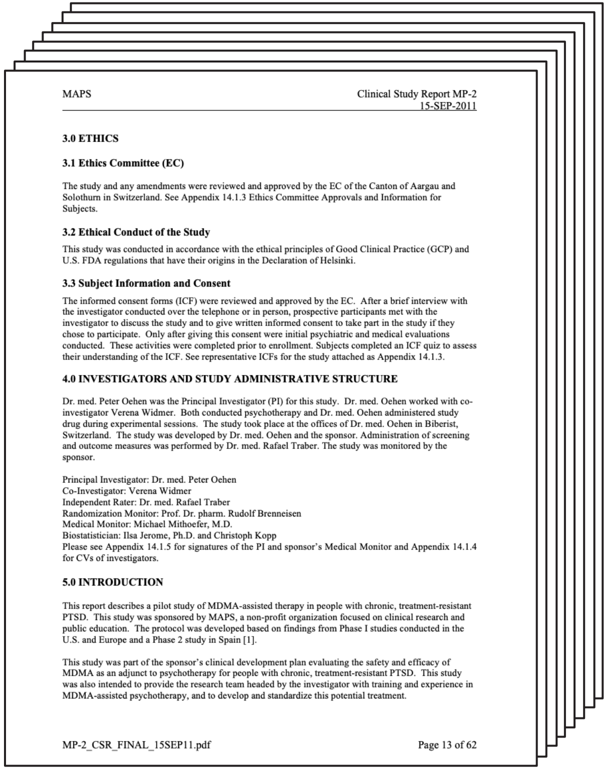
NLP SUMMIT
HEALTHCARE

# Long Document Abstractive Summarization with Large Language Models

**Natalia Vassilieva**
Director of Product
Cerebras Systems

# Summarization: long texts to short summaries



MAPS

Clinical Study Report MP-2
15-SEP-2011

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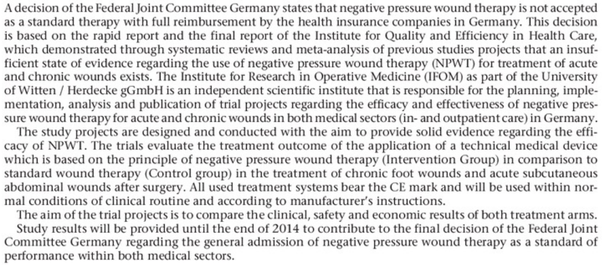

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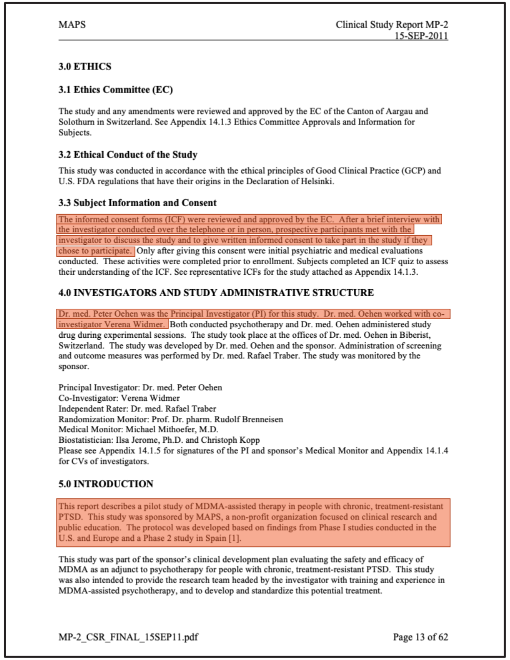
# Summarization: Extractive



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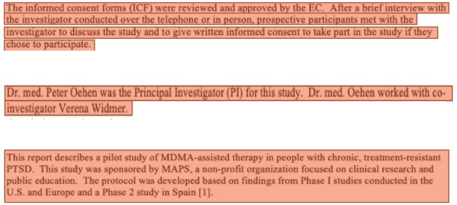

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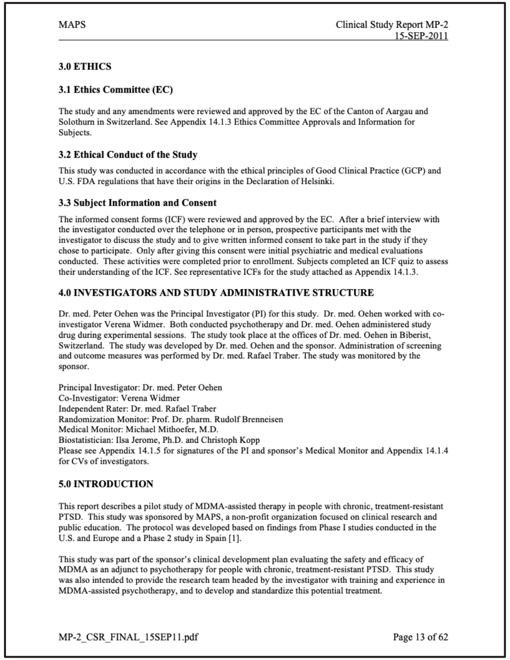

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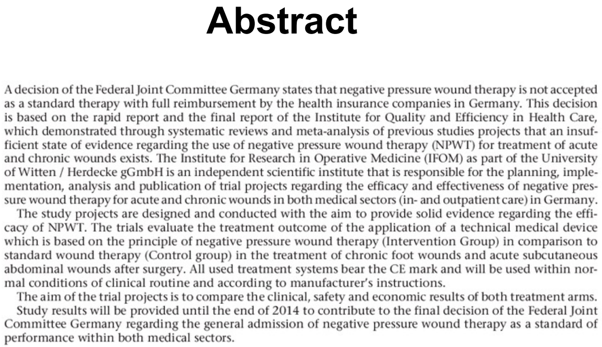

## Abstract

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# Extractive Summarization with Transformers

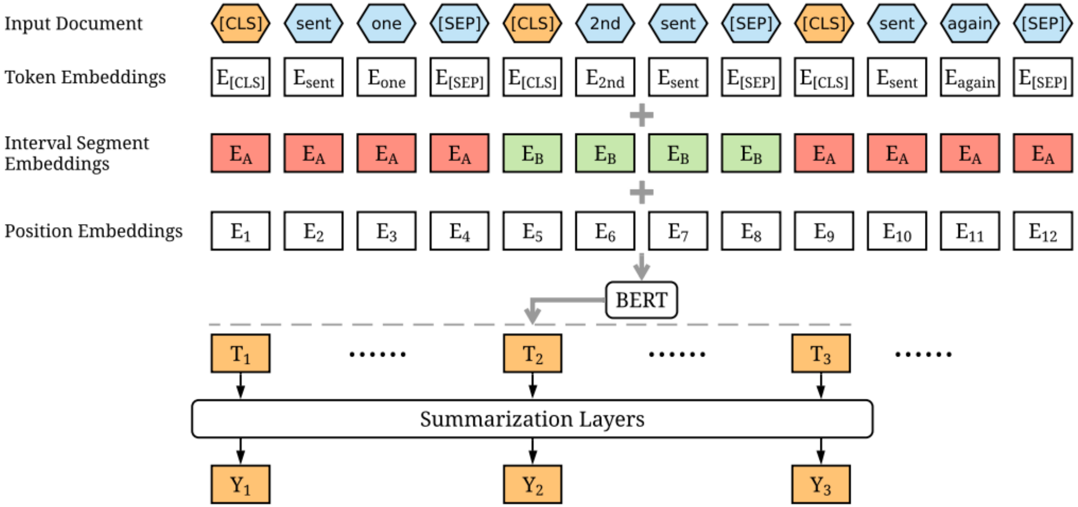

Input Document
[CLS]
sent
one
[SEP]
[CLS]
2nd
sent
[SEP]
[CLS]
sent
again
[SEP]
Token Embeddings
$E_{[CLS]}$ $E_{sent}$ $E_{one}$ $E_{[SEP]}$ $E_{[CLS]}$ $E_{2nd}$ $E_{sent}$ $E_{[SEP]}$ $E_{[CLS]}$ $E_{sent}$ $E_{again}$ $E_{[SEP]}$
Interval Segment Embeddings
$E_A$ $E_A$ $E_A$ $E_A$ $E_B$ $E_B$ $E_B$ $E_B$ $E_A$ $E_A$ $E_A$ $E_A$
Position Embeddings
$E_1$ $E_2$ $E_3$ $E_4$ $E_5$ $E_6$ $E_7$ $E_8$ $E_9$ $E_{10}$ $E_{11}$ $E_{12}$
BERT
$T_1$ $T_2$ $T_3$
Summarization Layers
$Y_1$ $Y_2$ $Y_3$

Figure 1: The overview architecture of the BERTSUM model.

https://arxiv.org/abs/1903.10318

# Abstractive Summarization with Transformers

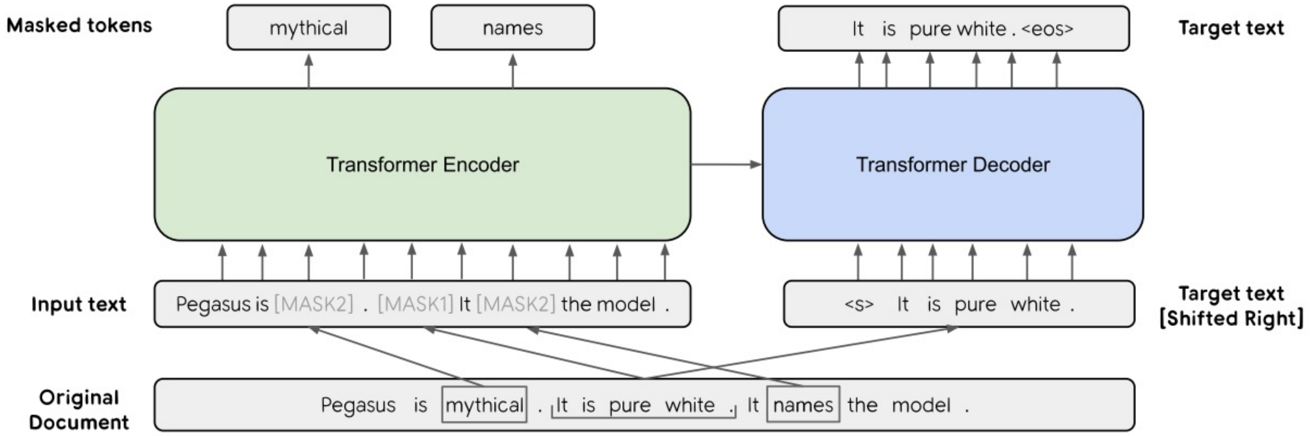


Figure 1: The base architecture of PEGASUS is a standard Transformer encoder-decoder. Both GSG and MLM are applied simultaneously to this example as pre-training objectives. Originally there are three sentences. One sentence is masked with `[MASK1]` and used as target generation text (GSG). The other two sentences remain in the input, but some tokens are randomly masked by `[MASK2]` (MLM).

https://arxiv.org/abs/1912.08777

# Input Length in Literature: Summarization Models

- BERTSUM (https://arxiv.org/abs/1903.10318 )
  - Fine-tuned BERT, max input length = **512 tokens**
- PEGASUS (https://arxiv.org/abs/1912.08777)
  - Max input length in pre-training = **512 tokens**, in fine-tuning = **1024 tokens**
  - **"…**average input length in BIGPATENT, arXiv, PubMed and Multi-News are well beyond 1024 tokens, further scaling up input length or applying a two-stage approach may improve performance…this is outside the scope of this work"
- LongT5 (https://arxiv.org/abs/2112.07916)
  - Max input length in pre-training = **4096 tokens**, in fine-tuning for summarization = **16384 + 512 tokens**
  - Rely on **local sparse attention** for fine-tuning
- How Far are We from Robust Long Abstractive Summarization? (https://arxiv.org/abs/2210.16732)
  - Limitations of existing approaches
    - "…current pre-trained Transformers have an input length limit that restricts them to be directly adapted to long document summarization…"
    - "…1,024 token input limit would lead to a significant loss in the information required to generate a high-quality summary."
  - Suggested approaches to increase input length up to **8K tokens**:
    - **Sparse attention**: "sparse attention models achieve competitive but lower ROUGE than state-of-the-art models"
    - **Reduce-then-summarize**: competitive, but burdensome; quality decreases as the input length is increased

# Some Summarization Datasets

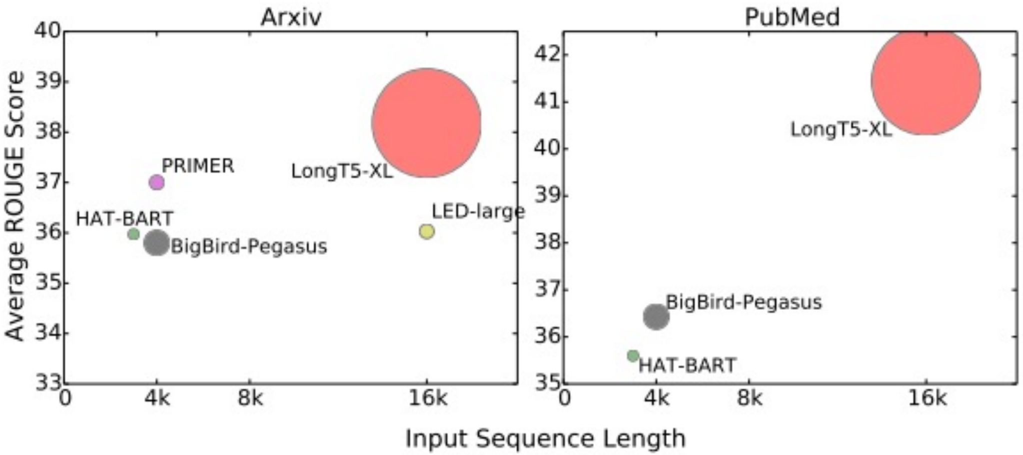
| Dataset | # Docs | Avg # Source Tokens | Avg # Summary Tokens | Avg # Tokens per Sample |
|---|---|---|---|---|
| arXiv/PubMed | 346,187 | 5,179.22 | 257.44 | 5,436.66 |
| arXiv | 215,913 | 10,720.18* | | |
| BigPatent | 1,341,306 | 3,629.04 | 116.66 | 3,745.70 |
| CNN/Daily Mail | 311,971 | 803.67 | 59.72 | 863.39 |
| Newsroom | 1,212,739 | 799.32 | 31.18 | 830.50 |
| BookSUM Chapter | 12,630 | 5,101.88 | 505.42 | 5,607.30 |
| BookSUM Full | 405 | 112,885.15 | 1167.20 | 114,052.35 |

* using a SentencePiece Model

https://arxiv.org/abs/2105.08209
https://arxiv.org/abs/2112.07916

# What about model size?

# Larger is better, right?



https://arxiv.org/abs/2112.07916

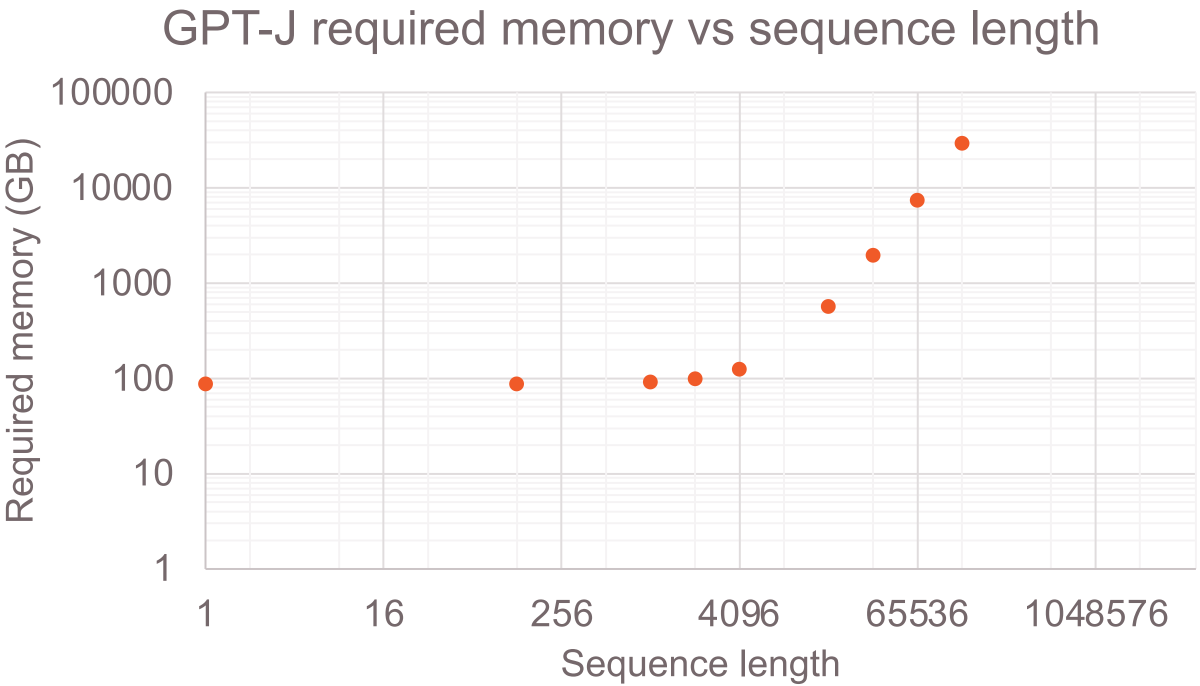
# Existing Pre-trained LLMs… and Their Contexts

| Model name | Model size (# params, B) | Dataset size (# tokens, B) | Hardware | Total # chips | Time to train | Context length |
|---|---|---|---|---|---|---|
| GPT-J | 6 | 402 | TPU v3 | 256 | | **2048** |
| GPT-NeoX | 20 | 472 | A100 | 96 | 76 days | **2048** |
| LLaMA | 65 | 1,400 | A100 | 2048 | 21 days | **2048** |
| Chinchilla | 70 | 1,400 | *TPU v3** | *4096** | | **2048** |
| HyperCLOVA | 82 | 315 | A100 | 1024 | 28 days | **2048** |
| OPT | 175 | 300 | A100 | 992 | 25 days | **2048** |
| BLOOM | 175 | 350 | A100 | 384 | 105 days | **2048** |
| Gopher | 280 | 300 | TPU v3 | 4096 | 38 days | **2048** |
| MT-NLG | 530 | 270 | A100 | 2240 | *47 days*** | **2048** |
| PaLM | 540 | 780 | TPU v4 | 6144 | 34 days** | **2048** |

* "Chinchilla uses the same … training setup as Gopher", J. Hoffmann et al., "Training Compute-Optimal Large Language Models"

** Estimated based on published utilization numbers, A. Chowdhery et al., "PaLM: Scaling Language Modeling with Pathways"

# Why context of 2048 tokens?



- 16 bytes per parameter
- 2 bytes per activation

What if we can train with longer context with dense attention?

What if we can leverage existing trained foundational LLMs?

# Leveraging Cerebras Wafer-Scale Cluster

## Foundational components:

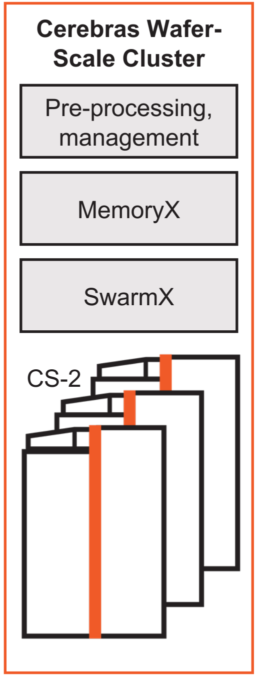
- Wafer-scale engine (WSE) **chip**
  - The world’s fastest AI processor
- CS-2 physical **system**
  - The world’s first wafer-scale system for AI
- **Wafer Scale Cluster**
  - Linear scaling with multiple systems
- Cerebras **software** (CSoft) platform

# Cerebras Wafer-Scale Cluster

**A purpose-built solution for scaling high performance AI compute**

**Components of the solution:**

- Cerebras CS-2 accelerator with Weight Streaming execution
- Input pre-processing and management nodes
- MemoryX parameter storage and streaming
- SwarmX scalable interconnect fabric



**Co-designed with Weight Streaming execution for large-scale neural networks**

# Differentiating Capabilities

- Support **largest models on single CS-2s** (even >>100B parameters)
- **Linear scaling** to multiple CS-2s **with only data parallel** distribution
- Simple single-node programmability, **no model parallel complexity**
- **Easy training with large inputs**: larger contexts for sequence models, high-resolution images and volumes
- Native **acceleration with weight sparsity** (structured and unstructured)

# Leveraging Existing Foundational LLMs

- Take publicly available **GPT-J** model
    - 6B parameters
    - Trained with context length of 2048 tokens
    - Trained on total of 402B tokens

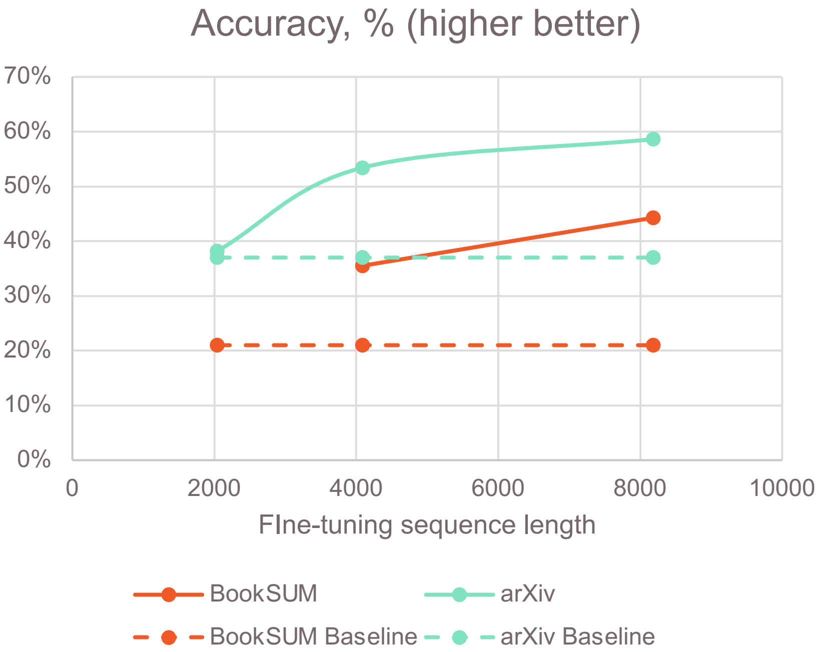
- Continuously train GPT-J on summarization datasets with longer contexts
    - Explore contexts of 4K, 8K tokens

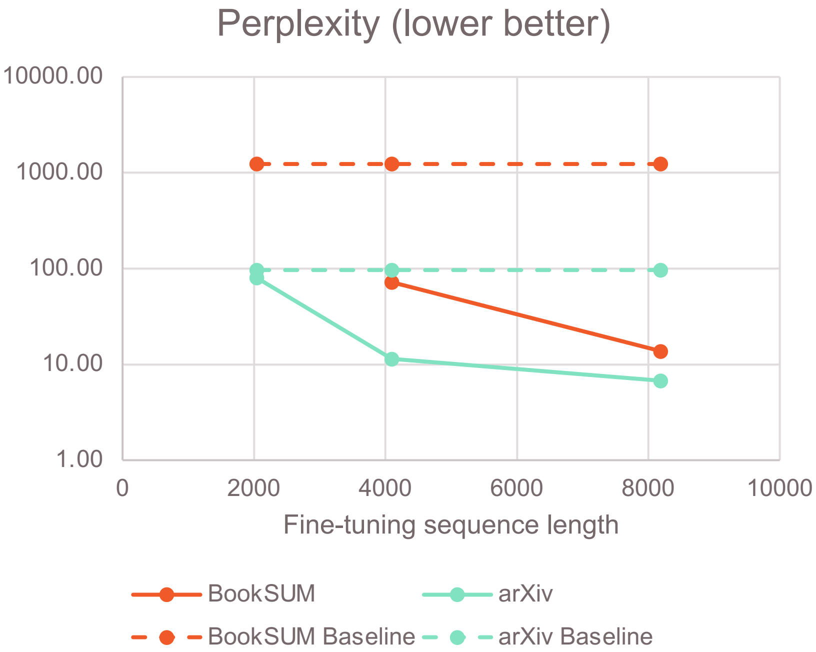
# Datasets and pre-processing

- Two datasets
  - BookSUM Chapter
    - Sample: [chapter] + [special token - ID 50257] + [summary]
  - arXiv
    - Sample: [article_text] + [special token - ID 50257] + [abstract_text]
- Both training and eval datasets are partitioned into parts based on the sample length
  - (200, 2K]
  - (2K, 4K]
  - (4K, 8K]

| | BookSUM, # tokens | ArXiv, # tokens |
|---|---:|---:|
| (200, 2K] | 13,568,080 | 79,339,520 |
| (2K, 4K] | 43,418,424 | 98,304,000 |
| (4K, 8K] | 50,107,740 | 201,326,592 |

# Results, all eval samples

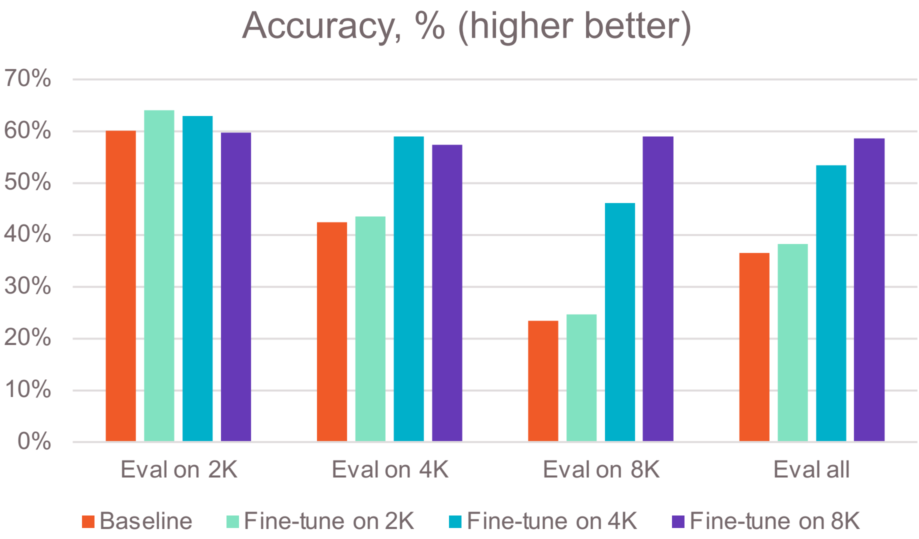


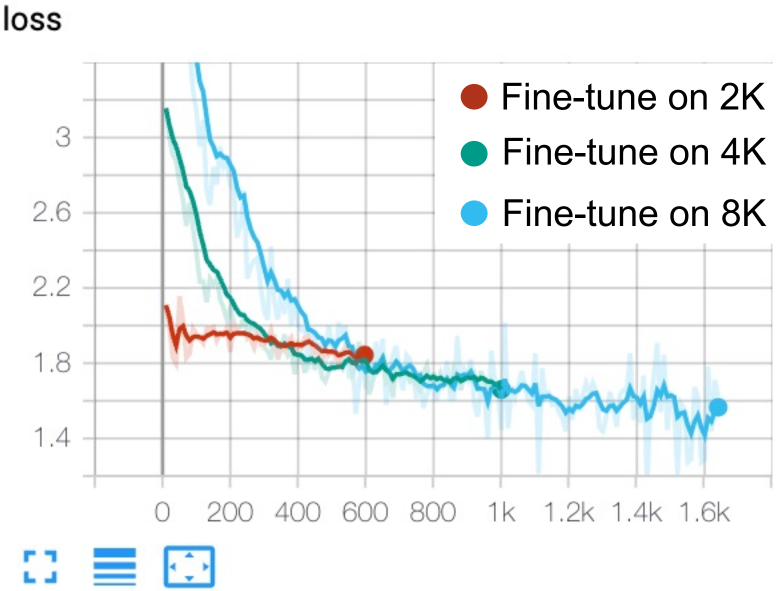


Baseline: GPT-J model “out-of-the-box”

**Longer context in fine-tuning => better results**

# Bucketed results, arXiv





- Within each length bucket, the best result is with a model fine-tuned on the samples of the same length
- Longer fine-tuning might be needed

# Conclusion and next steps

- Summarization task requires models capable to work with long contexts (>>2K tokens)
- Existing foundational LLMs support shorter contexts than required
- Promising initial results with fine-tuning with longer contexts
- This work became possible due to the capabilities of the Cerebras Wafer-Scale Cluster
  - Large models on single device, no complicated model parallel training
  - Support for long sequences out-of-the-box

- **Next steps:**
  - Explore foundational models with AliBi positional encodings: supposed to extrapolate to longer contexts better
  - Longer fine-tuning (fine-tune for > 1 epoch, collect/find larger summarization datasets)
  - Evaluation with summarization-specific metrics (ROUGE)

# Thank you

https://www.cerebras.net/

# NLP SUMMIT HEALTHCARE

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Presented by

John Snow LABS