Efficient Deep Learning Methods

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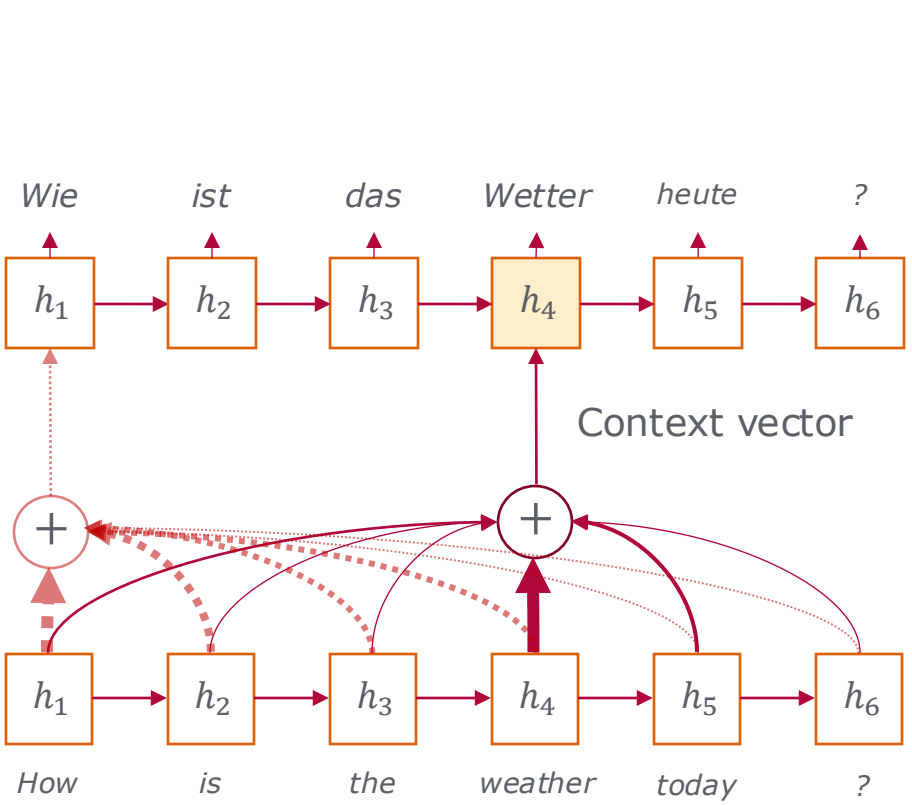
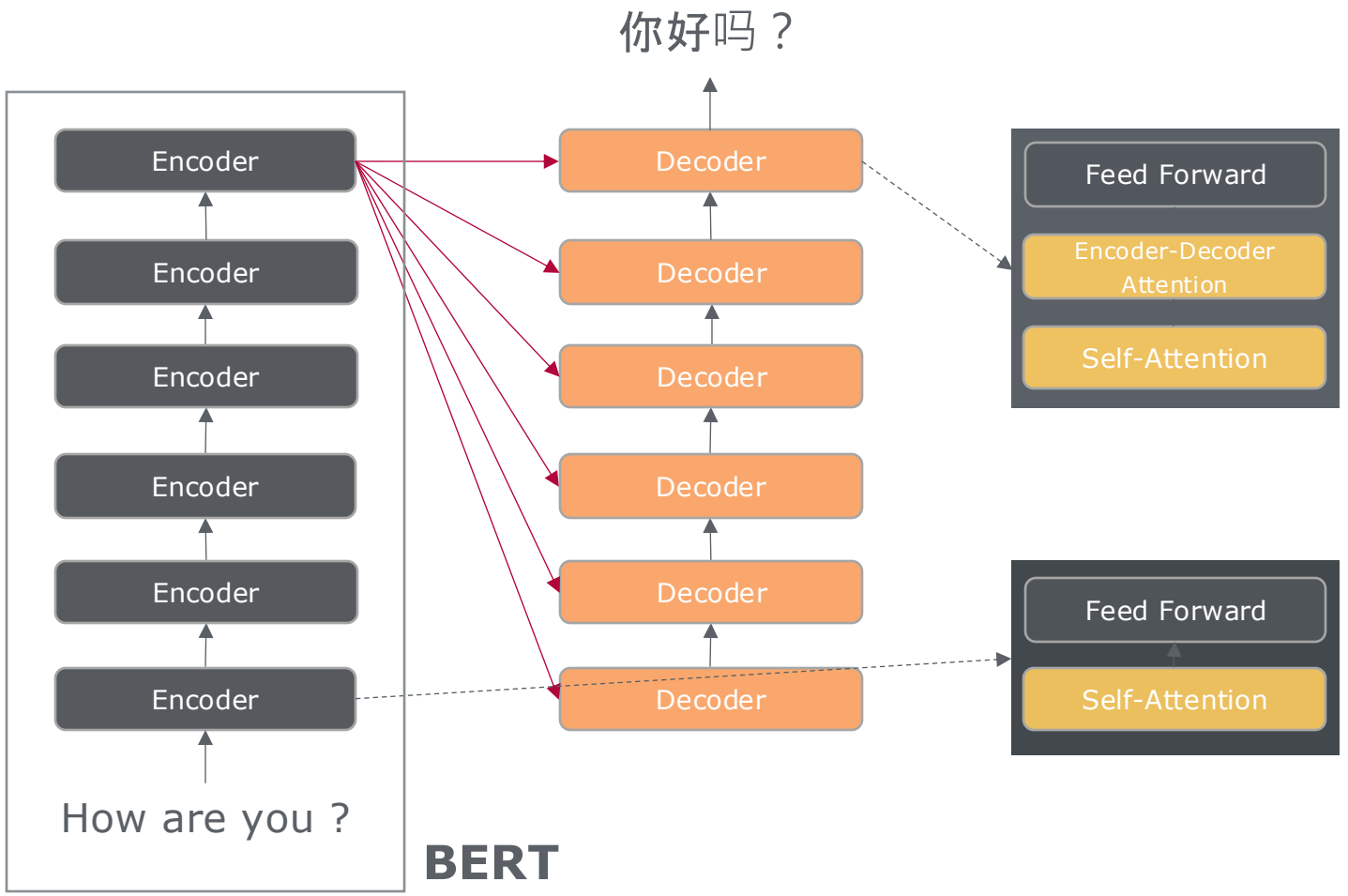
Design IT.
Create Knowledge.

www.hpi.de

Transformer, BERT and GPT





Vaswani, Ashish, et al. "Attention is all you need." NeurIPS 2017

Devlin, J et al. Bert: Pre-training of deep bidirectional transformers for language understanding. *NAACL-HLT 2019*

Modern AI Revolution

2013

- AlexNet, ResNet, NASNet, ViT etc. (< 3GB)
- large-scale fully supervised dataset (ImageNet: 1.2 million images)
- training: dozens to hundreds of GPUs, days-weeks

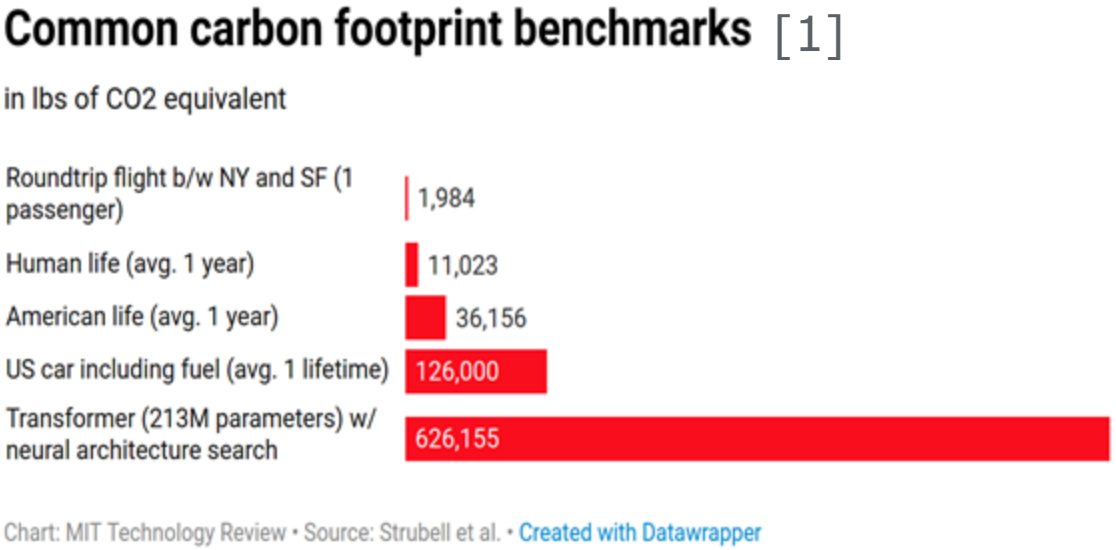
2025

- LLMs: GPT, LLaMA, DeepSeek (25-670GB)
- self-supervised learning using Internet (>3 trillion tokens)
- training: 4-20k GPUs, months

Example:

• GPT-1 (12 blocks,	125 million weights)	– June 2018	**1x**
• GPT-2 (48 blocks,	1.558 million weights)	– Februar 2019	**13x**
• GPT-3 (96 blocks,	175.000 million weights)	– June 2020	**1400x**
• GPT-4 (estimated	~1.000.000 million weights)	– March 2023	**8000x**

Deep Learning Models Spend Lots of Energy



GPT-3: 1287MW, 552 tons [2]

43 cars or 24 US families / year

GPT-4 is ~8x larger

[1] Strubell, Emma, Ananya Ganesh, and Andrew McCallum. "Energy and Policy Considerations for Deep Learning in NLP." In the 57th Annual Meeting of the Association for Computational Linguistics (ACL). Florence, Italy. July 2019

[2] David Patterson et al., "Carbon emissions and large neural network training", April 2021

Efficient AI Methods

- Knowledge distillation
  - Distills a large model (teacher) into a small model (student)
- Network pruning and dynamic network
  - Remove non-essential weights or dynamic width & depth
- Compact network designs
  - Use layer structures with less weights and operations
- Low-bit quantization
  - Quantizes 32-bit floating point params to a lower bit-width

Our selected publication 2020-2024:
[1] Supervised Knowledge May Hurt Novel Class Discovery Performance, Transaction on Machine Learning Research (TMLR) 2023
[2] SMKD: Selective Mutual Knowledge Distillation IJCNN 2023
[3] Not All Knowledge Is Created Equal: Mutual Distillation of Confident Knowledge, NeurIPS workshop 2022
[4] Flexible BERT with Width-and Depth-dynamic Inference, IJCNN 2023
[5] Boosting Bert Subnets with Neural Grafting, ICASSP 2023
[6] AsymmNet: Towards ultralight convolution neural networks using asymmetrical bottlenecks. CVPR 2021
[7] MeliusNet: Can Binary Neural Networks Achieve MobileNet-level Accuracy? WACV 2020
[8] Empirical Evaluation of Post-Training Quantization Methods for Language Tasks 2022
[9] A Study on Ultra Low-bit Compression of Generative Pretrained Transformers 2023
[10] Diode: Reinventing Binary Neural Networks Training with Sign Descent Optimization 2023
[11] BoolNet: Minimizing the Energy Consumption of Binary Neural Networks AAAI workshop 2024
[12] Towards Optimization-Friendly Binary Neural Network, TMLR 2024
[13] Enhancing Optimization Robustness in 1-bit Neural Networks through Stochastic Sign Descent. ECCV 2024