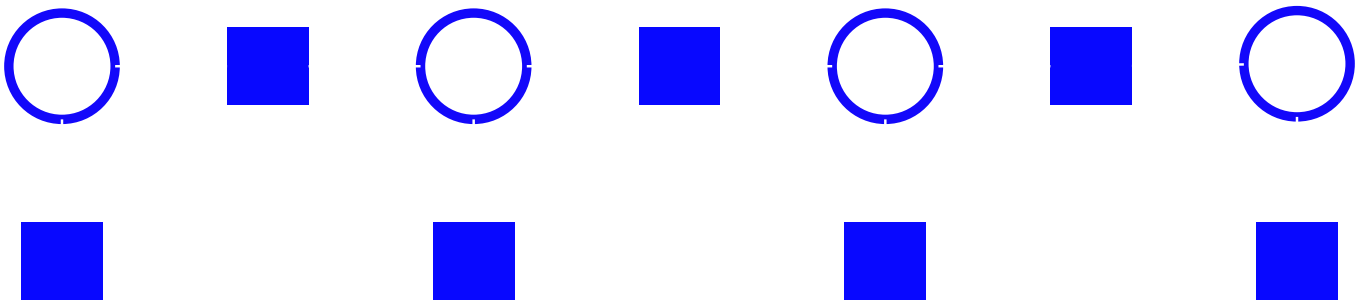
$$\begin{aligned} f(x, w) &= \arg\max_{y \in \mathcal{Y}} w^T \psi(x, y) \\ &= \arg\max_{y_1, y_2, \ldots, y_{n_i}} w^T \psi(x, y) \end{aligned}$$

Factor Graphs

$$g(x, y) = g_1(x, y_1, y_2, y_3) + g_2(x, y_3, y_4) + g_3(x, y_4) + g_4(x, y_4, y_5, y_6)$$

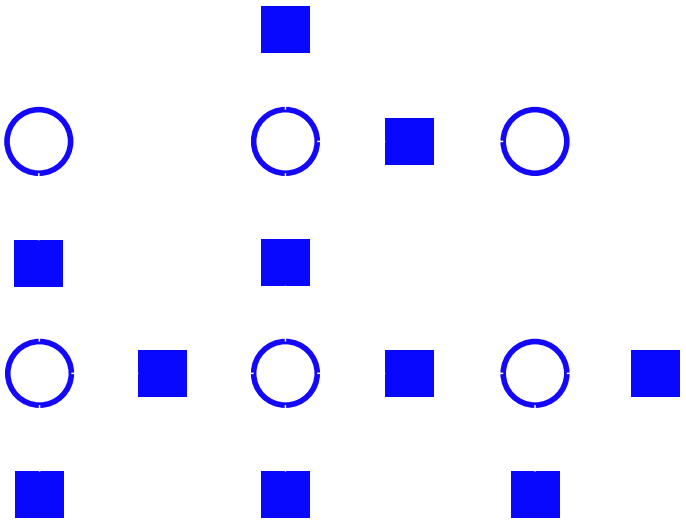


Factor Graph for HMM

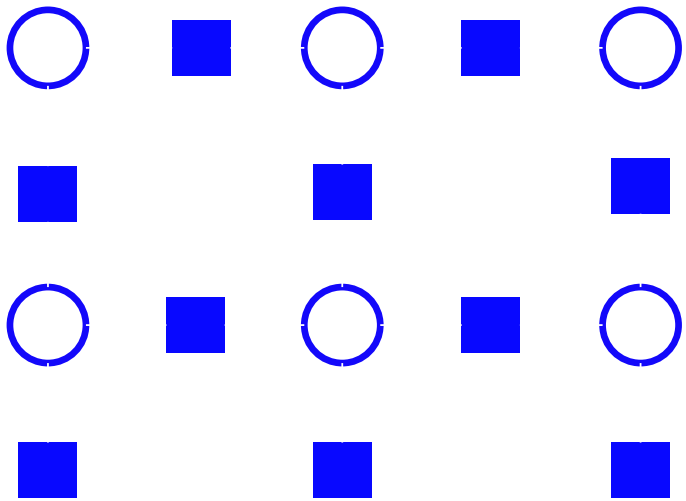


Inference

Easy



Tricky



Learning

Probabilistic Learning

$$p(y|x, w) = \frac{1}{Z} exp(w^T \psi(x, y))$$

$$Z = \sum_{y' \in \mathcal{Y}} exp(w^T \psi(x, y'))$$

Probabilistic Learning

$$p(y|x, w) = \frac{1}{Z} exp(w^T \psi(x, y))$$

$$Z = \sum_{y' \in \mathcal{Y}} exp(w^T \psi(x, y'))$$

Objective

$$\max_w \sum_i \log(p(y^i|x^i, w))$$

$$= \max_w \sum_i w^T \psi(x^i, y^i) - \log(Z)$$

Max-Margin Learning

$$\min_w \frac{1}{2}\|w\|^2 + C \sum_i \ell(x^i, y^i, w)$$

$$\ell(x^i, y^i, w) = [\max_{y \in \mathcal{Y}} \Delta(y^i, y) + w^T \psi(x^i, y) - w^T \psi(x^i, y^i)]_+.$$

PyStruct

Simple structured prediction

Estimator = Learner + Model + Inference

Simple structured prediction

Estimator = Learner + Model + Inference

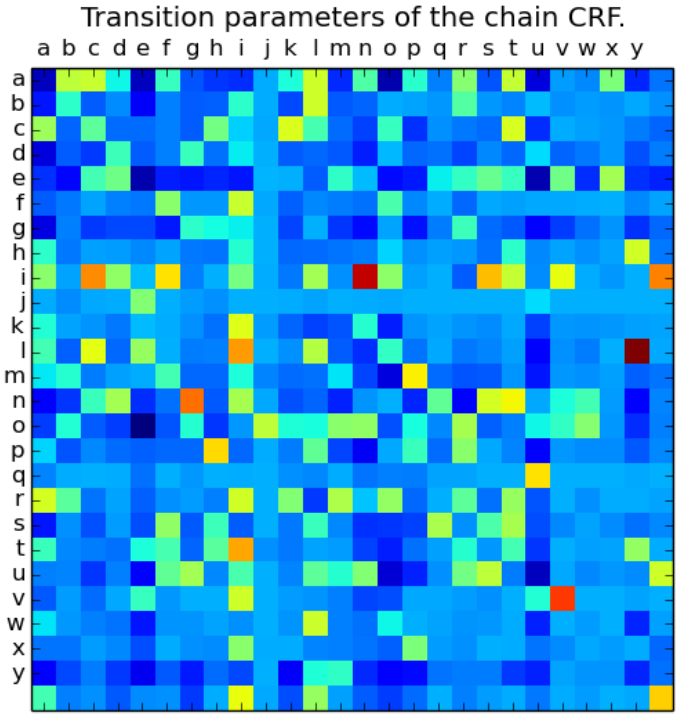
- Learner: SubgradientSSVM, StructuredPerceptron, OneSlackSSVM, LatentSSVM
- Model: BinaryClf, MultiLabelClf, ChainCRF, GraphCRF, EdgeFeatureGraphCRF
- Inference: Linear Programming, QPBO (PyQPBO), Dual Decomposition (AD3), Message Passing (OpenGM), Everything (OpenGM)

Example OCR

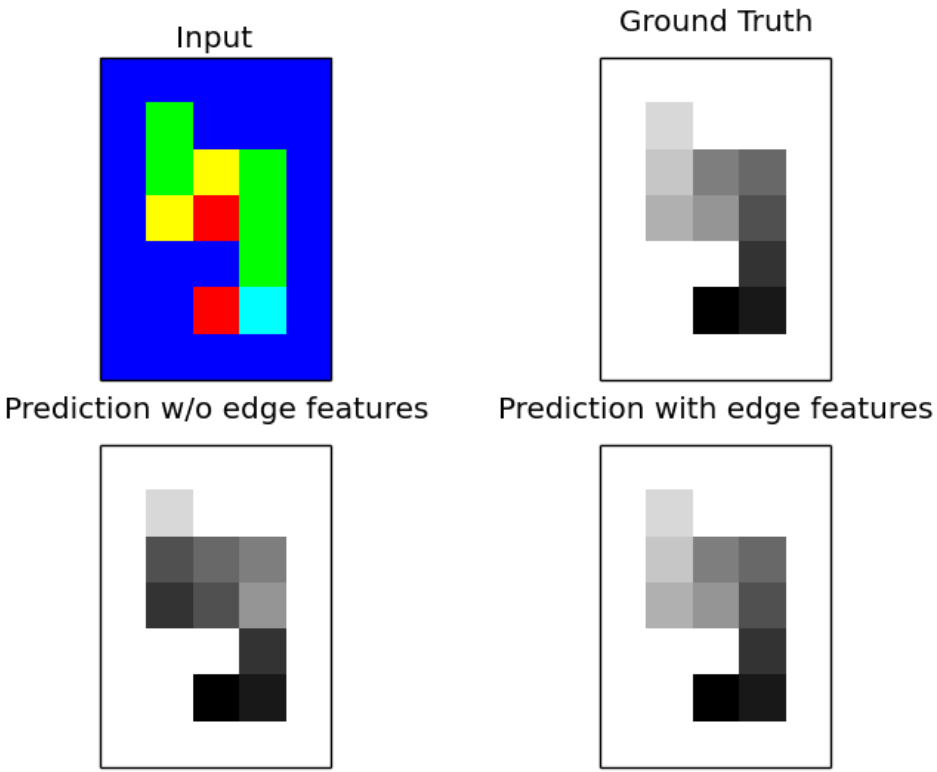
```
from pystruct.datasets import load_letters
from pystruct.models import ChainCRF
from pystruct.learners import OneSlackSSVM

abc = "abcdefghijklmnopqrstuvwxyz"

letters = load_letters()
X, y, folds = letters['data'], letters['labels'], letters['folds']
# we convert the lists to object arrays, as that makes slicing much more
# convenient
X, y = np.array(X), np.array(y)
X_train, X_test = X[folds == 1], X[folds != 1]
y_train, y_test = y[folds == 1], y[folds != 1]

# Train linear SVM
svm = LinearSVC(dual=False, C=.1)
# flatten input
svm.fit(np.vstack(X_train), np.hstack(y_train))

# Train linear chain CRF
model = ChainCRF()
ssvm = OneSlackSSVM(model=model, C=.1, inference_cache=50, tol=0.1, verbose=3)
ssvm.fit(X_train, y_train)
```

Example OCR


a f e t e r i a
a a f t a a f t m a r r i i a a
m b r a c e s
m m b b r r a a c c e e s s
p o i l f n g
p p a a i i c c i i m n d g
a f e t e r i a
a a f f o o d d o o l l z i n n

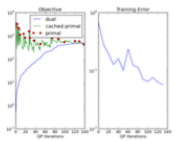

Transition parameters of the chain CRF.
a b c d e f g h i j k l m n o p q r s t u v w x y
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t
u
v
w
x
y

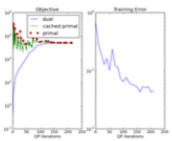
Example Snake

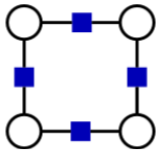


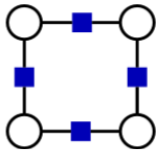
PyStruct Introduction Examples References Search

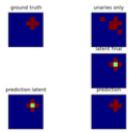
Examples

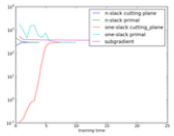

Plotting the objective and constraint caching in 1-slack SSVM

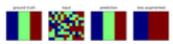

Efficient exact learning of 1-slack SSVMs

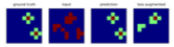

SVM as CRF


Semantic Image Segmentation on Pascal VOC

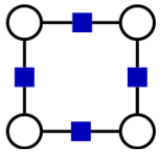

Latent Dynamics CRF


SVM objective values

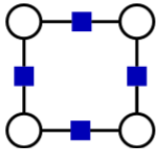

Learning directed interactions on a 2d grid


Learning interactions on a 2d grid

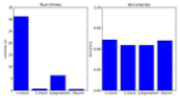

OCR Letter sequence recognition

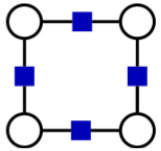

Crammer-Singer Multi-Class SVM


Latent SVM for odd vs. even digit classification


Mult-label classification


Latent Variable Hierarchical CRF


Binary SVM as SSVM


Comparing PyStruct and SVM-Struct

Back to top

http://pystruct.github.io