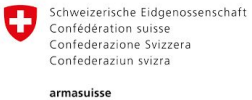
Assessing the Importance of Frequency versus Compositionality for Subword-based Tokenization in NMT

EAMT 2023
Research: Technical



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Introduction

Original:	Completely preposterous suggestions
BPE:	_Comple | t | ely | _prep | ost | erous | _suggest | ions
Unigram LM:	_Complete | ly | _pre | post | er | ous | _suggestion | s

Main advantages of subwords:

- **frequency**: frequent tokens are encoded with less symbols
- **compositionality**: meaning of a word is determined by the meanings of its parts
- unknown words: no out-of-vocabulary words

Which one is more important ?

Huffman Coding

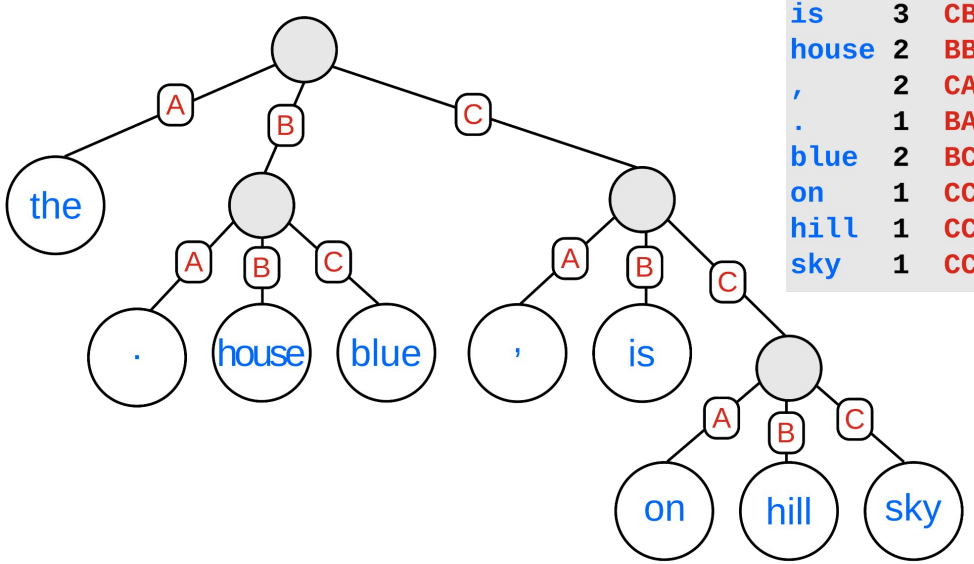
Separate **frequency** from **compositionality**.

Data: Word frequencies F: $\{(w_i, f_i), \ldots\}$,
Priority queue H: $\{(node_i, score_i), \ldots\}$ sorted by increasing scores,
Number of symbols: n
Result: Huffman tree
foreach $(w_i, f_i) \in F$ **do**
  Create $node_i$ with key w_i and score f_i;
  Add $node_i$ to H;
end
while *length*$(H) > 1$ **do**
  $L \leftarrow$ empty list of nodes;
  $S \leftarrow 0$;
  for $i \leftarrow 0$ **to** n **do**
    if $H = \emptyset$ **then**
      break;
    else
      Pop $(node_i, score_i)$ from H;
      Append $(node_i, score_i)$ to L;
      Add $score_i$ to S;
    end
  end
  Create new node N = ('None', S);
  foreach $node \in L$ **do**
    Add $node$ to N's children;
  end
  Push N to H;
end

the house is on the hill, the house is blue, the sky is blue.

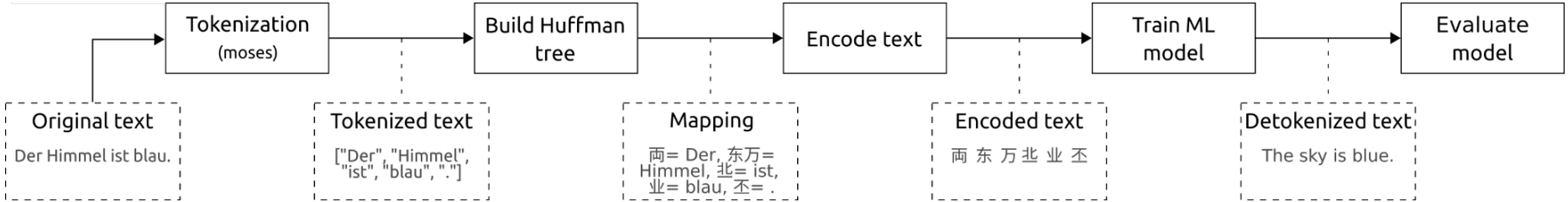
n = 3

type	nb	code
the	4	A
is	3	CB
house	2	BB
,	2	CA
.	1	BA
blue	2	BC
on	1	CCA
hill	1	CCB
sky	1	CCC



A BB CB CCA A CCB CA A BB CB BC CA A CCC CB BC BA

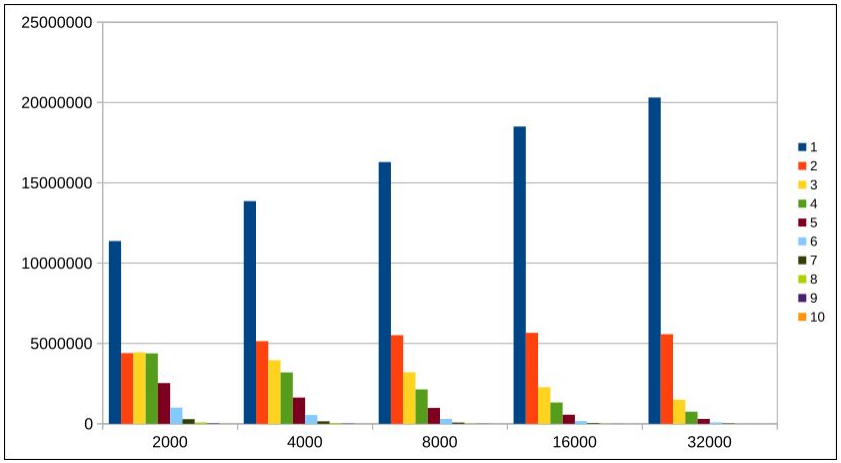
Experiments

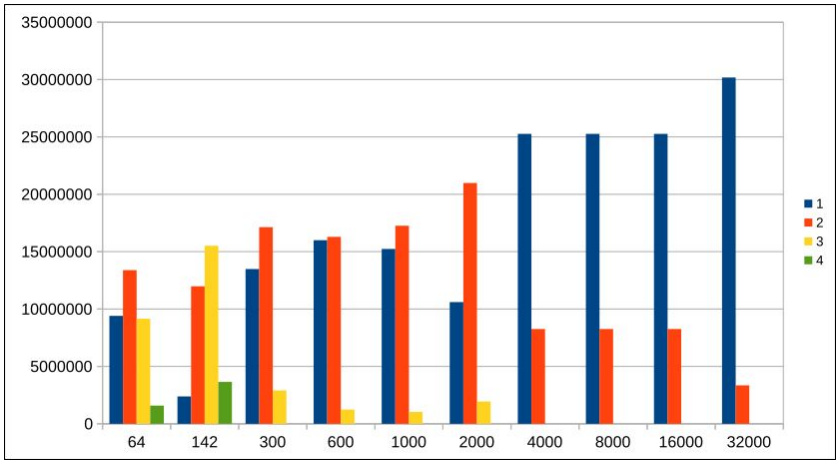


Corpora
News Commentary
Europarl
Common Crawl
JW300
Newstest

	Lines	
Languages	**Train**	**Test**
CS - DE	1'780'068	3444
EN - DE	4'547'445	4615
EN - FR	5'245'392	4448

Results: Segmentation





Histograms for the number of tokens using BPE (left) and Huffman coding (right)

Results: Translation quality

Lang. pair	Nb. of symbols	BLEU			ChrF			COMET		
		Huffman	BPE	%	Huffman	BPE	%	Huffman	BPE	%
CS-DE	2k	20.3	24.4	83.2	46.6	52.6	88.6	0.758	0.829	91.4
	4k	20.9	24.8	84.3	47.2	53.2	88.7	0.762	0.833	91.4
	8k	21.6	25.1	86.1	48.4	53.4	90.6	0.780	0.834	93.6
	16k	22.3	24.8	89.9	49.3	53.3	92.5	0.791	0.830	95.2
	32k	23.1	26.4	87.5	50.2	54.5	92.1	0.804	0.837	96.0
EN-DE	8k	19.5	22.4	87.1	46.4	49.7	93.4	0.709	0.769	92.2
	16k	20.3	22.2	91.4	46.6	49.3	94.5	0.718	0.768	93.5
	32k	19.8	22.5	88.0	46.9	49.5	94.7	0.712	0.772	92.2
EN-FR	8k	27.1	31.2	86.9	51.1	55.3	92.4	0.728	0.783	93.0
	16k	27.6	30.9	89.3	51.8	55	94.2	0.739	0.781	94.6
	32k	27.9	30.9	90.3	52.2	54.9	95.1	0.746	0.784	95.1

Frequency contributes to **90.2%** of BLEU, **93.7%** of ChrF and **94.4%** of COMET scores*.

Conclusion

- Alternative tokenization algorithm based on Huffman coding
- Study the importance frequency versus compositionality for subwords
- Translation quality does not deteriorate with Huffman
- Most of the gains brought by BPE can be attributed to **frequency** rather than **compositionality**

Thank you!