Title: T5 (language model)

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T5 (Text-to-Text Transfer Transformer) is a series of large language models developed by Google AI introduced in 2019. [1] [2] Like the original Transformer model, [3] T5 models are encoder-decoder Transformers , where the encoder processes the input text, and the decoder generates the output text.

T5 models are usually pretrained on a massive dataset of text and code, after which they can perform the text-based tasks that are similar to their pretrained tasks. They can also be finetuned to perform other tasks.

T5 models have been employed in various applications, including chatbots, machine translation systems, text summarization tools, code generation, and robotics. [4]

Training

The original T5 models are pre-trained on the Colossal Clean Crawled Corpus (C4), containing text and code scraped from the internet . This pre-training process enables the models to learn general language understanding and generation abilities. T5 models can then be fine-tuned on specific downstream tasks, adapting their knowledge to perform well in various applications.

The T5 models were pretrained on many tasks, all in the format of -> .

Some examples are:

restoring corrupted text: Thank you me to your party week. -> for inviting last , where the means "end of output", and the and denote blanks to be filled, called "sentinels" in the original report.

translation: translate English to German: That is good. -> Das ist gut. .

judging the grammatical acceptability of a sentence (CoLA sentence): The course is jumping well. -> not acceptable .

Architecture

The T5 series encompasses several models with varying sizes and capabilities, all encoder-decoder Transformers , where the encoder processes the input text, and the decoder generates the output text.

These models are often distinguished by their parameter count, which indicates the complexity and potential capacity of the model. The original paper [1] reported the following 5 models:

*The encoder and the decoder have the same shape. So for example, the T5-small has 6 layers in the encoder and 6 layers in the decoder.

In the above table,

n layer {\displaystyle n_{\text{layer}}} : Number of layers in the encoder; also, number of layers in the decoder. They always have the same number of layers.

n head {\displaystyle n_{\text{head}}} : Number of attention heads in each attention block.

d model {\displaystyle d_{\text{model}}} : Dimension of the embedding vectors.

d ff {\displaystyle d_{\text{ff}}} : Dimension of the feedforward network within each encoder and decoder layer.

d kv {\displaystyle d_{\text{kv}}} : Dimension of the key and value vectors used in the self-attention mechanism.

Note that unlike typical Transformers, the 3B and 11B models do not satisfy d model = d kv n head {\displaystyle d_{\text{model}}=d_{\text{kv}}n_{\text{head}}} . [6]

Compared to the original Transformer, it uses a few minor modifications: layer normalization with no additive bias; placing the layer normalization outside the residual path; relative positional embedding. [7]

For all experiments, they used a WordPiece tokenizer, with vocabulary size 32,000. The tokenizer is shared across both the input and output of each model. It was trained on a mixture of English , German , French , and Romanian data from the C4 dataset, at a ratio of 10:1:1:1.

Variants

Several subsequent models used the T5 architecture, with non-standardized naming conventions used to differentiate them. This section attempts to collect the main ones. An exhaustive list of the variants released by Google Brain is on the GitHub repo for T5X. [8]

Some models are trained from scratch while others are trained by starting with a previous trained model. By default, each model is trained from scratch, except otherwise noted.

T5 small, base, large, 3B, 11B (2019): The original models. [1]

T5 1.1 small, base, large, XL, XXL: Improved versions of the original T5 series. These have roughly equal parameters. The activation function is GEGLU [9] instead of ReLU. The 3B and the 11B were changed to "XL" and "XXL", and their shapes are changed: [8] [10] [11]

LM-adapted T5 (2021): a series of models (from small to XXL) that started from checkpoints of the T5 series, but trained further on 100B additional tokens from C4. [12]

Switch Transformer (2021): a mixture-of-experts variant of T5, by replacing the feedforward layers in the encoder and decoder blocks with mixture of expert feedforward layers. [13] [14]

T0 3B, 11B (2021): a series of models that started from checkpoints of LM-adapted T5 , and further trained to perform tasks based only on task instruction (zero-shot). [15] Different entries in the series uses different finetuning data. [16]

ByT5 (2021): a byte-level version of T5, trained on mC4 (multilingual C4) dataset. [17] It operates on text encoded as UTF-8 bytes, without tokenizers.

Flan-T5-XL (2022): a model that started with a checkpoint of T5 XL , then instruction-tuned on the FLAN dataset. [18] [19] [20] [21]

T5X (2022): a JAX -based re-implementation of the original T5 codebase. It is not a model. [22] The original T5 codebase was implemented in TensorFlow with MeshTF. [2]

UL2 20B (2022): a model with the same architecture as the T5 series, but scaled up to 20B, and trained with "mixture of denoisers" objective on the C4. [23] It was trained on a TPU cluster by accident, when a training run was left running accidentally for a month. [24]

Flan-UL2 20B (2022): UL2 20B instruction-finetuned on the FLAN dataset. [23] [20]

Pile-T5 (2024): has the same architecture of T5 , except it used the Llama tokenizer. It was trained on The Pile . It came in sizes of base, large, XL, XXL. [25]

Applications

The T5 model itself is an encoder-decoder model, allowing it to be used for instruction following. The encoder encodes the instruction, and the decoder autoregressively generates the reply.

The T5 encoder can be used as a text encoder, much like BERT . It encodes a text into a sequence of real-number vectors, which can be used for downstream applications. For example, Google Imagen [26] uses T5-XXL as text encoder, and the encoded text vectors are used as conditioning on a diffusion model . As another example, the AuraFlow diffusion model [27] uses Pile-T5-XL .

References

External links

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Notes

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Google

Google Brain

Google DeepMind

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OCR

Computer vision

Speech synthesis 15.ai ElevenLabs

15.ai

ElevenLabs

Speech recognition Whisper

Whisper

Facial recognition

AlphaFold

Text-to-image models Aurora DALL-E Firefly Flux Ideogram Imagen Midjourney Recraft Stable Diffusion

Aurora

DALL-E

Firefly

Flux

Ideogram

Imagen

Midjourney

Recraft

Stable Diffusion

Text-to-video models Dream Machine Runway Gen Hailuo AI Kling Sora Veo

Dream Machine

Runway Gen

Hailuo AI

Kling

Sora

Veo

Music generation Riffusion Suno AI Udio

Riffusion

Suno AI

Udio

Word2vec

Seq2seq

GloVe

BERT

T5

Llama

Chinchilla AI

PaLM

GPT 1 2 3 J ChatGPT 4 4o o1 o3 4.5 4.1 o4-mini 5

1

2

3

J

ChatGPT

4

4o

o1

o3

4.5

4.1

o4-mini

5

Claude

Gemini Gemini (language model) Gemma

Gemini (language model)

Gemma

Grok

LaMDA

BLOOM

DBRX

Project Debater

IBM Watson

IBM Watsonx

Granite

PanGu-Σ

DeepSeek

Qwen

AlphaGo

AlphaZero

OpenAI Five

Self-driving car

MuZero

Action selection AutoGPT

AutoGPT

Robot control

Alan Turing

Warren Sturgis McCulloch

Walter Pitts

John von Neumann

Claude Shannon

Shun'ichi Amari

Kunihiko Fukushima

Takeo Kanade

Marvin Minsky

John McCarthy

Nathaniel Rochester

Allen Newell

Cliff Shaw

Herbert A. Simon

Oliver Selfridge

Frank Rosenblatt
Bernard Widrow
Joseph Weizenbaum
Seymour Papert
Seppo Linnainmaa
Paul Werbos
Geoffrey Hinton
John Hopfield
Jürgen Schmidhuber
Yann LeCun
Yoshua Bengio
Lotfi A. Zadeh
Stephen Grossberg
Alex Graves
James Goodnight
Andrew Ng
Fei-Fei Li
Alex Krizhevsky
Ilya Sutskever
Oriol Vinyals
Quoc V. Le
Ian Goodfellow
Demis Hassabis
David Silver
Andrej Karpathy
Ashish Vaswani
Noam Shazeer
Aidan Gomez
John Schulman
Mustafa Suleyman
Jan Leike
Daniel Kokotajlo
François Chollet
Neural Turing machine
Differentiable neural computer
Transformer Vision transformer (ViT)
Vision transformer (ViT)
Recurrent neural network (RNN)

Long short-term memory (LSTM)

Gated recurrent unit (GRU)

Echo state network

Multilayer perceptron (MLP)

Convolutional neural network (CNN)

Residual neural network (RNN)

Highway network

Mamba

Autoencoder

Variational autoencoder (VAE)

Generative adversarial network (GAN)

Graph neural network (GNN)

Category