Big Bird: Transformers for Longer Sequences

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Motivation

What is old:

- Transformers are good
- self-attention is crucial for transformers
- self-attention = $O(n^2)$ memory + comp. requirements
- typical max sentence length = 512 tokens

What is new:

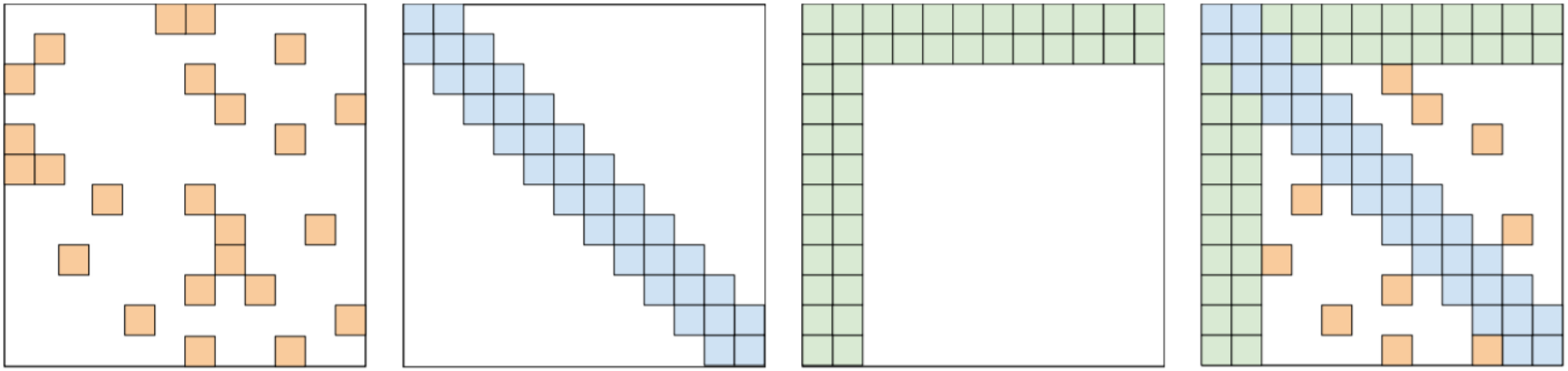
- is the $O(n^2)$ necessary?
- BigBird claims to replace self-attention with BigBird attention that is $O(n)$

Previous works

A lot of papers reducing the complexity of self-attention, notably:

- Synthesizer: synthesize the result of the full-attention
- Linformer: approximate full-attention by 2 low-rank matrices
- Longformer: Window + Global attention, 2 months earlier
- $\Longrightarrow$ BigBird = Longformer + Random attention

BigBird Attention



(a) Random attention (b) Window attention (c) Global Attention (d) BIGBIRD

Figure: Building blocks of the attention mechanism used in BigBird. White color indicates absence of attention. (a) random attention with $r = 2$, (b) sliding window attention with $w = 3$ (c) global attention with $g = 2$. (d) the combined BigBird model.

- **Random**: each token attends to r random other tokens
- **Window**: all tokens attend to their surrounding tokens = similar to Convolution
- **Global**: certain tokens (e.g. CLS) receive from all and send to all

BigBird attention

- r, w, g is fixed = constant = hyperparameter
- therefore it is $O(n)$
- capable of simulating full self-attention
- the random mask is different for each sentence but fixed through the layers

Attention as graph

- Random attention = graph where each edge is independently chosen with a fixed probability.
- In such a random graph with just $\Theta(n)$ edges, the shortest path between any two nodes is logarithmic in the number of nodes.
- $\Longrightarrow$ quick mixing of information between nodes in following layers
- however in worst case it takes n layers to simulate 1 full self-attention layer
- $\Longrightarrow$ in worst case we would have to have $n \times$ more layers $= O(n^2)$ again
- $\Longrightarrow$ not truly $O(n)$ attention replacement

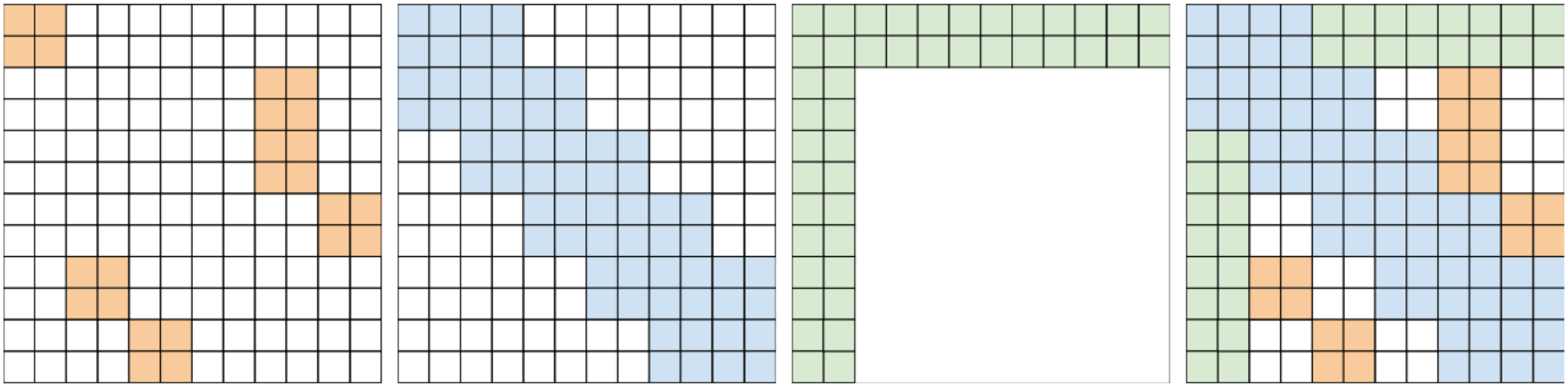
Global attention is necessary

Model	MLM	SQuAD	MNLI
BERT-base	64.2	88.5	83.4
Random (R)	60.1	83.0	80.2
Window (W)	58.3	76.4	73.1
R + W	62.7	85.1	80.5
Global + R + W	64.4	87.2	82.9

Table 1: Building block comparison @512

Figure: Random blocks and local window were insufficient in capturing all the context necessary to compete with the performance of BERT.

Cache optimization



(a) Random Attention (b) Window Attention (c) Global Attention (d) BigBird

Figure: Building blocks of the block-attention mechanism used in BigBird with block size $= 2$. This implies the attention matrix is split into blocks of size 2×2. All the previous BigBird parameters work on each block as a unit.

Question Answering results

Model	HotpotQA			NaturalQ		TriviaQA		WikiHop
	Ans	Sup	Joint	LA	SA	Full	Verified	MCQ
HGN [27]	**82.2**	88.5	**74.2**	-	-	-	-	-
GSAN	81.6	88.7	73.9	-	-	-	-	-
ReflectionNet [33]	-	-	-	77.1	**64.1**	-	-	-
RikiNet [62]	-	-	-	75.5	59.5	-	-	-
Fusion-in-Decoder [40]	-	-	-	-	-	**84.5**	90.3	-
SpanBERT [43]	-	-	-	-	-	79.1	86.6	-
MRC-GCN [88]	-	-	-	-	-	-	-	78.3
MultiHop [14]	-	-	-	-	-	-	-	76.5
Longformer [8]	81.2	85.8	73.2	-	-	77.3	85.3	81.9
BIGBIRD-ETC	81.2	**89.1**	73.6	**77.7**	57.8	80.9	**90.8**	**82.3**

Figure: Fine-tuning results on Test set for QA tasks. For Natural Questions Long Answer (LA), TriviaQA Verified, and WikiHop, **BigBird-ETC is the new state-of-the-art**.

Question Answering params = no random attention?

Parameter	HotpotQA	NaturalQ	TriviaQA	WikiHop
Global token location	ETC	ETC	ETC	ETC
# of global token, g	256	230	320	430
Window length, w	507	507	507	507
# of random token, r	0	0	0	0
Max. sequence length	4096	4096	4096	4096
# of heads	16	16	16	16
# of hidden layers	24	24	24	24
Hidden layer size	1024	1024	1024	1024
Batch size	32	64	32	64
Loss	cross-entropy	cross-entropy	cross-entropy	cross-entropy
Num epochs	$\{5, 9\}$	$\{3, 5\}$	$\{4, 6\}$	$\{5, 10\}$
Optimizer	Adam	Adam	Adam	LAMB
Learning rate	3×10^{-5}	$\{5, 10\} \times 10^{-5}$	$\{3, 5\} \times 10^{-5}$	$\{2, 5\} \times 10^{-5}$
Compute resources	4×4 TPUv3	4×8 TPUv3	4×4 TPUv3	4×8 TPUv3

Figure: Hyperparameters of large BigBird model for Question Answering submitted for test.

Conclusion

- a lot of engineering to optimize Window + Global + Random attention
- allows longer sequence length and larger batch size
- $\Longrightarrow$ which brings improvements on almost all tasks
- all in all it shows that the full self-attention can be balanced by an increase in sentence length

Sources

1. Zaheer, Manzil, et al. "Big bird: Transformers for longer sequences." arXiv preprint arXiv:2007.14062 (2020).
https://arxiv.org/abs/2007.14062v1