

Title: Google Neural Machine Translation

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Categories: Category:Applications of artificial intelligence, Category:Artificial neural networks, Category:Computational linguistics, Category:Google Translate, Category:Machine translation, Category:Tasks of natural language processing

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Google Neural Machine Translation ( GNMT ) was a neural machine translation (NMT) system developed by Google and introduced in November 2016 that used an artificial neural network to increase fluency and accuracy in Google Translate . [ 1 ] [ 2 ] [ 3 ] [ 4 ] The neural network consisted of two main blocks, an encoder and a decoder, both of LSTM architecture with 8 1024-wide layers each and a simple 1-layer 1024-wide feedforward attention mechanism connecting them. [ 4 ] [ 5 ] The total number of parameters has been variously described as over 160 million, [ 6 ] approximately 210 million, [ 7 ] 278 million [ 8 ] or 380 million. [ 9 ] It used WordPiece tokenizer , and beam search decoding strategy. It ran on Tensor Processing Units .

By 2020, the system had been replaced by another deep learning system based on a Transformer encoder and an RNN decoder. [ 10 ]

GNMT improved on the quality of translation by applying an example-based (EBMT) machine translation method in which the system learns from millions of examples of language translation. [ 2 ] GNMT's proposed architecture of system learning was first tested on over a hundred languages supported by Google Translate. [ 2 ] With the large end-to-end framework, the system learns over time to create better, more natural translations. [ 1 ] GNMT attempts to translate whole sentences at a time, rather than just piece by piece. [ 1 ] The GNMT network can undertake interlingual machine translation by encoding the semantics of the sentence, rather than by memorizing phrase-to-phrase translations. [ 2 ] [ 11 ]

## History

The Google Brain project was established in 2011 in the "secretive Google X research lab" [ 12 ] by Google Fellow Jeff Dean , Google Researcher Greg Corrado , and Stanford University Computer Science professor Andrew Ng . [ 13 ] [ 14 ] [ 15 ] Ng's work has led to some of the biggest breakthroughs at Google and Stanford. [ 12 ]

In November 2016, Google Neural Machine Translation system (GNMT) was introduced. Since then, Google Translate began using neural machine translation (NMT) in preference to its previous statistical methods (SMT) [ 1 ] [ 16 ] [ 17 ] [ 18 ] which had been used since October 2007, with its proprietary, in-house SMT technology. [ 19 ] [ 20 ]

Training GNMT was a big effort at the time and took, by a 2018 OpenAI estimate, on the order of 79 petaFLOP-days (or  $7 \times 10^{21}$  FLOPs) of compute which was 1.5 orders of magnitude larger than Seq2seq model of 2014 [ 21 ] (but about 2x smaller than GPT-J-6B in 2021 [ 22 ] ).

Google Translate's NMT system uses a large artificial neural network capable of deep learning . [ 1 ] [ 2 ] [ 3 ] By using millions of examples, GNMT improves the quality of translation, [ 2 ] using broader context to deduce the most relevant translation. The result is then rearranged and adapted to approach grammatically based human language. [ 1 ] GNMT's proposed architecture of system learning was first tested on over a hundred languages supported by Google Translate. [ 2 ] GNMT did not create its own universal interlingua but rather aimed at finding the commonality between many languages using insights from psychology and linguistics. [ 23 ] The new translation engine was first enabled for eight languages: to and from English and French, German, Spanish, Portuguese, Chinese, Japanese, Korean and Turkish in November 2016. [ 24 ] In March 2017, three additional languages were enabled: Russian, Hindi and Vietnamese along with Thai for which support was added later. [ 25 ] [ 26 ] Support for Hebrew and Arabic was also added with help from the Google Translate Community in the same month. [ 27 ] In mid April 2017 Google Netherlands announced support for Dutch and other European languages related to English. [ 28 ] Further support was added for nine Indian languages: Hindi, Bengali, Marathi, Gujarati, Punjabi, Tamil, Telugu, Malayalam and Kannada at the end of April 2017. [ 29 ]

By 2020, Google had changed methodology to use a different neural network system based on transformers , and had phased out NMT. [ 30 ]

## Evaluation

The GNMT system was said to represent an improvement over the former Google Translate in that it will be able to handle "zero-shot translation", that is it directly translates one language into another. For example, it might be trained just for Japanese-English and Korean-English translation, but can perform Japanese-Korean translation. The system appears to have learned to produce a language-independent intermediate representation of language (an " interlingua "), which allows it to perform zero-shot translation by converting from and to the interlingua. [ 2 ] Google Translate previously first translated the source language into English and then translated the English into the target language rather than translating directly from one language to another. [ 11 ]

A July 2019 study in Annals of Internal Medicine found that "Google Translate is a viable, accurate tool for translating non-English-language trials". Only one disagreement between reviewers reading machine-translated trials was due to a translation error. Since many medical studies are excluded from systematic reviews because the reviewers do not understand the language, GNMT has the potential to reduce bias and improve accuracy in such reviews. [ 31 ]

## Languages supported by GNMT

As of December 2021, all of the languages of Google Translate support GNMT, with Latin being the most recent addition.

Afrikaans

Albanian

Amharic

Arabic

Armenian

Azerbaijani

Basque

Belarusian

Bengali

Bosnian

Bulgarian

Burmese

Catalan

Cebuano

Chewa

Chinese ( Simplified )

Chinese ( Traditional )

Corsican

Croatian

Czech

Danish

Dutch

English

Esperanto

Estonian

Filipino ( Tagalog )

Finnish

French

Galician

Georgian

German

Greek

Gujarati

Haitian Creole

Hausa

Hawaiian  
Hebrew  
Hindi  
Hmong  
Hungarian  
Icelandic  
Igbo  
Indonesian  
Irish  
Italian  
Japanese  
Javanese  
Kannada  
Kazakh  
Khmer  
Kinyarwanda  
Korean  
Kurdish ( Kurmanji )  
Kyrgyz  
Lao  
Latin  
Latvian  
Lithuanian  
Luxembourgish  
Macedonian  
Malagasy  
Malay  
Malayalam  
Maltese  
Maori  
Marathi  
Mongolian  
Nepali  
Norwegian ( Bokmål )  
Odia  
Pashto  
Persian  
Polish

Portuguese

Punjabi ( Gurmukhi )

Romanian

Russian

Samoan

Scottish Gaelic

Serbian

Shona

Sindhi

Sinhala

Slovak

Slovenian

Somali

Sotho

Spanish

Sundanese

Swahili

Swedish

Tajik

Tamil

Tatar

Telugu

Thai

Turkish

Turkmen

Ukrainian

Urdu

Uyghur

Uzbek

Vietnamese

Welsh

West Frisian

Xhosa

Yiddish

Yoruba

Zulu

See also

Example-based machine translation

[Rule-based machine translation](#)

[Comparison of machine translation applications](#)

[Statistical machine translation](#)

[Artificial intelligence](#)

[Cache language model](#)

[Computational linguistics](#)

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[Machine translation](#)

[Universal translator](#)

[References](#)

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[Statistical Machine Translation](#)

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[Cloud Platform](#)

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[Crisis Response](#)

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[Registry](#)

DeepMind  
Fitbit  
ITA Software  
Jigsaw  
Looker  
Mandiant  
Security Operations  
Owlchemy Labs  
Actifio  
Adscape  
Akwan Information Technologies  
Anvato  
Apigee  
BandPage  
Bitium  
BufferBox  
Crashlytics  
Dodgeball  
DoubleClick  
Dropcam  
Endoxon  
Flutter  
Global IP Solutions  
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GreenBorder  
Gridcentric  
ImageAmerica  
Impermium  
Invite Media  
Kaltix  
Marratech  
Meebo  
Metaweb  
Neotonic Software  
Neverware  
Nik Software  
Orbitera  
Pyra Labs



Quest Visual  
Reqwireless  
RightsFlow  
Sidewalk Labs  
SlickLogin  
Titan Aerospace  
Typhoon Studios  
Urban Engines  
Vicarious  
Viewdle  
Wavii  
Wildfire Interactive  
YouTube Next Lab and Audience Development Group  
Business Groups  
Computing University Initiative  
Contact Lens  
Content ID  
CrossCheck  
Data Liberation Front  
Data Transfer Project  
Developer Expert  
DigiKavach  
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Digital News Initiative  
Digital Unlocked  
Dragonfly  
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Made with Code  
News Lab  
PowerMeter  
Privacy Sandbox  
Project Nightingale

Project Nimbus  
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Project Zero  
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YouTube Creator Awards  
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2018  
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AlphaGo versus Lee Sedol  
AlphaGo versus Ke Jie  
Android Developer Challenge  
Android Developer Day  
Android Developer Lab  
CNN/YouTube presidential debates  
Code-in  
Code Jam  
Developer Day  
Developers Live  
Doodle4Google  
Future of Go Summit  
G-Day  
Hash Code  
I/O  
Lunar X Prize  
Mapathon  
Science Fair

Summer of Code  
World Chess Championship 2024  
YouTube Awards  
YouTube Comedy Week  
YouTube Live  
YouTube Music Awards 2013 2015  
2013  
2015  
YouTube Space Lab  
YouTube Symphony Orchestra  
111 Eighth Avenue  
Android lawn statues  
Androidland  
Barges  
Binoculars Building  
Central Saint Giles  
Chelsea Market  
Chrome Zone  
Data centers  
GeoEye-1  
Googleplex  
Ivanpah Solar Power Facility  
James R. Thompson Center  
King's Cross  
Mayfield Mall  
Pier 57  
Sidewalk Toronto  
St. John's Terminal  
Submarine cables Dunant Grace Hopper Unity  
Dunant  
Grace Hopper  
Unity  
WiFi  
YouTube Space  
YouTube Theater  
Krishna Bharat  
Vint Cerf  
Jeff Dean

John Doerr  
Sanjay Ghemawat  
Al Gore  
John L. Hennessy  
Urs Hölzle  
Salar Kamangar  
Ray Kurzweil  
Ann Mather  
Alan Mulally  
Rick Osterloh  
Sundar Pichai (CEO)  
Ruth Porat (CFO)  
Rajen Sheth  
Hal Varian  
Neal Mohan  
Andy Bechtolsheim  
Sergey Brin (co-founder)  
David Cheriton  
Matt Cutts  
David Drummond  
Alan Eustace  
Timnit Gebru  
Omid Kordestani  
Paul Otellini  
Larry Page (co-founder)  
Patrick Pichette  
Eric Schmidt  
Ram Shriram  
Amit Singhal  
Shirley M. Tilghman  
Rachel Whetstone  
Susan Wojcicki  
Censorship  
DeGoogle  
FairSearch  
" Google's Ideological Echo Chamber "  
No Tech for Apartheid  
Privacy concerns Street View YouTube

Street View

YouTube

Trade unions Alphabet Workers Union

Alphabet Workers Union

YouTube copyright issues

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Blocking of YouTube videos in Germany

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American Fuzzy Lop

Android Cloud to Device Messaging

Android Debug Bridge

Android NDK

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Blink  
Closure Tools  
Cloud Connect  
Cloud Dataflow  
Cloud Datastore  
Cloud Messaging  
Cloud Shell  
Cloud Storage  
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Compute Engine  
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Dalvik  
Data Protocol  
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Exposure Notification  
Fast Pair  
Fastboot  
Federated Learning of Cohorts  
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Firebase Studio  
Firebase Cloud Messaging  
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GLOP  
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Gson  
Guava  
Guetzli  
Guice  
gVisor  
GYP  
JAX  
Jetpack Compose  
Keyhole Markup Language  
Kubernetes  
Kythe  
LevelDB  
Lighthouse  
Looker Studio  
Imctfy  
MapReduce

Mashup Editor  
Matter  
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Nomulus  
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Googlebot  
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Mobilegeddon  
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.app  
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google.by  
Croscore  
Noto  
Product Sans  
Roboto  
Aardvark  
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Dashboard  
Takeout  
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AdMob  
Ads  
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Affiliate Network  
Alerts  
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Analytics  
Android Auto  
Android Beam  
Answers  
Apture  
Arts & Culture  
Assistant  
Attribution  
Authenticator  
BebaPay  
BeatThatQuote.com  
Beam  
Blog Search  
Blogger  
Body  
Bookmarks  
Books Ngram Viewer  
Ngram Viewer  
Browser Sync  
Building Maker

Bump  
BumpTop  
Buzz  
Calendar  
Cast  
Catalogs  
Chat  
Checkout  
Chrome  
Chrome Apps  
Chrome Experiments  
Chrome Remote Desktop  
Chrome Web Store  
Classroom  
Cloud Print  
Cloud Search  
Contacts  
Contributor  
Crowdsource  
Currents (social app)  
Currents (news app)  
Data Commons  
Dataset Search  
Desktop  
Dictionary  
Dinosaur Game  
Directory  
Docs  
Docs Editors  
Domains  
Drawings  
Drive  
Duo  
Earth  
Etherpad  
Expeditions  
Express  
Family Link

Fast Flip  
FeedBurner  
fflick  
Fi Wireless  
Finance  
Files  
Find Hub  
Fit  
Flights  
Flu Trends  
Fonts  
Forms  
Friend Connect  
Fusion Tables  
Gboard  
Gemini  
Gesture Search  
Gizmo5  
Google+  
Gmail  
Goggles  
GOOG-411  
Grasshopper  
Groups  
Hangouts  
Helpouts  
iGoogle  
Images Image Labeler  
Image Labeler  
Image Swirl  
Inbox by Gmail  
Input Tools Japanese Input Pinyin  
Japanese Input  
Pinyin  
Insights for Search  
Jaiku  
Jamboard  
Kaggle

Keep  
Knol  
Labs  
Latitude  
Lens  
Like.com  
Live Transcribe  
Lively  
Map Maker  
Maps  
Maps Navigation  
Marketing Platform  
Meet  
Messages  
Moderator  
My Tracks  
Nearby Share  
News  
News & Weather  
News Archive  
Notebook  
NotebookLM  
Now  
Offers  
One  
One Pass  
Opinion Rewards  
Orkut  
Oyster  
Panoramio  
PaperofRecord.com  
Patents  
Page Creator  
Pay (mobile app)  
Pay (payment method)  
Pay Send  
People Cards  
Person Finder

Personalized Search  
Photomath  
Photos  
Picasa  
Picasa Web Albums  
Picnik  
Pixel Camera  
Play  
Play Books  
Play Games  
Play Music  
Play Newsstand  
Play Pass  
Play Services  
Podcasts  
Poly  
Postini  
PostRank  
Primer  
Public Alerts  
Public Data Explorer  
Question Hub  
Quick, Draw!  
Quick Search Box  
Quick Share  
Quickoffice  
Read Along  
Reader  
Reply  
Safe Browsing  
SageTV  
Santa Tracker  
Schemer  
Scholar  
Search AI Overviews Knowledge Graph SafeSearch  
AI Overviews  
Knowledge Graph  
SafeSearch



Searchwiki  
Sheets  
Shoploop  
Shopping  
Sidewiki  
Sites  
Slides  
Snapseed  
Socratic  
Softcard  
Songza  
Sound Amplifier  
Spaces  
Sparrow (chatbot)  
Sparrow (email client)  
Speech Recognition & Synthesis  
Squared  
Stadia  
Station  
Store  
Street View  
Surveys  
Sync  
Tables  
Talk  
TalkBack  
Tasks  
Tenor  
Tez  
Tilt Brush  
Toolbar  
Toontastic 3D  
Translate  
Travel  
Trendalyzer  
Trends  
TV  
URL Shortener

Video  
Vids  
Voice  
Voice Access  
Voice Search  
Wallet  
Wave  
Waze  
WDYL  
Web Light  
Where Is My Train  
Widevine  
Wiz  
Word Lens  
Workspace  
Workspace Marketplace  
YouTube  
YouTube Kids  
YouTube Music  
YouTube Premium  
YouTube Shorts  
YouTube Studio  
YouTube TV  
YouTube VR  
Pixel (2016)  
Pixel 2 (2017)  
Pixel 3 (2018)  
Pixel 3a (2019)  
Pixel 4 (2019)  
Pixel 4a (2020)  
Pixel 5 (2020)  
Pixel 5a (2021)  
Pixel 6 (2021)  
Pixel 6a (2022)  
Pixel 7 (2022)  
Pixel 7a (2023)  
Pixel Fold (2023)  
Pixel 8 (2023)

Pixel 8a (2024)  
Pixel 9 (2024)  
Pixel 9 Pro Fold (2024)  
Pixel 9a (2025)  
Pixel 10 (2025)  
Pixel 10 Pro Fold (2025)  
Pixel Watch (2022)  
Pixel Watch 2 (2023)  
Pixel Watch 3 (2024)  
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Pixel C (2015)  
Pixel Slate (2018)  
Pixel Tablet (2023)  
Chromebook Pixel (2013–2015)  
Pixelbook (2017)  
Pixelbook Go (2019)  
Pixel Buds (2017–present)  
Nexus One (2010)  
Nexus S (2010)  
Galaxy Nexus (2011)  
Nexus 4 (2012)  
Nexus 5 (2013)  
Nexus 6 (2014)  
Nexus 5X (2015)  
Nexus 6P (2015)  
Nexus 7 (2012)  
Nexus 10 (2012)  
Nexus 7 (2013)  
Nexus 9 (2014)  
Nexus Q (2012)  
Nexus Player (2014)  
Android Dev Phone  
Android One  
Cardboard  
Chromebit  
Chromebook  
Chromebox  
Chromecast

Clips  
Daydream  
Fitbit  
Glass  
Liftware  
Liquid Galaxy  
Nest smart speakers  
Thermostat Wifi  
smart speakers  
Thermostat  
Wifi  
Play Edition  
Project Ara  
OnHub  
Pixel Visual Core  
Project Iris  
Search Appliance  
Sycamore processor  
Tensor  
Tensor Processing Unit  
Titan Security Key

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European Union (2010–present)  
United States v. Adobe Systems, Inc., Apple Inc., Google Inc., Intel Corporation, Intuit, Inc., and Pixar (2011)  
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Rocky Mountain Bank v. Google, Inc. (2009)  
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Beauty YouTuber  
BookTube  
BreadTube  
" Don't be evil "  
Gayglers  
Google as a verb  
Google bombing 2004 U.S. presidential election  
2004 U.S. presidential election  
Google effect  
Googlefight  
Google hacking  
Googleshare  
Google tax  
Googlewhack  
Googlization  
Illegal flower tribute  
Objectives and key results  
Rooting  
Search engine manipulation effect  
Side project time  
Sitelink  
Site reliability engineering

StudyTube

VTuber

YouTube Poop

YouTuber list

list

Booting process

Custom distributions

Features

Recovery mode

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Most-liked videos

Most-subscribed channels

Most-viewed channels

Most-viewed videos Arabic music videos Chinese music videos French music videos Indian videos Pakistani videos

Arabic music videos

Chinese music videos

French music videos

Indian videos

Pakistani videos

Official channel  
Social impact  
YouTube Premium original programming  
Gmail interface  
Maps pin  
Most downloaded Google Play applications  
Stadia games  
AlphaGo  
Google: Behind the Screen  
Google Maps Road Trip  
Google and the World Brain  
The Creepy Line  
Google Hacks  
The Google Story  
Googled: The End of the World as We Know It  
How Google Works  
I'm Feeling Lucky  
In the Plex  
The MANIAC  
Google Feud  
Google Me (film)  
" Google Me " (Kim Zolciak song)  
" Google Me " (Teyana Taylor song)  
Is Google Making Us Stupid?  
Proceratium google  
Matt Nathanson: Live at Google  
The Billion Dollar Code  
The Internship  
Where on Google Earth is Carmen Sandiego?  
" Attention Is All You Need "  
elgooG  
Generative pre-trained transformer  
" Me at the zoo "  
Predictions of the end  
Relationship with Wikipedia  
" Reunion "  
Robot Constitution  
Category

Outline

v

t

e

Dictionary-based

Rule-based

Transfer-based

Statistical

Example-based

Interlingual

Neural

Hybrid

v

t

e

Ambient intelligence Internet of things

Internet of things

Artificial intelligence Applications of artificial intelligence Machine translation Machine vision Mobile translation Progress in artificial intelligence Semantic Web Speech recognition

Applications of artificial intelligence

Machine translation

Machine vision

Mobile translation

Progress in artificial intelligence

Semantic Web

Speech recognition

Atomtronics

Carbon nanotube field-effect transistor

Cybermethodology

Augmented reality

Fourth-generation optical discs 3D optical data storage Holographic data storage

3D optical data storage

Holographic data storage

GPGPU

Memory CBRAM ECRAM FRAM Millipede MRAM NRAM PRAM Racetrack memory RRAM SONOS UltraRAM

CBRAM

ECRAM

FRAM



Millipede  
MRAM  
NRAM  
PRAM  
Racetrack memory  
RRAM  
SONOS  
UltraRAM  
Optical computing  
RFID Chipless RFID  
Chipless RFID  
Software-defined radio  
Three-dimensional integrated circuit  
Automation  
Collingridge dilemma  
Differential technological development  
Disruptive innovation  
Ephemerization  
Ethics AI Bioethics Cyberethics Neuroethics Robot ethics  
AI  
Bioethics  
Cyberethics  
Neuroethics  
Robot ethics  
Exploratory engineering  
Proactionary principle  
Technological change Technological unemployment  
Technological unemployment  
Technological convergence  
Technological evolution  
Technological paradigm  
Technology forecasting Accelerating change Future-oriented technology analysis Horizon scanning  
Moore's law Technological singularity Technology scouting  
Accelerating change  
Future-oriented technology analysis  
Horizon scanning  
Moore's law  
Technological singularity

Technology scouting  
Technology in science fiction  
Technology readiness level  
Technology roadmap  
Transhumanism  
List  
v  
t  
e  
AI-complete  
Bag-of-words  
n -gram Bigram Trigram  
Bigram  
Trigram  
Computational linguistics  
Natural language understanding  
Stop words  
Text processing  
Argument mining  
Collocation extraction  
Concept mining  
Coreference resolution  
Deep linguistic processing  
Distant reading  
Information extraction  
Named-entity recognition  
Ontology learning  
Parsing Semantic parsing Syntactic parsing  
Semantic parsing  
Syntactic parsing  
Part-of-speech tagging  
Semantic analysis  
Semantic role labeling  
Semantic decomposition  
Semantic similarity  
Sentiment analysis  
Terminology extraction  
Text mining

Textual entailment  
Truecasing  
Word-sense disambiguation  
Word-sense induction  
Compound-term processing  
Lemmatisation  
Lexical analysis  
Text chunking  
Stemming  
Sentence segmentation  
Word segmentation  
Multi-document summarization  
Sentence extraction  
Text simplification  
Computer-assisted  
Example-based  
Rule-based  
Statistical  
Transfer-based  
Neural  
BERT  
Document-term matrix  
Explicit semantic analysis  
fastText  
GloVe  
Language model ( large )  
Latent semantic analysis  
Seq2seq  
Word embedding  
Word2vec  
Corpus linguistics  
Lexical resource  
Linguistic Linked Open Data  
Machine-readable dictionary  
Parallel text  
PropBank  
Semantic network  
Simple Knowledge Organization System

Speech corpus  
Text corpus  
Thesaurus (information retrieval)  
Treebank  
Universal Dependencies  
BabelNet  
Bank of English  
DBpedia  
FrameNet  
Google Ngram Viewer  
UBY  
WordNet  
Wikidata  
Speech recognition  
Speech segmentation  
Speech synthesis  
Natural language generation  
Optical character recognition  
Document classification  
Latent Dirichlet allocation  
Pachinko allocation  
Automated essay scoring  
Concordancer  
Grammar checker  
Predictive text  
Pronunciation assessment  
Spell checker  
Chatbot  
Interactive fiction  
Question answering  
Virtual assistant  
Voice user interface  
Formal semantics  
Hallucination  
Natural Language Toolkit  
spaCy