Interpretable Structure Induction Via Sparse Attention

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→ **Vlad Niculae** IT
André Martins IT & Unbabel

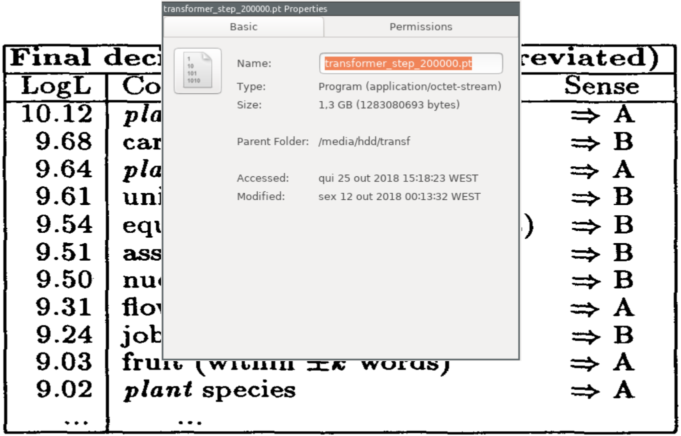
github.com/vene/{sparseattn, sparsemap} @vnfrombucharest

Sparse linear models are more interpretable...

Final decision list for *plant* (abbreviated)		
LogL	Collocation	Sense
10.12	*plant* growth	$\Rightarrow$ A
9.68	car (within $\pm k$ words)	$\Rightarrow$ B
9.64	*plant* height	$\Rightarrow$ A
9.61	union (within $\pm k$ words)	$\Rightarrow$ B
9.54	equipment (within $\pm k$ words)	$\Rightarrow$ B
9.51	assembly *plant*	$\Rightarrow$ B
9.50	nuclear *plant*	$\Rightarrow$ B
9.31	flower (within $\pm k$ words)	$\Rightarrow$ A
9.24	job (within $\pm k$ words)	$\Rightarrow$ B
9.03	fruit (within $\pm k$ words)	$\Rightarrow$ A
9.02	*plant* species	$\Rightarrow$ A
...	...	

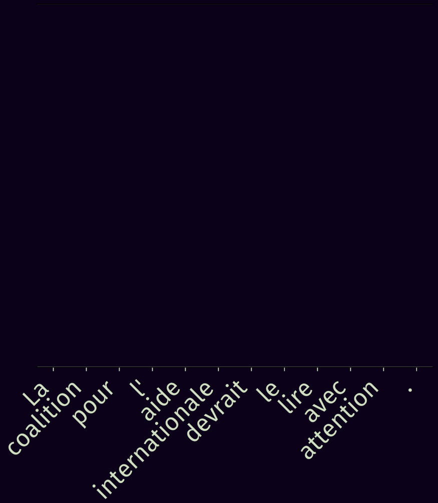
(Decision list from Yarowsky (1995)

Sparse linear models are more interpretable... but we use bigger models today!

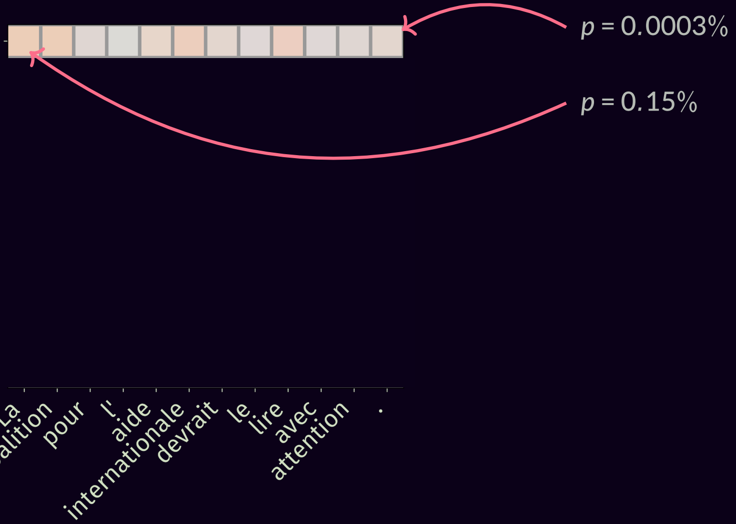


(Decision list from Yarowsky (1995))

Neural Attention Mechanisms



Neural Attention Mechanisms



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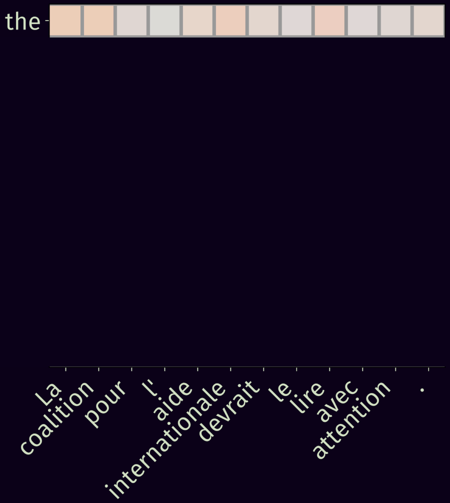

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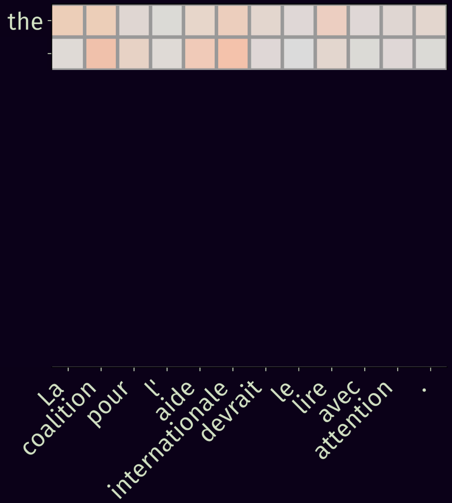

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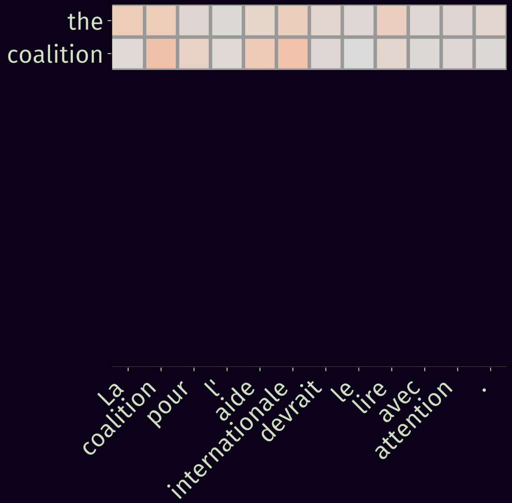

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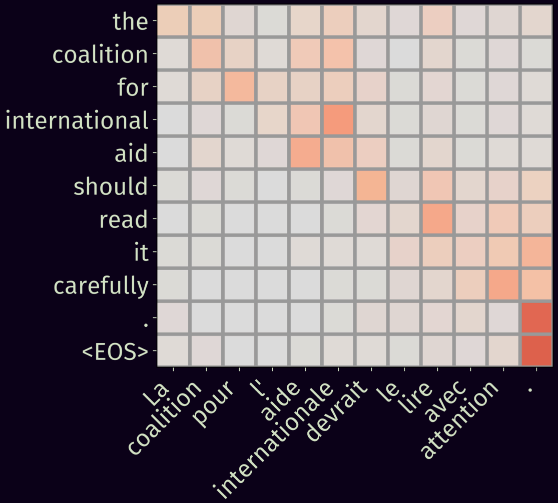
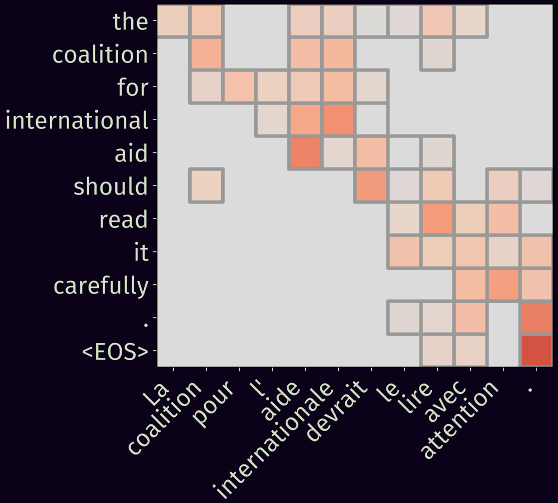
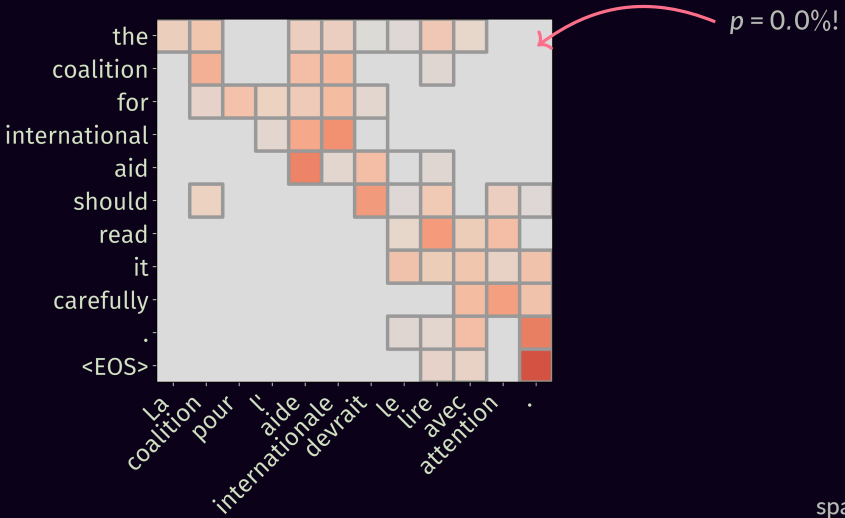


Sparse Neural Attention



sparsemax
(Martins & Astudillo, 2016)

Sparse Neural Attention



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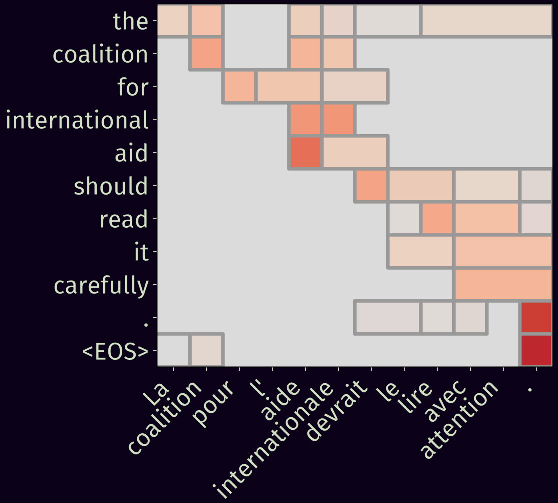
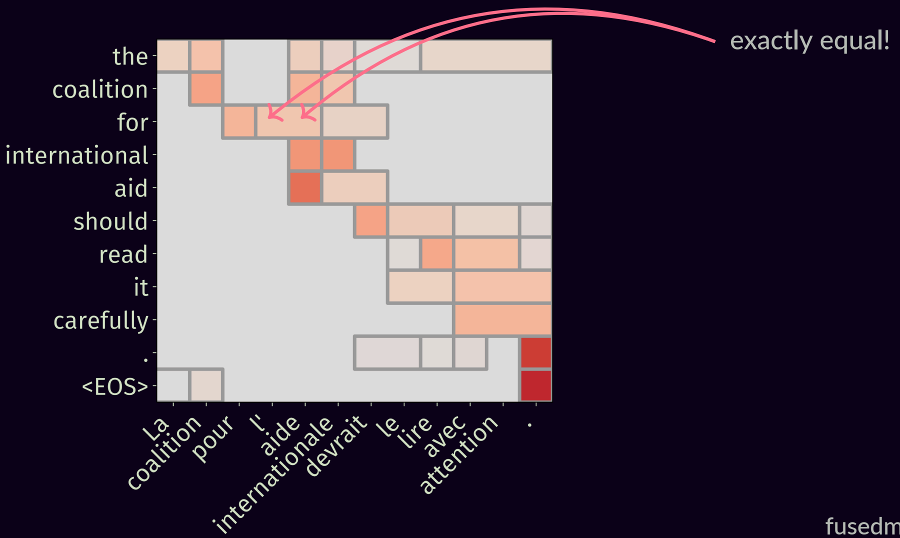
Structured & Sparse Attention



fusedmax
(Niculae & Blondel, 2017)

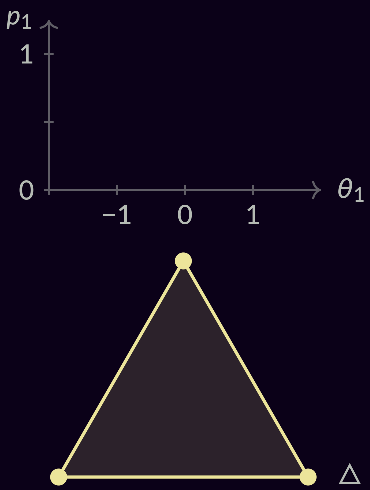
Structured & Sparse Attention



fusedmax
(Niculae & Blondel, 2017)

Smoothed Max Operators

$$\Pi_\Omega(\boldsymbol{\theta}) = \arg\max_{\boldsymbol{p} \in \triangle} \boldsymbol{p}^\top \boldsymbol{\theta} - \Omega(\boldsymbol{p})$$



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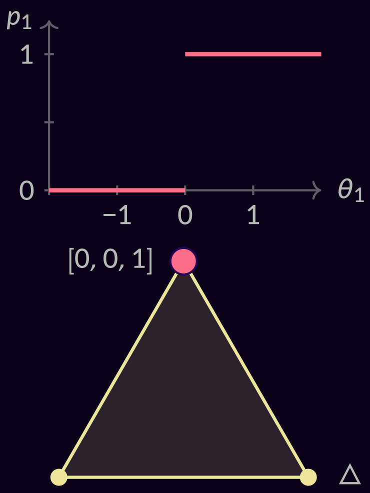
- argmax: $\Omega(\boldsymbol{p}) = 0$



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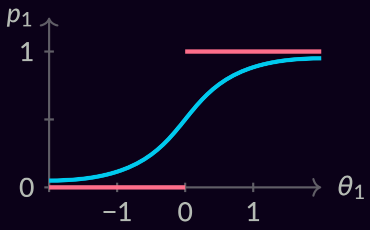
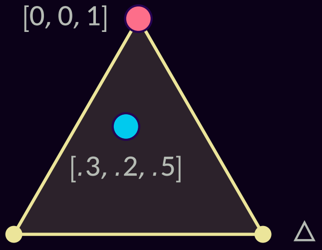
- softmax: $\Omega(\boldsymbol{p}) = \sum_j p_j \log p_j$





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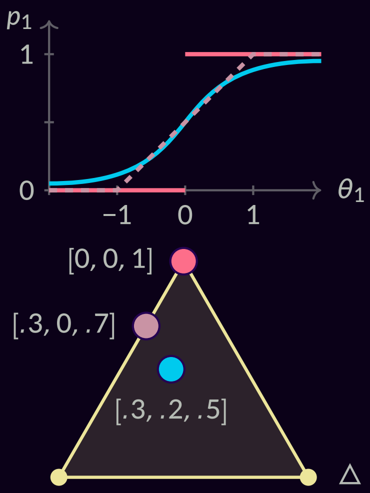
- sparsemax: $\Omega(\boldsymbol{p}) = 1/2\|\boldsymbol{p}\|_2^2$



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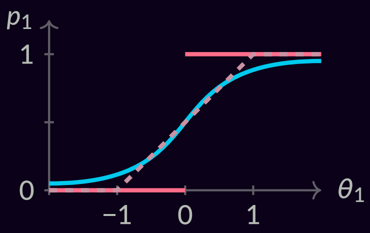

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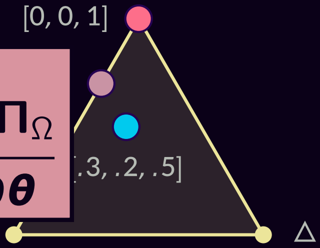
Unlike lasso,

sparse attention needs $\dfrac{\partial\, \Pi_\Omega}{\partial \boldsymbol{\theta}}$



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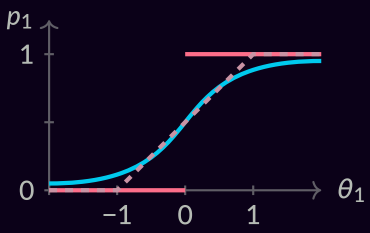
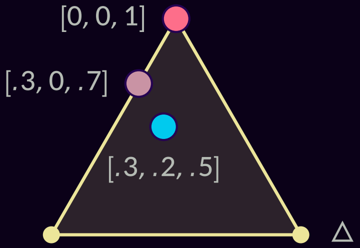
- sparsemax: $\Omega(\boldsymbol{p}) = 1/2\|\boldsymbol{p}\|_2^2$
- fusedmax: $\Omega(\boldsymbol{p}) = 1/2\|\boldsymbol{p}\|_2^2 + \sum_j |p_j - p_{j-1}|$
- oscarmax: $\Omega(\boldsymbol{p}) = 1/2\|\boldsymbol{p}\|_2^2 + \sum_{i,j} \max(p_i, p_j)$



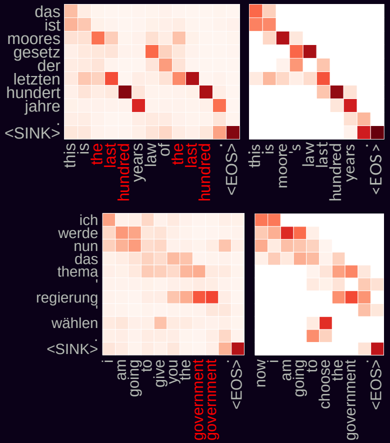


Constrained Attention

$$\arg\max_{\substack{\boldsymbol{p}\in\triangle \\ \boldsymbol{a}\le\boldsymbol{p}\le\boldsymbol{b}}} \boldsymbol{p}^\top\boldsymbol{\theta} - \Omega_1(\boldsymbol{p})$$

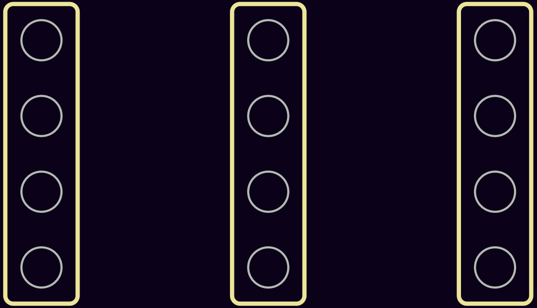
$$= \arg\max_{\boldsymbol{p}\in\triangle} \boldsymbol{p}^\top\boldsymbol{\theta} - \underbrace{\Omega(\boldsymbol{p})}_{:=\Omega_1+\mathrm{Id}_{[a,b]}}$$

e.g., fertility constraints for NMT



(Kreutzer & Martins, 18)
(Malaviya et al, 18)

Structured Attention & Graphical Models



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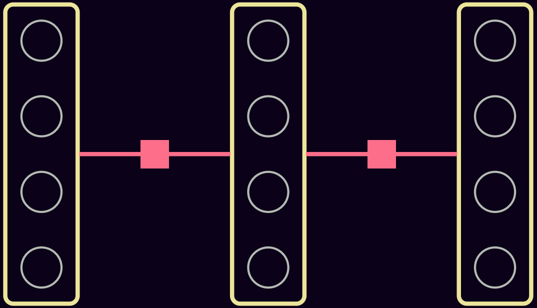
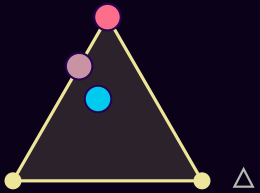


- **argmax** $\arg\max_{\boldsymbol{p}\in\triangle} \boldsymbol{p}^\top \boldsymbol{\theta}$
- **softmax** $\arg\max_{\boldsymbol{p}\in\triangle} \boldsymbol{p}^\top \boldsymbol{\theta} + \mathrm{H}(\boldsymbol{p})$
- **sparsemax** $\arg\max_{\boldsymbol{p}\in\triangle} \boldsymbol{p}^\top \boldsymbol{\theta} - 1/2\|\boldsymbol{p}\|^2$



argmax $\arg\max_{\boldsymbol{p}\in\triangle} \boldsymbol{p}^\top\boldsymbol{\theta}$

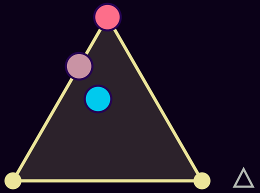
softmax $\arg\max_{\boldsymbol{p}\in\triangle} \boldsymbol{p}^\top\boldsymbol{\theta} + \mathrm{H}(\boldsymbol{p})$

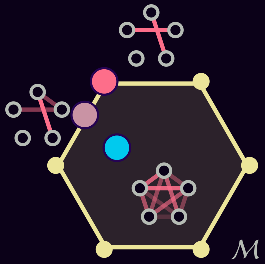
sparsemax $\arg\max_{\boldsymbol{p}\in\triangle} \boldsymbol{p}^\top\boldsymbol{\theta} - 1/2\|\boldsymbol{p}\|^2$

MAP $\arg\max_{\boldsymbol{\mu}\in\mathcal{M}} \boldsymbol{\mu}^\top\boldsymbol{\eta}$

marginals $\arg\max_{\boldsymbol{\mu}\in\mathcal{M}} \boldsymbol{\mu}^\top\boldsymbol{\eta} + \widetilde{\mathrm{H}}(\boldsymbol{\mu})$

SparseMAP $\arg\max_{\boldsymbol{\mu}\in\mathcal{M}} \boldsymbol{\mu}^\top\boldsymbol{\eta} - 1/2\|\boldsymbol{\mu}\|^2$





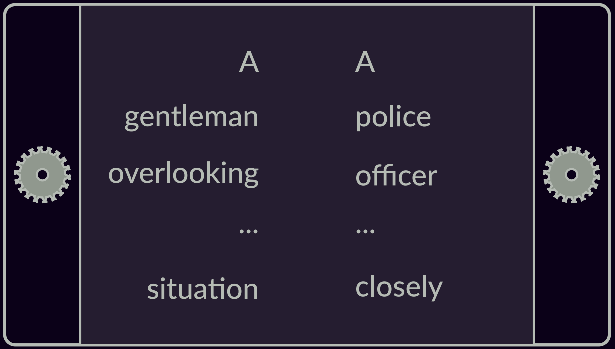
Structured Attention for Alignments

NLI

premise: A gentleman overlooking a neighborhood situation.
hypothesis: A police officer watches a situation closely.

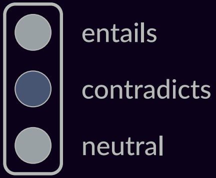
input

(P, H)



(Model: ESIM)

output



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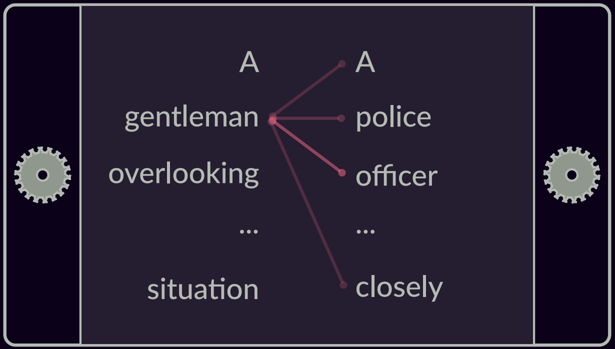
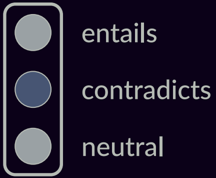


(Model: ESIM)

output



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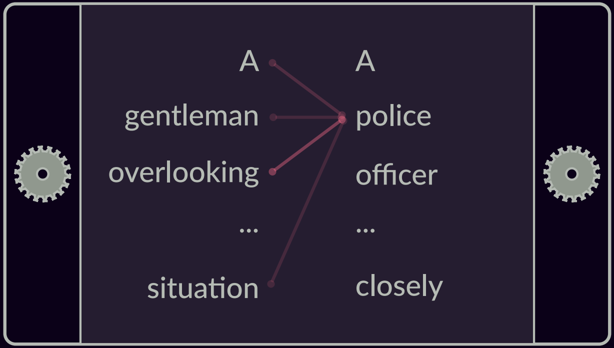

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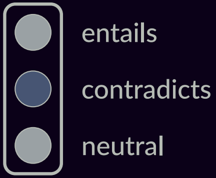

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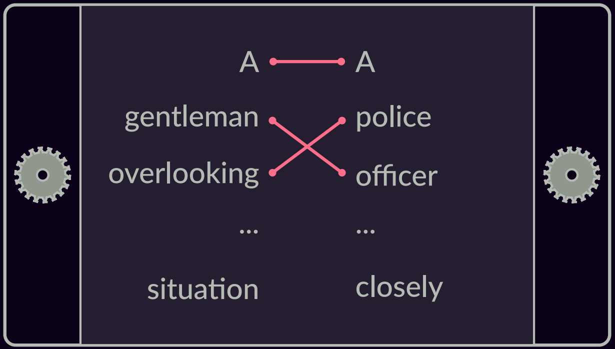
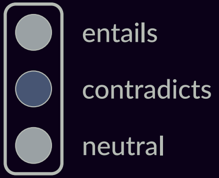
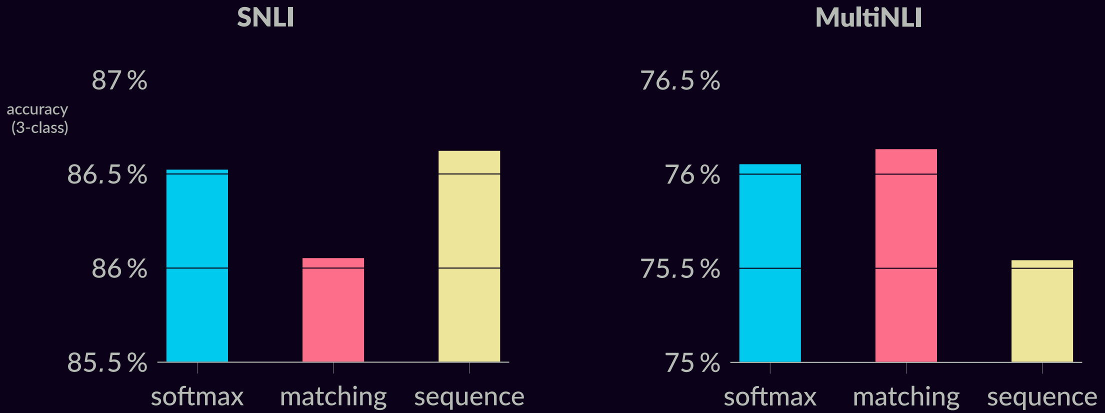


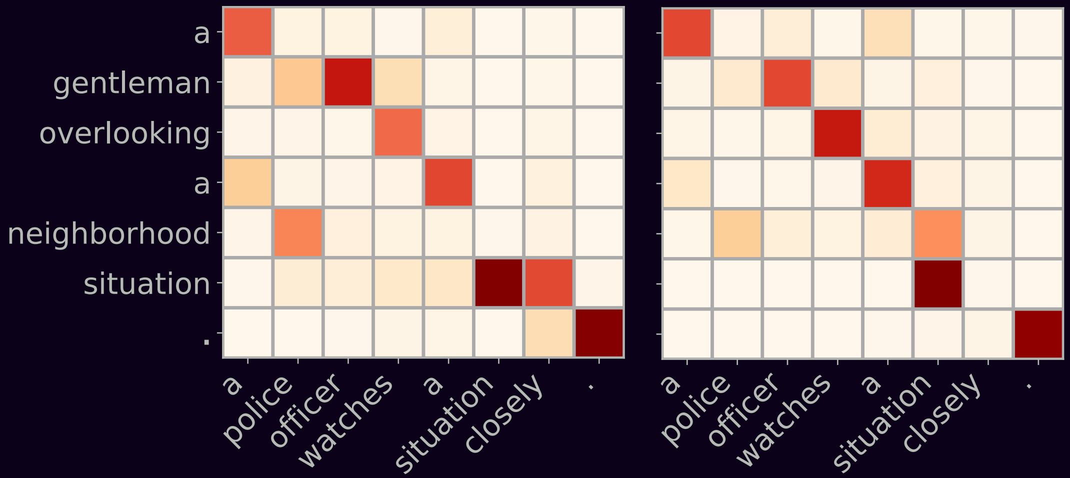
output



(Proposed model: global matching)



SNLI
MultiNLI
accuracy
(3-class)
87 %
86.5 %
86 %
85.5 %
76.5 %
76 %
75.5 %
75 %
softmax
matching
sequence
softmax
matching
sequence


a
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neighborhood
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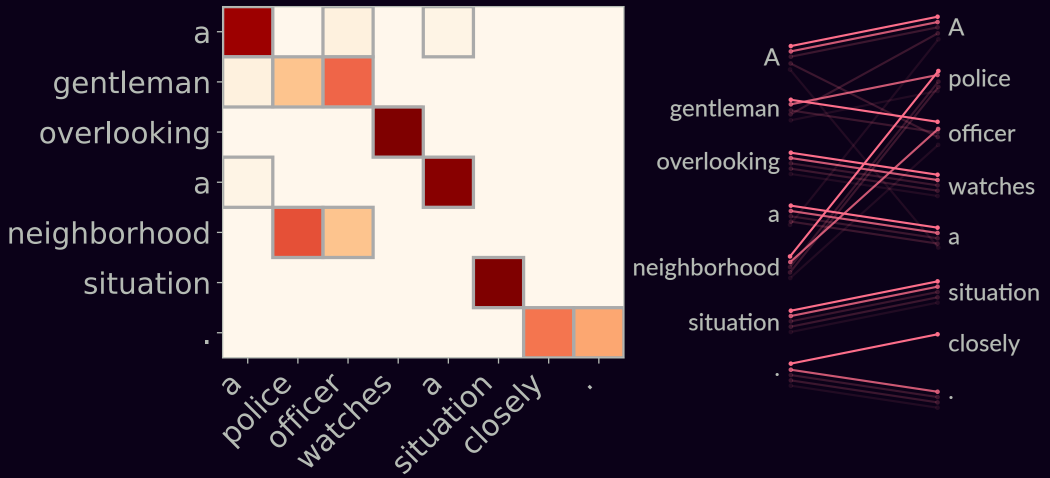

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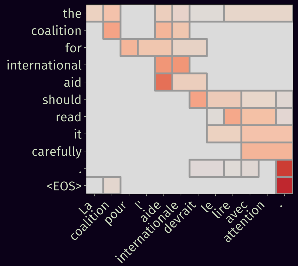
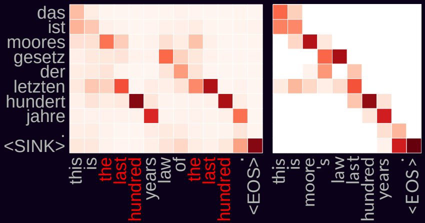
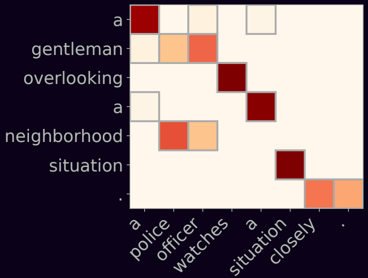
Summary: Neural attention with...



structured sparsity
(*e.g.* fusedmax)



constraints
(*e.g.* csparsemax — fertility)

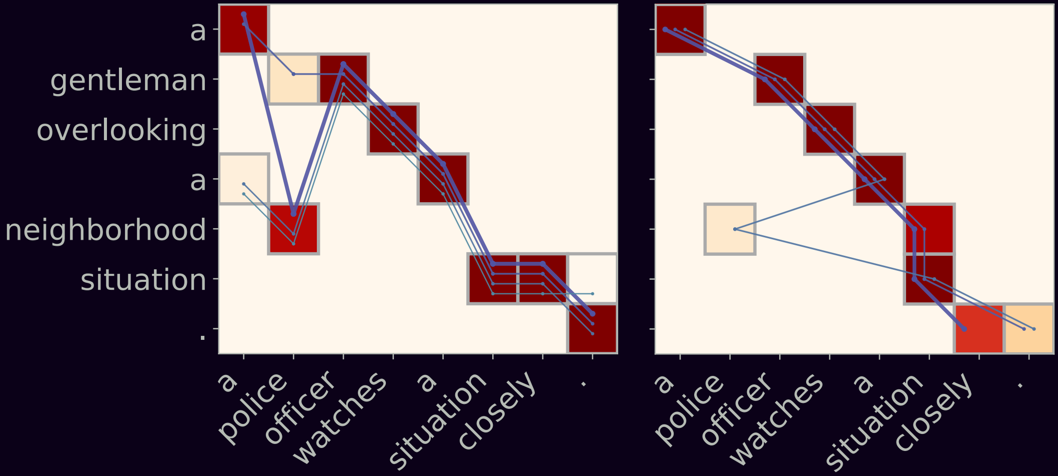


structure
(*e.g.* SparseMAP alignments)

and dynamic computation graphs with structured latent variables! (Friday 15:36 in 3B)

vlad@vene.ro github.com/vene/sparsemap https://vene.ro @vnfrombucharest

Some icons by Dave Gandy and Freepik via flaticon.com.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