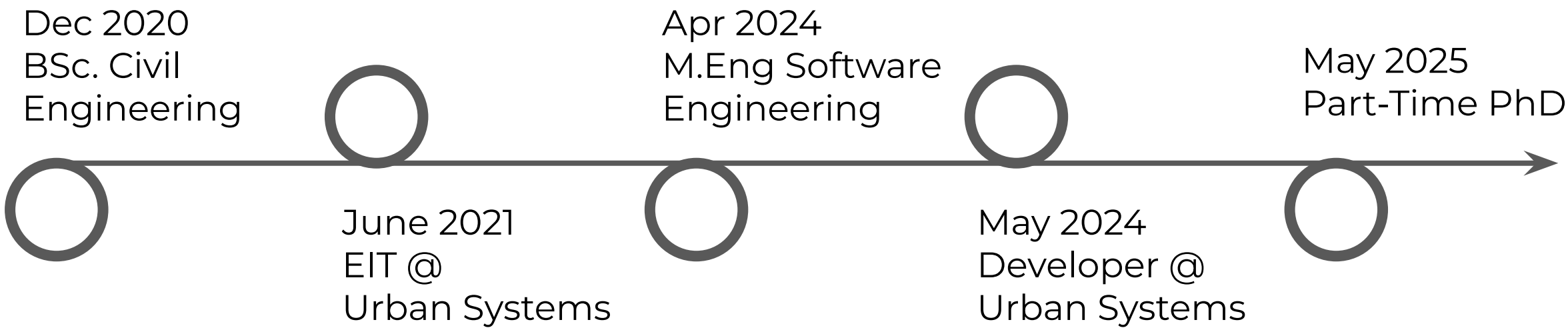
Intro to Large Language Models

UC Workshop

INTRODUCTION, OVERVIEW, & FINE-TUNING

URBAN SYSTEMS

Who is Corey Yang-Smith?



URBAN SYSTEMS

Who is Corey Yang-Smith?

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Dec 2020
BSc. Civil
Engineering

June 2021
EIT @
Urban Systems

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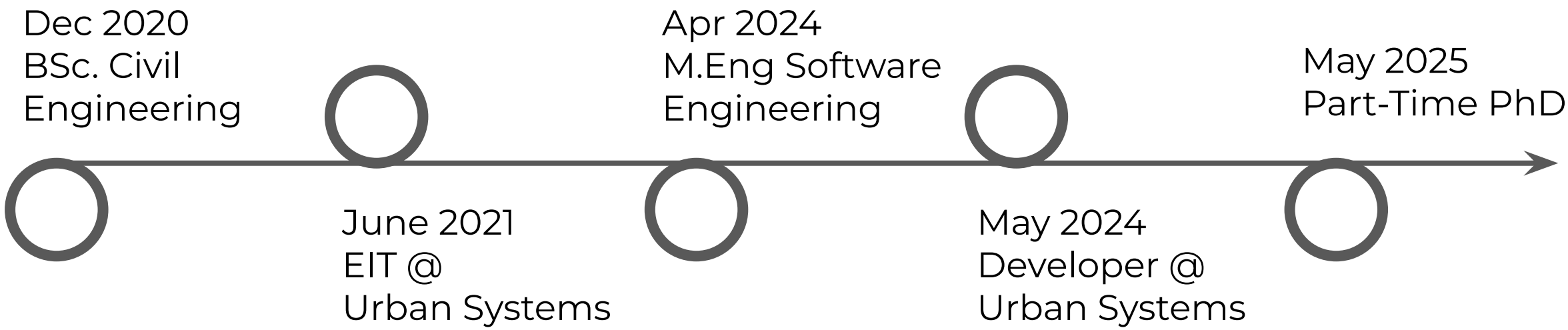

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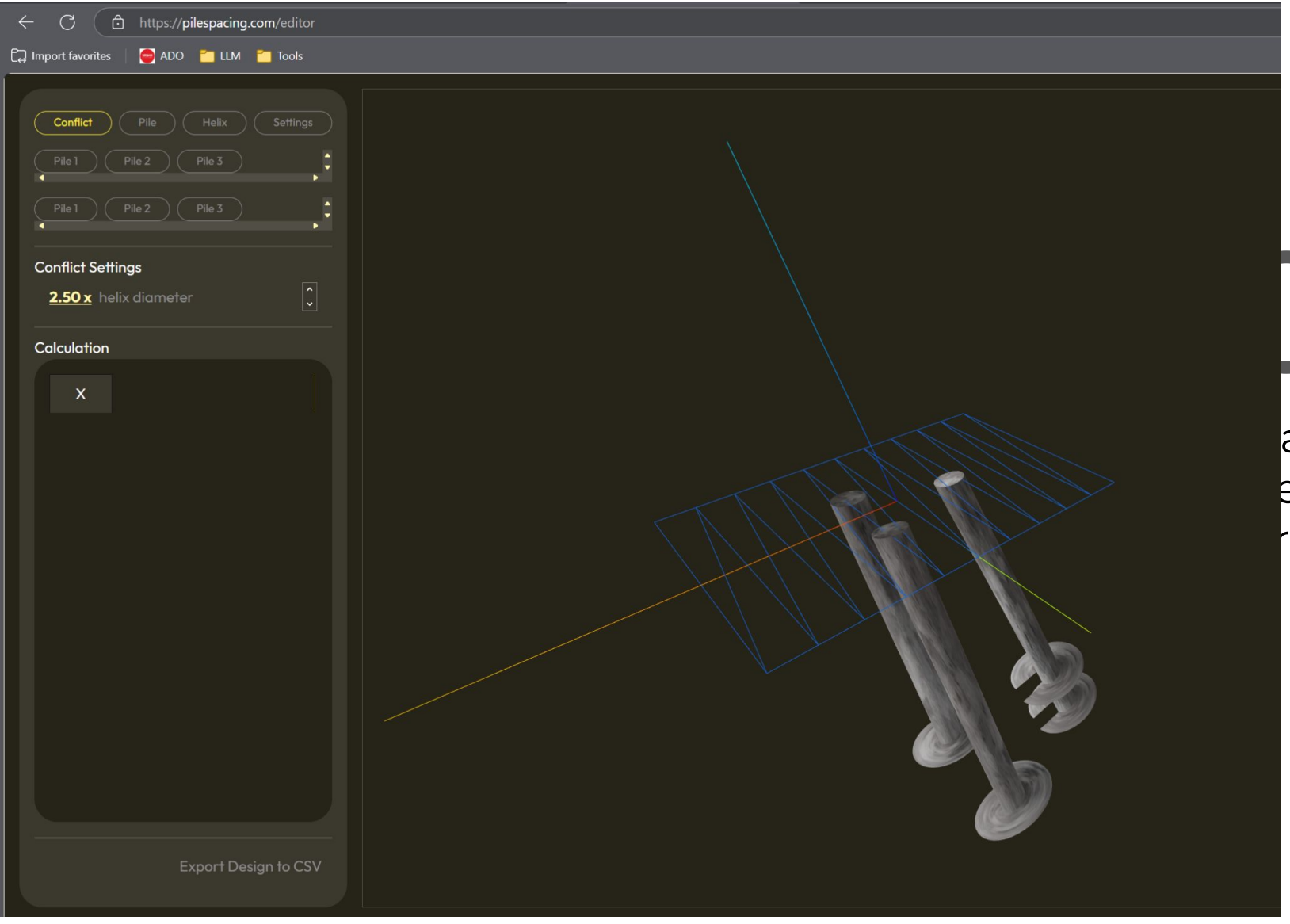

May 2025
Part-Time PhD

ay 2024
eveloper @
rban Systems

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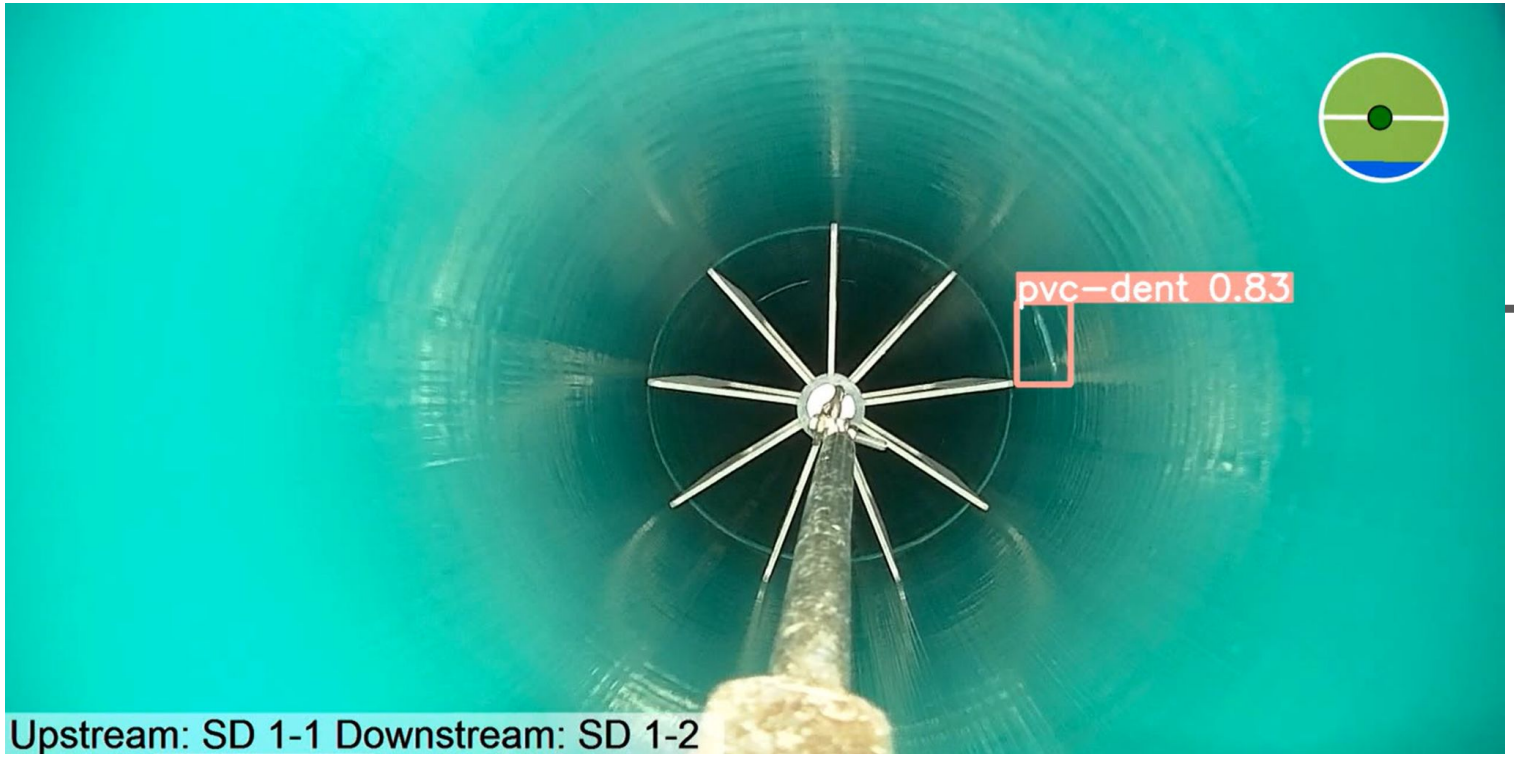

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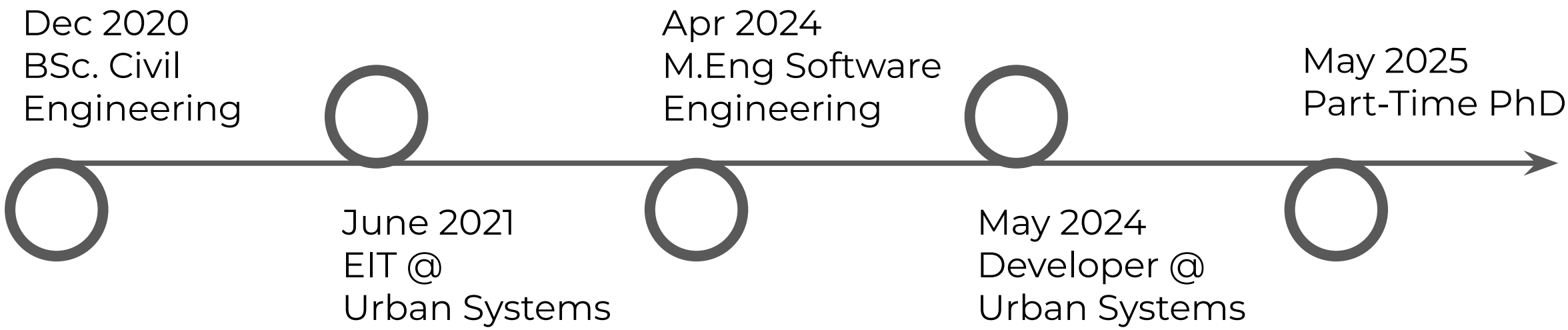

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OBJECTIVES

LECTURE

- Cover fundamentals of large language models (LLMs)
- Explore design considerations and trade-offs
- Explore model training (pre-training, fine-tuning)
- Explore high-impact prompting techniques

WORKSHOP

- Gain hands-on experience interfacing with LLMs through API and libraries
- Gain experience with different prompting techniques
- Fine-tune a local model

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AGENDA

#1

COMPONENTS OF AN LLM

- Model Construction
- Model Design
- Model Sizing

#2

PROMPTING STRUCTURE

- Prompting Structure
- Parameters
- Model Interface

#3

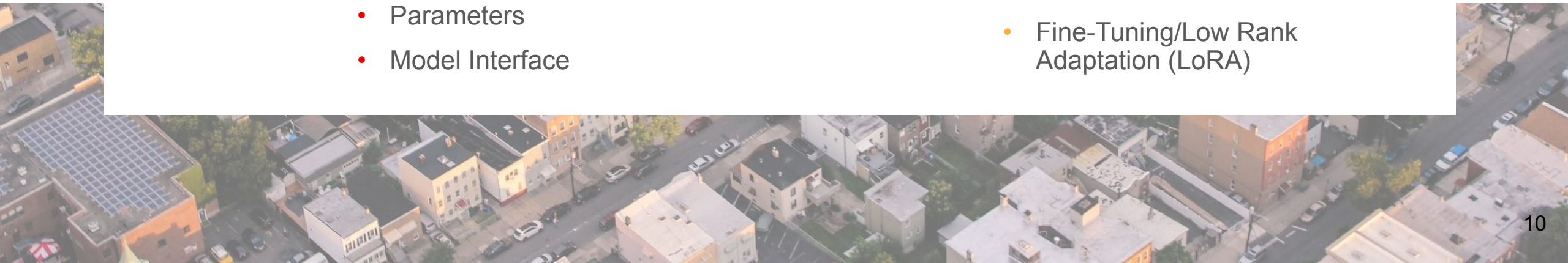
PROMPTING TECHNIQUES

- Few-Shot
- Chain-of-Thought

#4

MODEL TRAINING

- Pre-Training
- Fine-Tuning/Low Rank Adaptation (LoRA)



WHAT IS A LARGE LANGUAGE MODEL?

WHAT IS A ~~LARGE~~ LANGUAGE MODEL?

URBAN SYSTEMS

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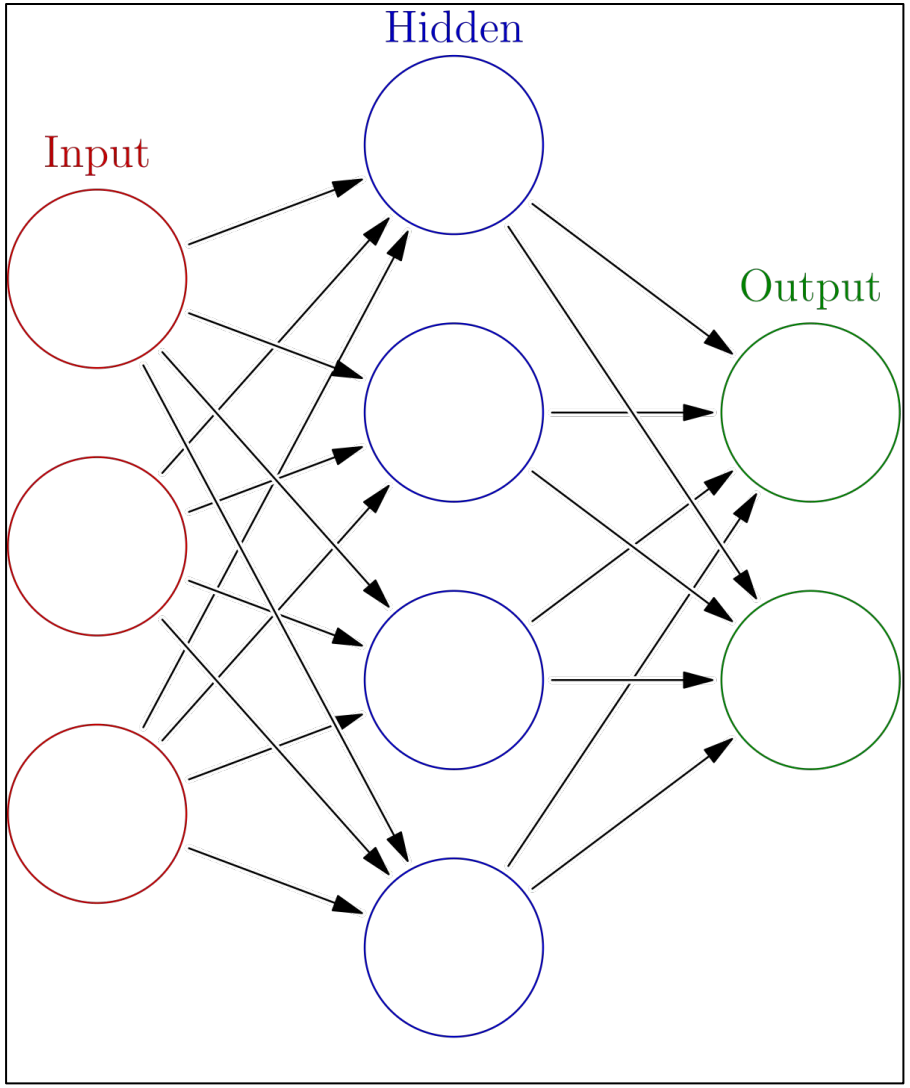

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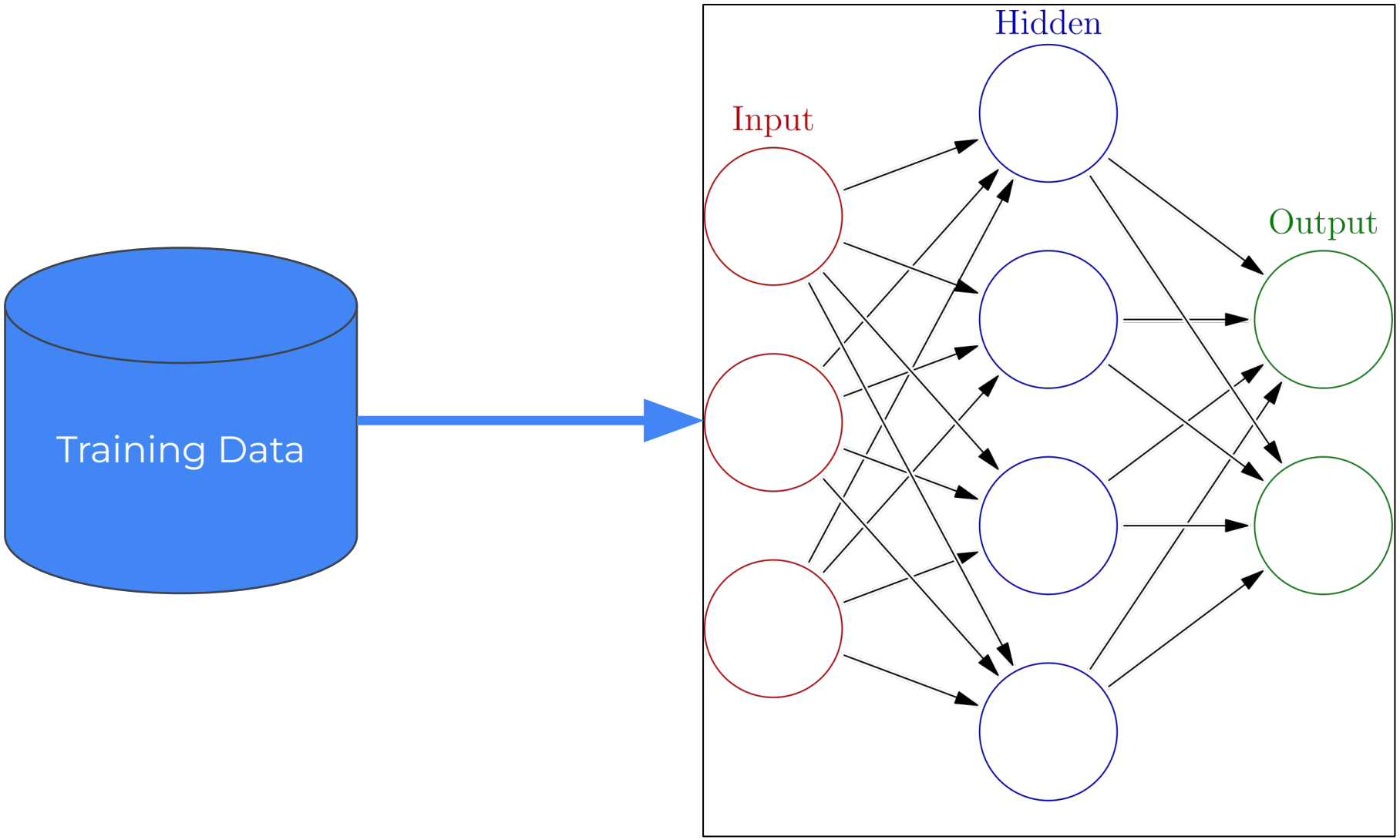

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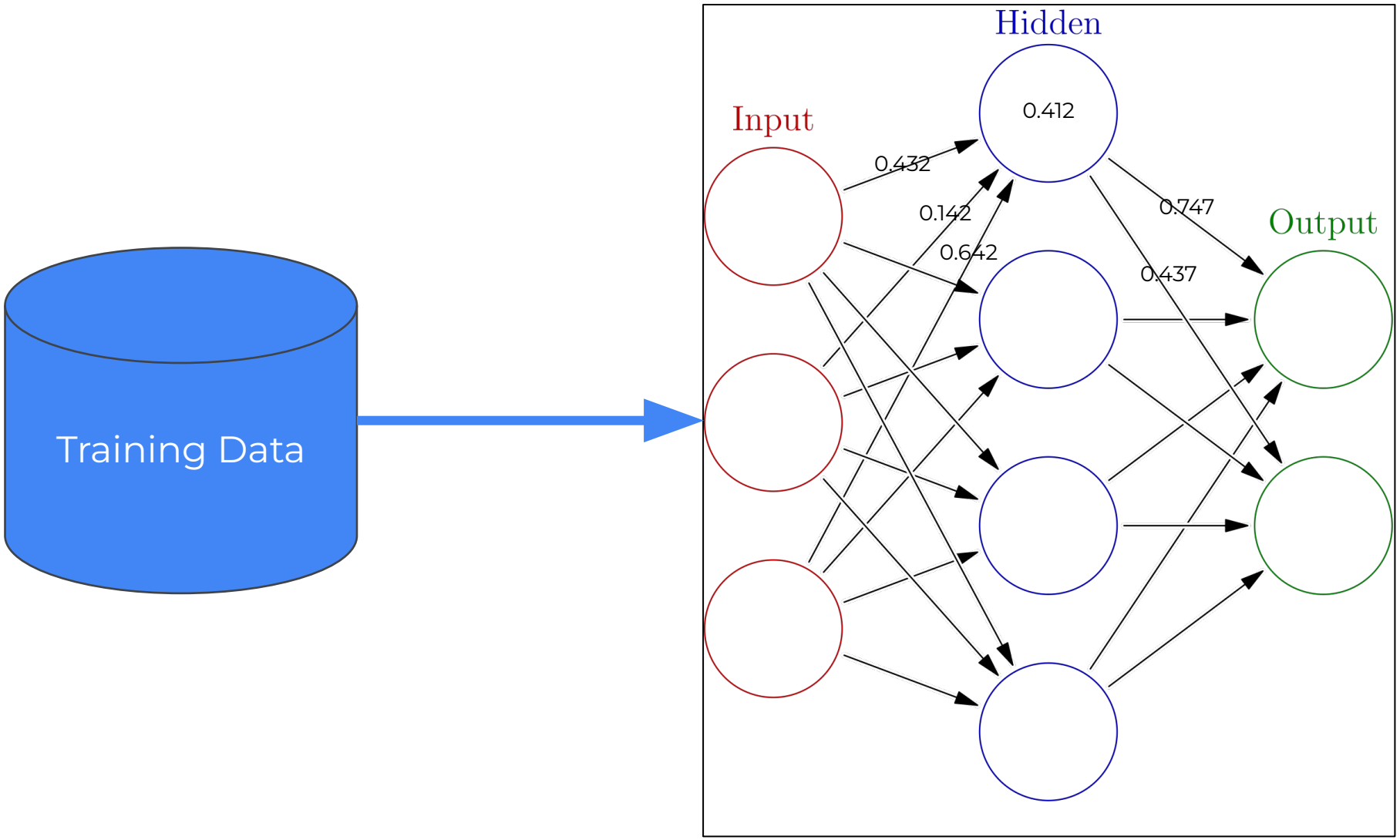
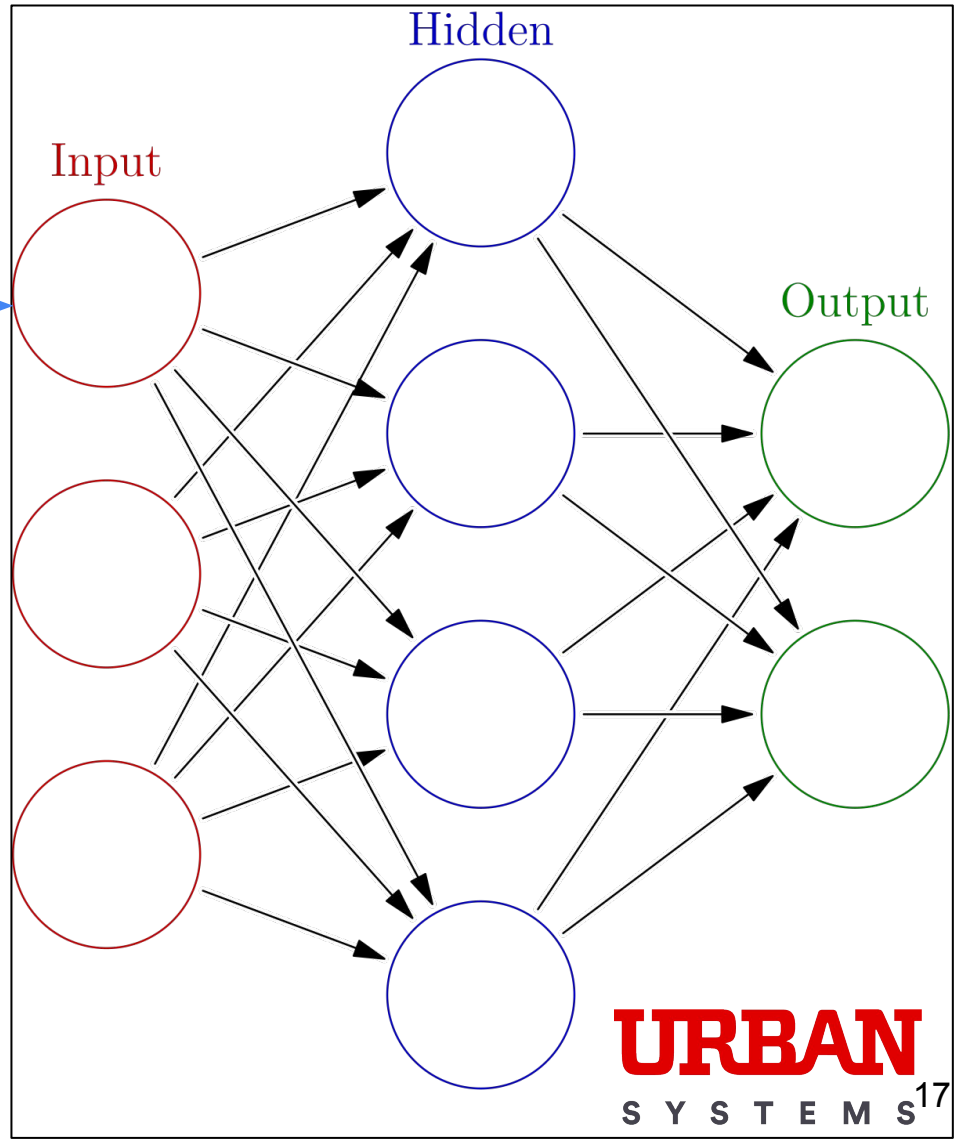


WHAT IS A ~~LARGE LANGUAGE~~ MODEL?

Speed
40km/hr

40



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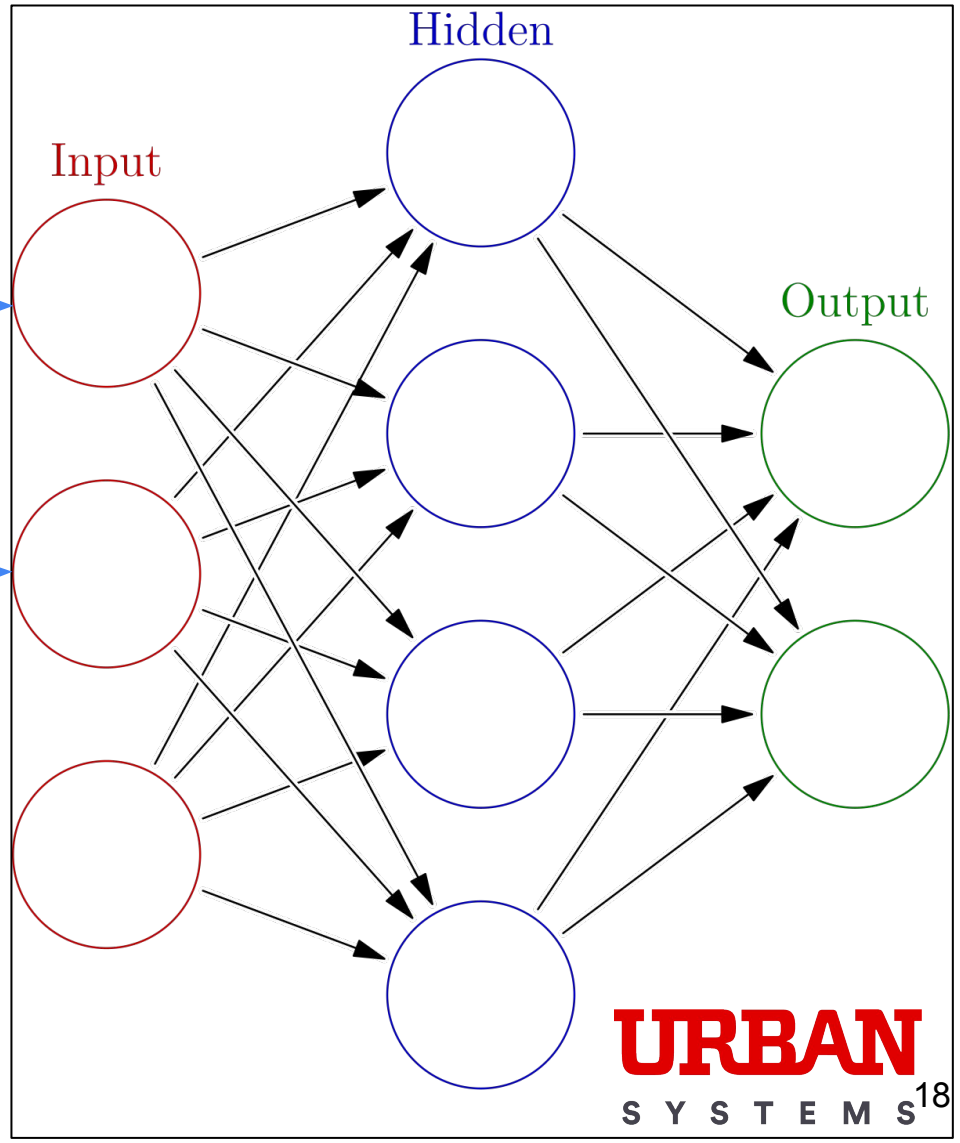
WHAT IS A ~~LARGE LANGUAGE~~ MODEL?

Speed
40km/hr

40

Time of Day
Midday

2



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WHAT IS A ~~LARGE LANGUAGE~~ MODEL?

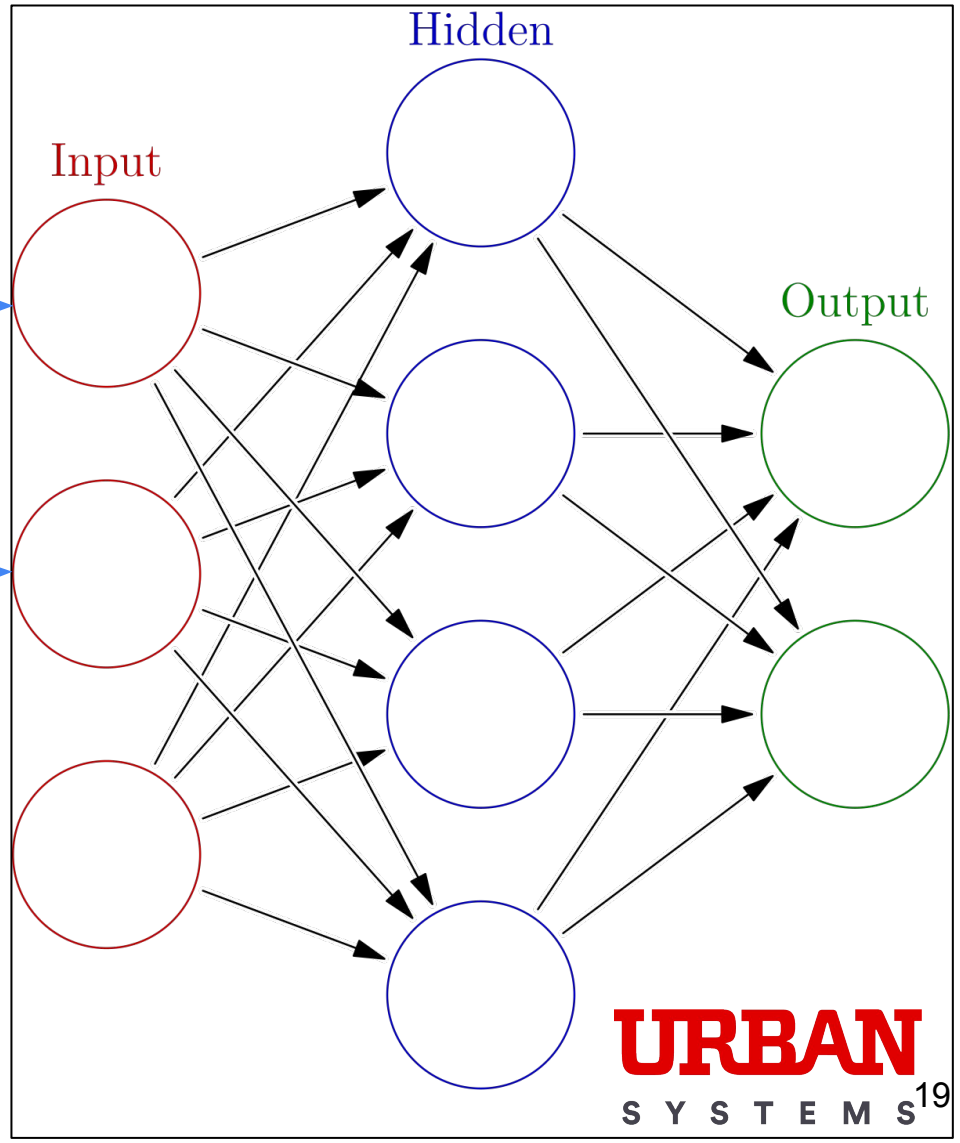
Speed
40km/hr

40

Time of Day
Midday

Ordinal Encoding

2



URBAN SYSTEMS

WHAT IS A ~~LARGE LANGUAGE~~ MODEL?

Speed
40km/hr

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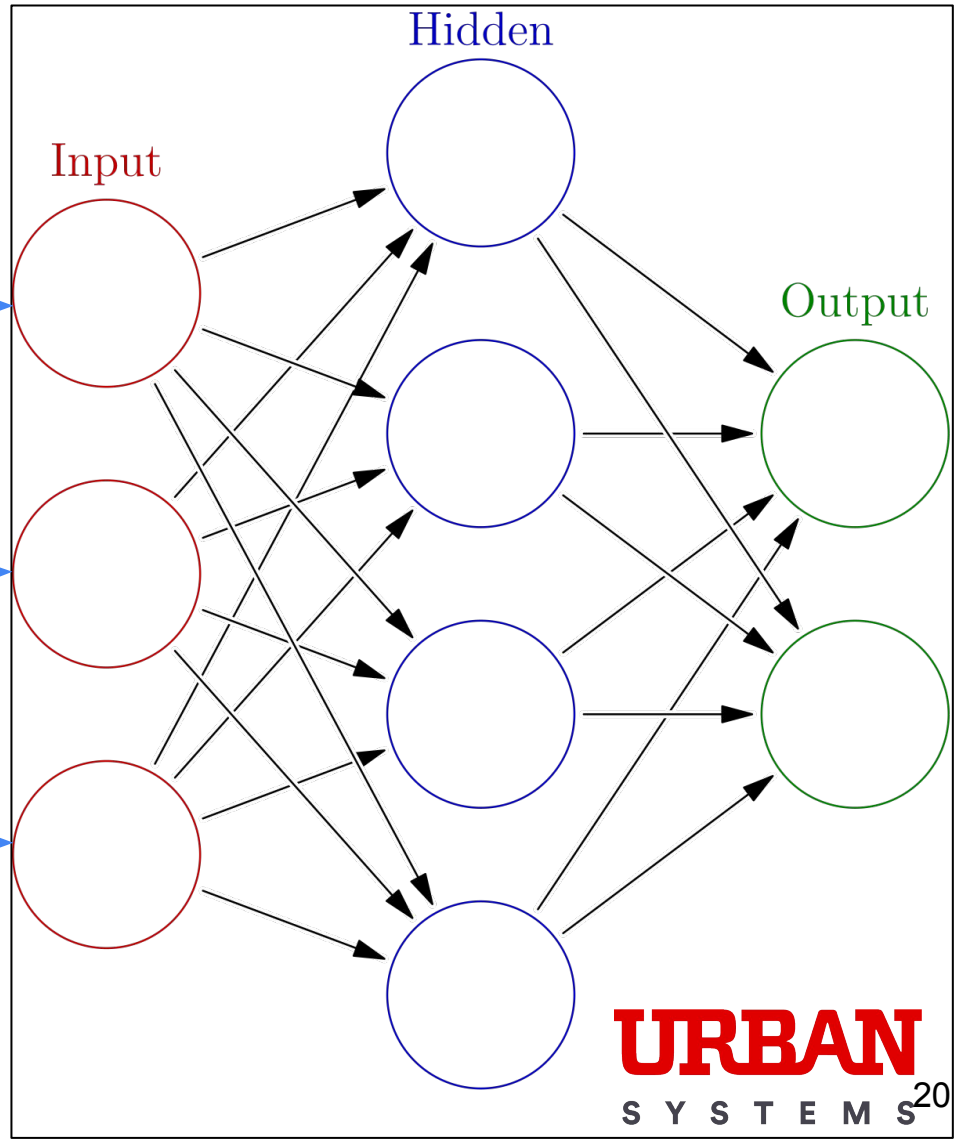
Time of Day
Midday

Ordinal Encoding

2

Image Preprocessing

[[232,12,123],
[231,11,143],
...]



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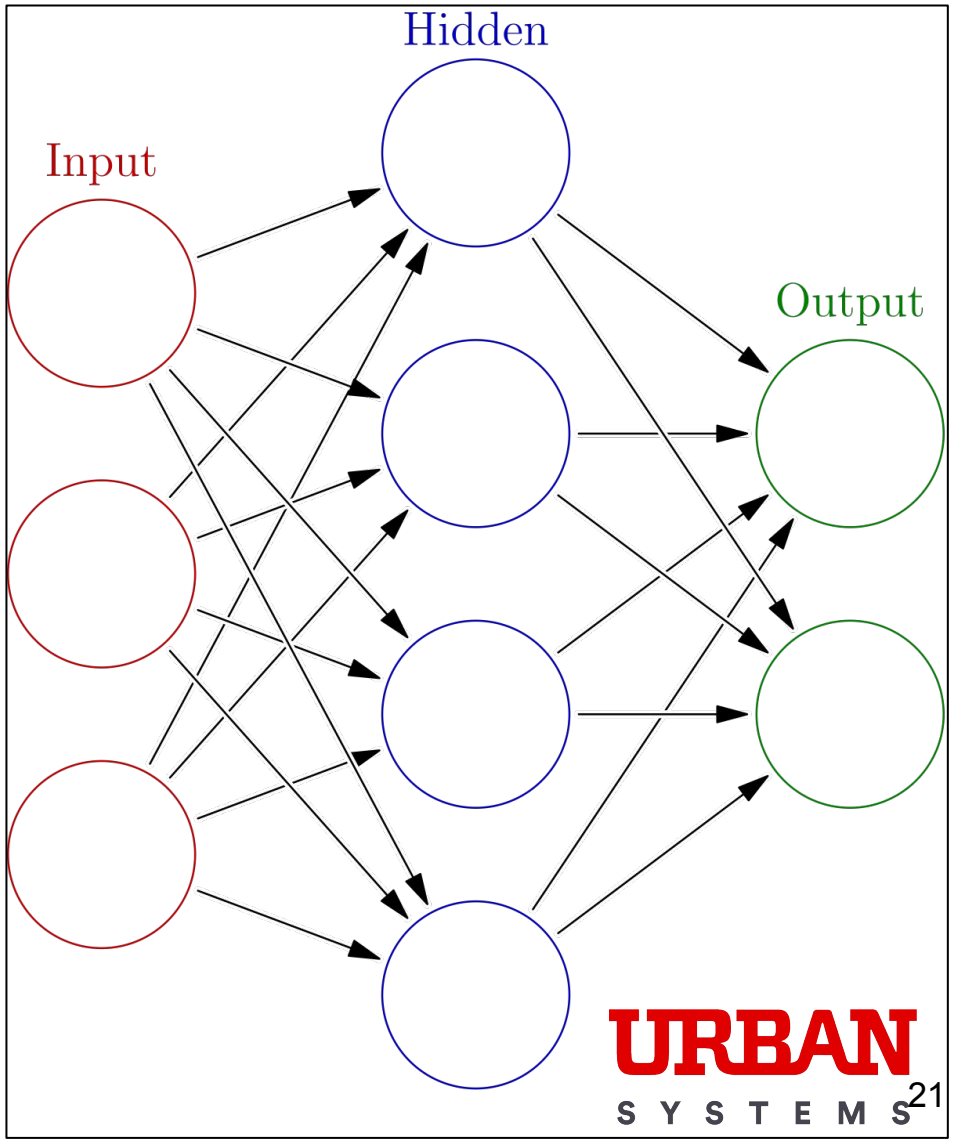
WHAT IS A ~~LARGE~~ LANGUAGE MODEL?

Text Description

Busy, multi-lane collector road near the University of Calgary, connecting commuters and nearby amenities.

?



URBAN SYSTEMS

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amenities.

amenities.

amenities.

amenities.

amenities.

amenities.

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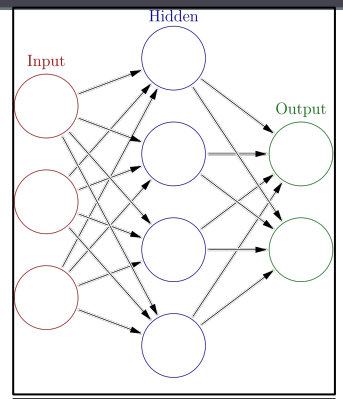
amenities.

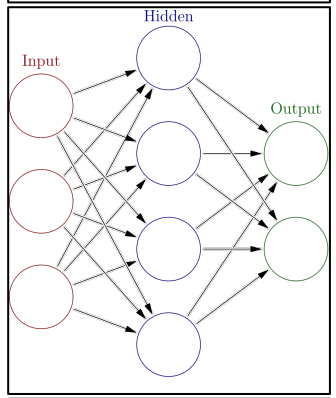
amenities.

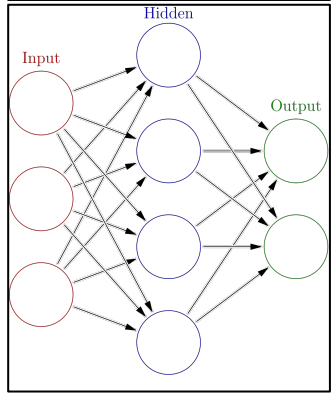
amenities.

amenities.

?







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COMPONENTS OF AN LLM

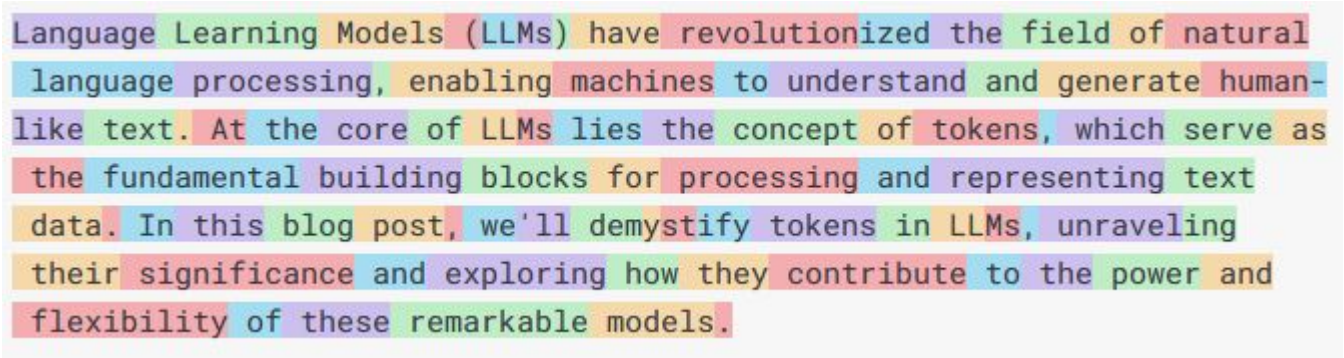
From Paper to Practice

URBAN SYSTEMS

MODEL CONSTRUCTION

TOKENIZATION

- *“Tokenization is used in NLP to split paragraphs and sentences into smaller units that can be more easily assigned meaning”* [Source]



Useful Resources

- [tool] OpenAI Tokenizer
- [tool] Token Visualizer

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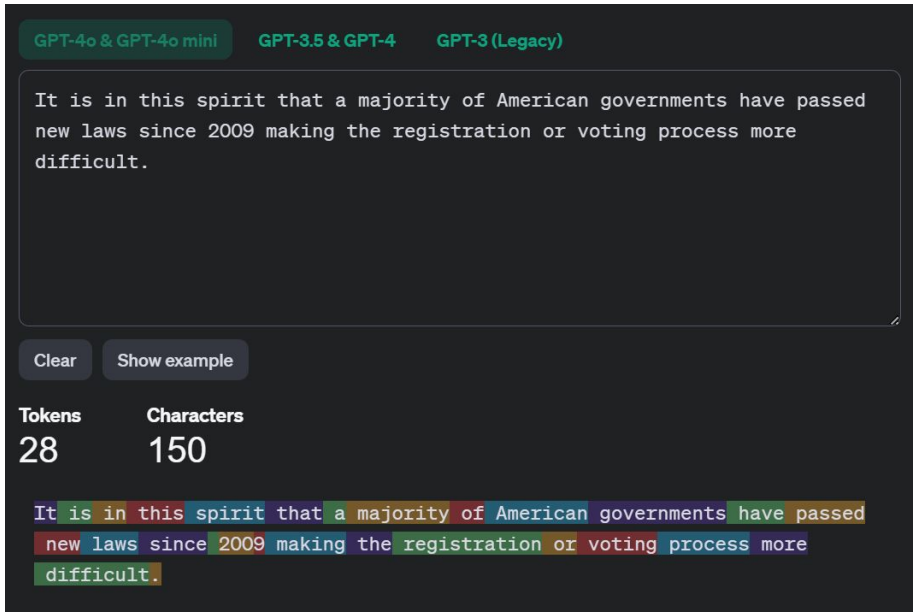
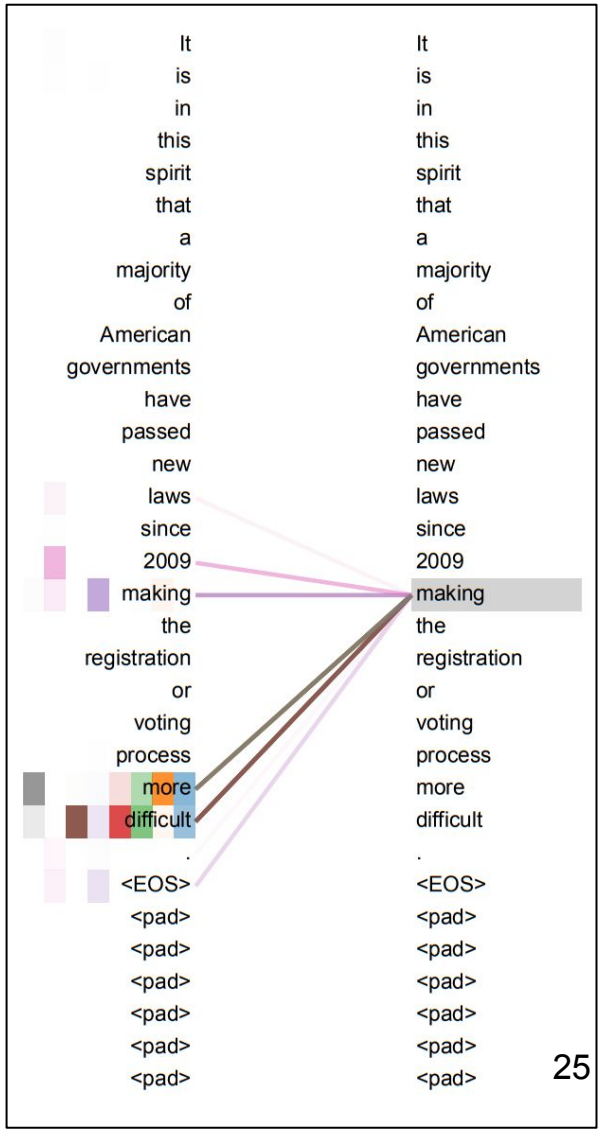
MODEL CONSTRUCTION

TOKENIZATION

- Words
- Subwords
- Characters
- Punctuation
- Special Tokens





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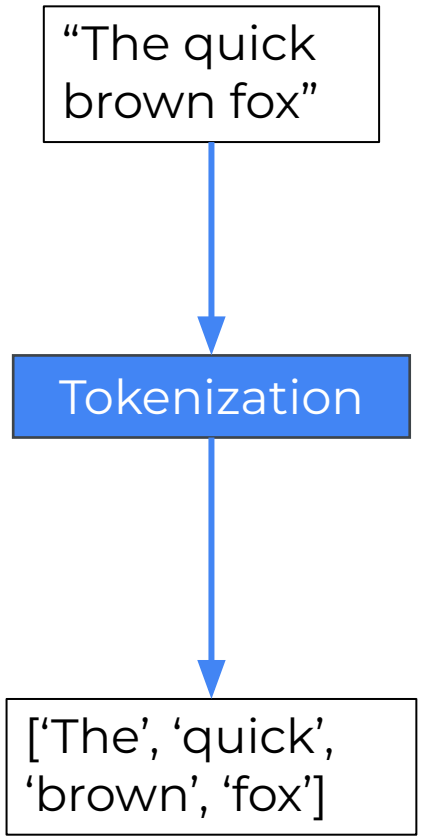
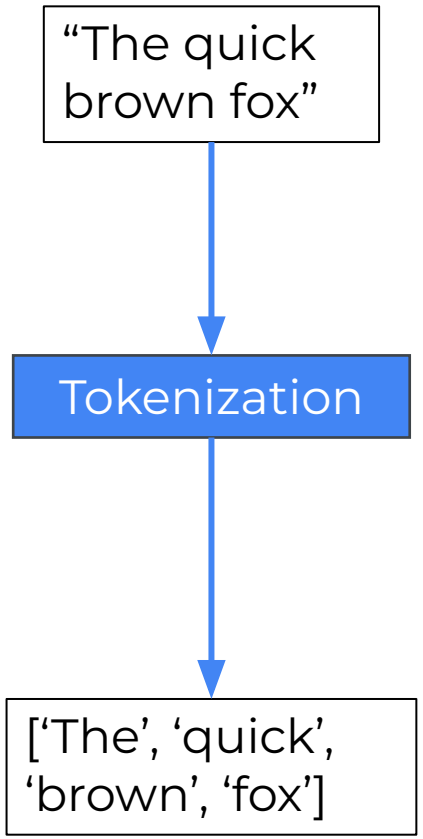
MODEL CONSTRUCTION

Tokenization



MODEL CONSTRUCTION

Tokenization



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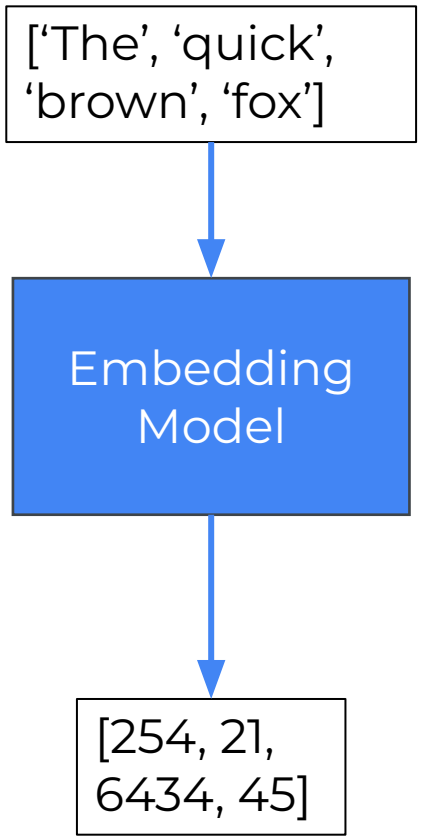

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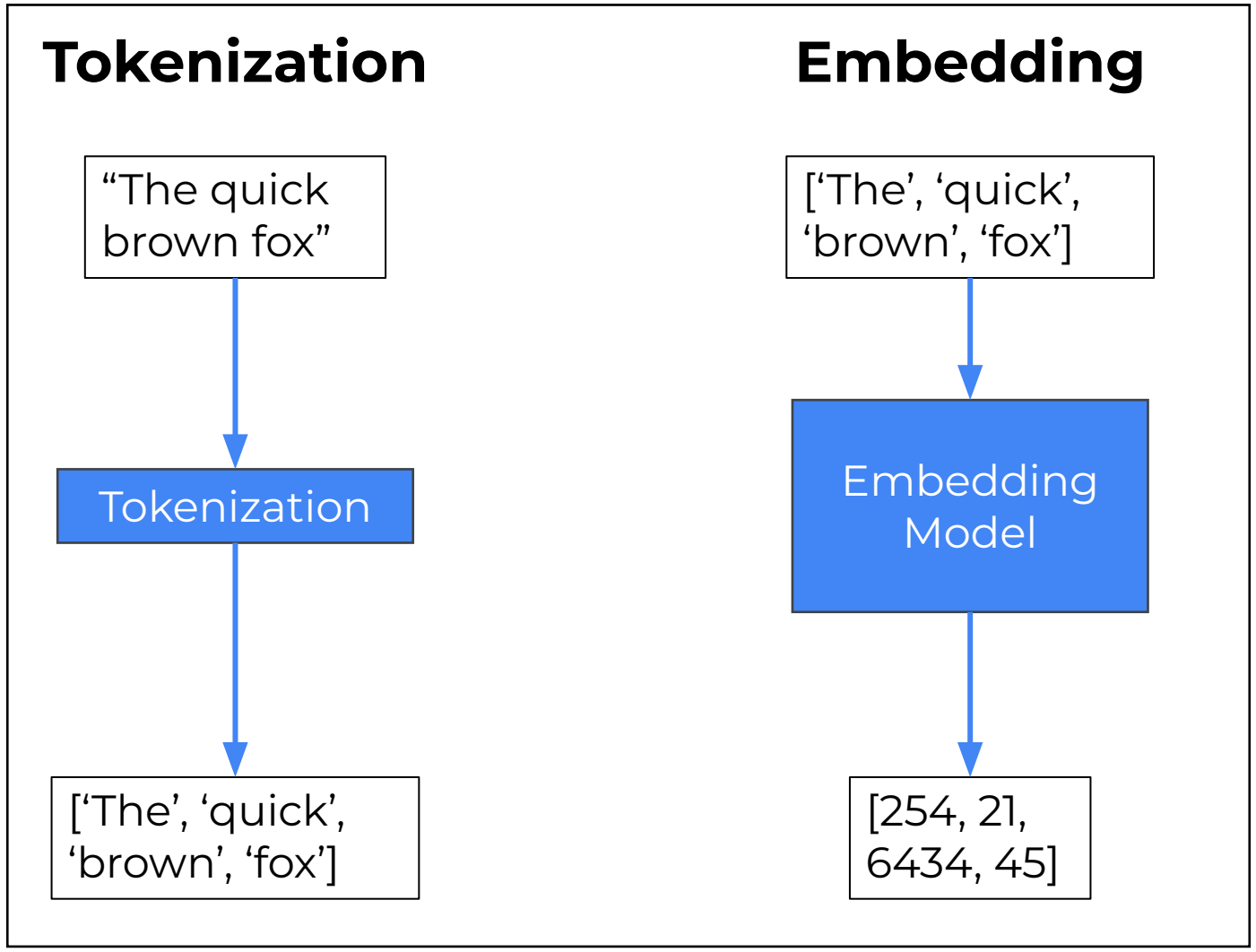
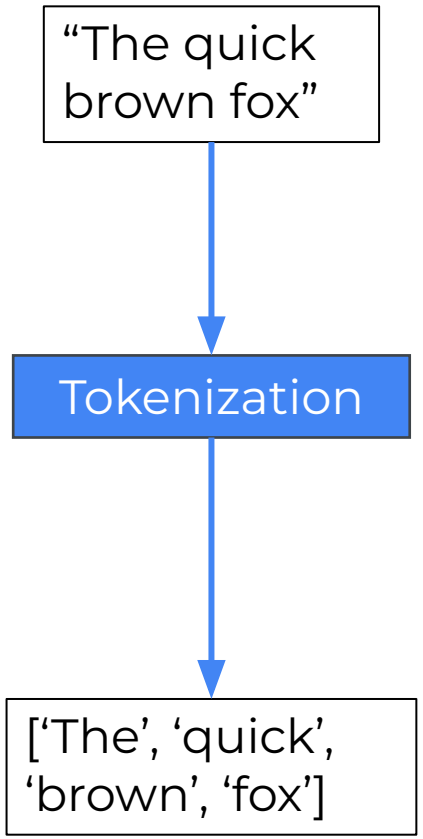
MODEL CONSTRUCTION



Encoding Process

MODEL CONSTRUCTION

Tokenization



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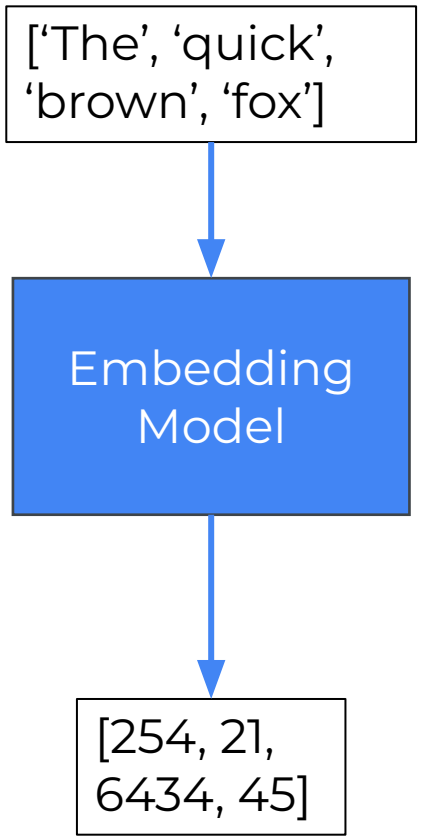
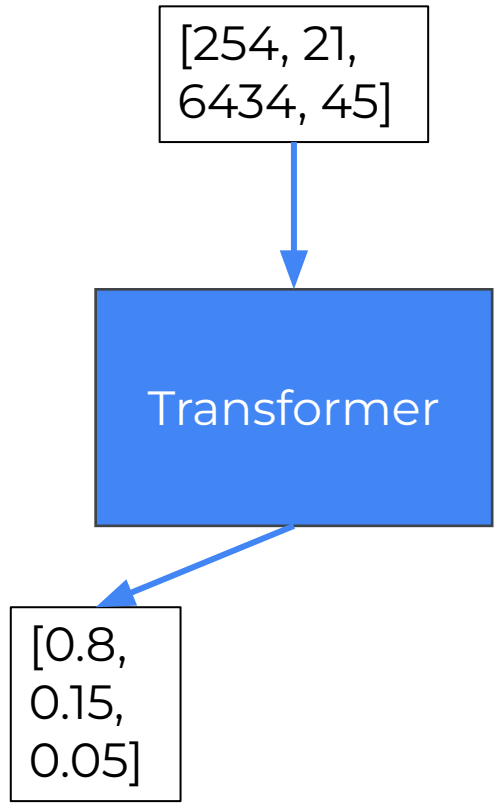


Transformer



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MODEL CONSTRUCTION

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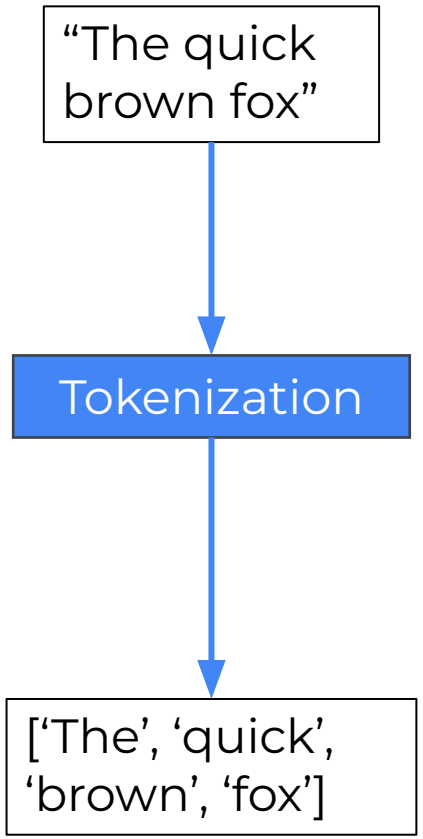

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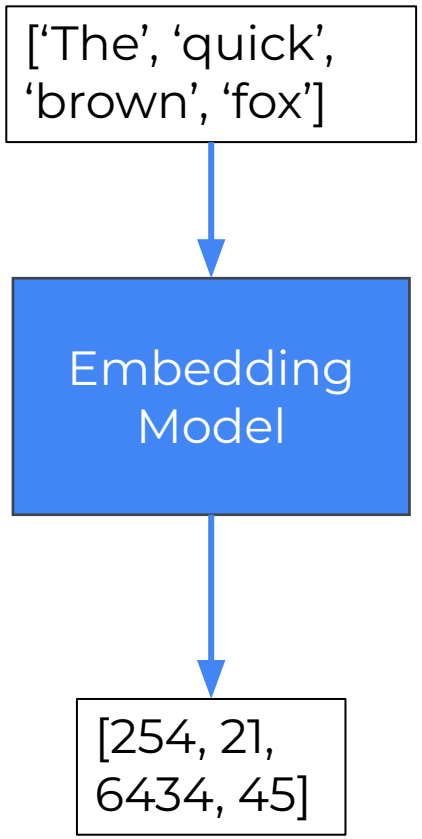

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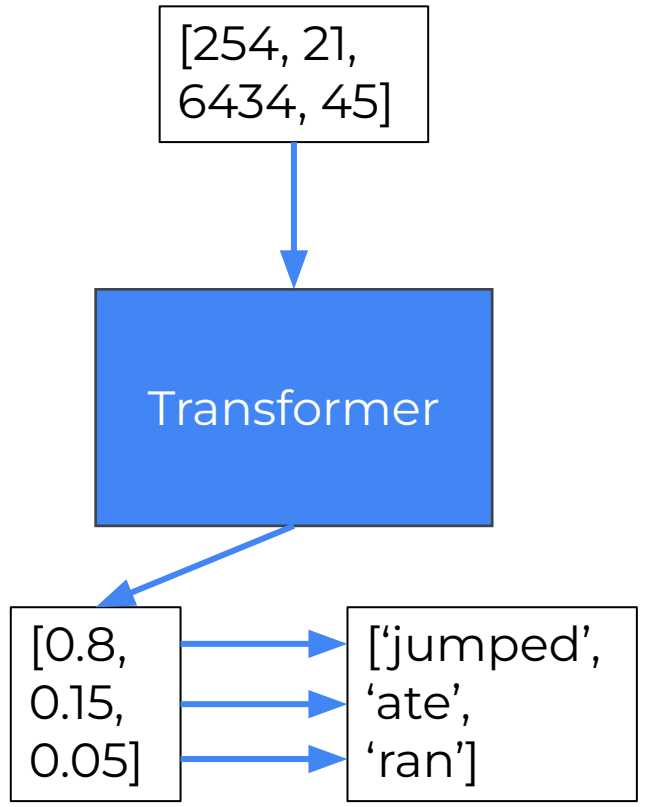

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MODEL CONSTRUCTION

TRANSFORMER ARCHITECTURE

- Compared to historical models (RNN, LSTMs), they're much faster
  - CPU vs GPU

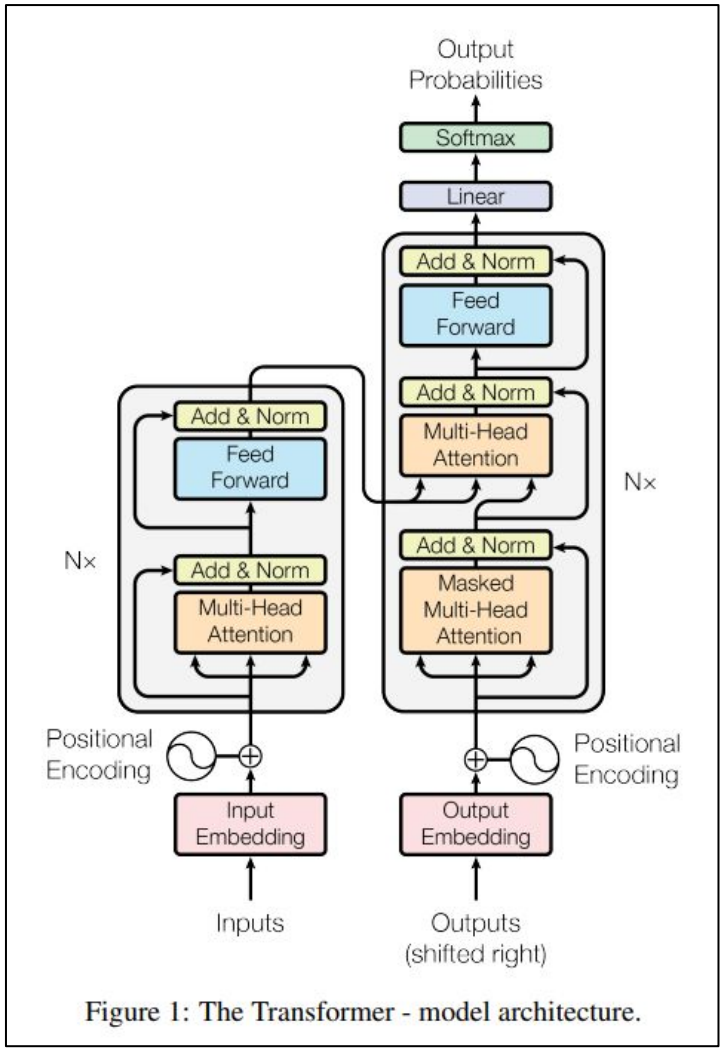

Figure 1: The Transformer - model architecture.

Useful Resources

- [arxiv] Attention Is All You Need
- [youtube] Large Language Models explained briefly
- [tool] Transformer Explained

URBAN SYSTEMS

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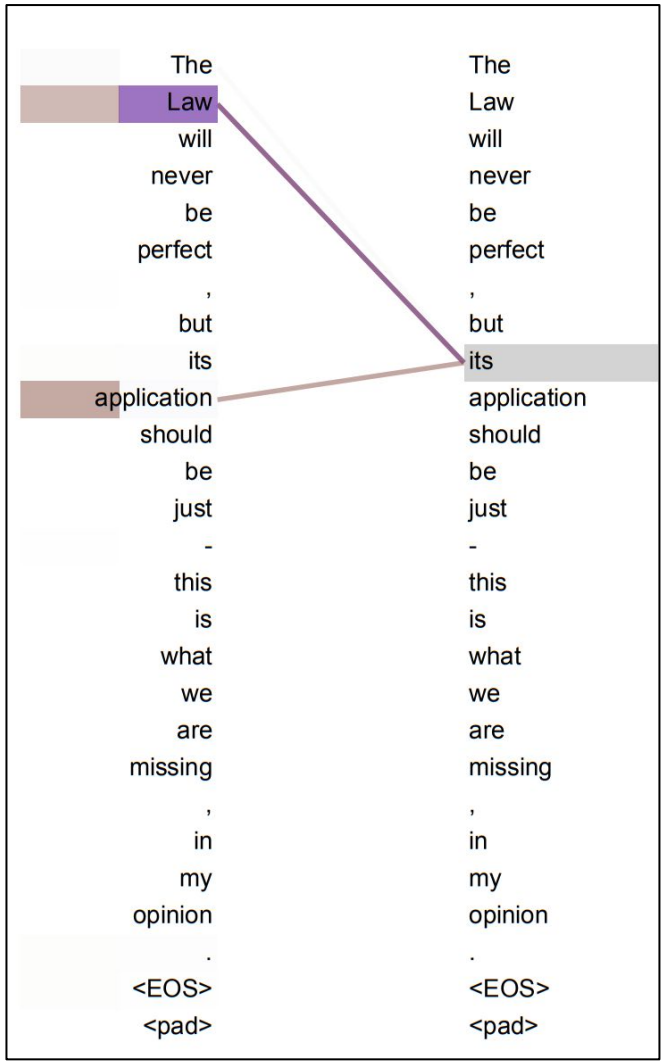
- Attention Mechanism: Understands relationships between words



Attention Visualization, self attention layer in layer 5 of 6

Figure 4 from Attention is All You Need

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URBAN SYSTEMS

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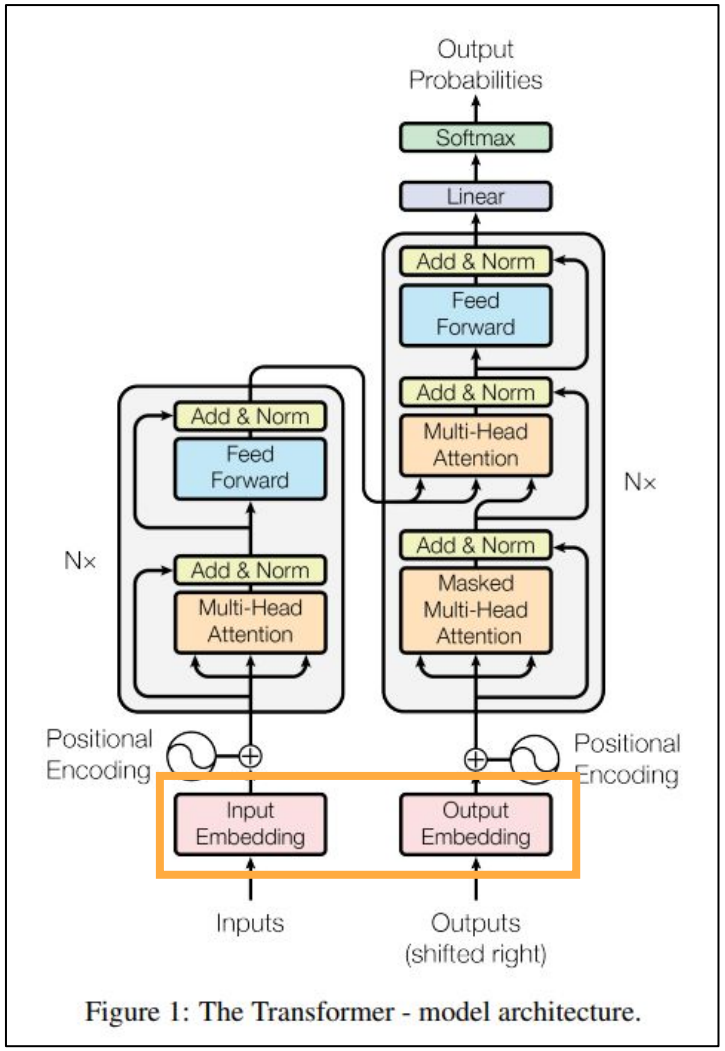
- Tokenization: Operates on tokens (not words)
  - Numerical representation of a word, character, or sub-word



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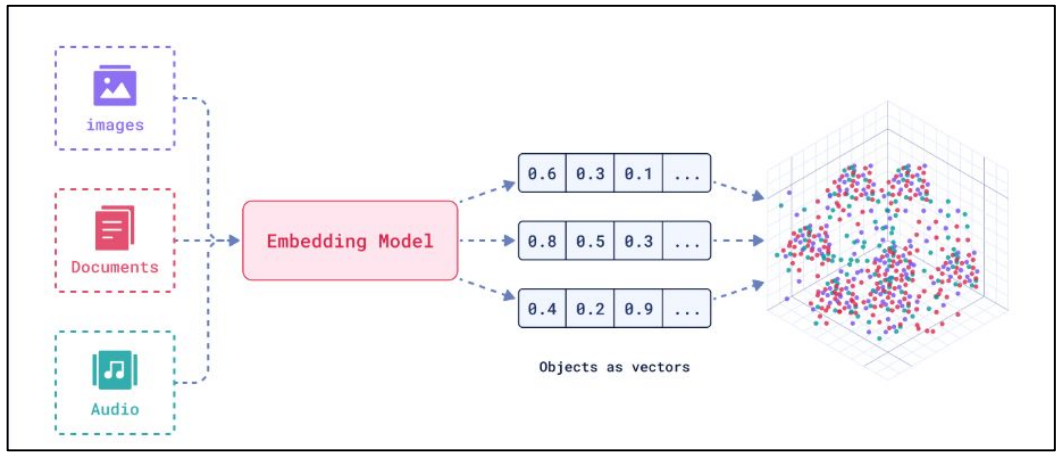

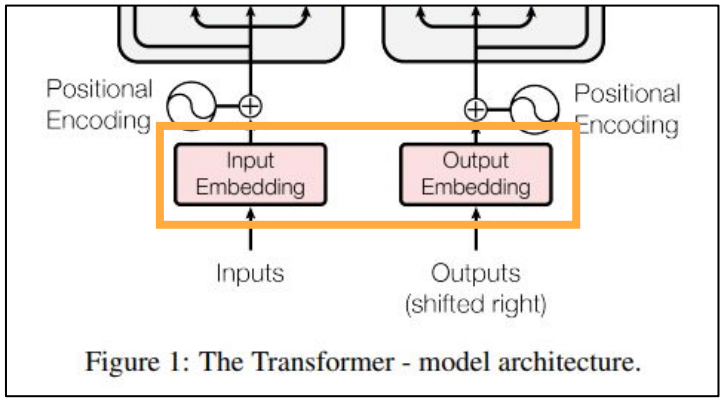

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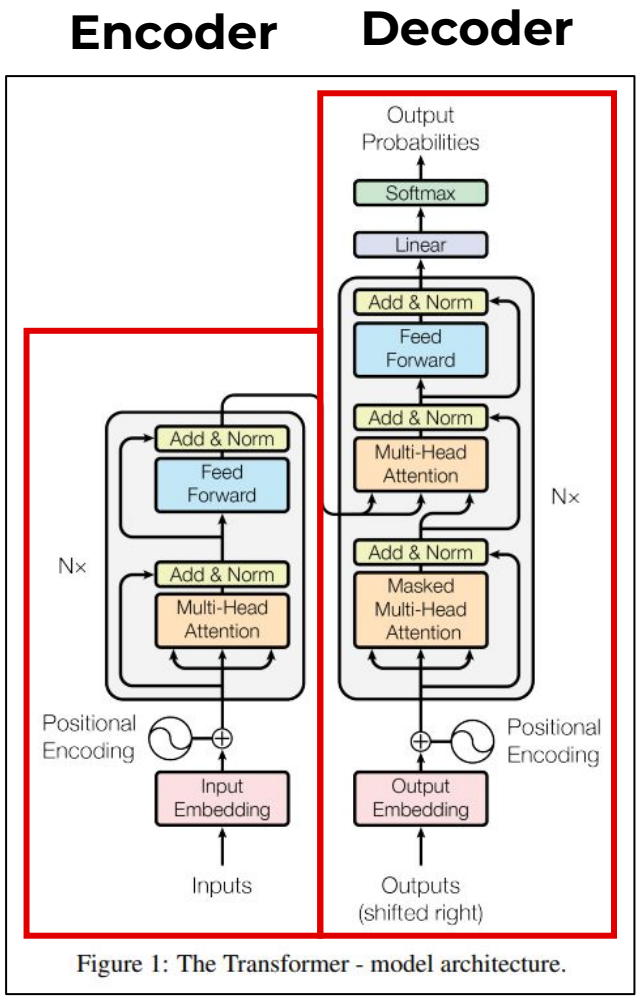
URBAN SYSTEMS

MODEL DESIGN

MODEL TYPES



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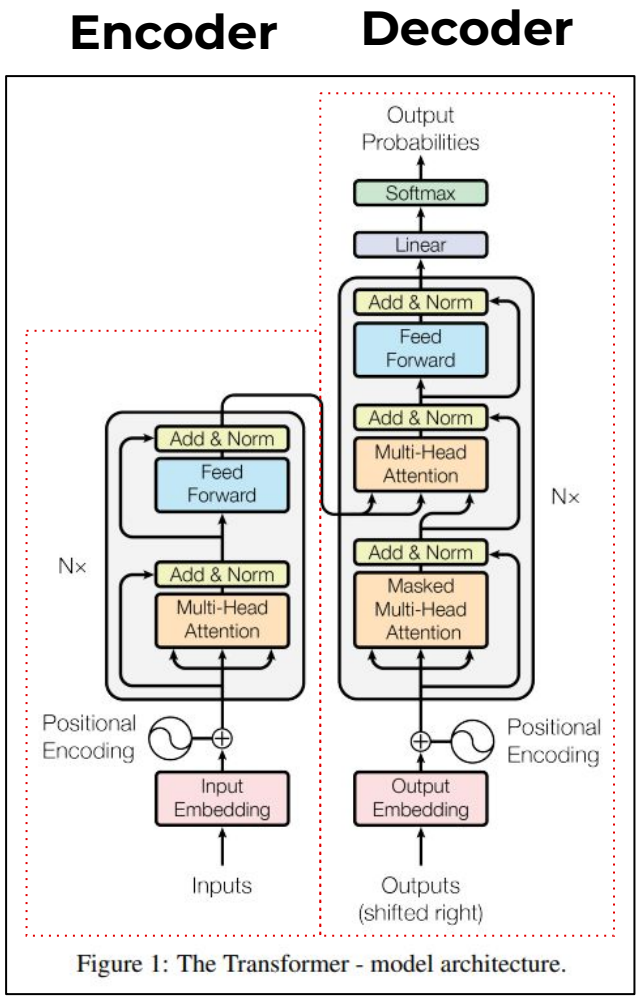

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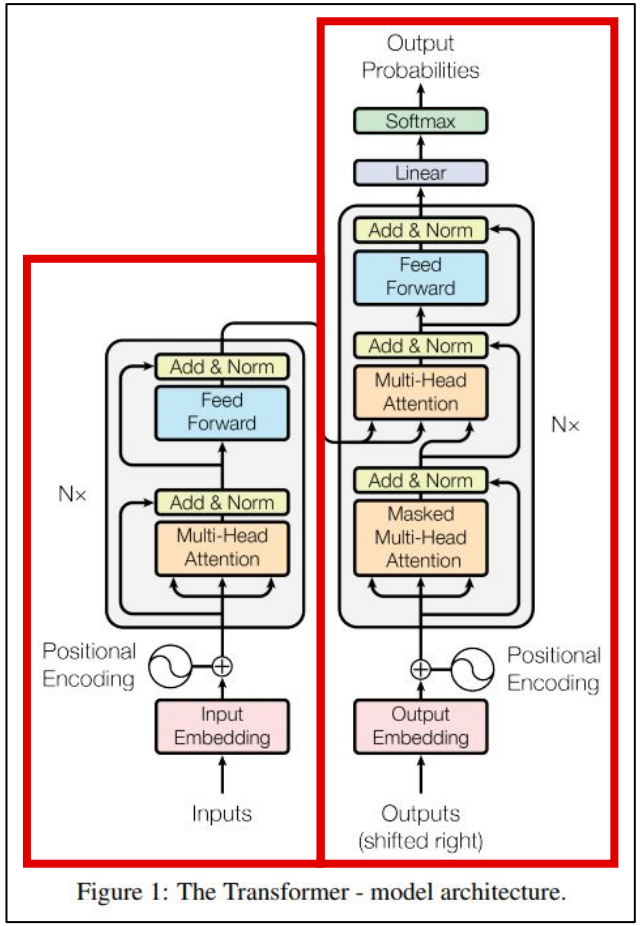
MODEL DESIGN

MODEL TYPES

- Encoder vs Decoder
  - **Encoder-Decoder:** output heavily relies on input, good for translation or summarization tasks. Models: T5, BART



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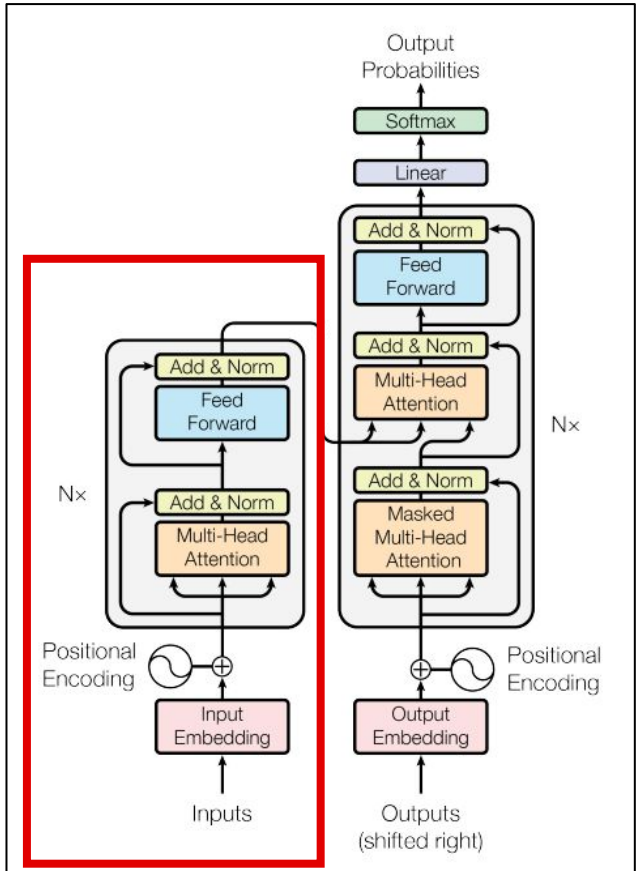
  - **Encoder-only:** Encodes input sequence, optimized for understanding but does not generate output, good for text classification, named entity recognition. Models: BERT



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URBAN SYSTEMS

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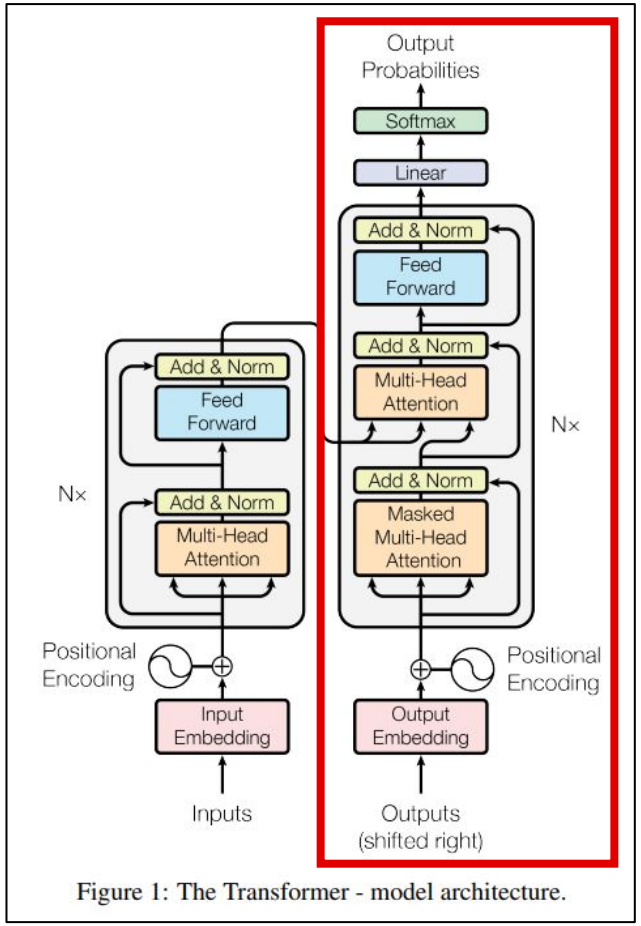
MODEL TYPES

- Encoder vs Decoder
  - **Encoder-Decoder:** output heavily relies on input, good for translation or summarization tasks. Models: T5, BART
  - **Encoder-only:** Encodes input sequence, optimized for understanding but does not generate output, good for text classification, named entity recognition. Models: BERT
  - **Decoder-only:** Focus on autoregressively generating sequences, good for text generation, open-ended QA. Models: ChatGPT



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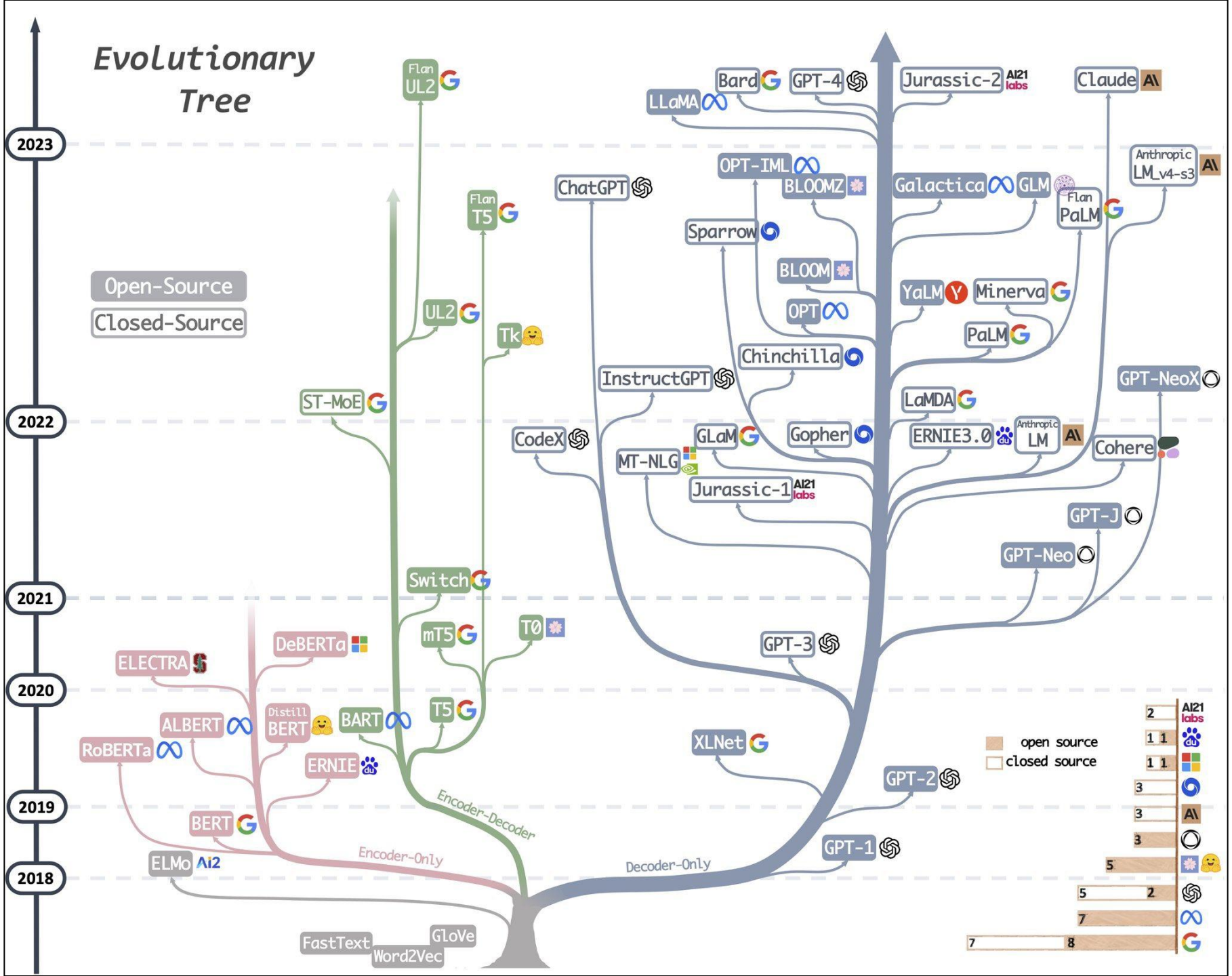

Evolutionary Tree
2023
2022
2021
2020
2019
2018
Open-Source
Closed-Source
Flan UL2
Flan T5
UL2
Tk
ST-MoE
Switch
mT5
T0
DeBERTa
ELECTRA
ALBERT
Distill BERT
BART
T5
RoBERTa
ERNIE
BERT
ELMo Ai2
FastText
GloVe
Word2Vec
Encoder-Only
Encoder-Decoder
Decoder-Only
LLaMA
Bard
GPT-4
Jurassic-2 AI21 labs
Claude A\
ChatGPT
OPT-IML
BLOOMZ
Galactica
GLM
Anthropic LM_v4-s3
Flan PaLM
Sparrow
BLOOM
YaLM
Minerva
OPT
PaLM
Chinchilla
InstructGPT
GPT-NeoX
LaMDA
CodeX
GLaM
Gopher
ERNIE3.0
Anthropic LM A\
Cohere
MT-NLG
Jurassic-1 AI21 labs
GPT-J
GPT-Neo
GPT-3
XLNet
GPT-2
GPT-1
open source
closed source
2
1 1
1 1
3
3
3
5
5 2
7
7 8

MODEL DESIGN

MODEL TYPES

Base Model vs Chat/Instruct

- Base: Simply next-token prediction
- Instruct: Fine-tuned base model to be more helpful for QA and task completion. Often further refined through reinforcement learning with human feedback (RLHF, post-training)

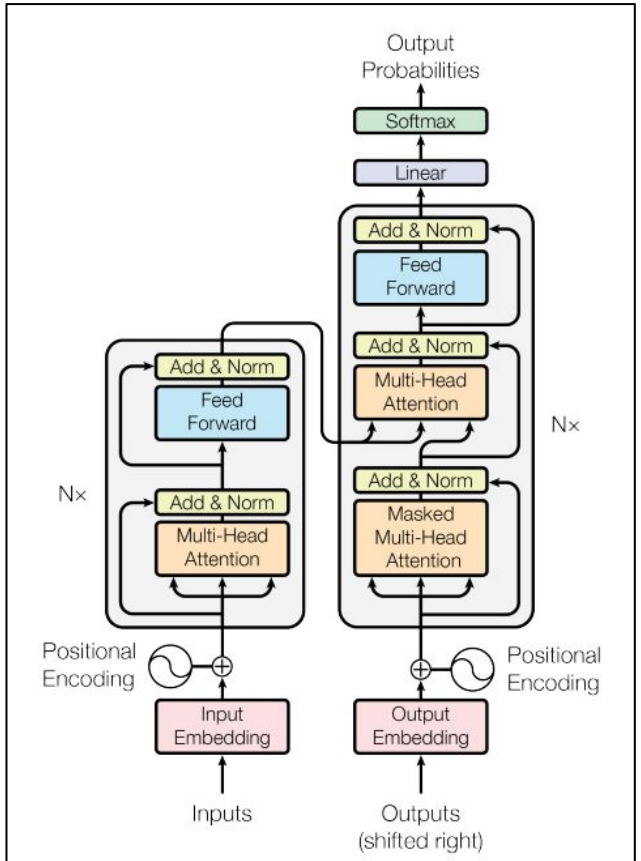


Figure 1: The Transformer - model architecture.

Useful Resources

- [blog] Base LLM vs. Instruction-tuned LLM

URBAN SYSTEMS

MODEL DESIGN

MODEL SIZE

Classification	Model Size	Example
Small	<1B	NanoGPT
Medium	1-10B	Phi-4
Large	10-100B	Llama 3.3
Massive	100B+	GPT 4o

Useful Resources

- [arxiv] Training Compute-Optimal Large Language Models
- [arxiv] A Theory of Emergence of Complex Skills in Language Models
- [arxiv] Skill-Mix: a Flexible and Expandable Family of Evaluations for AI Models

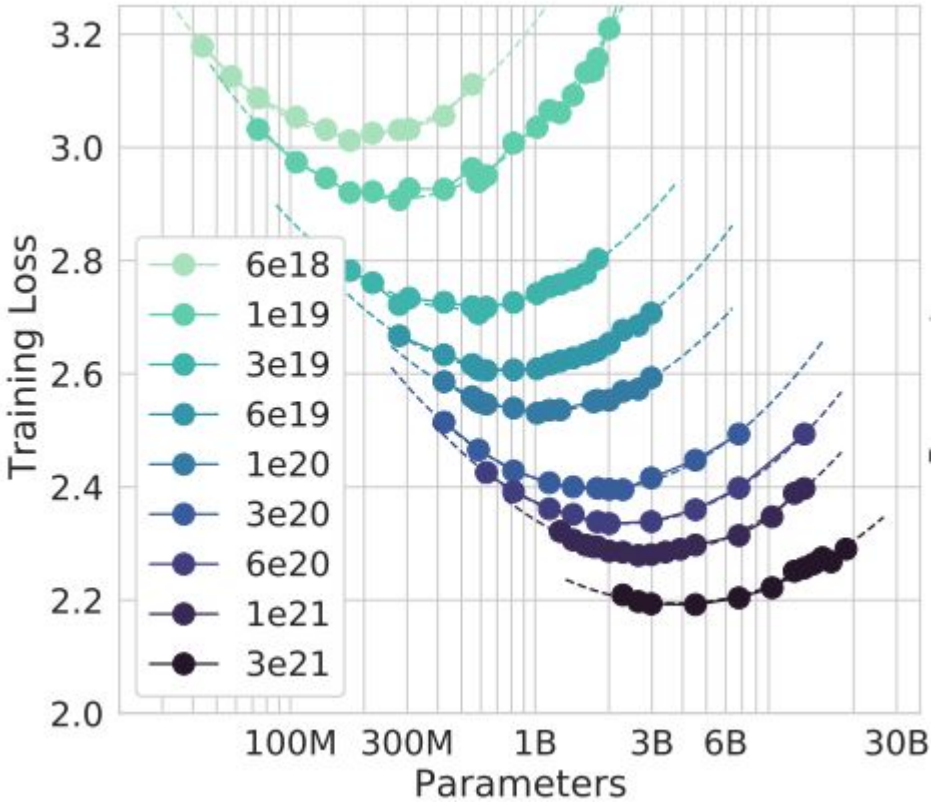
URBAN SYSTEMS

MODEL DESIGN

MODEL SIZE

- Emergent properties from scaling
- There is some relationship between training data and model size
- Scaling laws and diminishing returns?

We can expect more intelligence “for free” by scaling up



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URBAN SYSTEMS

PROMPTING STRUCTURE

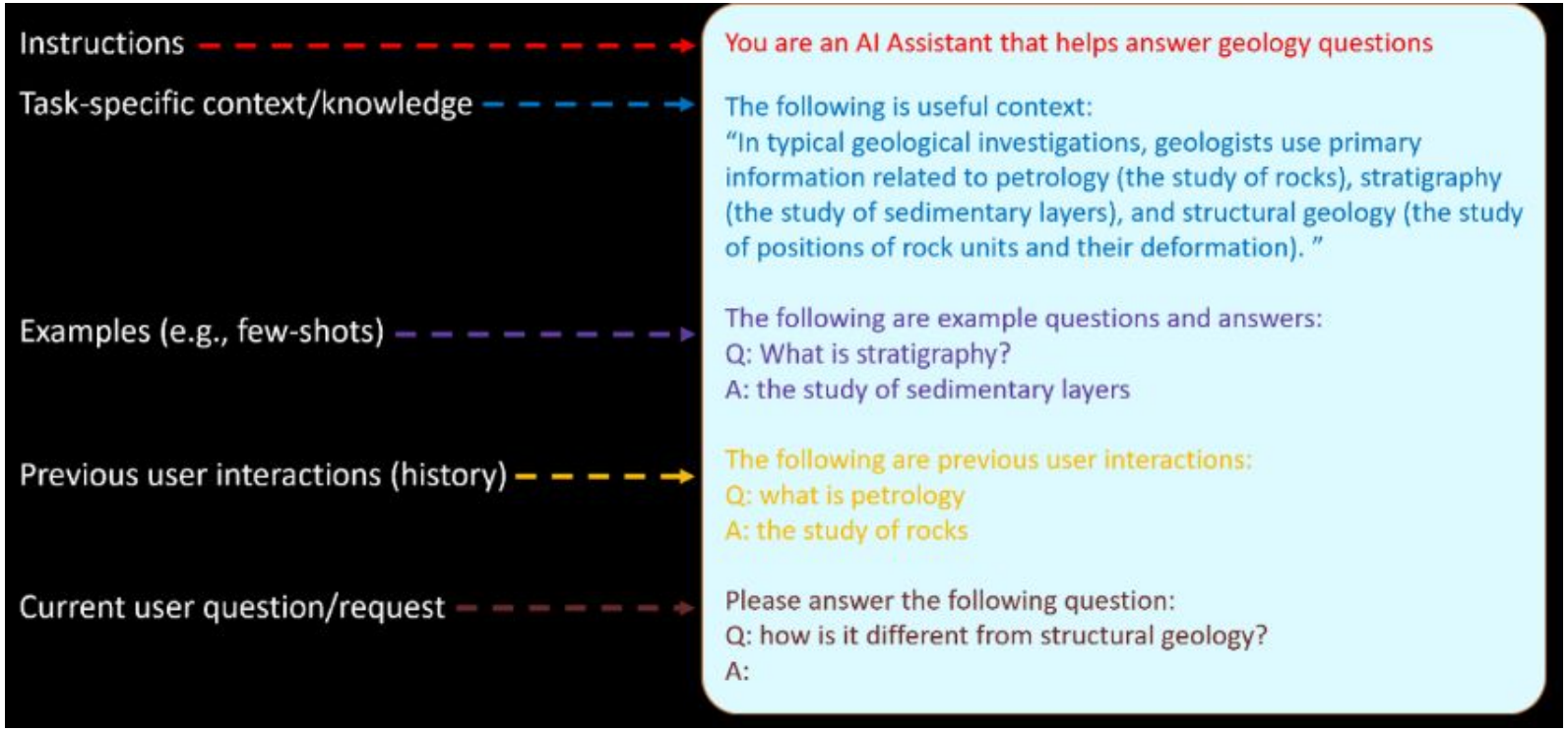
The API of AI

URBAN SYSTEMS

PROMPTING STRUCTURE

PROMPT STRUCTURE

- System
- Human Input
- Assistant/Output



Useful Resources

- [Microsoft] Getting Started with LLM Prompt Engineering
- [huggingface] LLM Prompting Guide

URBAN SYSTEMS

PROMPTING STRUCTURE

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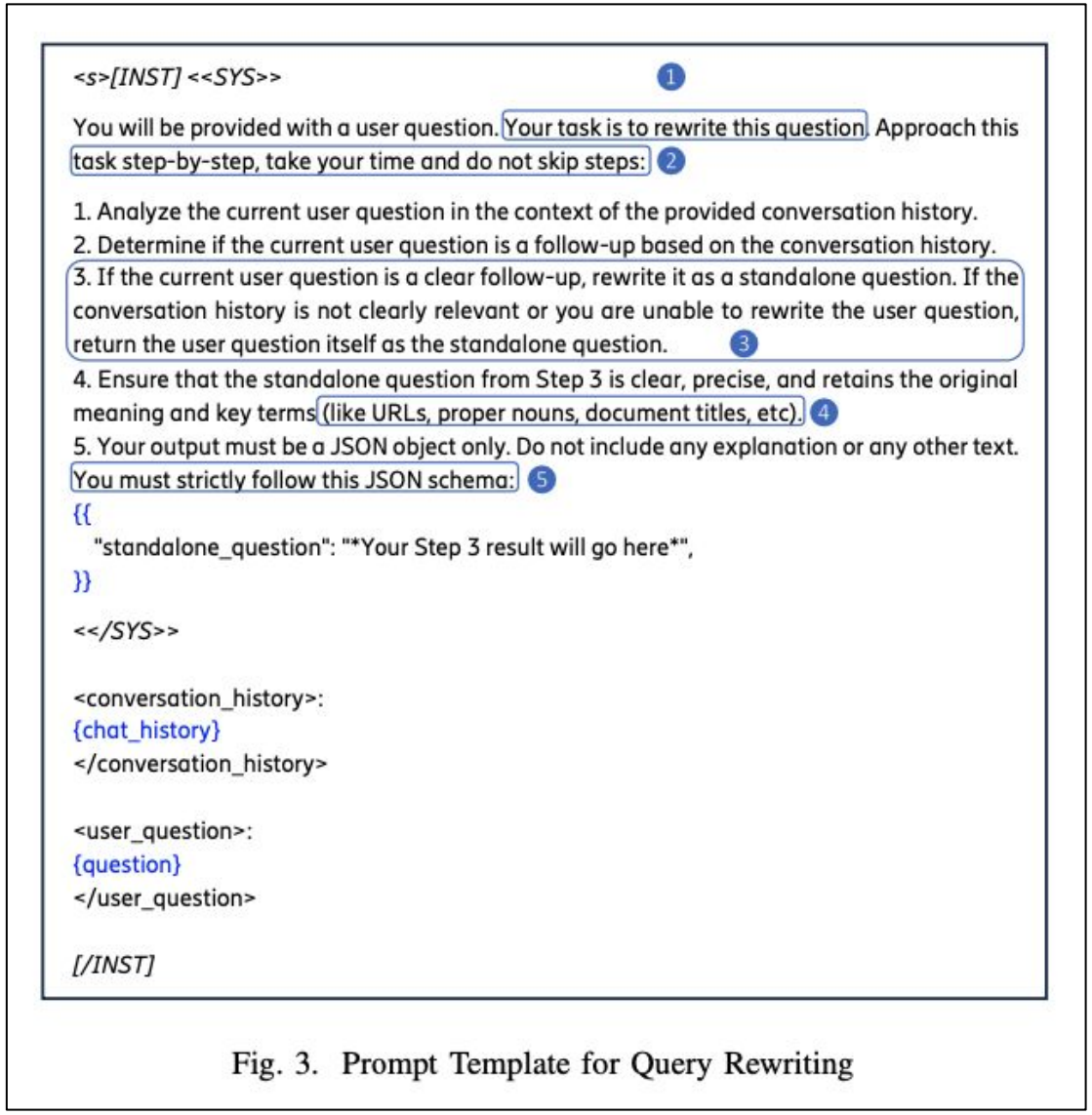


```
<s>[INST] <<SYS>>                                                    1

You will be provided with a user question. Your task is to rewrite this question. Approach this
task step-by-step, take your time and do not skip steps: 2

1. Analyze the current user question in the context of the provided conversation history.
2. Determine if the current user question is a follow-up based on the conversation history.
3. If the current user question is a clear follow-up, rewrite it as a standalone question. If the
conversation history is not clearly relevant or you are unable to rewrite the user question,
return the user question itself as the standalone question.                                    3
4. Ensure that the standalone question from Step 3 is clear, precise, and retains the original
meaning and key terms (like URLs, proper nouns, document titles, etc). 4
5. Your output must be a JSON object only. Do not include any explanation or any other text.
You must strictly follow this JSON schema: 5
{{
  "standalone_question": "*Your Step 3 result will go here*",
}}

<</SYS>>

<conversation_history>:
{chat_history}
</conversation_history>

<user_question>:
{question}
</user_question>

[/INST]
```

Fig. 3. Prompt Template for Query Rewriting

URBAN SYSTEMS

PROMPTING STRUCTURE

PROMPT FORMATS

- If prompting through an API or Web App, this is handled for you.
- If you're interfacing with models locally and directly, you will have to structure this yourself

```
<|begin_of_text|><|start_header_id|>system<|end_header_id|>

Cutting Knowledge Date: December 2023
Today Date: 23 July 2024

You are a helpful assistant<|eot_id|><|start_header_id|>user<|end_header_id|>

What is the capital of France?<|eot_id|><|start_header_id|>assistant<|end_header_id|>
```

Useful Resources

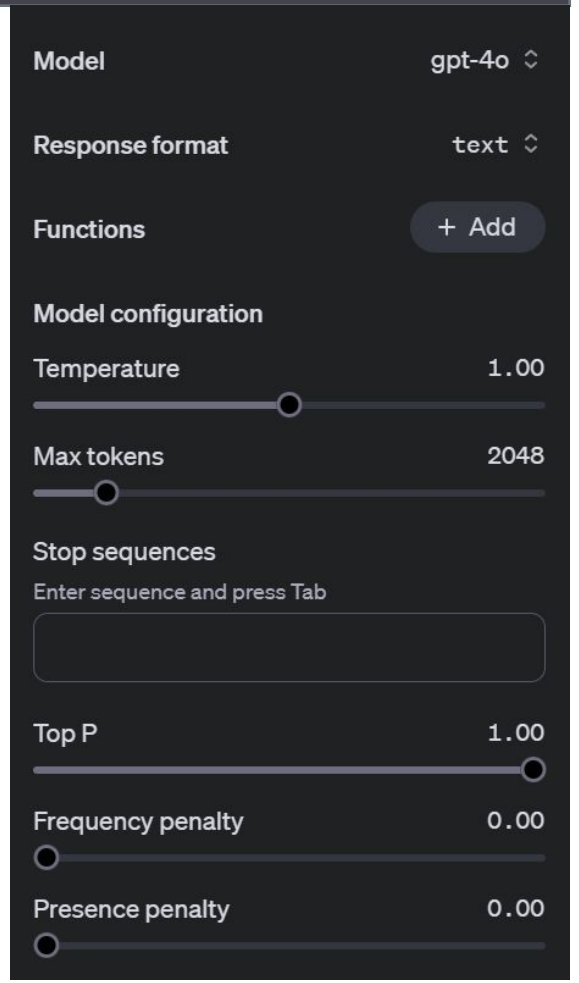
- [docs] Meta Llama 3.1 Prompt Format
- [docs] Meta Llama 2 Prompt Format
- [huggingface] LLM Prompting Guide

URBAN SYSTEMS

PROMPTING STRUCTURE

MODEL PARAMETERS

- **Temperature:** A control of **creativity** or randomness in text generation.
  - Higher = more creative
  - Lower = more deterministic
- **Top K:** LLM selects from top K most likely tokens
  - Higher = more diversity
  - Lower = more fluency
- **Top P:** retains tokens with a total cumulative probability above P
  - Higher = more diversity
  - Lower = less randomness
- **Max Tokens:** max tokens in model output



Useful Resources

- [blog] What is Temperature in NLP?
- [blog] Tuning LLM Parameters for Optimal Performance
- [youtube] Top-P vs Top-K

URBAN SYSTEMS

EXERCISE

https://tinyurl.com/uc-llm-workshop

Prompting Notebook
https://colab.research.google.com/drive/1YH_Cr6N6qgYGUu26McQa086xvern61p0?usp=sharing

Fine-Tuning Notebook
https://colab.research.google.com/drive/1Nz1t1LnCPiXrkAyQcPG61VTPziFJcuLM?usp=sharing

URBAN SYSTEMS

PROMPTING TECHNIQUES

FEW-SHOT PROMPTING/IN-CONTEXT LEARNING

- “Shot” is synonymous with examples
- Can tweak for style/tone of writing by providing examples
- Can improve performance for outputting specific formats
- Can be used for creative writing, formatting, data transformations, reasoning tasks, etc…
- Order of examples maybe matters
- Negative examples likely confuse models

Useful Resources

- [arxiv] Language Models are Few-Shot Learners
- [arxiv] Lost in the Middle: How Language Models Use Long Contexts

URBAN SYSTEMS

PROMPTING TECHNIQUES

FEW-SHOT PROMPTING/IN-CONTEXT LEARNING

Zero-shot

The model predicts the answer given only a natural language description of the task. No gradient updates are performed.

```
1  Translate English to French:      ← task description
2  cheese =>                         ← prompt
```

Few-shot

In addition to the task description, the model sees a few examples of the task. No gradient updates are performed.

```
1  Translate English to French:      ← task description
2  sea otter => loutre de mer        ← examples
3  peppermint => menthe poivrée      ←
4  plush girafe => girafe peluche    ←
5  cheese =>                         ← prompt
```

Useful Resources

- [arxiv] Language Models are Few-Shot Learners
- [arxiv] Lost in the Middle: How Language Models Use Long Contexts

URBAN SYSTEMS

PROMPTING TECHNIQUES

CHAIN-OF-THOUGHT

- Slow down silly AI!
- Helps break down complex tasks, improves performance for reasoning/logic based tasks
- Incited through the phrase, “Lets think step by step”, or similar
- LLMs are sensitive to semantics, each model is different

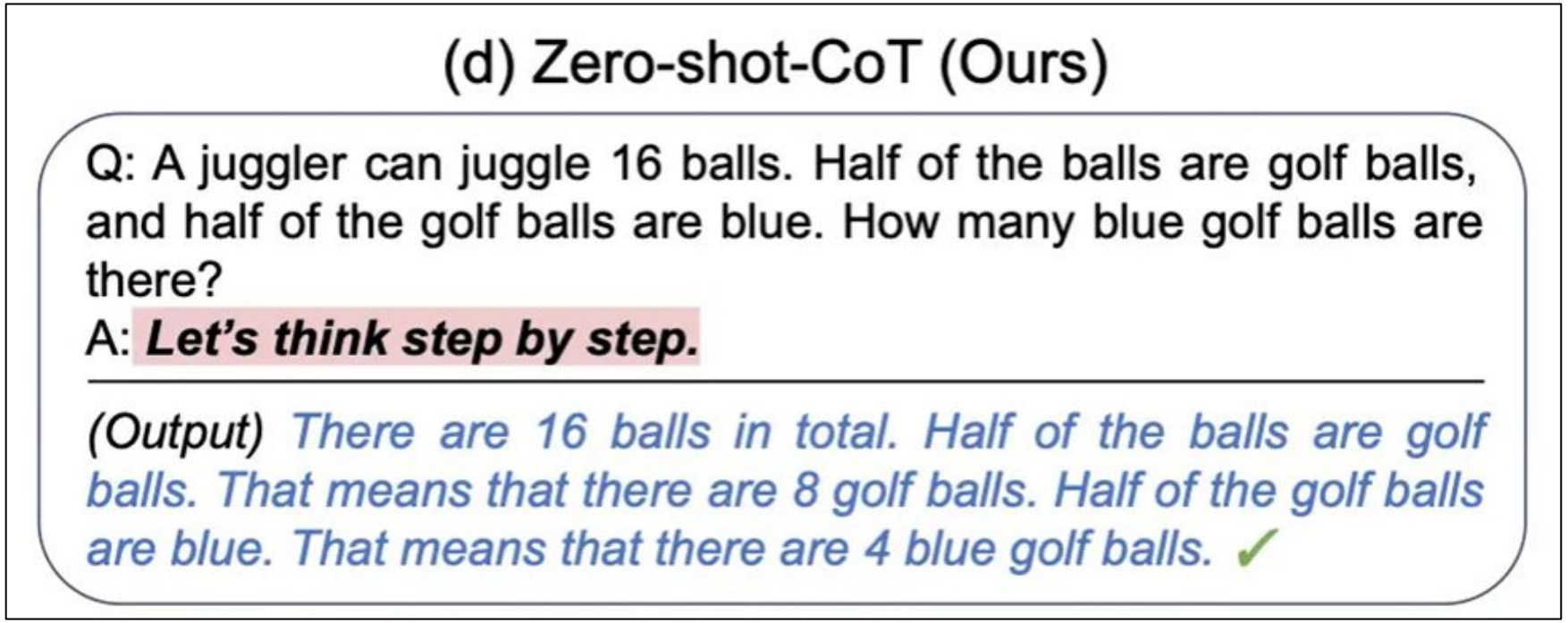
Useful Resources

- [arxiv] Large Language Models are Zero-Shot Reasoners
- [arxiv] Large Language Models as Optimizers

URBAN SYSTEMS

PROMPTING TECHNIQUES

CHAIN-OF-THOUGHT



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URBAN SYSTEMS

PROMPTING TECHNIQUES

CHAIN-OF-THOUGHT

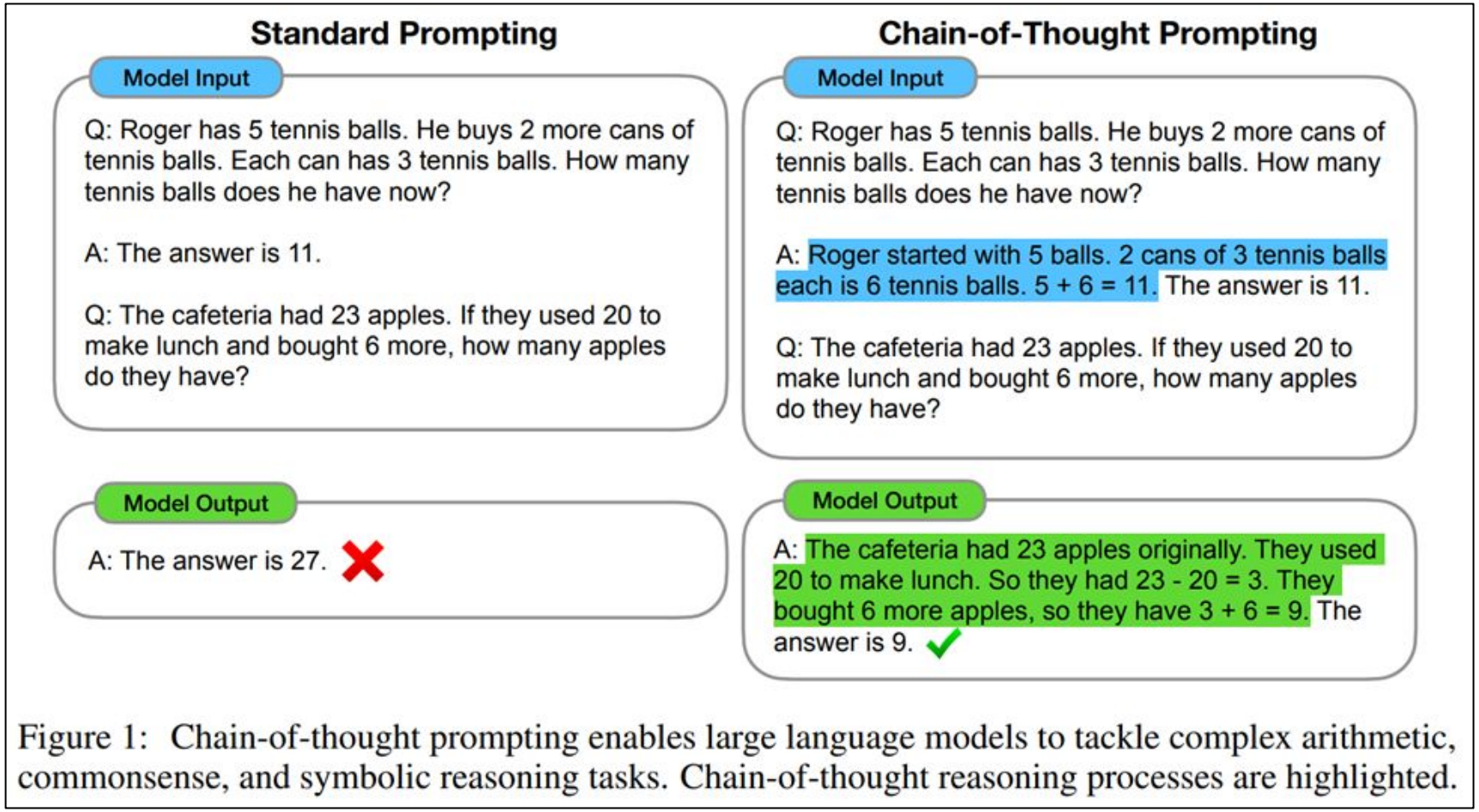

Figure 1: Chain-of-thought prompting enables large language models to tackle complex arithmetic, commonsense, and symbolic reasoning tasks. Chain-of-thought reasoning processes are highlighted.

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PROMPTING TECHNIQUES

CHAIN-OF-THOUGHT

Scorer	Optimizer / Source	Instruction position	Top instruction	Acc
Baselines				
PaLM 2-L	(Kojima et al., 2022)	A_begin	Let's think step by step.	71.8
PaLM 2-L	(Zhou et al., 2022b)	A_begin	Let's work this out in a step by step way to be sure we have the right answer.	58.8
PaLM 2-L		A_begin	Let's solve the problem.	60.8
PaLM 2-L		A_begin	(empty string)	34.0
text-bison	(Kojima et al., 2022)	Q_begin	Let's think step by step.	64.4
text-bison	(Zhou et al., 2022b)	Q_begin	Let's work this out in a step by step way to be sure we have the right answer.	65.6
text-bison		Q_begin	Let's solve the problem.	59.1
text-bison		Q_begin	(empty string)	56.8
Ours				
PaLM 2-L	PaLM 2-L-IT	A_begin	Take a deep breath and work on this problem step-by-step.	**80.2**
PaLM 2-L	PaLM 2-L	A_begin	Break this down.	79.9
PaLM 2-L	gpt-3.5-turbo	A_begin	A little bit of arithmetic and a logical approach will help us quickly arrive at the solution to this problem.	78.5

URBAN SYSTEMS

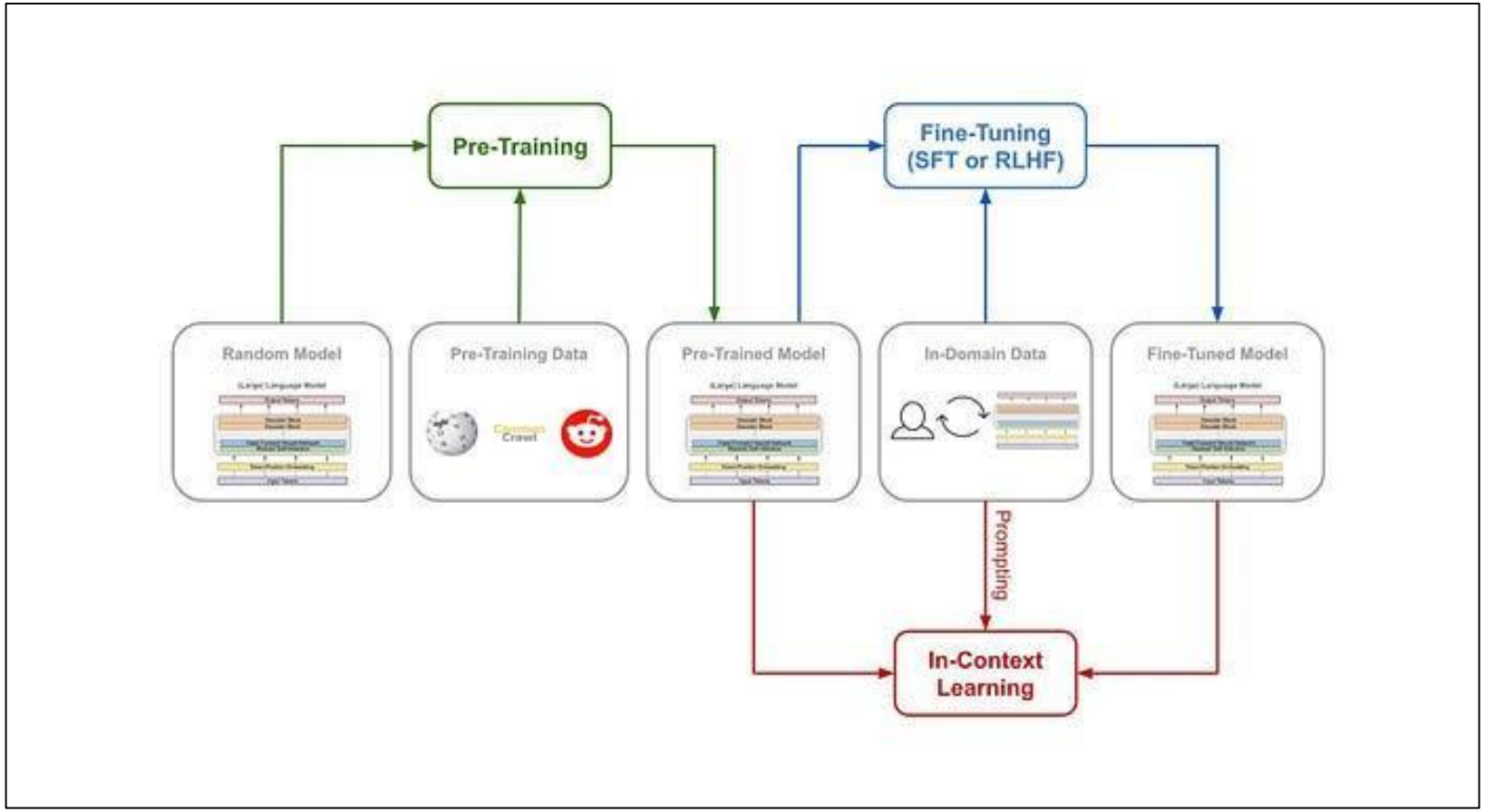
MODEL TRAINING

Getting the most from a query

MODEL TRAINING

PRE-TRAINING

- What can data look like?
- Variety of sources and domains
  - Books
  - Wikipedia
  - News Article
  - Scientific Papers
  - Code Repositories
  - Reddit
  - Dialogues/Conversations
  - Etc…



Useful Resources

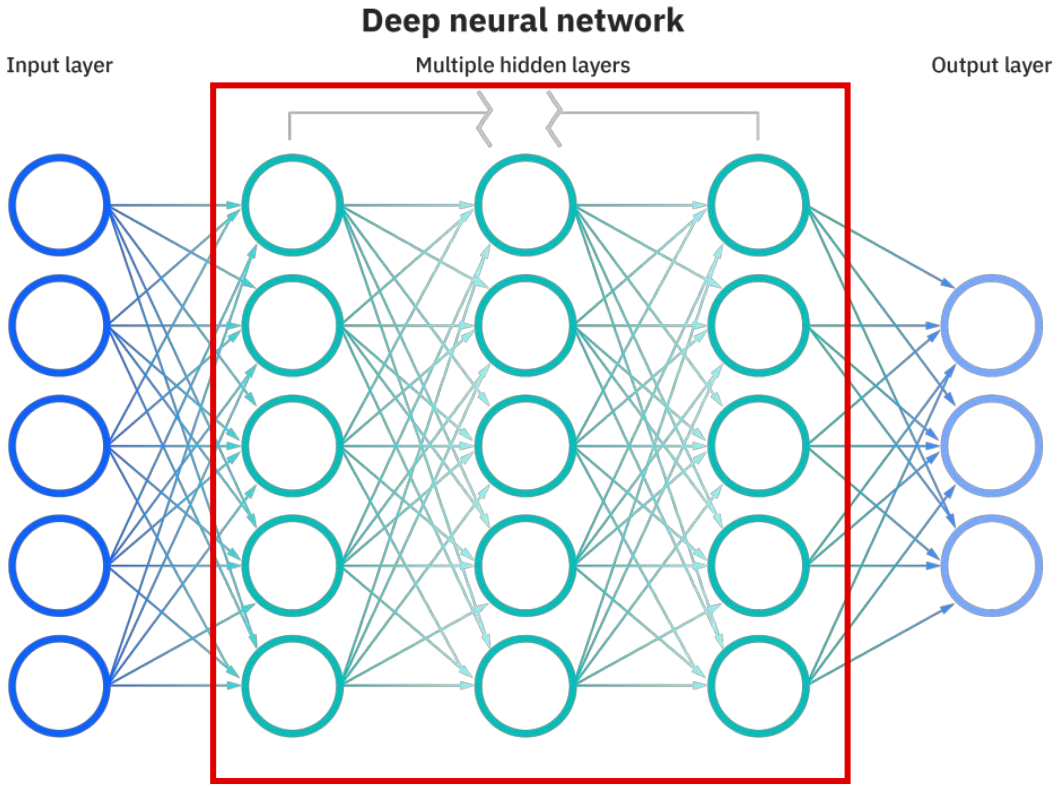
- [blog] Empowering Language Models: Pre-training, Fine-tuning, and In-Context Learning
- [youtube] Intro to Large Language Models – Andrej Karpathy

URBAN SYSTEMS

MODEL TRAINING

FINE-TUNING / TRANSFER LEARNING

- Can fine-tune all the weights



Useful Resources

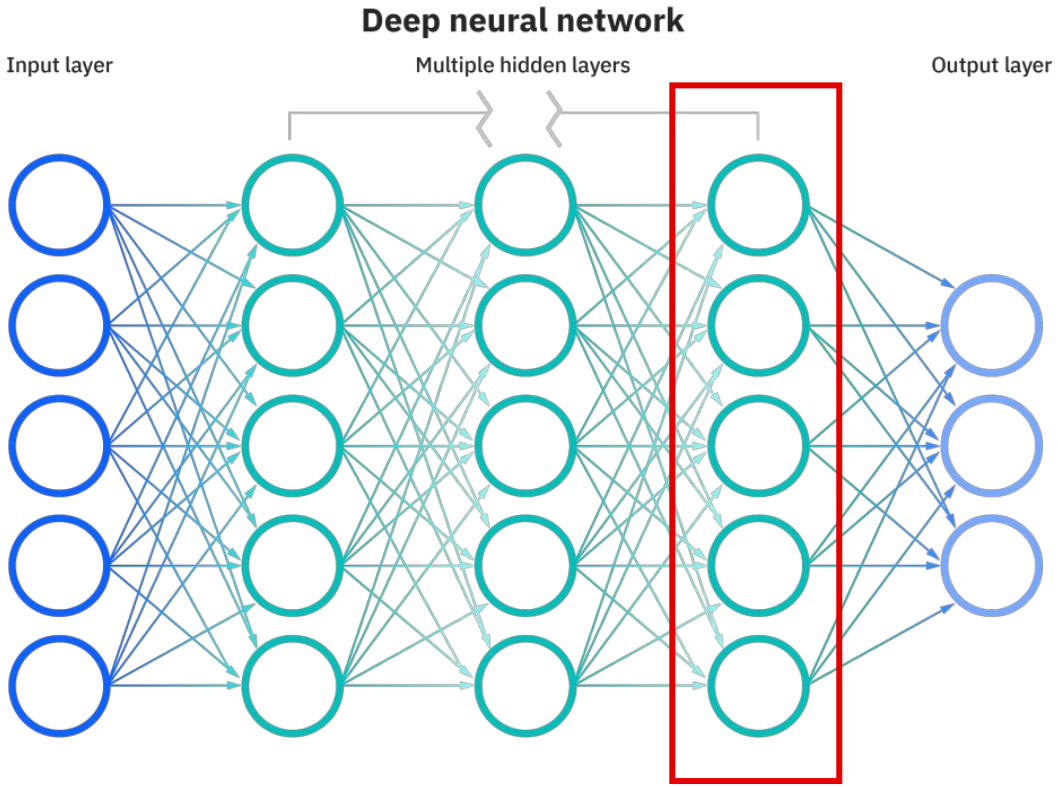
- [youtube] LoRA for fine-tuning LLM models
- [arxiv] LoRA: Low-Rank Adaptation of Large Language Models

URBAN SYSTEMS

MODEL TRAINING

FINE-TUNING / TRANSFER LEARNING

- Can fine-tune all the weights
- Can freeze different sections



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MODEL TRAINING

FINE-TUNING / TRANSFER LEARNING

- Can fine-tune all the weights
- Can freeze different sections
- Can add adapter layers

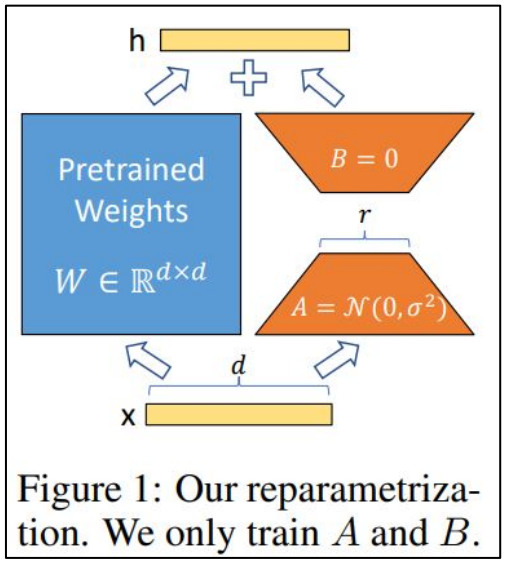
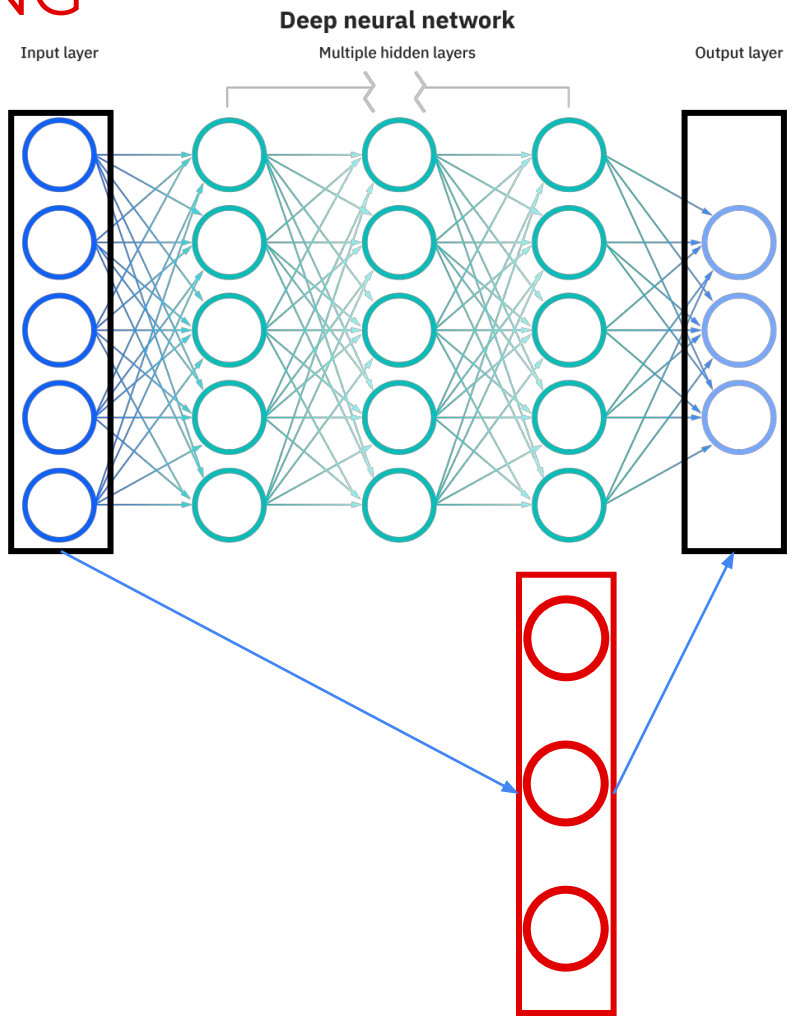


Figure 1: Our reparametrization. We only train A and B.



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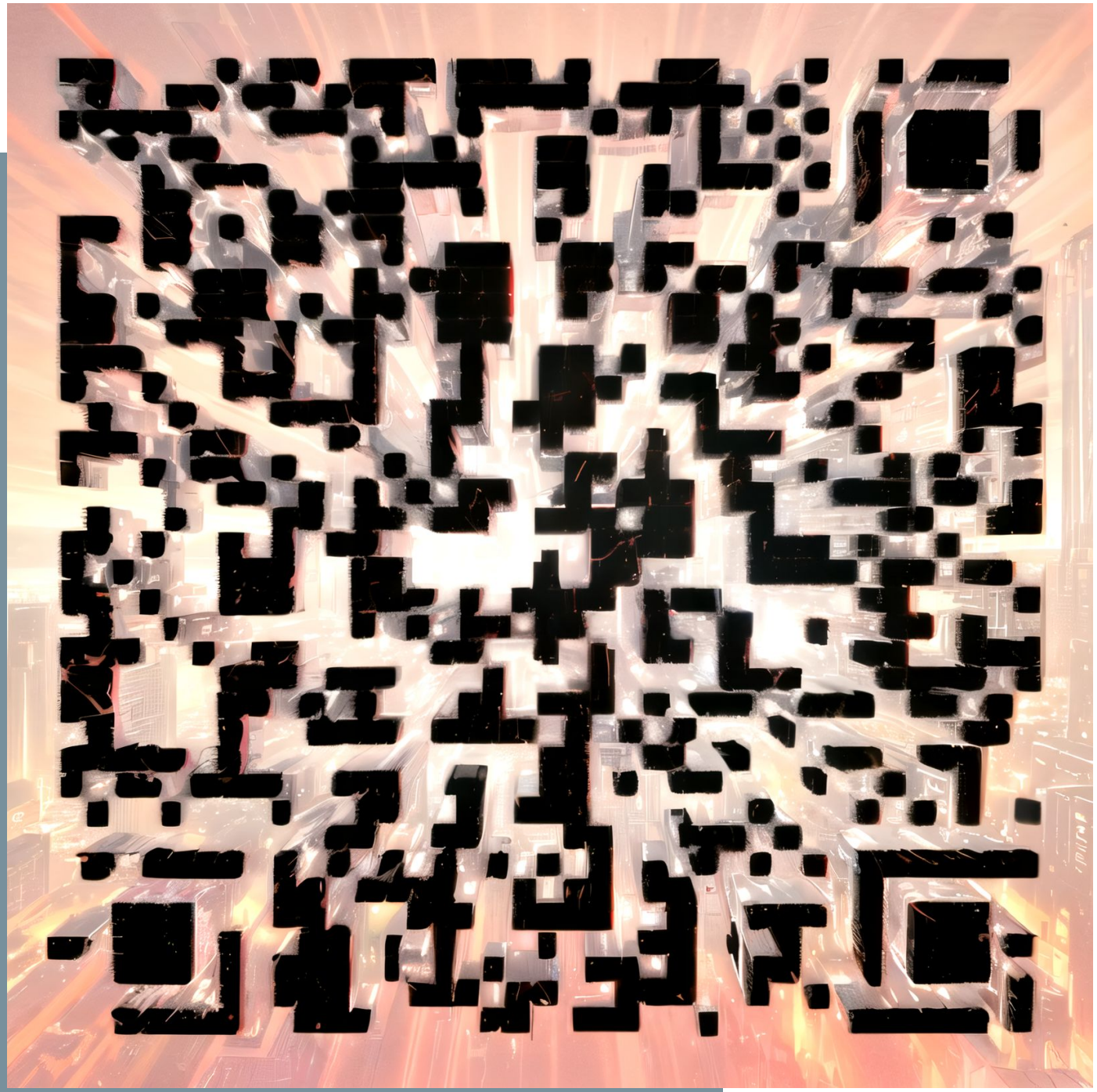

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