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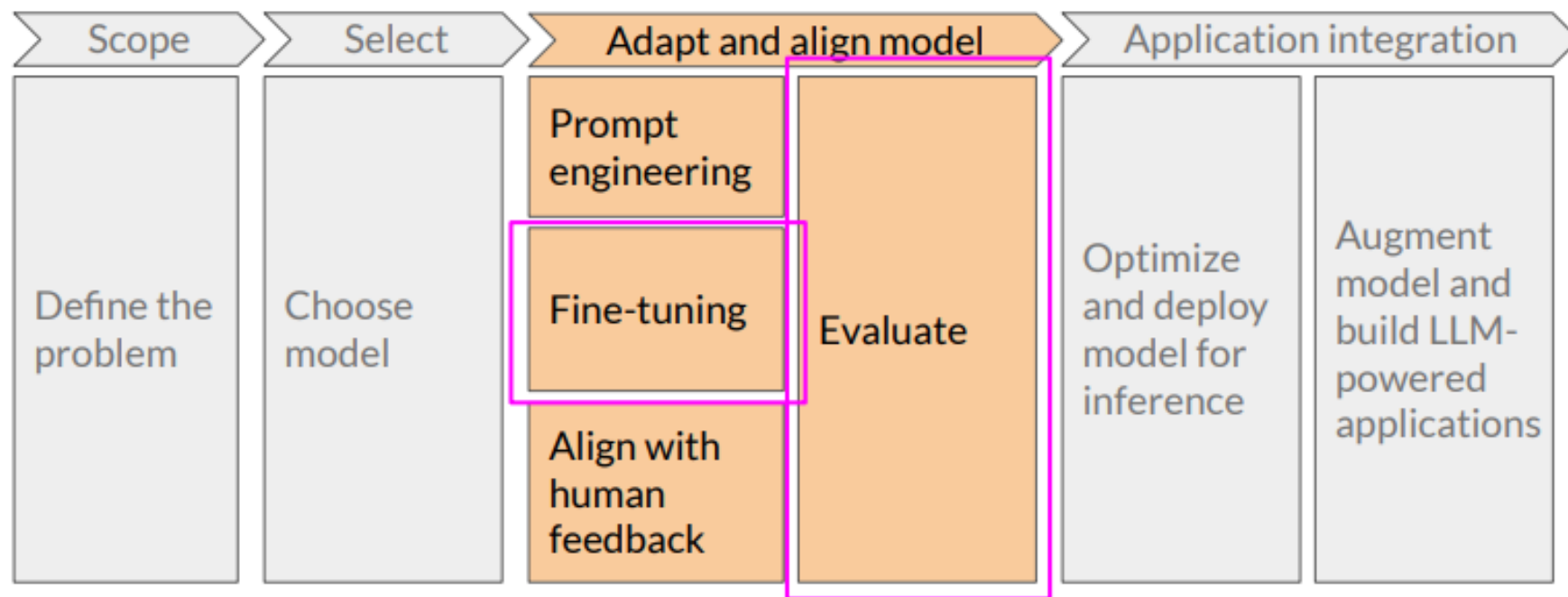# Generative AI and large-language models (LLMs)

FINE-TUNING, INSTRUCTION PROMPTS, AND PARAMETER EFFICIENT FINE-TUNING

GenAI project lifecycle

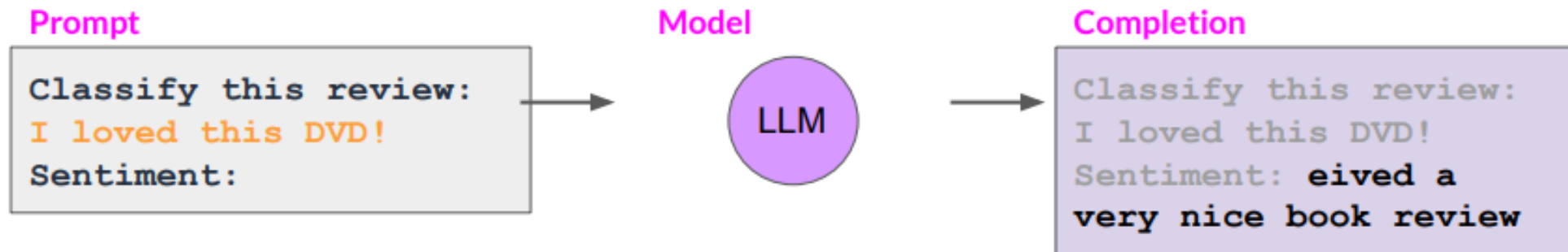| Scope	Select	Adapt and align model		Application integration	
Define the problem	Choose model	Prompt engineering	Evaluate	Optimize and deploy model for inference	Augment model and build LLM-powered applications
		Fine-tuning			
		Align with human feedback			

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In-context learning (ICL) - zero shot inference

Prompt

```
Classify this review:
I loved this DVD!
Sentiment:
```

Model

LLM

Completion

```
Classify this review:
I loved this DVD!
Sentiment: eived a
very nice book review
```

In-context learning (ICL) - one/few shot inference

Prompt

```
Classify this review:
I loved this DVD!
Sentiment: Positive

Classify this review:
I don't like this
chair.
Sentiment:
```

Model

LLM

Completion

```
Classify this review:
I loved this DVD!
Sentiment: Positive

Classify this review:
I don't like this
chair.
Sentiment: Negative
```
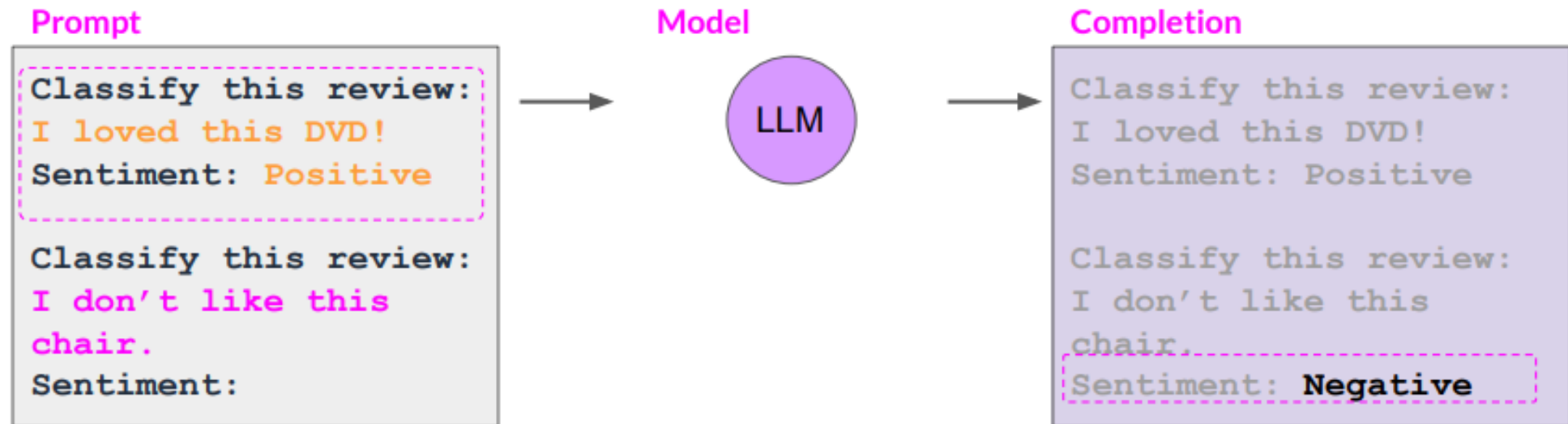
One-shot or Few-shot Inference

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Limitations of in-context learning

```
Classify this review:
I loved this movie!
Sentiment: Positive


Classify this review:
I don't like this chair.
Sentiment: Negative


Classify this review:
This sofa is so ugly.
Sentiment: Negative


Classify this review:
Who would use this product?
Sentiment:
```
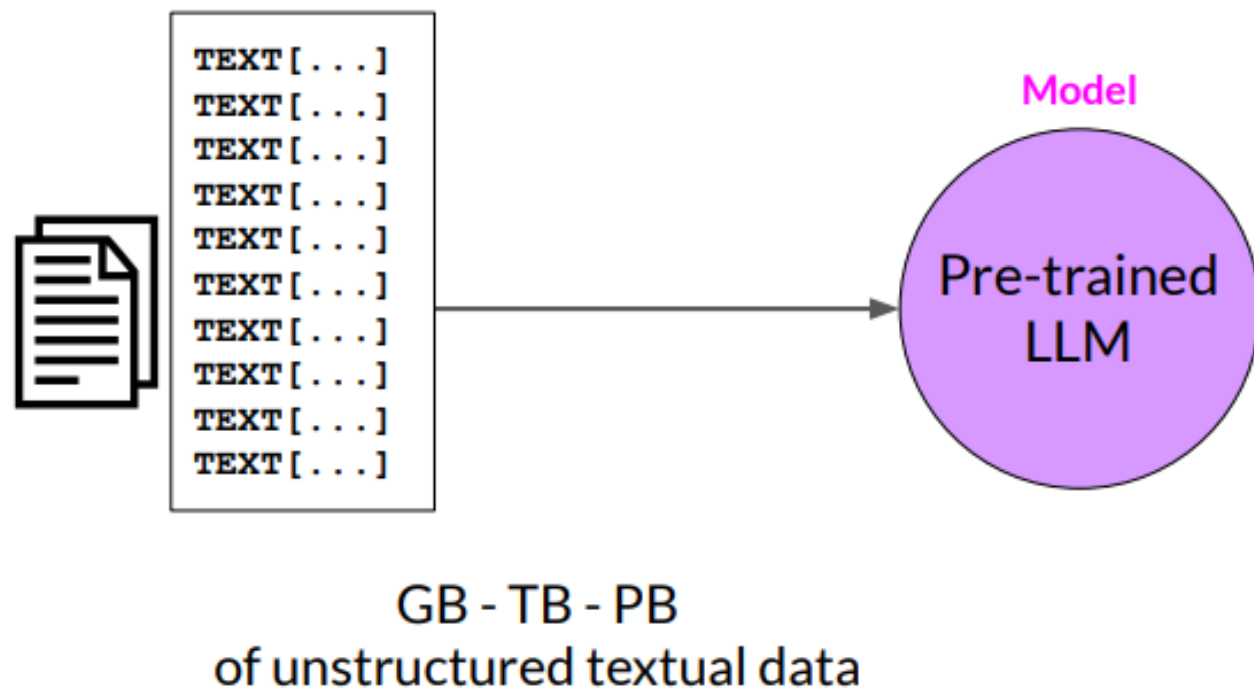
Context Window

Even with multiple examples

- In-context learning may not work for smaller models LLM

- Examples take up space in the context window
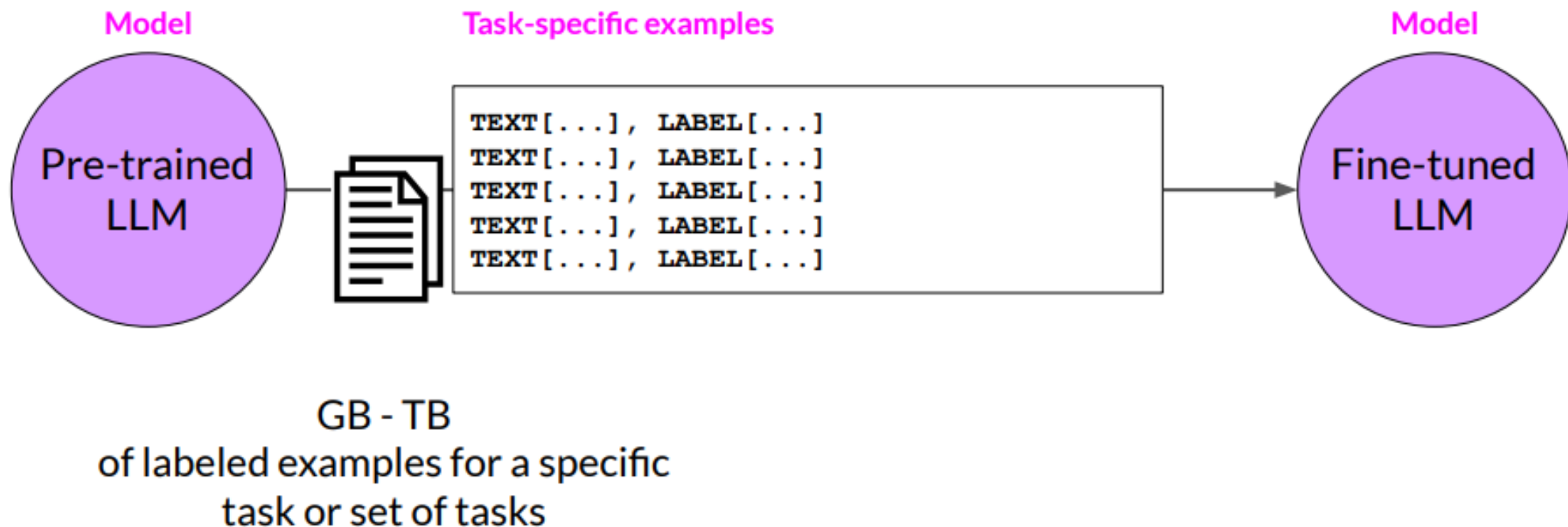
Instead, try **fine-tuning** the model
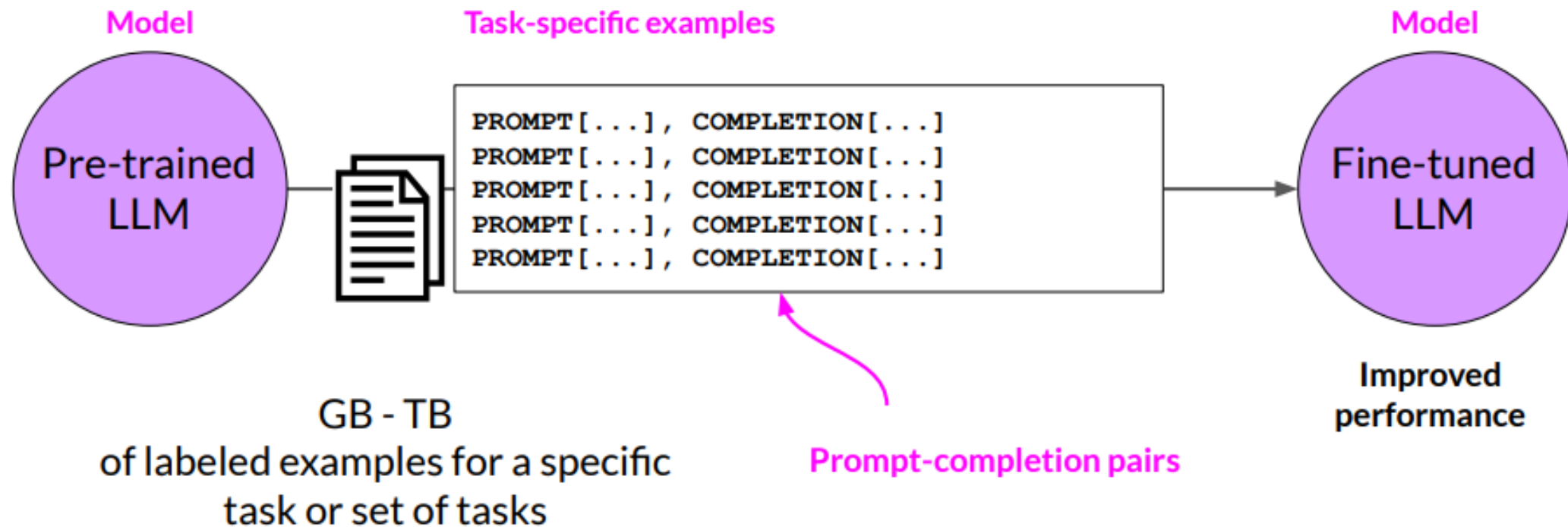
LLM fine-tuning at a high level

LLM pre-training


```
TEXT[...]
TEXT[...]
TEXT[...]
TEXT[...]
TEXT[...]
TEXT[...]
TEXT[...]
TEXT[...]
TEXT[...]
TEXT[...]
```

Model

Pre-trained
LLM

GB - TB - PB
of unstructured textual data

LLM fine-tuning at a high level

LLM fine-tuning

Model

Task-specific examples

Model

Pre-trained
LLM

```
TEXT[...], LABEL[...]
TEXT[...], LABEL[...]
TEXT[...], LABEL[...]
TEXT[...], LABEL[...]
TEXT[...], LABEL[...]
```

Fine-tuned
LLM

GB - TB
of labeled examples for a specific
task or set of tasks

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LLM fine-tuning at a high level

LLM fine-tuning

Model

Task-specific examples

Model

Pre-trained LLM

```
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
```

Fine-tuned LLM

Improved performance

GB - TB
of labeled examples for a specific task or set of tasks

Prompt-completion pairs

Using prompts to fine-tune LLMs with instruction

LLM fine-tuning

Model

Pre-trained LLM

Classify this review:
I loved this DVD!
Sentiment: Positive

Classify this review:
I don't like this chair.
Sentiment: Negative

Model

Fine-tuned LLM

Each prompt/completion pair includes a specific "instruction" to the LLM

Using prompts to fine-tune LLMs with instruction

LLM fine-tuning

Model

Task-specific examples

Model

Pre-trained LLM

```
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
```

Fine-tuned LLM

```
Summarize the following text:
[EXAMPLE TEXT]
[EXAMPLE COMPLETION]
```

```
Translate this sentence to...
[EXAMPLE TEXT]
[EXAMPLE COMPLETION]
```

Using prompts to fine-tune LLMs with instruction

LLM fine-tuning

Model

Task-specific examples

Model

Pre-trained LLM

```
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
```

Fine-tuned LLM

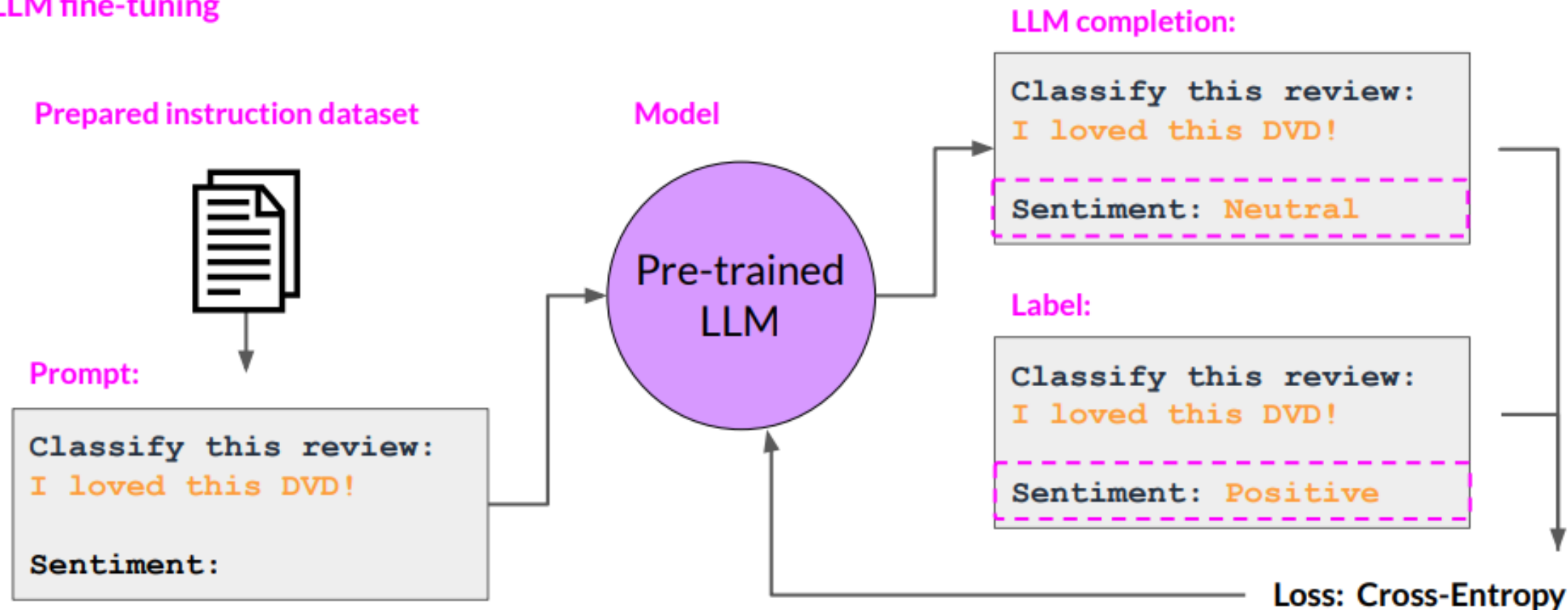**Full fine-tuning updates all parameters**

Improved performance

Sample prompt instruction templates

Classification / sentiment analysis

```
jinja: "Given the following review:\n{{review_body}}\npredict the associated rating\
\ from the following choices (1 being lowest and 5 being highest)\n- {{ answer_choices\
\ | join('\\n- ') }} \n|||\n{{answer_choices[star_rating-1]}}"
```

Text generation

```
jinja: Generate a {{star_rating}}-star review (1 being lowest and 5 being highest)
about this product {{product_title}}.          |||          {{review_body}}
```

Text summarization

```
jinja: "Give a short sentence describing the following product review:\n{{review_body}}\
\ \n|||\n{{review_headline}}"
```

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LLM fine-tuning process

LLM fine-tuning

Prepared instruction dataset   **Training splits**


```
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
```
Training

```
PROMPT[...], COMPLETION[...]
...
```
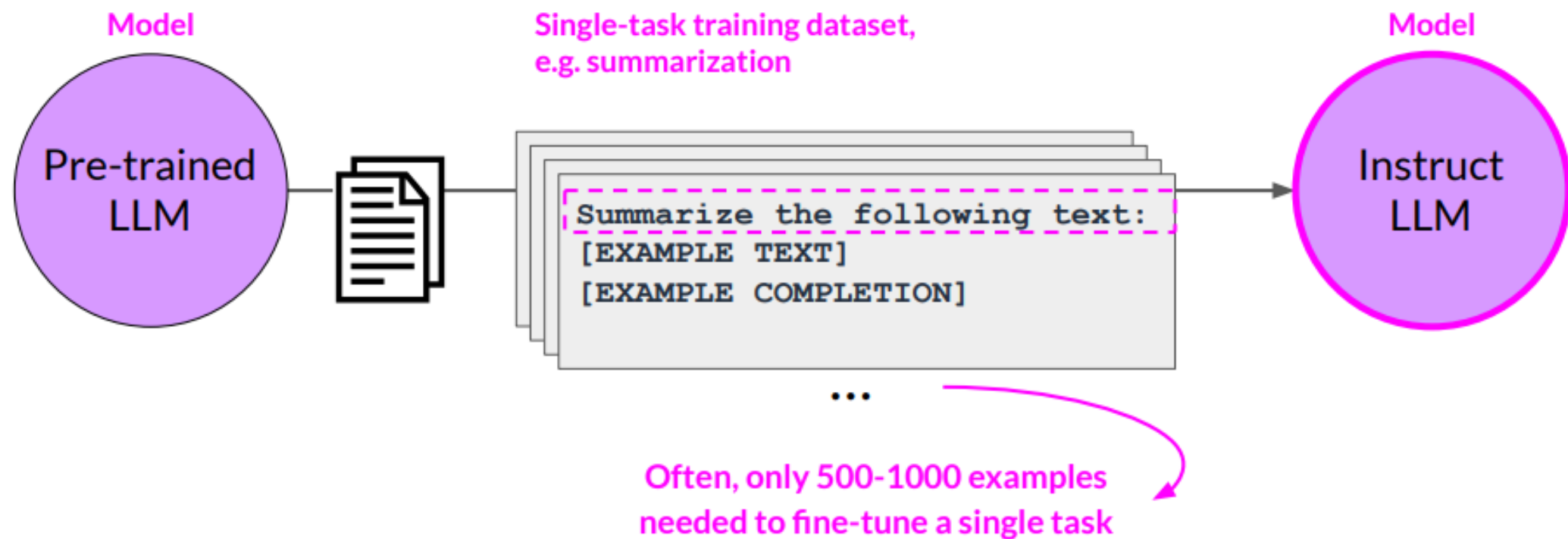**Validation**

```
PROMPT[...], COMPLETION[...]
...
```
Test

LLM fine-tuning process

LLM fine-tuning

Prepared instruction dataset

Model

LLM completion:

```
Classify this review:
I loved this DVD!

Sentiment: Neutral
```

Prompt:

```
Classify this review:
I loved this DVD!


Sentiment:
```

Pre-trained LLM

Label:

```
Classify this review:
I loved this DVD!

Sentiment: Positive
```

Loss: Cross-Entropy

LLM fine-tuning process

LLM fine-tuning

Prepared instruction dataset   **Training splits**


```
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
                          Training
```

```
PROMPT[...], COMPLETION[...]
...
                          Validation
```
validation_accuracy

```
PROMPT[...], COMPLETION[...]
...
                          Test
```

LLM fine-tuning process

LLM fine-tuning

Prepared instruction dataset   **Training splits**

```
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]
PROMPT[...], COMPLETION[...]           Training
```

```
PROMPT[...], COMPLETION[...]
...                                    Validation
```

```
PROMPT[...], COMPLETION[...]
...                                    Test
```
test_accuracy

LLM fine-tuning process

Fine-tuning on a single task

Model

Pre-trained LLM

Single-task training dataset, e.g. summarization

```
Summarize the following text:
[EXAMPLE TEXT]
[EXAMPLE COMPLETION]
```

...

Often, only 500-1000 examples needed to fine-tune a single task

Model

Instruct LLM

Catastrophic forgetting

- Fine-tuning can significantly increase the performance of a model on a specific task...

Before fine-tuning

Prompt

```
Classify this review:
I loved this DVD!
Sentiment:
```

Model

LLM

Completion

```
Classify this review:
I loved this DVD!
Sentiment: eived a
very nice book review
```

Catastrophic forgetting

- Fine-tuning can significantly increase the performance of a model on a specific task...

After fine-tuning

Prompt

```
Classify this review:
I loved this DVD!
Sentiment:
```

Model

LLM

Completion

```
Classify this review:
I loved this DVD!
Sentiment: POSITIVE
```

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Catastrophic forgetting

- ...but can lead to reduction in ability on other tasks

Before fine-tuning

Prompt

```
What is the name of
the cat?
Charlie the cat roamed
the garden at night.
```

Model

LLM

Completion

```
What is the name of
the cat?
Charlie the cat roamed
the garden at night.
Charlie
```

Catastrophic forgetting

- ...but can lead to reduction in ability on other tasks

After fine-tuning

Prompt

What is the name of
the cat?
Charlie the cat roamed
the garden at night.

Model

LLM

Completion

What is the name of
the cat?
Charlie the cat roamed
the garden at night.
**The garden was
positive.**

How to avoid catastrophic forgetting

- First note that you might not have to!
- Fine-tune on **multiple tasks** at the same time
- Consider **Parameter Efficient Fine-tuning** (PEFT)

Multi-task, instruction fine-tuning

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Multi-task, instruction fine-tuning

Model

Pre-trained LLM

Instruction fine-tune on many tasks

Summarize the following text:

Rate this review:

Translate into Python code:

Identify the places:

[EXAMPLE TEXT]
[EXAMPLE COMPLETION]

...

Many examples of each needed for training
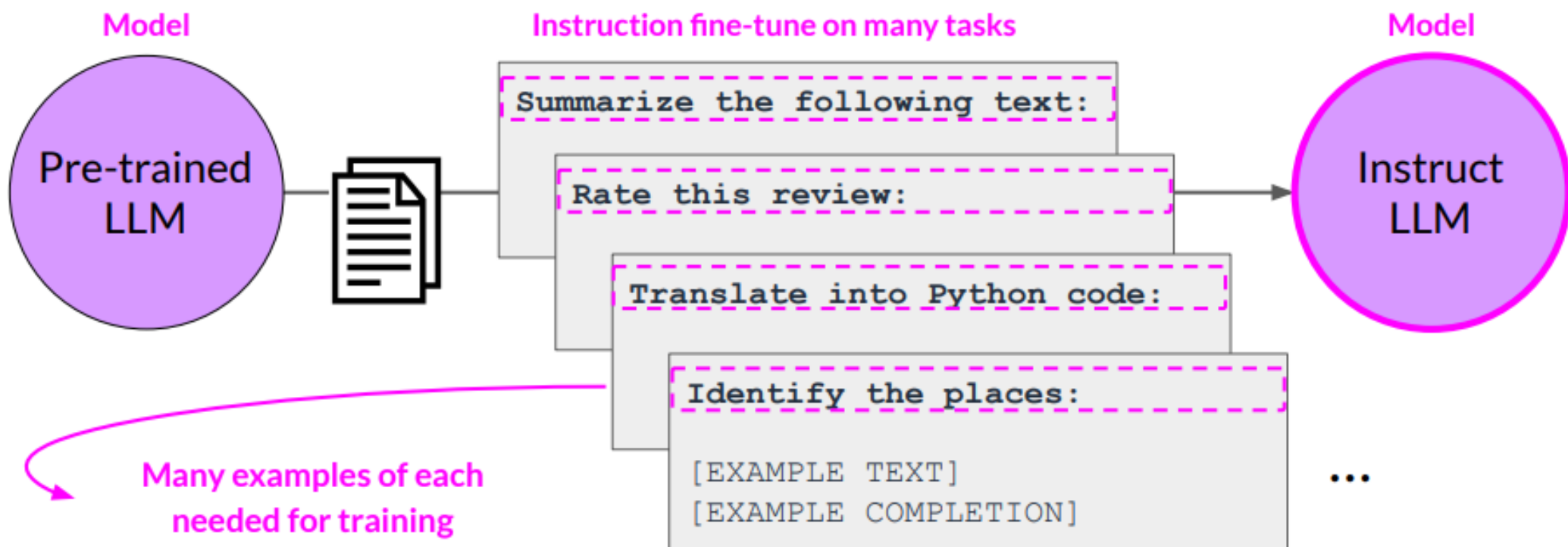
Model

Instruct LLM

Instruction fine-tuning with FLAN

- FLAN models refer to a specific set of instructions used to perform instruction fine-tuning

FLAN
(**F**ine-tuned
LAnguage **N**et)

T5 → T5   FLAN-T5

PALM → PALM   FLAN-PALM
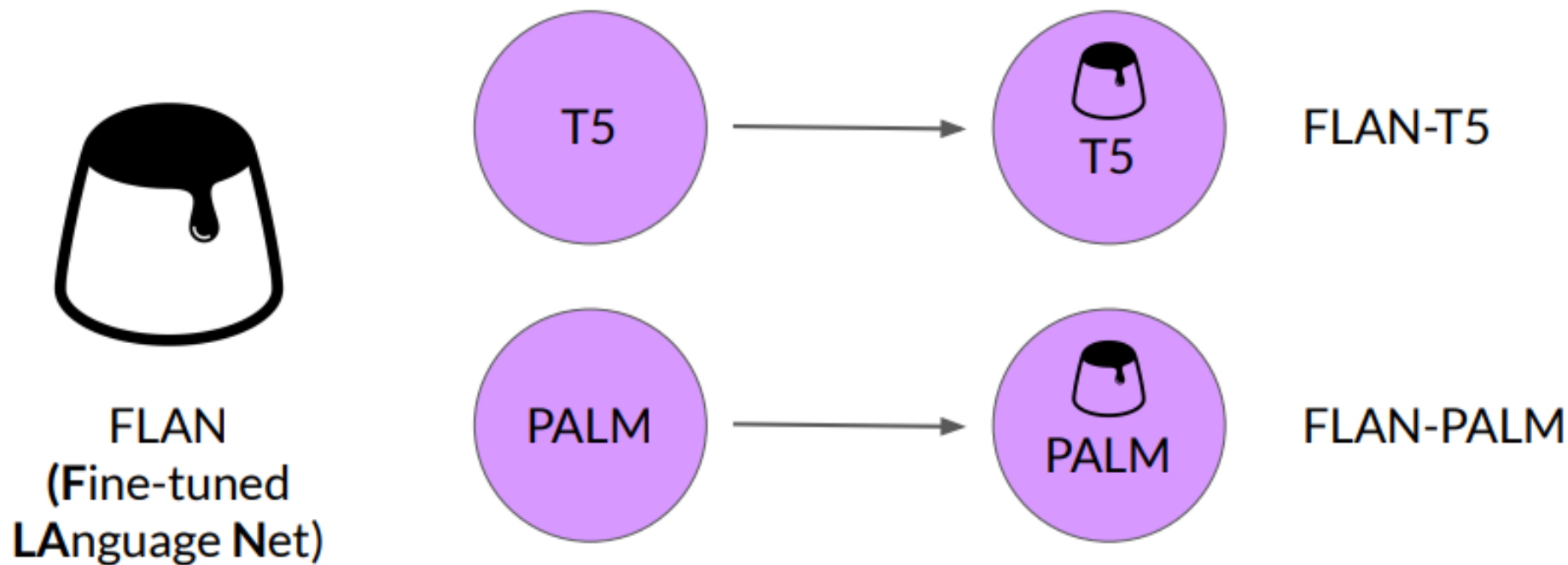
FLAN-T5: Fine-tuned version of pre-trained T5 model

- FLAN-T5 is a great, general purpose, instruct model

T0-SF	Muffin	CoT (reasoning)	Natural Instructions
- Commonsense Reasoning, - Question Generation, - Closed-book QA, - Adversarial QA, - Extractive QA ...	- Natural language inference, - Code instruction gen, - Code repair - ~~Dialog context generation,~~ - **Summarization (SAMSum)** ...	- Arithmetic reasoning, - Commonsense reasoning - Explanation generation, - Sentence composition, - Implicit reasoning, ...	- Cause effect classification, - Commonsense reasoning, - Named Entity Recognition, - Toxic Language Detection, - Question answering ...
55 Datasets **14 Categories** **193 Tasks**	**69 Datasets** **27 Categories** **80 Tasks**	**9 Datasets** **1 Category** **9 Tasks**	**372 Datasets** **108 Categories** **1554 Tasks**

Source: Chung et al. 2022, "Scaling Instruction-Finetuned Language Models"

SAMSum: A dialogue dataset

Sample prompt training dataset (**samsum**) to fine-tune FLAN-T5 from pretrained T5

🗄 **Datasets: samsum**	Tasks: 📋 Summarization	Languages: 🌐 English

dialogue (string)	summary (string)
"Amanda: I baked cookies. Do you want some? Jerry: Sure! Amanda: I'll bring you tomorrow :-)"	"Amanda baked cookies and will bring Jerry some tomorrow."
"Olivia: Who are you voting for in this election? Oliver: Liberals as always. Olivia: Me too!! Oliver: Great"	"Olivia and Olivier are voting for liberals in this election. "
"Tim: Hi, what's up? Kim: Bad mood tbh, I was going to do lots of stuff but ended up procrastinating Tim: What did…	"Kim may try the pomodoro technique recommended by Tim to get more stuff done."

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Sample FLAN-T5 prompt templates

```
"samsum": [
    ("{dialogue}\n\Briefly summarize that dialogue.", "{summary}"),
    ("Here is a dialogue:\n{dialogue}\n\nWrite a short summary!",
     "{summary}"),
    ("Dialogue:\n{dialogue}\n\nWhat is a summary of this dialogue?",
     "{summary}"),
    ("{dialogue}\n\nWhat was that dialogue about, in two sentences or less?",
     "{summary}"),
    ("Here is a dialogue:\n{dialogue}\n\nWhat were they talking about?",
     "{summary}"),
    ("Dialogue:\n{dialogue}\nWhat were the main points in that "
     "conversation?", "{summary}"),
    ("Dialogue:\n{dialogue}\nWhat was going on in that conversation?",
     "{summary}"),
]
```

Improving FLAN-T5's summarization capabilities

Further fine-tune FLAN-T5 with a domain-specific instruction dataset (**dialogsum**)

Example support-dialog summarization

Summarize the following conversation.

Tommy: Hello. My name is Tommy Sandals, I have a reservation.
Mike: May I see some identification, sir, please?
Tommy: Sure. Here you go.
Mike: Thank you so much. Have you got a credit card, Mr.
Sandals?
Tommy: I sure do.
Mike: Thank you, sir. You'll be in room 507, nonsmoking,
queen bed.
Tommy: That's great, thank you!
Mike: Enjoy your stay!

Source: https://huggingface.co/datasets/knkarthick/dialogsum/viewer/knkarthick--dialogsum/

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Summary **before** fine-tuning FLAN-T5 with our dataset

Prompt (created from template)
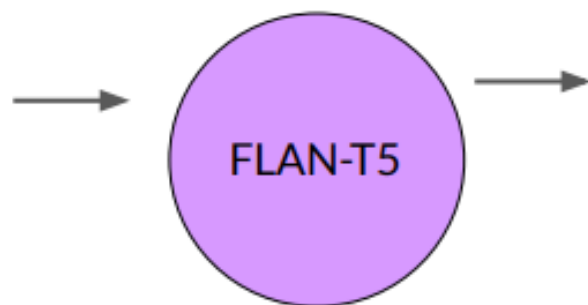
```
Summarize the following
conversation.
Tommy: Hello. My name is
Tommy Sandals, I have a
reservation.
Mike: May I see some
...

...

...
Tommy: That's great, thank
you!
Mike: Enjoy your stay!
```

Model

FLAN-T5

Completion (Summary)

```
Tommy Sandals has a reservation
for a room at the Venetian
Hotel in Las Vegas.
```

Adequate completion, but does not match human baseline.

```
Human baseline summary:
Tommy Sandals has got a
reservation. Mike asks for his
identification and credit card
and helps his check-in.
```

Summary **after** fine-tuning FLAN-T5 with our dataset

Prompt (created from template)

```
Summarize the following
conversation.
Tommy: Hello. My name is
Tommy Sandals, I have a
reservation.
Mike: May I see some
...
...
...
Tommy: That's great, thank
you!
Mike: Enjoy your stay!
```
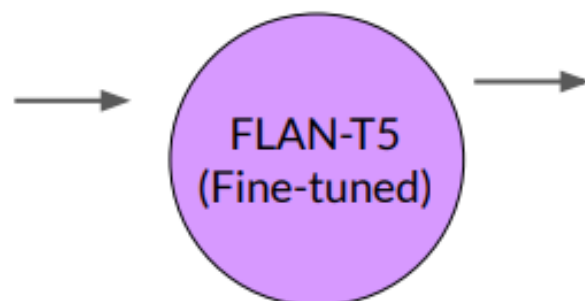
Model

FLAN-T5
(Fine-tuned)

Completion (Summary)

```
Tommy Sandals has a
reservation and checks in
showing his ID and credit
card. Mike helps him to
check in and approves his
reservation.
```

*Better summary,
more-closely matches
human baseline.*

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Fine-tuning with your own data