

What is Temperature in LLMs?

Temperature is a parameter that determines the probability distribution of the next word in text generation. It controls the randomness and diversity of the output:

Low Temperature (e.g., 0.0–0.4):

Results are deterministic, precise, and repetitive.

Moderate Temperature (e.g., 0.5–1.0):

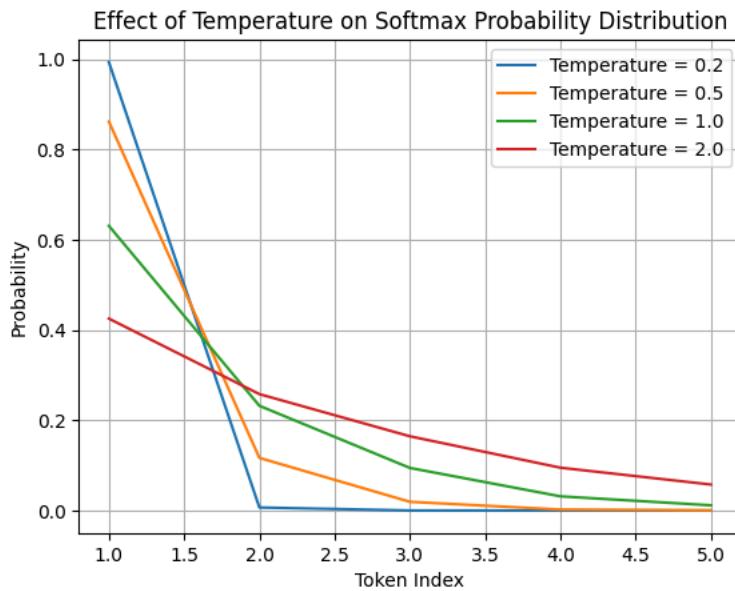
Outputs become more diverse while maintaining coherence.

High Temperature (e.g., 1.1–2.0):

Text becomes creative and experimental, often at the cost of relevance and focus.

```
import numpy as np
import matplotlib.pyplot as plt
def softmax_with_temperature(logits, temperature):
    logits = np.array(logits) # Convert input list to numpy array
    exp_logits = np.exp(logits / temperature) # Scale logits by temperature and exponentiate
    return exp_logits / np.sum(exp_logits) # Normalize to get probabilities
# Raw scores for 5 tokens
logits = [2.0, 1.0, 0.1, -1.0, -2.0]
temperatures = [0.2, 0.5, 1.0, 2.0]
# Calculate probabilities for each temperature
probabilities = {temp: softmax_with_temperature(logits, temp) for temp in temperatures}
# Plotting
for temp, probs in probabilities.items():
    plt.plot(range(1, len(probs) + 1), probs, label=f'Temperature = {temp}')

plt.title("Effect of Temperature on Softmax Probability Distribution")
plt.xlabel("Token Index")
plt.ylabel("Probability")
plt.legend()
plt.grid()
plt.show()
```



What The Numbers Mean

Let's look at the probabilities for different temperatures:

Temperature = 0.2 (Very Cold)

Token 1: 99.3%

Token 2: 0.67%

Other tokens: nearly 0%

This makes the model very focused on the highest-scoring token.

Temperature = 2.0 (Very Hot)

Token 1: 42.5%

Token 2: 25.8%

Token 3: 16.4%

Token 4: 9.5%

Token 5: 5.8%

This spreads out the probabilities, making the model more random.

Visual Explanation

The plot shows how temperature affects token selection:

Blue line (T=0.2):

Very steep, almost all probability goes to the highest-scoring token

Orange line (T=0.5):

Still favors high-scoring tokens but less extremely

Green line (T=1.0):

Moderate distribution Red line (T=2.0): Flatter distribution, giving more chances to lower-scoring tokens

Example of how temperature works in text generation (Using GROQ API)

Below is a simple python code which uses GROQ API for accessing LLAMA 3.3 70B parameter model.

```
!pip install groq
Collecting groq
  Downloading groq-0.34.0-py3-none-any.whl.metadata (16 kB)
Requirement already satisfied: aiohttp<2.0>=3.5.0 in /usr/local/lib/python3.12/dist-packages (from groq) (4.11.0)
Requirement already satisfied: distro<2,>=1.7.0 in /usr/local/lib/python3.12/dist-packages (from groq) (1.9.0)
Requirement already satisfied: httpx<1,>=0.23.0 in /usr/local/lib/python3.12/dist-packages (from groq) (0.28.1)
Requirement already satisfied: pydantic<3,>=1.9.0 in /usr/local/lib/python3.12/dist-packages (from groq) (2.11.10)
Requirement already satisfied: sniffio in /usr/local/lib/python3.12/dist-packages (from groq) (1.3.1)
Requirement already satisfied: typing-extensions<5,>=4.10 in /usr/local/lib/python3.12/dist-packages (from groq) (4.15.0)
Requirement already satisfied: idna>=2.8 in /usr/local/lib/python3.12/dist-packages (from aiohttp<2.0>=3.5.0->groq) (3.11)
Requirement already satisfied: certifi in /usr/local/lib/python3.12/dist-packages (from httpx<1,>=0.23.0->groq) (2025.10.5)
Requirement already satisfied: httpcore==1.* in /usr/local/lib/python3.12/dist-packages (from httpx<1,>=0.23.0->groq) (1.0.9)
Requirement already satisfied: h11>=0.16 in /usr/local/lib/python3.12/dist-packages (from httpcore==1.*->httpx<1,>=0.23.0->groq)
Requirement already satisfied: annotated-types>=0.6.0 in /usr/local/lib/python3.12/dist-packages (from pydantic<3,>=1.9.0->groq)
Requirement already satisfied: pydantic-core==2.33.2 in /usr/local/lib/python3.12/dist-packages (from pydantic<3,>=1.9.0->groq)
Requirement already satisfied: typing-inspection>=0.4.0 in /usr/local/lib/python3.12/dist-packages (from pydantic<3,>=1.9.0->groq)
  Downloading groq-0.34.0-py3-none-any.whl (135 kB)
  136.0/136.0 kB 2.9 MB/s eta 0:00:00
Installing collected packages: groq
Successfully installed groq-0.34.0
```

GROQ

GROQ (short for Generative Retrieval Optimized Query) is a chip and AI inference engine developed by Groq Inc.

It's not a model, but hardware and software optimized to run AI models super fast, especially large language models (LLMs).

Think of it like this: if LLaMA is a powerful brain, then GROQ is a lightning-fast body helping it move.

Groq is known for ultra-low latency, meaning it can return responses almost instantly, which is perfect for real-time AI chatbots, robotics, and edge AI.

✓ LLaMA

LLaMA stands for Large Language Model Meta AI.

It's an open-source language model family developed by Meta (Facebook).

Similar to OpenAI's GPT models, it can do:

Text generation

Summarization

Translation

Coding

Reasoning, etc.

There are different versions: LLaMA 1, 2, and 3 (latest as of 2024).

LLaMA models are trained on huge datasets and optimized to run efficiently, even on smaller hardware (compared to GPT-4).

```
import numpy as np
from groq import Groq
def generate_completion(client, model, prompt, temperature):
    completion = client.chat.completions.create(
        model=model,
        messages=[{"role": "user", "content": prompt}],
        temperature=temperature,
        max_tokens=100,
        top_p=1,
        stream=False,
        stop=None,
    )
    return completion.choices[0].message.content

def main():
    client = Groq(api_key="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")
    model = "llama-3.3-70b-versatile"
    prompt = "Explain AI in exactly 50 words. Do not exceed this limit."
    # Generate temperatures from 0 to 2 with a step of 0.1
    temperatures = np.arange(0, 2.1, 0.1)
    for temp in temperatures:
        print(f"\nTemperature: {temp:.1f}")
        result = generate_completion(client, model, prompt, temp)
        print(result)
    #divider line
    print("-" * 50)
if __name__ == "__main__":
    main()
```

```
Temperature: 0.0
Artificial Intelligence (AI) refers to computer systems that mimic human intelligence, learning, and problem-solving. AI uses a

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Temperature: 0.1
Artificial Intelligence (AI) refers to computer systems that mimic human intelligence, learning, and problem-solving. AI uses a

-----
Temperature: 0.2
AI refers to artificial intelligence, where machines learn, reason, and interact like humans, using algorithms and data to make

-----
Temperature: 0.3
Artificial Intelligence (AI) refers to computer systems that simulate human intelligence, learning, and problem-solving ability

-----
Temperature: 0.4
Artificial intelligence (AI) refers to computer systems that simulate human intelligence, learning, and problem-solving. AI uses a

-----
Temperature: 0.5
Artificial Intelligence (AI) refers to machines that simulate human intelligence, learning, and problem-solving. AI uses algor
```

Temperature: 0.6

Artificial intelligence (AI) is a technology that enables machines to think, learn, and act like humans, using algorithms and data to perform tasks.

Temperature: 0.7

AI refers to intelligent machines that learn, reason, and interact like humans. Using algorithms and data, AI systems perform tasks.

Temperature: 0.8

Artificial intelligence (AI) refers to computer systems that simulate human intelligence, learning, and problem-solving. AI uses algorithms to enable machines to think, learn, and act like humans, automating tasks and making decisions.

Temperature: 0.9

Artificial Intelligence (AI) uses algorithms to enable machines to think, learn, and act like humans, automating tasks and making decisions.

Temperature: 1.0

Artificial Intelligence (AI) refers to computer systems that simulate human thought, learning, and problem-solving. AI uses algorithms to enable machines to think, learn, and act like humans, automating tasks and making decisions.

Temperature: 1.1

Artificial intelligence (AI) refers to computer systems that mimic human intelligence, learning, and problem-solving abilities.

Temperature: 1.2

Artificial intelligence (AI) refers to machines that simulate human thought, using algorithms and data to learn, reason, and interact like humans.

Temperature: 1.3

Artificial intelligence (AI) refers to computer systems that mimic human intelligence, learning from data and performing tasks.

client.chat.completions.create(...)

client: This is your Groq client (already authenticated with your API key).

.chat: You're using the chat endpoint (for conversational prompts, like ChatGPT).

.completions: Refers to chat-based completions (responses to messages).

.create(...): This method sends a new request to generate a completion.

top_p=1 — Nucleus Sampling (a.k.a. "top-p sampling")

Purpose: Controls how many of the most likely words are considered when picking the next token.

top_p sets a cumulative probability threshold.

🧠 1. `top_p=1` — Nucleus Sampling (a.k.a. "top-p sampling")

- **Purpose:** Controls how many of the most likely words are considered when picking the next token.
- `top_p` sets a **cumulative probability threshold**.

💡 Example:

Let's say the model assigns the following probabilities for the next word:

Word	Probability
"AI"	0.45
"machine"	0.25
"robot"	0.15
"art"	0.10
"apple"	0.05

- If `top_p=0.9` : The model picks from the top set of words whose combined probabilities $\leq 0.9 \rightarrow$ "AI", "machine", "robot".
- If `top_p=1` : No filtering — consider all possible tokens (100%).

```
import nltk
nltk.download('punkt')
nltk.download('punkt_tab') # Add this line to download the missing resource
from nltk.tokenize import word_tokenize

sentence = "Machine learning is fun!"
tokens = word_tokenize(sentence)

print("Tokens:", tokens)

Tokens: ['Machine', 'learning', 'is', 'fun', '!']
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
[nltk_data] Downloading package punkt_tab to /root/nltk_data...
[nltk_data]   Package punkt_tab is already up-to-date!
```

```
from transformers import BertTokenizer

# Load pretrained tokenizer
tokenizer = BertTokenizer.from_pretrained('bert-base-uncased')

sentence = "Unhappiness is contagious."
tokens = tokenizer.tokenize(sentence)

print("Subtokens:", tokens)
```

```
/usr/local/lib/python3.12/dist-packages/huggingface_hub/utils/_auth.py:94: UserWarning:  
The secret `HF_TOKEN` does not exist in your Colab secrets.  
To authenticate with the Hugging Face Hub, create a token in your settings tab (https://huggingface.co/settings/tokens), set it  
You will be able to reuse this secret in all of your notebooks.  
Please note that authentication is recommended but still optional to access public models or datasets.  
    warnings.warn(  
tokenizer_config.json: 100%                                         48.0/48.0 [00:00<00:00, 1.40kB/s]  
vocab.txt: 100%                                              232k/232k [00:00<00:00, 3.64MB/s]
```

```
import numpy as np  
from numpy.linalg import norm  
  
A = np.array([2, 1, 2, 3, 2, 9])  
B = np.array([3, 4, 2, 4, 5, 5])  
  
# compute cosine similarity  
cosine = np.dot(A, B) / (norm(A) * norm(B))  
print("Cosine Similarity:", cosine)
```

```
Cosine Similarity: 0.8188504723485274
```

```
from transformers import AutoTokenizer  
  
# Load a tokenizer (e.g., BERT)  
tokenizer = AutoTokenizer.from_pretrained("bert-base-uncased")  
  
text = "Machine learning is transforming materials science!"  
  
# Tokenize  
tokens = tokenizer.tokenize(text)  
token_ids = tokenizer.encode(text)  
  
print("Tokens:", tokens)  
print("Token IDs:", token_ids)
```

```
/usr/local/lib/python3.12/dist-packages/huggingface_hub/utils/_auth.py:94: UserWarning:  
The secret `HF_TOKEN` does not exist in your Colab secrets.  
To authenticate with the Hugging Face Hub, create a token in your settings tab (https://huggingface.co/settings/tokens), set it  
You will be able to reuse this secret in all of your notebooks.  
Please note that authentication is recommended but still optional to access public models or datasets.  
    warnings.warn(  
tokenizer_config.json: 100%                                         48.0/48.0 [00:00<00:00, 2.54kB/s]  
config.json: 100%                                              570/570 [00:00<00:00, 13.8kB/s]
```