NeuralREG: an end-to-end approach for Referring Expression Generation

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NATURAL LANGUAGE GENERATION

Non-linguistic data → natural language

Subject	Relation	Object
Aarhus_Airport	cityServed	Aarhus,_Denmark
Aarhus_Airport	elevation	25.0
Aarhus_Airport	runwayName	10R/28L

$\downarrow_{NLG}$

The Aarhus Airport is located in Aarhus, Denmark. It is situated 25.0 meters above sea level. The airport has a runway called 10R/28L.

REFERRING EXPRESSION GENERATION (REG)

Task responsible for generating references to discourse entities

Subject	Relation	Object
Aarhus_Airport$_1$	cityServed	**Aarhus,_Denmark$_2$**
Aarhus_Airport$_1$	elevation	**25.0$_3$**
Aarhus_Airport$_1$	runwayName	**10R/28L$_4$**

$\downarrow REG$

The Aarhus Airport$_1$ is located in **Aarhus, Denmark$_2$**. **It$_1$** is situated **25.0$_3$** meters above sea level . **The airport$_1$** has a runway called **10R/28L$_4$**.

MOTIVATION

Novel "end-to-end" NLG models

Generation of delexicalized templates from different meaning representations...

AMR → template → text

(Konstas et al., 2017)
(Castro Ferreira et al., 2017)

Dialog Act → template → dialogue text

(Wen et al., 2015)
(Dušek and Jurčíček, 2016)

RDF triples → template → text

WebNLG Challenge (Gardent et al., 2017)

...for accounting data sparsity and unseen entities
(Konstas et al., 2017)

DATA

WebNLG corpus

25,298 text describing 9,674 triple sets
Manually delexicalized

TEMPLATE GENERATION

Subject	Relation	Object
SUBJECT-1	cityServed	OBJECT-1
SUBJECT-1	elevation	OBJECT-2
SUBJECT-1	runwayName	OBJECT-3

$\downarrow template$

SUBJECT-1 is located in **OBJECT-1** . **SUBJECT-1** is situated **OBJECT-2** meters above sea level . **SUBJECT-1** has a runway called **OBJECT-3** .

WIKIFICATION

Tag	Entity
SUBJECT-1	Aarhus_Airport
OBJECT-1	Aarhus,_Denmark
OBJECT-2	25.0
OBJECT-3	10R/28L

$\downarrow Wiki$

Aarhus_Airport is located in **Aarhus,_Denmark** .
Aarhus_Airport is situated **25.0** meters above sea level .
Aarhus_Airport has a runway called **10R/28L** .

Conversion in constant time

GOAL

Aarhus_Airport is located in **Aarhus,_Denmark** . **Aarhus_Airport** is situated **25.0** meters above sea level . **Aarhus_Airport** has a runway called **10R/28L** .

$$\downarrow REG$$

The Aarhus Airport is located in **Aarhus, Denmark** . **It** is situated **25.0** meters above sea level . **The airport** has a runway called **10R/28L** .

Underestimated process so far.

PROBLEM

Aarhus Airport is located in **Aarhus, Denmark** . Aarhus Airport is situated **25.0** meters above sea level . Aarhus Airport has a runway called **10R/28L** .

vs.

The Aarhus Airport is located in **Aarhus, Denmark** . It is situated **25.0** meters above sea level . The airport has a runway called **10R/28L** .

REG is crucial for the coherence of the text

REG MODELS

Extensively studied in pipeline architectures of NLG

GREC Challenges (Belz et al., 2010)

Decisions taken by different subtasks (modular)

Choice of referential form

Surface realization

Bottlenecks

Feature engineering

Difficulties in developing and maintaining

Propagation of errors in cascade along the modules

NEURALREG

End-to-end REG approach taking **context** into account

No need for feature engineering
Choice of referential and surface realization in one go!

INPUT

Target

Target reference to be realized

Pre-context

Lowercased, tokenized and delexicalized piece of text **before** the target reference

Pos-context

Lowercased, tokenized and delexicalized piece of text **after** the target reference

NEURALREG

EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .
Aarhus_Airport is situated **25.0** meters above sea level .
Aarhus_Airport has a runway called **10R/28L** . *EOS*

Pre-context
Target
pos-context

↓

The Aarhus Airport

NEURALREG

EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .
Aarhus_Airport is situated **25.0** meters above sea level .
Aarhus_Airport has a runway called **10R/28L** . *EOS*

Pre-context
Target
pos-context

↓

Aarhus, Denmark

NEURALREG

EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .

Aarhus_Airport is situated **25.0** meters above sea level .

Aarhus_Airport has a runway called **10R/28L** . *EOS*

Pre-context

Target

pos-context

↓

It

NEURALREG

EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .
Aarhus_Airport is situated **25.0** meters above sea level .
Aarhus_Airport has a runway called **10R/28L** . *EOS*

Pre-context
Target
pos-context

25.0

NEURALREG

EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .
Aarhus_Airport is situated **25.0** meters above sea level .
Aarhus_Airport has a runway called **10R/28L** . *EOS*

Pre-context
Target
Pre-context

↓

The airport

NEURALREG

EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .
Aarhus_Airport is situated **25.0** meters above sea level .
Aarhus_Airport has a runway called **10R/28L** . *EOS*

Pre-context
Target
Pre-context

↓

10R/28L

NEURALREG

Encoder Attention-Decoder architecture

Context encoders

Vector representations for pre- and pos-contexts

Decoder

Combining representations and decoding the referring expression

NEURALREG

EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .
Pre-context

Aarhus_Airport

TARGET

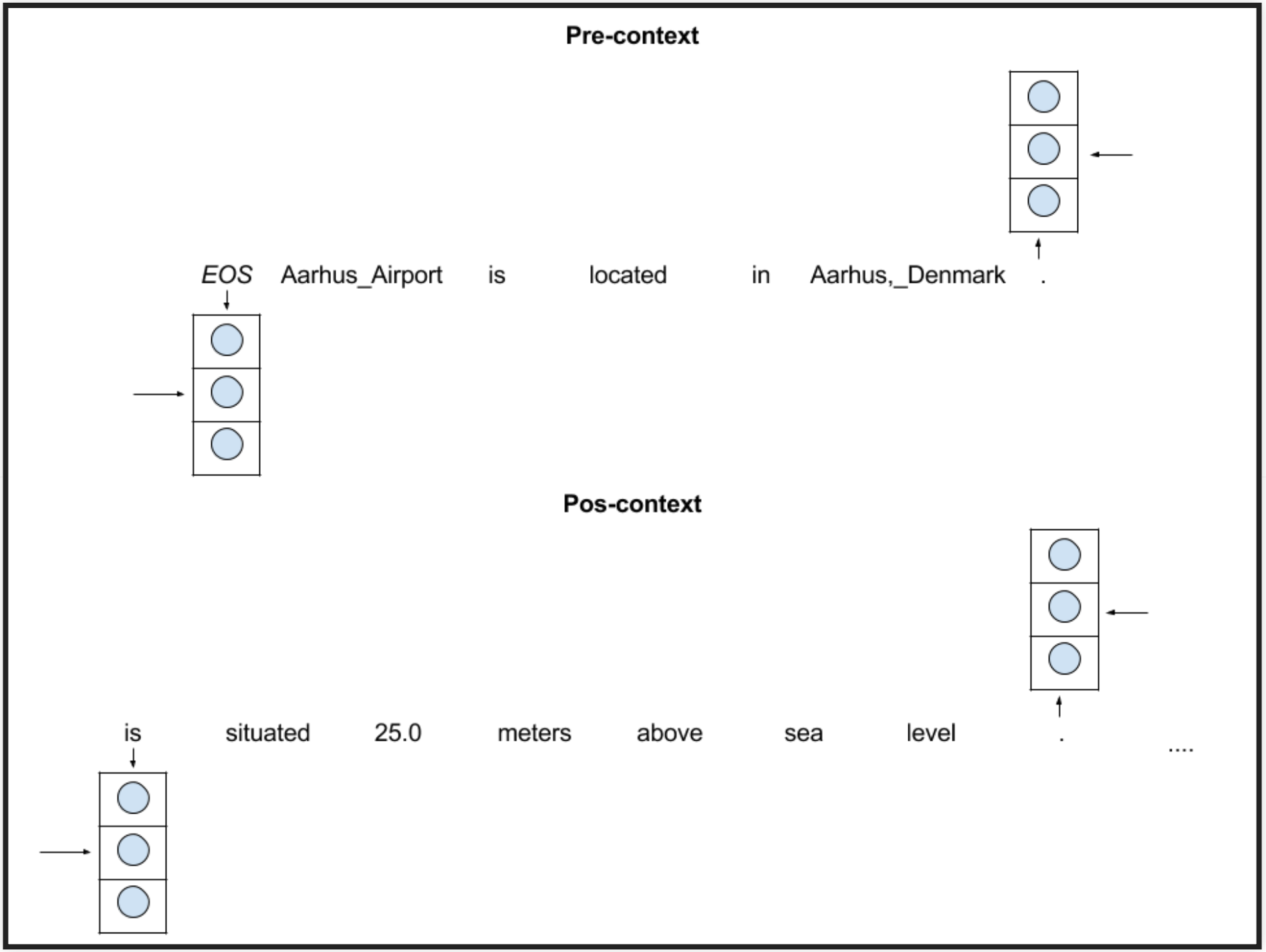
is situated **25.0** meters above sea level . **Aarhus_Airport** has a runway called **10R/28L** . *EOS*
Pos-Context

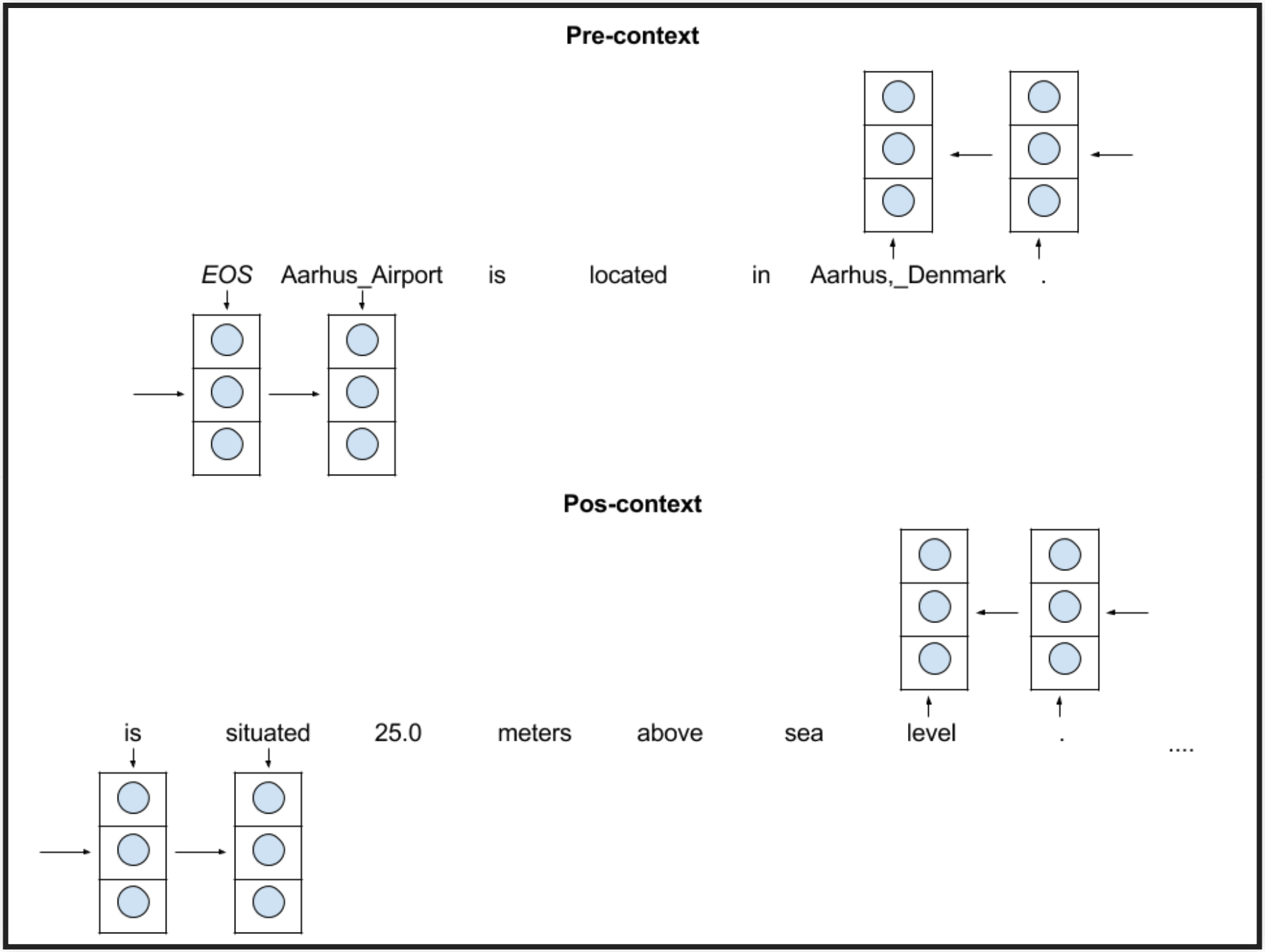
Pre-context

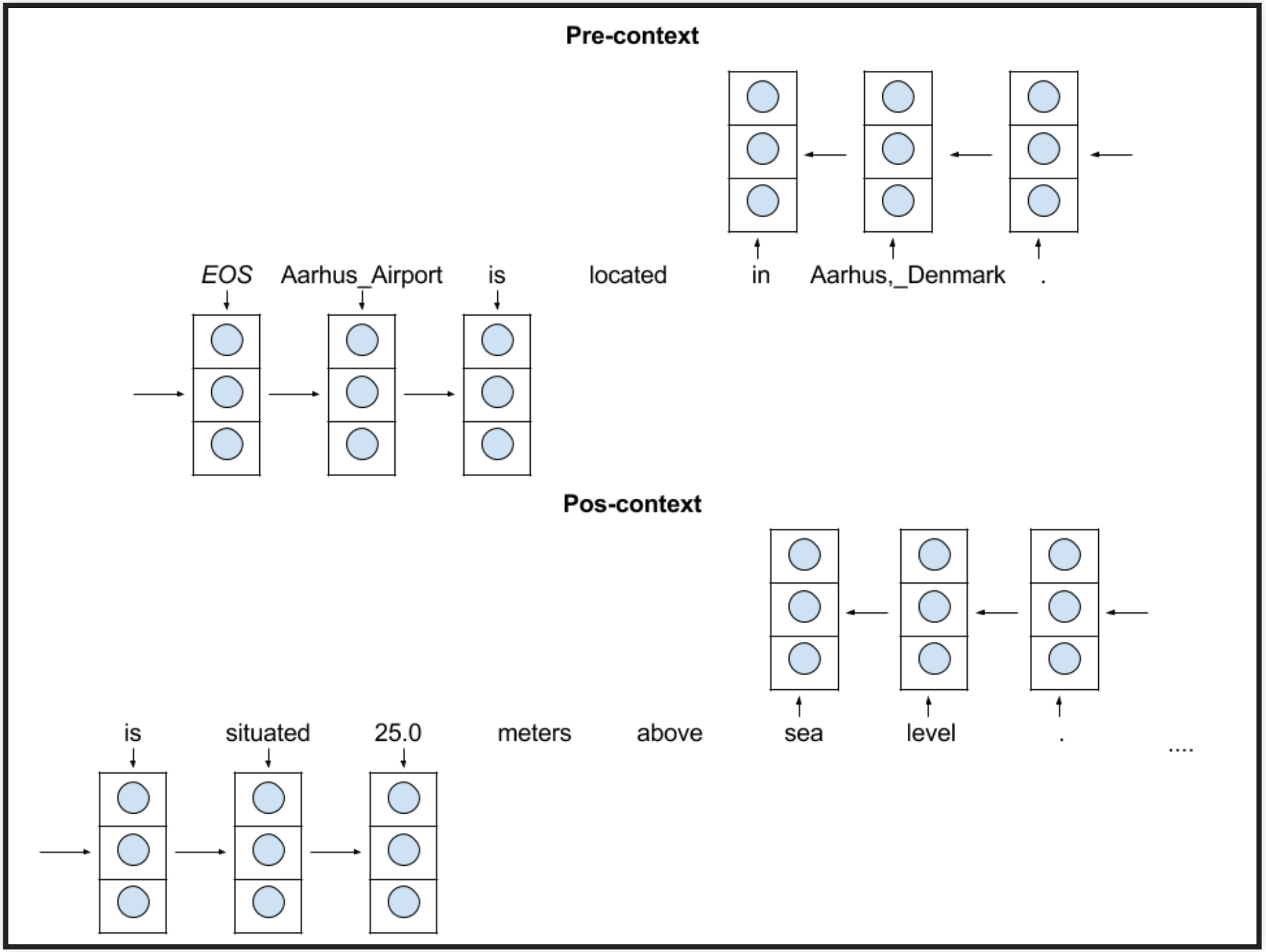
EOS Aarhus_Airport is located in Aarhus,_Denmark .

Pos-context

is situated 25.0 meters above sea level . ....


Pre-context
EOS Aarhus_Airport is located in Aarhus,_Denmark .
Pos-context
is situated 25.0 meters above sea level . ....


Pre-context
EOS
Aarhus_Airport
is
located
in
Aarhus,_Denmark
.
Pos-context
is
situated
25.0
meters
above
sea
level
.
....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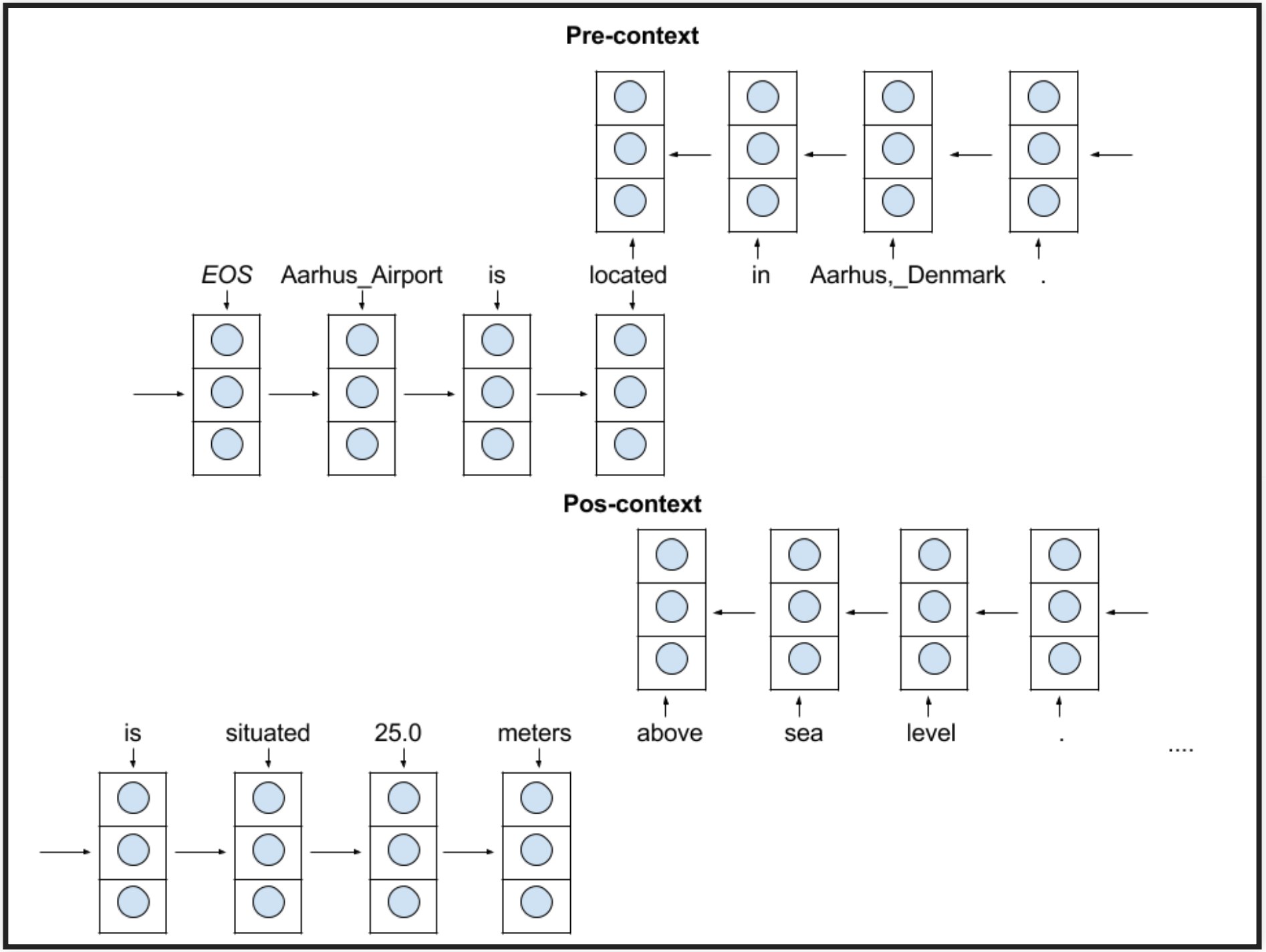
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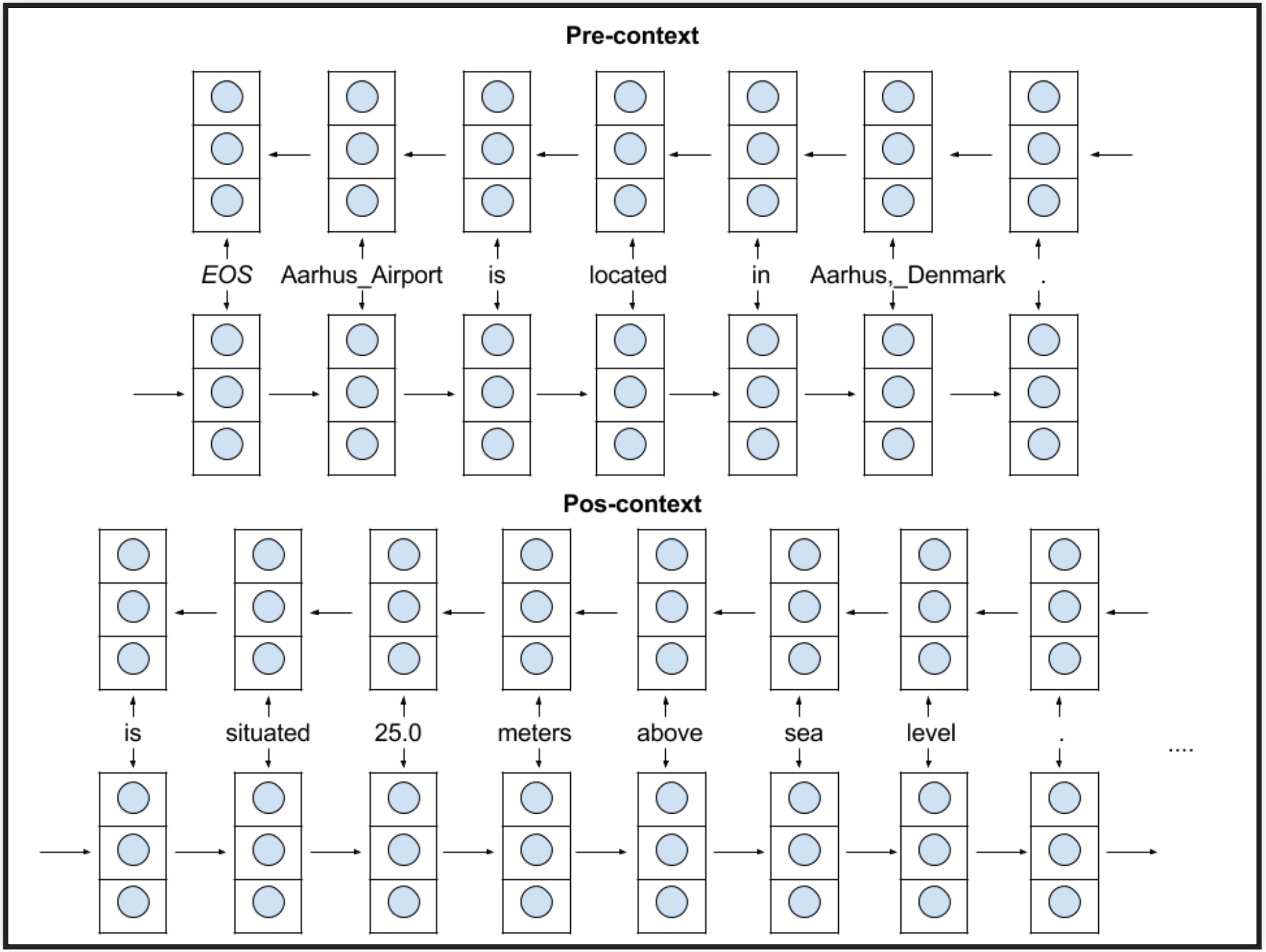
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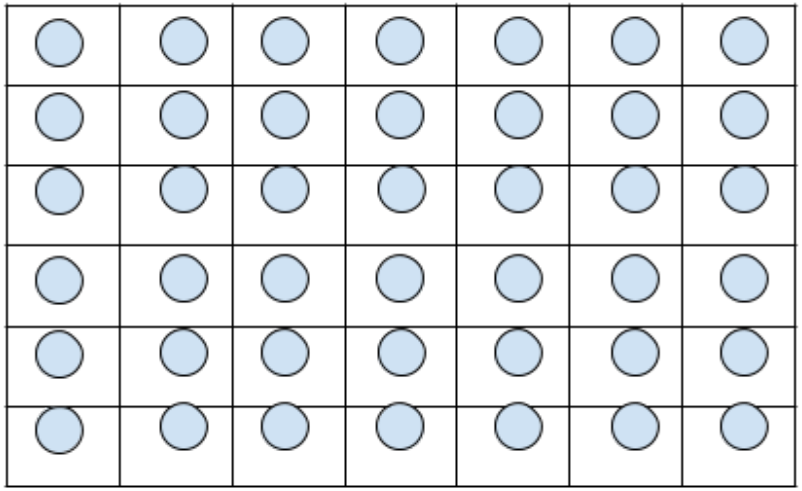
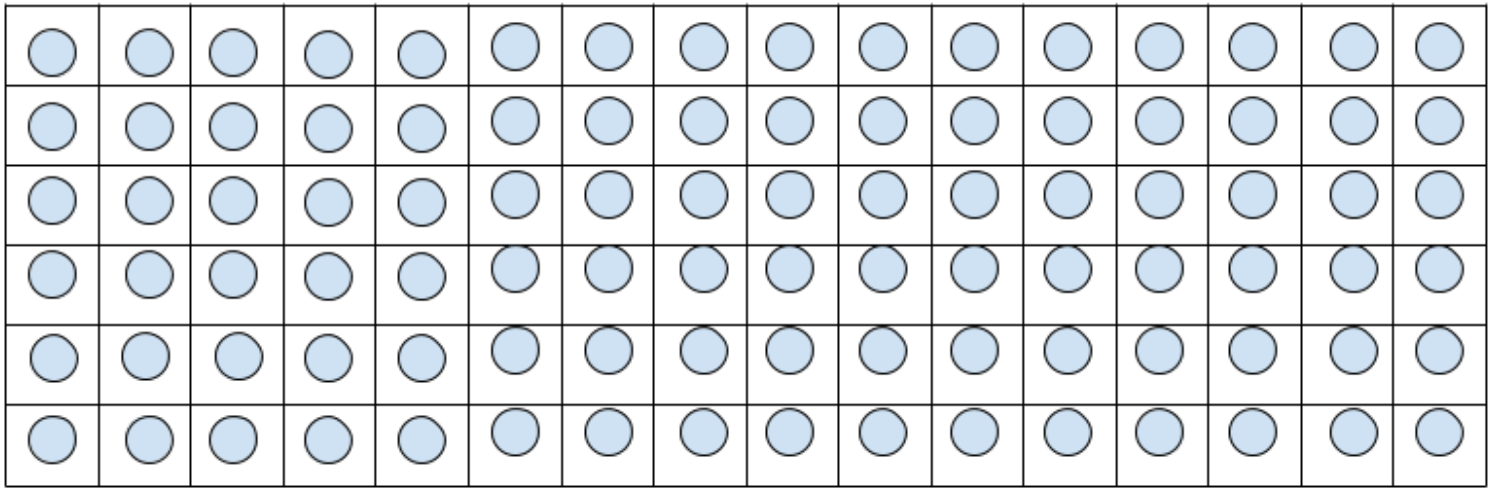
Pre-context

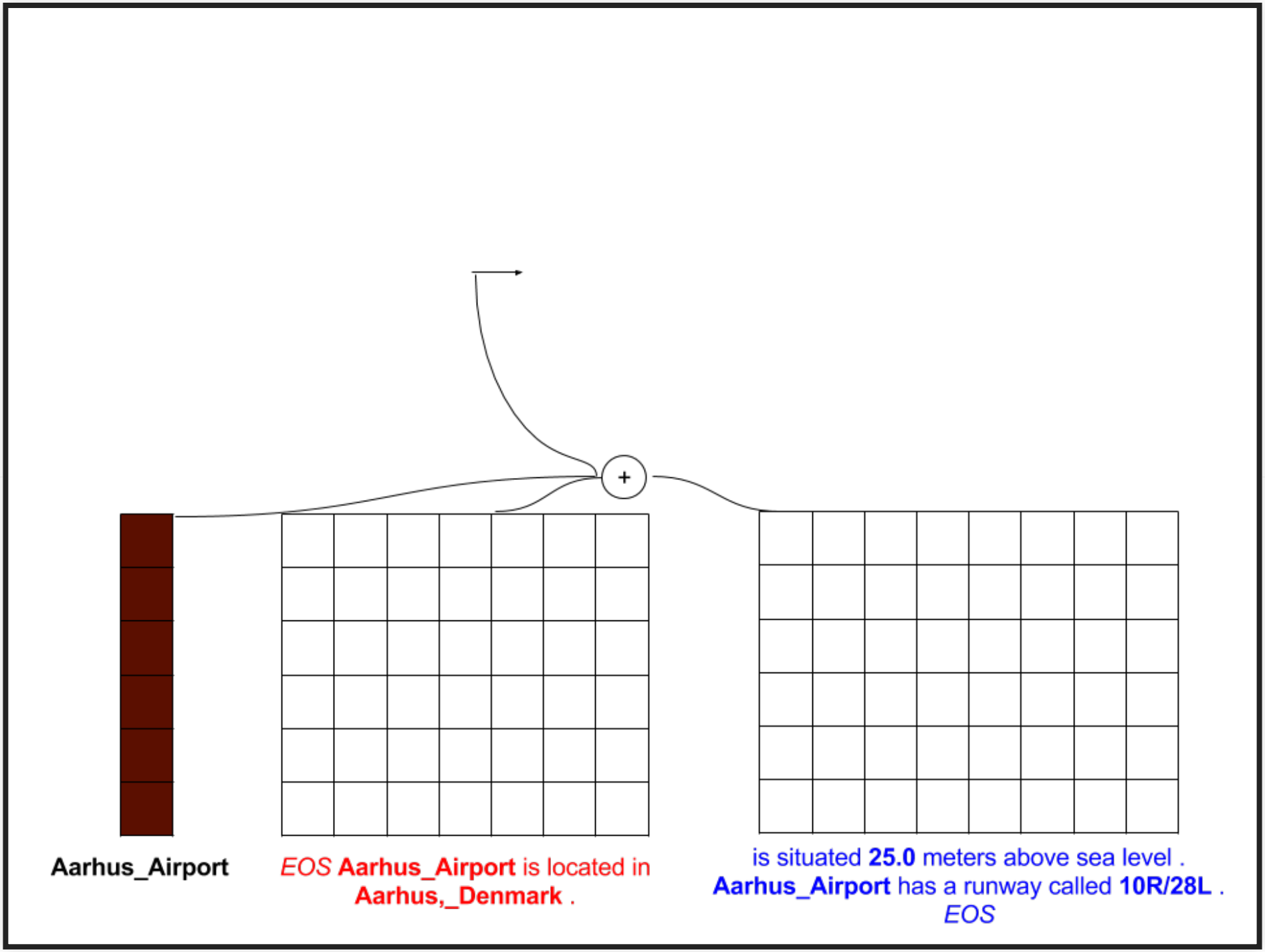
EOS **Aarhus_Airport** is located in **Aarhus,_Denmark** .



Pos-context

is situated **25.0** meters above sea level . **Aarhus_Airport** has a runway called **10R/28L** . *EOS*




+
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is situated 25.0 meters above sea level .
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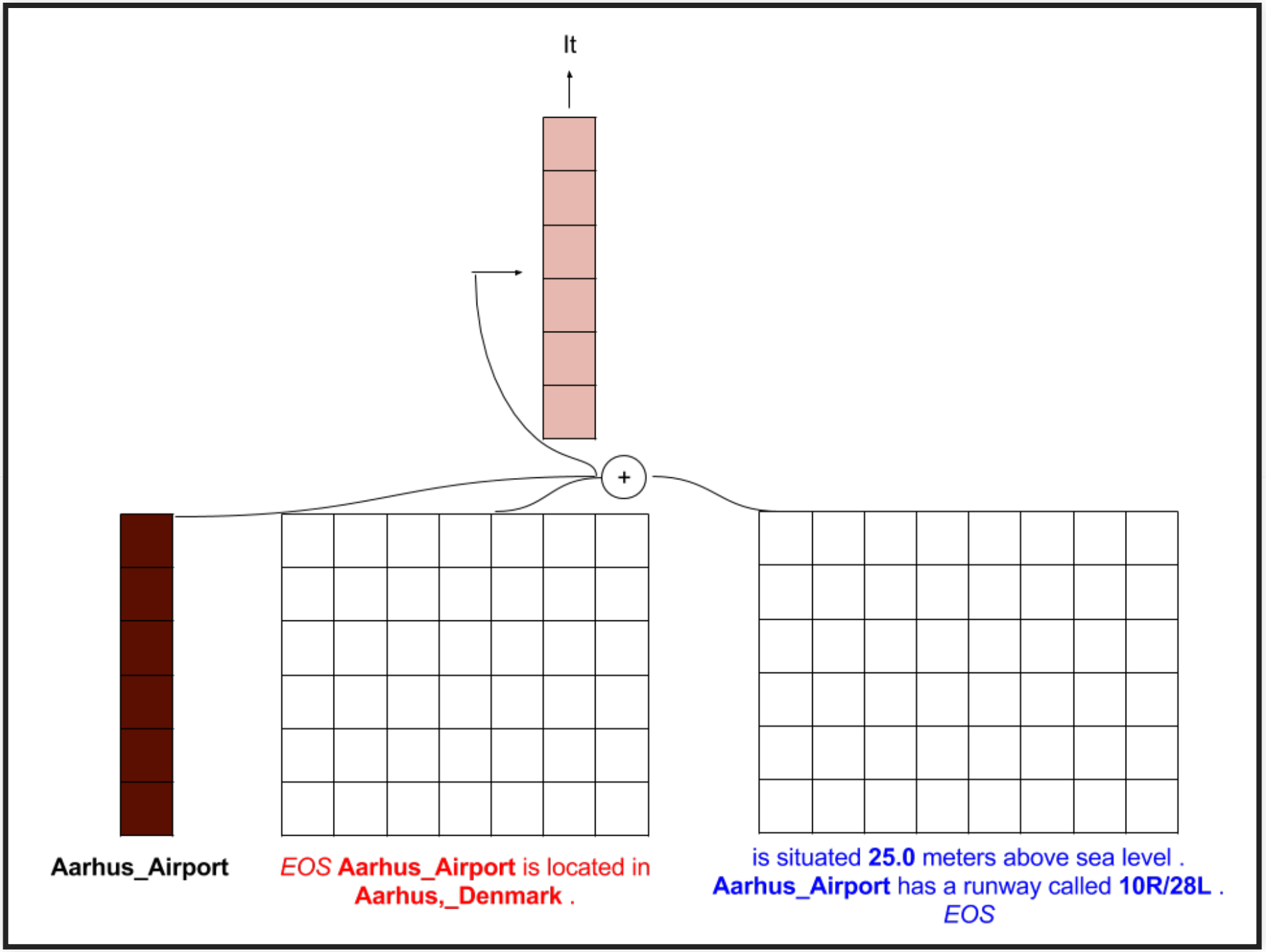
EOS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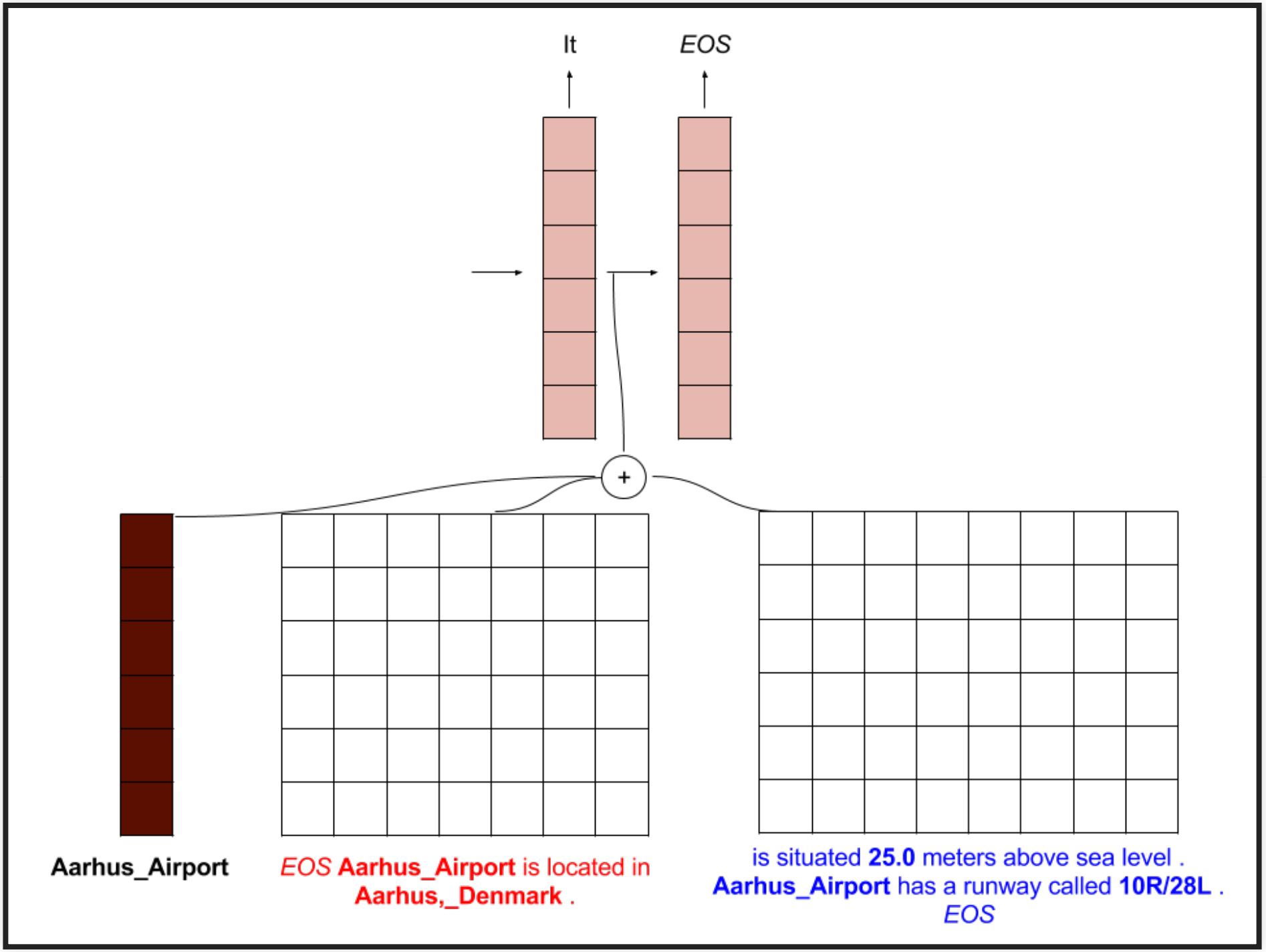
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EOS

DECODER

$$s_i = \Phi_{\text{dec}}(s_{i-1}, [c_i, V_{y_{i-1}}, V_{target}])$$

$$y_i = \text{beam}(\text{softmax}(W_c s_i + b))$$

evaluation of 3 methods to compute c_i...

SEQ2SEQ

Average and concat matrixes $h^{(pre)}$ and $h^{(pos)}$

$$\hat{h}^{(k)} = \frac{1}{N} \sum_i^N h_i^{(k)}$$

$$c_i = [\hat{h}^{(pre)}, \hat{h}^{(pos)}]$$

CATT

Concatenative attention

$$e_{ij}^{(k)} = v_a^{(k)T} \tanh(W_a^{(k)} s_{i-1} + U_a^{(k)} h_j^{(k)})$$

$$\alpha_{ij}^{(k)} = \frac{\exp(e_{ij}^{(k)})}{\sum_{n=1}^{N} \exp(e_{in}^{(k)})}$$

$$c_i^{(k)} = \sum_{j=1}^{N} \alpha_{ij}^{(k)} h_j^{(k)}$$

$$c_i = [c_i^{(pre)}, c_i^{(pos)}]$$

HIERATT

Hierarchical Attention
(Libovický and Helcl, 2017)

$$e_i^{(k)} = v_b^{(k)T} \tanh(W_b^{(k)} s_{i-1} + U_b^{(k)} c_i^{(k)})$$

$$\beta_i^{(k)} = \frac{\exp(e_i^{(k)})}{\sum_n \exp(e_i^{(n)})}$$

$$c_i = \sum_k \beta_i^{(k)} U_b^{(k)} c_i^{(k)}$$

NEURALREG

$$s_i = \Phi_{\text{dec}}(s_{i-1}, [c_i, V_{y_{i-1}}, V_{target}])$$

NeuralREG+Seq2Seq

$$c_i = [\text{avg}(h^{(pre)}), \text{avg}(h^{(pos)})]$$

NeuralREG+CAtt

$$c_i = [\text{attend}(h^{(pre)}), \text{attend}(h^{(pos)})]$$

NeuralREG+HierAtt

$$c_i = \text{hierattend}(\text{attend}(h^{(pre)}), \text{attend}(h^{(pos)}))$$

EVALUATION

WebNLG corpus

25,298 text describing 9,674 triple sets
Manually delexicalized

78,901 references to 1,483 entities

Train: 63,031 - **Dev:** 7,127 - **Test:** 8,743

BASELINES

Only Names

Ferreira

ONLY NAMES

(WikiID) : underline → whitespace

Aarhus_Airport is located in **Aarhus,_Denmark** . **Aarhus_Airport** is situated **25.0** meters above sea level . **Aarhus_Airport** has a runway called **10R/28L** .

$$\downarrow_{REG}$$

Aarhus Airport is located in **Aarhus, Denmark** . **Aarhus Airport** is situated **25.0** meters above sea level . **Aarhus Airport** has a runway called **10R/28L** .

FERREIRA

Choice of referential form

(Castro Ferreira et al., 2016)

Aarhus_Airport is located in **Aarhus,_Denmark** . **Aarhus_Airport** is situated **25.0** meters above sea level . **Aarhus_Airport** has a runway called **10R/28L** .

$\downarrow_{form}$

NAME$_{S1}$ is located in **NAME**$_{O2}$. **PRONOUN**$_{S1}$ is situated **NAME**$_{O3}$ meters above sea level . **DESCRIPTION**$_{S1}$ has a runway called **NAME**$_{O4}$.

FERREIRA

Surface Realization

NAME$_{S1}$ is located in **NAME**$_{O2}$. **PRONOUN**$_{S1}$ is situated **NAME**$_{O3}$ meters above sea level .
DESCRIPTION$_{S1}$ has a runway called **NAME**$_{O5}$.

$\downarrow realize$

Pick the most frequent referring expression, given entity, form, syntactic position and referential status.

Features extracted from the dependency tree of the wikified text

AUTOMATIC EVALUATION

REG metrics

Accuracy, string edit distance and pronoun accuracy

Text metrics

Text accuracy and BLEU

REG METRICS

	Acc	String	Pronoun
Only Names	53%^{D}	4.05^{D}	-
Ferreira	61%^{C}	3.18^{C}	43%^{B}
NeuralREG+Seq2Seq	74%^{A,B}	2.32^{A,B}	75%^{A}
NeuralREG+CAtt	74%^{A}	2.25^{A}	75%^{A}
NeuralREG+HierAtt	73%^{B}	2.36^{B}	73%^{A}

TEXT METRICS

	Acc	BLEU
Only Names	15%^{D}	69.03^{C}
Ferreira	19%^{C}	72.78^{C}
NeuralREG+Seq2Seq	28%^{B}	79.27^{A,B}
NeuralREG+CAtt	30%^{A}	79.39^{A}
NeuralREG+HierAtt	28%^{A,B}	79.01^{B}

HUMAN EVALUATION

Material

144 trials (= 6 triple set sizes × 4 instances × 6 text versions)

Method

Latin square design

24 trials/list (= 144 trials ÷ 6 lists)

60 participants (10 participants/list)

Metrics

Fluency, Grammaticality and Clarity

7-Likert scale

HUMAN EVALUATION

	Fluency	Grammar	Clarity
Only Names	4.74^{C}	4.68^{B}	4.90^{B}
Ferreira	4.74^{C}	4.58^{B}	4.93^{B}
NeuralREG+Seq2Seq	4.95^{B,C}	4.82^{A,B}	4.97^{B}
NeuralREG+CAtt	5.23^{A,B}	4.95^{A,B}	5.26^{A,B}
NeuralREG+HierAtt	5.07^{B,C}	4.90^{A,B}	5.13^{A,B}
Original	5.41^{A}	5.17^{A}	5.42^{A}

CONCLUSION

First end-to-end approach for REG in text discourse

Improvements over reference accuracy and text fluency
Concatenative attention (CAtt) best decoding method

Delexicalized version of WebNLG corpus

Useful resource for NLG in general

Data and code available

https://github.com/ThiagoCF05/NeuralREG

QUESTIONS?

Model	Text
OnlyNames	**alan shepard** was born in **new hampshire** on **1923-11-18** . before **alan shepard** death in **california** **alan shepard** had been awarded **distinguished service medal (united states navy)** an award higher than **department of commerce gold medal** .
Ferreira	**alan shepard** was born in **new hampshire** on **1923-11-18** . before **alan shepard** death in **california** **him** had been awarded **distinguished service medal** an award higher than **department of commerce gold medal** .
`Seq2Seq`	**alan shepard** was born in **new hampshire** on **1923-11-18** . before **his** death in **california him** had been awarded **the distinguished service medal by the united states navy** an award higher than **the department of commerce gold medal** .
`CAtt`	**alan shepard** was born in **new hampshire** on **1923-11-18** . before **his** death in **california he** had been awarded **the distinguished service medal by the us navy** an award higher than **the department of commerce gold medal** .
`HierAtt`	**alan shephard** was born in **new hampshire** on **1923-11-18** . before **his** death in **california he** had been awarded **the distinguished service medal** an award higher than **the department of commerce gold medal** .
Original	**alan shepard** was born in **new hampshire** on **18 november 1923** . before **his** death in **california he** had been awarded **the distinguished service medal by the us navy** an award higher than **the department of commerce gold medal** .

Thank you! :-)

https://github.com/ThiagoCF05/NeuralREG

SETTINGS

Layers	LSTM
Training Method	Adam
Matrices init	Xavier
Batch Size	40
Epochs	60
Embedding Size	300
Hidden Layer Size	512
Dropout	0.2/0.3