DRS Parsing

based on the works of van Noord et al. &
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Contents

- Definition & Motivation
- Discourse Representation Structures (DRS)
- Parallel Meaning Bank
- DRS Parsing
- DRS Alignment

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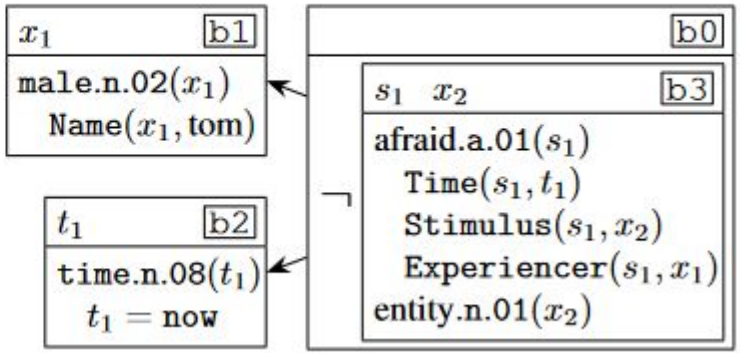
Definition & Motivation

- **Semantic parsing** is the task of mapping a natural language expression to a meaning representation
- **DRS** (Discourse Representation Structure) is one of many meaning representations

Raw input:

```
Tom isn't afraid of anything.
```

The same DRS in a box format:



Definition & Motivation

- Why do we need formal meaning representations of natural language?
  - Language understanding cannot be learn from form alone [Bender and Koller, 2020]
  - DRS is grounded in formal logic
  - Use in downstream tasks

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Discourse Representation Structure

- Is a well studied formalism from the early 80s
- Has many different versions / extensions
- Contain **discourse-referents**, -**conditions** and **-relations**
- Are recursive structures
- Usually consist of several presuppositional DRSs and a main DRS
- The version of DRS used by van Noord et al. also uses wordsenses grounded in Verbnet and Wordnet
- Two ways of displaying DRS used by Noord et al.:
  - Box-format (for human readability)
  - Flat-clause format (for machine readability)

Discourse Representation Structure

- **Discourse referents** are objects under discussion and represented as a variable (e.g *x1* or *s1)*
- **Discourse conditions** add meaning to the discourse referents and can be viewed as predicate functions that take one or two arguments (e.g male(*x1*) or experiencer(*x1, s1*))
- **Discourse relations** describe the relation between DRSs and can also be viewed as predicate functions that take arguments (e.g continuation(*b1, b2*))

Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

Raw input:

```
Tom isn't afraid of anything.
```

System output of a DRS in a clausal form:

Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

Raw input:

```
Tom isn't afraid of anything.
```

System output of a DRS in a clausal form:

```
b1 REF x1
```

Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

Raw input:

```
Tom isn't afraid of anything.
```

System output of a DRS in a clausal form:

```
b1 REF x1
b1 Name x1 "tom"
```

Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

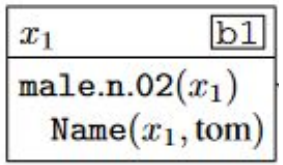
Raw input:

```
Tom isn't afraid of anything.
```

System output of a DRS in a clausal form:

```
b1 REF x1
b1 Name x1 "tom"
b1 male "n.02" x1
```

The same DRS in a box format:



Noun

- S: (n) **male** (an animal that produces gametes (spermatozoa) that can fertilize female gametes (ova))
- S: (n) **male**, male person (a person who belongs to the sex that cannot have babies)
- S: (n) **Male** (the capital of Maldives in the center of the islands)

Discourse Representation Structure

- S: (n) fourth dimension, **time** (the fourth coordinate that is required (along with three spatial dimensions) to specify a physical event)

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

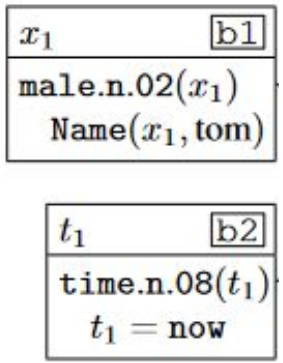
Raw input:

```
Tom isn't afraid of anything.
```

System output of a DRS in a clausal form:

```
b1 REF x1
b1 male "n.02" x1
b1 Name x1 "tom"
b2 REF t1
b2 EQU t1 "now"
b2 time "n.08" t1
```

The same DRS in a box format:



Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

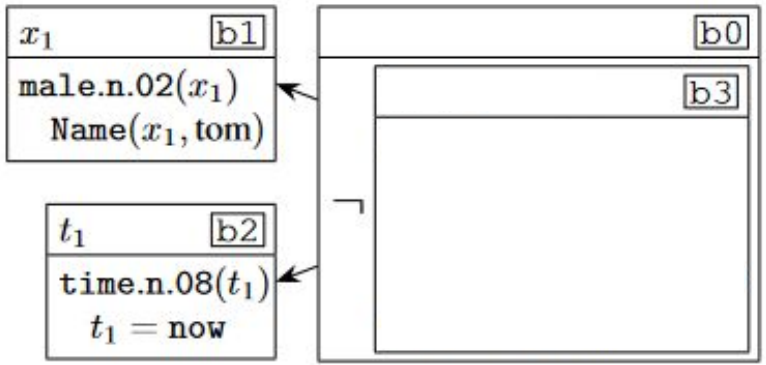
Raw input:

Tom isn't afraid of anything.

System output of a DRS in a clausal form:

```
b1 REF x1
b1 male "n.02" x1
b1 Name x1 "tom"
b2 REF t1
b2 EQU t1 "now"
b2 time "n.08" t1
b0 NOT b3
```

The same DRS in a box format:



Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

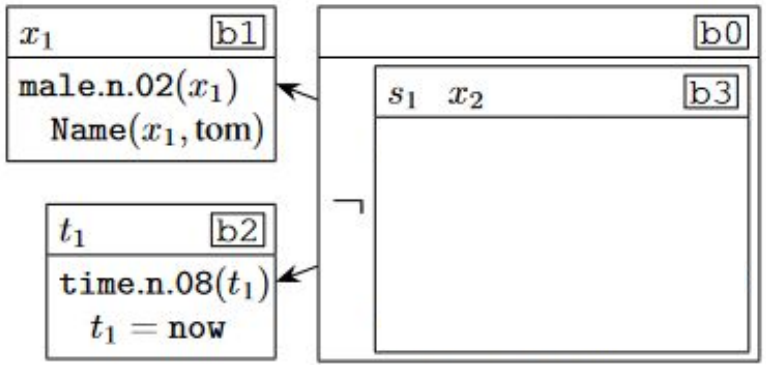
Raw input:

```
Tom isn't afraid of anything.
```

System output of a DRS in a clausal form:

```
b1 REF x1                b3 REF s1
b1 male "n.02" x1
b1 Name x1 "tom"              .
b2 REF t1                     .
b2 EQU t1 "now"               .
b2 time "n.08" t1        b3 REF x2
b0 NOT b3
```

The same DRS in a box format:



Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

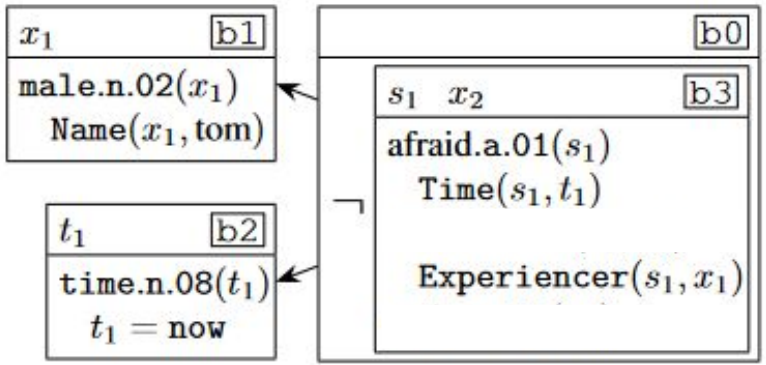
Raw input:

Tom isn't afraid of anything.

System output of a DRS in a clausal form:

```
b1 REF x1                b3 REF s1
b1 male "n.02" x1        b3 Time s1 t1
b1 Name x1 "tom"         b3 Experiencer s1 x1
b2 REF t1                b3 afraid "a.01" s1
b2 EQU t1 "now"
b2 time "n.08" t1        b3 REF x2
b0 NOT b3
```

The same DRS in a box format:



Discourse Representation Structure

- Contain **discourse-referents**, -**conditions** and -relations
- Example:

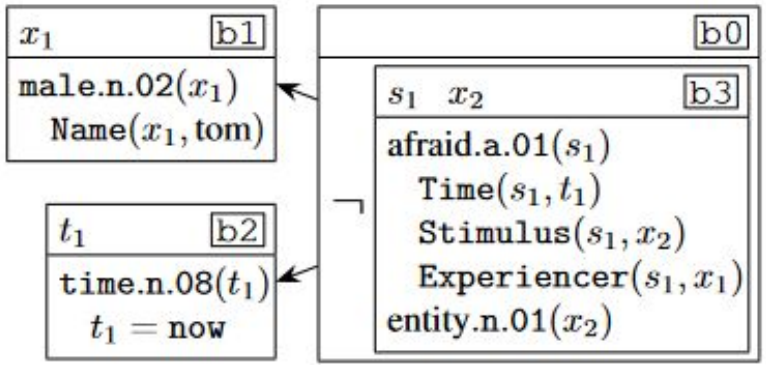
Raw input:

```
Tom isn't afraid of anything.
```

System output of a DRS in a clausal form:

```
b1 REF x1                b3 REF s1
b1 male "n.02" x1        b3 Time s1 t1
b1 Name x1 "tom"         b3 Experiencer s1 x1
b2 REF t1                b3 afraid "a.01" s1
b2 EQU t1 "now"          b3 Stimulus s1 x2
b2 time "n.08" t1        b3 REF x2
b0 NOT b3                b3 entity "n.01" x2
```

The same DRS in a box format:

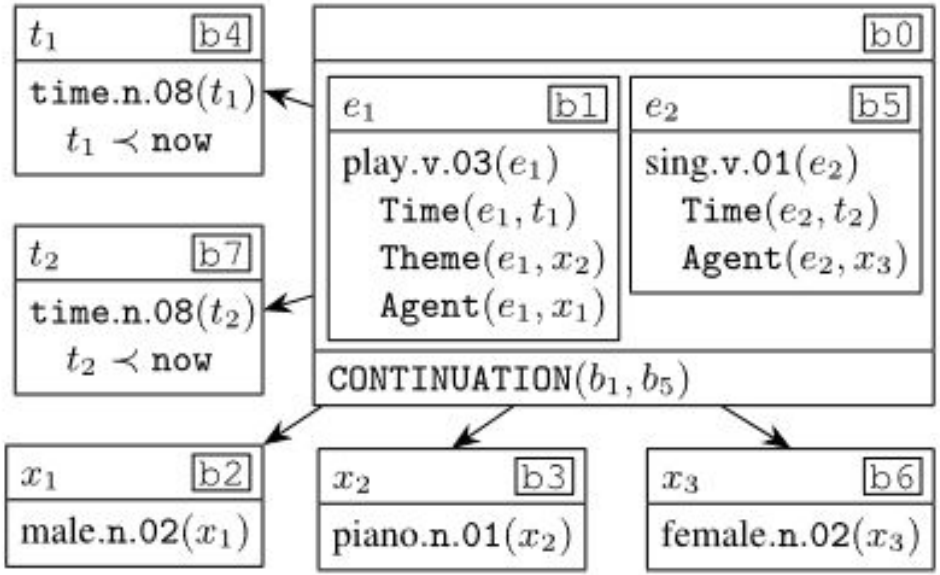


Discourse Representation Structure

- Contain discourse-referents, -conditions and **-relations**
- Example:

Raw input:

`He played the piano and she sang.`



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- Parallel Meaning Bank (PMB)
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Parallel Meaning Bank

- Corpus containing sentences in multiple languages (English, Italian, Dutch and German) and their corresponding (english) DRS
- Created using **Boxer**, a (non-NN) DRS-parser which uses a combination of rule-based and statistical methods
- Boxer output is manually corrected -> Gold standard
- Contains a large number of short, grammatically correct sentences that display a number of linguistic phenomena

Parallel Meaning Bank

- https://pmb.let.rug.nl/explorer/explore.php?part=00&doc_id=0715&type=raw&alignment_language=en
-

Parallel Meaning Bank

		Gold			Silver	Bronze
		Train	Dev	Test	Train	Train
2.2.0	English	4,597	682	650	67,965	120,662
	German	0	727	747	4,235	102,998
	Italian	0	374	400	2,515	61,504
	Dutch	0	370	341	1,051	20,554
3.0.0	English	6,620	885	898	97,598	146,371
	German	1,159	417	403	5,250	121,111
	Italian	0	515	547	2,772	64,305
	Dutch	0	529	483	1,301	21,550

Table 1: Number of documents for the four languages, for the two PMB releases considered.

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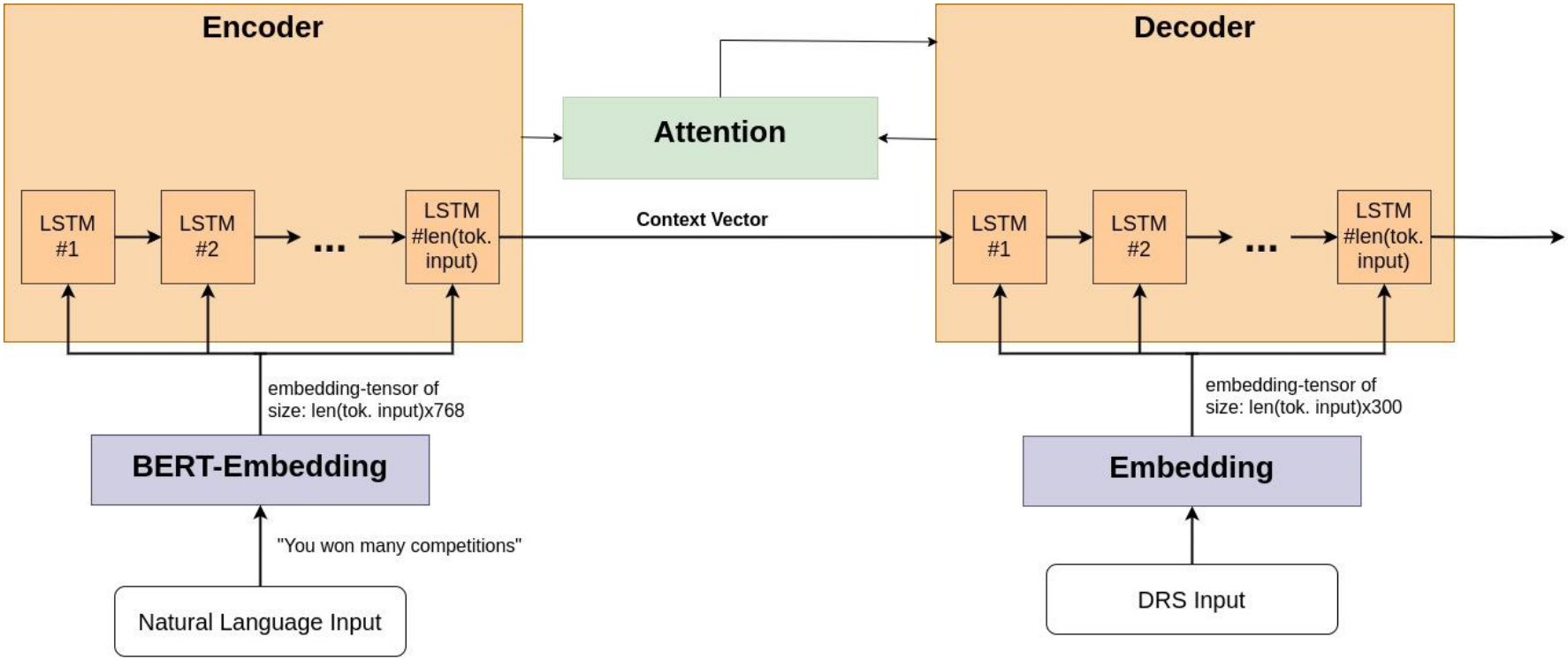
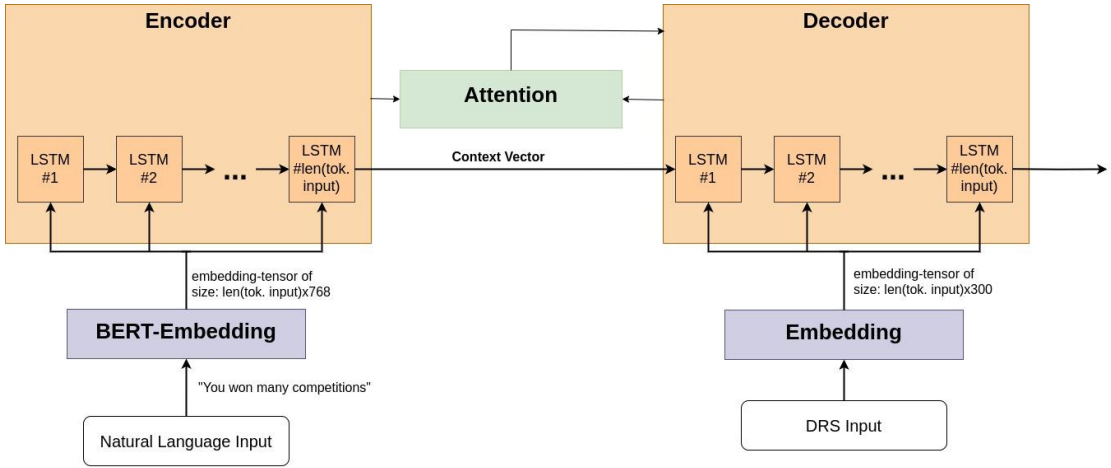
DRS Parsing - Neural architecture



DRS Parsing - Neural architecture

- Encoder/Decoder architecture with (cross-)attention
- Not a transformer!
- (Though BERT technically is a transformer, it is only used for dynamic word embeddings)
- No self attention



DRS Parsing - Neural Architecture

- Issues:
  - Generic encoder-decoder architecture / seq2seq task
  - Nothing to enforce output DRS to be syntactically and semantically valid
  - Variable names are arbitrary but their type (discourse variable or box variable) is relevant

DRS Parsing - Neural Architecture

- Solution:
  - Generated DRS are checked for validity (programmatically using a number of checks). Invalid DRSs are considered completely incorrect for evaluation.
  - For evaluation, a hill-climbing approach that compares a number of variable mappings are used

DRS Parsing - Evaluation

- How to compare output DRS to gold label?
- 2 options:
  - Evaluate the DRSs as logical formulas and check if they are equivalent => produces binary output (equal or not equal), which is problematic for learning
  - Compare all possible clause-pairs of both DRSs => output reflects the degree to which the DRSs, but arbitrary variable names are problematic

DRS Parsing - Evaluation

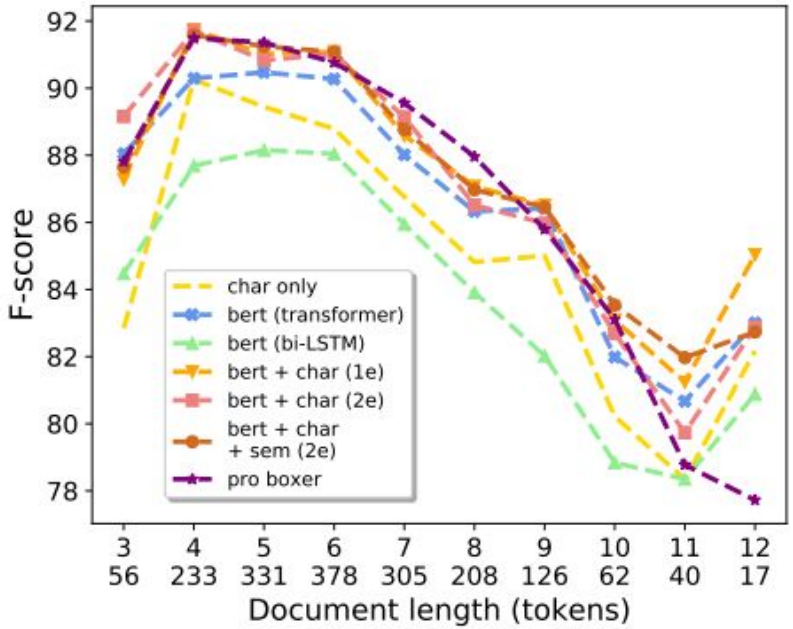
- Counter, a tool for evaluating DRS, compares all clause-pairs of the DRSs under a variable mapping -> Calculate **F1-Score**
- Example sentence: *I am not working for tom*

```
b1 REF t1
b1 EQU t1 "now"
b1 time "n.08" t1
b2 Time e1 t1
b1 NOT b2
b2 REF e1
b2 Agent e1 "speaker"
b2 work "v.02 e1
b2 Co-Agent e1 x1
b3 REF x1
b3 Name x1 "tom"
b3 male "n.02" x1
```

```
b2 REF x1
b2 EQU x1 "now"
b2 time "n.08" x1
b1 Time x2 x1
b2 NOT b1
b1 REF x2
b1 Agent x2 "speaker"
b1 work "v.01 x2
b1 Goal x2 x3
b1 REF x3
b1 Name x3 "tom"
```

DRS Parsing - Performance

	3.0.0	
	Dev	Test
Amateur Boxer	78.2	78.8
van Noord et al. (2018b)	84.3	84.9
van Noord et al. (2019)	86.8	87.7
Liu et al. (2019b)	NA	NA
This work - BERT	87.6	88.5
This work - Best model	**88.4**	**89.3**



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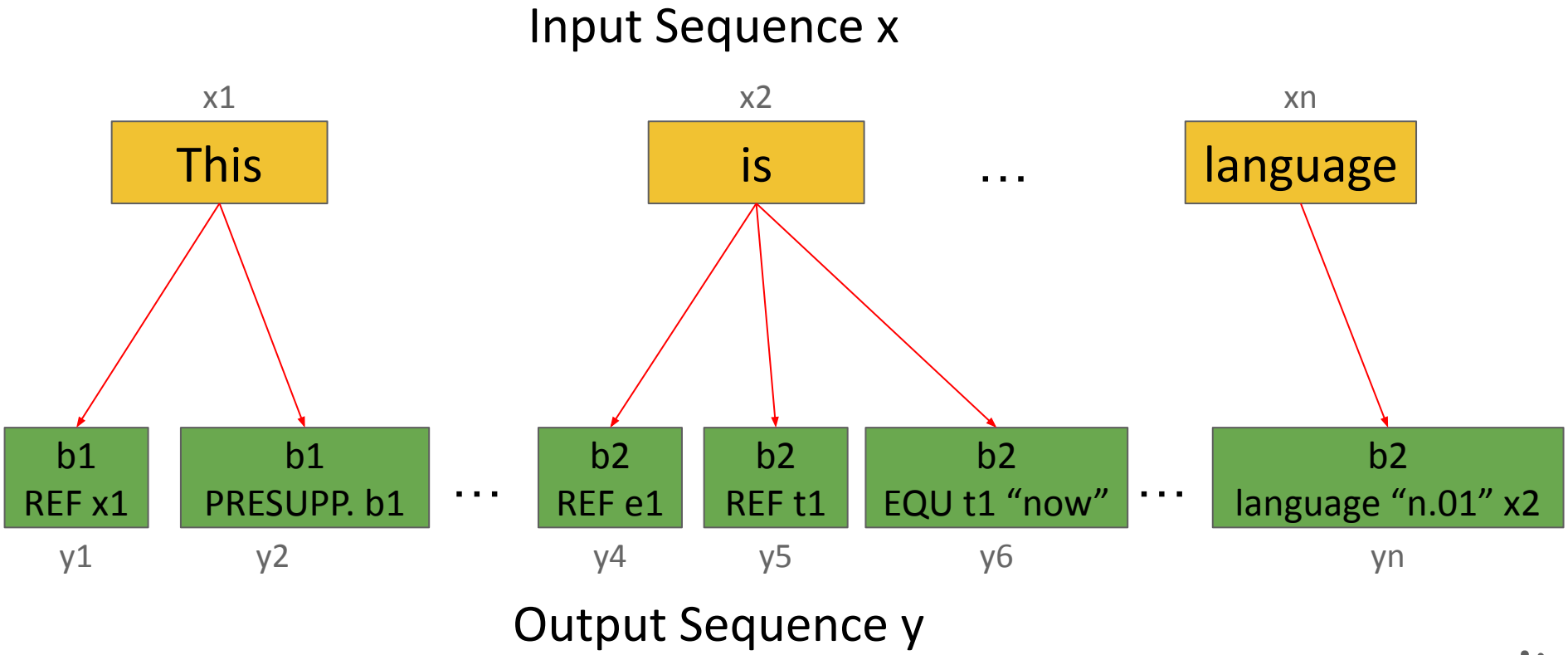
DRS Alignment

- Parallel Meaning Bank also contains information about which token in the input is most relevant for a given clause (and the indices of that token)
- This is generated by Boxer and not manually corrected

```
This is a man-made language .
b1 REF x1                    % This [0...4]
b1 PRESUPPOSITION b2         % This [0...4]
b1 entity "n.01" x1          % This [0...4]
b2 REF e1                    % is [5...7]
b2 REF t1                    % is [5...7]
b2 Co-Theme e1 x2            % is [5...7]
b2 EQU t1 "now"              % is [5...7]
b2 Theme e1 x1               % is [5...7]
b2 Time e1 t1                % is [5...7]
b2 be "v.01" e1              % is [5...7]
b2 time "n.08" t1            % is [5...7]
b2 REF x2                    % a [8...9]
b2 REF s1                    % man-made [10...18]
b2 AttributeOf s1 x2         % man-made [10...18]
b2 man-made "a.01" s1        % man-made [10...18]
b2 language "n.01" x2        % language [19...27]
```

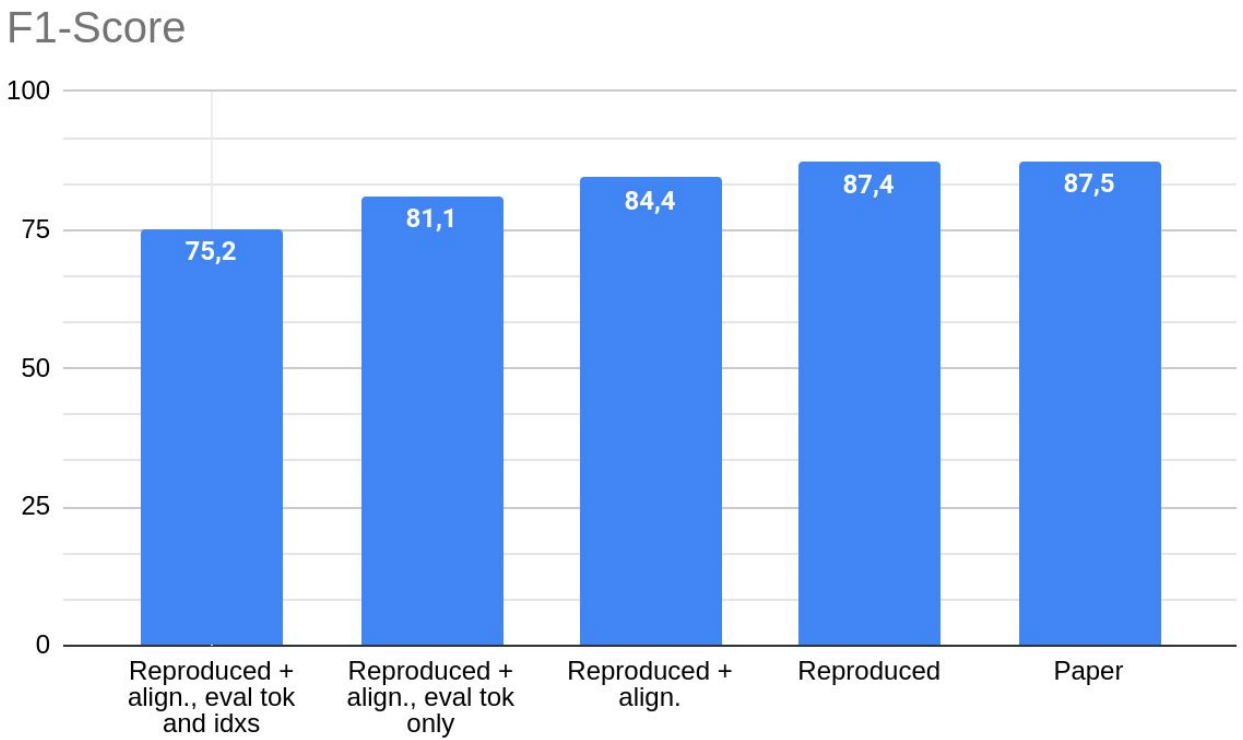
DRS Alignment



DRS Alignment

- Try to predict alignment as part of the output sequence
- No changes to model architecture
- Adapt evaluation to only consider a clause as correctly classified only if the DRS-clause as well as the aligned token and indices all match

DRS Alignment

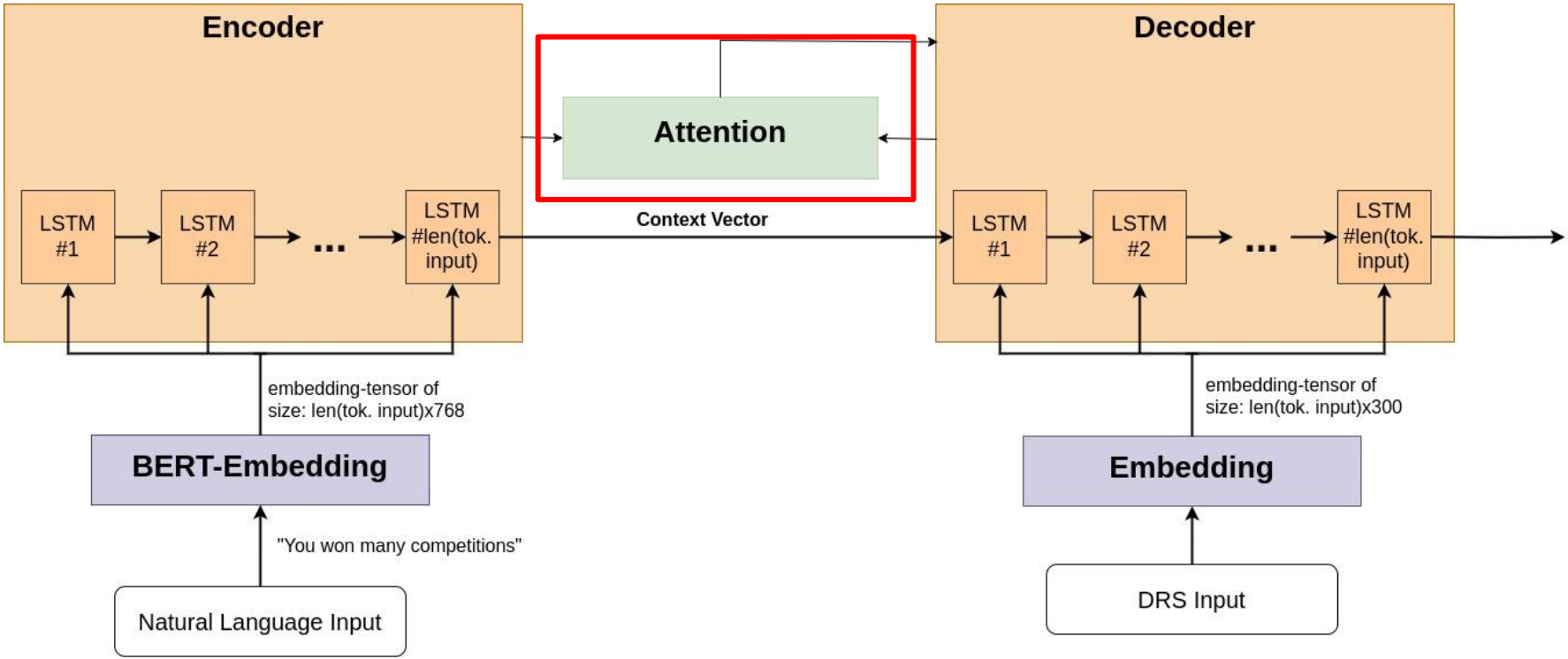


DRS Alignment

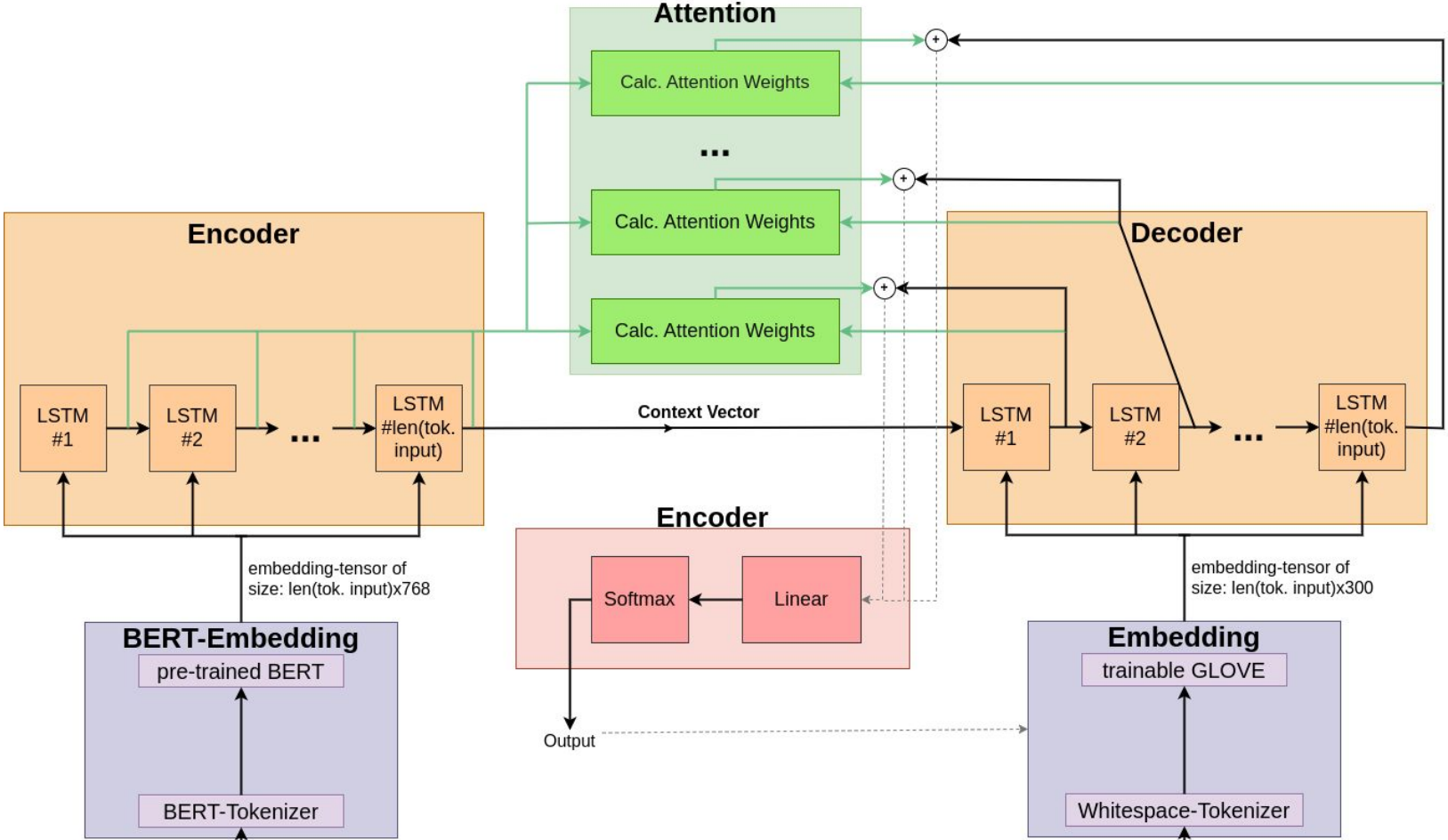
- “Neural Machine Translation by Jointly Learning to Align and Translate”, Bahdanau et al. 2014
- For each hidden-state (LSTM output for a given timestep) of the output sequence, calculate attention weights to each hidden-state of the input sequence
- Attention weight can be viewed as a relevance/similarity score

Look for alignment in the attention weights / force attention mechanism to learn alignment?

DRS Alignment - Attention



DRS Alignment - Attention

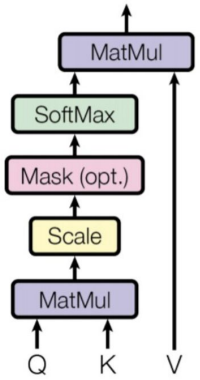


DRS Alignment - Attention

- Many possible ways of calculating attention weights, e.g:
  - Dot-Product Attention[1] $\text{score}(\boldsymbol{h}_t, \bar{\boldsymbol{h}}_s) = \boldsymbol{h}_t^\top \bar{\boldsymbol{h}}_s$
  - General Attention[1] $\text{score}(\boldsymbol{h}_t, \bar{\boldsymbol{h}}_s) = \boldsymbol{h}_t^\top \boldsymbol{W}_a \bar{\boldsymbol{h}}_s$
  - Scaled Dot Product Attention[2]

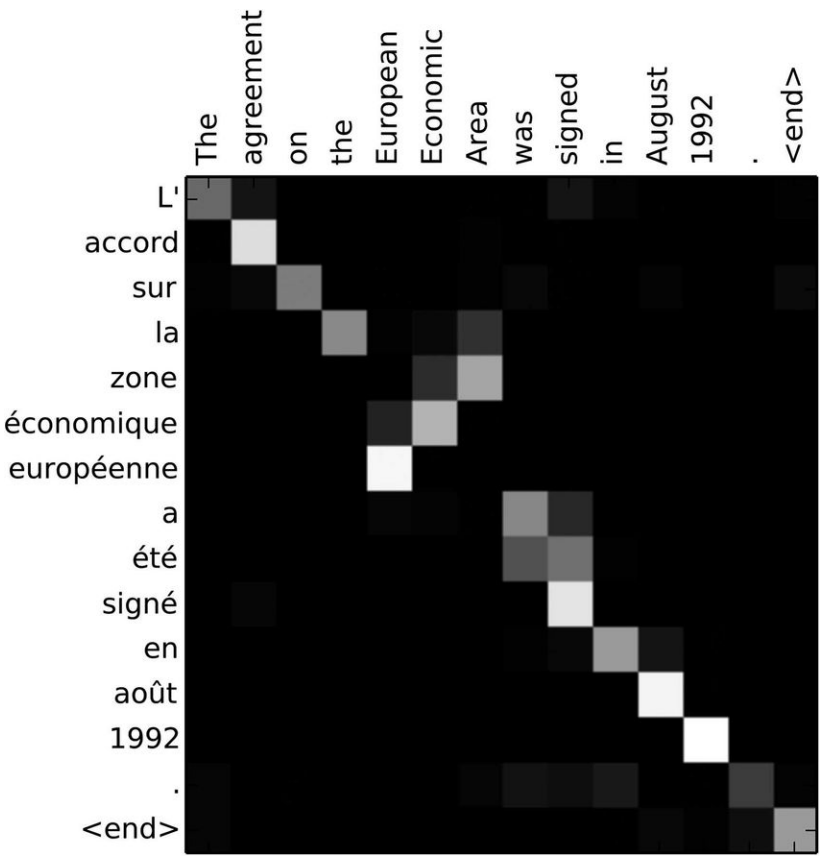
$\boldsymbol{h}_t^\top$ … current target state

$\bar{\boldsymbol{h}}_s$ … all source states



[1] Effective Approaches to Attention-based Neural Machine Translation, Luong et al., 2015
[2] Attention Is All You Need, Vaswani et al., 2017

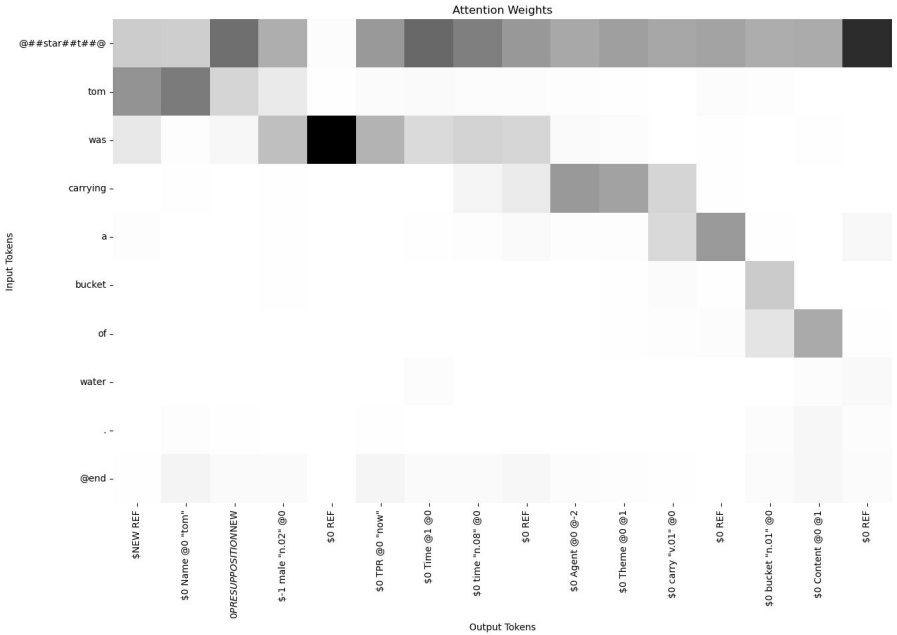
DRS Alignment - Attention



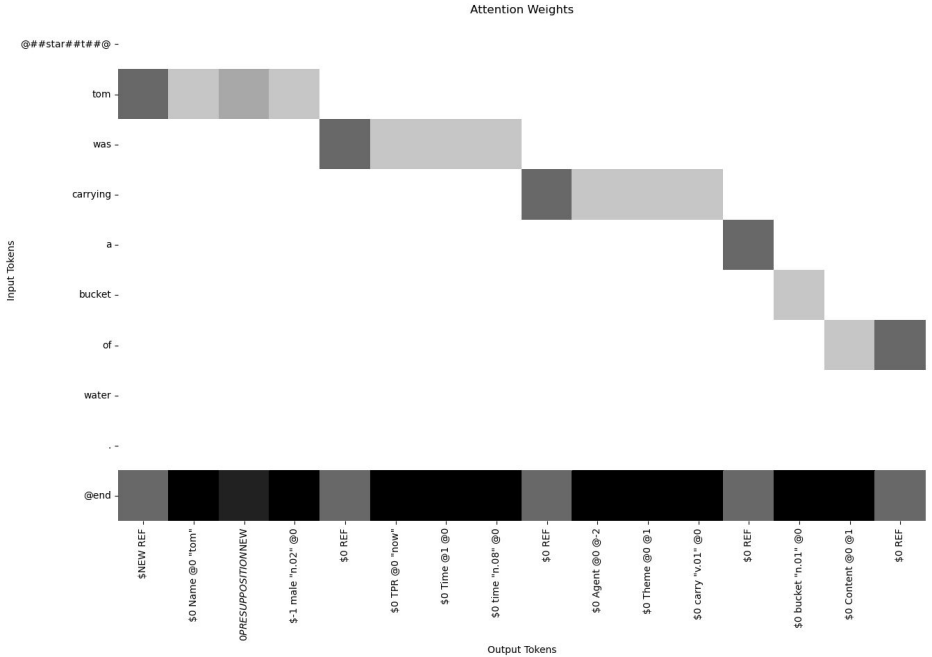
DRS Alignment - Attention

Visualizing attention-weights as heatmap:

Dot-Product Attention



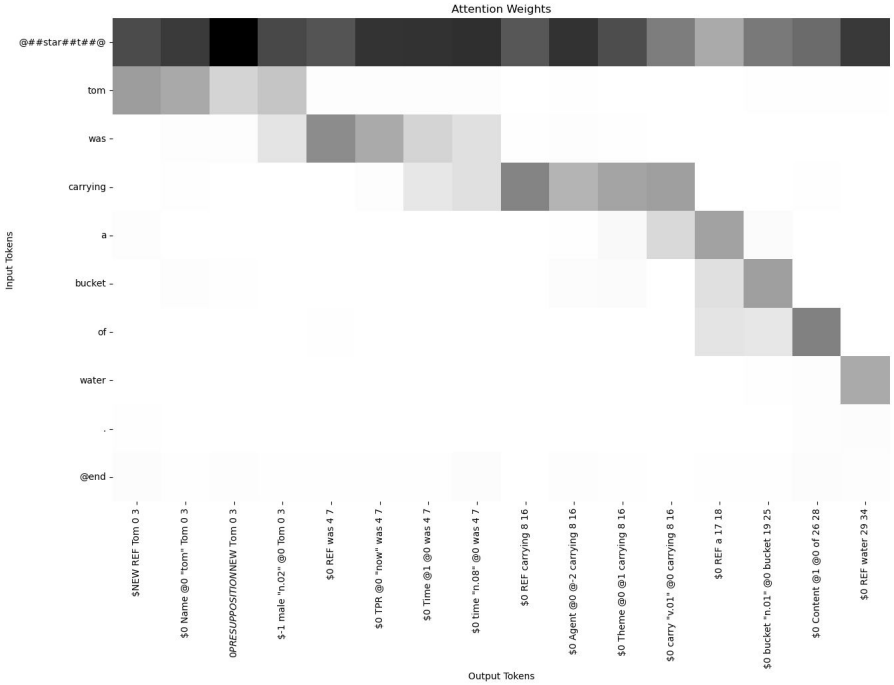
General Attention



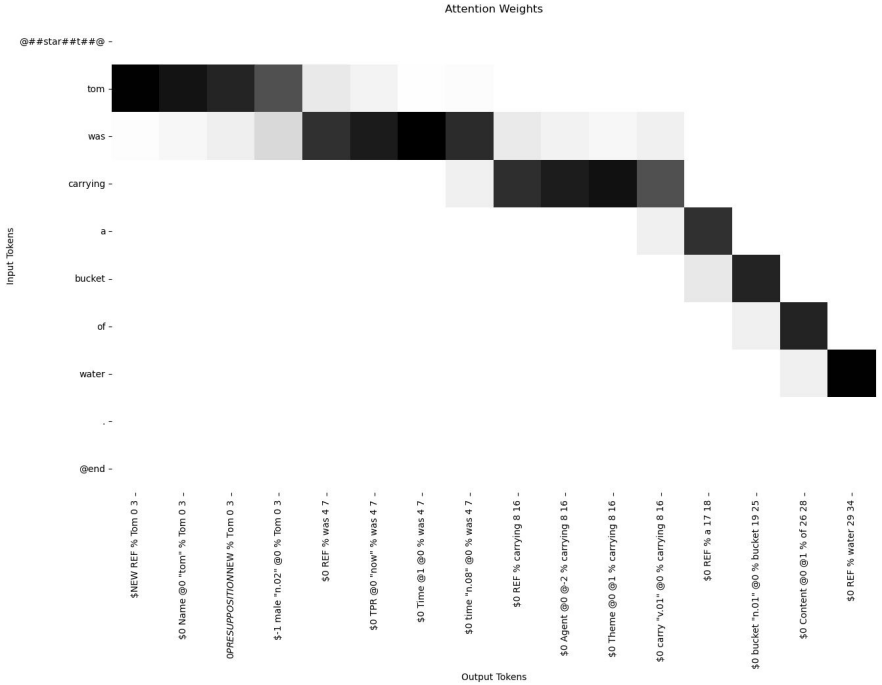
DRS Alignment - Attention

Visualizing attention-weights as heatmap, **when gen. alignment**:

Dot-Product Attention



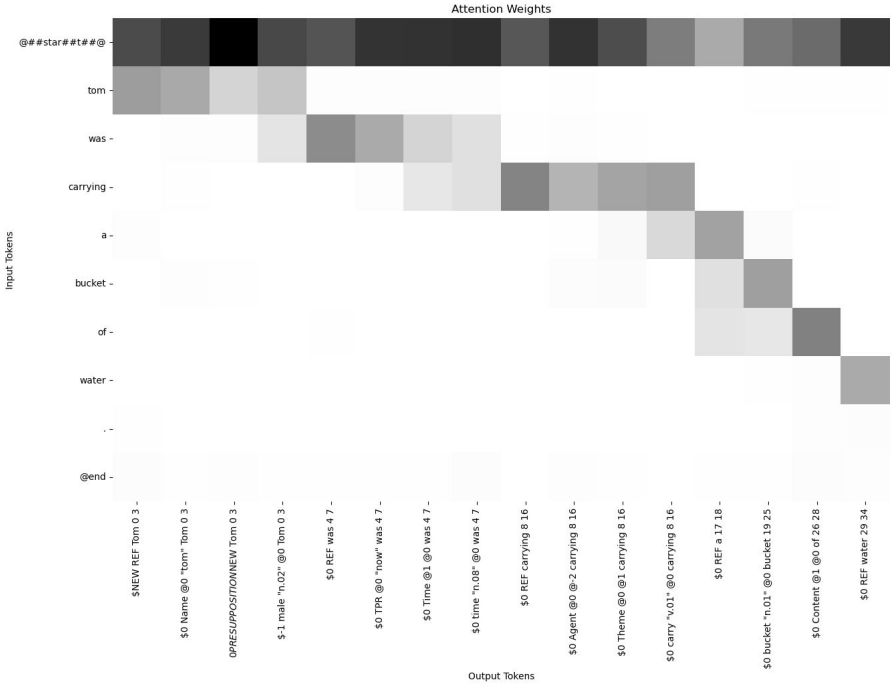
General Attention



DRS Alignment - Attention

Visualizing attention-weights as heatmap, **when gen. alignment**:

Dot-Product Attention



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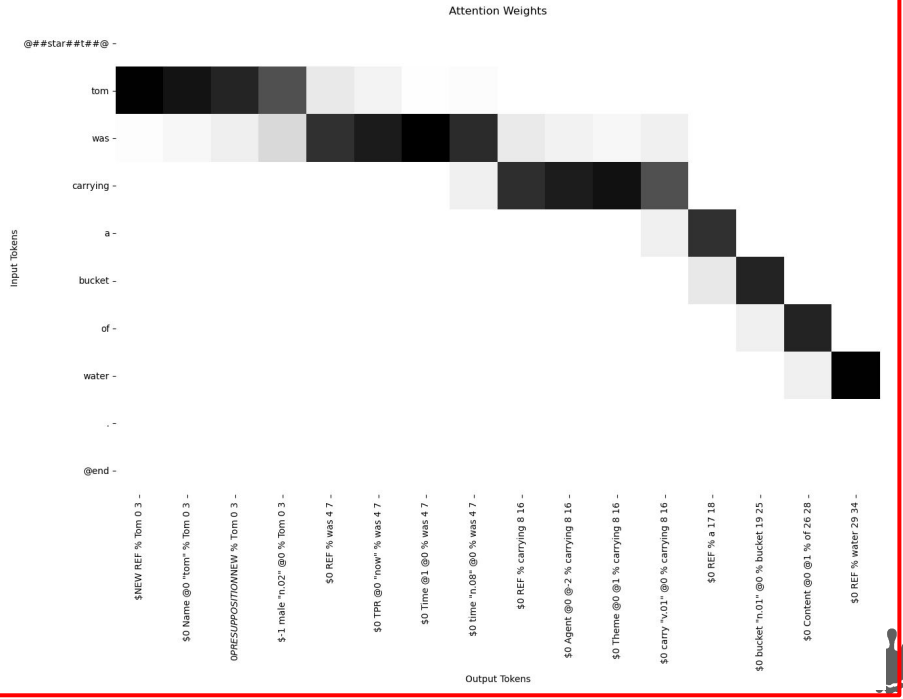

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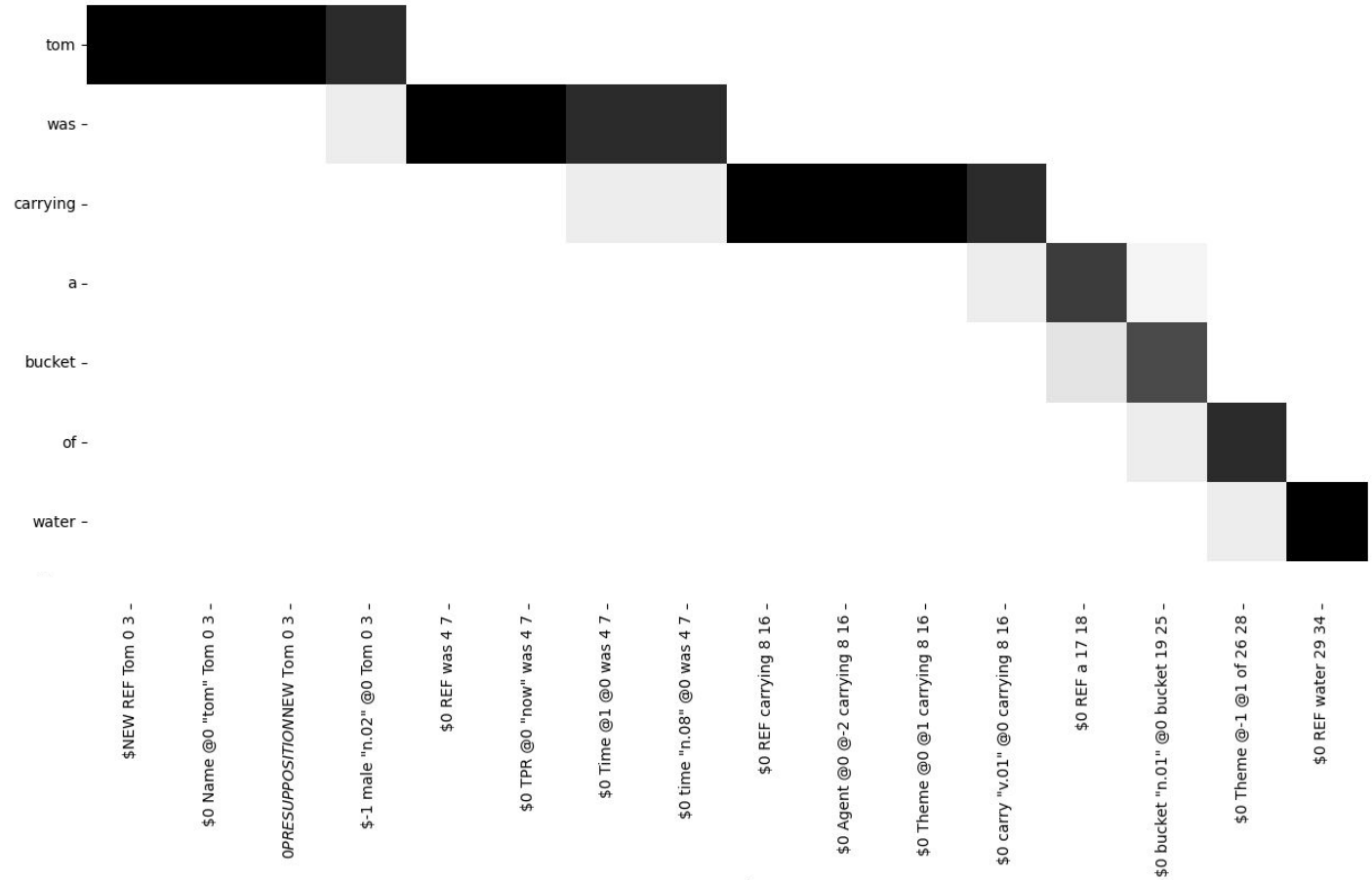

DRS Alignment

- At the moment, alignment seems to be reflected in attention weights
- Is this alignment any better than the (textual) alignment produces as part of the output sequence?
- Can the attention-alignment be learned without producing alignment as part of the output sequence? -> Masking

DRS Alignment - Masking

- Requires attention that uses learned weights (such as General Attention $\text{score}(\boldsymbol{h}_t, \bar{\boldsymbol{h}}_s) = \boldsymbol{h}_t^\top \boldsymbol{W}_a \bar{\boldsymbol{h}}_s$)
- Add this as additional attention to the existing on, in order to not negatively impact performance
- During training, mask out (set to zero) all weights of the learned matrix that do not correspond to an alignment
- Thus force this additional attention to learn the alignment

Sources

Exploring Neural Methods for Parsing Discourse Representation Structures

Character-level Representations Improve DRS-based Semantic Parsing Even in the Age of BERT

Open-Domain Semantic Parsing with Boxer

The Parallel Meaning Bank: Towards a Multilingual Corpus of Translations Annotated with Compositional Meaning Representations

Evaluating Scoped Meaning Representations

Effective Approaches to Attention-based Neural Machine Translation, Luong et al., 2015