Skip to main content

[![Cornell University](/static/browse/0.3.4/images/icons/cu/cornell-reduced-white-SMALL.svg)](https://www.cornell.edu/)

We gratefully acknowledge support from the Simons Foundation, [member institutions](https://info.arxiv.org/about/ourmembers.html), and all contributors. [Donate](https://info.arxiv.org/about/donate.html)

[](/IgnoreMe)

[![arxiv logo](/static/browse/0.3.4/images/arxiv-logo-one-color-white.svg)](/) > [cs](/list/cs/recent) > arXiv:2106.09685

open search

GO

open navigation menu

quick links

  * [Login](https://arxiv.org/login)
  * [Help Pages](https://info.arxiv.org/help)
  * [About](https://info.arxiv.org/about)

Computer Science > Computation and Language

arXiv:2106.09685 (cs)

[Submitted on 17 Jun 2021 ([v1](https://arxiv.org/abs/2106.09685v1)), last revised 16 Oct 2021 (this version, v2)]

Title:LoRA: Low-Rank Adaptation of Large Language Models

Authors:[Edward J. Hu](https://arxiv.org/search/cs?searchtype=author&query=Hu,+E+J), [Yelong Shen](https://arxiv.org/search/cs?searchtype=author&query=Shen,+Y), [Phillip Wallis](https://arxiv.org/search/cs?searchtype=author&query=Wallis,+P), [Zeyuan Allen-Zhu](https://arxiv.org/search/cs?searchtype=author&query=Allen-

Zhu,+Z), [Yuanzhi

Li](https://arxiv.org/search/cs?searchtype=author&query=Li,+Y), [Shean

Wang](https://arxiv.org/search/cs?searchtype=author&query=Wang,+S), [Lu

Wang](https://arxiv.org/search/cs?searchtype=author&query=Wang,+L), [Weizhu

Chen](https://arxiv.org/search/cs?searchtype=author&query=Chen,+W)

View a PDF of the paper titled LoRA: Low-Rank Adaptation of Large Language Models, by Edward J. Hu and 7 other authors

[View PDF](/pdf/2106.09685)

> Abstract:An important paradigm of natural language processing consists of
> large-scale pre-training on general domain data and adaptation to particular
> tasks or domains. As we pre-train larger models, full fine-tuning, which
> retrains all model parameters, becomes less feasible. Using GPT-3 175B as an
> example -- deploying independent instances of fine-tuned models, each with
> 175B parameters, is prohibitively expensive. We propose Low-Rank Adaptation,
> or LoRA, which freezes the pre-trained model weights and injects trainable
> rank decomposition matrices into each layer of the Transformer architecture,
> greatly reducing the number of trainable parameters for downstream tasks.
> Compared to GPT-3 175B fine-tuned with Adam, LoRA can reduce the number of
> trainable parameters by 10,000 times and the GPU memory requirement by 3
> times. LoRA performs on-par or better than fine-tuning in model quality on
> RoBERTa, DeBERTa, GPT-2, and GPT-3, despite having fewer trainable
> parameters, a higher training throughput, and, unlike adapters, no
> additional inference latency. We also provide an empirical investigation
> into rank-deficiency in language model adaptation, which sheds light on the

> efficacy of LoRA. We release a package that facilitates the integration of
> LoRA with PyTorch models and provide our implementations and model
> checkpoints for RoBERTa, DeBERTa, and GPT-2 at [this https
> URL](https://github.com/microsoft/LoRA).

Comments: | Draft V2 includes better baselines, experiments on GLUE, and more on adapter latency

---|---

Subjects: | Computation and Language (cs.CL); Artificial Intelligence (cs.AI); Machine Learning (cs.LG)

Cite as: | [arXiv:2106.09685](https://arxiv.org/abs/2106.09685) [cs.CL]

| (or [arXiv:2106.09685v2](https://arxiv.org/abs/2106.09685v2) [cs.CL] for this version)

| <https://doi.org/10.48550/arXiv.2106.09685> Focus to learn more arXiv-issued DOI via DataCite

Submission history

From: Edward J. Hu [[view email](/show-email/e4479443/2106.09685)]

[[v1]](/abs/2106.09685v1) Thu, 17 Jun 2021 17:37:18 UTC (1,791 KB)

[v2] Sat, 16 Oct 2021 18:40:34 UTC (896 KB)

Full-text links:

Access Paper:

View a PDF of the paper titled LoRA: Low-Rank Adaptation of Large Language Models, by Edward J. Hu and 7 other authors

* [View PDF](/pdf/2106.09685)
* [TeX Source](/src/2106.09685)
* [Other Formats](/format/2106.09685)

References & Citations

* [NASA ADS](https://ui.adsabs.harvard.edu/abs/arXiv:2106.09685)
* [Google Scholar](https://scholar.google.com/scholar_lookup?arxiv_id=2106.09685)

* [Semantic Scholar](https://api.semanticscholar.org/arXiv:2106.09685)

[12 blog links](/tb/2106.09685)

([what is this?](https://info.arxiv.org/help/trackback.html))

[DBLP](https://dblp.uni-trier.de) \- CS Bibliography

[listing](https://dblp.uni-trier.de/db/journals/corr/corr2106.html#abs-2106-09685 "listing on DBLP") |
[bibtex](https://dblp.uni-trier.de/rec/bibtex/journals/corr/abs-2106-09685 "DBLP bibtex record")

[Yelong Shen](https://dblp.uni-trier.de/search/author?author=Yelong%20Shen
"DBLP author search")
[Phillip Wallis](https://dblp.uni-
trier.de/search/author?author=Phillip%20Wallis "DBLP author search")
[Zeyuan Allen-Zhu](https://dblp.uni-
trier.de/search/author?author=Zeyuan%20Allen-Zhu "DBLP author search")
[Yuanzhi Li](https://dblp.uni-trier.de/search/author?author=Yuanzhi%20Li "DBLP
author search")
[Weizhu Chen](https://dblp.uni-trier.de/search/author?author=Weizhu%20Chen
"DBLP author search")

[a](/static/browse/0.3.4/css/cite.css) export BibTeX citation Loading...

BibTeX formatted citation

×

loading...

Data provided by:

Bookmark

[![BibSonomy logo](/static/browse/0.3.4/images/icons/social/bibsonomy.png)
](http://www.bibsonomy.org/BibtexHandler?requTask=upload&url=https://arxiv.org/abs/2106.09685&
description=LoRA:
Low-Rank Adaptation of Large Language Models "Bookmark on BibSonomy") [
![Reddit logo](/static/browse/0.3.4/images/icons/social/reddit.png)
](https://reddit.com/submit?url=https://arxiv.org/abs/2106.09685&title=LoRA:
Low-Rank Adaptation of Large Language Models "Bookmark on Reddit")

Bibliographic Tools

Bibliographic and Citation Tools

Bibliographic Explorer Toggle

Bibliographic Explorer _([What is the
Explorer?](https://info.arxiv.org/labs/showcase.html#arxiv-bibliographic-
explorer))_

Connected Papers Toggle

Connected Papers _([What is Connected

Papers?](https://www.connectedpapers.com/about))_

Litmaps Toggle

Litmaps _([What is Litmaps?](https://www.litmaps.co/))_

scite.ai Toggle

scite Smart Citations _([What are Smart Citations?](https://www.scite.ai/))_

Code, Data, Media

Code, Data and Media Associated with this Article

alphaXiv Toggle

alphaXiv _([What is alphaXiv?](https://alphaxiv.org/))_

Links to Code Toggle

CatalyzeX Code Finder for Papers _([What is

CatalyzeX?](https://www.catalyzex.com))_

DagsHub Toggle

DagsHub _([What is DagsHub?](https://dagshub.com/))_

GotitPub Toggle

Gotit.pub _([What is GotitPub?](http://gotit.pub/faq))_

Huggingface Toggle

Hugging Face _([What is Huggingface?](https://huggingface.co/huggingface))_

Links to Code Toggle

Papers with Code _([What is Papers with Code?](https://paperswithcode.com/))_

ScienceCast Toggle

ScienceCast _([What is ScienceCast?](https://sciencecast.org/welcome))_

Demos

Demos

Replicate Toggle

Replicate _([What is Replicate?](https://replicate.com/docs/arxiv/about))_

Spaces Toggle

Hugging Face Spaces _([What is

Spaces?](https://huggingface.co/docs/hub/spaces))_

Spaces Toggle

TXYZ.AI _([What is TXYZ.AI?](https://txyz.ai))_

Related Papers

Recommenders and Search Tools

Link to Influence Flower

Influence Flower _([What are Influence

Flowers?](https://influencemap.cmlab.dev/))_

Core recommender toggle

CORE Recommender _([What is CORE?](https://core.ac.uk/services/recommender))_

* Author
* Venue
* Institution
* Topic

About arXivLabs

arXivLabs: experimental projects with community collaborators

arXivLabs is a framework that allows collaborators to develop and share new arXiv features directly on our website.

Both individuals and organizations that work with arXivLabs have embraced and accepted our values of openness, community, excellence, and user data privacy. arXiv is committed to these values and only works with partners that adhere to them.

Have an idea for a project that will add value for arXiv's community? [**Learn more about arXivLabs**](https://info.arxiv.org/labs/index.html).

[Which authors of this paper are endorsers?](/auth/show-endorsers/2106.09685) | [Disable MathJax](javascript:setMathjaxCookie\(\)) ([What is MathJax?](https://info.arxiv.org/help/mathjax.html))

* [Web Accessibility Assistance](https://info.arxiv.org/help/web_accessibility.html)

* [arXiv Operational Status](https://status.arxiv.org)

Get status notifications via

[email](https://subscribe.sorryapp.com/24846f03/email/new) or

[slack](https://subscribe.sorryapp.com/24846f03/slack/new)