Towards Localisation of Keywords in Speech using Weak Supervision

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Introduction

Detection

Query: ***snow***

Utterance

Does it occur?

Localisation

Query: ***snow***

Utterance

Where does it occur?

Weak supervision

Visual supervision

Image

Utterance

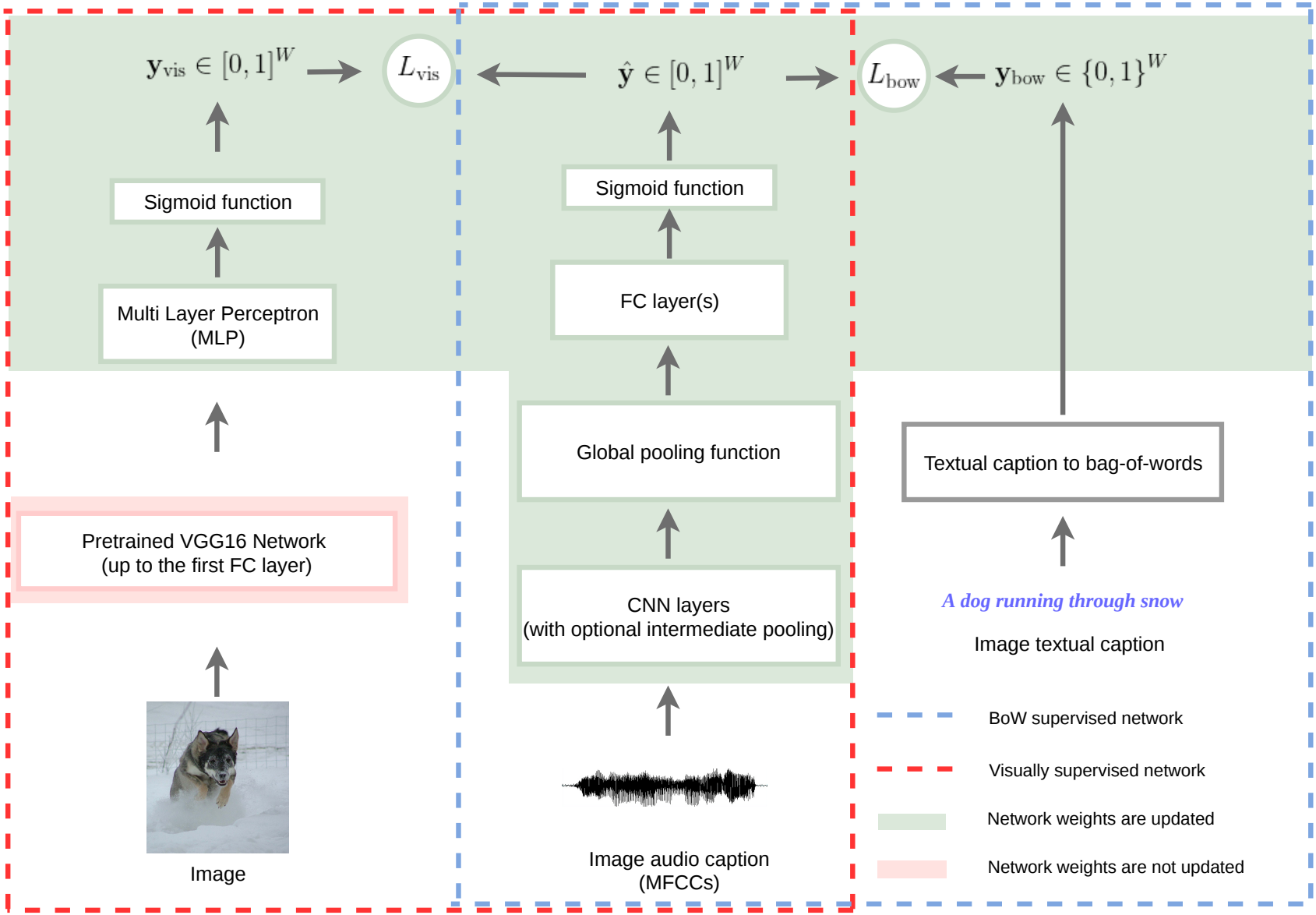
Bag-of-Word (BoW) supervision

snow, running, through, dog

BoW

Utterance

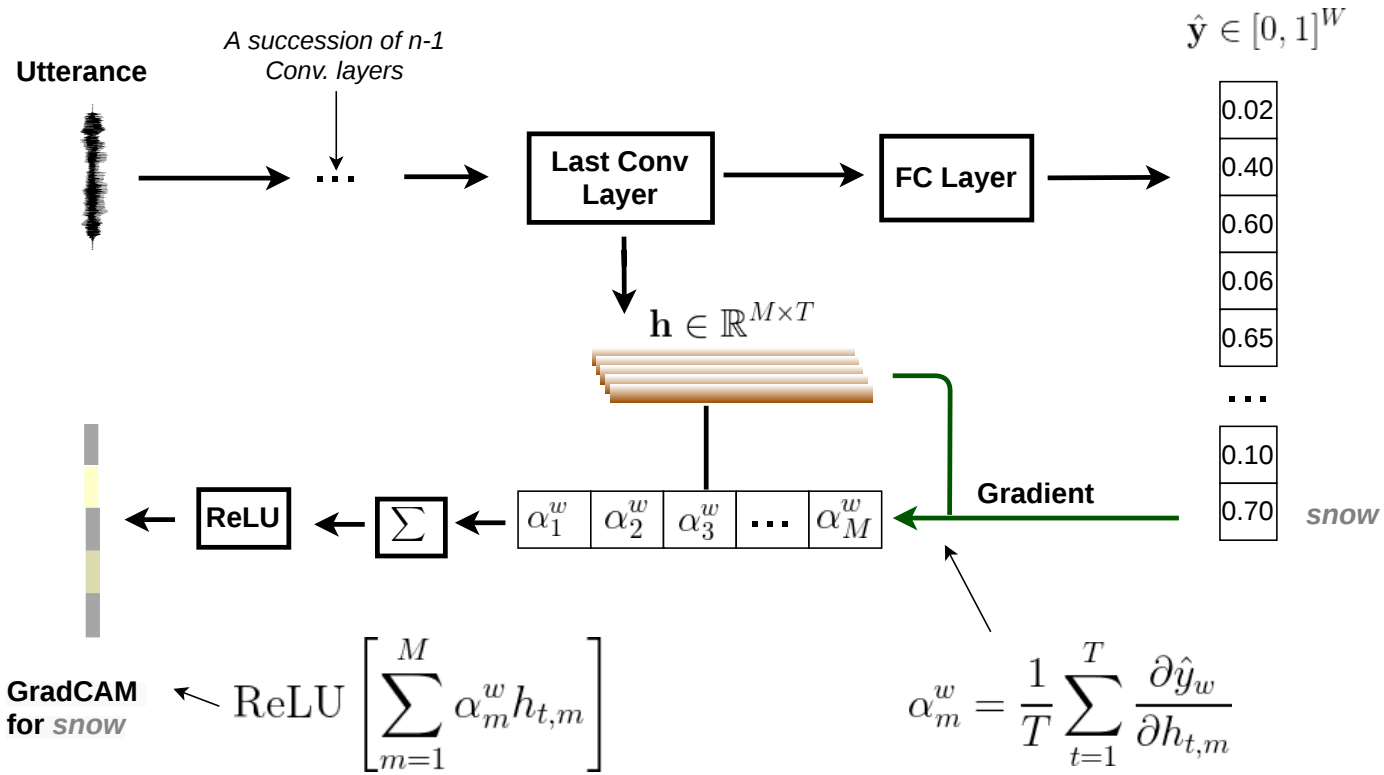
Model structure

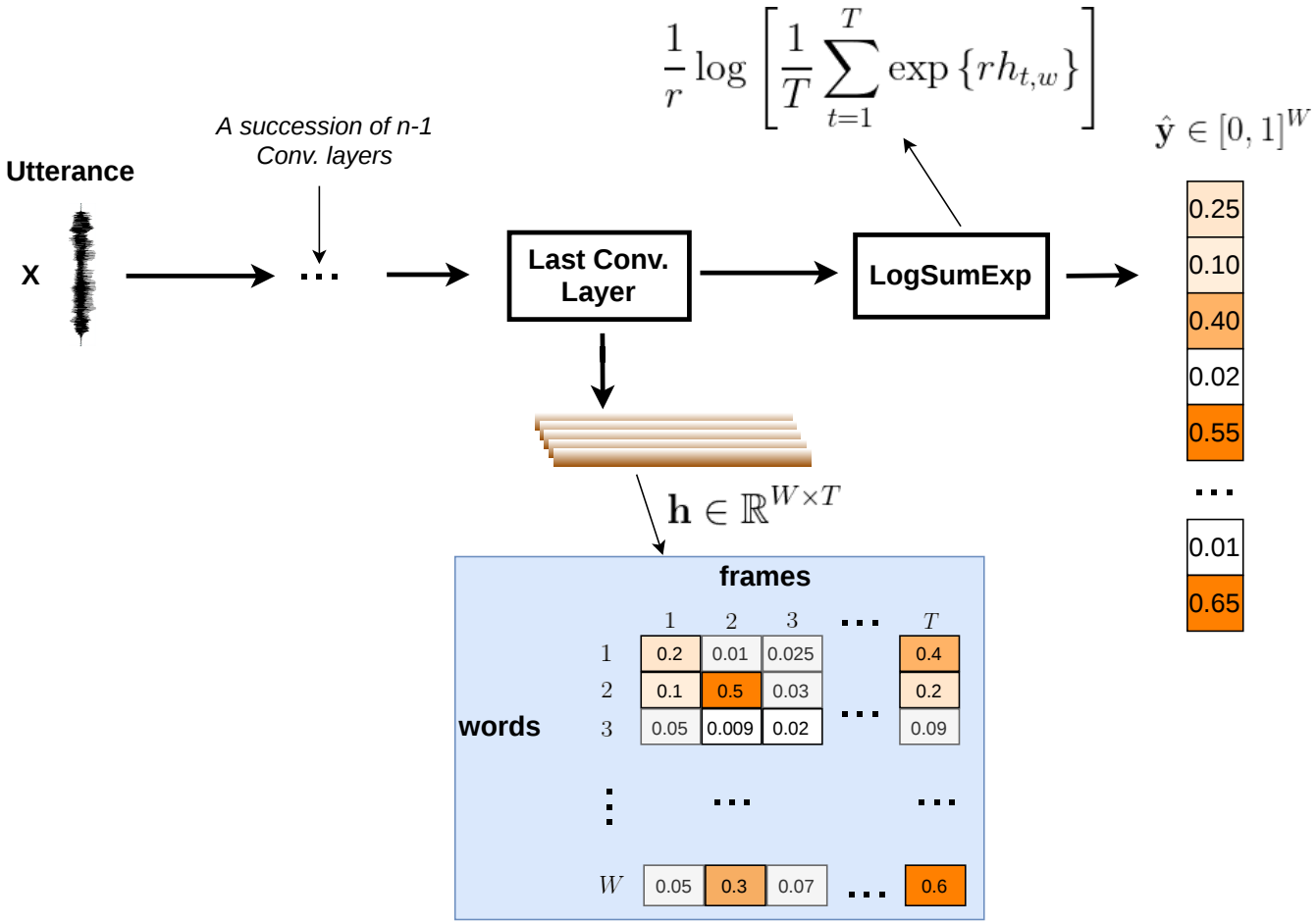


Localisation methods

- **GradCAM**
  - Introduced in the vision domain to localise an object in an image.
  - Works with any **trained** CNN architecture.
  - Determines the portion of an input that contributes to a decision of interest using gradient information.
- **Palaz, Synnaeve, and Collobert (PSC)**
  - Designed to simulateneously perform detection and localisation of keywords in speech utterance.
  - The CNN architecture is restricted in some ways (*No intermediate max-pooling; no fully-connected layers; LogSumExp function as the global pooling function*).

GradCAM


Utterance
A succession of n-1 Conv. layers
Last Conv Layer
FC Layer
$\hat{\mathbf{y}} \in [0,1]^W$
0.02
0.40
0.60
0.06
0.65
...
0.10
0.70
snow
$\mathbf{h} \in \mathbb{R}^{M \times T}$
Gradient
α_1^w α_2^w α_3^w ... α_M^w
$\sum$
ReLU
GradCAM for snow
$\text{ReLU}\left[\sum_{m=1}^{M} \alpha_m^w h_{t,m}\right]$
$\alpha_m^w = \frac{1}{T}\sum_{t=1}^{T} \frac{\partial \hat{y}_w}{\partial h_{t,m}}$


$\frac{1}{r}\log\left[\frac{1}{T}\sum_{t=1}^{T}\exp\{rh_{t,w}\}\right]$
A succession of n-1 Conv. layers
Utterance
x
Last Conv. Layer
LogSumExp
$\hat{\mathbf{y}} \in [0,1]^W$
0.25
0.10
0.40
0.02
0.55
0.01
0.65
$\mathbf{h} \in \mathbb{R}^{W \times T}$
frames
words
1 2 3 ... T
1 0.2 0.01 0.025 ... 0.4
2 0.1 0.5 0.03 ... 0.2
3 0.05 0.009 0.02 ... 0.09
W 0.05 0.3 0.07 ... 0.6

Two forms of weak supervision:

- BoW
- Visual

Two localisation methods:

- PSC
- GradCAM

Evaluation and Results

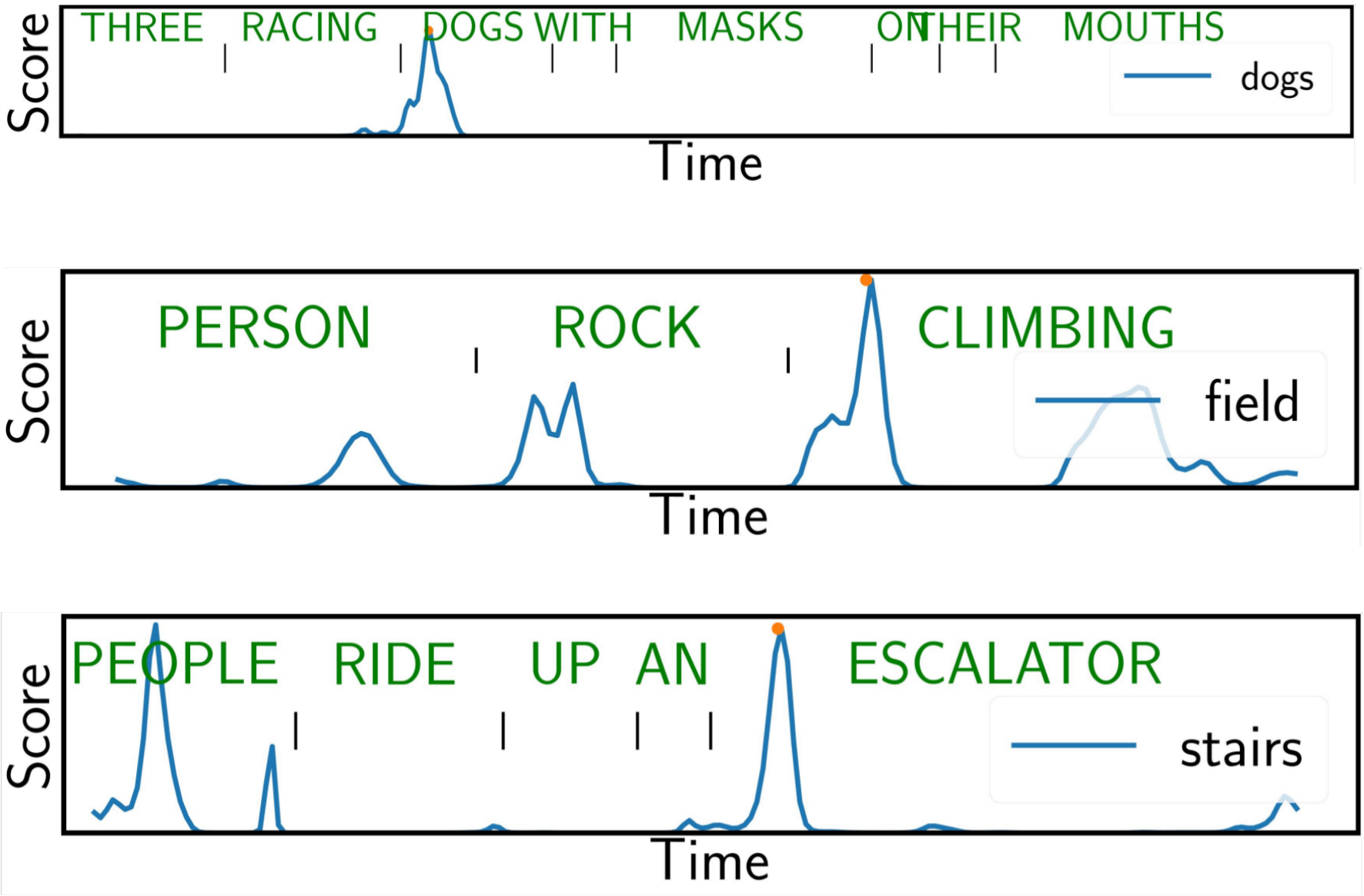
Oracle accuracy

	Supervision method	
Mechanism	BoW	Visual
PSC	63.6	19.1
GradCAM	17.8	16.0

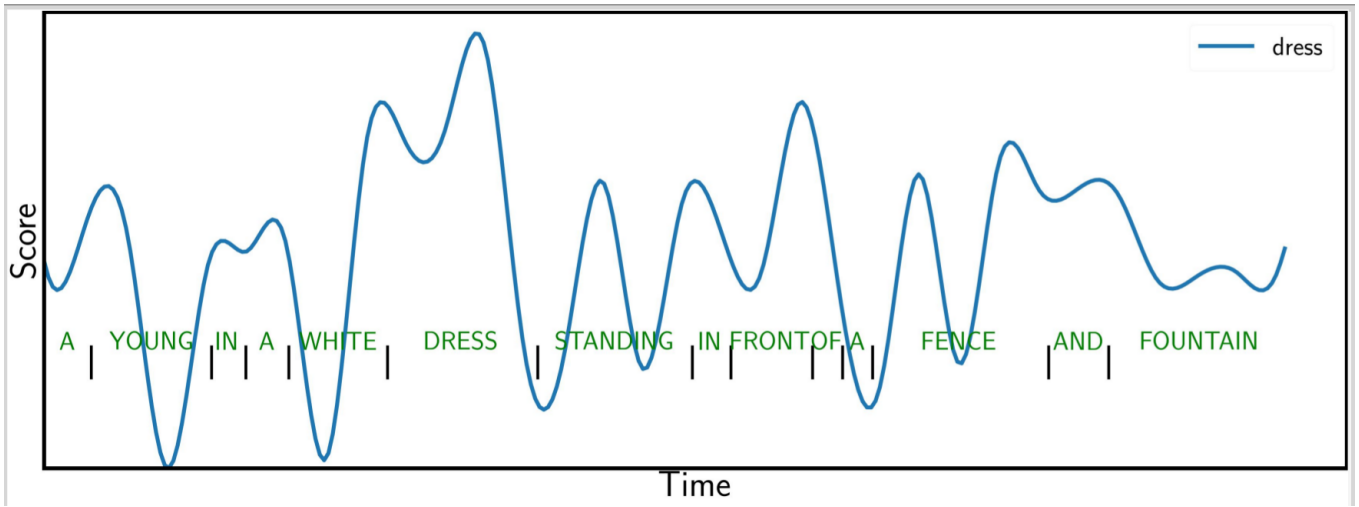
Actual accuracy

	BoW				Visual			
Mechanism	P	R	$F1$	Accuracy	P	R	$F1$	Accuracy
PSC	75.2	53.0	62.2	50.4	28.6	8.0	12.5	7.6
GradCAM	17.7	24.5	20.5	13.2	5.0	5.7	5.3	4.4

Examples from PSC model (with visual supervision)



Issues with GradCAM



- Method is optimised for multi-class classification: high probability for a particular class implies low probabilities for others.
- We use it here for a multi-label classification. Hence, during backward pass, Gradcam puts peaks over all the words in the utterance while locating *"dress"*

Conclusions

- Our question: Is keyword localisation in speech possible with two forms of weak supervision where location information is not provided?
- Compared BoW supervision versus visual supervision, and PSC versus GradCAM.
- BoW-trained model outperformed visually-trained model. PSC outperformed GradCAM on the localisation task.
- Visual supervision provides potential for high precision localisation.
- Mismatch between GradGAM and multi-label classification loss: poor performance.
- Should investigate better localisation methods.

Thank you for listening!

Supplementary materials

Keyword detection scores (without considering localisation) with threshold α.

	$\alpha = 0.4$			$\alpha = 0.6$		
Model	*P*	*R*	*F*1	*P*	*R*	*F*1
Visual supervision:						
PSC	44.5	9.8	16.1	74.7	4.3	8.1
GradCAM	29.3	22.0	25.1	42.7	12.7	19.6
BoW supervision:						
PSC	82.2	49.0	61.4	87.8	46.1	60.4
GradCAM	79.3	52.6	63.2	82.5	50.9	63.0

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